APPLICATION TO FSANZ

Application to amend Standard 1.5.3 irradiation of Food of the Food Standards Code to include Raspberry (*Rubus idaeus)* and Blueberry (*Vaccinium corymbosum, Vaccinium strigosus, Vaccinium angustifolium, Vaccinium virgatum* v *ashei)*

Date submitted 8 June 2015

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Executive Summary

This application seeks a variation to the Food Standards Code, Standard 1.5.3 Irradiation of Food, by adding

- Raspberry (*Rubus idaeus*)
- Blueberry (*Vaccinium corymbosum, Vaccinium strigosus, Vaccinium angustifolium, Vaccinium virgatum* v *ashei)*

to the Table of Clause 4 under the same dose and usage conditions presently prescribed for tropical fruits, tomato and capsicum, currently approved in the Australia New Zealand Food Standards Code. No other variation to Standard 1.5.3 is sought. The purpose of irradiation will be for a phytosanitary objective and the minimum and maximum doses allowed will be 150 Gy and 1 kGy respectively.

Applicant

This application is submitted by NSW Department of Primary Industries (NSW DPI), a division of NSW Department of Trade and Investment, Regional Infrastructure and Services. Biosecurity NSW has the vision that government, industry and the people of NSW will work together to protect the economy, environment and community from the negative impacts of animal and plant pests, diseases and weeds for the benefit of all people in NSW.

Purpose

Raspberry and blueberry are potential hosts to fruit flies and other regulated pests, and are subject by regulation to phytosanitary treatments against specified pests as a condition of entry into many plant quarantine jurisdictions. This applies to both domestic and international markets.

Queensland fruit fly (Qff) is considered to be one of the world's worst pests of fruiting crops and is listed as a pest requiring treatment by most international and interstate markets trading in the movement of fresh fruit.

Irradiation at levels between 150 Gray (Gy) and 1 kGy is effective at killing or sterilising regulated insect pests, such as fruit fly, without posing a risk to human health or significantly affecting product quality (WHO 1977).

Food Standards Australia and New Zealand (FSANZ) previously stated "Decades of research worldwide has shown that irradiation of food is a safe and effective way to kill bacteria in foods, extend its shelf life and reduce insect infestation."

Irradiation is potentially a valuable tool to help the raspberry and blueberry trade ensure biosecurity and phytosanitary requirements are met by controlling insects.

The need for irradiation

Several approved options exist for phytosanitary treatments of raspberry and blueberry. Among the most commonly used are pre and postharvest treatments with insecticides. Following the review of dimethoate and fenthion use by the Australian Pesticides and Veterinary Medicines Authority (APVMA), many phytosanitary uses of these insecticides were lost or restricted severely (APVMA 2011).

NSW DPI and the horticulture industry consider trade in these fruits at risk of market disruption. The Gross Value of Production (GVP) for raspberry was $40 million (PHA 2014) and for blueberry $120 million for 2013/14 (HAL 2014a). Production areas for blueberry can be found in all States and Territories of Australia except Northern Territory. In 2013/14, 6100 tonnes of blueberries were produced with 84% came from NSW, 6% from Tasmania, 5% from Queensland, 4% from Victoria, 0.5% from South Australia and 0.5% from Western Australia (HAL 2014b). Northeast NSW centred on Coffs Harbour grows 88% of national production. Smaller production areas can be found in southern Queensland, southern NSW, Victoria and Tasmania with minor areas in Western Australia and South Australia. Production areas in northern Queensland are being developed.

In 2013/14, total raspberry production in Australia was 1452 tonnes (DSG 2014). In 2011/12 41% were produced in Victoria, 30% in Tasmania, 22% in Queensland, 6% in NSW and 1% in Western Australia (PHA 2014). The expansion of the growing area into northern NSW and southern Queensland is driven by the need to extend the seasonal availability of raspberry. The majority of blueberries (90%) and raspberries (81%) are sold fresh on the domestic market. As raspberries and blueberries are sold interstate, access to interstate markets is vital to the industry's ongoing economic viability and regional health.

In addition to increased regulatory restrictions on the use of dimethoate and fenthion, there is growing awareness within the horticulture sector of the need for alternative treatments to insecticides due to consumer concerns about chemical residues and the potential occupational health and safety issues associated with the use of chemicals in the supply chain.

Methyl bromide is approved for use in all states and territories within Australia however it can result in inferior product quality and does not address consumer concerns regarding chemical treatments. The lack of harmonisation on the use of systems approaches (pre-harvest cover sprays and postharvest inspection) within Australia could mean that the only option for entry into several Australian markets may be methyl bromide fumigation.

Irradiation is already an approved phytosanitary treatment for many tropical fruit and vegetables. The treatment would provide an alternative phytosanitary treatment for the raspberry and blueberry industries. It is anticipated that industry can commercially incorporate irradiation treatment into their supply chain with minimal impact on efficiency and profitability of the supply chain.

Irradiation as a quarantine measure

The International Plant Protection Convention (IPPC) has several International Standards for Phytosanitary Measures (ISPM) relating to the use of irradiation for phytosanitary purposes. ISPM 18, "*Guidelines for the Use of Irradiation as Phytosanitary Measure*" provides technical guidance on the specific procedures for the application of ionising radiation that countries should adopt when trading in irradiated fresh fruit and vegetables. ISPM 28 "*Phytosanitary Treatments for Regulated Pests*" sets out minimum doses for a range of pests.

In this application the minimum dose requested is 150 Gy which is a generic treatment for fruit fly species of economic importance. The proposed treatment range of 150 Gy minimum dose to 1 kGy maximum dose will comply with ISPM 18 and 28 requirements and is identical to the current levels approved in Standard 1.5.3. A 'generic' irradiation treatment at 150 Gy minimum absorbed dose will prevent the emergence of adults of fruit flies for all fruits.

Irradiation treatment is suitable for fruits and vegetables as the minimum effective dose for a phytosanitary purpose is lower than the radiation tolerance level of the fresh produce.

Studies on the effect of low dose irradiation on the fruits raspberry and blueberry (Golding *et al.* 2014a, Golding *et al.* 2014b) and previous studies (Part 3.1) show that the nutritional value of irradiated fruits were not significantly affected.

The Codex Recommended Code of Practice for Radiation Facilities for Processing of Food and the ASTM International Standards provide internationally accepted guidance on the establishment and routine operation of irradiation facilities, including detailed advice on dosimetry and record-keeping.

Exports of irradiated Australian mango, papaya and litchi have been approved by Biosecurity New Zealand for several years and trade in irradiated fruits and vegetables, particularly in the US are increasing, with imports of irradiated fruits from many developing countries.

In 2011, the use of irradiation for phytosanitary purposes for domestic trade was approved and accepted by all states and territories in Australia. This treatment is available to businesses under the national Interstate Certification Assurance Scheme as Operational Procedure number 55 (ICA 55). It applies to all insects, excluding only Lepidoptera that pupate internally, and to all fruits for which FSANZ has approved the use of irradiation. Gamma-radiation is a proven and sound technique for insect disinfestation in a range of tropical fruits (Moy 1985, Moy and Wong 2002, Moy 2005).

Safety

The safety of food irradiation has been thoroughly studied and evaluated comprehensively over the past 60 years. No food technology has ever been as extensively studied with respect to food safety as food irradiation. Panels of experts have systematically evaluated data from animal feeding tests and multi-generation tests in animals and in 1980, the Joint FAO/IEAE/WHO Expert Committee on the Wholesomeness of Irradiated Food (WHO 1977, JECFI 1981) affirmed that “Irradiation of any food commodity up to an overall average dose of 10 kGy introduces no toxicological hazard; hence toxicological testing of food so treated is no longer required”. The JECFI also stated that irradiation of food up to a dose of 10 kGy introduces no special microbiological or nutritional problems. Investigations since 1981 have continued to support the JECFI’s conclusions.

Codex Alimentarius issued a general Standard for Irradiated Foods (CODEX 2003b), that any food irradiated up to an overall dose of 10 kGy is safe and wholesome. Irradiation for a phytosanitary purpose has a maximum dose of 1 kGy. The evidence that irradiated food is toxicologically safe, and presents no special nutritional problems is overwhelming. The Food Irradiation Clearances Database (IAEA 2012b) shows over 60 countries have at least one use of food irradiation, 30 countries have approved irradiation as a disinfestation treatment (includes approvals for delayed ripening and inhibition of sprouting), about 23 countries have approved irradiation up to 1 kGy for all fruit and vegetables and, 12 countries for specified fruits and vegetables (including Australia and New Zealand through FSANZ 1.5.3).

Various studies on toxicology and chemistry of irradiated foods and food components have been reviewed, particularly of alkylcyclobutanones. These substances also exist in non-irradiated foods and in foods processed by more conventional processes such as cooking. While minute amounts of such alkylcyclobutanones were detected in foods that contained high levels of total lipid and palmitic acid, such as chicken and beef, the amounts as a result of irradiation at doses up to 1 kGy would be minute and insignificant, and therefore would not pose a toxicological problem and is safe to eat. The lipid content of these fresh fruits is nil or very low compared to the 5–25% in meat products. No evidence of a hazard has been found on examination of radiolytic products produced.

The American Council on Science and Health (ACSH) and the Centres for Disease Control and Prevention in the US support food irradiation as a science-based technology that has been proven to be safe and effective (Loaharanu 2003). The use of irradiation provides consumers with a wider choice of safe, high-quality food. The most important public health benefit is its ability to destroy pathogenic organisms in food. The application in this submission is for a phytosanitary purpose, for a maximum dose 1 kGy.

FSANZ has previously assessed the toxicological hazard and nutritional adequacy of various irradiated tropical fruits (breadfruit, carambola, custard apple, litchi, longan, mango, mangosteen, papaya, persimmon and rambutan), vegetables (tomato and capsicum) and other specified fruit (apple, apricot, cherry, honeydew, nectarine, peach, plum, rockmelon, strawberry, table grape, zucchini and scallopini / summer squash) and concluded that there are no public health and safety issues associated with their consumption when irradiated up to a maximum dose of 1 kGy.

At doses at <1 kGy carbohydrates, proteins, dietary fibre and levels of minerals or trace elements in fruits and vegetables largely were not affected. Overall vitamin changes were minimal or non-significant between treated and untreated fresh produce, and after storage. The impact of storage rather than irradiation generally impacted fruit nutritional status and postharvest quality (Golding *et al.* 2014a, Golding *et al.* 2014b). More importantly, irradiated food will be consumed as part of a mixed diet, and the process therefore will have little impact on the total intake of specific nutrients.

Irradiation of fresh produce for a pest disinfestation purpose has no microbiological implications and the maximum absorbed dose allowed (1 kGy) is one-tenth of the general maximum permitted under the Codex Standard.

Other implications

Irradiation at low doses is an effective alternative phytosanitary treatment that is safe to use. The treatment method overall does not significantly impact on the nutritional and postharvest quality of fruit. The approval for its use for a phytosanitary purpose will ensure continued access for fresh produce within Australia and overseas. Literature and NSW DPI data show this to be the case for many fresh fruits and vegetables. The data indicated that the irradiated fruits treated under the same conditions for a phytosanitary purpose, would not present any nutritional concerns and postharvest quality is not severely impacted.

Packaging materials used for packing raspberry and blueberry are suitable for irradiation treatment and comply with regulated articles both domestically and overseas, and approved for use in food irradiation by the US Food and Drug Administration. The irradiation treatment does not impair package integrity nor deposit toxic radiation reaction products or additives on the produce.

Packages containing treated produce will be labelled in accordance with the labelling requirement as stated in FSANZ Code Standard 1.5.3 (FSANZ 2014b). Labelling identifies that the fruit was treated by irradiation and ensures that all parties are informed, thus providing choice for consumers. Interestingly, foods that are chemically treated do not have to be labelled.

The irradiation facility carrying out the treatment will be a licensed and regulated radiation facility, and abides by requirements of good manufacturing practice and acts in accordance with the Codex Alimentarius General Standard for Irradiated Foods (CODEX 2003d) and its associated Code of Practice for the Operation of Irradiation Facilities Used for the Treatment of Foods (CODEX 1983a). Proper dosimetry systems and compliance by the approved irradiation facility with accurate records allow tracking of the irradiated produce from receiving through shipping.

Australia has very strict food safety standards that apply to retail, wholesale, exporting and processing. These standards are developed jointly be leading Australian retailers and Food Standards Australia New Zealand (FSANZ). All reputable Australian and New Zealand fruit and vegetable producers operate an independently audited HACCP-based food safety system. These systems cover all facets of production and include periodic testing of fruit to ensure it complies with maximum residue level (MRL) requirements in proposed destination markets.

Conclusion

The approval of irradiation of raspberry and blueberry for a phytosanitary purpose will provide a safe and effective option to maintain market access throughout Australia and New Zealand for those berries grown in areas with endemic fruit fly populations and other regulated pests. Consumers will benefit from the continued availability, choice and price stability of these fresh produce. The harmonisation of phytosanitary irradiation treatments for regulated pests could mean access to new markets for Australian fresh blueberries and raspberries, particularly with production generally counter-seasonal.

PART 1 – GENERAL INFORMATION

1.1 Applicant

(a) Name of: Biosecurity NSW / NSW Department of Primary Industries / NSW Department of Trade and Investment, Regional Infrastructure and Services

(b) A.B.N.: **72 189 919 072**

(a) Address: Central Coast Primary Industries Centre
Locked Bag 26
Gosford, NSW. 2250

(b) Contact: [redacted]

(c) Nature of Applicant's Business:

Biosecurity NSW has the vision that government, industry and the people of NSW will work together to protect the economy, environment and community from the negative impacts of animal and plant pests, diseases and weeds for the benefit of all people in NSW.

(d) Other companies associated with application:

Horticulture Innovation Australia Limited (HIA)

Steritech Pty Ltd, which is a sterilisation and decontamination processor

Portions of this Application have been reproduced from applications previously submitted by the Queensland Department of Agriculture and Fisheries:

- A1038 Irradiation of Persimmon and;
- A1069 Irradiation of Tomatoes & Capsicums
- A1092 Irradiation of Specific Fruits

1.2 Nature of application

This application seeks an amendment to an existing standard: Standard 1.5.3 – Irradiation of Food (FSANZ, 2013), to provide for the safe use of ionising radiation (irradiation) as a phytosanitary measure for Raspberry and Blueberry only.

1.3 Support for the application

Letters of support from:

- Australian Blueberry Growers Association (Phillip Wilk, Industry Development Officer)
- Costa Exchange ([redacted], Farm Manager – Berry Category)
- Raspberries & Blackberries Australia Inc ([redacted], Executive Officer/Industry Development Manager)
- Mount Nimmel Blueberry Farm ([redacted])
- Perfection Agri Fresh ([redacted])
- Bundaberg Fruit & Vegetable Growers (Peter Hockings, Executive Officer)

PART 2 – SPECIFIC INFORMATION

2.1 Details of the application

This application seeks to amend the Food Standards Code, Standard 1.5.3 by adding the following fruit to the Table to Clause 4:

- raspberry (*Rubus idaeus*)

- blueberry (*Vaccinium corymbosum, Vaccinium strigosus, Vaccinium angustifolium* and *Vaccinium virgatum* v *ashei)*

These are to be added under the same dose and usage conditions presently prescribed for tropical fruit, persimmon, tomato and capsicum currently approved in this Standard (Table 1). No other variation to Standard 1.5.3 is sought.

Table 1. Requested amendment to Standard 1.5.3, Table to Clause 4

Column 1	**Column 2**	**Column 3**
Food	**Minimum and Maximum Dose (kGy)**	**Purpose**
Raspberry Blueberry	Minimum: 150 Gy Maximum: 1 kGy	Pest disinfestation for a phytosanitary objective

Many varieties of both raspberry and blueberry are grown in Australia and New Zealand but all significant commercial varieties fall into the respective genus notified above.

The raspberry and blueberry are potential fruit fly hosts and are subject by regulation to plant quarantine (phytosanitary) treatments against fruit fly and other regulated pests[1] as a condition of entry and/or movement into certain plant quarantine[1] jurisdictions. This applies to both domestic and international markets.

The use of irradiation as a quarantine treatment for fruits and vegetables[2] harmonises the domestic and foreign requirements for the movement of all fruit and vegetables that are hosts of quarantine pests and relieves unnecessary restrictions for producers.

Under the proposed amendment to Standard 1.5.3 it would be permitted to irradiate raspberry and blueberry as a postharvest phytosanitary treatment between a minimum dose of 150 Gray (Gy) and a maximum dose of 1 kGy. The defined minimum absorbed dose will depend upon the specific pests to be treated and directives from quarantine agencies.

The amendment to Standard 1.5.3 would provide the blueberry and raspberry industries with a phytosanitary option that is

- Justified (Part 2.3) due to a technical need for alternative options for phytosanitary treatments -

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[1] Plant quarantine - All activities designed to prevent the introduction and/or spread of quarantine pests or to ensure their official control. Pest - Any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products (FAO 2010). A pest is considered neutralized when it is killed, rendered sterile or its further development into an adult is stopped.

