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Industry Analysis: Identifying Research and Extension Priorities for Hawai'i's Avocado, Banana, Citrus, and Specialty Fruits

Mike Nagao
Department of Tropical Plant and Soil Sciences

Steps to coordinate the state's research and extension resources and further the development of Hawai'i's fruit industries involve assessing the current condition of these industries, identifying bottlenecks to expansion and sustainability, and developing action plans to alleviate these bottlenecks. Data from the USDA National Agricultural Statistics Service show that some commodities have been successful in increasing or sustaining their farmgate value, others have shown decreases in value and acreages, while other industries, such as cacao, are relatively new and data on their production, acreage under cultivation, and farmgate value are not available, thus making it difficult to assess their position within Hawai'i's fruits industry. Approximately 200 edible fruits that are native to the tropics and subtropics have been test-grown in Hawai'i, and several CTAHR publications have identified those with potential value as fresh fruit, value-added products, or for the culinary industry (Hamilton 1987, Love et al. 2007, Chan-Halbrendt et al. 2007).

This analysis focuses on the specialty fruits industry, along with other crops including cacao, avocado, and citrus, but it will not deal with papaya or pineapple. Bottlenecks faced by the banana and avocado industries are presented; however, input from the Hawaii Banana Industry Association and Hawaii Avocado Association is needed to validate or expand upon the information contained in this document. Because only limited input on guava was obtained, consultations with processors, the Hawaii Guava Growers Cooperative, and Hawaiian Sun Products growers should be held to expand upon this industry's concerns.

The farmgate value of Hawai'i's specialty fruits industry more than doubled between 2003 and 2007, from $2.128 million to $4.485 million (Table 1). Total production during this period increased by 97.6 percent and reached 2.28 million pounds of fresh fruit. Rambutan, longan, lychee, and mango were the principal crops, accounting for 87.8 percent of production and contributing 90.3 percent of the farmgate value of the industry (Table 2). The 2007 farm prices per pound for these crops were $2.98 for longan, $2.80 for lychee, $2.39 for rambutan, and $0.97 for mango.

Other specialty fruits under cultivation include abiu, atemoya, breadfruit, caimito, durian, jaboticaba, jackfruit, langsat, loquat, mangosteen, persimmon, poha, rollinia, sapodilla, soursop, starfruit, and white sapote, with durian, mangosteen, and dragonfruit gaining in popularity with growers. Among these other fruits, statistical data on production are available only for atemoya and persimmon (Table 2). The contribution of the remaining fruits to the overall value of the specialty fruit industry was $309,000. The 2.28 million pounds of fresh fruit in 2007 was 59 percent higher than the production in 2006, and higher production occurred with all major specialty fruits except mango. The higher value in 2007 was due to greater output rather than increases in farmgate prices. The area cultivated with specialty fruits was 1,470 acres, which was 7 percent more than in 2006. Between 2003 and 2007, the area under cultivation with longan, lychee, rambutan, and mango increased from 1045 to 1245 acres, with more than 50 percent found on Hawai'i. The greatest increase in acreage occurred with longan, mango, and rambutan. The number of specialty fruit farms also increased from 170 to 310.

Annual production of lychee and rambutan fluctuate greatly because flowering and production are closely tied

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Table 1. Fruit production in Hawai'i for 2007.

Crop	Farms	Crop acres	Production (1000 lb)	Value ($1,000s)	2006 inshipments (1000 lb)
Banana	225	1200	19,700	8,007	15,408
Specialty fruits	310	1470	2280	4,485	-
Avocado	225	340	840	571	2349
Citrus	485	145	221	185	9357

to weather conditions. Flowering of lychee is influenced by several factors working in unison: winter weather conditions, levels of nitrogen in the leaves, and the stage of growth of terminal branches during the flower-induction season. Good flowering is associated with cool-dry winter weather and low N levels in the leaves. Poor flowering is associated with warm-wet winters and trees that are over-fertilized.

