Irradiation in Horticulture

- An Australian perspective -

Information paper for the Australian horticulture industry prepared for Horticulture Australia Limited - April 2003

By Dennis Richards, Stephen Winter, Michael Daysh & John Oakeshott

Horticulture Australia

Summary

This short paper is designed to provide background information and raise the awareness of the likely uses of irradiation technology in the Australian horticultural industry. With some exceptions, food irradiation has not been used in Australia or around the world until quite recently. However, the technology is increasingly being adopted for food safety or phytosanitary purposes and, in some instances, horticultural products are leading the way. Irradiation is safe and very effective in reducing spoilage or pathogenic organisms when applied to many kinds of processed foods. For fresh horticultural products, low doses of irradiation can be an effective phytosanitary treatment for insect pests of quarantine concern. Horticulture-producing countries such as Brazil, Chile, South Africa, Thailand and the USA are actively establishing the technology to assist in either food security or to provide a phytosanitary treatment and capture export opportunities. In Australia and New Zealand, recent amendments to the Food Standard have allowed the use of irradiation in herbs, spices and a range of tropical fruits. In the latter case, a dedicated horticulture irradiation facility is planned for north Queensland. Where appropriate information has been disseminated, consumers are quite accepting that irradiation can provide them with worthwhile benefits and their purchasing patterns are surprisingly positive. The Australian horticulture industry, either as a whole, or in those commodity groupings where benefits might be anticipated, may wish to analyse in more depth the strategic importance of irradiation to provide a marketing edge or offset competition. This paper provides a starting point to such analysis.

Purpose of this paper

The purpose of this paper is to inform and raise the awareness of industry members about the potential uses of irradiation in horticulture. As a result, industry members will be in a better position to formulate their views on the importance and requirements for R&D on irradiation. R&D should be viewed in its broadest sense and may embrace desktop studies, consumer and industry surveys, economic analysis as well as science-based studies. Whatever the activities there is a need to focus on commercial opportunities on a commodity-by-commodity basis. Any industry views will be of importance to HAL if it is to initiate any on-going R&D of a commercially strategic nature.

What is food irradiation?

There are three types of radiation used in food processing: gamma rays, X-rays and accelerated electrons. None of these sources cause the target itself to become radioactive, rather, energy passes through the target creating ions that, in turn, causes disruption to metabolic processes.

Irradiation sources

Cobalt-60 is a man-made irradiation source and since it continuously emits radiation as gamma rays it must be contained, for example in a water pool. This irradiation source is the most controversial because of concerns about contamination of the environment following accidents during transport and operations, or as a result of natural disasters.

Gamma rays have no mass and high energy, therefore, they are completely able to penetrate the product and its packaging. An alternative to gamma rays is an Electron beam system (E-beam) which uses a concentrated stream of electrons produced from electricity and therefore sometimes referred to as "machine sourced". Electrons cannot penetrate as deeply as gamma rays so packaged products are commonly passed through the beam twice after turning the package over to the opposite side. This "double-sided" treatment can typically penetrate 10 cm depending on the product density. The third alternative, X-rays, are also machine generated and because X-rays have no mass they have good penetration.

Radiation dose

The unit of radiation dose is the Gray (Gy), often recorded as kGy (=1,000Gy), and is the quantity of radiation energy absorbed by the target product. Treated food is not heated substantially by this process, though there is heat generated from a Cobalt-60 source. Minimal heat is generated when using either E-beam or X-ray so that any cold chain regime, including a frozen cold chain, can be readily maintained when using these processes. Treated food does not come into contact with the radiation source and cannot, itself, become radioactive. International food and safety authorities have endorsed a safe irradiation dose for food at 10 kGy. However, it has been shown that food treated anywhere above this 10 kGy dosage is also safe for consumption. There is no dosage limit that has been shown to be unsafe.

Why use irradiation?

