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IRRADIATION AS A PHYTOSANITARY TREATMENT FOR AGRICULTURAL PRODUCE: MALAYSIA'S EXPERIENCE

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ABSTRACT

Phytosanitary treatments are used to disinfest agricultural commodities of quarantine pests so that the commodities can be exported to areas where the pests do not occur. Ionizing irradiation is a promising phytosanitary treatment that is it prevents the emergence of adult insects capable of flight or of adult insects capable of reproduction. The treatment is broadly effective against insects and mites at doses that do not compromise quality of most commodities. Advantages over other treatments include tolerance by most fresh commodities, ability to treat in the final packaging and in pallet loads, and absence of pesticide residues. Malaysia has initiated research on the potential of the application since 1990. The studies include the investigation of the treatment effect against pests in cocoa beans, cut flowers and fruits such as carambola, mango, papaya and sapodilla. Recently, interest in the use of irradiation as a phytosanitary treatment for other agricultural commodities is growing, particularly since generic irradiation treatments have been approved in the USA to control broad groups of insects in five types of Malaysian fruits such as rambutan, papaya, pineapple, jackfruit and starfruit. Generic treatment is a single dose irradiation treatment of minimum 400 Gy that controls a broad group of pests with the exception of the pupa and adult stages of Lepidoptera. Thus, a pest risk assessment that does not demonstrate any presence of pupae or adult Lepidoptera associated with any of those five fruits means no further research is needed to get the export approval from the importing country. Generic radiation treatments can be applied as long as the technical objectives of the treatments are met, in which, the minimum treatment dose must exceed 400 Gy and yet remaining below maximum allowable dose where the quality of fresh fruits are still maintained.

Keywords: *phytosanitary, irradiation, quarantine, generic treatment, pests, agricultural commodities*

INTRODUCTION

Trade in fresh horticultural products represents one of the main contributors to the economy of both developing and developed countries, with direct contributions between 9 and 29% of gross income [1]. Accompanying increased trade in agricultural products is the increased risk for inadvertently transporting quarantine pests to countries or regions where they do not occur. Quarantined pests, including insects such as fruit flies, beetles, moths, scales, mealy bugs, thrips, and mites, can seriously disrupt marketing of fresh agricultural products not only between countries, but also between geographical areas within countries. The establishment of new pests can be costly due to increased crop damage, control programmes, and phytosanitary restrictions on trade. Phytosanitary or quarantine treatments eliminate, sterilize, or kill regulatory pests in exported commodities to prevent their introduction and establishment into new areas. As exclusion is the goal for quarantine pests, the tolerance for the pest in the commodity is essentially zero. Methods available to disinfest a commodity of quarantine pests include cold storage, heating, ionizing radiation, modified atmosphere storage, fumigation, pesticide applications or a combination of these [2]. Interest in the use of irradiation as a phytosanitary treatment for agricultural commodities is growing worldwide, particularly since publication of the International Plant Protection Convention (IPPC) standard that endorses and facilitates trade based on this disinfestation method. Irradiation is broadly effective against arthropod pests at dose levels that have minimal adverse effects on the quality of most commodities.

Irradiation technology

Irradiation is the process whereby the specimen is exposed to ionizing energy that penetrates objects and break molecular bonds including the DNA of living organisms. Sources of approved ionizing radiation for food are gamma rays from cobalt-60 or caesium-137 (radiosiotopes), electrons generated from machine sources (up to 10 MeV), and X-rays (up to 5 MeV). By inhibiting cellular reproduction, irradiation can be used for sanitary and phytosanitary purposes, depending on the applied dose (measured in kilograys, kGy). Low doses of irradiation (less than 1 kGy) only disrupt cellular activity enough to prevent reproduction (as with Mediterranean fruit flies on guava) or sprouting (on onions, potatoes). Medium doses (1-10 kGy) eliminate pathogenic microbes such as *Salmonella* in meat or reduce spoilage microorganisms in food and extend the shelf life of perishable foods such as strawberries. High doses (10 - 25 kGy) kill a comprehensive spectrum of fungi and bacteria (as with spice imports) and very high doses (greater than 25 kGy) sterilize medical equipment, hospital food and pet food. The treatment is done in a licensed and registered irradiation facility prior to export or on arrival in the importing country.

Irradiation as a phytosanitary treatment

Irradiation as a phytosanitary treatment was first studied against fruit flies by Koidsumi (1930) in Taiwan in the late 1920s [3]. Over the years, research data demonstrated the technical efficacy and feasibility of irradiation against a large range of insect pest species that infest various fruits and vegetables. Phytosanitary uses of irradiation also include the devitalization of plants (e.g. seeds may germinate but seedlings do not grow; or tubers, bulbs or cuttings do not sprout).

