CHAPTER 20

Global Status and Commercial Applications of Food Irradiation

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20.1 Background

A relatively small amount of irradiated food became available at retail stores during the late 1970s, 80s, and 90s. Most of the irradiated food was specialty items, such as frog legs in France and Belgium, seafood in Asia, potatoes, and onions. Spices and seasonings were routinely irradiated in many countries beginning in the 1980s but labeling was not required. During the 1980s, Carrot Top, a retailer in the Chicago, Illinois area, successfully marketed irradiated strawberries from Florida and found a strong preference for berries that had been irradiated because of their higher quality and longer shelf life.1,2 In 1998, Minnesota-based Rainbow Foods began to offer irradiated papaya from Hawaii. Prior to the year 2000, the availability of irradiated food in supermarkets was very limited. Since 2000, a rapidly increasing number of consumers around the world have purchased and continue to purchase irradiated fresh produce, meat, seafood, and other foods. The introduction of irradiated foods into the commercial market place has largely gone quietly, with positive consumer response and negligible or non-existent negativity. In most cases, the fact that a product has been irradiated and labeled as such is not an important consideration at
the point of purchase, unless an obvious benefit such as food safety is highlighted.

Retailers play a key role in the expansion of the availability of foods that have been irradiated since they decide whether to offer these products on their shelves. Merchants generally found that consumers were eager to purchase the items, not because they were irradiated but because the customer wanted to serve the product at the dinner table.

Some retailers still falsely believe consumers will not purchase irradiated food, even though foods that have been irradiated, especially imported fruits and vegetables, have been on their store shelves and successfully sold for several years. Lately retailers have become more open to adding irradiated foods to their shelves and the volume of irradiated items has increased dramatically, especially in the US, New Zealand, Australia, and several Asian countries.

### 20.2 Historical Perspective

The first successful marketing of irradiated ground beef in the US took place in Minnesota in May 2000 when several retailers began to offer frozen ground beef that had been irradiated. Following a series of massive product recalls due to bacterial contamination with *E. coli* O157:H7 and subsequent disease outbreaks, the Minnesota Department of Health took a pro-active role in encouraging retailers to add irradiated ground beef to their meat department. Minnesota-based Schwan’s, Inc., a nationwide foodservice provider through home delivery started marketing irradiated ground beef in 2000. Omaha Steaks of Nebraska, a highly respected meat company, has successfully marketed irradiated ground beef through mail order since 2000. Today, all non-cooked ground beef offered by Schwan’s and Omaha Steaks is irradiated. Wegmans, based in Rochester, New York, with over 90 supermarkets in the states of New York, New Jersey, Pennsylvania, and Virginia continues to be a strong believer in the irradiation process and is one of the most visible retail marketers of irradiated ground beef.\(^3\)\(^4\) Although Wegmans takes every measure to ensure that all its ground beef products are safe, the retailer views irradiation as a value-adding process that offers the consumer an additional layer of food safety protection. The fact that Omaha Steaks, Schwan’s, and Wegmans are retailers with impeccable reputations was an incentive for other retailers to at least “warm-up” to the idea of irradiation. Additional meat companies have begun to add irradiated ground beef to their product line and, in 2016, at least two more are strongly considering it.

During the first decade of the 2000s, an increasing amount of irradiated produce, mostly from Hawaii, Mexico, and Asia began to appear on US supermarket produce sections. In 2004/05, Australia began to market several irradiated produce items in New Zealand. By 2011, Australia was irradiating over one thousand metric tons (mostly mangoes) annually for the growing New Zealand market. In 2008, Mexico began marketing a large volume of
irradiated produce, mostly guavas in the US market. Actual market success in several countries showed other retailers that there was ample opportunity to expand the availability of irradiated fruit in the produce section. Currently, 22 countries, including the UK, France, Germany, Finland, Japan, China, the Republic of Korea, and India, are using about 515 radiation plants based on Russian technology. Moreover, the Rosatom State Atomic Energy Corporation plans to expand the use of food irradiation to the UAE, the Republic of Mauritius, and Malaysia.

20.3 Current Status

In this section, we will review the situation in regions that have significant amounts of irradiated food consumed or produced in their countries. We will provide a recap of recent developments in other areas that are successfully expanding the use of irradiation to gain market access (disinfestation), extend product freshness (shelf life extension), or improve food safety.

In the following, the irradiated food status is presented by continent, in alphabetic order, and in each region starting with the major irradiated food suppliers, followed by the countries expanding the use of irradiation.

20.3.1 Africa

20.3.1.1 South Africa

There are currently four commercial facilities in South Africa. The history of irradiation in South Africa commenced in the early 1960s when the Pelindaba plant was set up as part of the Atomic Energy Board’s efforts to use nuclear material for peaceful purposes under the auspices of Dr Rocco Basson. Long life, high-dose food packs were produced for use by the military, as well as fresh produce such as strawberries, demonstrating the successful use of irradiation for shelf life extension.

It became clear that the technology was commercially viable, which led to the establishment of an irradiator in Johannesburg in the early 1970s to treat a wide variety of products, including medical and food. This facility is currently owned by Steris.

The possibility of irradiating fruit destined for European countries, the biggest market for South Africa fruit, led to a facility being established in Tzaneen, a fruit growing area, in the early 1980s. The purpose of the irradiation was shelf life extension. When the EU finally decided irradiation was not an option, that facility was decommissioned in the mid-1980s.

Then followed Hepro Cape, established in 1986 in Cape Town, thereafter Gamwave in 1989 situated in Durban.

The Pelindaba facility was decommissioned in the mid-1990s and recommissioned in 2013, now run by Gamwave.

South Africa exported its first air shipment of litchis to the United States in 2016. This was the first time the South African litchi sector had supplied the
US market, following long negotiations for market access. South African officials consider this achievement as one of the major contributions on the country's initiative of expanding exports markets, positioning South Africa as one of the significant exporters in the world. One of the conditions stipulated by the US Department of Agriculture (USDA) includes irradiation treatment to eliminate certain pests and insects. A total of 54 ton of South African litchis reached US consumers in 2015. This is in addition to 203 tons of persimmons.

Foods Irradiated in South Africa. The figures supplied to the Department of Health from all four facilities span the past 10 years, up to the end of 2015, and are summarized in the bar graph below (Figure 20.1).

Shown in the following graph (Figure 20.2) are the food categories of which all but honey are dwarfed by the spice volume. A change in the legislation in 2011 led to the increase shown.

Spices are by far the biggest food category being irradiated (reaching 19 000 tons in 2014). They are either imported or local and irradiated for control of insects, yeasts, molds, and bacteria. The spices are sold as is, or as prepacks used in marinades.

The next largest category is honey, around 3200 tons, which is irradiated to combat American Foulbrood disease (AFB). Large volumes of honey are imported from around the world to supplement the local honey, the volumes of which are inadequate due to adverse drought conditions. The potential for foulbrood in honey is great as it is a devastating international problem. The bacterium causing this disease kills off the grubs in the hives, eventually leading to the death of the hive. It is a spore former and can therefore survive most things, except irradiation.