[2] Fruit to be treated should be of good overall quality and reflect the results of good agricultural practices (GAP). Fruit should be in an acceptable hygienic condition appropriate for the purpose of such processing. Recommended handling and storage procedures should be used prior to and after treatment.

- To provide an alternative method to using insecticide treatments;
- To maintain existing access and ensure the possibility of continual year round access to fresh raspberry and blueberry from fruit fly endemic areas to other states of Australia which are either totally or partly free from fruit flies (and other regulated pests);
- To re-open and further expand export markets such as New Zealand, Japan, China, India, Korea, Russia ;
- To assist the growth and maintenance of the economic viability of the raspberry and blueberry industries as segments of the horticulture sector of growing importance to the vitality of regional communities;
- To provide consumers with a choice of buying fresh raspberry and blueberry with sufficient labelling to clearly inform consumers of the treatment method (Standard 1.5.3 Mandatory labelling, Appendix A).

- Toxicologically and microbiologically safe and which results in nutritionally adequate food (Part 3.2).

- Highly effective as a broad spectrum method of pest disinfestation that is more practical than most other non-chemical treatment options and is cost-competitive (Part 2.2). Raspberry and blueberry are radio-tolerant of low dose irradiation.

- Approved by the international authorities responsible for international standards and guidelines in the fields of human and plant health and by many national authorities (Part 4) and which is being put into practice in Australasia, North America and Asia (Part 2.2).

2.2 Purpose and efficacy of the proposed variation

2.2.1 Purpose

The purpose of this proposed variation is to provide the raspberry and blueberry industries with the option to use irradiation as a phytosanitary measure. Approval of an accepted phytosanitary measure for a disinfestation purpose can ensure biosecurity and limit disruptions to market access and trade of these fresh commodities. These berries are potential hosts to fruit flies and other regulated pests, which are subject by regulation to phytosanitary treatments against specified pests as a condition of entry into many plant quarantine jurisdictions, in both domestic and international markets.

The raspberry industry does not use dimethoate or fenthion as phytosanitary treatments for market access. Currently it is prohibited to use dimethoate as a foliar, postharvest or quarantine treatment on raspberries and blueberries. Methyl bromide fumigation is the usual phytosanitary treatment for raspberry and can also be used on blueberries though it does cause deterioration in fruit quality. Cold disinfestation is used for blueberries but this is not possible for raspberries due to the timeframe of the treatment being longer than the shelf life of raspberry. The addition of irradiation as a regulatory treatment will diminish the dependence on other currently available treatments. Its use at the doses appropriate for tephritid fruit flies is less detrimental to the environment and to the treated fruit (Hallman 2007). The horticulture industry also has to deal with the rising costs and increasing occupational safety and health issues associated with the use of chemicals in the supply chain.

Other postharvest options for example, cold disinfestation, fumigants, new insecticides, systems approaches, exclusion netting and area freedom are available although unsuited for use due to efficacy, phytotoxicity and quality issues, length of treatment time, practicalities, detrimental effects on pollination, as well as costs or the time frame needed to gain approval from quarantine authorities. Irradiation is a cost-competitive disinfestation process that is simple, safe, efficacious and already in use for some Australian exports, for example, litchi, mango papaya, tomato and capsicum.

While pesticide usage in these industries is being modified through increased utilisation of integrated pest management in the field and system approaches, the need for strategic pesticide use and other postharvest technological method continues. The purpose of the proposed variation is to provide the blueberry and raspberry industries with the option to use irradiation as a phytosanitary measure so that the marketing of fresh fruits between geographical regions within Australia will not necessarily be disrupted. This will apply also to export market access.

Irradiation is a rapid treatment and treated produce can be released into trade immediately. Approval to irradiate blueberry and raspberry for a phytosanitary purpose will allow transition by the industry to irradiation technology and minimize potential economic loss.

Thus irradiation is potentially a valuable treatment for the raspberry and blueberry trade in ensuring biosecurity and phytosanitary requirements are met by controlling insects. It is anticipated that these industries can commercially incorporate irradiation treatment into their supply chain with minimal impact on efficiency and profitability of the supply chain. Successful incorporation of irradiation treatment can be seen in the mango, papaya and litchi examples.

Approval for the use of irradiation regulatory treatment would promote and facilitate trade, in particular to export markets, and national trading protocols for fruit fly host product would be consistent across Australia and New Zealand and with international standards.

2.2.2 Efficacy

Australian and New Zealand quarantine agencies support irradiation against fruit flies and other regulated pests. Further support for the efficacy of irradiation as a phytosanitary treatment for fruit fly exists in the United States (US), with approved generic irradiation doses of 150 Gy to reduce fruit fly infestation on specific fruits (USDA Animal and Plant Health Inspection Service (APHIS) (USDA 2006).

To date, FSANZ has approved the irradiation of herbs, spices and herbal infusions and the irradiation of ten fruits (breadfruit, carambola, custard apple, litchi, longan, mango, mangosteen, papaya, persimmon and rambutan), two vegetables (tomato and capsicum) and other specified fruit (apple, apricot, cherry, honeydew, nectarine, peach, plum, rockmelon, strawberry, table grape, zucchini and scallopini / summer squash). FSANZ has established that there is a technological need to irradiate these foods, and that there are no safety concerns or significant loss of nutrients as a result of irradiation. A recent review by FSANZ of the nutritional impact of phytosanitary irradiation on fruits and vegetables (FSANZ 2014) found that it did not pose a nutritional risk to the Australian and New Zealand populations. Though for the majority of fruit and vegetables studied there was no decrease in vitamin C on irradiation at these doses, they did recommend that for each fruit or vegetable to be considered for approval, the impact of the irradiation on vitamin C content be documented as well as for other nutrients to be determined on a case-by-case basis.

The end point of phytosanitary irradiation is not acute mortality but prevention of further biological development and reproduction. Since insects do not rapidly die after irradiation, extensive research by various plant protection agencies and by the IPPC, has been undertaken to prove that the treatment is efficacious. This has resulted in the issue of an International Standard (IPPC 2003) that addresses the concern regarding efficacy.

Examples of previous approvals by the New Zealand authorities for irradiation for quarantine purposes include fresh mango (IHS 2010), papaya (IHS 2009a) and litchi (IHS 2009b) tomatoes (IHS 2013) and capsicum (IHS 2014a) from Australia to New Zealand. Irradiation is the approved treatment for the insects of concern to New Zealand and the minimum dose required by New Zealand for the insect pests of concern is 250 Gy.

Australia has approved irradiation as a treatment for Indian mangoes (BA 2011) and in 2009 Malaysia approved irradiation as a treatment for Australian mangoes (MICOR 2013), with the minimum dose of 300 Gy.

In Australia the national Interstate Certification Assurance (ICA) Scheme as Operational Procedure Number 55 (ICA 2011) permits the use of irradiation for phytosanitary purposes for fresh fruits and vegetables for domestic trade. ICA 55 applies to any fresh produce approved by FSANZ and currently includes 10 fresh fruits and two vegetables. This procedure conforms to the principles of ISPM 18 and 28. The minimum doses required are 150 Gy for fruit flies of the family *Tephritidae*, 300 Gy for the mango seed weevil and 400 Gy for all pests of the class Insecta except pupae and adults of the order of Lepidoptera.

Under ICA 55 preliminary trials of irradiated Queensland mango to Melbourne and Tasmania were carried out in late 2011 and the irradiated fruit were sold successfully at five retail outlets in Melbourne and several outlets in Hobart and the Salamanca markets (G. Robertson, pers. comm.).

The concept of chemiclearance, used in the evaluation of the safety of food, facilitated the generic clearance of irradiated foods (Joint FAO/IAEA/WHO Committee, JECFI 1981), where foods of similar composition will respond similarly to irradiation and thus wholesomeness established for one member of a class of irradiated foods could be extended to all similar members of the same class.

2.2.3 Efficacy – phytosanitary effectiveness

The principles of radiation processing are well understood. Operational controls are based on internationally agreed and established protocols. While industrial radiation processing has been a global commercial business for over 50 years with applications that include sterilisation of medical, pharmaceutical and other products and the cross-linking of polymers (IAEA 2008), approval and uptake for irradiation processing of food has been slower. The main applications are to eliminate food pathogens, to control maturation of horticultural products and to provide a postharvest method of disinfestation for fresh produce.

Use of low dose irradiation to sterilise insect pests has been known for many years (Koidsumi 1930). Until recently, except in the USA, its use as a quarantine treatment however was not considered seriously. Bilateral agreements between countries (or states) are required and there was no international guidance on how this could be safely and fairly conducted until 2003.

In 2003, the International Plant Protection Convention (IPPC) published its *Guidelines for the Use of Irradiation as Phytosanitary Measure* International Standards for Phytosanitary Measures 18 (IPPC 2003). ISPM 18 outlines basic protocols that countries should adopt when trading in irradiated fresh fruit and vegetables. This standard is recognised under the World Trade Organisation Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) to which Australia and New Zealand are signatories (WTO 2011).

The required treatment efficacy for raspberry and blueberry will comply with ISPM 28, *Irradiation Treatment for Fruit Flies of the Family Tephritidae* (generic) (Annex 7) (IPPC 2009) at 150 Gy minimum absorbed dose to prevent the emergence of adults of fruit flies at the stated efficacy. This treatment should be applied in accordance with the requirements outlined in ISPM 18: 2003. This irradiation treatment should not be applied to fruit and vegetables stored in modified atmospheres.

Irradiation at levels between 150 Gy and 1 kGy is effective at killing or sterilising regulated insect pests, such as fruit fly, without posing a risk to human health or significantly affecting product quality. For fruits and vegetables that are hosts to the fruit fly, the required treatment is applied in accordance with international requirements (under ISPM 18) – *Guidelines for the Use of Irradiation as a Phytosanitary Measure*, International Plant Protection Convention, 2003 (IPPC 2003).

ASTM International produced a *Standard Guide for Irradiation of Fresh Agricultural Produce as a Phytosanitary Treatment* (ASTM 2006) where it details procedures for the radiation disinfestation of fresh produce for a quarantine treatment, with an absorbed dose range between 150 Gray (Gy) and 600 Gy. The practical maximum dose may be higher or lower, depending on the radiation tolerance of a particular type of fruit.

The International Database on Insect Disinfestation and Sterilization (IDIDAS) contains over 3300 references of technical data on irradiation studies of 300 species of arthropods (IDIDAS undated). For almost all insects the minimum phytosanitary doses lie in a narrow dose range, between 100 to 600 Gy (ASTM 2006, Hallman 2011, Arvanitoyannis and Stratakos 2010a). Irradiation is unique among phytosanitary treatments in its ability to be a broad-spectrum treatment for almost all important arthropod pests. In turn, this led to the consideration of a “generic” minimum dose that would guarantee sterility and/or mortality in all or a defined sub-set of arthropods in any host plant material (Follett and Neven 2006).

In 2006, the US Department of Agriculture ruled that 150 Gy was a generic minimum dose for all Tephritid fruit flies and that 400 Gy was a generic minimum dose for all insects except pupae and adults of Lepidoptera in all fruits and vegetables (USDA 2006). By 2009, the IPPC adopted ISPM 28 which includes acceptance of 150 Gy as a generic minimum dose for all Tephritid fruit flies in all host fruits and vegetables (IPPC 2009).

The USDA has accepted a set of generic irradiation doses for many fruits exported from Hawaii, Vietnam, Thailand, India, Pakistan, Malaysia and Mexico to the US mainland (USDA 2007a, b; 2008a, b, c; 2010, 2011a). Similarly, the New Zealand Ministry of Agriculture and Forestry accepts “generic” irradiation treatments for a range of regulated pests on Australian mango, papaya, litchi, tomato and capsicum currently exported to New Zealand (IHS 2010, IHS 2009a, IHS 2009b, IHS 2013, IHS 2014a), and papaya from Hawaii (IHS 2006).

The use of irradiation for phytosanitary purposes for domestic trade was approved by all states and territories in Australia in 2011, under the national Interstate Certification Assurance (ICA) Scheme as Operational Procedure Number 55 (ICA 55). ICA 55 applies to all insects, excluding only Lepidoptera that pupate internally, and to all fruits and vegetables for which FSANZ has approved the use of irradiation, and conforms to the principles of ISPM 18 and 28.

ICA 55 also sets the minimum doses required as follows –

- 150 Gy for fruit flies of the family Tephritidae.
- 300 Gy for the mango seed weevil.
- 400 Gy for all pests of the class Insecta except pupae and adults of the order of Lepidoptera.

2.2.4 Efficacy – commodity tolerance

A phytosanitary treatment of a fresh fruit or vegetable may be effective but it will only be used commercially if it does not degrade the qualities valued by consumers. Reviews on radio-tolerance of various fresh commodities have been conducted by Akamine and Moy (1983), Kader (1986), Urbain (1986a), Thomas (1986a, b, c; 1988), Morris and Jessup (1994), Wall (2008) and Arvanitoyannis and Stratakos (2010b). Possible adverse effects of irradiation on fruit quality such as softening, altered ripening, pitting, darkening, discoloration, scalding, loss of flavour or aroma, higher disease incidence and lower vitamin C and organic acids were observed in various fruit and vegetables. Economics however dictate that growers and retailers will also be interested in any change in shelf-life.

Ensuring postharvest quality at potentially maximum irradiation doses while providing quarantine security is significant when considering using irradiation as a phytosanitary method. Many of these studies were completed before irradiation was recognised internationally as a phytosanitary option and at a time when the purpose of irradiation was usually to increase shelf-life either through delaying ripening or controlling spoilage organisms. Much of the literature describes fruit quality effects at doses exceeding 1 kGy. Significant decrease in storage decay in fresh produce generally involved doses in excess of 1 kGy.

NSW DPI has assessed the postharvest quality of raspberry and blueberry after irradiation at doses in the disinfestation range up to 1kGy (Golding *et al.* 2014a). This study showed no impact of irradiation of up to 1kGy on fruit quality and though storage time did affect fruit quality, there was no effect of irradiation on the rate of deterioration with storage. No rots were observed. It was concluded that raspberry and blueberry are radiotolerant up to 1kGy.

The absorbed dose, commodity maturity and physiological state at harvest, pre- and post-irradiation handling, storage environment and storage time all interact to affect product quality and shelf-life. Different outcomes after similar treatments can occur between different varieties of the same fruit or vegetable. These complex interactions and the varying extents to which researchers took them into account or reported on them have resulted in a literature that can appear confused and conflicting, as noted by Eaton (1970), Thomas (1988), Morris and Jessup (1994), Wall (2008) and Arvanitoyannis and Stratakos (2010b).

Irradiation at around 1 kGy can produce multiple effects on fresh fruits and vegetables, and can easily confound some of the generalisations (Morris and Jessup 1994). They include

- initial softening in the first few hours after irradiation; better retention of firmness in irradiated unripe fruit; general softening after higher doses (> 1 kGy);
- an increase in respiration (CO_2 and ethylene production) in some pre-climacteric fruit which can be associated with accelerated ripening in some fruits or a delay in ripening in others; yet other fruit experience a delay in ripening with no increase in respiration;
- no delay found after the onset of climacteric respiration;
- some respiration increase in non-climacteric fruits, mimicking the climacteric;
- external and internal damage (discolouration, surface pitting, spotting, blackening, internal cell wall integrity);
- accelerated or delayed colour development.

Overall, there is agreement that the majority of fruits and vegetables will be of acceptable quality irradiated at doses within the phytosanitary range up to 600 Gy (Arvanitoyannis and Stratakos 2010b, Heather and Hallman 2008a, b; DAFF 2013). More types of fresh fruit and vegetables tolerate irradiation than any other commercially available phytosanitary treatment (Hallman 2011). An exception may be products that naturally auto-oxidize rapidly, such as avocado. In general, as the dose delivered increases towards 1 kGy, a slight loss of quality can be observed in some fruits and vegetables with loss in firmness and other attributes at doses above 1.5 kGy, except in strawberries.

2.3 Justification for the application

The use of irradiation at doses of up to 1kGy for phytosanitary purposes provides adequate control of pests and diseases ensuring biosecurity and allowing market access with free movement and trade of fresh fruit and vegetables across borders. The market access relates to facilitating exports to overseas markets and to interstate and intrastate trade.

Fruit flies and other regulated pests can interrupt export shipments of fruit and vegetables that are pest hosts to pest-free areas in Australia, New Zealand and other overseas markets where these pests are absent. Quarantine restrictions apply. Not unlike the Interstate Certificate Assurance (ICA) scheme in Australia, under a system of plant phytosanitary certification based on quality management principles, accredited businesses must be able to demonstrate it has effective procedures that ensure that the specified produce meets specified quarantine requirements in force.