Irradiation has several major advantages over other quarantine treatments. Whereas development of heat, cold and fumigation treatments involves generating data for each fruit pest combination, irradiation treatments are developed for a pest species irrespective of commodity. This is possible because most commodities can tolerate irradiation at doses that kill the pest, while other treatments involves finding the balance between killing the pest and minimizing the adverse effects of the process on commodity quality. Moreover, because irradiation is effective against most insects and mites at dose levels that do not affect the quality of commodities, it is the ideal technology for developing “generic” treatments [4]. A generic quarantine treatment is one that provides quarantine security for a broad group of pests. Table 1 showed possible generic doses for control of pest groups [3]. In 2006, USDA-APHIS approved generic doses of 0.15 kGy for tephritid fruit flies and 0.4 kGy for all insects except pupa and adult Lepidoptera [5]. Other advantages include tolerance by the vast majority of fresh commodities, ability to treat in final packaging in pallet loads, and lack of residues.

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Table 1: Possible generic doses that might provide control of various quarantine pest groups

Pest group[a]	**Measure of efficacy**	**Possible generic dose (kGy)**
Aphids	Prevent reproduction of adult	0.1
Whiteflies	Prevent reproduction of adult	0.1
Dried seed weevils	Prevent reproduction of adult	0.1
Fruit fly larvae	Prevent adult emergence	0.15[b]
Fruit weevils	Prevent reproduction of adult	0.15
Thrips	Prevent reproduction of adult	0.25
Lepidoptera larvae	Prevent adult emergence	0.25
Scale insects	Prevent reproduction of adult	0.25
Mealybugs	Prevent reproduction of adult	0.25
All insects except pupae and adults of Lepidoptera[c]	Prevent reproduction of adult or development to adults by eggs, nymphs and larvae	0.25
Lepidoptera pupae	Prevent reproduction from subsequent adult	0.35
Mites	Prevent reproduction of adult	0.35
All arthropods except adults of Lepidoptera	Prevent reproduction of adult	0.35

[a]Pest group assumes adult is most tolerant stage that maybe present in the shipped commodity.
[b]Generic doses of 0.15 kGy accepted by APHIS and IPPC.
[c]APHIS currently accepts 0.4 kGy, but might be lowered if additional research continues to support a dose of 0.25 kGy.

Currently, importing countries may inspect samples of products on arrival at the points of entry. If live quarantine pests are found upon inspection, the consignment is rejected on the basis that the treatment was not done properly, or the commodity was reinfested after treatment. However, irradiation differs from other treatments: the end point is not necessarily immediate mortality of target pests to provide quarantine security but most often accomplished by preventing development to the reproductive stage or sterilizing the reproductive stage of the insect as shown in Table 2 [3]. Therefore live (but sterile or not viable) insects may occur with the exported irradiated commodity, thus making inspection for the target pests redundant. This places an added level of importance on the certification procedures for irradiation facilities and proper documentation accompanying export shipments confirming treatment at approved doses. Radiation doses necessary to kill pests within a day are usually too high for most agricultural produce to tolerate. However, much lower doses (0.05 to 0.35 kGy) can prevent successful development or reproduction of the pest, which is equivalent to mortality in preventing an infestation. If multiple species on a commodity are regulated pests, the radiation dose applied should provide quarantine security for the commodity against the most tolerant stage of the most tolerant species.

Table 2: Subjective comparison of major phytosanitary treatments

Treatments	**End point**	**Commodity tolerance**	**Cost**	**Speed**	**Logistics**	**Commonly treated commodity**
Cold	Mortality	Moderate	Low	Very slow	Easy	Citrus, apple
Heated air	Mortality	Moderate	Moderate	Moderate	Moderate	Mango, papaya
Hot water immersion	Mortality	Moderate	Low	Fast	Moderate	Mango
Methyl bromide fumigation	Mortality	Moderate	Low	Fast	easy	Citrus
Irradiation	Stop development	High	Moderate	Fast	Moderate	Mango, guava

Commercial application of phytosanitary irradiation

Despite extensive research demonstrating that the irradiation of horticultural products offered significant benefits, interest in commercial applications was tempered by several factors such as regulatory barriers, higher cost, inadequate treatment facilities and poor industry/consumer acceptance [3]. The publication of International Standard for Phytosanitary Measures No. 18 'Guidelines for the use of irradiation as a phytosanitary measure' in 2003 marked a significant step forward in adopting radiation technology as a means to facilitate international trade in horticultural products. The first commercial treatment was in 1986 when Puerto Rico sent irradiated mangoes to Florida, followed by shipment of irradiated papaya from Hawaii to California in 1987.

Currently, trade in irradiated horticultural products involves only seven countries. New Zealand and United States are the importing countries and Australia, India, Thailand, Vietnam and Mexico are the exporting countries [1]. In Hawaii, irradiation is an accepted quarantine treatment to control fruit flies in ten fruits and four vegetables and the mango seed weevil in mangoes; and in Florida, sweet potatoes are irradiated to control sweet potato weevil before shipment to California. The USDA approval for phytosanitary irradiation in 2006 and the adoption of ISPM No.18 have greatly enhanced its application as a potential strategy to overcome quarantine restrictions on a wide range of products for both developed and developing countries seeking access to lucrative US markets. This has resulted in preclearance export programs for five countries: India, Thailand, Vietnam, Pakistan and Mexico. Exports under the APHIS program for generic doses started in 2007 with the first shipments of irradiated mangoes from India. Since then, Thailand has exported mangoes, mangosteen, longan and rambutan, and has authorization from APHIS to also ship irradiated litchi and pineapple. Irradiated dragon fruit has also been exported from Vietnam and guava, mango, grapefruit, sweet lime and manzano pepper from Mexico. Mexico is currently the world's largest exporter of irradiated fruit.