Bees are critical to the pollination of crops and, in an agrarian economy, their work is essential to the safe supply of food. Many bee farmers also send their empty hives to be irradiated. South Africa is the only country in the world legislating for the irradiation of imported honey to control AFB. Outbreaks that have occurred recently were traced back to honey imported, but not irradiated.

Fresh garlic is irradiated for the prevention of sprouting. As the commodity is lifted during harvesting, it is cooled down and imported into South Africa. Irradiating garlic early on in the growth cycle is effective in preventing sprouting, as well as the added advantage of phytosanitary control.

Dehydrated vegetables and powders are irradiated to control bacteria, yeasts, molds, and insects. These products are used in the manufacture of instant soups.

Dried fruits are usually treated with sulfur to prevent mold growth. Many people are allergic to sulfur and irradiation offers an excellent alternative. These fruits are mostly used in the manufacture of confectionary, yoghurt, and chocolates.

Eggs are irradiated in both the frozen and broken state, as are whole eggs. Eggs become rather runny when irradiated, and so are irradiated in the
Figure 20.1 Irradiated food quantity in South Africa in 2005–2015.
Figure 20.2 Irradiated food in South Africa per food category.
frozen state, adequate for use by confectioners. When irradiated whole, they are mostly used as a quarantine control mechanism to supply whole eggs to ecologically sensitive areas.

Rooibos tea has been irradiated since the 1980s, when *Salmonella* was found in tea exported to Australia. The Australian and Japanese governments refused irradiated produce in their country. An alternative was sought and Steam Sterilization was chosen, leading to lesser flavor and color.

Meat, meat casings, and seafood are irradiated in very tiny quantities for bacterial control and mostly in the frozen state. Nuts are irradiated at low doses to control insects. Doses are very low as the lipid content is high and can lead to organoleptic changes.

**Future of Irradiation in South Africa.** A radiant future is on the cards as food companies grow and more variety and complex recipes requiring top quality uncontaminated ingredients are offered to clients.

The phytosanitary application of irradiated fruits allows access to markets currently unavailable. South Africa has a very big fruit export market and, as more countries accept irradiation as a phytosanitary control, this will put the country in a position to offer a wide array of fruit to a greater number of markets. A Framework Equivalency Workplan with the US is in place. Other countries are enquiring about the process and the possibility of irradiating their imported fruit from South Africa.

### 20.3.1.2 Algeria

The Russian State Atomic Energy Corporation “Rosatom” and The Commissariat À l’Energie Atomique of the People’s Democratic Republic of Algeria signed a Memorandum of Understanding on cooperation in the field of nuclear energy for peaceful uses in May 2016. The cooperation will include health products as well as irradiation of food and seems to be part of a continuing effort to increase worldwide presence in the field of nuclear energy.⁶

### 20.3.1.3 Ghana

Ghana is in the process of establishing an irradiation program, with the US market being its primary target. Irradiation of eggplant, okra, and pepper are mandatory pre-requisites for US market access.

### 20.3.1.4 Zambia

The Zambian Government has signed agreements with Russia’s State Nuclear Agency Rosatom to lay the groundwork to build nuclear power plants in Zambia. A press release states that the cooperation will, among other things, develop a strategy to produce electricity and isotopes for diagnosis, cancer treatment, and the irradiation of food.⁷
20.3.2 America

20.3.2.1 United States of America (USA)

The USA has the most advanced commercial food irradiation program in the world and the volume of irradiated food consumed in the US is second only to China. Information on the current status of irradiation in the USA can be obtained at www.foodirradiation.org or from the Food Irradiation Update Newsletter published by the author.

A significant amount of the international trade in irradiated food has been driven by consumer acceptance of irradiated food in the US and access to that large and lucrative market. More than ten countries currently export produce to US retailers.

Food products irradiated or marketed in the US during 2015 included approximately 68,000 tons of spices, 30,000 tons of fruits and vegetables, and an estimated 12,500 tons of meat, poultry, and live oysters. An estimated 10,000 tons of other food items are also irradiated. Thus, approximately 125 thousand tons of food is irradiated or consumed annually in the US. The quantity of fruits and vegetables irradiated for disinfection increased by six-fold in 2015 compared to 2010, and the levels for other food items including ground beef are gradually increasing. The irradiated produce volume for 2015 includes about 6000 metric tons (14 million pounds) from Hawaii. Much of the additional irradiated produce consumed in the US is imported from countries that have signed trade agreements with the USDA. The irradiation of spices for decontamination continues to be the main food irradiation practice in the US. Approximately one-third of all commercial spices consumed in the US are irradiated.

US Imports. In 2015, the US imported almost 23 million tons of irradiated produce from seven countries. This is in addition to the approximately 6000 tons of irradiated produce from Hawaii that required irradiation to enter the continental US.

Exports of irradiated fruits from Asia to the US were initiated by India in 2007. In 2008, India exported 275 tons to the US. By 2016, the quantity reached over 600 tons. Thailand started to export irradiated fruits (longan and mango) to the US in 2007 and four kinds of irradiated fruit (mangosteen, 330 tons; longan, 595 tons; litchi, 18 tons; and rambutan, 8 tons) were exported in 2010. In 2015, Thailand exports to the US included mangosteen (466 tons), longan (21.5 tons), and mango (2 tons). Vietnam started shipping irradiated dragon fruit to the US in 2008 and the shipping of rambutan started in 2011. Exports from Vietnam to the US in 2015 included dragon fruit (1928 tons), litchi (35 tons), longan (383 tons), and rambutan (more than 200 tons). Pakistan has begun to access the US market and in 2015 exported 152 tons of mango. In 2015, South Africa exported over 200 tons of litchis and persimmons to the US. While Vietnam, India, and Thailand are the most active countries in pursuing US exports, other countries such as
Malaysia, Laos, and the Philippines are also expected to export irradiated fruits to the US in the future.

Mexico started shipment of irradiated guava to the US in 2008. Total exports were 257 tons in 2008 and 3521 tons in 2009. In 2010, these exports increased markedly to 10,318 tons and included guava (9121 tons) as well as sweet lime (600 tons), mango (239 tons), grapefruit (101 tons), and Manzano pepper (257 tons). In 2015, nearly 12,000 tons of Mexican produce crossed the US border. Over 9700 tons of the Mexican exports were guavas and the market for this fruit in the US is expanding beyond the ethnic markets. The major retailer offering Mexican guavas reports that their purchases in 2016 have quadrupled over 2015. Mexico has become the largest exporter of irradiated produce to the US because of the distinct cost advantage and rapid land transport between the two countries.6

**Irradiation Service Providers.** Gateway America, Gulfport, Mississippi, has become a major player in food irradiation in the US and increasingly has expanded their international business. Gateway America installed a Gray*Star Genesis II irradiator in 2012 and began offering commercial irradiation phytosanitary services on 2013. Gateway irrigates a large variety of food items, including ground beef, oysters, fruits, vegetables, and other products.

Gateway already irradiates ground beef for major suppliers and is currently having discussions with two additional processors. Irradiation of fresh oysters was initiated at Gateway America in 2015 and the volume is significantly increasing. Gateway America irradiates fresh oysters for several large seafood companies. With Vibrio cases on the rise, irradiation appears more attractive each day.