The harmonisation of phytosanitary irradiation treatments for regulated pests (through ISPM No. 18 (IPPC 2003); ISPM No. 28 (IPPC 2009); ICA 55 (ICA 2011)) to support efficient phytosanitary measures can enhance the mutual recognition of treatment efficacy, which would facilitate trade. Harmonisation of domestic interstate regulation improves and enhances Australia's capacity to negotiate strong international market access arrangements.

While there are various pre-harvest options for treatment such as bait sprays and cover sprays with maldison (APVMA PER13677, APVMA PER12940), trichlorphon (APVMA PER12486), spinetoram (APVMA PER12927) and dimethoate (APVMA PER13290 – approved for blueberries but not raspberries) and post-harvest options for phytosanitary treatments (references) against fruit flies for raspberry and blueberry such as methyl bromide (APVMA PER11092 – Queensland only, APVMA PER10145 – Tasmania only (*NOTE: Up to date versions of these APVMA permits may be viewed on the APVMA website at https://portal.apvma.gov.au/permits*). Other options for treatment are prescribed by fumigation with methyl bromide ICA 04) and cold treatment (ICA 07) *NOTE: Up to date versions of these Interstate Certification Assurance (ICA) agreements for each Australian State jurisdiction may be viewed on the Subcommittee on Domestic Quarantine Market Access (SDQMA) website at http://domesticquarantine.org.au/ica-database*). Horticultural industries have relied quite heavily on the two insecticides, dimethoate and fenthion. Insufficient residue data to support their continued use in applications has resulted in usage registrations being restricted or cancelled (APVMA 2012, APVMA 2014). A national response to any change in use patterns of these insecticides was co-ordinated by the Office of the Chief Plant Protection Office (OCPPO) and details of these activities can be found on the Domestic Quarantine and Market Access Working Group (DQMAWG 2010) website. Variations in domestic trading regulations and operational procedures may result in added costs to industry and reduced competitiveness and confusion in market access has already occurred.

The availability of irradiation as a safe, viable and sustainable option for the phytosanitary treatment of fruit flies and other regulated pests will fulfil a technical need. Irradiation will provide a viable treatment option for these affected industries, exporters and importers with a chemical-free postharvest treatment. Access to an effective treatment may help ensure the economic viability of growers will not be compromised and consumers will not be disadvantaged through decreased availability and increasing prices.

Concern about pesticide and chemical residues is greater than concern about irradiation in the various surveys conducted in the UK and USA in which consumers were prompted to rank various concerns about food (FSA 2004, Johnson *et al.* 2004, Eustice and Bruhn

2006). This is also the case found in the few surveys in Australasia (Gamble *et al.* 2002, FSANZ 2008). Implications for predicting consumer acceptance of emerging food technologies, including food irradiation, are highlighted in other studies (Farkas and Farkas 2011, Frewer *et al.* 2011).

In 2002, Moy and Wong indicated that markets in the US are not averse to irradiated produce if the quality and price are decent and that consumers are increasingly accepting irradiated food. In 2006, the regulatory agency (US Department of Agriculture) had taken the initiative and moved to take the technology forward ruling 150 Gy was a generic minimum dose for all Tephritid fruit flies and that 400 Gy was a generic minimum dose for all insects except pupae and adults of Lepidoptera in all fruits and vegetables (USDA 2006). This ruling has opened up trade between the US and many developing nations such as Vietnam and Thailand.

Australian consumption of fresh raspberries is entirely from Australian production and at present none are exported. In the case of blueberries Australian consumption is almost entirely from Australian production and only limited amounts are exported. In the Australian fresh market, competition is mainly between Australian producers so maintaining domestic market access is high priority.

This application to FSANZ to amend the Food Standards Code 1.5.3 – Irradiation of Food to include raspberry and blueberry demonstrates that irradiation is an effective phytosanitary treatment that is safe and does not cause significant deterioration in the nutritional and postharvest quality of these fresh fruits. The treatment method is available for immediate implementation and already in use as a phytosanitary treatment in Australia and New Zealand and in many other trading partners. The decision to use this option will be a commercial decision by the industry, the supply chain and market.

2.3.1 Domestic trade

In 2010-11 Australian agriculture had a gross value of production (GVP) of $46.02 billion of which $3.01b is from fruit, excluding grapes. The GVP for blueberries was $82.3m and for raspberries it was $27.9m (ABS 2012). For the 2013-14 season (July 2013 to June 2014) the GVP for blueberries has been estimated at $156m based on production figures, which is a large increase from the ABS 2012 figure (*Phillip Wilk, Development Officer – Blueberries, NSW DPI, personal communication, June 2014*). The current GVP for raspberries is estimated at around $60m based on estimated total production data (HAL, personal communication). The majority of blueberries (90%) and raspberries (81%) are sold fresh on the domestic market (freshlogic 2014a, freshlogic 2014b).

Production areas for blueberry can be found in all States and Territories of Australia except Northern Territory (Figure 1). In 2012, 5916 tonnes of blueberries were produced with 93% (5502 tonnes) came from NSW, 5% (296 tonnes) from Tasmania and 2 % (118 tonnes) from Victoria. Northeast NSW centred on Coffs Harbour grows 88% of national production. Smaller production areas can be found in southern Queensland, southern NSW, Victoria and Tasmania with minor areas in Western Australia and South Australia (freshlogic 2014a). Production areas in northern Queensland are being developed to further extend the seasonal availability of this fruit.

In 2012/13, total raspberry production in Australia was 1448 tonnes with 54% (782 tonnes) from Victoria, 31% (449 tonnes) from Tasmania, 11% (159 tonnes) from NSW with the remaining 4% coming mainly from Queensland (freshlogic 2014b). Raspberry production areas are shown in Figure 2. The expansion of the growing area into northern NSW and southern Queensland is driven by the need to extend the seasonal availability of raspberry.

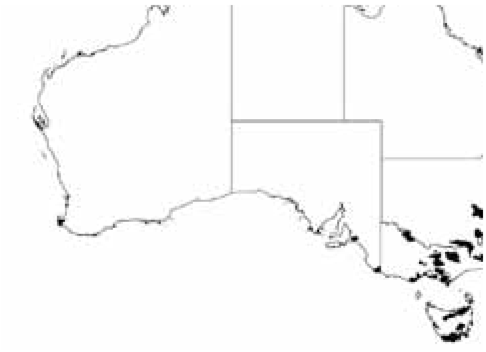


Figure 1. Blueberry production regions within Australia based on ABS data for 2005-6 (RIRDC 2010a) *(Source: RIRDC Publication No 10/112, Pollination Aware - Case Study 5 - Blueberry).* Since 2006, south eastern Queensland has seen an increase in the area and volume of blueberry production.

Figure 2. Raspberry production regions of Australia in 2005-06 (RIRDC 2010b)*(Source: Pollination Aware - Case Study 30 – Rubus (RIRDC Publication No. 10/137))*

Given that in NSW, Queensland and Victoria blueberries and raspberries are grown in Qff endemic regions and regions of low pest prevalence (Figure 3), there is concern within the industry that domestic trade in these fruits is at risk of market disruption if adequate phytosanitary measures are not available. As raspberries and blueberries are sold interstate, access to interstate markets is vital to the industry's ongoing economic viability and regional health. If adequate phytosanitary measures are not available, customers will be disadvantaged on price and supply of these berries into fruit fly free markets such as Tasmania, South Australia, some areas of Victoria, areas of Western Australia and other fruit fly free areas, particularly during out-of-season periods. Producers are at risk of no alternative options for market access in the short term, and in the medium to long term significant shifts in production may occur (SDQMA 2010).

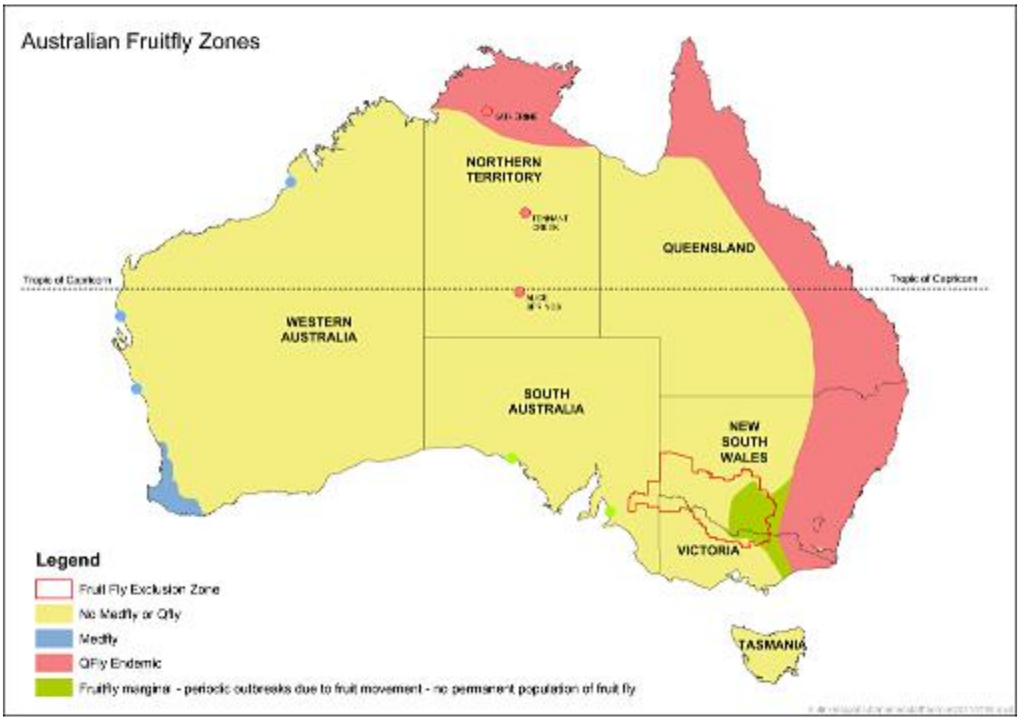


Figure 3. Fruit fly zones of Australia *(Source:* Dominiak & Daniels, 2012*).*
Note: From 1 July 2013, area freedom for Qff ceased across Victoria with the exception of the Greater Sunraysia Pest Free Area (DEPI 2013). As of April 2, 2014, the Greater Sunraysia Pest Free Area (Fruit Fly Exclusion Zone) voluntarily and temporarily suspended its freedom status for export markets (national and international) (DEPI, 2014a). Also in April 2014, in Victoria, the Yarra Valley Pest Free Place of Production (PFPP) was established with individual PFPPs within a buffer area (DEPI, 2014b). These PFPPs include rubus (raspberry and blackberry) growers, as well as strawberry and cherry growers.

The national Interstate Certification Assurance (ICA) Scheme provides a harmonised approach to the audit and accreditation of businesses trading in fresh fruit and vegetables in Australia. ICA is based on documented operational procedures developed and established by the state or territory's quarantine authority in conjunction with industry and interstate quarantine authorities. Each operational procedure clearly describes the management system, process and controls implemented.

Depending on the commodity, ICA treatments currently approved for domestic interstate trade in Australia include preharvest treatment or bait-spraying and inspection, unbroken skin condition of approved fruits, green condition, postharvest fumigation with methyl bromide, cold treatment, vapour heat treatment and hot water treatment.

For raspberries and blueberries the following ICA and allied arrangements apply:

- Post-harvest fumigation with methyl bromide – ICA 04
- Post-harvest cold treatment – ICA 07
- Post-harvest irradiation (subject to FSANZ approval) - ICA 55
- Pre-harvest treatment and postharvest inspection (blueberries only) – ICA 21
- CA-14 Pest free place of production – QFF Monitoring and Inspection (blueberries grown under certain conditions in Tumbarumba only)
- Recognition as grown in a Pest Free Area

Methyl bromide is highly toxic to humans and is a recognised ozone depletor which is currently under restrictions worldwide under the Montreal Protocol. Its future use for quarantine and pre-shipment use (currently under exemption from the Montreal Protocol) is uncertain. Blueberries are suitable for cold treatment but the time required to kill eggs and larvae of fruit flies in raspberries exceeds product tolerance. Cold treatment typically takes up to two weeks to carry out which impinges on market supply and demand logistics. ICA 21 and CA-14 apply only to blueberries and not raspberries. No blueberries or raspberries, with the exception of the State of Tasmania, are grown in any areas that are legislated as free from pest fruit flies. The currently available treatments are not viable for maintaining domestic market access and, as a result of the usage restrictions and suspensions of dimethoate and fenthion, industries are encouraged to seek alternative treatment options.

Irradiation is a viable, safe and sustainable alternative phytosanitary treatment.

2.3.2 Export trade

Although a very small player (1%) by world standards, Australia is considered a niche, high quality exporter of fruit and vegetables and can supply in counter seasons to the northern hemisphere. Horticulture is the third largest industry within the agricultural sector in Australia and has a strong domestic market focus. With a strong domestic market in Australia, profitability is often higher than in export markets and is a disincentive to develop export competitiveness particularly with a high Australian dollar.

Fruit flies can have a major impact on Australia’s capacity to trade in domestic and international horticultural markets. Phytosanitary market access is a major obstacle to expanding export performance for the nation’s horticulture industry. In a 2008 submission to the Department of Foreign Affairs and Trade Review of Export Policies and programs, HAL estimated that the overall constraint resulting from phytosanitary access was worth about another 50% ($400 million) of the then current level of fresh horticultural exports ($800 million) (HAL 2008). Hence, Australia’s annual export potential for primary horticulture was valued at $1.2 billion with appropriate market access. Whilst the system is designed to provide sufficient protection, based on scientific assessment, against new pest and disease incursion, phytosanitary access is only achievable in the context of and under the approach mandated to WTO members through the SPS Agreement.

Free-trade, bilateral and regional agreements such as those with South Korea, Malaysia, Japan, China, Singapore, US, Thailand, the Gulf States and India could open up export markets for Australian fresh produce, however phytosanitary access, which is independent of these agreements is a key element of ‘regional architecture’ which impacts on horticultural exports. The existence of sanitary and phytosanitary non-tariff barriers blocks or affects the potential of trade liberalisation under bilateral and regional agreements (HAL 2010).

Irradiation as the phytosanitary option can lessen the constraint imposed. Irradiation is an existing phytosanitary treatment that already is accepted and adopted by many nations in global trade. The absence of chemical residues is an advantage since any international situation addressing chemical residues is complex, slow and subject to various regulatory considerations.

At present Australian raspberry exports are negligible due to the highly perishable nature of the fresh fruit. Fresh raspberry imports are also negligible for the same reason. There are potential opportunities to expand into the New Zealand market to broaden their seasonal availability of fresh raspberries.

For blueberries, exports have historically been a significant part of Australia’s blueberry industry with estimates for 2010/11 being 25-30% of the total production. In September 2011 the Japanese market, a major market for Australian blueberries, closed suddenly due to biosecurity concerns related to Mediterranean fruit fly (Medfly) and Queensland fruit fly (Qff) (AQIS 2011).

Blueberry exports have decreased since 2009 (Tables 2 and 3). Current blueberry export trade is estimated at 1-10% of production, with the major Australian blueberry exporter, Berry Exchange, exporting 149 tonnes being 7.5% of their total production of 2081 tonnes in 2013-14 (*Ryan Davidson, Berry Exchange, private communication*). Reasons for this drop include an increase in the Australian dollar ($A), phytosanitary concerns relating to Qff and Medfly and the introduction of new and very low Maximum Residue Limits (MRLs) for Qff chemical controls (dimethoate and fenthion). The England/Ireland market was particularly impacted by the rise in the Australian dollar and the increasing availability of lower cost berries from South America since 2011/12.

Table 2. Australian exports of blueberry through "Berry Exchange" – volume (in tonnes) exported to each country during years 2009/10 till 2013/14.

	2009/10 Volume (Tonnes)	2010/11 Volume (Tonnes)	2011/12 Volume (Tonnes)	2012/13 Volume (Tonnes)	2013/14 Volume (Tonnes)
England	92.87	65.46	96.73	-	2.21
Japan	145.53	83.49	-	-	-
Hong Kong	22.16	21.91	25.38	18.21	28.12
Singapore	11.29	10.53	21.82	19.56	48.15
Agent in Australia	6.25	5.75	9.85	11.89	19.93
Russia	-	-	12.36	10.64	13.11
China	-	-	-	-	31.60
Ireland	2.95	16.79	11.28	-	-
Malaysia	-	-	-	-	3.76
Italy	-	-	3.70	-	-
Indonesia	-	-	-	1.06	1.03
Thailand	-	-	-	0.76	1.16
Netherlands	-	-	0.75	-	-
Total	**281.04**	**203.93**	**181.86**	**62.13**	**149.07**

Source: Berry Exchange, personal communication, May 2014

Table 3. Australian exports of blueberry through "Berry Exchange" - percentage of total exported to each country during years 2009/10 till 2013/14.