The New Zealand Ministry of Agriculture and Forestry approved access for Australian mangoes in 2004, papaya in 2006 and litchi in 2008 using irradiation. The minimum dose required by New Zealand for the insect pests of concern is 0.25 kGy. The USDA is considering access for Australian mangoes and litchi irradiated at 0.4 kGy. Biosecurity Australia has approved irradiation as a treatment for mangoes imported from India [6].

Phytosanitary irradiation of Malaysia agricultural produce

The development of food irradiation began in 1980s when Malaysia actively conducted research on the treatment efficacy on various agricultural commodities. Commercial food irradiation in Malaysia amounted to 785 metric tonnes in 2010, mainly for sanitary purposes. There are 4 commercial gamma and 7 electron beam facilities available, but only MINTec-Sinagama (government-owned gamma facility at Malaysian Nuclear Agency, strength 0.6 MCi) provides service for research and processing of food. Presently, the application of food irradiation is controlled by the Food Act 1983 and Food Regulation 1985 which requires approval from the Director-General of the Ministry of Health. However, a new Food Irradiation Regulation 2011 was gazzetted in April 2011, which has provisions for approval of 9 classes of food, requirement for registration of food irradiation premises, certificate of irradiation, packaging and labeling of irradiated food on sale. For phytosanitary purposes, no specific regulation on the use of irradiation as phytosanitary treatment has been provided Under the Plant Quarantine Act 1976. The Malaysian Department of Agriculture, as the National Plant Protection Organisation, regulates irradiation as one of the plant quarantine treatment measures, following closely the ISPM No. 18 guidelines.

Studies on phytosanitary applications were limited to cocoa beans, fruits and cut flowers as summarized in Table 3. Malaysia develops interest to commercially apply irradiation for tropical fruits upon approval of this technique by USA. Currently, Malaysia is awaiting clearance from USA for the export of irradiated rambutan, pineapple, papaya, carambola and jackfruit. Fruits will be treated at MINTec-Sinagama and the facility must be approved and certified by APHIS to be authorized to apply phytosanitary treatments. Pest risk assessment, phytotoxicity and dose mapping studies are being conducted at the generic minimum dose of 0.4 kGy. Application of the irradiation treatment requires dosimetry and dose mapping to ensure that the treatment is effective in particular facilities and with specific commodity configurations. Preliminary dose mapping study of rambutan cv. Anak Sekolah at MINTec-Sinagama showed a minimum and maximum dose of 0.53 kGy and 0.71 kGy, respectively with dose uniformity ratio of 1.34 [10]. Malaysia has also approved irradiation as a treatment for

exported Australian mangoes. The minimum dose required by Malaysia for the insect pests of concern is 0.3 kGy. In 2009 and 2010, Australia exported 263 tonnes of irradiated mangoes to Malaysia.

Table 3:Research on irradiation as phytosanitary treatment in Malaysia

Commodity	**Objective**	**Findings**
Cocoa beans [7]	Mold disinfection (*Penicillium* spp., *Aspergillus* spp.) and insect disinfestation (*Triboleum castaneum, Orizaephilus surinamensis* (L.) *Lasioderma serricorne*.	• Doses 2-6 kGy reduced mold growth • Dose 0.1 kGy induced sterility in major storage beetles . • 5 kGy - instant mortality • No effect on chemical and flavour quality
Fruits (carambola, mango, papaya and sapodilla [7]	Fruit fly disinfestaion	• 0.08 kGy prevented third instar larvae (most resistant stage) from emerging into complete adult capable of flight • 0.15 kGy - carambola showed phytotoxic effects
Cut flowers (roses, (chrysanthemums, carnations, orchids) [8]	Mites *Tetranychus piercie* disinfestation	• Dose 0.3–0.4 kGy for mites treatment • 0.1-0.4 kGy - phytotoxic effects on roses, carnations and orchids but not chrysanthemums
Rambutan [9]	Mealy bug *Dysmicocus neobrevioes* disinfestation	• 0.4 kGy inhibit development and reproduction

CONCLUSIONS

Ionizing irradiation is gaining recognition as a promising phytosanitary treatment with broad spectrum activity against arthropod pests at dose levels that have minimal adverse effects on the quality of most commodities. Among challenges to further expand its use in facilitating international trade are unharmonised regulation, high treatment cost, lack of facilities and concerns about the process by the fruit industry and consumers. By adopting this technology, it is anticipated that Malaysia's agricultural produce can penetrate new markets and thus contribute towards economic growth of country.

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