General benefits

The often-cited advantages of using irradiation treatment for food products include:

- reduce food-borne gastro-intestinal pathogens (*E. coli*, *Salmonella* etc.)
- reduce food-borne spoilage organisms (rots, moulds etc.)
- disinfestation of insect pests (often targeting quarantinable pests)
- eliminate the need to use toxic chemicals (like methyl bromide, a known ozone-depleting chemical)
- increase shelf-life and delay ripening or senescence
- prevent sprouting (garlic, onions, potatoes etc)
- treatment can occur after packaging as the package is "transparent" to irradiation

Herbs & spices- a special case

The case for herbs & spices is perhaps the best example of how irradiation technology has delivered world-wide benefits, reduced the use of toxic chemicals and has been accepted (or overlooked) by consumers and/or antagonists.

Unlike any other food products, the irradiation of spices, seeds, culinary herbs, teas and dry vegetable seasoning has for many years been commercially practiced in a number of countries. Twenty-four countries approve the irradiation of herbs and forty-two countries approve the irradiation of spices. As from September 2001 the amended Australian New Zealand Food Standard 1.5.3 allows the sale of irradiated herbs, spices and herbal infusions in Australia and New Zealand. Irradiations levels, generally below 10kGy but sometimes as high as 30kGy, are used to reduce or eliminate bacterial, fungal and insect pest contamination. This treatment overcomes the need to decontaminate using the once routine process of ethylene oxide gassing which is now largely prohibited throughout the world because it is a known carcinogen. In Australia, ethylene oxide for use on food products is to be phased out by 3 September 2003.

What are the concerns?

The major objections to irradiation technology focus on its use in the food industry. Without exception, the routine use of irradiation to sterilise medical and surgical equipment and food containers receives no complaint. In fact, many common everyday objects are produced using irradiation processes to apply coatings, adhesives and change the properties of plastics. Notably these consumer goods are used without any negative connotations for the consumer. Examples include: computer floppy discs, credit cards, wiring in cars, printing ink, even food packaging materials (like “bag-in-a-box”).

Usual food irradiation doses & uses

Dose scale	Dose (kGy)	Use	Products
Low	Less than 1	Insect control, delay ripening, inhibit sprouting	Fresh foods, horticultural commodities
Medium	1-10	Control spoilage & pathogenic organisms	Some fruits, meat and seafood
High	More than 10	Commercial sterilization	Spices and special foods *eg* hospital & army meals

What are the negatives?

The negative viewpoints concerning irradiated food usually involve the view that irradiation:

- uses hazardous nuclear materials
- causes treated food to become radioactive
- results in the production of toxic substances
- denatures the nutritional value of treated food
- will not be clearly identified as a production process on a label

What are the responses?

Governments, regulators, producers, marketers, retailers and technicians are all very aware of these concerns and have frequently addressed them when formulating their regulations, recommendations and viewpoints. In addition, a large number of both international scientific and regulatory bodies (including the Food & Agriculture Organisation of the United Nations (FAO), the World Health Organisation (WHO) and the American Food & Drug Administration) have studied these negative viewpoints. Without exception they have all discounted the contention that irradiated food is either rendered radioactive, toxic or nutritionally denatured when using approved food irradiation protocols.

Responses to the perceived negative reactions listed earlier include:

- A number of existing irradiation facilities in and around Australia already use radioactive "nuclear" materials (usually Cobalt-60) as an irradiation source. The laws, regulations and codes of practice that govern these facilities (as well as those using other sources) are both comprehensive and demanding. Those responsible authorities with a regulatory function embrace all levels of government, namely national (eg. Australian Radiation Protection and Nuclear Safety Agency, Food Standards Australia New Zealand and Environment Australia), state (eg. Departments of Health, Planning or Infrastructure) and local (eg. Regional Planning, Food Standards). Thus, the regulatory framework for such facilities is stringent and embraces environmental, safety and health issues throughout the production and processing chain. It should be noted that the use of E-beam or X-rays as the radiation source excludes the use of any radionuclides in the process. Whatever the source, the regulations ensure that food would be produced under "best practice" regimes. Irradiation does not replace other food manufacturing and food safety protocols.

- Using the heavily regulated protocols associated with the technology, treated food does not become radioactive above the normal background levels measured in non-treated food, nor is it ever in direct contact with a radioactive material.

