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Phytosanitary irradiation in ports of entry: a practical solution for developing countries

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Summary The advantages of using ionising irradiation as a phytosanitary treatment have been demonstrated commercially in the past two decades and several countries currently use the technology for commercial treatments to meet plant quarantine requirements. Although many countries have expressed interest in using phytosanitary irradiation (PI) and it provides a viable alternative for overcoming a wide range of phytosanitary restrictions for numerous fresh products, the use of PI for fresh fruits and vegetables faces economic obstacles due to the sizeable initial investment required to build an irradiation facility. Projecting the market demand for irradiated products to justify the investment in treatment facilities is a business challenge limited by the potential for all countries to invest in this technology, especially developing countries. A recent change in import regulations by the United States allows for treatment upon entry, thus removing the immediate need for treatment facilities in the exporting country. This change makes it possible for exporting countries to explore and develop new markets prior to investing in treatment facilities at the origin. This paper discusses the economic potential of products that could be shipped to the United States for irradiation from selected countries in the Americas, Asia and Africa.

Keywords cost, export, food, fruit, Irradiation, phytosanitary, profitability.

Introduction

The increasing demand by modern consumers for a greater variety and better quality fresh fruits and vegetables has driven international trade in horticultural produce to record levels in the last decades (Thow & Priyadarshi, 2013). A diversity of fruits and vegetables is grown in tropical and subtropical countries where climatological conditions favour the cultivation of a broad range of produce. The same factors that favour diversity in agricultural production also favour diversity in pests, which can be inadvertently introduced into importing countries via trade in fresh products. Quarantine restrictions designed to prevent the introduction and spread of pests can also limit the potential for trade in many commodities known to be hosts for the pests of concern to importing countries. Phytosanitary treatments make it possible to avoid quarantine prohibitions by removing, killing or making the pests, otherwise unable to establish via imports from infested areas.

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Phytosanitary irradiation (PI) has gradually come into commercial use for a growing number of commodities and countries. Australia, India, Thailand, Vietnam, Mexico and South Africa have sent shipments of nine different irradiated commodities to New Zealand, the United States and Malaysia over the past decade (Bustos-Griffin *et al*., 2012; Food Irradiation, 2014). The trade opportunities afforded by PI have been noticed by other countries, especially those that export principally to the United States. However, many countries have been limited by the reluctance of public or private sectors to invest in treatment facilities. Although PI treatment facilities have been shown to be cost-effective over the long term, a substantial initial investment is required to establish a new facility and some assurance of adequate throughput is needed for profitability (Kunstadt, 2001; Gray*Start, 2013; ThePacker, 2014).

A recent change in regulations by the Animal and Plant Health Inspection Service, USDA, allows for irradiation at the port of entry in the United States (APHIS, 2012). This change provides the opportunity for exporting countries to take advantage of the

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markets that are opened by PI without the high investment required to build a facility at the point of origin. The new rule allows countries in Asia, Africa and the Americas to explore the market potential for their fresh agricultural products with minimum investment and risk. It also allows countries to utilise PI where low volumes or short-season commodities would not provide sufficient throughput to justify the investment in a facility. This study contrasts the position of PI in relation to other treatment technologies using selected examples from possible markets, countries and commodities affected by the availability of irradiation facilities.

Agricultural production

The estimated global production of fruit was more than 500 million tons in 2013 and more than 800 million tons of vegetables (FAO, 2003). Asia contributes 60% to this total; the Americas 13% and Africa 10%.

Many developing countries depend heavily on agriculture to support their local and national economies. Opening and expanding markets for fresh produce can make a significant contribution to creating employment and reducing poverty (FAO, 2013b; Diop & Jaffe, 2005). A major barrier for much of this trade is plant quarantine restrictions imposed by importing countries to prevent harmful plant pests from being introduced. (Heather & Hallman, 2008)

