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Process control in phytosanitary irradiation of fresh fruits and vegetables as a model for other phytosanitary treatment processes

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ABSTRACT

Phytosanitary treatments reduce the risk of commodities carrying invasive quarantine pests to negligible levels. Ionizing radiation processing of fresh fruits and vegetables to prevent successful infestation from these pests is steadily growing in commercial use because it provides safe solutions to quarantines and is tolerated by more fresh produce than any alternative treatment in use. Unlike all other commercial phytosanitary treatments (heat, cold, fumigation), the burden of proof of efficacy of phytosanitary irradiation is entirely on process control. Facilities for phytosanitary irradiation processing are more tightly controlled than facilities for other treatments, and the process control involved can serve as a model to harmonize and streamline the latter. Basing treatment certifications of efficacy on process control instead of inspection will help guide phytosanitation towards a phytosanitary hazard analysis and critical control point approach more consistent with other forms of food process control.

1. Introduction

Searches of the FAO (2015) statistical database show marked per capita increases in production and trade in fresh fruits and vegetables in recent years. Still, many populations of the world over the entire economic range from wealthy to poor do not eat sufficient fruits and vegetables that would be consistent with a healthy lifestyle (Siegel, Ali, Srinivasiah, Nugent, & Venkat Narayan, 2014). The reasons for insufficient fruit and vegetable consumption range from agricultural policies that favour meat, dairy, and grain production over healthier foods, to pests, inadequate production, and undependable distribution of highly perishable commodities, especially in hot, humid areas. Trade in fresh fruits and vegetables can help alleviate local inadequacies in supply due to seasonal and other factors. Export of high value fresh fruits and vegetables from developing countries generally has positive economic, social, and environmental effects for those countries (Schwarz, Mathijs, & Maertens, 2015).

The objectives of this paper are to illuminate factors of the control of radiation processing that are unique to phytosanitary irradiation of fresh fruits and vegetables compared with other forms of food irradiation with which facility operators, regulators, and potential users of the technology may not be aware and to indicate how process control of phytosanitary irradiation can be a model for process control of other phytosanitary treatments.

2. Phytosanitary treatments

Fresh fruits and vegetables pose risks of carrying invasive agricultural pests, thus, are often quarantined against export to areas where the pests do not exist but could establish (Table 1). Phytosanitary measures are used to permit trade in quarantined commodities by providing means to reduce the risk of carrying quarantine pests to extremely low, acceptable levels (Heather & Hallman, 2008). Phytosanitary treatments comprise a group of phytosanitary measures whereby commodities are subjected to a process that kills, removes, or otherwise renders harmless quarantine pests that might be present. There is often a narrow gap between a process that will kill or otherwise prevent virtually 100% of an invasive species from surviving but not damage the live fruit or vegetable to prevent its successful marketing and consumption.

The most widely used phytosanitary treatments for fresh fruits and vegetables are temperatures near 0 or 47 °C for days or hours, respectively, and fumigation with methyl bromide. However, the fumigant is considered a stratospheric ozone depleting substance, and its uses are being regulated and reduced (Doniger, 2015). Although it is still permitted for phytosanitary purposes many

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Table 1
Examples of key invasive plant pests that are often found on fresh fruits and vegetables for export market.