- Irradiation can cause the production of "radiolytic" compounds in foods; however, the concentration of each individual compound is extremely low. Virtually all the radiolytic products that have previously been found in irradiated foods are either already naturally present in food or have also been detected in temperature-processed foods. Indeed, foods with similar chemical composition yield a similar spectrum of predictable radiolytic products. Any potentially unique radiolytic products found in irradiated food are at levels so low that it is only just technologically feasible to measure them. Moreover, in animal and human toxicology tests where irradiated food (and any internal radiolytic products therein) is ingested, no adverse effects have ever been measured. In fact in the UK, Germany, Finland and the Netherlands, various hospital patients and immune-depressed people are routinely given irradiated food.

- Depletion of nutritional value following irradiation is normally insignificant and far less than that associated with common food preparation technologies such as pasteurisation, canning and heating.

- With regard to labelling, most regulatory bodies require a form of notification on a label that food, or food ingredients, have been irradiated. The Australian New Zealand Food Standard 1.5.3 requires that irradiated food be labelled with a statement that the food has been treated with ionising radiation, such as “Treated with ionising radiation” or, simply, “Irradiated (name of food)”.

What do consumers think?

Generally, consumers do not relish any processes that "tamper" with their food. However, where there are clear benefits to them, particularly in terms of food safety, food quality and price, their reactions are often quite positive.

The single issue that has most assisted in the introduction and increasingly widespread acceptance of food irradiation in the US is food safety. The incidence of food-borne illness associated with contamination by bacteria (such as *Salmonella* spp., *Escherichia coli* O157: H7, *Listeria monocytogenes* and *Campylobacter jejuni)* in both local and imported foods is increasing. It is estimated that 7 to 30 million cases of food poisoning occur annually in the US with about 9000 resulting deaths per year. Australia too has had a spate of food poisoning outbreaks, some with devastating consequences. Media coverage has raised awareness of food safety and the likelihood that contamination can occur anywhere along the processing, manufacturing and distribution chain. Consequently, up to 60-80% of respondents in a number of US surveys indicated they would buy irradiated food if it offered protection. Indeed in the US, irradiated food (including ground beef, poultry, tropical fruits and strawberries) are increasingly available and appear to sell well. In meeting this demand it is also well understood that consumers, almost unanimously:

- favour clear and informative labelling of food so that they can make an informed and personal choice
- place their greatest trust on opinions and advice from the health professionals, consumer associations and government
- want to know more about the technology and prefer to receive their information in newspapers, current affairs programs and government brochures
- do not readily compromise on quality and taste
- recognise that irradiation does not, and should not, replace proper food processing and handling procedures

In summary, where market surveys have been undertaken around the world, consumers are favourably disposed to irradiated food products when they perceive benefits.

In an attitudinal survey, undertaken as a HAL supported project in 2001/02 (see reference list), Australian and New Zealand consumers appeared to have little knowledge of irradiated foods which is not surprising given a long period where the technology was under moratorium. However, with some preliminary explanation, irradiation was of minor concern to consumers and much less so than chemical use, fumigation and food spoilage. In general, Australasian consumers are concerned about the same issues as previously stated but are only about half as motivated to buy irradiated food compared to US consumers.

Irradiation and quarantine

Overview

The role of irradiation as a quarantine treatment for horticultural products has been under evaluation for over 30 years. The motivation is:

a) the need to find alternatives to chemical treatments such as ethylene di-bromide (now banned), methyl bromide (currently exempt from phase out for quarantine and pre-shipment uses but under increasing scrutiny) and dimethoate (under review by the Codex Alimentarius Commission and the National Registration Authority);

b) find faster alternatives to thermal treatments such as heat and cold and

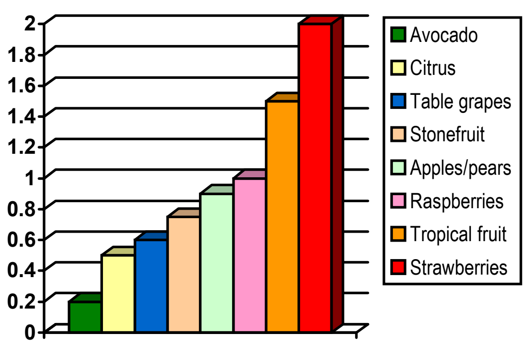
c) find treatments for products and pests that have no alternative treatment. Irradiation is seen as a "clean" alternative to chemical use with the advantage that a single treatment will control a multitude of quarantinable pests after produce has been packaged.