	2009/10	2010/11	2011/12	2012/13	2013/14
England	33.0%	32.1%	53.2%	-	1.5%
Japan	51.8%	40.9%	-	-	-
Hong Kong	7.9%	10.7%	14.0%	29.3%	18.9%
Singapore	4.0%	5.2%	12.0%	31.5%	32.3%
Agent in Australia	2.2%	2.8%	5.4%	19.1%	13.4%
Russia	-	-	6.8%	17.1%	8.8%
China	-	-	-	-	21.2%
Ireland	1.0%	8.2%	6.2%	-	-
Malaysia	-	-	-	-	2.5%
Italy	-	-	2.0%	-	-
Indonesia	-	-	-	1.7%	0.7%
Thailand	-	-	-	1.2%	0.8%
Netherlands	-	-	0.4%	-	-

Source: Berry Exchange, personal communication, May 2014

For the year ending December 2012, Australian blueberry production was 5916 tonnes and the estimated export volume was 64 tonnes (freshlogic 2014a). NSW is the largest producer and exporter of blueberries in Australia. Current markets include Singapore, China, Hong Kong, Russia, Malaysia and small volumes to England, Thailand and Indonesia (Tables 2 and 3). It is hoped the Japanese market can be reopened to the Australian (mainly NSW) blueberries if adequate and acceptable phytosanitary protocols can be put in place to eliminate satisfactorily the risk to biosecurity by Qff and Medfly.

There are opportunities to expand into the New Zealand market to broaden the seasonal availability of fresh blueberries.

A key impediment for accessing export markets is that the presence of various pests and diseases in Australia means potential markets which are pest-sensitive would require phytosanitary measures to be undertaken before market access is granted. Acceptable and alternative options need to be developed and negotiated.

There are various import health standards for fruits and vegetables to New Zealand from Australia, and the treatments required to meet New Zealand quarantine requirements depends on the product. New Zealand currently approves irradiation as a disinfestation treatment for fruit flies for fresh mango (IHS 2010), papaya (IHS 2009a) and litchi (IHS 2009b) from Australia. More recently, the approval for irradiation treatment for tomato (IHS 2013) and capsicum (IHS 2014a) will provide a phytosanitary option to permit market access to lucrative New Zealand markets

Irradiation is increasingly approved in many countries for phytosanitary disinfestation and approval for its use will provide plant quarantine authorities with an additional phytosanitary option to current phytosanitary measures for fruit flies of the family Tephritidae (ISPM 28, Annex 7). It is effective in promoting harmonization, facilitates trade and encourages bilateral collaboration through the WTO–SPS framework[3].

Generic doses of 150 Gy for Tephritid fruit flies and 400 Gy for all insects except pupa and adult Lepidoptera was approved by USDA-APHIS (USDA 2006) and the generic and specific doses apply to all agricultural products.

Methyl bromide treatment can be carried out on fruit already packaged. However, using methyl bromide as a quarantine measure damages the product causing quality decline and reduces its shelf life to only a few days. Dimethoate is used in the field on blueberry for pest management but not for market access purposes. Dimethoate is not used on raspberries. The use of both methyl bromide and dimethoate is restricted and being phased out. Cold disinfestation under controlled atmosphere is acceptable for blueberries; however for raspberries the timeframe required for cold disinfestation of fruit flies is greater than the fruit's shelf-life. Irradiation can be carried out on fruit already packaged, thus reducing post-treatment handling costs with potential damages to quality, results in no chemical residue and as discussed in Section 3, blueberries and raspberries are radiotolerant at phytosanitary doses.

2.3.2.1 Export trade - Raspberry

The Australian raspberry industry is focussed on the domestic fresh fruit market and, due to the highly perishable nature of the fruit, export and import of fresh product are negligible. New Zealand is a potential fresh raspberry market. Australia does import processed (frozen and pulped) raspberries for use in manufactured goods (such as jams and desserts) and for the frozen retail market. In 2012/13, 5105 tonnes of processed raspberries were imported, mainly from Chile (53%), China (20%) and Serbia (10%) (freshlogic 2014a).

[3] The WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) recognizes recommendations from relevant international organizations including the Codex Alimentarius Commission. A worldwide standard for irradiated food adopted by the Codex Alimentarius Commission accepts that irradiation is a food process comparable to heating and freezing preservation of food, accepts the safety and effectiveness of irradiation, and accepts that there are no microbiological and nutrition problems caused by irradiation of food.

2.3.2.2 Export trade - Blueberry

The blueberry industry is focussed on domestic fresh fruit marketing. Historically exports have been a significant part of Australia's blueberry industry. Figures for the tonnage and percentage of production exported vary from year to year and from source to source. The Australian Horticulture Statistics Handbook (HAL, 2012) with data up to 2010/2011 states that on average 30% of production is exported. The Australian Blueberry Industry Strategic Plan 2009-2014 released in November 2010 gives a figure of 25% being exported to Asia and Europe. Data collected from industry by the NSW DPI (Table 4) show the percentage of total production which was exported has decreased from 23% in 2007/08 to 8% in 2011/12, with the volume decreasing from 450 tonnes in 2007/08 to 270 tonnes in 2009/2010 then rising slightly to 320 tonnes in 2010/11 and 2011/12. Meanwhile the domestic fresh blueberry market more than doubled between 2007/08 to 2010/11 and continues to rise. In 2011/12 NSW was the highest exporter accounting for over 90% of the national total with Tasmania second (freshlogic 2014a). Currently export trade is estimated to account for between 1 and 10% of annual production. The largest grower and marketer of blueberries in Australia reports that 7.5% of their total production was exported in 2013/14 (R. Davidson, private communication). The figures showing decreased exports as a percentage of production are a reflection of increased production and increased domestic demand and consumption rate, as well as reduced market access due to quarantine restrictions and the increased value of the Australian dollar.

Table 4. Australian blueberry industry data for years 2007/8 till 2011/12 collected by NSW DPI.

	2007/08	2008/09	2009/10	2010/11	2011/12
Total Volume (t)	1984	2330	2775	3615	3780
Area (ha)	545	600	625	650	700
Fresh Domestic (t)	1090	1360	1640	2320	2410
Fresh export (t)	450	320	270	320	320
Fresh export (% of TVP)	23%	14%	10%	9%	8%
Processed (t)	360	450	550	450	450
Fresh $/kg	20.9	21.24	21.55	18.98	19.65
Processed $/kg	5.76	5.45	3.95	3.03	3.83
Total value of Australian industry $M	**32.1**	**35.68**	**41.1**	**50.7**	**53.69**

(Source: Phillip Wilk, Development Officer – Blueberries, NSW DPI – personal communication, May 2014)

In September 2011 the Japanese market, a major market for Australian blueberries (about 50% of exports), closed suddenly due to biosecurity concerns related to Mediterranean fruit fly (Medfly) and Queensland fruit fly (Qff). The UK market collapsed the following year due to the increase in the Australian dollar and availability of low cost product from South America. Asian markets are now the most significant with Singapore, China and Hong Kong together taking 70% of the exports (Table 3). Russia and Malaysia as well as England, Thailand and Indonesia are also current markets for Australian fresh blueberries. Concerns about Qff and Medfly biosanitary issues and the introduction of new and very low Maximum Residue Limits (MRLs) for Queensland fruit fly chemical controls remain issues in gaining market access to increase exports.

Imports of blueberry for the year ending December 2012 totalled 2722 tonnes. Of this 70% (1905 tonnes) was frozen, pulped or otherwise processed. These processed blueberries came mainly from China, Chile, New Zealand and the USA (freshlogic 2014a). The frozen market in Australia cannot be satisfied from local market as Australia mainly grows blueberry for the fresh market. Imports of fresh blueberry totalled 817 tonnes in 2012, with New Zealand being the major source and these imports supplement the Australian grown supply during the period January to March (freshlogic 2014a). Fresh imports have grown moderately along with Australia's increasing consumption rate.

2.3.3 Phytosanitary treatments

A range of phytosanitary treatments is approved currently for domestic interstate trade and for export market access. However, with usage restrictions and suspensions imposed on dimethoate and fenthion and the phasing out of methyl bromide, it is essential that an alternative and effective quarantine treatment be available that can be implemented promptly otherwise there could be significant economic loss to industries. Overseas quarantine agencies are also reviewing their phytosanitary procedures and may well insist on irradiation treatment for imports. For example, the Ministry of Health, Malaysia, advised Biosecurity Australia that on 1 March 2009 all mango (*Mangifera indica*) fruit must be irradiated prior to export with a minimum irradiation dose of 300 Gy because of Malaysia's concern about the detection of Mango Seed Weevil (MSW) in consignments of Australian mangoes (AQIS 2009).

The IPPC Recommendation on the replacement or reduction of the use of methyl bromide as a phytosanitary measure (IPPC 2008) has outlined alternative treatments that include cold treatment, high temperature forced air, hot water, quick freeze, vapour heat treatment, controlled atmosphere storage, chemical dip, phosphine, combination of treatments and irradiation as alternative phytosanitary measures for fresh fruit and vegetables. There are advantages and disadvantages for all the various quarantine treatments (EPA 1996, IPPC 2008).

Phytosanitary treatments currently available for use on blueberry include methyl bromide fumigation, cold disinfestation, dimethoate dip or flood spray. Methyl bromide causes quality decline in blueberry, cold disinfestation does not affect quality and dimethoate is an in-field preharvest treatment that is also good. For raspberry, current approved phytosanitary treatments are methyl bromide fumigation, cold treatment and dimethoate dip or flood spray. Of these options, cold treatment is ruled out as the timeframe of treatment is longer than the shelf-life of raspberries; methyl bromide fumigation which has been traditionally used for interstate trade in Australia is being phased out is and damaging to this already perishable fruit; and dimethoate use is restricted. Fenthion is prohibited for use on blueberries and raspberries.

Other protocols may involve the implementation of systems approaches, pest free areas (PFAs), areas of low pest prevalence (ALPPs), pest free places of production and pest free production sites. "Area freedom" from fruit fly, though not a post-harvest phytosanitary treatment, allows for the acceptance of fruit for interstate/export market access. A certified systems approach including physical exclusion using netting would make interstate/export market access possible. The cost of developing, implementing and maintaining these systems and pest-free areas is significant. It should be noted that in the Victorian Yarra Valley rubus (raspberry and blackberry) growers together with strawberry and cherry growers, HAL, Agribusiness Yarra valley and DEPI, Victoria, funded a project aimed at developing a pest Free Place of Production (PFPP) program in the region. In April, 2014, it was announced that PFPP status has been achieved and DEPI negotiated acceptance of the PFPP with interstate counterparts. Accredited PFPP fruit growers within the Yarra Valley PFPP Buffer Area can now send their produce to fruit fly sensitive markets including Western Australia, South Australia and Tasmania without the need to treat it for Qff. An extensive network of Qff traps is used to verify the regions continuing freedom from Qff.

In response to the threat of withdrawal from use or changes in the approved uses of dimethoate and fenthion as phytosanitary treatments that allow trade of *Rubus* spp. fruit into fruit fly sensitive markets, the Rubus industry, through HAL, commissioned a desktop study of market access options to determine areas of future research with the view to developing viable market access protocols (Duthie, 2011). The review of international protocols allowing trade of *Rubus* spp. fruit into fruit fly sensitive markets found no potentially new postharvest fruit fly disinfestation methodologies which could be adapted domestically in Australia. The focus of international protocols was on fruit fly free areas. Internet searches for research into postharvest disinfestation methods confirmed the lack of new methodologies. Given the fragile and perishable nature of *Rubus* spp. fruit which makes them unsuitable for many disinfestation methods (such as cold disinfestation and methyl bromide fumigation), the study identified only two methods that would potentially provide a suitable level of phytosanitary security. These two methods were irradiation and fruit fly exclusion netting. Exclusion netting would need to be integrated into a fruit fly management system (systems approach) and appropriate trials would need to be carried out to determine the merit of this method. Exclusion netting has the draw back that it introduces the problem of bee-exclusion and hence a pollination problem. Irradiation, the study found, is "an extremely effective phytosanitary measure that is gaining in national and international acceptance". They also found that "*Rubus* spp. are known to withstand doses of irradiation needed to kill fruit flies very well." They recommended that a study be conducted to confirm the radiotolerance of each commodity and look at the effect of irradiation at phytosanitary doses on the nutritional value of the fruit. This would allow the application to FSANZ to get specific permission to irradiate the fruit through appropriate amendment to Food Standard 1.3.5. Subsequent to the findings of this desktop study, DPI NSW has conducted the recommended studies and found that fruit quality and the nutritional profile of "Maraville" raspberry were unaffected by treatment with phytosanitary doses of gamma irradiation ≤ 1 kGy and that this treatment did not affect the storage properties of this fruit (Golding *et al.* 2014a). This is the basis of this application to FSANZ to permit the irradiation of raspberry for phytosanitary purposes.

Irradiation is more efficient and less phytotoxic than thermal, cold or fumigation treatments (Moy 1993, Moy and Wong 2002, Hallman 2008, Hallman 2011, Follett and Sanxter 2000, 2002, 2003) with product quality generally maintained. From the point of view of market opportunities, irradiation at the doses for Tephritid fruit flies (<1 kGy) is the most broadly applicable commercial treatment developed for a pest species.

The ruling by USDA-APHIS in 2006, approving generic doses of 150 Gy for Tephritid fruit flies (USDA 2006), applicable to all agricultural products offers exporting countries an alternative to chemical treatments. Exporting countries negotiating trade in fresh fruit and vegetables can use of the generic irradiation treatment, which is simple and straightforward. Since its introduction, there have been increasing imports of several tropical fresh produce from developing countries into the US.

Trading partners in Asia, for example, Thailand, Vietnam and India, have developed uniform quarantine treatments using irradiation technology to export fruit to the US and these same countries are currently considering moving to irradiation treatment for imported fruits and vegetables.

The small concentrations of chemical residues in fresh produce treated with any chemical treatment and concerns about phytotoxic effects, are still of significant and increasing consumer concern (Johnson *et al.* 2004, FSA 2004, 2007) and have directed research to focus on non-chemical phytosanitary treatments. Radiofrequency heating, microwaves, ultrasound and pressure treatments are all at experimental stage but will take many years before they are considered to be proven, practical, and accepted by the IPPC and national plant protection bodies (chapters in Heather and Hallman 2008b).

In contrast irradiation does not produce chemical residues. It is known in advance that most fruits and vegetables are radiation-tolerant at low doses (≤ 1 kGy) and that there are approved generic minimum doses for Tephritid fruit flies, mango seed weevil and all other insects except pupae and adults of Lepidoptera in Australia, New Zealand and the USA.

Comparisons between costs for irradiation treatment with costs of other alternative disinfestation treatments while worthwhile are often not simple and straightforward since facility capacity, annual throughput, and amortization method are important factors in the calculation. Hallman 2011, in a more general categorisation, places heated air and irradiation as moderate cost alternatives and cold, hot water immersion and methyl bromide as low cost alternatives.

Lacson 2007 presented Australian data indicating treatment costs of about $250/tonne for hot water treatment, $200–250/tonne for vapour heat treatment, $46- 600/tonne for cold treatment and $50–600/tonne for forced air heat treatment.

The current cost for irradiation treatment by an Australian facility is in the range A$90-120 per tonne/pallet of fruit (Steritech, private comm. June, 2014) and is dependent on the minimum dose required, e.g. 150 Gy – 400Gy. The cost is expected to decrease if greater disinfestation use is made of the irradiation facility. Irradiation treatment cost is greater than the cost of the insecticide treatments although the cost differential would be reduced if the full costs of assurance, occupational safety and health and chemical disposal of insecticides were taken into account. However, the relative advantage of insecticide treatments becomes irrelevant if their use is withdrawn.

Industry will make commercial decisions based only partly on treatment costs. Superior quality of irradiated fresh produce (Hallman 2011, Heather and Hallman 2008b, EPA 1996), rapid turnaround time and convenience offer significant advantages of irradiation over other treatment options.

2.4 Costs and benefits

The most recent ABS data on the Gross Value of Agriculture and the sub-group of Fruit and Nuts (excluding grapes) in Australia and the states and territories for the year 2012/13 (Table 5) shows that the NSW, Victoria and Queensland are the major production areas for fruit and nuts in Australia together contributing 77% of the $3.7b of the value of these commodities in Australia. These eastern coast states lie within the Qff zone for Australia.