Pest	Some products infesting	Regions infested	Export destinations not infested
Mediterranean fruit fly, *Ceratitis capitata*	Many fruits	Africa, Mediterranean basin, Central and South America, Western Australia	Much of Asia and Oceania, eastern Australia, North America
Oriental fruit fly, *Bactrocera dorsalis*	Many fruits	Africa, Asia, Hawaii	The Americas, Australia, most of Oceania
Melon thrips, *Thrips palmi*	Many ornamental and vegetable plants	Africa, the Americas, Asia, Australia	Europe, New Zealand
Spotted cucumber beetle, *Diabrotica undecimpunctata*	Many ornamental and vegetable plants	North America,	Africa, Asia, Australia, Europe, South America
Lychee erinose mite, *Aceria litchii*	Lychee fruit	Australia, Brazil, China, Hawaii India, Japan, Pakistan, Taiwan, Thailand	Americas except Brazil, Africa
Brown garden snail, *Cornu aspersum*	Many ornamental and vegetable plants as well as foliage of citrus and grape	Most of the world where winter is not severe	Various countries and parts of countries
Mango pulp weevil, *Sternochetus frigidus*	Mango fruit	Bangladesh, Burma, north-east India, Indonesia, Malaysia, the Philippines, Singapore, Thailand	The Americas, Africa, Australia, Oceania
False codling moth, *Thaumatotibia leucotreta*	Many fruits, beans, cotton, maize	Africa	The Americas, Asia, Australia, Europe
Grape mealybug, *Pseudococcus maritimus*	Grapes, and a variety of other plants	The Americas, Asia, Europe, New Zealand	Africa, Australia
Red scale, *Aonidiella aurantii*	Citrus and some other plants	Much of the world	Isolated countries and parts of countries

importing countries do not accept methyl bromide fumigation, and alternatives should be developed.

2.1. Phytosanitary irradiation

Irradiation was first attempted to control insects (ineffectively) in the 1910s on tobacco products (Morgan & Runner, 1913). Phytosanitary irradiation (PI) was first imagined as a phytosanitary treatment in 1930, first used commercially (Puerto Rican mangoes to Florida) in 1986, began being used on a continual basis within the same country (United States) in 1995, and began being used internationally (Australian mangoes to New Zealand) in 2004 (Hallman, 2011). Today total volume of fresh commodities treated for phytosanitation is near 20,000 tons/yr, with volumes increasing by > 10% each year. Australia, India, Mexico, Pakistan, South Africa, Thailand, United States, and Vietnam export while Malaysia, New Zealand, and United States import irradiated produce. Most irradiated fruits are processed in Mexico at two facilities, and the most processed fruit is guava, *Psidium guajaba* L. The United States is the largest market for fresh irradiated commodities, importing fruit from all of the exporting countries. Per year 5500 tons of sweetpotato, *Ipomea batatas* (L.) Lam. plus a few other items are irradiated in the state of Hawaii for shipment to the mainland United States.

PI differs from all other commercially-used phytosanitary treatments in one key aspect that impacts regulation of the process: while all other treatments are expected to result in dead pests shortly after the treatment is terminated insects irradiated at the doses used for PI (current minimum target doses are 150–500 Gy) will live for days after irradiation but not develop further or reproduce. Phytosanitary inspectors accept live pests in certified PI treatments, although in any case it is not common to encounter insects in marketed fruits and vegetables under modern production systems.

PI developed largely as a form of food irradiation, thus, some of its characteristics are more common to food irradiation than they are to other phytosanitary treatments. For example, from the beginning PI was approached as a generic treatment with regard to pests and commodities (Hallman, 2012). All other phytosanitary treatments are usually specific for pest, commodity, and country. Food irradiation is usually proposed as generic for food groups and multiple risk factors, not individual food items or specific risk agents. The fact that PI is applied mostly as a generic treatment gives it an advantage over other treatments as not only is it broadly applicable to current quarantines it is applicable to many new commodity/pest combinations that may require phytosanitary treatment in the future.

3. Process control in phytosanitary irradiation

As with other applications of radiation processing, process control in PI is fundamental and critical and must be understood for efficacious application of the technology. It is key to the successful use of PI because, unlike other treatments, any insects that might be present in the commodity are expected to be alive (but not feeding) for some days after successful treatment. Efficacy of all other commercial treatments (heat, cold, and fumigation) is corroborated by inspection; therefore, if any live insects are found after these treatments the commodity lot must be re-treated, returned, redirected to another destination, or destroyed. Therefore, process control and certification of PI serve as the corroboration of efficacy, and inspection is non-informative and not necessary (Fig. 1).

Figure 1. Time consuming and costly inspection is not necessary for phytosanitary irradiation.