Food irradiation

Approximately sixty countries have established regulatory frameworks that allow for the irradiation of at least one type of food (IAEA, 2013). Seventeen countries use the technology commercially. In recent years, more than 500 million kg of food were irradiated (Kume & Todoriki, 2013). These treatments were carried out with various objectives including sprout inhibition, disinfestation of fresh produce and decontamination of meat, meat products, fish, seafood, spices and dried food. Forty per cent of this volume was treated in China, 20% United States, 13% Vietnam, 8% Mexico and 19% the remainder of the world (Kume *et al.*, 2009; Hallman, 2011). Many more countries could use irradiation as a commercial food processing technology, but they do not have the necessary facilities, and investors are reluctant to construct new facilities without proven markets (Bustos-Griffin *et al.*, 2012). This situation has limited the use of irradiation compared to other food processing technologies such as canning, drying, chilling, freezing and fumigation (US Department of Commerce, 2011; MarketLine Industry Profile, 2013a,b,c). The volumes associated with different processing technologies are summarised in Table 1. The volume of products treated with irradiation is relatively low in part because irradiation technology has not become competitive in price. A key reason for this is the lack of facilities. As a result, very little treated product is available for consumers, which leads to a general lack of awareness among consumers about the quality of irradiated products.

Table 1 Volumes of food processed by different technologies

Processing technology	Volume (Mt × 10[3)]
Canned[a]	17 000
Frozen[b]	24 300
Chilled & deli[c]	102 518
Dried[d]	6498
Fumigation& hot water treatment[e]	1307
Irradiation (total volume)	500
Spices and dried food	280
Sprout inhibition	85
Decontaminated meat	9
Fruit and vegetables	17
Decontaminate fish, sea food and others	109

[a]Market Line Industry Profile. Global Canned Food, February, 2013.
[b]MarketLine Industry Profile. Global Frozen Food, March, 2013.
[c]MarketLine Industry Profile. Global chilled & Deli, February, 2013.
[d]ICON Group International Inc. World Market for Dried food (2011).
[e]Mangoes, grapes and asparagus imported by the United States (Department of Commerce, 2011).

Phytosanitary irradiation in commerce

The first commercial use of PI was in 1986 when Puerto Rico sent treated mangoes to Florida (Hallman, 2011). Since then, only eight countries have used PI commercially for trade in nine different fresh commodities; mango, longan, mangosteen, dragon fruit, rambutan, guava, manzano pepper, sweet lime and grape. The total volume treated for trade in 2013 was 12 853 500 kg. Fifty per cent of this was guava exported from Mexico to the United States (Food Irradiation, 2014).

There are currently fourteen facilities certified by APHIS, six in the United States, two in Thailand, two in Vietnam, two in Mexico, one in South Africa and one in India. Australia certified a facility to treat fresh commodities (CTIS, 2013). Central America, South America, the Caribbean and Africa have the greatest need for facilities. Some countries in these regions have an abundance of products to export (Bustos-Griffin *et al.*, 2012). Access to irradiation facilities might allow these countries to generate new markets. The United States is a proven market for produce irradiated for phytosanitary purposes. Ninety per cent of PI used today is for export to the United States.

As the volume of high quality produce available for the global market rises and the number and size of potential markets also increases, the opportunities for PI applications continue to grow (Diop & Jaffe, 2005; Thow & Priyadarshi, 2013).

Many countries produce enough fresh fruit and vegetables to support investment in new facilities for export. Table 2 shows the estimated volume of fruits and vegetables that might benefit from either phytosanitary or commodity quality treatments in Africa, Asia, Latin America and the Caribbean. Existing irradiation facilities in the regions that are presently certified by APHIS (a total of eight) could only treat a small fraction of that potential. Several countries are seriously considering new facilities, including Peru and Guatemala (Byron & Luckman, 2008).

Irradiation at port of entry

The United States at present time has eight commercial irradiation facilities certified by APHIS for phytosanitary treatments. These facilities are located at Sioux City, IA; College Station, TX; Gulfport, MS; Mulberry, FL; and two facilities in Hawaii (Hilo and Honolulu). A facility is also being built in McAllen, TX, on the border between Mexico and the United States (CTIS, 2013). Exporting countries could use these facilities to irradiate commodities upon arrival in the US. The summary that follows describes the potential for selected countries in different regions to utilise port of entry treatment to increase or expand their markets for fruits and vegetables in the United States.

Asia

The continent has forty-eight countries and produces 60% of global horticultural products. The percentage of Gross Domestic Product due to agriculture in South-east Asia averages 33.4% (FAO, 2013b). Sixteen countries in Asia are involved in food irradiation treating 280 223 tons of food. China is the leader with 200 facilities treating 60% of the total for this region. Japan has been practicing food irradiation since 1973, but only treats potato to prevent sprouting (Kume & Todoriki, 2013).