Rambutan flowering is triggered by water stress. Hawai'i's climate is fairly stable throughout the year, and instead of having a single, distinct dry season to induce synchronous and uniform flowering, as occurs in its monsoon-influenced, native growing areas in Southeast Asia, Hawai'i tends to have two short, drier periods during the winter and spring. As a result, two flowering periods can occur in Hawai'i, but the level and duration of flowering depend on the intensity of the dry season, maturity of the terminals, and developmental condition of the plant: flowering will not occur on terminals that are flushing or immature during the period when weather conditions are favorable for flowering induction.

Year-round flowering of longan trees can be stimulated by potassium chlorate ($KClO_3$). Flowering occurs within 2 months after evenly broadcasting the chemical onto the soil surface beneath the canopy of the tree and irrigation (or rainfall) that moves it into the root zone. All longan varieties tested, such as 'Kohala', 'Sri Chompoo', 'Biew Khiew', and 'E-Wai', were responsive to the treatment. The mode of action of potassium chlorate for stimulating longan flowering is not known, but the treatment is effective in all soil types and many different climatic areas.

Hawai'i's mango industry, with 130 farms generating $669,000 in 2007 from 11,800 trees, is equivalent in size to the rambutan industry in terms of the number of bearing trees, but farm prices per pound are much lower compared to rambutan, lychee, and longan. Imports of mangoes to the USA during 2006 to 2007 amounted to 295,250 metric tons, valued at $196 million, with the majority coming from Mexico, Equador, and Peru. According to HDOA's Wholesale Market Arrival Reports, mango in-shipments to Hawai'i in 2003 amounted to 799,000 pounds and were up to 1.01 million in 2007. Imports were highest in April and May and lowest in September, October, and November, with December, January, and February also being months experiencing high import totals. The amount of in-shipments is likely related to high production periods in Mexico in early summer and production in Ecuador and Peru during winter. Extending local production into the fall could target a period with low imports.

Hawai'i's avocado production between 1998 and 2007 increased from 500,000 to 840,000 pounds (Table 1), and prices increased from $0.52 to $0.68 per pound. Prices between 2005 and 2007 remained stable at about $0.66–0.68 per pound. In 2006, locally grown avocado was only 27.3 percent of the volume of avocado utilized within the state, with the remaining 72.7 percent consisting of imported fruit. Chan-Halbrendt et al. (2007) summarized the status of Hawai'i's avocado industry and suggested that nearly half of the state's production does not reach the market. Increasing the efficiency of production and coordinating production and marketing to target consumer preferences were strategies put forth in the report to increase consumers' willingness to purchase locally grown avocados.

Hawai'i's current banana production is 19.7 million pounds, valued at $8.1 million (Table 1). The acreage under production decreased from a high of 1760 acres in 1999 to 1200 acres in 2007. Total production in 2000 was 29 million pounds, 47 percent higher than the 2007 production. The latest data on in-shipments, for 2006, showed that approximately 15 million pounds of banana were brought into Hawai'i, which was equivalent to 44 percent of the state's market in 2006.

Table 2. Specialty fruit production in Hawai'i for 2007.

Crop	Farms	Crop acres	Production (1000 lb)	Value ($1,000)
Rambutan	75	330	824	1,969
Longan	75	245	263	784
Lychee	175	330	224	627
Mango	130	340	690	669
Persimmon	25	30	60	98
Atemoya	25	10	22	29
Others		185	197	309

Citrus production in Hawai'i is relatively small, with grapefruits, lemons, limes, and tangerines being the major citrus crops. The combined area under cultivation for these fruits in 2007 was 145 acres, with a combined total value of $185,000 (Table 1). The tangerine crop, valued at $70,000 and producing 89,000 pounds of fruit, represented the largest segment of the citrus industry. As with avocado, the volume of citrus in-shipments is far greater than local production.