On the international scene, Gateway America has worked closely with several countries including Peru and Grenada to help them gain US market access through Framework Equivalency Agreements with the USDA/Animal and Plant Inspection Service (APHIS). Currently, Gateway is helping Colombia gain a foothold in the US market. Mexican fruit importers are also working with Gateway to expand their rapidly growing business.

**Framework Equivalency Agreements.** The USDA/APHIS has entered into agreements with more than a dozen countries. These agreements, known as Framework Equivalency Work Plans (FEWP), allow the import of specified commodities into the USA with the understanding that the partnering country will allow similar US products into their country. In many cases, irradiation is a mandatory phytosanitary intervention. As of 2016, 13 countries have signed the agreement. These include Australia, Dominican Republic, Guyana, India, Laos, Malaysia, Mexico, Pakistan, Peru, Philippines, South Africa, Thailand, and Vietnam. More are pending. The support of irradiation and encouragement of use by the USDA/APHIS has had a positive impact on increasing trade between the US and signatory countries.
20.3.2.2 Bolivia

In 2015, the government of Bolivia concluded a $300 million deal with Rosatom, Russia’s state-owned nuclear engineers, to build a research complex that will lay the technical basis for the country’s future civil nuclear industry.8

20.3.2.3 Brazil

United Innovation Corporation (UIC), a subsidiary of the Russian State Nuclear Corporation Rosatom, signed a memorandum of understanding (MOU) with Brazilian consultancy CK3 for the development, construction, and operation of an irradiation center in Brazil in 2015.

The agreement establishes cooperation between the parties and involves the coordination of efforts to implement and operate projects for an irradiation center in Brazil, using technologies based on the use of electron accelerators for the sterilization of pharmaceuticals, cosmetics, and healthcare products, among other applications including food irradiation.9

20.3.2.4 Canada

Currently, the list of items with irradiation protocol treatments includes whole and ground spices and dehydrated seasonings. Nordion is the only gamma facility processing food in Canada. Isotron, an e-beam facility in British Columbia, also irradiates some food products. The current volumes are shown in Table 20.1.

The above table shows a steadily increasing quantity of irradiated food. While volumes are relatively small, such a steady rise shows that consumers are “warming up” to food that has been irradiated.

The Canadian beef cattle industry has been asking the Canada government to approve ground beef irradiation since 1998, and it was only recently, at the beginning of 2017, that it was finally approved by Health Canada.10

20.3.2.5 Dominican Republic

In 2016, APHIS lifted import restrictions on a range of crops grown in the Dominican Republic, provided they meet certain pest mitigation standards including irradiation. The list includes clementines, grapes, grapefruit,

<table>
<thead>
<tr>
<th>Year</th>
<th>Total carriers</th>
<th>Total # of pieces</th>
<th>Total weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>3172</td>
<td>69,696</td>
<td>951,600</td>
</tr>
<tr>
<td>2011</td>
<td>3581</td>
<td>80,541</td>
<td>1,074,300</td>
</tr>
<tr>
<td>2012</td>
<td>3470</td>
<td>78,609</td>
<td>1,041,000</td>
</tr>
<tr>
<td>2013</td>
<td>3602</td>
<td>85,248</td>
<td>1,080,600</td>
</tr>
<tr>
<td>2014</td>
<td>3768</td>
<td>81,772</td>
<td>1,130,400</td>
</tr>
<tr>
<td>2015</td>
<td>4168</td>
<td>90,429</td>
<td>1,250,400</td>
</tr>
<tr>
<td>2016 (through 10/16)</td>
<td>4308</td>
<td>97,716</td>
<td>1,292,400</td>
</tr>
</tbody>
</table>
lemons, litchis, longans, sapote, mandarins, mangoes, oranges, papayas, peppers, pomelos, tangelos, tangerines, tomatoes, and cactus fruit.\textsuperscript{6}

20.3.2.6 Guyana and Grenada

Guyana was added to the USDA FEWP list of cooperating countries in 2016. Grenada will be irradiating June plums for access to the US market.\textsuperscript{6}

20.3.2.7 Hawaii

Hawaii is a pioneer in the use of phytosanitary irradiation. The first phytosanitary irradiation as a quarantine treatment of tropical fruits for export took place in Hawaii in the early 1970s.

Following the approval of irradiation by the US Food and Drug Administration for control of insects in produce in 1986, a permit was issued for a one-time shipment of papayas from Hawaii to California to test for the first time consumer in-store response to irradiated food.

Between 1995 and 2000, more than 300,000 kg (300 tons) of papayas and 100,000 kg (100 tons) of other fruits were shipped from Hawaii to the continental US for distribution in 16 states.

The number one irradiated Hawaiian export crop is purple (boniato) sweet potato. The volume of irradiated sweet potatoes increased from 1780 tons (57\%) in 2005 to 5370 tons (94\%) in 2010. In 2015, well over 90\% of the 6500 tons irradiated in Hawaii was sweet potato.

Hawaii also irradiates longan, rambutan, sweet basil, dragon fruit, papaya, curry leaf, banana, and mango (volumes roughly of the same order). To date, all irradiated produce has been sent to the US mainland; however, Hawaii will soon be sending their first irradiated papayas to New Zealand. In 2015, more than 6500 tons (6500 tons (about 15 million pounds)) of produce was irradiated. The volume has grown substantially in recent years.\textsuperscript{11}

There are two irradiation facilities operating in Hawaii; Pa’ina Hawaii and Hawaii Pride. The two Hawaiian irradiation companies irradiate about 6500 tons (about 15 million pounds) of products annually.

Irradiation Facilities. The commercial X-ray irradiation facility Hawaii Pride LLC has been shipping papaya and other tropical fruits and vegetables to the US mainland using irradiation since 2000. In 2008, Calavo Growers, Inc. purchased Hawaii Pride and the focus of irradiation switched from papayas to purple sweet potatoes.

Pa’ina Hawaii installed a Gray*Star Genesis II irradiator in 2012 and began offering commercial irradiation phytosanitary services on January 31, 2013. The facility is currently treating papaya, Okinawan purple sweet potato, sweet and Thai basil, Moringa leaves and pods (i.e., drumsticks), ginger, melons, taro leaves, curry leaves, longan, litchi, mangosteen, and rambutan using low-dose irradiation. A higher dose is used to sterilize the finely ground macadamia nut shell used as an ingredient in cosmetics. Thus far,
Pa’ina has been irradiating mostly Hawaii-grown products, but some imports from the US mainland to the Hawaii market are anticipated because irradiation is an alternative to methyl bromide fumigation. Potential also exists for high-risk pest commodities, such as cut flowers and foliage from Pacific Island areas for pest disinfestation. Plans are to use the Pa’ina Hawaii facility to irradiate Asian-grown produce destined for the US mainland.\textsuperscript{12}

\subsection*{20.3.2.8 Mexico}

The volume of produce irradiated in Mexico has shown steady growth. Mexico’s geographic proximity to the United States has been a key factor in this dramatic growth. Mexico was one of the first countries to establish a Framework Equivalency Work Plan with the United States. The first product to be irradiated in Mexico was guava in 2008. In that year, 265 tons were irradiated. That volume has increased about 15\% annually. In 2015, 11 700 tons of irradiated Mexican produce was exported to the US (see Table 20.2). This was a 17\% increase over 2014. Eighty-three percent of the amount was guava, followed by chile Manzano (\textit{Capsicum pubescens}) at 8.4\%, and mango at 6.7\%. While the bulk of products irradiated in Mexico are guavas, mangoes, and chile Manzano, other fruits of interest include grapefruit, mandarin, carambola, pomegranate, fig, dragon fruit, prickly pear, starfruit, and rambutan. Many major US retailers proudly offer irradiated Mexican produce on their store shelves. Consumer acceptance has been extremely strong.