Under the auspices of the International Consultative Group on Food Irradiation (ICGFI), an international research program on fresh horticultural products collated data that concluded that a generic dose of 0.15 kGy for the control of fruit fly and a generic dose of 0.30 kGy for the control of other insect pests would provide an effective quarantine treatment. Subsequent work, including a recent Australian report supported by HAL (see reference list), confirmed that these dosage levels provide quarantine security for a variety of insect pests.

Crop tolerance to irradiation

Tolerances to irradiation dose, before any detrimental effects on quality, are highly dependent on product type, cultivar and also the irradiation source. For example, with strawberries, a very tolerant crop, some cultivars show unacceptable damage at 2 kGy whilst others tolerate 4 kGy.

Irradiation tolerances (kGy) of some fruit products



Despite this variation, many horticultural products have good tolerances to irradiation levels of up to 0.30 kGy.

Most vegetable types, with the exception of some cultivars of leafy vegetables like lettuce and fresh herbs, also tolerate 0.30 kGy. Cut flowers and other ornamental plants are very variable with respect to tolerance of irradiation. For example, carnations tolerate about 0.7 kGy whilst roses and chrysanthemums need less than 0.20 kGy to avoid damage and loss of quality.

Tolerance at 1.0 kGY	*Horticultural Crop*
High	Apple, cherry, tropical fruit, nectarine, peach, raspberry, strawberry, tomato
Medium	Apricot, banana, citrus, pear, plum, Pineapple
Low	Avocado, grape, squash, broccoli, Cauliflower, leafy vegetables

Insect pest control

It is important to note that the quarantine dose of irradiation to control a specific pest may not necessarily result in an immediate 100% mortality. A quarantine dose is established to achieve a quarantine standard which can be 'mortality', 'non-emergence' to the next life stage or 'sterility' to render all adults, nymphs, larvae and egg unable to reproduce further. Under all cases, the insects are no longer a quarantine threat. Thus the presence or otherwise of 'live' insects as an indicator of satisfactory phytosanitation is not a valid test, and border quarantine inspectors will need to concentrate on assessing whether the declared irradiation treatment (and the documentation that accompanies the consignment) complies with predetermined quarantine specifications.

Irradiation to control various horticultural pests

Dose (kGy)	*Generic Pest*	*Horticultural Products*
0.15	• Fruit flies	Tropical fruits Citrus Temperate fruits Vegetables Flowers Ornamentals
0.25	• Beetles & weevils • Thrips • Moths & butterflies • Bugs, aphids, mealy bugs & scale • Scale	
0.35	• Mites	
2 - 6	• Nematodes	Potatoes, garlic & onions

Postharvest rot control

Rots, moulds, bacteria and fungi are also potentially pests of plant quarantine concern. The dose of irradiation required to control these spoilage organisms is higher than for insect pests and is on the verge of being too high for some horticultural produce. However, as with insect control, some product types or cultivars are sufficiently tolerant of the required levels of irradiation to warrant its further investigation or use.

Irradiation to control horticultural rots and moulds

Dose (kGy)	*Generic Pest*	*Horticultural Products*
0.5 -1.2	Penicillium, moulds	Citrus, apples & pears, strawberries
2.0-2.5	Brown rot, Botrytis,	Stonefruit, berries & grapes
3.0	Alternaria	Citrus

It is notable that the use of irradiation in the generic control of spoilage organisms on fresh strawberries is a very effective treatment and has already been used commercially in the US. However, there is currently little definitive research and no scientific consensus on the specific application of irradiation as a phytosanitary treatment for a fungus or bacteria pest on fresh horticultural products.