Table 5. ABS 2012/13 data on the Gross value of Agriculture and Total for Fruit and Nuts (excluding grape) (ABS 2014)

2012-13	Gross value ($m)		
	Total agriculture	Total Fruit and nuts (excl. grapes)	State Fruit & Nuts - % of Australia Fruit & Nuts
Australia	48,048.02	3,662.38	100%
New South Wales	12,128.17	655.68	17.90%
Victoria	11,630.64	1,081.78	29.54%
Queensland	10,300.01	1,085.23	29.63%
South Australia	5,621.50	428.60	11.70%
Western Australia	6,690.26	239.98	6.55%
Tasmania	1,190.34	112.61	3.07%
Northern Territory	478.59	58.46	1.60%
ACT	8.52	0.04	0.00%

The lack of reliable and discoverable horticultural statistical data is a common problem in Australia and it has been difficult to obtain up-to-date and consistent data on both blueberry and raspberry production and value of production. The 2010/11 ABS data contains data on the Gross value of Production (GVP) for agriculture, the subgroup of fruit and nuts (excluding grapes), and the most recent ABS data on blueberry and raspberry production in Australia and the states and territories. The GVP of agriculture in this year was $46b with $3b from fruit and nuts (excluding grapes). The GVP for blueberries was $82.3m with 88% of this from NSW and 8% from Victoria. The GVP for raspberries was $27.9m with 41% of this from Victoria, 30% from Tasmania, 23% from Queensland and 6% from NSW. As can be seen the majority of blueberry and raspberry production comes from within the Qff zone.

The next set of ABS data for raspberry and blueberry will not be available until 2015/6 when the next Agricultural Census will be conducted, however data collected by NSW DPI for the year July 2013 to June 2014 estimates the GVP for blueberries at $156m (P. Wilk, private communication) which is a large increase from the 2010/11 data and reflects the rapid expansion of this industry. Much of this expansion is in northern NSW and Queensland.

Recent data on Gross Value of Production of the Australian raspberry crop has not been able to be obtained. However, it can be estimated from production figures for the 2012/13 season provided by HAL (*private communication*) of 1565 tonnes of production subject to levies plus about 20% not subject to levies, giving a national Rubus production of about 2000 tonnes (the majority of which is raspberry), that the GVP was between $78m and $100m. The HAL Australian Horticulture Statistics Handbook 2012 (HAL 2012) contains data on Rubus production by state from the 2007/08 season till the 2011/12 season. From these data the rapid increase in the production in NSW and Queensland can be seen; in NSW, from 100 tonnes in 2007/08 to 320 tonnes in 2011/12; for Queensland, from 20 tonnes in 2007/08 to 135 tonnes in 2011/12. Production in Victoria and Tasmania has not grown at the same rate: in Victoria, from 250 tonnes in 2007/08 to 360 tonnes in 2011/12; in Tasmania, from 130 tonnes in 2007/08 to 185 tonnes in 2011/12. Like blueberries, the expansion of the raspberry industry into northern NSW and Queensland is making the industry more vulnerable to Qff and more at threat of reduced market access if alternative phytosanitary methodologies are not made available.

The approval of this application can ensure continued market access for raspberry and blueberry and safeguard the economic viability, related community and regional health and downstream effects that come with a growing and mature horticultural industry. An overview of benefits and impacts is presented in Table 6 and considered further in the following sections.

Table 6. Summary of benefits to government and industry

The Australian Government	State and territory governments	Australian horticultural industries and growers
Unified trade regulations and harmonisation	Improved state quarantine and streamlined regulations	New or improved market access
New and/or improved market access	Unified interstate trade regulations	Increased interstate trade
Reduced management costs	Reduced risk of non-endemic fruit flies	Increased international trade
Reduced impact on the environment	Maintain healthy regional communities	Improved and streamlined regulations
Improved regional economies and healthy regional communities	Improved environmental WHS	Improved supply chain
Food security		Improved on-farm profitability
Improved value of non-commercial amenities		Reduced impact on the environment and farm WHS (chemical use)
		Reduced risk of non-endemic fruit flies
		Maintain healthy regional communities

There is limited awareness and understanding of irradiation among consumers. The need for information is evident. Some updates informing about the use of irradiation as a postharvest phytosanitary treatment option can be found from the various States and Territories and Commonwealth agencies portals.

Irradiation has the following practical advantages when compared with other phytosanitary options:

- it is the only treatment that is internationally endorsed as a generic treatment of fruit flies;
- it is a broad spectrum treatment (few insects and other arthropod pests have or develop resistance);
- free of chemical treatment residues;
- well-tolerated by most fresh produce, generally better than alternatives such as cold, heat, hot water and methyl bromide (Hallman 2011);
- a cold process (no heat is generated during treatment and fruit can be harvested at a more mature stage than fruit that are heat treated);
- penetrating (treatment can be in the final package and is insensitive to the size and shape of the fruit);
- a simple operation depending only on the power of the source and the conveyer speed. It is not sensitive to temperature, humidity or other physical parameters;
- a rapid treatment and treated products are available for immediate distribution into trade;
- cost competitive (see Phytosanitary treatment options).

Discussion and reviews of the history, development and research on irradiation as a phytosanitary treatment can be found in Burditt (1996), Follett and Griffin (2006), Hallman (2000), Heather and Hallman (2008b), Hallman (2011). IAEA (2001) provides a summary of the history of food irradiation development and its adoption, while US regulatory considerations are examined by Morehouse (2002). Physiological responses of fresh produce - fruits and vegetables, tuber and bulbs - to irradiation are covered elsewhere (Morris and Jessup 1994, Thomas 1986).

2.4.1 To consumers

Assuring the on-going, year-round supply of fresh blueberry and raspberry throughout Australia will ensure that consumers can continue to access these nutritious and tasty foods. Maintaining existing supply, including from NSW, Queensland and Victoria to fruit fly sensitive markets, will guard against shortages and price rises.

The benefits of irradiation as a safe and efficient treatment for various purposes are well documented (Morris 1987, Thayer and Rajkowski 1999, Thomas *et al*. 1995). Irradiation of fruits at low levels, usually less than 1.0 kGy, is applied to control or kill insects and pests, and extend shelf-life or delay spoilage. This low dose treatment was shown to only cause minimal changes in nutritional and organoleptic qualities of fresh produce. Low-dose irradiation does not alter macronutrient or mineral content of fruits and vegetables. In relation to vitamins and other non-vitamin bioactive compounds, the literature review by FSANZ (FSANZ 2014a) demonstrated that phytosanitary doses of irradiation had no effect on carotene levels, did not decrease the vitamin C levels in the majority of fruits and vegetables and had little effect on non-vitamin bioactive compounds. Recent research on phytosanitary irradiation of raspberry and blueberry conducted by NSW DPI (Golding *et al.* 2014a) also demonstrated a lack of significant effect on vitamin C, anthocyanins and macronutrients and minerals. Also, this study showed no effect of irradiation treatment on fruit quality on storage.

The safety of food irradiation has been studied more extensively than any other food preservation process, including freezing, canning, dehydration and chemical additives. Radiolytic products that may be formed are similar to thermolytic products in heat treatment of foods. The amounts that are found have been demonstrated to be non-toxic by any modern toxicological methods (Loaharanu 2003).

Irradiation is an effective phytosanitary method that leaves no chemical residues. High quality fruits and vegetables can be shipped to quarantine sensitive regions and states and the possibility of cross-contamination prior to reaching the consumer is minimised since produce is treated after packaging.

Part 3.1 considers the nutritional adequacy of irradiated produce. In summary, no significant change in dietary intake of nutrients will occur as a result of consuming irradiated (low dose) raspberry and blueberry. The nutritional value of fresh fruits and vegetables that have been irradiated is essentially unchanged (see 3.1 nutritional data).

Research showed that macronutrients, such as protein, carbohydrates, and fat, are relatively stable to radiation doses of up to 10 kGy. Under optimal conditions, vitamin losses in foods irradiated at doses up to 1 kGy are considered insignificant. Fruits and vegetables are the predominant dietary sources of vitamin A (as carotene) and vitamin C. Carotene levels are variably increased, decreased or unchanged depending on the effect of irradiation on the ripening of the commodity and vitamin C is generally more effected by storage than irradiation (FSANZ 2014a). While the level of some of the B-group vitamins can be reduced by irradiation at higher doses, the losses also occur in other food preservation technologies, such as canning or blanching. In general, the irradiation process produces very little chemical change in food. Radiolytic products that can be produced are also naturally present in foods or are formed by conventional processing methods.

The concept of chemiclearance is recognised to include all irradiated fruits and vegetables since they will be treated in the same way for a disinfestation purpose. Generic irradiation treatments at the low dose rate of 150 – 1000 Gy is proven and effective because irradiation is broadly effective against fruit flies at doses that typically do not harm product quality (Follett and Armstrong, 2004; Follett and Neven, 2006; Wall, 2008).

In its assessment of Application A443 Irradiation of tropical fruits – breadfruit, carambola, custard apple, litchi, longan, mango, mangosteen, papaya and rambutan, FSANZ concluded that "…. irradiation would have minimal impact on the nutrient status of the tropical fruits."

In its assessment of Application A1038 Irradiation of persimmon, FSANZ concluded that…" ….available data indicate that the carbohydrate, fat, protein and mineral content of foods are unaffected by irradiation at doses up to 1 kGy. Therefore, irradiation is unlikely to affect the presence of macronutrients and minerals in persimmons."

In its assessment of Application A1069 Irradiation of tomatoes and capsicums, FSANZ concluded that "….there are no public health and safety issues associated with the consumption of tomatoes and capsicums which have been irradiated up to a maximum dose of 1 kGy. Available data indicate that the carbohydrate, fat, protein and mineral content of foods are unaffected by irradiation at doses up to 1 kGy."

In its assessment of Application A1092, FSANZ states the "published literature indicates that irradiation up to 1 kGy does not reduce the nutritional quality of fruits and vegetables. Vitamin C levels can be diminished by irradiation, but the extent of diminution is generally similar to that produced by other post-harvest handling and processing. The data provided by the applicant found no significant change in vitamin C levels attributable to irradiation. In the assessment of the current application, there is no evidence to indicate that vitamin C levels in the specified irradiated fruits and vegetables would be lower than that found in comparable non-irradiated fruits and vegetables." The specified fruits and vegetables are: apples, apricots, cherries, honeydew melons, nectarines, peaches, plums, rockmelons, strawberries, table grapes, zucchinis and scallopini / summer squash.

The recently released review of the literature by FSANZ on the "Nutritional impact of phytosanitary irradiation of fruits and vegetables" (FSANZ 2014a) concluded "that phytosanitary doses of irradiation do not pose a nutritional risk to the Australian and New Zealand populations". Though "in some cultivars of some fruits vitamin C decreased with irradiation", "in the majority of cases the vitamin C content of irradiated fruit remained within the range of natural variation" and "these changes were unlikely to impact on the dietary vitamin C intakes in Australia and New Zealand".

Raspberry and blueberry are mainly sold in 125g polyethylene terephthalate (PET) clamshell punnets with a soaker pad in a cardboard tray of 12. All berry packaging material is radiotolerant at the phytosanitary doses of irradiation. PET has been shown to be stable to irradiation with no significant effects with respect to its use for packaging of foods at doses up to at least 200kGy (Jeon et. al., 2007). Absorbent pads exposed to an irradiation dose of 7kGy have been shown to be unaffected and stable (Komolprasert, 2007). Cardboard has a radiotolerance level of 100-200 kGy (Nordion (2007). Though the FSANZ ruling does not specify the specific packaging materials, raspberry and blueberry packaging material comply with ASTM *Standard Guide F1640-09 Selection and Use of Packaging Materials for Foods to Be Irradiated"* (ASTM 2009) and the materials have been approved by the Food and Drug Administration in the US. The FDA lists PET film for use as a packaging material in 21 CFR 179.45 for use during irradiation of prepackaged foods at a maximum dose of 60 kGy (FDA 2007), well above the maximum dose of 1kGy requested in this application.

There is a published Codex Standard for Irradiated Foods and Recommended International Code of Practice for the Operation of Radiation Facilities Used for the Treatment of Foods (1984) and this is regulated by responsible government entities.

Consumers are assured that the processing and handling of fruit before and after irradiation adhere to good manufacturing principles and quality assurance systems. As commodities to undergo phytosanitary irradiation can be prepacked and stacked in pallets, there is reduced post-treatment handling and thus reduced potential for damage which would result in decreased quality. Additionally, the possible reduction in surface spoilage bacteria and mould of irradiated fruit and vegetables could reduce wastage and extend shelf life (Akamine and Moy, 1983; Prakash and Foley, 2004; Niemira and Fan, 2006; Jordan, 2007; in raspberries specifically: Guimaraes *et al.* 2013, and Tezotto-Uliana, *et al*. 2013). Decrease in some costs of wastage can offset the added costs of irradiation. The cost of irradiated foods is expected to decrease as irradiated foods become more widespread and continue to gain acceptance.

Consumer attitudes and responses to irradiated foods are discussed in detail in Part 5.7. Nevertheless, the export of irradiated mango to New Zealand is a success story for Australian horticulture. According to the Australian Mango Industry Association (Sexton-McGrath 2010), New Zealand is the fastest growing market for Australian mango.

Consumers increasingly perceive a human health risk from chemical pesticide/insecticide residues in food, although their tolerance for more regulation or to pay more for residue-free food varies (Baker and Crosbie 1993, Baker 1999, FSA 2004, 2007). Irradiation leaves no toxic residues in food while producing a safe, nutritionally adequate product (JECFI 1981, FSANZ 2011a). Surveys of public opinion have often shown initial reluctance among consumers to consider eating irradiated foods (Part 5.3). However, the level of support for irradiated food increases when accurate information is provided, and is greater than for chemically treated food (Gamble *et al.* 2002, Johnson *et al.* 2004, FSA 2004, Eustice and Bruhn 2006).

Some consumers are likely to always reject irradiated foods and want to avoid consuming them. The mandatory labelling requirements of Standard 1.5.3 (Appendix A) will ensure that consumers are informed that the food has been irradiated and that they can make informed choices.

2.4.2 To Governments

In 2012/13 agriculture in Australia had a gross value of $48b (ABS 2014) with NSW being the leading agricultural production state closely followed by Victoria and Queensland; together these three states are responsible for $34b or 71% of Australia's total agricultural production (Table 7). For the same year fruit and nuts (excluding grapes) represented 7.6% of total agriculture and had a total Gross Value of $3.66b for Australia with $2.82b together from the three most productive states, NSW, Victoria and Queensland.

Horticultural industry is the principal driver of many local and regional economies. For the blueberry industry, the region on the NSW mid-north coast centred on Coffs Harbour, often referred to as Australia's "Blueberry Capital", employs up to 3000 locals during peak harvesting periods and it is estimated that the industry contributes in excess of $50m to the local economy. In 2010/11 fruit contributed 43% ($82m) to the total GVP for agriculture in the Coffs Harbour-Grafton region with blueberries being the major crop ($48m) followed by bananas ($10m) (Binks *et al*. 2013). The importance of blueberry production in the regional economy cannot be denied.

The horticultural industry contributes significantly to the prosperity of people living in rural and regional Australia. It is a primary and secondary source of income for families in regional Australia. There are 59,500 people employed in Australia to grow fruit, vegetables and nuts for the domestic and export markets. A further 6,250 are employed in fruit and vegetable processing (excluding wine manufacturing) (source: DAFF Australian Food Statistics 2012-13 (DAFF 2014a)).

Fruit and nuts and vegetables are major contributors to regional economies and the foundation of many regional communities. It is the most labour intensive of all agricultural industries with labour representing at least 50 % of the overall operating costs; for Rubus (raspberries and blackberries) labour costs are about 60% of total production, transport and marketing costs (ARGA, 2009). The fruit, nut and vegetable industry has a significant link to the tourism industry, providing income for backpackers each year; this is particularly true of the blueberry industry. In the blueberry and raspberry industries many privately owned farms provide sales to customers, often tourists, on a "pick-your-own" basis. Local, interstate and overseas markets are supplied through a range of outlets including wholesalers, supermarkets, green grocers, farmers' markets and direct to consumers. If fresh produce such as blueberries and raspberries, which are hosts for Qff and Medfly, are to be shipped out of quarantine areas to pest free regions, phytosanitary measures to prevent the introduction or spread of quarantine pests must be implemented.

Table 7. The Gross Value of total agriculture and total fruit and nuts (excluding grapes) for Australia and all Australian states and territories for the year 2012/13 (ABS 2014)

2012/13	Gross value ($m)				
	Total Agriculture	Total Fruit and Nuts (excl. grapes)	State or Territory Agriculture - % of Total Australian Agriculture	Fruit & Nuts - % of Total Agriculture	State Fruit & Nuts - % of Australia Fruit & Nut
Australia	48,048.02	3,662.38		7.6%	
New South Wales	12,128.17	655.68	25.24%	5.4%	17.90%
Victoria	11,630.64	1,081.78	24.21%	9.3%	29.54%
Queensland	10,300.01	1,085.23	21.44%	10.5%	29.63%
South Australia	5,621.50	428.60	11.70%	7.6%	11.70%
Western Australia	6,690.26	239.98	13.92%	3.6%	6.55%
Tasmania	1,190.34	112.61	2.48%	9.5%	3.07%
Northern Territory	478.59	58.46	1.00%	12.2%	1.60%
ACT	8.52	0.04	0.02%	0.5%	0.00%

Growers will continue to produce blueberry and raspberry while it is profitable. In Australia blueberries and raspberries are mainly grown for the fresh market. While fresh raspberries exports are negligible due to the highly perishable nature of the fruit and biosecurity issues, in particular relating to Qff, currently there are no imports of fresh raspberries due to perishability and because of the potential entry of exotic pests and diseases of rubus.