The first shipment consisted of 257 kilograms of Mexican irradiated fresh figs, which arrived in the US in 2016. The first figs sent came from the Mexican states of Morelos and Puebla. Following the first shipment, a second load of 628 kilograms of fresh figs was sent. In July 2015, there were 200 hectares of fig production in Mexico, mostly in Morelos, Baja California Sur, Puebla, and Hidalgo. The current Mexican production is estimated at just over 6000 tons of figs, valued at about US$3 million. Irradiation is a mandatory phytosanitary requirement for the entry of Mexican figs into the US, which shows significant opportunity for growth.\textsuperscript{6}

\begin{table}[h]
\centering
\caption{Historical perspective of the export of irradiated Mexican fruit to the US.}
\begin{tabular}{lrr}
\hline
Product & 2010/11 & 2015/16 \\
\hline
Guavas & 5345 & 9709 \\
Mangoes & 213 & 781 \\
Chile Manzano & 97 & 982 \\
Pomegranate & 0 & 135 \\
Carambola & 0 & 27 \\
Pitaya/dragon fruit & 0 & 66 \\
Figs & 0 & 8 \\
Sweet lime & 0 & 5 \\
Total & 5655 & 11712 \\
\hline
\end{tabular}
\end{table}
ASEFIMEX (Asociación de Empacadoras de Frutas Irradiadas de México) is the cooperating organization with the USDA for the irradiation program. Benebion, Mexico’s first irradiation facility devoted entirely to food, based in Matehuala, San Luis Potosi, is playing a major role in making Mexican fruit exports to the US a reality.¹³

20.3.2.9 Peru

The volumes of irradiated food products in Peru are still very small, mostly because the only facility available is stuck in the middle of an administrative and legal quarrel between the government and a private investor. We hope this will be worked out with the new administration elected recently in the country. This private investor has the back up from Australian investors, so this gives some leverage, knowing the leading role in food irradiation of such a country.

In 2016, the USDA and APHIS determined that commercial consignments of fresh fig fruit (*Ficus carica*) and fresh pomegranate fruit (*Punica granatum*) could be safely imported into the continental US from Peru with safeguards in place. APHIS scientists conducted a pest risk assessment and determined the phytosanitary measures that will mitigate plant pests.

These mitigation measures, such as commercial consignments of fresh fig fruit required to be irradiated and inspected upon arrival to the US and also accompanied by a phytosanitary certificate from the national plant protection organization (NPPO) of Peru, have been determined to sufficiently protect the United States from the entry of high risk pests.⁶

**Food Irradiation Facilities.** Sydney, Australia-based ESA Accountants Pty Ltd., is upgrading Peru’s irradiation infrastructure with the aim of certifying a Lima plant for US-bound produce exports in 2017. A Peruvian company, Inmune S.A., has operated with a mainly domestic focus since its inception in 1995, but because of its close proximity to the Port of Callao and Lima International Airport, saw an opportunity and acquired the facility in 2014.

The fresh products scheduled for irradiation for the Peruvian domestic market are potatoes, beans, citrus, and pineapples and for the export market fresh asparagus, grapes, mangoes, avocados, mandarins, pomegranates, figs, peppers, blueberries, peas, cherimoyas, vegetables, and other products destined for the North American and European markets.⁶

20.3.3 Asia

Todoriki *et al.* compared available data from 2010, with information gathered five years earlier in 2005.¹⁴ Data on food irradiation in Asia in 2010 were obtained from participants at the International Atomic Energy Agency (IAEA)/Regional Cooperation Agreement (RCA) Final Progress Review Meeting of Project RAS/5/050 and the Project Planning Meeting of RAS/5/057,
which was held in Hanoi, Vietnam from March 26 to 30, 2012. Data for the EU in 2010 were obtained from a report published by the European Commission. In most cases, the year 2015 has served as the benchmark. Todoriki’s study showed that the quantity of foods irradiated in Asia had increased by approximately 100 000 tons between 2005 and 2010. There were 285 200 metric tons of food irradiated in the ten surveyed countries during 2010 compared to 183 243 tons in 2005 (see Table 20.3).

China saw an increase of 120 000 tons between 2005 and 2010 and an increase of 334 000 tons during the next five years. China leads the world in irradiated food volume, with an estimated 600 000 tons irradiated in 2015. Vietnam saw an overall increase of approximately 50 000 tons from 2005 to 2010. The total volume for 2015 in Vietnam is not available, but exports to the US were over 2500 tons and non-existent five years earlier. In 2010, China was responsible for 70% of all irradiated food in Asia, followed by Vietnam with 23%. In 2005, these figures changed to 80% and 8% for China and Vietnam, respectively. After China and Vietnam, Indonesia (6923 tons) and Japan (6246 tons) irradiated the largest quantity of food in 2010.

20.3.3.1 China (PRC)

The largest volume of irradiated food consumed in the world is irradiated in China. It is estimated that a total of 600 000 tons of irradiated food was treated and consumed in China in 2015. Irradiated products include garlic, spices, grain, cooked meat, chicken feet, health foods, and herbal ingredients (see Table 20.4). Irradiated pickled chicken feet account for more than half of the volume. The volume of food irradiated in China is increasing at a rate of about 20% annually.

In China, food products are treated at about 120 irradiation $^{60}$Co facilities and 20 e-beam facilities. The designed capacity of 16 $^{60}$Co facilities is larger than 2 MCi (74 000 TBq) in 2015.