A significant portion of Hawai'i's longan and rambutan crops is exported to the U.S. mainland after postharvest disinfestation by irradiation in a facility in Kea'au. There are no suitable disinfestation (hot, cold, or irradiation) treatment facilities available in West Hawai'i or on other islands. Transportation costs for access to treatment facilities add to the difficulties small-scale growers have when going after potential export markets. Because the only irradiation facility is located in Kea'au, most of the exports of these crops originate from East Hawai'i. The remaining fruits are sold locally on Hawai'i island or exported to O'ahu.

Hawai'i possesses climates that are suitable for production of a wide range of tropical and subtropical fruits, from those adapted to the humid tropics of Southeast Asia and Central and South America to subtropical species that can thrive at higher elevations that lack the threat of damaging frosts. Hawai'i and Florida are states that have environments suitable for tropical and subtropical fruit production. In south Florida, production in Miami-Dade County in 2002 was dominated by avocado (7154 acres), followed by mango and limes, with about 1650 acres devoted to their production. Florida is ranked first in the USA for production of lychee and longan, which are cultivated on 1200 ($2.8 million value) and 400 acres, respectively. 'Mauritius' and 'Brewster' lychee and 'Kohala' longan are the principal cultivars grown. Other fruits under cultivation in Florida include carambola, guava, mamey sapote, passionfruit, dragonfruit, and sapodilla.

Status of quarantine treatments for export

Movement of tropical fruits from Hawai'i to the U.S. mainland requires that the commodities undergo a postharvest treatment before export, unless the commodity has status as a non-host for fruit flies or other pests of quarantine concern. Fruits with non-host status include green banana, durian, and pineapple having 50 percent or more 'Smooth Cayenne' parentage. An outline of approved quarantine treatments for fruits and vegetables involving the use of irradiation, cold, heat, fumigation, and postharvest dips was compiled by Dr. Peter Follett, research entomologist, Postharvest Tropical Commodities Research Unit at the USDA/ARS Pacific Basin Agricultural Research Center, and presented to Hawai'i's specialty fruit industry at the 18th Annual Hawaii International Tropical Fruit Growers Conference in Keauhou-Kona in September 2008 (see Appendix, p. X). Quarantine treatments have been approved for abiu, atemoya, avocado, banana, breadfruit, carambola, citrus, dragonfruit, jackfruit, longan, lychee, mango, melons, mangosteen, papaya, pineapple, rambutan, and sapodilla. In addition, a "systems approach" to allow export of 'Sharwil' avocado is undergoing study.

Identifying industry bottlenecks

Specialty fruits production and management has been identified as a CTAHR initiative. ***Hawai'i has the potential to be a major supplier of specialty fruits. To achieve this potential, a consistent supply, reliable production methods, and postharvest management practices are of***

paramount importance. This industry analysis focuses on setting research and extension priorities for specialty fruits management, production, handling, and marketing.

To identify and prioritize bottlenecks facing the specialty fruits industry and determine the actions and agencies required to alleviate the bottlenecks, participants at the 18th Annual Hawaii International Tropical Fruit Growers Conference in Keauhou-Kona on September 25–27, 2008, met in commodity focus groups. These breakout sessions focused on the following crops: Sapindaceae family (lychee, longan, rambutan), Moraceae family (breadfruit, jackfruit, fig), and cacao, banana, mango, citrus, and other specialty fruits. During each facilitated session, bottlenecks, actions, and agencies responsible for addressing the bottlenecks were recorded, compiled, and shared with conference participants. Priorities, bottlenecks, action indications, and responsible agencies are presented in Table 3.

Summary

For Hawai'i to be a major supplier of tropical and subtropical specialty fruits, a consistent supply and reliable production methods and postharvest handling practices are of paramount importance. The bottlenecks and action indications given in Table 3, developed by industry stakeholders, provide information on knowledge gaps and factors pertinent to achieving consistent and sustainable production of these fruits in Hawai'i.