World trade of irradiated food

The global trend

World trade in horticultural food products has become increasingly liberalised following the GATT Uruguay Round and the establishment of the World Trade Organization (WTO). The Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) and on Technical Barriers to Trade (TBT) requires governments to harmonize their sanitary and phytosanitary measures and to base their decisions regarding market access and international trade on sound scientific and technological concerns. Standards, guidelines and recommendations of international bodies such as the Codex Alimentarius Commission (food safety and human health) and the International Plant Protection Convention (plant protection and quarantine) are being used to formulate the benchmarks.

The International Plant Protection Convention (IPPC) is currently consulting with member countries on a draft international standard for irradiation as a phytosanitary treatment (see reference list). This standard is being presented for formal adoption at an international forum in April 2003.

In parallel, the adoption, regulation and harmonization of standards concerning irradiation of foods is being based on the Model Regulation on Food Irradiation recommended by the International Consultative Group on Food Irradiation (ICGFI).

All of the above bodies, in one way or another, endorse food irradiation as a safe process based on worldwide assessment of technical data. Australia is a member, signatory and an active participant in all of these global agreements and standard-setting bodies.

The SPS Agreement, enforced by the WTO, has paved the way for much more transparent decision-making with regard to international trade in food and horticultural products. Under SPS, governments are not only obliged to consider requests (supported by appropriate science) for market access of irradiated products but also must furnish technical or other justification for any decision to restrict a food import. In addition, the principle of "equivalence" ensures that interacting governments are obliged to accept each other's phytosanitary measures if they can be shown to achieve the same result. Thus, following the development of these broadly accepted guidelines, governments are now approving irradiated food more on the basis of food classes than individual food items.

What is the situation now?

In recent years, there has been considerable development around the world in the regulation and commercial use of food irradiation. As previously mentioned, one of the major contributors to this change is the USA. The US government has revisited its policies on irradiation following a spate of food poisoning incidents, the need to replace methyl bromide and pressure to remove interstate trade barriers (eg. access to mainland states for tropical fruits grown in Hawaii and Florida).

In 2003, approximately 40 countries use irradiation as an approved process in food production. Arguably the most important recent development was the approval in the US of irradiation of meat for pathogen control and its rapid, widespread commercial adoption.

Interestingly, seven countries around the world, including the USA, now permit the use of irradiation as a disinfestation and/or quarantine treatment for all fruits and all vegetables, regardless of type (see Irradiation Clearance Database Extract).

A recent USDA ruling, effective on 23 October 2002, approves irradiation of imported product as a phytosanitary treatment for fruit fly (11 species) and mango seed weevil, regardless of the host product at doses of between 0.1 and 0.30 kGy.

In December 2002, Food Standards Australia New Zealand (FSANZ, formerly ANZFA) granted food safety approval for irradiation (at 0.15 -1.0 kGy) as a technique for pest disinfestation of fresh tropical fruit (namely: breadfruit, carambola, custard apple, litchi, longan, mango, mangosteen, papaya and rambutan). However, it should be noted that this FSANZ approval does not include permission to import irradiated fruit. Biosecurity Australia (BA) have the responsibility to determine appropriate phytosanitary doses for imports and to negotiate with overseas quarantine authorities on doses to apply to Australian exports.

Under the WTO, Australia is obliged not to discriminate between domestic and imported products where similar phytosanitary circumstances prevail. As of March 2003, BA has an application for access for mangosteen from Thailand and irradiation is a potential pest management option. An initial request from USDA for irradiation as an alternative treatment for papaya from Hawaii is also with BA.

ICGFI have compiled and maintained a large and searchable "Irradiation Clearance Database" which lists all approvals for food irradiation use by product and by country. The following is an extract that lists, by product, those countries that currently approve the use of irradiation for disinfestation and/or quarantine treatment. The whole ICGFI database (see references) shows many more approvals for irradiated food products, including other horticultural products where approval is for general purposes such as "shelf-life extension" or specific effects like "sprout inhibition".