It is estimated that currently Australia exports less than 10% of its total production of blueberries as fresh fruit. Before the closure of some export markets due to concerns about Qff and Medfly, increase in the value of the Australian dollar and competition for export markets from cheaper South American exports, such as from Chile, Australian export of fresh blueberries was about 30% of total production.

Australia has a free-trade agreement with Chile and this poses a potential threat from imports from Chile if the domestic market is opened up. Were Australia to grant quarantine access for Chilean blueberries and raspberries into Australia, a significant share of the domestic market, perhaps 40% or more, could be lost to the Chileans. Chilean blueberries and raspberries have a much lower cost of production than Australia and their season clashes with the Australian peak season. Access for Chilean blueberries and raspberries into Australia would result in materially lower market returns significantly impacting on the profitability of Australian growers. (HAL 2008)

Free-trade, bilateral and regional agreements such as those with South Korea, Malaysia, Japan, China, Singapore, US, Thailand, the Gulf states and India could open up export markets for Australian fresh produce, however phytosanitary access, which is independent of these agreements is a key element of ‘regional architecture’ which impacts on horticultural exports. Competitive access across borders must, in the case of fresh produce, be supplemented by phytosanitary access under commercial conditions. Phytosanitary access is negotiated at official bilateral level in the case of each commodity or group of commodities under the terms of the World Trade Organisation’s (WTO) Sanitary and Phytosanitary (SPS) Agreement (HAL 2010). Unsuitable or non-existent sanitary or phytosanitary access protocols result in non-tariff barriers which block or affect the potential of trade liberalisation under bilateral and regional agreements. In the case of horticulture, the ability to export adds greatly to the industry’s economic performance and welfare. Higher value and additional markets can be accessed and returns improved. The impact on the domestic market is also favourable as product will not need to find its way onto local markets putting pressures on price and returns. New and improved phytosanitary access is important. (HAL 2010).

Phytosanitary market access is the greatest single obstacle to the expansion of the Australian horticulture industry’s export performance. In 2008 it was estimated the overall extent of this constraint is probably of the order of half again (around $400 million) of the then current level of fresh horticultural exports (around $800 million) i.e. Australia had an annual export potential for primary horticulture of $1.2 billion with appropriate market access (HAL 2008).

For blueberries, at present, imports of fresh fruit can be considered an alternative to domestic grown produce but are mainly used to extend the season of availability and supplement the domestic supply. These imports are almost exclusively from New Zealand. With the new growing areas being developed and the growing of new varieties in northern NSW, Tasmania, southern Queensland and even further north in Queensland, fresh Australian grown blueberries are now available year round. To facilitate the movement and trade of fresh blueberries around Australia to enable the year-round availability of fresh fruit, adequate phytosanitary treatments must be available and used. This would ensure the continuing development and maturation of the industry and allow increased production and profitability. Thus, it is significant that access to markets be maintained.

The use of irradiation as a phytosanitary measure will result in reduced use of and less dependence of pesticides resulting in greater environmental benefit. Also the risks to environmental quality are negligible because of adherence and compliance to proper safety procedures regulated by the relevant authorities. Approval of irradiation would also provide industry with the opportunity to reject or lessen the use of methyl bromide as a treatment option and contribute to a reduction in Australia's use of this fumigant in accord with Australia's commitments under the Montreal Protocol.

A regulatory drawback is the lack of an independent verification of the irradiation treatment efficacy, except from records, because pests may be found alive during commodity inspection, although the pests are sterilised. This will undoubtedly result in delays until the matter is resolved and the technology is better understood.

Reviews of the benefits of ionizing radiation as an alternative treatment for various purposes are well documented (Morris 1987, Thayer and Rajkowski 1999, Thomas *et al*. 1995) and there are international standards relevant to the irradiation of fruit and vegetables. Irradiation is a phytosanitary option used around the world including the United States and is approved by the World Health Organisation and Australian Government.

The treatment method has been successfully tried and tested and been applied to several types of food in more than 30 countries, including Canada, Japan, France, the Netherlands, Belgium, South Africa, Australia, China, India, Mexico, Vietnam, Thailand and the United States. These clearances can be viewed on the Irradiated Food Authorization Database (IFA) website http://nucleus.iaea.org/ifa/.

Extensive studies conducted over more than 50 years supports the safety of irradiated food for consumption (Diehl 1995, WHO 1994, WHO 1999). The overall conclusion is that there is very little chemical change in irradiated foods and the radiolytic products formed with irradiated fruit (if any) up to a maximum of 1 kGy does not present any health problems.

The FAO/IAEA/WHO Expert Committee on Food Irradiation (JECFI) concluded that "…the irradiation of any food commodity up to an overall average dose of 10 kGy presents no toxicological hazard, hence, toxicological testing of food so treated no longer required." Also, in the same report, it was concluded that "…irradiation of foods up to an overall average dose of 10 kGy introduces no special nutritional or microbiological problems" (JECFI 1981).

For irradiation, fruit is treated in a special fully licensed and regulated processing facility after grading and packaging thus avoiding re-contamination or re-infestation of the product. There are approved packaging materials suitable for irradiation treatment. The facilities that carry out the treatment are approved and licensed facilities for the purpose, the correct doses used are as required by law and only good quality produce are accepted for irradiation as the treatment cannot be used as a substitute for poor hygienic practices.

Various International Standards already exist for the application for irradiation of fruits and vegetables. New Zealand and Australia are members of the World Trade Organisation (WTO) and have obligations under the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement). The SPS Agreement (WTO 2011) recognises the standards, guidelines and recommendations of competent international organisations. These international organisations include the Codex Alimentarius Commission for human health. Codex has adopted a General Standard for Irradiated Foods which in summary recommends that irradiation should be regarded as any other food process and as providing a safe and nutritionally adequate product generally up to a maximum dose of 10 kGy (CODEX 1983, CODEX 2003a).

ISPMs already in place, under the SPS Agreement (Australia and New Zealand are contracting parties), include:

- ISPM 18 - for harmonising the use of irradiation as a phytosanitary treatment for international trade (IPPC 2003) and has adopted a generic minimum dose of 150 Gy as a treatment measure for Tephritid fruit flies within ISPM 28 (IPPC 2009, Appendix 7).

- ISPM No.18 – *Guidelines for the Use of Irradiation as a Phytosanitary Measure* (IPPC 2003) provides technical guidance on the procedures for the application of irradiation as a phytosanitary treatment for regulated pests or articles. It is the international standard for harmonising the use of irradiation as a phytosanitary treatment.

- ISPM 28 – *Phytosanitary Treatments for Regulated Pests* (IPPC 2009) describes the requirements for submission and evaluation of the efficacy data and other relevant information on a phytosanitary treatment, with *Irradiation Treatment for Fruit Flies of the Family Tephritidae* (*Generic*) in Annex 7.

FSANZ Standard 1.5.3 is in general conformity with the principles of the Codex Standard although it reserves the right to evaluate irradiated foods on a case-by-case basis. The amendment of Standard 1.5.3 to add raspberry and blueberry to the Table of Clause 4 would therefore put Australia and New Zealand in further compliance with the SPS Agreement. It would be consistent with the SPS principles that all phytosanitary measures should be the least restrictive to trade possible and be based on sound scientific principles. ICA 55 (for Australia) and the Import Health Standards (for New Zealand) outline phytosanitary measures that are in conformity with ISPM 18 and ISPM 28.

There would be minimal disruption to domestic and interstate marketing and enhanced market opportunities and trade between Australia and New Zealand and other international markets. Potentially new markets and other export opportunities could be developed in view of the international treaty relating to plant health and biosecurity (ISPM 18) and the approved US generic radiation dose of 150 Gy for all Tephritid fruit flies and 400 Gy for all other insects except Lepidoptera pupae and adults.

2.4.3 To industry

Accurate and up-to date data are difficult to find on the value of the blueberry and raspberry industry. In 2012/13 agriculture in Australia had a gross value of $48b (ABS 2014) with NSW being the leading agricultural production state closely followed by Victoria and Queensland; together these three states are responsible for $34b or 71% of Australia's total agricultural production (Table 7). For the same year fruit and nuts (excluding grapes) represented 7.6% of total agriculture and had a total Gross Value of $3.66b for Australia with $2.82b together from the three most productive states, NSW, Victoria and QLD. The total value of blueberry production in 2010/11 was estimated at $82.3m with a production volume of 2903 tonnes (ABS 2012); in 2012/13 total value of production was estimated at

$54m and in 2013/14 the estimate is $156m (NSW DPI, P. Wilk, private communication). Total gross value of raspberry production in 2010/11 was $27.9m when total production volume was 796 tonnes (ABS 2012); the total production volume for 2013/14 is estimated at 2000 tonnes (HAL, private communication) so GVP for this year would be at least double that and estimated at $60m.

Australian horticulture exports more than 90 fresh fruit and vegetable products to more than 60 countries and was worth $672M in 2012/13. The largest destinations are Hong Kong, Japan, USA and Singapore; although many other countries and regions such as Middle East, Pacific Islands and Europe are also key markets (Australian Horticultural Exporters Association (AHEA)).

Currently, Australia is not a significant exporter of blueberries. In the early 2000's, exports represented variably around 30% of fresh consignments. Current exports are estimated at less than 10% of fresh blueberry production. The lack of phytosanitary access to the Japanese market due to perceived fruit fly risk in particular has caused this decrease. Australia does not export raspberries at present due to the highly perishable nature of this fruit and phytosanitary concerns.

Socio-economic benefit within the distribution and supply chain and the jobs involved in the horticulture sector are a significant addition to the jobs created on-farm. Horticulture also accounts for about 20% of total employment in agriculture, employing about 100 000 people (HAL 2008). In 2009-10 an estimated 63 300 people were employed in Australia to grow fruit, vegetables and nuts for the domestic and export markets, with a further 9800 employed in processing (HAL 2012, DAFF 2011).Production volumes, farm gate and retail values and import/export figures can differ quite dramatically year-on-year, but nevertheless the sector contributes to significant regional economies and community health.

Approval for the use of irradiation as a disinfestation treatment for horticultural produce will provide an alternative phytosanitary measure for use on fresh produce shipped to pest-free areas within Australia at a time when existing measures are under threat of further restrictions or suspension.

A significant advantage of the treatment method is its tolerance by a majority of fresh produce. The availability of an alternative option can help reduce the risk of product shortages, higher prices and uninterrupted access. Recently, approval was obtained to irradiate tomatoes and capsicums and this means renewed market access for these two popular fresh commodities.

Irradiation is a phytosanitary measure that can be implemented rapidly since ICA 55 is already in place in Australia and there is experience of exporting irradiated papaya, mango, litchi, tomato and capsicum to New Zealand under existing approvals. No other alternative presently offers this advantage.

At present over 90% of Australian blueberries and about 80% of Australian raspberry are sold fresh domestically and both local production and local consumption is rising. The use of irradiation as a phytosanitary measure will maintain the ability to ship produce to pest-free areas within Australia at a time when existing measures are under threat of further restrictions or suspension and will allow the continued growth of the industry. The ability to provide good quality fruit in all markets throughout the year may result in reduced price variations and increased consumption overall.

As, at present, there are no imports of fresh raspberries, there is no potential impact on markets in countries exporting to Australia. New Zealand is the only significant exporter of fresh blueberries into Australia – 817 tonnes in 2012 (freshlogic 2014b). These act as an extension of the Australian season and peak in January-March. This coincides with southern Australian production, particularly from Tasmania, but with growing consumption of blueberries in Australia fresh imports have had modest growth. Given the present low but growing household penetration of blueberries in Australia, it cannot be envisaged that imports of New Zealand fresh blueberries will be affected if irradiation of this fruit is allowed. Imports of frozen and processed raspberries and blueberries will be unaffected.

Entry of Australian fresh produce into other markets is not expected to have a significant economic impact on prices or production in export destinations, especially given the costs of treatment and transport. Given that phytosanitary market access is the greatest single obstacle to the expansion of the Australian horticulture industry's export performance, the ability to use irradiation as a phytosanitary measure would increase export opportunities. Irradiation is a phytosanitary option used around the world including the United States and is approved by the World Health Organisation and Australian Government.

Approval to permit irradiation of raspberry and blueberry for a phytosanitary purpose would ensure both minimal economic loss to the industry and continued supply. With economies becoming global, the need to meet the high phytosanitary requirement of trade partners would be uppermost and irradiation treatment is suitable for this purpose.

Reduced use and less dependence of chemical pesticides is the principal environmental benefit. There would be no requirement to store and dispose of pesticides on-farm and there is no associated withholding period, no chemical residues are left on the product surface and cost-savings are expected with reduced wastage resulting from expected reduced damage to produce quality. Furthermore, the ability to treat in the final packaging and in pallet loads is an obvious advantage.

The cost of irradiation to industry is not fully known, however, it is expected that these would be comparable to treatments currently employed. The current costs for irradiating 1 tonne of fresh produce in Australia, ranges from $90 - $120 per tonne/pallet and is dependent on the minimum dose required e.g. 150Gy – 400Gy (Steritech, private communication, 2014). This equates to $0.01 to $0.015 per punnet of raspberry or blueberry. This is expected to decrease as volumes increase.

Incorporating irradiation treatment into the commercial supply chain could be effectively and efficiently achieved; however, the decision to do so is a commercial one considered and assessed fully by the industry. Logistical bottlenecks resulting from current limited availability of the technology in Australia and New Zealand for the purpose of phytosanitary disinfestation may be a disadvantage.

Benefits to industry would be stability in the fresh produce market and prices, and access to export markets is maintained. There is potential for increased export returns and new opportunities. The continued prosperity and growth of the blueberry and raspberry industries and its associated supply chain partners would have a positive benefit to government revenue and regional communities and society generally.

2. 5 Produce – Industry structure and fruit production and consumption

2.5.1 Raspberry industry structure and production

Current and consistent statistics relating to raspberry production in Australia are difficult to obtain. The difficulty in quantifying the Australian production levels is to a large extent due to the geographical diversity and range of business sizes involved in growing raspberries. Also, production has been rapidly increasing year by year, particularly in NSW and Queensland.

Data are available for the Rubus industry as a whole and these are a reasonably accurate measure of raspberry totals as raspberry is by far the major rubus grown in Australia. Statistics on production which is subject to levies is available from Raspberries & Blackberries Australia (RABA) through HAL.

RABA (formerly known as The Australian Rubus Growers Association, ARGA) has over 150 members around Australia. It is the peak industry body representing the rubus and ribes industry. The Rubus industry statutory levy commenced on 1st July 2006. The levy is collected at the first point of sale for wholesale fresh market fruit. Wholesalers, market agents, supermarkets and export agents collect the levy on behalf of growers and send it to the Levies Revenue Service. The levy applies to fresh market fruit only. The current levy is

$0.12/kg consisting of $0.10/kg for research and development projects and $0.02/kg for marketing and promotion.

ABS data for the year 2010/11 show for Australian raspberry production that 149 businesses produced 796 tonnes of raspberries on an area of 269 ha with a GVP of $27.9m. There were another 34 ha of non- productive immature plantings owned by 47 businesses. The industry is made up of three major players spread over three key growing areas (Wilk and Simpson 2014). A 2004 survey of ARGA's commercial members found that 65% grew less than 1 ha of rubus (ARGA 2009).

Rubus (mainly raspberry) production statistics obtained from HAL for the 2007/08 to 2011/12 seasons are given in Table 8. RABA data for the 2012/13 season show production subject to levies was 1,565 tonnes. Assuming that about 20% of total current production is not subject to levies, national Rubus production is currently approximately 2,000 tonnes (*HAL, private communication July 2014*) with an estimated value of production of between $78m and $100m.

Table 8. Australian Rubus (mainly raspberry) production (in tonnes) by state

Production by state (tonnes)							
Season	**NSW**	**VIC**	**QLD**	**SA**	**WA**	**TAS**	**Total**
2007/08	100	250	20	minor	minor	130	500
2008/09	175	350	35	minor	minor	140	700
2009/10	200	200	80	minor	minor	160	800
2010/11	270	360	135	minor	minor	135	900
2011/12	320	360	135	minor	minor	185	1,000

(Source: HAL Horticultural Statistics Handbook 2012; 2011/12 estimates, RABA)

As can be seen from Table 8, while Victoria and Tasmania have been the traditional area of raspberry growing, production in NSW and Queensland has expanded rapidly since the 2007/08 season and it continues to grow and mature. This expansion has been supported by an increase in the adoption of protective cropping practices (freshlogic 2014b).The industry has been growing by between 10 and 15% annually for the past 5 years and is likely to continue this trend into the foreseeable future (HAL 2014b).