Knowledge gaps identified for the crops fall into four principal areas: marketing and economics, postharvest handling, disease and pest management, and field culture and management. Across the various commodity groups, information is available on the production of these fruit crops, but the information needs to be adapted to Hawai'i's growing conditions. Greater marketing and promotion efforts, more grower education on cultural practices and pest management, and increased efforts on selection of cultivars adapted to Hawai'i are among the specific action areas that have been identified.

Marketing should not be limited to fruits for export. Action plans for avocado, banana, and citrus indicate that greater marketing efforts should focus on promoting locally grown fruits to increase market awareness of local fruits to compete with in-shipments, as in-shipments for crops such as avocado and citrus far exceed local production (Table 1). Although quarantine procedures for export for many fruits have been developed and approved, postharvest fruit quality, decay control, and shelf life continue to be major concerns. Additional concerns associated with postharvest treatments include lack of information getting to the growers and lack of ability of some marketers and growers to carry through with the necessary treatments. Due to the renewed interest in cacao production in Hawai'i, priorities for this crop include accumulating data on the size of the industry, production costs, and information on handling and processing of the harvested product.

To update the status and address current bottlenecks of the specialty fruits industry, action plans need to be revised periodically. This analysis should be considered a working document and can serve as a starting point for identifying bottlenecks and action plans. Growers representing the various commodities can take this information and gather either as an independent association or a working group of the Hawaii Tropical Fruit Growers to periodically update the analysis. Continuous feedback from the specialty fruits industry participants should be sought so that resource agencies can appropriately address current priorities and bottlenecks within the industry. Rapidly changing global economics, production constraints, and market opportunities suggest that a similar analysis should be completed within two years.

Acknowledgments

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Table 3. Industry bottlenecks and action plans.

Sapindaceae (lychee, longan, rambutan)

Priority/bottleneck	*Action required*	*Agency responsible*
1. Lack of marketing and postharvest technology	Consumers, brokers, wholesalers, and marketers need education regarding the availability and quality of tropical Sapindaceae fruits.	Industry, HDOA, CTAHR
	Marketing plans and research are needed to expand the current market and develop new markets.	CTAHR, HDOA
	Development of postharvest technology involving packaging, modified atmosphere storage is needed to maintain quality of harvested fruit.	CTAHR, USDA-PBARC
2. Lack of improved production methods	Cost of production studies are needed to help new and established growers develop farm plans.	CTAHR, HDOA
	Disease management strategies are needed to control field and postharvest diseases.	CTAHR, USDA-PBARC
	Grower education programs are needed to help new and established growers deal with field culture/management and postharvest issues.	CTAHR
3. Lack of development for value-added products	Development of value added products is needed to increase markets and to utilize off-grade fruits.	CTAHR, USDA-PBARC

Mango

Priority/bottleneck	*Action required*	*Agency responsible*
1. Lack of information to extend production season	Improved cultural techniques such as pruning, irrigation management, and potassium nitrate treatments are needed to extend the bearing season.	USDA-PBARC, CTAHR
	New cultivars with different bearing periods are needed to extend season.	USDA-PBARC, CTAHR
	Coordination among growers is needed to fill larger orders.	Industry
	Education program (posters, brochures) is needed for consumers and buyers regarding seasonality of production for different cultivars.	Industry, CTAHR
	Postharvest handling information is needed to extend shelf-life and maintain quality.	USDA-PBARC, CTAHR
2. Industry lacks pest management strategies	Best management strategies are needed to control powdery mildew, mango seed weevil, and mango midge.	CTAHR, USDA-PBARC
3. Need to manage tree size for more efficient production	Grower education program on pruning techniques is needed to manage tree size.	Industry, CTAHR
	Cultivars with shorter stature and growing habits are needed.	Industry, USDA-PBARC, CTAHR
	Dwarfing rootstocks and use of airlayered plants need investigation as methods for controlling tree size.	Industry, USDA-PBARC, CTAHR

4. Irrigation requirement for trees is not known	Information on irrigation requirements of trees is needed along with the best periods to irrigate.	USDA-PBARC, CTAHR
	Water costs are high and more reasonable rates are needed for irrigation.	State, County