Irradiation Clearance Database Extract

Country	Vegetables	Fruit
*Australia**	-	Tropical fruits
Bangladesh	Beans	Mango, papaya
Brazil	Beans, corn	ALL
Chile	Beans	Mango, papaya
China	-	Apricot, litchi
Costa Rica	Beans	Mango, papaya
Ghana	ALL	ALL
India		Mango
Israel	ALL	ALL
Korea (Rep)	Mushrooms	-
Mexico	ALL	ALL
Netherlands	Beans	-
*New Zealand**	-	Tropical fruits
Pakistan	ALL	ALL
South Africa	-	Avocado, mango, papaya
Syria	Beans	Mango, papaya
Thailand	Beans	Mango, papaya
Turkey	ALL	ALL
USA	ALL	ALL
Vietnam	Beans, corn	-
Yugoslavia	Beans	-

* Not yet added to the published database. Last update: August 2002

Potential of irradiation for export

Existing export treatments

Quarantine is a fact of life for exporters of fresh fruit and vegetables from Australia to most markets. When a particular pest or disease is not endemic, our trading partners place stringent quarantine protocols in place (as does Australia for imports).

To tackle the various export market requirements, Australian horticulture exporters have to access a range of different phytosanitary treatments depending on the product, the pests of concern to the importing market and the 'Acceptable Level of Protection' (ALOP) required by the importing market. These treatments currently include:

- Non-host status
- Area freedom
- Fumigation
- Chemical treatments
- Unbroken skin
- Thermal treatments (heat or cold treatments)

Cold disinfestation

Cold disinfestation at temperatures of <3.3°C for about 16-22 days is widely used by Australian exporters to ship commodities such as citrus to the US and stonefruit to Taiwan. Cold disinfestation is frequently used as a treatment against fruit flies.

A commonly used export option is to cold disinfest fruit whilst in transit at sea. However, slight fluctuations in temperature (above the minimum) during cold shipment can result in rejection of the whole consignment. This, in turn, may require that, at considerable cost, fruit be retreated or redirected to other markets at much reduced prices. This is not an infrequent outcome.

For perishable commodities, like some stonefruit, the time required for the cold treatment is verging on too long to guarantee a satisfactory quality and shelf life. Another constraint noted when cold shipping some citrus at low temperatures is the loss of skin lustre, which results in a substantial loss of market value.

Methyl Bromide (MB) fumigation

MB is successfully used as a postharvest treatment in horticulture on a range of crops for a wide range of target insects. A typical treatment involves fumigation for 3 hours at temperatures of about 25-28°C. However, fumigation at these elevated temperatures can result in unsatisfactory outturn of some perishable commodities (e.g. unacceptable outturn following MB treatment has severely depleted the export trade of high value stonefruit).

A major concern about MB is its phase-out under the Montreal Protocol because it is an ozone depleter. The timetable for this phase-out is difficult to determine. There is currently an exemption from phase-out for quarantine and pre-shipment (QPS) uses, but this is under increasing scrutiny. Whatever the exact phase-out date, Australia needs to plan for the contingency that, in all likelihood, as MB commercial production slows prices will rise.

Not surprisingly, alternative treatments to using MB are actively under development in Australia and elsewhere. Some of these alternatives rely on utilizing different chemicals whilst others focus on changing the ambient gases around stored produce or involve various hot or cold treatments.

Irradiation as an alternative

In Australia, the development of irradiation as an alternative technology has been sporadic, mainly due to access to alternative treatments and to the imposition of a long-term moratorium (now lifted). However, the evidence, as already presented, shows that irradiation has been technologically proven to be a viable and scientifically sound disinfestation treatment. Moreover, irradiation is increasingly becoming an approved and agreed application in the world trade of food and horticultural products. Preliminary indications are that irradiation might find a use to overcome particular quarantine concerns, while ensuring acceptable product integrity and quality.

Irradiation has the potential to become an additional and alternative treatment available to Australian horticulture exporters.

Which Crops?

The following Table illustrates, on a commodity basis, some potential impacts of the adoption of irradiation as a phytosanitary measure to facilitate export. Although the Table is a very summarised view, there are strong indications that irradiation could be a good alternative to other phytosanitary treatments across the horticulture commodity spectrum.

Many commodity groupings have good tolerance to quarantine doses. However, the required dose may depend on the pest(s) of quarantine concern, mitigating measures and the level of security required by the importing market. Research to date has focused on insects, particularly fruit flies. There is currently less data available on the efficacy of irradiation on other insect pests and on other organisms such as fungi and contaminating weed seeds. Commodities recorded as having variable tolerance indicate that product testing of specific varieties is highly recommended; irradiation treatment may result in loss of quality in some cultivars but not in others.