<table>
<thead>
<tr>
<th>Country</th>
<th>Quantity (tons)</th>
<th>2005</th>
<th>2010</th>
<th>2015/16</th>
<th>Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td></td>
<td>146 000</td>
<td>&gt;266 000</td>
<td>&gt;600 000</td>
<td>Garlic, spices, grain, meat, chicken feet, health foods, other</td>
</tr>
<tr>
<td>India</td>
<td></td>
<td>160</td>
<td>210</td>
<td>&gt;700</td>
<td>Mangoes</td>
</tr>
<tr>
<td>Indonesia</td>
<td></td>
<td>4011</td>
<td>6923</td>
<td></td>
<td>Cocoa, frozen sea foods, spices, other</td>
</tr>
<tr>
<td>Japan</td>
<td></td>
<td>8096</td>
<td>6246</td>
<td>5767</td>
<td>Potatoes</td>
</tr>
<tr>
<td>Korea</td>
<td></td>
<td>5394</td>
<td>300</td>
<td>NA</td>
<td>Dried vegetables</td>
</tr>
<tr>
<td>Malaysia</td>
<td></td>
<td>482</td>
<td>785</td>
<td></td>
<td>Spices, herbs, other</td>
</tr>
<tr>
<td>Pakistan</td>
<td></td>
<td>0</td>
<td>940</td>
<td></td>
<td>Legumes, spices, and fruits</td>
</tr>
<tr>
<td>Philippines</td>
<td></td>
<td>326</td>
<td>445</td>
<td></td>
<td>Spices, dried vegetables</td>
</tr>
<tr>
<td>Thailand</td>
<td></td>
<td>3000</td>
<td>1485</td>
<td></td>
<td>Fruits, other</td>
</tr>
<tr>
<td>Vietnam</td>
<td></td>
<td>14 200</td>
<td>66 000</td>
<td></td>
<td>Frozen seafood, fruit, other</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>183 243</td>
<td>285 223</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Chapter 20
Food Irradiation Facilities in China. China General Nuclear Power Group (CGN) Nuclear Technology Application Co, Ltd, Haidian District, Beijing, and CGN Dasheng Electron Accelerator Co Ltd, Jiangsu, are major players in food irradiation. The CGN Shenzhen-based leading nuclear power provider in PRC with 30,000 employees has extensive, diverse, and growing interests in energy with substantial resources. The CGN is largely government-owned.

20.3.3.2 India

Since 2006, all mangos moving between India and the US are expected to undergo irradiation treatment. In 2016, more than 700 tons of mangoes were exported to the US after irradiation. The quantity of mangoes irradiated for phytosanitary purposes for US export has grown substantially from 157 tons in 2007 to 275 tons in 2008. It then decreased to 130 tons in 2009, and to 95 tons in 2010. USDA has also approved irradiation of pomegranate for its export from India to the US. Mandatory irradiation is required by the US for import of mango and pomegranate from India.16

The first shipment of 1.2 tons of mangoes and pomegranates produced at Innova Agri Bio Park was exported from India to the US in June. The shipment contained 250 boxes of mangoes and 50 boxes of pomegranates under the brand ‘FarmRus.’ All were irradiated as a mandatory USDA requirement.6

In 2016, India gained irradiation protocol access for their counter seasonal mangoes to the Australian market. Prior to this, India had an alternate protocol treatment, which complicated quality control for exporters. Financial losses for exporters and growers were common and partly related to the detrimental impact on the arrival quality of mangoes. The industry is hopeful that the new irradiation protocol will be a significant step forward in meeting Australian market expectation for quality and maturity.

Food Irradiation Facilities in India. Currently, there are 16 radiation-processing facilities in India, two in the public sector and 14 in the private sector. Only five of these are dedicated to food irradiation. Others also irradiate medical and pet food products. In food specifically, most of these facilities irradiate spices, condiments, and dehydrated vegetables, mainly for export.

In 2016, India and Russia signed a pact to set up 25 integrated infrastructure centers for irradiation treatment of perishable food items to improve the shelf life and cut post-harvest losses. The agreement was signed between Russia’s United Innovation Corporation (UIC) – a subsidiary of
Rosatom State Atomic Energy Corporation – and Hindustan Agro Co-op Ltd on the sidelines of the BRICS Business Forum. Plans are to set up at least seven centers in Maharashtra, with the first center near Shirdi to be ready in 2017. Perishable items ranging from flowers to fish will be treated there on a commercial scale.

The use of this irradiation technology will make it possible to reduce the loss of onions in India, which currently go bad because of germination and inadequate storage, by 42,000 tons per year on average, as well as to reduce grain losses from 15% to 35% per year.\(^8\)

Mangoes are irradiated only in USDA approved units. These are Krushak, Lasalgaon, and Maharashtra State Agricultural Marketing Board, Mumbai.

Maharashtra-based Kay-Bee Exports became the first Indian company to export pomegranates to the North American market. A year-round supply of fresh Indian pomegranates looks set to provide Kay Bee Exports with a new window of opportunity in the US. India is the only country in the world with 365-day availability and fresh pomegranate harvest. Irradiation is a mandatory protocol.\(^6\)

20.3.3.3 Bangladesh

A \(^{60}\)Co gamma irradiation facility of 30 kCi (1110 TBq) was installed at the research institute (AERE) of the Bangladesh Atomic Energy Commission in 2010, and four tons of spices were irradiated in 2010. A commercial plant (85 kCi, 3145 TBq) was built in 1993 and 120 tons of fruit and dry fish were treated from 1994 to 1998.\(^{17}\)

20.3.3.4 Indonesia

The first regulations for food irradiation were established in 1987 and updated in 1995, with further revisions in 2009. The volume of food irradiated in Indonesia is increasing annually. Twelve food items are now approved, including cocoa (80%), frozen foods (7%), spices (5%), and other foods including dehydrated vegetables, seaweed, and honey. In Indonesia, 6923 tons of food was irradiated in 2010. This was carried out at a private irradiation facility (30 kCi, 1110 TBq) installed in 1992. In 2009, the regulations were modified to include fruit disinfection (1 kGy for mango and mangosteen), meat disinfection (7 kGy for beef and chicken), and sterilization of pre-cooked foods (65 kGy). Ready-to-eat foods have been approved at a minimum dose of 45 kGy.\(^{13,18}\)

Indonesia approved 44 Australian varieties of fresh produce for irradiation in 2015.\(^{19}\) Current limitations for Indonesian importers of Australian products under new protocols include the logistical cost of accessing irradiation services from the Australian grape production regions and restricted import windows for some citrus varieties. Although the latter cannot be easily rectified, Australia’s leading provider of irradiation services Steritech has strategic plans to increase access to treatment services within Australia.
Irradiated grapes from Australia made their debut in Indonesia in 2016. It is expected that more Australian food items will reach Indonesia in the future.

### 20.3.3.5 Iran

The history of radiation processing in Iran dates back to the establishment of a Gamma Irradiation Center (GIC), IR-136, in 1985 in Tehran. Later in January 1998, the Yazd Radiation Processing Center (YRPC) was created using e-beam technology. Both of these centers are subordination to the Atomic Energy Organization of Iran (AEOI). Food irradiation, sterilization of medical products, and to some extent polymer modification is performed in these centers, with a total irradiated volume of approximately 36,000 cubic meters per year.

Moreover, there are two irradiation centers which will start operation in 2017. The first multipurpose gamma irradiation facility named Bonab Industrial Irradiation Unit (BIIU) will have an annual throughput of 50,000 cubic meters. The other facility, the biggest multipurpose gamma irradiation facility in Iran, named Shahr-e Kord Multipurpose Gamma Irradiation Facility (SMGIF) with a throughput of 100,000 cubic meters, will be implemented by SPI Co. (Private Joint Stock Co.) in the heart of Iran, in the Special Economic Zone of Chaharmahal and Bakhtiari Province. The main objectives of these multipurpose gamma irradiation facilities will be gamma sterilization of health care products and food irradiation. By operation of these two facilities, Iran’s total throughput of irradiated products will rise to 186,000 cubic meters per year. The list of the largest volumes of irradiated foods includes spices, dried vegetables, herbs, starch, cereals, shallot, onions, rice flour, tea, cumin, pepper, mushroom, celery, flowers, ginger, and soups.