Avocado

Priority/bottleneck	*Action required*	*Agency responsible*
1. Lack access to mainland market	Stronger effort is needed to allow export of Hawai'i-grown 'Sharwil' fruit to mainland markets.	USDA-PBARC, USDA-APHIS, HDOA, CTAHR
	Certification of 'Sharwil' orchards is needed.	CTAHR, USDA-APHIS
	Education on production for small farmers is needed through the Cooperative Extension Service.	CTAHR
2. Need to increase market awareness of local cultivars to compete with imported fruit	Marketing and education programs are needed that target stores and consumers regarding the quality and availability of the different cultivars grown in Hawaii. Programs should include store demonstrations and sampling to push locally grown fruit and produce.	Industry, HDOA, CTAHR
	Hawai'i-grown cultivars need to compete favorably with imported 'Haas' and at similar prices.	Industry, HDOA, CTAHR

Cacao

Priority/bottleneck	*Action required*	*Agency responsible*
1. Lack of information on management of Chinese rose beetle	Best management strategies are needed to control Chinese rose beetles (e.g., chickens, cages, sleeves, etc).	USDA-SARE, USDA-PBARC, CTAHR
2. Need to determine the current volume produced in the state	A consistent method is needed to measure state production based on wet bean, pod weight, or dry beans.	USDA-NASS
3. Cost of production not known	Cost analysis from the grower's perspective is needed and should be made available to potential growers. Since cost of production is not known, it is difficult to determine the farmgate price growers should receive to be profitable.	CTAHR
4. Lack of information on fermentation of beans	Research is needed on the conditions, temperatures, climates, solar radiation, and locations in Hawai'i that provide optimum conditions for postharvest fermentation.	CTAHR
5. Lack of information on the cost of processing	Studies are needed to determine equipment costs and operational costs associated with conventional and organic processing, and procedures for starting and funding a processing cooperative.	CTAHR, USDA/Rural Development
6. Lack of information on overstory crops for field cultivation	Studies are needed to identify suitable overstory crops including N fixing trees such as leucaena and *Gliricidia sepium* (madre de cacao), and banana, and situations where they are applicable.	USDA-SARE, CTAHR
7. Need for development of raw food market	Information needed on value added products.	USDA-PBARC, CTAHR
8. Need to determine origin of product	Protocols are needed to identify origin of beans and trees.	HDOA

9. Labeling and branding of products needed	Regulations are needed to identify the origin of products in the marketplace and verify composition (% HI grown) to protect HI industry and consumers and keep production profitable for growers.	Legislature, HDOA

Moraceae (figs, breadfruit, jackfruit)

Priority/bottleneck	*Action required*	*Agency responsible*
1. Lack of information clearinghouse	Coordination among agencies needed to provide industry with available information on culture and management, postharvest handling and marketing. An information "czar" is needed to oversee the coordination and insure that research and extension focus on economic sustainability of producers.	CTAHR, USDA-PBARC, HARC, County, HDOA, Industry
2. Lack of cultivar selection and evaluation for specific microclimates	Identification and selection of cultivars (figs, breadfruit, jackfruit, mulberry, other species) suited for various growing environments in HI are needed for production of high and consistent quality fresh fruit, and to extend the production season.	CTAHR, NTBG, USDA-PBARC, National Plant Germplasm System, HARC, Industry
	Nursery stock of these cultivars needs to be made available to the industry (e.g., breadfruit from the National Tropical Botanic Garden) to commercialize the cultivars.	CTAHR, NTBG, USDA-PBARC, NPGS, HARC, Industry
3. Lack of new fruit crops, processing technology, marketing	Patenting new selections needs to be explored.	USDA-PBARC, CTAHR, HARC, Industry
	Value-added products (e.g., chips) need to be developed.	USDA-PBARC, CTAHR, HARC, Industry
	Minimal processing technology (breadfruit, jackfruit), and other processing and handling information are needed to create units with broader consumer appeal and to extend shelf life.	USDA-PBARC, CTAHR, HARC, Industry
	Infrastructure for large-scale processing and preservation is needed.	HDOA, Industry
	Quality standards need to be established and policed.	HDOA, CTAHR
	Need to identify multi-use opportunities by working with NRCS to utilize species for ecological purposes.	NRCS