In all likelihood, NZ and the US will be among the first to approve import of irradiated produce from Australia. This opens up the prospect that commodities like tropical fruit, that are both good and approved targets, will be the first irradiated horticultural crops to be exported. There are already commercial developments to this end occurring in north Queensland. These same markets may also be appropriate export destinations in the future for Australian citrus and high-value stonefruit, like cherries and white-fleshed peaches.

Potential irradiation use for imports

In general terms, the benefits already outlined for Australian exporters will also apply to other countries targeting Australia as a market. As stated previously, Australia is bound not to discriminate between domestic and imported products where similar phytosanitary circumstances prevail. Irradiation is among the risk mitigation measures that may be appropriate for a variety of insect pests. To determine this, BA must first undertake Import Risk Analysis or Quarantine Policy Reviews to identify pests of potential concern.

BA has received a request from the US to consider irradiation as an alternative pest management measure for papaya (Hawaiian papaya is currently allowed entry into Australia using a heat treatment as the pest control measure). Other major horticulture-producing countries (eg. Thailand, Brazil, Chile and South Africa) are embracing irradiation as a viable disinfestation treatment and may also see Australia, or Australia's current export markets, as future or potential markets for their treated produce.

In the foreseeable future, irradiation is unlikely to be considered as an appropriate treatment for non-insect pests such as fungi and bacteria. There is a lack of supporting scientific evidence and effective irradiation doses may prove to be too high for satisfactory outturn of many horticultural products. Long-term and precise scientific studies will be needed before compelling technical information can be provided to quarantine authorities. Thus, the prospect of irradiation as a phytosanitary measure to allow, for example, the importation of "fire blight free apples" from NZ or "black sigatoka disinfested bananas" from the Philippines is not a foreseeable scenario.

The potential for irradiation as an export phytosanitary treatment

Tropical & Sub-tropical fruits	**Avocado**	**Bananas**	**Custard apple**	**Litchi & Longan**	**Mango**	**Pineapple**	**Papaya**	**Citrus**	**Melon**
Tolerance to irradiation	Variable	Good	Good	Good	Good	Good	Good	Variable	Good
Effective against insects of quarantine concern	Yes		Yes	Yes	Yes		Yes	Yes	Yes
Alternative to MB and post harvest insecticides	Yes		Yes	Yes	Yes		Yes	Yes	Yes
Alternative to land or in-transit cold treatment	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes
Potential to maintain & open new export markets	Moderate		High	High	High		High		
Temperate fruits & nuts	**Apples**	**Pears**	**Berries**	**Cherries**	**Nuts**	**Nashi**	**Persimmon**	**Stonefruit**	**Grapes**
Tolerance to irradiation	Good	Good	Good	Good	Good	Unknown	Good	Variable	Variable
Effective against insects of quarantine concern	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes
Alternative to MB and post harvest insecticides	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes
Alternative to land or in-transit cold treatment	Yes	Yes	N/A	Yes		Yes	Yes	Yes	Yes
Potential to maintain & open new export markets				High				High	
Vegetables & Flowers	**Asparagus**	**Garlic**	**Mushroom**	**Onion**	**Potato**	**Tomato**	**Root Vegetables**	**Other Vegetables**	**Cut Flowers**
Tolerance to irradiation	Good	Good	Good	Good	Good	Good	Good	Variable	Variable
Effective against insects of quarantine concern	Yes			Yes	Yes	Yes	Yes	Yes	Yes
Alternative to MB and post harvest insecticides	Yes				Yes	Yes	Yes	Yes	Yes
Alternative to land or in-transit cold treatment	N/A								
Potential to maintain & open new export markets									

Conclusions

Irradiation has proven a viable and effective treatment for use on food and horticultural produce. At present, the major commercial use of this technology is in the food industry as a treatment to mitigate against food spoilage due to pathogenic organisms such as *Salmonella* and *E. coli*. In horticulture, irradiation is finding a developing usefulness as a phytosanitary treatment to mitigate against insect pests such as fruit fly and other arthropods. In this capacity, irradiation offers a good and efficacious alternative to chemical use, especially methyl bromide, in facilitating exports of fresh horticultural products. There is growing worldwide acceptance that for many horticultural commodities, irradiation can serve as a commercially viable phytosanitary treatment. Other horticultural uses for irradiation, such as prevention of sprouting in onions, garlic and potatoes and for prevention of spoilage in strawberries have also been commercially applied.