Table 2 Estimated volumes (Mt) of fruits and vegetables[a] that may take advantage of phytosanitary or commodity quality treatment by irradiation in three regions and the number of APHIS-certified facilities in each region

	Latin America and the Caribbean	Asia	Africa
Fruit	3 113 958	9 890 691	1 107 694
Vegetables	535 690	12 195 582	1 092 655
Total	3 649 548	22 086 272	2 200 349
APHIS-certified facilities[b]	2	5	1

[a]Based on selected fruits and vegetables commonly treated either for quarantine pests or to increase shelf life, or both, including pome fruit, stone fruit, bananas, mango, papaya, grapes, strawberries, asparagus, peppers, garlic, potatoes and sweet potatoes. (FAO, 2013a).
[b]CTIS, 2013.

The three Asian countries that are already exporting to the United States are India, Thailand and Vietnam. Pakistan and Philippines have recently received clearance to export to the United States, and Pakistan has exported some mangoes, which were irradiated in the US upon arrival. Bangladesh, Indonesia, Israel, Malaysia, Sri Lanka, Korea and Turkey have suitable facilities and regulations and use irradiation for domestic products (ICGFI, 1999).

Laos, Mongolia and Syria have regulations that allow the use of irradiation to treat food, but have not yet seen commercialisation of the technology (Bustos-Griffin *et al.*, 2012). Table 3 summarises the Asian countries and commodities with potential for export to the United States using PI. Many of the fruits and vegetables listed in the table have already had risk assessments by APHIS and are approved for import into the United States with treatment.

Example: Philippines

In February 2013, APHIS authorised commercial importations of fresh litchi, longan and rambutan fruit from the Philippines into the continental United States using PI, and the country already had the possibility to export mango from pest free areas. Obra *et al.* (2013) determined that a PI dose of 165 Gy is an effective disinfestation for mango pulp weevil, *Sternochetus frigidus;* the presence of this pest in Palawan province has prevented the export of Philippine mangos to the United States.

The availability of facilities for treatment on arrival in the United States allows Philippine producers/exporters to take advantage of export possibilities and build a market before investing in new facilities in the Philippines.

Africa

This continent has sixty countries and remains largely marginalised in global trade. In 2009, the continent accounted for only 3% of world merchandise exports, corresponding roughly to its share in global GDP. At the same time, African trade is more outward-oriented than in any other continent; only ~12% of its total trade is directed intraregionally. Agriculture represents from 20% to 43% of GDP in sub-Saharan Africa (FAO, 2013b).

Although sixteen countries in Africa are involved in food irradiation and have treated more than 16 000 tons, one country, South Africa, does most of the treatments and is the only country with an

Table 3 Countries in Asia with potential food products to irradiate

Country	Principal commodities	Status
Bangladesh	Potato, sweet potato, mango, mangosteen, guava, tomato	IDM[a]
Indonesia	Mango, chilli, pepper, dried food, frozen food	IDM
Laos	Sweet potato, citrus, chilli, pepper.	Authorised irradiated food
Malaysia	Papaya, rambutan, starfruit, jack fruit	Imported irradiated fruit
Mongolia	Potato, other vegetables	Authorised irradiated food
Pakistan	Apple, apricot, mango, orange, tangerine	Clearance for APHIS
Philippines	Lichee, longan, rambutan, mango, papaya, asparagus	Clearance for APHIS
Sri Lanka	Potato, sweet potato, tomato, mango, dried vegetables, fruit	IDM
Turkey	Apple, pear, grape, peach	IDM

[a]Irradiation for domestic market (FAO, 2013a), IAEA (2013).

APHIS-certified facility. In 2013, South Africa exported PI-treated grapes and persimmons to the United States. (Food Irradiation, 2014) Algeria, Egypt, Ghana, Libya, Nigeria, Zambia and Cote d'Ivoire also have facilities that could be used for export treatments, currently only used to treat products for domestic markets. Burundi, Congo, Ethiopia, Kenya, Libya, Senegal and Tanzania have small facilities and have performed economic studies for the construction of an irradiation facility, but the next steps remain uncertain (IAEA, 2002; Bustos-Griffin, 2007; Byron & Luckman, 2008).

The remaining countries of Africa are presently not in a favourable economic position to utilise the technology, although risk assessments are pending for export to the United States from Benin, Burkina Faso, Gambia, Guinea, Liberia, Niger and Senegal (Ferrier, 2010). Table 4 summarises the African countries and commodities with potential for export to the United States with irradiation treatment. Many of the fruits and vegetables listed in the table have already had risk assessments by APHIS and are approved for import into the United States with treatment.