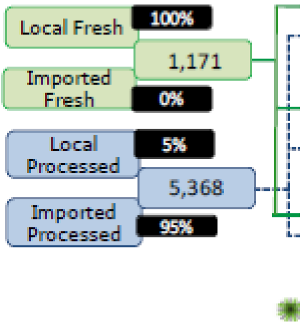
Fresh raspberries are currently available in Australian supermarkets and green grocer stores throughout the year. Raspberries produced in southern states are available November to May and those grown in the northern states have their main seasonal window from April to November (HAL 2012). The growing areas for raspberries in Australia in 2005-06 are shown in Figure 2.

On the world scale, Australia is not a significant raspberry producer; in 2012, by volume of production, Australia was ranked 42, with the Russia ranked 1 (133,000 tonnes), Poland ranked 2 (127,055 tonnes) and USA ranked 3 (100,775 tonnes) (FAO Stat Agricultural Database (FAO 2014)).

In Australia, first grade fruit is directed towards the fresh market. For many growers this is represented by a local greengrocer, farm-gate sales of packaged fruit, or "pick-your-own" (PYO) sales. Larger businesses that can provide greater volumes over a longer period direct their fruit to supermarkets and wholesale markets. Second grade fruit is processed into juices, puree and jams. A large quantity of processed raspberries is imported annually mainly from Chile, China and Serbia. The Australian industry is considered uncompetitive against these processed imports; however, in 2009, at least one major business was considering specialized mechanically-harvested plantings to supply the processed market (ARGA, 2009).

Figure 4 shows the quantity and proportion of fresh and processed local and imported raspberries which are exported or sold in the domestic retail and food service industry for 2012/13.

Figure 4. Raspberry supply chain in Australia showing tonnes and proportion of Australian raspberries sold fresh and processed/frozen through export, retail and foodservice markets for the year ending June, 2013. (Source: Raspberry Market Profile updated March 2014, freshlogic 2014b)



The Australian raspberry industry is focussed on the domestic fresh fruit market, with negligible exports due to the highly perishable nature of the fruit and phytosanitary concerns. For the same reasons, imports of fresh fruit are also negligible, although there are significant imports of processed raspberry products.

2.5.2 Raspberry consumption

The combination of production areas ranging from Queensland to Tasmania provides a year-round national supply, primarily as fresh fruit for the retail or hospitality market. About 80% of the national raspberry production is destined for domestic consumption and it is a growing niche industry within Australia's agricultural sector. However, of total domestic supply, which also includes imported and local grown processed raspberries, only 18% is used in the fresh form. Fresh raspberries are available through the retail market (supermarkets and greengrocers) and through foodservice channel, such as restaurants and cafés. The fresh raspberries are consumed at home as a snack, at breakfast, for example with cereal and yoghurt, or fresh for dessert. For the year ending June 2013, the estimated domestic retail market value of fresh raspberries purchased by consumers was $37m with an average retail price of $50.30/kg. At an average price of $6 per 125g punnet, fresh raspberries are one of the highest cost fruits (freshlogic 2014b).

In Australia, raspberries are consumed mainly processed or frozen. It is estimated that 82% of the total domestic supply (Australian grown plus imports) is used in a processed form (freshlogic 2014b). There is a large retail market for frozen berries, either as raspberries by themselves of as part of a mixed berry pack. These are used in the home, in retail products and by the food service industry in such goods as desserts, muffins, cakes, juices, breakfasts and smoothies. The food service industry mainly (about 90%) uses processed raspberries (freshlogic 2014b). Raspberries are also consumed processed as juice, sauces and jams.

HAL statistics indicate that nationally the household penetration for raspberries in 2010/11 was only 7.04% and that the average weight of purchase was 0.28kg/year (HAL, 2012). Another estimate of per capita consumption, in this case for the year ending June 2013, is 0.27kg consisting of 0.03kg fresh raspberries bought through the retail channel for home consumption, 0.01kg fresh berries purchased and consumed in foodservice away from home, 0.23 kg of processed raspberry products purchased through retail for home and foodservice consumption (freshlogic, 2014b). There is considerable scope for increased consumption with increased household penetration.

Current (2013/14) per capita consumption figures for raspberries could not be obtained; however with increased local production and increasing availability of high quality fresh raspberries throughout the year, consumption could be assumed to be rising.

2.5.3 Blueberry industry structure and production

Reliable current and consistent statistics relating to blueberry production in Australia are difficult to obtain. One reason for this is that the blueberry industry is a rapidly expanding industry with production increasing rapidly year by year, particularly in NSW and Queensland. Recent increases in have been estimated at about 20% per year. Data collected by the NSW DPI Blueberries Development Officer are shown in Table 9.

Table 9. Australian blueberry production data for years 2007/08 to 2013/14 collected by NSW DPI. *2013/14 data is preliminary.

	2007/08	*2008/09*	*2009/10*	*2010/11*	*2011/12*	*2012/13*	*2013/14**
Volume (t)	1984	2330	2775	3615	3780	N/A	5865
Area (ha)	545	600	625	650	700		
Fresh Domestic (t)	1090	1360	1640	2320	2410		
Fresh export (t)	450	320	270	320	320		
Processed (t)	360	450	550	450	450		
High Chill	17%	25%	30%	33%	35%		
Low chill	83%	75%	70%	67%	65%		
Fresh$/kg	20.9	21.24	21.55	18.98	19.65		26.60
Processed $/kg	5.76	5.45	3.95	3.03	3.83		
Total value of Australian industry $M	**32.1**	**35.68**	**41.1**	**50.7**	**53.69**	**N/A**	**156.33**

(Source: Phillip Wilk, Development Officer – Blueberries, NSW DPI – personal communication, May 2014.)

ABS data for the year 2010/11 (the most recent with blueberry data) show for Australian blueberry production that 177 businesses produced 2903 tonnes of blueberries berries on an area of 731 ha with a GVP of $82.3m. There were another 196 ha of non-productive immature plantings owned by 104 businesses (ABS 2012). One marketer has an 80% share of blueberry distribution. The Australian blueberry industry GVP for 2013/14 has been estimated at $156m (Table 9, NSW DPI, P. Wilk, personal communication) reflecting the rapid growth of the industry.

The industry is dominated by 3 major growers in the Coffs Harbour region who together account for about 80% of Australia's total blueberry production. One company grows over 60% of the Australian crop and markets more than 80% of Australian blueberries. This company produces blueberries on 250ha at Corindi (near Coffs Harbour), on 40ha in Tumbarumba (southern NSW) and on 50ha in Sulphur Creek in Tasmania and in this way aims at year round production. They also have a marketing alliance with major producers in NSW (another 125ha), Victoria and Tasmania. They have also developed an alliance with an international berry company. Another NSW producer with an area of 50 ha continues to be independent of this group. In contrast to the NSW blueberry industry, in Victoria and Tasmania the industry is made up of a large number of smaller producers having 1 to 3 ha of production area each and a few larger producers.

The aim of the industry is to provide year-round supply of fresh blueberries. By careful selection and breeding of varieties to suit differing climates and geographical positions from North Queensland south to Tasmania, fresh blueberries can be supplied to markets throughout the year. This is exemplified by very low chill varieties being grown in northern Queensland to provide supplies in winter and high chill varieties grown in Tasmania for summer production.

The area centred around Coffs Harbour on the NSW Mid-North Coast is the main area of the Australian blueberry production. ABS data for GVP for blueberries for 2010/11 show NSW to be responsible for 88% of the national GVP with 93% of this (or 83% of national GVP) coming from the Mid-North Coast region (Tables 10 and 11, ABS 2012). Smaller production areas are located in southern NSW, southern Queensland, Victoria and Tasmania with minor production in South Australia, Western Australia and northern Queensland. Production in northern NSW and Queensland is from June to February, in southern NSW and Victoria from December to April, Western Australia and South Australia December to March, and Tasmania from January to April.

Table 10. Gross Value of Production (GVP) for blueberries nationally and by state for the year 2010/11 (ABS 2012)

2010-11	Australia	NSW	VIC	QLD	SA	WA	TAS
GVP ($m)	82.3	72.6	6.6	0.2	0.3	0	2.6
% of GVP		88.2	8.0	0.2	0.4	0	3.2
Local ($m)	74.6	65.2	6.4	0.1	0.3	0	2.5

Table 11. GVP for blueberries by NSW region for 2010/11 (ABS 2012)

Blueberries 2010/11	**GVP ($m)**	**% of Australian GVP**
Australia	82.3	
NSW	72.6	88.2
Central West	0.0	0.0
Far West	0.0	0.0
Hunter	0.0	0.0
Illawarra	0.4	0.5
Mid-North Coast	68.0	82.6
Murray	1.9	2.3
Murrumbidgee	0.0	0.0
Northwestern	0.0	0.0
Northern	0.1	0.1
Richmond-Tweed	2.2	2.7
South Eastern	0.0	0.0
Sydney	0.0	0.0

On the world scale, Australia is not a significant blueberry producer. By volume, in 2012, the USA was ranked 1 (214,708 tonnes), Canada was ranked 2 (120,929 tonnes) and Poland was ranked 3 (11251 tonnes) (FAO Stat Agricultural Database (FAO2014)). Australia was unlisted in these rankings though New Zealand was ranked 10 with production of 2526 tonnes which would be less than Australia's volume of production; in 2011/12 Australia's production was estimated at 3780 tonnes in data collected by NSW DPI (Table 9, P. Wilk, personal communication).

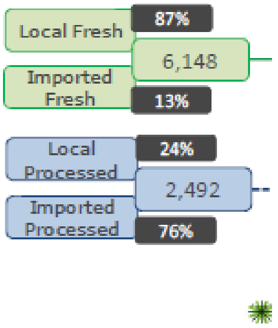
Currently Australia is not a significant exporter of blueberries. Data for 2013/14 provided by Australia's largest blueberry exporter (*Costa Berries, private communication*) show only 149.07 tonnes (7.5% of their total production) were exported. In 2012, FAO data has the USA exporting 49,036 tonnes, Canada, 20,090 tonnes, Spain, 4790 tonnes and New Zealand, 667 tonnes; for 2011/12, NSW DPI data estimates 320 tonnes were exported (Table 9, P. Wilk, *private communication*). In the 1990's Australian fresh blueberry exports represented an estimated 70% of the fresh blueberry consignments. In the early 2000's, exports represented variably around 30% of fresh consignments. Current exports are estimated at less than 10% of fresh blueberry production.

In 2012 Australia imported an estimated 817 tonnes of fresh blueberries and 1905 tonnes of processed blueberries. The fresh fruit were imported from New Zealand usually between January and March (freshlogic 2014a) to supplement the seasonal demand. Levels of fresh imports have grown in response to the increase in consumption of blueberries by

Australians. Processed blueberries were imported from mainly China, Chile and the USA.

The proportions and volume of Australian and imported blueberries sold fresh or processed to domestic retail and foodservice and exported for 2012 are shown in Figure 5.

Figure 5. The Australian Blueberry supply chain showing proportions and tonnage of Australian and imported blueberries sold fresh or processed to export, retail and foodservice. (Source: Blueberry Market Profile (updated March 2014) freshlogic 2014a.)



In summary, currently the industry is focussed on the domestic fresh fruit market, with the aim of providing year-round fresh blueberry supplies throughout Australia. Exports do occur but at a reduced proportion of total fresh production compared to in the past. Imports of fresh fruit have increased and there are significant imports of processed blueberry products.

2.5.4 Blueberry consumption

Consumption of blueberries in Australia is growing. The demand for blueberries has been driven by the wide promotion of the health benefits of consuming these fruit. They have been described as a “superfood” with significant health benefits related to their high antioxidant content.

With the combination of numerous plant varieties and production areas, ranging from Queensland to Tasmania and across to WA, plus some imported fresh blueberries, a year-round supply of fresh blueberries can now be provided nationally to consumers via the retail or hospitality markets. About 90% of the national blueberry production is destined for domestic consumption and it is a growing niche industry within Australia’s agricultural sector. Blueberries are also purchased and consumed processed, pulped or frozen and in manufactured goods, such as desserts and baked goods. The majority (about 76%) of processed, pulped and frozen blueberries in Australia are imported. The proportion of the locally grown fruit which is processed is decreasing as the domestic demand for fresh blueberries increases (freshlogic 2014a).

Current per capita data could not be sourced, however, it has been estimated that about 70% of the volume of blueberries consumed in Australia is consumed fresh. For the year ending December, 2012, it was estimated that the per capita consumption of fresh blueberries was 254g; 203g were purchased through retail (supermarkets and greengrocers) for home consumption, and 51g consumed in foodservice, such as restaurant or café. Another 109g of blueberries was consumed per capita as processed products, either through retail or foodservice, giving a total per capita consumption of blueberries of 363g (freshlogic 2014a). In 2010/11 the household penetration of blueberries was estimated at 29.77% and an average annual weight of purchase of 0.74kg (HAL 2012), so there is potential for increased consumption.

Australia is one of the highest per capita blueberry consumers in the world, though still not as high as in the USA where consumption was estimated at between 450 and 570g per capita in 2011/12. Australians consume blueberries mainly as a dessert, either fresh or cooked. They are also eaten as a snack, at breakfast with cereal and yoghurt or pancakes, and are added to “smoothies” (freshlogic 2014a).

Consumption peaks in the last three months of the year when volumes are highest and prices lowest, so price appears to be affecting consumption rates. They are sold in 125g punnets and are high cost fruit. In 2012, the estimated domestic retail market value of fresh blueberries purchased by consumers was $132m at an average retail price of $28.62/kg. In 2012, wholesale prices for fresh blueberries ranged from $14.75 to $52.13 per kg with a peak in May to July and through November to January (freshlogic 2014a).

PART 3 – SAFETY ASSESSMENT CONSIDERATIONS

3.1 Nutritional data

A wide variety of fresh produce is available in Australia and New Zealand. The 1997 National Nutrition Survey in New Zealand (MOH 1999) found that in the New Zealand population aged 15 years and over, the five most commonly eaten fruits (percentage of the population consuming one serve at least once per week) were banana (82%), apples (73%), oranges (67%) stone fruit (56%) and pear (47%). Berry fruit, including strawberry and other berries or cherries, came in sixth with 39% of the population consuming at least one serve per week; this would have included raspberry and blueberry. The most common types of vegetables consumed by New Zealanders at least once a week were potato (95%), carrots (83%), tomatoes (77%), lettuce (73%), onions/leeks (71%) and peas (68%). Sub-populations may have a higher than average consumption for a fresh produce but overall, raspberry and blueberry, the fruit of concern in this application are not a major part of the diet of the Australian or New Zealand population. For the Australian population, in 2013, the annual per capita consumption for fresh and processed raspberry was 0.28 kg (of which 0.04 kg is fresh) (freshlogic 2014b). For the Australian population, in 2032, the annual per capita consumption for fresh and processed blueberry was 0.363 kg (of which 0.254 kg is fresh) (freshlogic 2014a). From the dietary consumption patterns (ABS 1998, 1999, MOH 1999) and the nutrient tables (MOH 2009, FSANZ 2010, USDA 2011b), it appears that the major contribution to daily dietary intake of macronutrients and micronutrients will come from foods other than raspberry and blueberry.

The nutritional profile for both raspberry and blueberry before and after irradiation treatment is discussed separately in the following sections.

Raspberry and blueberry are relatively high priced, tasty and antioxidant-rich (mainly due to anthocyanin and vitamin C content) fruit. In 2011 the average retail price of raspberry in Australia was $42.25 per kg. In 2012 the average retail price of blueberry in Australia was $28.62 per kg. The relatively high prices for these berries results in them being consumed in lower quantities than other lower priced fruit such as bananas ($2.19/kg), red delicious apples ($3.89/kg) and navel oranges ($3.98/kg) (prices on 30 Jan 2014 from Woolworthsonline.com.au). The pattern of blueberry consumption illustrates the strong connection between lower prices and higher consumption. Although blueberries are available most of the year, consumption peaks in the last three months of the year coinciding with peak supply volume and lower pricing (freshlogic 2014a).

Table 13 compares vitamin and pro-vitamin values for raspberry and blueberry with produce currently approved by FSANZ within Standard 1.5.3 for irradiation and for the most commonly consumed fruit and vegetables in New Zealand (MOH 1999). Regarding vitamin C levels, raspberry levels are higher than blueberry, for both berries levels are similar to or lower than for commodities presently approved to be irradiated and raspberry has higher levels than the most commonly consumed fruit and vegetables with the exception of orange and peas. Compared to tomato, blueberry has similar levels of vitamin C and beta-carotene equivalents. Raspberry is not a rich source of beta-carotene equivalents. Blueberry and raspberry are not particularly high in any other vitamin or provitamin and so are not expected to significantly contribute to the daily nutritional intake.