Citrus

Priority/bottleneck	*Action required*	*Agency responsible*
1. Lack of consumer education on availability and quality of locally produced citrus	Locally grown fruits need to be marketed better.	Industry, HDOA, CTAHR
	Growers and consumers need face-to-face interaction via store demos, farmers markets, and direct marketing to increase exposure to local fruit.	Industry, HDOA, CTAHR

	Need to work with Dept. of Health on regulations prohibiting cut fruit samples.	Industry, DOH
	HTFG needs to work with members on marketing through a citrus committee.	Industry
2. Field culture and management information lacking	New varieties need to be evaluated for suitability in Hawaii environments.	Industry, CTAHR, USDA-PBARC
	Strategies to control pests and diseases needed.	Industry, CTAHR, USDA-PBARC
3. Farmer education is needed	Growers need education on growing and selling products and organizing a coop.	Industry, CTAHR, USDA/Rural Development

Banana

Priority/bottleneck	*Action required*	*Agency responsible*
1. Bunchy top virus disease limits production	Education on disease management and resistant cultivars is needed to control disease. High probability of success lies with tissue culture propagation of disease-free material and utilizing the appropriate cultural practices. Low probability of success and long-duration research requiring large amount of resources ($) are associated with GMO research.	Industry (HBIA), CTAHR, USDA-PBARC
2. Preservation of germplasm needed	Protocols for allowing importation of tissue cultured material need to be examined to facilitate easier import of new cultivars.	HDOA, Industry (HBIA), CTAHR, USDA-PBARC
	Need to establish a repository for germplasm after a search of databases and by utilizing tissue culture technology.	Industry (HBIA), CTAHR, USDA-PBARC
3. Lack of promotion of exotic cultivars to expand traditional and gourmet markets	Education of the consumer needed to promote new cultivars through advertising, promotion and marketing.	Industry (HBIA), CTAHR, USDA-PBARC
	Production of more planting material via tissue culture will be needed to meet consumer demand.	Industry (HBIA), CTAHR, USDA-PBARC

Other specialty fruits (dragonfruit, jaboticaba, guava, etc.)

Priority/bottleneck	*Action required*	*Agency responsible*
1. Introduction of new germplasm	More institutional support is needed for programs to introduce (and evaluate) new germplasm.	CTAHR, USDA-PBARC, HDOA
2. Market development	In addition to growing a new crop, promotion is needed to create demand at the local level through farmers' markets, exposure at chefs' professional organization meetings, direct marketing to hotels and restaurants. Collaboration with regulatory agencies (APHIS) regarding new fruit fly disinfestation protocols is needed for export.	HDOA, Industry, CTAHR, USDA-PBARC, APHIS
3. Lack of information clearinghouse	Information clearinghouse needed so institutions (CTAHR, HDOA, USDA) coordinate efforts rather than compete for resources. Institutions need to focus on clientele questions: What should I plant? Where can I get plants? How do I	Industry, CTAHR, USDA-PBARC, HDOA

grow and market it?
1) Big Island needs an "Agbudsman" to run an information clearinghouse separate from UH, HDOA, USDA (a "Big Island Dept. of Ag.")
2) Need information on "hot-demand" crops from marketers and use Malaysia, Australia, and Thailand research websites, which have better culture-management information than our institutions.
3) Use Web-based resources such as www.ATTRA.org, which collects information and research available online to farmers; federally funded, but not through USDA.

Appendix. Quarantine Update by Dr. Peter Follett

Quarantine Updates

USDA-ARS, U.S. Pacific Basin Agricultural Research Center
PO Box 4459, Hilo, Hawaii
Issue 11, September 2008

Finally!