### 20.3.3.6 Japan

Commercial irradiation has been successfully carried out for approximately 40 years at the Hokkaido Shihoro Irradiation Center. Only potato irradiation is permitted in Japan. The initial quantity of over 21,707 tons of irradiated potatoes in 1975 decreased to 8,096 tons in 2005. It further dropped to 3,339 tons in 2006 because of new retail labeling regulations, but gradually recovered to 6,246 tons by 2010 after concerted efforts from businesses. A total of 57,666.6 tons of potatoes were irradiated in 2015 for sprout inhibition. While the total volume is relatively small, the irradiated volume continues to be steady, indicating continuing consumer demand for the product.

### 20.3.3.7 Malaysia

In 2010, 785 tons of spices and herbs were irradiated; the products included curry powder, coriander, and pepper. Commercial irradiation started in 1970 at the 60Co γ-irradiation facility (SINAGAMMA) of the Malaysian Institute for Nuclear Technology Research. This plant has processed 70–80
tons every year since 2006. Recently, there have been discussions with the US concerning the possible disinfestation of fruits (star fruit, papaya, rambutan, and jack fruit) for quarantine purposes. Although Malaysia is a relatively open market for horticultural trade with few import biosecurity requirements, Australian mangoes are subject to an irradiation treatment protocol. Malaysia is one example of a growing trend for open markets that are increasing import requirements. Proactively developing effective protocols can be an important tool to limit the risks of losing market access with limited notice.

20.3.3.8 Pakistan

A private sector company initiated commercial food irradiation in 2010. A total of 940 tons of legumes, spices, and fruits were processed in that year. In 2010, permission was given for the development of three new food irradiation facilities and the export of irradiated mango began.

20.3.3.9 Philippines

In 2015, 500 tons of spice, dehydrated vegetables and meat, and herbal products were treated at the Co-60 Irradiation Facility of the Philippine Nuclear Research Institute. Food irradiation is still in the semi-commercial stage in this country, but fruit irradiation for quarantine processing for export to the US is expected to take place in the near future. A newly built electron beam facility was completed in 2015 and will serve as another irradiation facility for treating foods.

20.3.3.10 South Korea

In 2010, total food irradiation in South Korea comprised only 30 tons of dehydrated vegetables. This was a sharp decrease from the 540 tons in 2005 because of the introduction of rules that had mandated the labeling of ingredients for various products. There is no recent data on irradiated foods in Korea. Although the Korea Atomic Energy Research Institute (KAERI) has been investigating food irradiation for allergy patients, as well as irradiation of foods suitable for use for military personnel and astronauts, it remains unclear whether food irradiation levels in Korea will recover. Currently, there are seven irradiation-processing facilities in Korea, two in the public sector and five in the private sector. The five private facilities are approved for irradiation of food for human and pet consumption. Medical and industrial products are irradiated at these same facilities. Due to the mandatory labeling of all irradiated foods including ingredients since 2010, the food industry has been hesitant to use irradiation for their food products. The Animal and Plant Quarantine Agency of Korea amended “Regulations for phytosanitary treatment of import and export plant” on December 2, 2015 to include radiation treatment with gamma rays, electron beam, and X-rays for
some fresh fruits and cut flowers, which is a positive step.¹⁴,²⁵ The global trade increase in irradiated foods is expected to reassure the food communities and Korean consumers that irradiation is a safe and viable procedure.

20.3.3.11 Sri Lanka

Food irradiation in Sri Lanka is in its infancy; however, a multipurpose irradiation facility (30 kCi; 1110 TBq) for radiation processing and food irradiation was opened in 2014 and a commercial facility is now operating.²⁶

20.3.3.12 Thailand

In 2010, a total of 1484 tons of agricultural products, herbs, frozen foods, and processed foods were irradiated at the irradiation center of the Thailand Institute of Nuclear Technology and at a private sector facility. Although the 2010 total had decreased compared to the 3000 tons processed in 2005, it is presumed that the actual total amount is increasing because private-sector data for 2010 was obtained only for fruits. The export of irradiated fruits to the US was 951 tons in 2010.¹⁴,²⁷

20.3.3.13 Vietnam

In 2016, the USDA/APHIS published a proposed rule to allow the importation of fresh mango fruit (*Mangifera indica L.* ) from Vietnam into the continental United States.⁶ In 2015, the following quantities of irradiated produce were exported to the US; dragon fruit (1928 tons), longan (383 tons), rambutan (200 tons), and litchi (36 tons). Litchi was the first Vietnamese fruit shipped to Australia, starting May 2015. Litchi exports reached 28 tons at the end of 2015. Mango has been accessible since November and the first shipment is expected soon. In 2014, Vietnam became the first country to export dragon fruit to New Zealand, after the two countries agreed on procedures to ensure safety requirements, which include irradiation. In 2015, Vietnam sold over 200 tons of rambutan, 357 tons of litchi, and nearly 2000 tons of dragon fruit to the US, as well as some longan. A year earlier, 2.1 tons of litchis were taken straight from Noi Bai, Vietnam International Airport, to Ho Chi Minh City for irradiation and quality quarantine before being exported to the US. In the future, Vietnam expects to export about 3000 metric tons of irradiated mangoes to the US annually.²⁸

Vietnam signed an agreement with Australia in 2015, which approved oranges, mandarin, and table grapes for import into Vietnam. Australia commenced work on granting market access for fresh dragon fruit from Vietnam into Australia. Australia is also considering other Vietnamese fruits. During the 2015/16 season, Vietnamese importers aircfreighted 800 pallets of irradiated Australian grapes to service their high value market. Industry figures show that the total Australian grape exports to Vietnam during
2015/16 were just under 5000 Mt. This suggests that over 10% of all exports from Vietnam’s Australian grape imports were treated with irradiation and airfreighted.\textsuperscript{16}

Industry participants noted that the additional cost for road freight to access the irradiation treatment for the Vietnam–Australian grape imports was approximately 10% of the total grower return without factoring in the additional cost of airfreight to Vietnam. Vietnam's strong demand justified a significant price premium for this fresher premium product. This proves to be a strong indication of the potential growth in table grape trade between these two nations, if more efficient access to irradiation services can be developed.

The APHIS published a rule proposing to allow fresh Vietnamese mangoes into the continental United States. The rule proposes that Vietnamese mango fruit can be safely imported into the continental United States if it meets several conditions. Under the proposal, the fruit would be required to be grown in an orchard that has been treated for pests or certified as pest-free. Shipments will also need to be treated with irradiation.\textsuperscript{29}

**Food Irradiation Facilities.** Food irradiation in Vietnam has developed rapidly and Vietnam has become a major supplier of irradiated produce and other foods. Both Vietnam Atomic Energy Institute's Ho Chi Minh Irradiation Center (VINAGAMMA) and private sector companies irradiate large quantities of frozen seafood and fruit.

\section*{20.3.4 Europe}

\subsection*{20.3.4.1 European Union}

The irradiation of dried aromatic herbs, spices, and vegetable seasonings is authorized at EU level by Directive 1999/3/EC of the European Parliament and of the Council on the establishment of a Community list of food and food ingredients treated with ionizing radiation.\textsuperscript{30} In addition, seven Member States have notified to the Commission that they maintain national authorizations for certain food and food ingredients, in accordance with Article 4(4) of Directive 1999/2/EC. The list of national authorizations has been published by the Commission.