Whatever the end-use or food type consumers are not overly negative about the use of irradiation as long as they perceive a benefit and can make an informed choice when they purchase. They want information, preferably from a "respected" authority, and they want appropriate labelling.

There are export opportunities for Australian growers to utilise irradiation but progress is not likely to be rapid and any developments must be commercially driven. From all accounts, at least one consortium in Queensland sees some real benefits for the export of irradiated tropical fruit and they are planning to that end. It is possible that further detailed analysis may indicate additional export opportunities for products using irradiation as a phytosanitary measure. A thorough investigation of commercial possibilities can only come from an analysis on a commodity-by-commodity basis where target markets have been identified. In addition, it would seem that for some commodities there is a strong interaction between cultivar and irradiation dose response. This may necessitate further and more basic R&D to develop effective export protocols using irradiation treatment.

With respect to imports of irradiated horticultural commodities, there is every likelihood that in the future requests will be received that nominate irradiation as a risk mitigation measure to address a quarantine concern. Australian authorities will need to process these requests on their merit and in a similar fashion to any other application.

This paper is presented as the first stage in an on-going analysis by the horticulture industry of irradiation use and its commercial importance.

Selected references

(For further information refer to the citations accompanying each reference)

Cold Pasteurization of Food by Irradiation. Tim Roberts, Extension Specialist, Food Safety, Virginia Tech. Publication Number 458-300, posted on website August 1998. http://www.ext.vt.edu/pubs/foods/458-300/458-300.html#L9

Irradiation and Trade in Food and Agricultural Products. International Consultative Group on Food Irradiation, Vienna, 1998, pp.21.

ICGFI Clearance Database - a list of clearances for food irradiation treatment, updated annually and searchable by country and by products. International Consultative Group on Food Irradiation website. http://www.iaea.org/icgfi/

Irradiation as a quarantine treatment of arthropod pests. Proceedings of a final research Co-ordination Meeting by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Honolulu, Hawaii, 3-7 November 1997. International Atomic Energy Agency, Vienna, May 1999, pp.174.

Preparation of an Export Submission for Irradiation Treatment of Tropical Fruit. R.J.Corcoran and B.C.Waddell. Horticulture Australia Limited Report No. FR 02035, February 2003, pp.22.

Irradiation Phytosanitary Treatment of Imported Fruits and Vegetables. Final rule. Animal and Plant Health Inspection Service, USDA. Federal Register: October 23, 2002 (Volume 67, Number 205)
http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=2002_register&docid=fr23oc02-2

Final Assessment Reports A413 **"Irradiation of Herbs, Spices and Nuts",** 19 September 2001 and A443 **"Irradiation of Tropical Fruits",** 18 December 2002. Use search facility to recover from Food Standards Australia New Zealand website.
http://www.foodstandards.gov.au/

Perceptions of food irradiation in New Zealand and Australia. K.L Rossiter, J.C.Gamble, K.J.K.Lau, F.A.Gunson and F.R.Harker. Horticulture Australia Limited Report No. HG00046, June 2001, pp.47.

Consumer Attitudes and Market Response to Irradiated Food. International Consultative Group on Food Irradiation, Vienna, 1998, pp.39.

Infeasibility of irradiating fresh fruits and vegetables. E.C.Maxie, N.F.Sommer and F.G.Mitchell. 1971 HortScience 6(3): 202-204

Guidelines for the use of irradiation as a phytosanitary measure. Standards Committee draft for country consultation. International Plant Protection Convention, Food and Agriculture Organization of the United Nations, Rome May 2002.
http://www.ippc.int/IPP/En/Publ/ISPM/Drafts/Irradiation_SC1rev1.pdf