The long-awaited rule allowing export of mangosteen, dragonfruit, and 3 other fruits hits the street

What's New: A new rule to allow export of five new fruits—breadfruit, jackfruit, dragon fruit, mangosteen, and melons—was published as a proposed rule just as we held the last conference. The final rule was published May 6, 2008 approving export from Hawaii to the U.S. mainland with irradiation quarantine treatment. Also, HDOA suggested to APHIS that irradiation could be substituted for a heat treatment approved for Hawaii citrus spp., and irradiation is now allowed for export of citrus for the first time. A pest risk assessment for guava is in preparation by APHIS.

The following is a list of the main tropical fruits in Hawaii and quarantine treatments developed to disinfest fruits of fruit flies and other insect pests before shipment from Hawaii to the U.S. mainland and foreign markets. Treatments are categorized as submitted, proposed, or accepted. Accepted treatments are underlined, and only accepted treatments are available for exporting fruit at this time. This is general information only; consult APHIS-PPQ for complete quarantine treatment or protocol regulations.

Abiu

- Irradiation -- 150 Gy -- or 400 Gy to control surface insects in addition to fruit flies.

Atemoya

- Irradiation -- 150 Gy -- or 400 Gy to control surface insects in addition to fruit flies.

Avocado

- Cold treatment -- all cultivars, 14 days at $\leq 1.1^{o}C$ ($34^{o}F$), 16 days at $\leq 1.67^{o}C$ ($35^{o}C$), 18 days at $\leq 2.2^{o}C$ ($36^{o}C$); requires heat shock pretreatment.
- Systems approach for 'Sharwil' in preparation.

Bananas

- Nonhost status -- green bananas, cv. 'Williams', 'Valery' and 'dwarf Brazilian'. Regulation includes specific conditions.
- Irradiation – all cultivars, 400 Gy if free of banana moth, 150 Gy if free of green scale and banana moth.

Appendix. Quarantine Update by Dr. Peter Follett (continued)

Breadfruit
- Irradiation ***(New)*** -- 150 Gy and post-harvest dip or orchard treatment for control of surface pests -- or 400 Gy to control surface insects in addition to fruit flies. Fungicide dip required for *Phytophthora tropicalis*.

Carambola
- Cold treatment -- storage for 10 days at ≤ 0.0°C (32°F), 11 days at ≤ 0.6°C (33°F), 12 days at ≤ 1.1°C (34°F), 14 days at ≤ 1.67°C (35°F).
- Irradiation -- 150 Gy -- or 400 Gy to control surface insects in addition to fruit flies.

Citrus
- High temperature forced air -- fruit core temperature heated to > 47.2°C (117°F) in not less than 4 hours.
- Irradiation ***(New)*** -- 150 Gy -- or 400 Gy to control surface insects in addition to fruit flies.

Dragon fruit
- Irradiation ***(New)*** -- 150 Gy and post-harvest dip or orchard treatment for control of surface pests -- or 400 Gy to control surface insects in addition to fruit flies.

Durian
- Nonhost status -- must be inspected and free of surface pests.

Guava
- Irradiation -- pest risk assessment in preparation

Jackfruit
- Irradiation ***(New)*** -- 150 Gy and post-harvest dip or orchard treatment for control of surface pests -- or 400 Gy to control surface insects in addition to fruit flies. Fungicide dip required for *Phytophthora tropicalis*.

Longan
- Hot water immersion -- 49°C (120°F) or above for 20 minutes.
- Irradiation -- 150 Gy -- or 400 Gy to control surface insects in addition to fruit flies.

Lychee
- Hot water immersion -- 49°C (120°F) or above for 20 minutes.
- Irradiation -- 150 Gy -- or 400 Gy to control surface insects in addition to fruit flies.
- Vapor heat -- internal fruit temperature raised by saturated water vapor (≥90% RH) to 47.2°C (117°F) (or above) in at least 60 min. Hold at 47.2°C for 20 min. Hydrocool with a cool water spray.