Any irradiated foodstuff containing one or more irradiated food ingredient must be labelled with the words “irradiated” or “treated with ionizing radiation”. If an irradiated product is used as an ingredient in a compound food, the same words shall accompany its designation in the list of ingredients. In the case of products sold in bulk, these words shall appear together with the name of the product on a display or notice above or beside the container in which the products are placed.

**Summary for the European Union.** Table 20.5 summarizes the quantities of foodstuffs (in tons) treated by ionizing radiation in the approved
irradiation facilities located in 14 Member States within the European Union.

The European Commission publishes statistics for commercial food irradiation in the EU every year. Table 20.5 shows the quantities of irradiated foods in the EU in 2015 and the 2010 data are also provided for comparison. Ten countries reported commercial irradiation and the total quantities of irradiated foods were 9264 tons in 2010 and 5686 tons in 2015. Belgium (3917 tons), the Netherlands (629 tons), and France (377 tons) irradiated more than 100 tons of food in 2015. Compared to the 2010 quantities, there was a decreasing trend: Belgium had decreased its output by 33%, Netherlands had reduced in 60% its food irradiation levels, and France had reduced these levels by approximately one-third.

20.3.4.2 Belgium

Many food items are irradiated commercially in Belgium. In 2010, the total quantity of 5840 tons comprised 3572 tons of frog legs, 1481 tons of poultry, 285 tons of herbs and spices, 178 tons of dehydrated vegetables, and 101 tons of fish, shellfish, and others (meat, vegetables, starch, and egg powder). The volume decreased to 3917 in 2015.

20.3.4.3 Czech Republic, Estonia, Germany, Poland, and Spain

In the Czech Republic, Estonia, Germany, Poland, Romania, and Spain, only dried aromatic herbs, spices, and vegetable seasoning are irradiated. The quantity of irradiated food was 6 tons in the Czech Republic, 37 tons in Estonia, 211 tons in Germany, 46 tons in Poland, and 326 tons in Spain. Food irradiation started only after 2005 in Estonia, Romania, and Spain.

20.3.4.4 France

In France, the food products irradiated in 2010 comprised 474 tons of frozen frog legs, 463 tons of poultry, 85 tons of gum Arabic, and 2 tons of herbs, spices, and dried vegetables, which represented 1024 tons in total. The volume decreased to 377 in 2015.

20.3.4.5 Hungary

In Hungary, irradiated food products in 2010 included 143 tons of herbs and spices and 8 tons of dehydrated vegetables, representing 151 tons in total.

20.3.4.6 The Netherlands

In the Netherlands, many different food products were irradiated. In 2010, these food products included 482 tons of dehydrated vegetables, 36 tons of frog parts, 30 tons of spices/herbs, 160 tons of egg white, 137 tons of poultry
Table 20.5  Volume of food irradiated in 14 European Union member states in 2015 versus 2010.

<table>
<thead>
<tr>
<th>Member state</th>
<th>Approved food irradiation facilities</th>
<th>Quantity irradiated in tons (2010)</th>
<th>Quantity irradiated in tons (2015)</th>
<th>Types of food products irradiated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>1</td>
<td>5840</td>
<td>3917</td>
<td>Frog legs, poultry, herbs and spices, dehydrated vegetables, fish, shellfish, meat, starch, egg powder</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>—</td>
</tr>
<tr>
<td>Croatia</td>
<td>1</td>
<td>—</td>
<td>12</td>
<td>Dried aromatic herbs, spices, and vegetable seasoning</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>1</td>
<td>27</td>
<td>6</td>
<td>Foodstuffs, aromatic herbs, spices, and vegetable seasoning (dried)</td>
</tr>
<tr>
<td>Estonia</td>
<td>1</td>
<td>10</td>
<td>37</td>
<td>Dried aromatic herbs, spices, and vegetable seasoning</td>
</tr>
<tr>
<td>France</td>
<td>5</td>
<td>1024</td>
<td>377</td>
<td>Poultry, gum arabic, herbs, spices and dried vegetables, frozen frog legs</td>
</tr>
<tr>
<td>Germany</td>
<td>4</td>
<td>127</td>
<td>211</td>
<td>Dried aromatic herbs, spices, and vegetable seasoning</td>
</tr>
<tr>
<td>Hungary</td>
<td>1</td>
<td>151</td>
<td>103</td>
<td>Herbs, spices, dehydrated products</td>
</tr>
<tr>
<td>Italy</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>—</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>2</td>
<td>1539</td>
<td>629</td>
<td>Include dehydrated vegetables and fruits, frog parts, spices/herbs, egg white, poultry (frozen), shrimps (frozen), and others.</td>
</tr>
<tr>
<td>Poland</td>
<td>2</td>
<td>160</td>
<td>46</td>
<td>Dry spices, dried flavored, herbs, vegetable, and root spices</td>
</tr>
<tr>
<td>Romania</td>
<td>1</td>
<td>17</td>
<td>0</td>
<td>Dried aromatic herbs</td>
</tr>
<tr>
<td>Spain</td>
<td>3</td>
<td>369</td>
<td>326</td>
<td>Dried aromatic herbs, spices, and vegetable seasoning</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>—</td>
</tr>
<tr>
<td>Total EU-MS:</td>
<td>25</td>
<td>9264</td>
<td>5686</td>
<td></td>
</tr>
<tr>
<td>Norway</td>
<td>1</td>
<td>8</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Total:</td>
<td>26</td>
<td>9272</td>
<td>5690</td>
<td></td>
</tr>
</tbody>
</table>
The total food irradiated amounted to 1539 tons in 2010 and 629 in 2015.

The main irradiated products were frog legs (54.75%), herbs and spices (16.10%), and poultry (15.46%). Commercial food irradiation in the EU decreased rapidly after strict EU regulations on the checking and labeling of irradiated foods were introduced in 1998. In 1998, the disinfection of more than 200 tons of herbs and spices comprised the main food irradiation activity in France. Conversely, irradiation of special foods such as frozen frog legs has remained constant even though the labeling of irradiated products is obligatory. Frog legs have now become the main irradiation product in the EU.

Countries including Spain, Estonia, and Romania started food irradiation recently; moreover, new irradiation facilities were approved in Bulgaria and Estonia during 2010.

The European Commission has also approved facilities in third countries for the irradiation of food; these include South Africa, Thailand, Turkey, Switzerland, and India.

20.3.5 Oceania

20.3.5.1 Australia

The predominant interest in food irradiation in Australia is as phytosanitary treatment to ensure viable insect pests are not exported along with fresh produce.

In 1999, Australia and New Zealand established Food Standards Australia New Zealand (FSANZ), a joint body to set food standards. FSANZ Standard 1.5.3 (Irradiation of Food) was established to permit food irradiation subject to application and approval on a case-by-case basis. Adoption of the Standard ensured consistency with the strong support of both countries for trade rules to be based on science and the recommendations of the recognized international bodies for food (Codex and the International Plant Protection Commission, IPPC). In 2003, FSANZ approved nine tropical fruits that could be irradiated up to 1 kGy for phytosanitary purpose. The original (1980–1990s) opposition to irradiated food in New Zealand was significantly reduced when it was made clear that labeling would ensure that consumers would have the choice whether to purchase or not. Since 2010, the availability of irradiated fruit, especially mangoes and tomatoes, in New Zealand has been substantial. The opening of the US market for irradiated Australian mangoes has been a recent highlight.