Table 4 Countries in Africa with potential food products to irradiate for export

Country	Product	Status
Ghana	Eggplant, okra, pepper, mango, papaya	IDM[a]
Nigeria	Mango, papaya	Irradiation facility
Zambia	Green bean, garlic, leek, okra, pepper, sugar snap bean, snow pea	Pilot plant
Cote d'Ivoire	Mango, papaya	IDM

[a]Irradiation for domestic market (FAO, 2013a), IAEA (2013).

Example: Kenya

Nearly, 80% of the population of Kenya works in agriculture, contributing 25% to the gross domestic product. Due its location on the coast, astride the equator and bordering the Indian Ocean, Kenya enjoys a generally moderate climate with a long rainy season from April to June and a short rainy season from October to November. This allows Kenya to produce fresh agricultural products all year (Bustos-Griffin, 2007).

The Kenya Plant Health Inspectorate Service (KEPHIS) has requested official authorisation from USDA to export fourteen fresh products to the United States, some of which present phytosanitary problems (KEPHIS, 2005). The country does not have a specific law or standard that addresses the use of irradiation for sanitary or phytosanitary purposes. The Ministry of Health's Food Laws require only that irradiated food must be labelled. Kenya has only one small irradiator that is used to control trypanosomiases (Bustos-Griffin, 2007). Table 5 describes Kenyan commodities with potential for export with irradiation treatment.

The Americas

The Americas includes fifty-three countries of North America, Central America, South America and the Caribbean. The agri-food sector has great importance in Latin America and the Caribbean countries where agriculture contributes 25% to the GDP and comprises 40% of exports. Seventeen countries use food irradiation, and in 2012, 173 600 tons of food products were treated. The United States irradiated close to 60% of the total and is the country with more facilities. Canada, Argentina, Brazil, Chile, Costa Rica, Cuba, Mexico, Peru and Uruguay have practiced commercial food irradiation. Colombia, Ecuador, Venezuela and Bolivia have research facilities. Jamaica, Haiti, Paraguay and most of the countries of

Table 5 Fresh commodities from Kenya with the potential for PI at the port of arrival in the United States

Commodities	Volume	Varieties
Mango	50 956	Tommy Atkins, Van Dyke, Keitt, Kent, Apple, Haden, Ngowe, Boribo
Passion fruit	9800	Purple passion fruit
Bean	13 000	Monel, Claudia, Gloria, Espada, Maasai and Morgan.
Peppers	300	Anaheim, Fresno, Jalapeno, Long red cayenne
Zucchini	1624	Ambassador F1 hybrid, Cocozelle, Dark green zucchini, Little gem
Okra	4116	Pusa sawani, Clemson spineless, Green emerald, Dwarf long pod green, White velvet.
Eggplant	6449	Black beauty, Florida high bush, Ravaya

Bustos-Griffin, 2007; KEPHIS, 2005.

Table 6 Countries in America and their commodities with potential for PI at the port of arrival in the United States

Countries	Product	Volume (MT)
Argentina	Citrus	10 000
	Pome fruit	10 000
Nicaragua	Mango	3000
Costa Rica	Mango	1000
Chile	Grape	200 000
Peru	Mango	40 000
	Asparagus	80 000
Jamaica	Mango	5000
	Citrus	5000
Haiti	Mango	9000
	Citrus	
Ecuador	Mango	30 000
Guatemala	Mango	17 000

IAEA-SAGARPA, 2007; FAO, 2013a.

the Caribbean basin do not have facilities or experience in food irradiation (IAEA-SAGARPA, 2007).

Mexico is the only country in this region with APHIS-certified facilities (two) for phytosanitary treatments. Nine commodities are authorised for export from Mexico to the United States with irradiation: carambola, grapefruit, guava, lime, mango, orange, manzano pepper, tangelo and tangerine. Many more fresh commodities that are authorised for export from Mexico to the United States could be treated by irradiation. Table 6 summarises countries in the Americas and potential commodities for export with treatment on arrival in the United States.