Appendix. Quarantine Update by Dr. Peter Follett (continued)

Mango

- Irradiation -- To U.S. -- 300 Gy -- treatment carried out only in an approved facility in Hawaii or in non-fruit fly supporting areas of the mainland U.S.
- Vapor heat -- To Japan -- cv. 'Haden' and 'Keitt.' Fruit core temperature heated to > 47.2°C (117°F) in not less than 4 hours. Other conditions apply. Request submitted to Japan to add all other cultivars.

Melons (cantaloupe, honeydew, watermelon)

- Irradiation ***(New)*** -- 150 Gy and post-harvest dip or orchard treatment for control of surface pests -- or 400 Gy to control surface insects in addition to fruit flies. Sepals must be removed.

Mangosteen

- Irradiation ***(New)*** -- 150 Gy and post-harvest dip or orchard treatment for control of surface pests -- or 400 Gy to control surface insects in addition to fruit flies. Sepals must be removed.

Papaya

- High temperature forced air -- fruit core temperature heated to > 47.2°C (117°F) in not less than 4 hours.
- Vapor heat -- fruit core temperature heated by saturated water vapor to 44.4°C (112°F). Hold fruit temperature at 44.4°C for 8.75 hours, then cool immediately, OR, fruit core temperature heated to > 47.2°C (117°F) in not less than 4 hours.
- Irradiation -- 150 Gy -- or 400 Gy to control surface insects in addition to fruit flies.

Pineapple

- Nonhost status -- for cultivars with 50% or more 'smooth Cayenne' parentage; includes 'Sugarloaf'.
- Irradiation -- 150 Gy -- for cultivars other than 50% 'smooth Cayenne'.
- Vapor heat -- for cultivars other than 50% 'smooth Cayenne'. Fruit core temperature heated by saturated water vapor to 44.4°C (112°F). Hold fruit temperature at 44.4°C for 8.75 hours, then cool immediately.

Rambutan

- Irradiation -- 150 Gy -- or 400 Gy to control surface insects in addition to fruit flies
- Vapor heat -- internal fruit temperature raised by saturated water vapor (≥90% RH) to 47.2°C (117°F) (or above) in at least 60 min. Hold at 47.2°C for 20 min. Hydrocooling is optional.

Sapodilla

- Irradiation -- 150 Gy -- or 400 Gy to control surface insects in addition to fruit flies.

Appendix. Quarantine Update by Dr. Peter Follett (continued)

Summary: Commodity quarantine treatments for Hawaii's fruits and vegetables

Abiu	I	Longan	I, H
Atemoya	I	Lychee	I, H
Avocado	C	Mango	I
Banana	I, N	Mangosteen	I
Breadfruit	I	Melons	I
Capsicum spp.	I	Papaya	I, H
Carambola	I, C	Pineapple	I, N, H
Citrus	I, H	Rambutan	I, H
Cucurbita spp.	I	Sapodilla	I
Dragon fruit	I	Sweet potato	I, F, H
Durian	N	Tomatoes	I
Eggplant	I	Cowpea	I
Jackfruit	I	Moringa	I

I = irradiation, C = cold, N = non-host status, H = heat (hot water immersion or vapor heat), F = fumigation

Vegetables update: Vapor heat was removed in 2007 as a treatment for bell pepper, eggplant, Italian squash, and tomato due to potential infestation by solanum fruit fly (*Bactrocera latifrons*) and the absence of data for this fruit fly. At the same time irradiation treatment (150 Gy) was expanded from Italian squash to all *Cucurbita* sp. (squashes) and from bell peppers to all *Capsicum* sp. (peppers).

Compiled by:
Dr. Peter Follett, Research Entomologist, Postharvest Tropical Commodities Research Unit
Tel. (808) 959-4303, Fax (808) 959-5470, E-mail: peter.follett@ars.usda.gov (*new*)