Recently, there has been exciting growth of Australian fresh fruit and vegetable trade utilizing phytosanitary irradiation as a 100% chemical and gas free alternative. Food Standards Australia New Zealand (FSANZ) has now approved 24 different commodities for phytosanitary irradiation treatment with a number of additional commodities under consideration, including blueberries and raspberries. These commodities are tomato, capsicum, table
grape, cherry, strawberry, zucchini, nectarine, rock melon, honeydew, apricot, apple, peach, plum, and tropical fruits (mango, litchi, papaya), for both the Australian domestic and New Zealand markets.6

Australia has strict quarantine rules on fresh produce moving across the borders of its States and Territories. Queensland fruit fly is the pest of greatest significance but there are many others. All Australian states and territories have approved the use of irradiation as a market access treatment under a new Interstate Assurance Agreement (ICA - 55). This allows any approved commodity to be irradiated as a phytosanitary treatment to gain market access.

This allows irradiation to be used for shipping of approved products into restricted markets in Australia, such as the states of Tasmania, South Australia, and Western Australia. In doing so, Australia’s unique and varied production environments are protected and Australian consumers have increased access to fresh fruit treated with a chemical and gas free process.

Australia exports fresh produce to six other countries under phytosanitary irradiation protocols. These include the United States of America, New Zealand, Vietnam, Malaysia, Indonesia, and Cook Islands. Thailand has also approved an irradiation export work plan with Australia, but is awaiting administrative steps to be completed before trade begins. Products treated with phytosanitary irradiation for shipping to these markets are now in excess of 3000 tons a year. Over the past three years, the annual volume has displayed an annual growth rate of 50%. This volume is still a very small percentage of Australia’s total exports, suggesting great potential as new protocols are developed (see Table 20.6).

In June 2016, Australia’s Department of Agriculture and Water Resources hosted its first ever phytosanitary irradiation workshop with government delegates attending from Brunei, Cambodia, India, Indonesia, Malaysia, Myanmar, South Korea, Taiwan, and Vietnam. The purpose of the event was to share and advance the understanding and application of phytosanitary irradiation. Some of these markets already import irradiated food from Australia, while many also produce and consume their own irradiated food domestically.

Awareness and understanding for phytosanitary irradiation continues to expand among Australia’s growers and exporters. As well as looking at it as a market access tool, many now recognize it as a competitive marketing advantage that helps deliver higher quality, fresher fruit faster meeting premium markets’ needs. A key advantage of the treatment is improved quality through maintaining the cold chain integrity during treatment, unlike other processes that require excessive heating or cooling.

Phytosanitary irradiation has also played a valuable role in re-opening premium airfreight windows, most common at the start and end of each Australian season. In multiple markets, Australian exporters can only ship via cold disinfestation protocols, which typically take between two and three weeks to complete, increasing the age of the product and delaying the time to market. During the 2015/16 grape season, Australia enjoyed strong
Table 20.6  History of irradiation in Australia by season.

<table>
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<tr>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mangoes (NZ, US, Malaysia)</td>
<td>19</td>
<td>129</td>
<td>201</td>
<td>346</td>
<td>585</td>
<td>1095</td>
<td>620</td>
<td>918</td>
<td>1018</td>
<td>866</td>
<td>1480</td>
</tr>
<tr>
<td>Tomatoes (NZ)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>413</td>
<td>430</td>
</tr>
<tr>
<td>Capsicum (NZ)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>Litchis (NZ)</td>
<td>5</td>
<td>10</td>
<td>20</td>
<td>57</td>
<td>110</td>
<td>15</td>
<td>132</td>
<td>76</td>
<td>29</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Papaya (NZ)</td>
<td>12</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plums (Indonesia)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>28</td>
</tr>
<tr>
<td>Table grapes (Indonesia)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
<td>134</td>
<td>223</td>
<td>367</td>
<td>642</td>
<td>1205</td>
<td>635</td>
<td>1050</td>
<td>1094</td>
<td>1388</td>
<td>2002</td>
</tr>
</tbody>
</table>
airfreight grape sales of almost 1000 Mt to Vietnam under the new irradiation protocols. The option to air freight ensured Australian export programs could deliver higher quality and service levels to their customers, creating a point of differentiation from other major growing regions in the southern hemisphere.

Australian fruits and vegetables continue to be perceived by consumers around the world as some of the safest, highest quality available. Phytosanitary irradiation is a strategic tool in protecting, maintaining, and enhancing this marketing advantage. Under irradiation protocols, Australian fruit and vegetables can now arrive in multiple Asian markets within 72 h of leaving the Australian farm gate without a chemical or gas treatment. Retailers can capitalize upon this, differentiating their stores through consumer marketing messages focused on 'Fresh'.

The first shipment of mangoes from Australia’s Northern Territory arrived in the US in September 2016. The fruit was loaded at Brisbane and flown over the Pacific Ocean. About 100 tons of Queensland mangoes were sent last year, but now with three Top End farmers on board, the trade was expected to double. Manbulloo initially sent 240 cartons of the Kensington Pride variety to the Produce Marketing Association’s conference held in Florida in October. 33

Momentum continues to build for phytosanitary irradiation as volumes of Australian fresh produce treated for export show consistent growth. The unique combination of benefits in quality, freshness, speed, and flexibility create value for the consumer, retailer, and grower alike, positioning it as an effective and efficient treatment for the future. New and improved Australian export protocols using phytosanitary irradiation are expected, with strong support and interests from both the industry in Australian and foreign markets.

20.3.5.2 New Zealand

New Zealand’s two major supermarket chains did not stock irradiated mangoes during the first year they were available, but watched the reaction to display in smaller independent stores. Since then, irradiated labelled mangoes have been available in both major and independent stores. Today, the outlook is very positive with New Zealand now being the single largest Australian mango export market under protocol trade. New Zealand, with a population of just over 4 million citizens, imports roughly as many Australian mangoes as Japan, South Korea, and China combined. These major Asian markets only have access to Australian mangoes using a Vapor Heat Treatment process, which is a slow batch-driven process that heats the mangoes to approximately 47 °C (116 °F), often stressing the fruit and triggering early ripening. Although there are other factors to be considered when assessing the New Zealand import volumes, it remains a strong indication of the superior operational efficiency and effectiveness of irradiation protocols for global mango trade. 34
20.3.5.3  Cook Islands

The Cook Islands are a small and unique Pacific island nation, isolated and free of fruit fly. As of November 2016, the Cook Islands implemented new irradiation protocols for most fresh fruit imports from Australia. The local economy depends on tourism and seafood exports, while land for agricultural production remains in short supply. The limited variation in production conditions means that the local fruit and vegetable production is suited to a limited number of mostly seasonal crops and meeting the dining expectations of tourists requires year round importation of most fresh fruit and vegetable lines.

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References