Example: Colombia

Colombia has several advantages for exporting fresh products to the United States. It is a tropical country with a variety of ecosystems where more than ninety-

Table 7 (a) Principal commodities from Colombia and potential export volume, and freight costs to the US. (b) Second group of commodities from Colombia with potential to export to United States

Commodity	Volume Production (ton)	Volume Exportation (ton)	Cost (US kg^{-1}) Air Cargo	Cost (US kg^{-1}) Maritime Cargo
(a)				
Strawberry (*Fragaria* sp.)	45 000	13 500		
Gulupa (*Passiflora pinnatistipula*)			2.02	1.47
Mango (*Mangifera indica*)	200 000	60 000	1.37	1.18
Papaya (*Carica papaya*)	140 000	42 000		
Patilla (*Citrullus lanatus*	70 000	21 000		
Pitahaya (*Stenocereus* sp.)	6000	1800	4.68	4.13
Tangerine (*Citrus tangerina*)	100 000	30 000		
Uchuva (*Physalis peruviana*)	10 000	3000	2.90	2.35
(b)				
Curuba (*Passiflora* sp.)	15 000	4500	1.22	0.705
Feijoa (*Acca sellowiana*)	1400	420	2.02	1.47
Granadilla (*Passiflora ligularis*)	40 000	12 000	1.96	1.41
Guanábana (*Annona muricata*)	24 000	7200	1.16	1.06
Guayaba (*Psidium* spp.)	80 000	24 000	1.32	0.77
Lulo (*Solanum quitoense*)	60 000	18 000	1.57	1.026
Maracuya (*Passifora edulis*)	80 000	24 000	1.504	0.95
Tomate de Arbolo (*Solanum betaceum*)	120 000	36 000	1.41	0.886

AGRONET, 2013; Inversion en Hortofruticola, 2013.

Table 8 Unit cost of some commodities that could be irradiated for export to the US and the net margins

Country	Commodity	Import vol (MT year^{-1})	Unit cost (US/lb)	Retail store (US/lb)	Margin (US$/lb)
Haiti	Mango	9222.10	0.47	2.00	1.53
Guatemala	Mango	17 874	0.23	2.00	1.77
Peru	Asparagus	86 139.70	1.0116	3.99	2.974
Colombia	Mango	64 479.05	0.658/0.574	2.00	1.342 /1.426[a]
Colombia	Guava	24 191.62	0.648/0.395	2.99	2.342/2.545[a]

[a]The first cost is if shipped by air, the second by sea.
US Department of Commerce (2011), AGRONET (2013).

five types of fruit trees are planted and about forty-two species of vegetables, which include native species, as well as species brought from other continents. Colombia is the ninth biggest exporter of tropical fruits in the world (AGRONET, 2013).

Colombia has actively pursued authorisations with APHIS for a wide variety of products and has performed research to determine the minimum dose for several pests and the dose tolerance for fresh commodities. This country has the additional advantage of ports in Barranquilla, Cartagena and Santa Marta, which offer rapid navigation to Gulfport, Mississippi where facilities are available to perform treatments. Table 7a summarises the principal commodities from Colombia and volumes for potential treatment on arrival in the United States. The table also lists the unit cost of the freight by sea or by air. Table 7b lists a second group of commodities that can also be exported but require more research and risk analysis studies.

Cost and profitability of treatment

The primary challenge for constructing a new irradiation facility is the cost. A modest facility designed for PI (low dose treatments) requires an investment of US $2.5 million, but the cost could easily range from US $5 million to US $15 million depending on the size and amenities. Facility and labour costs will vary according to local conditions. To recover the investment, it is necessary to have consistently high volumes of product to treat.

Examples of profit margins for three countries that currently export commodities to the United States without PI are presented in Table 8. Haiti and Guatemala export mango disinfested with hot water treatment, and Peru exports asparagus using methyl bromide fumigation. Assuming that these commodities are treated with irradiation, on average the price for treatment ranges from US$0.0315 to 0.28/lb for doses of 150 to 400 Gy (Casar, 2008; Deecke, 2013; and Liquido, 2013). The cost of the treatment was added to the cost/pound of mangos or asparagus, and subtracting the cost/lb from the retail price, the margin in US$/pound is provided. By multiplying that by the import volume, it is possible to have an idea of the profitability of using PI in those instances. Another example in Table 8 shows two commodities from Colombia not currently exported to the United States.

Conclusion

International trade of fresh commodities irradiated for phytosanitary purposes has increased every year since the first routine commercial treatments in 2004. The quantity of irradiated product is small, but there is tremendous potential for PI to be competitive if exporters can open new markets without high initial investments in new facilities. Changes in the import requirements for the United States now make it possible to have treatments carried out in US facilities after arrival. This creates many new opportunities for exporting countries that may be interested in the US market, but are unable to build or use facilities in the exporting country.

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