Provitamin A (carotenes) and Vitamin C are present in other fresh produce and preformed vitamin A is present in foods such as organ meats, dairy products, eggs and ready-to-eat cereals. Green vegetables, grains and dairy and egg products generally are excellent sources of Vitamin K and nuts, seeds, vegetable oils and many fresh vegetables are good sources of Vitamin E. Folate can be found in small amounts in many foods with a major dietary source being enriched and fortified foods.

Anthocyanins are water-soluble plant pigments responsible for the blue, red and purple colours of many fruit and vegetables including blueberry and raspberry. They are classed as flavonoids and are phytonutrients valued for their antioxidant properties. Foods high in anthocyanins are widely consumed for these antioxidant and other health promoting qualities, such as cancer prevention and, more recently, dementia prevention.

Blueberry is one of the highest sources of anthocyanins of any fruit or vegetable. A study in the USA of the anthocyanin content of 100 commonly consumed foods (including fruits, vegetables, nuts and dried fruit, spices, cereals, juices and other foods) found 24 foods, mainly fruit and vegetables, containing anthocyanins (Wu *et al.* 2006). It should be noted that in this study some of the most commonly consumed fruits and vegetables in Australia and New Zealand were found not to contain anthocyanins; these were bananas, navel orange, pears, carrots, peas, potatoes and tomatoes. Cultivated blueberry was found to have one of the highest concentrations of total anthocyanins (387 mg/100g) and red raspberry also had relatively high levels (92.1 mg/100g). A list of anthocyanin-containing fruits and vegetables commonly consumed in Australia and New Zealand is shown in Table 12 with their anthocyanin content (Wu *et al.* 2006). When the daily consumption of anthocyanins in the USA population was calculated using the average daily intake of the anthocyanin containing foods (using data from the National Health and Nutrition Examination Survey 2001-2002 (Wu *et al.* 2006)) it was estimated to be 12.53 mg/day. Raw blueberry contributed 3.39 mg/day making it the single biggest contributor to total intake. Raw raspberry contributed 0.93 mg/day, though this included black raspberry which have about 7 times higher anthocyanin content than red raspberry. Though the consumption of blueberry and raspberry may be higher in the USA than in Australia and New Zealand at present, consumption is trending up, so their contribution to anthocyanin dietary intake could be significant. The anthocyanin content of raspberry and blueberry before and after irradiation treatment is discussed separately in the following sections.

Table 12. Anthocyanin content of commonly consumed fruits and vegetables. (Adapted from Wu *et al*, 2006).

Commodity	*Total anthocyanin mg/100g*
Fruits	
black raspberry	**687**
black currant	476 ± 115
blueberry, cultivated	**386.6 ± 77.7**
blackberry	245 ± 68
cranberry	140 ± 28.5
black plum	124.5 ± 21.6
cherry, sweet	122 ± 21.3
red raspberry	**92.1 ± 19.7**
red grape	26.7 ± 10.9
strawberry	21.2 ± 3.3
apple, red delicious	12.3 ± 1.9
nectarine	6.8 ± 1.5
peach	4.8 ± 1.2
apple, Gala	2.3 ± 0.8
apple Fuji	1.3 ± 0.7
Vegetables	
red cabbage	322 ± 40.8
red radish	100.1 ± 30.0
eggplant	85.7
red onion	48.5
black bean	44.5
red leaf lettuce	2.2 ± 1.5

Raspberry and blueberry are consumed in lesser amounts than many popular fruit and vegetables. They will not be a significant contributor to overall micronutrient intake as daily intake of micronutrients will come from a range of types of foods. Furthermore, socio-economic position, preferences, parental intake, and home availability/accessibility are all consistently positively associated with intake.

Early studies on the effects of irradiation on fruit quality parameters, colour, flavour and texture showed that many factors can influence fruit responses to irradiation, including fruit maturity, cultivar, storage temperature and controlled atmosphere storage (Massey and Bourke 1967, Narvaiz *et al*. 1988, Maxie and Abdel-Kader 1966, Bhushan and Thomas 1998, Miller and McDonald 1996). Arvanitoyannis *et al.* (2009) summarised the various applications of gamma irradiation in fruit and vegetables from 1978 through to 2007 – nutritional and fruit quality and shelf life extension, reducing postharvest losses and controlling stored product insects and microorganisms. Compared to other widely employed processing methods, irradiation offered greater advantages in shelf life extension, no change in physical and organoleptic properties and at lower cost.

The absorbed dose, commodity maturity and physiological state at harvest, pre- and posthandling, transportation, presence of microorganisms, storage environment and storage time all interact to affect product quality and shelf life. Different outcomes in nutritional quality after similar treatments can occur between different varieties of the same fruit, as noted by Thomas (1988), Morris and Jessup (1994) and Lee and Kader (2000). It is a well-known fact that the nutritional components measured depends upon the degree of ripeness of the fruit, and quite different results would no doubt have been obtained had unripe or over-ripe fruits been analysed. Furthermore, fresh produce today are generally harvested at a less mature stage for better product shelf life, than 15-20 years ago. However with regard to raspberry and blueberry, which are soft fruit with limited shelf life, there are guidelines about fruit maturity at harvest to ensure fruit is picked at the correct stage for optimum sweetness and flavour. However, fruit quality can be inconsistent due of differences in taste, colour and shelf life between varieties and at different times in the season (Australian Blueberry Industry Strategic Plan 2009-2014 (ABISP 2015)).

Table 13: Vitamin and provitamin values (per 100g) for raspberry and blueberry, [†]produce presently approved within Standard 1.5.3 and for the most commonly consumed [a]fruit and [b]vegetables in New Zealand (MOH 1999).

Commodity	*Vitamin C*	*Thiamin (B1)*	*Riboflavin (B2)*	*Niacin (B3)*	*Niacin equiv*	*Folate, natural*	*Dietary folate equiv*	*Alpha carotene*	*Beta carotene*	*Crypto-xanthin*	*Beta carotene equiv*	*Retinol equiv*	*Alpha tocopherol*	*Vitamin E*
Units/100g	*mg*	*mg*	*mg*	*mg*	*mg*	*ug*	*ug*	*ug*	*ug*	*ug*	*ug*	*ug*	*mg*	*mg*
Raspberry	**32**	**0.037**	**0.027**	**0.36**	**0.56**	**34**	**34**	**0**	**28**	**0**	**28**	**5**	**0.8**	**0.77**
Blueberry	**13**	**0.02**	**0.06**	**0**	**0.1**	**5**	**5**	**0**	**39**	**160**	**119**	**20**	**0.5**	**0.47**
[†]Breadfruit*	29	0.11	0.03	0.9			14					0	0.1	
[†]Carambola*	34	0.014	0.016	0.367			12					3	0.15	
[†]Custard apple	43	0.05	0.08	0.8	1.03			10	0	0	5	1		
[†]Longan*	84	0.031	0.14	0.3										
[†]Lychee	49	0.05	0.07	0.5	0.68			0	0	0	0	0		
[†]Mango	26	0.018	0.037	0.56	0.84			9	1433	1516	2195	366	1.3	1.3
[†]Papaya	60	0.03	0.03	0.3	0.37			0	240	1350	915	152		
[†]Rambutan	70	0.015	0.065	0.79	0.96			0	0	0	0	0		
[†]Tomato	18				0.17	16	16	0	150	7	153	26	0.2	0.26
[†]Capsicum	152	0.035	0.044	0.88	1.13	60	60	9	282	2011	1292	215	3.9	4.03
[a]Banana	4	0.02	0.047	0.35	0.6	33	33	23	23	0	34	6	0.1	0.12
[a]Apple, Red	4	0.021	0.013	0.13	0.18	16	16	0	11	3	13	2	0.2	0.23
[a]Orange	53	0.083	0.038	0.2	0.49	43	43	19	72		82	14	0.2	0.22
[a]Peach[‡]	9	0.006	0.023	1.01	1.21	0	0	2	147	0	148	25	0.7	0.7
[a]Pear	5	0.02	0.028	0.08	0.14			0	20	5	22	4	0.4	0.35
[b]Potato	1	0.06	0.09	1.26	1.68	12	12	0	0	0	0	0	0	0
[b]Carrot	6	0.079	0.04	0.69	0.9	18	18	3678	5996	124	7896	1316	0.4	0.42
[b]Tomato	18				0.17	16	16	0	150	7	153	26	0.2	0.26
[b]Lettuce	4	0.032	0.032	0.43	0.54	24	24	11	120	21	136	23	0	0.04
[b]Onion	8	0.032	0.022	0.32	0.71	0	0	22	0	0	11	2	0	0
[b]Peas	33	0.317	0.143	2.35	3.37	56	56	0	409	51	435	72	0	0.09

* Values from USDA Food Composition Tables; all other values are from the FSANZ database, NUTTAB 2010; Vitamin C is Total Ascorbic acid; Values for Vitamins B5 (pantothenic acid), B6 (pyrodoxine) and B7 (biotin) are not included as fruit and vegetables are not a good source of these vitamins. "Tomato" is "Tomato, common, raw"; "Capsicum" is "Capsicum, red, raw"; "Banana" is "Banana, cavendish, peeled, raw"; "Apple, Red" is "Apple, red skin, unpeeled, raw"; "Orange" is "Orange, navel (all varieties), peeled, raw"; "Peach" is "Peach, unpeeled, raw" ; "Pear" is "Pear, unpeeled, raw "; "Potato" is "Potato, sebago, unpeeled, boiled"; "Carrot" is "Carrot, mature, peeled, raw"; "Lettuce" is "Lettuce, Iceberg, raw", "Onion" is "Onion, mature, brown skinned, peeled, raw"; 'Peas" is "Peas, green, fresh, raw". [‡]representative of "stone fruit".

3.1.1 Effects of irradiation on nutritional content and postharvest fruit quality

There are many studies on the general effects of irradiation on the nutritional content of food. They have been extensively reviewed by several organisations and individual scientists (JECFI 1981, 1999, Murray 1983, FDA 1986, Urbain 1986b, Thomas 1988, Thayer *et al*. 1991, Diehl *et al*. 1991, Kilcast 1994, Morris and Jessup 1994, WHO 1994, Diehl 1995, FDA 2008, Crawford and Ruff 1996; SCF 2003, EFSA 2011). Most recently FSANZ has released a review of the literature on the "Nutritional impact of phytosanitary irradiation of fruits and vegetables" (FSANZ 2014a).

The reviews are in broad agreement. Irradiation up to the general 10 kGy limit of the Codex General Standard has little or no effect on the energy, macronutrient (carbohydrate, protein, total fat and dietary fibre) and mineral content of foods. Many vitamins in food are largely unaffected by irradiation but some are destroyed with the extent increasing with increasing dose. At doses below 1 kGy vitamin losses are minimal. The losses are probably within variations found between varieties of a specific food or the losses caused by storage (Mitchell *et al.* 1992, Farkas *et al*. 1997, Boylston *et al*. 2002, Fan and Sokorai 2008). Above 1 kGy losses may be significant but are no greater, and often less than, found after more conventional processing methods such as heating, freezing or canning (Kraybill 1982, Murray 1983, WHO 1994, JECFI 1999, SCF 2003, EFSA 2011).

The Food and Agriculture Organisation (FAO) and the World Health Organisation (WHO) of the United Nations convened a series of Joint Expert Committees on Food Irradiation (JECFI) which evaluated the safety and wholesomeness of irradiated foods. Prior to the approval of the Codex General Standard for Irradiated Foods, JECFI (1999) concluded that "irradiation of food up to an overall average dose of 10 kGy introduces no special nutritional or microbiological problems". JECFI did not rule out nutritional changes, but believed that any changes that did occur would be similar to those found from other processing technologies and would not present any hazard to consumers with a reasonably varied diet. (Attention should be paid to any significant changes in relation to each particular food and its role in the diet, including for sub-populations). The American Dietetics Association (ADA 2000) and ACHS (Loaharanu, 2003) concluded that the nutritional value of food is not adversely affected by irradiation up to an overall dose of 10 kGy, and supports the technology.

Literature reports on the sensitivities of water-soluble and fat-soluble vitamins and other key vitamins in foods are shown in Tables 14 and 15. Vitamin A, thiamin (Vitamin B1), ascorbic acid (Vitamin C) and alpha-tocopherol (Vitamin E) in foods are relatively sensitive to radiation while other B vitamins such as riboflavin, niacin and Vitamin D are not as sensitive.

Table 14. The radiation sensitivity of water and fat soluble vitamins [JECFI 1999]

	Radiation sensitivity decreasing left to right
Water-soluble	Thiamine (B1) > Vit C > Vit B6 > Vit B2 > Folate, Niacin > Vit B12
Fat-soluble	Vit E > Carotene > Vit A > Vit D > Vit K

Table 15. The radiation sensitivity of some key vitamins in food [Kilcast 1994]

High	Medium	Low
Vitamin C		
Thiamine (B1)	K (in meat)	K (in vegetables)
α-tocopherol (E)		Riboflavin (B2)
Retinol (A)		Pyridoxine (B6)
		Cobalamin (B12)
		Niacin (B3)
		Folic acid
		Pantothenic acid
		Biotin (B10)

However, thirty five countries including the USA and United Kingdom have approved the use of irradiation for pest disinfestation or maturation control of fresh produce. Studies show that more fresh fruits and vegetables tolerate radiation than any other commercially available treatment (Heather and Hallman 2008). FSANZ has also concluded that irradiation up to 1 kGy has no impact on the nutritional adequacy of 10 tropical fruits, persimmons, tomatoes and capsicums and 11 other fruits and vegetables (FSANZ 2002, 2011a, 2013a, 2014c).

More recently FSANZ has stated that the only micronutrient/vitamin to be of concern in regards to loss on low level irradiation is Ascorbic acid (Vitamin C).The FSANZ Board concluded as a result of a FSANZ literature review (in relation to applications to amend Standard 1.5.3 by the addition fruit or vegetables to the list of those permitted to be irradiated):

More recently the FSANZ literature review (FSANZ, 2014a) concluded that irradiation at phytosanitary doses (0.15 to 1 kGy) had no effect on macronutrient or mineral levels in fresh fruit and vegetables. Vitamin C and carotenes are the only irradiation-sensitive vitamins generally found in high levels in fresh fruit and vegetables. The review found that at this low level of irradiation there was no effect on carotene levels. Vitamin C levels decrease significantly with storage for many fruit and while in some studies low dose irradiation appeared to increase this rate of loss, in other studies irradiation ameliorated or prevented this storage-related loss. Overall, in fruit, phytosanitary doses of irradiation are not associated with significant losses of vitamin C and certainly no more than in normal maturation, storage, handling and processing. The FSANZ 2014 (FSANZ 2014a) literature review concluded that "*irradiation of fruits and vegetables with phytosanitary doses do not pose a nutritional risk to the Australian and New Zealand populations."* On the basis of the review it was recommended that application to FSANZ to amend Food Standard 1.5.3, the only nutrient composition data needed is total vitamin C but for fruits or vegetables with atypical nutrient composition or irradiation at higher doses data on other nutrients may be required.

Raspberry and blueberry irradiated at the low dose (150 – 1000 Gy) requested in this application is expected to have no significant impact on the average dietary intakes of nutrients, essential vitamins and minerals. As can be seen from Table 13 and the following nutritional tables for these two fruit (Tables 16 -, neither provides significant amounts of any essential vitamins, except vitamin C, or micronutrients. For raspberry, intake as a processed fruit is greater than as a fresh fruit and it is not expected that fruit used for processing will be irradiated.

The essential findings from numerous studies and reviews have concluded that the change in the chemical composition of the irradiated food is minimal and the resulting compounds are the same as those formed when food is cooked or processed in the more traditional ways (Josephson *et al*. 1978, Wilkinson 1985, Gholap *et al*. 1990, Diehl 1991, Diehl 1995, JECFI 1999). Vitamin losses between varieties and those effects caused by growth conditions, physiological maturity and storage are greater than responses at low radiation doses < 1 kGy. Beyers and Thomas (1979) showed that carotenoid losses in mangoes and papaya irradiated up to 2 kGy were reported to be negligible compared with the considerable losses resulting from freezing or canning.

In the literature, there have been no reported studies of low dose irradiation on the full proximate, nutritional and fruit quality aspects of low dose radiation of blueberry and raspberry fruit following storage. However, a study of this has been carried out recently by the NSW Department of Primary Industries (NSW DPI) and is fully documented in Golding *et al*. 2014a.

There have been very few reports on the effects of irradiation on raspberry (*Rubus idaeus*) fruit and nutritional quality. Studies that have been reported in the literature have been carried out for the purpose of investigating the use of irradiation at doses up to 2 kGy as a method of cold pasteurization and extension of shelf-life of these perishable fruit. Guimarães *et al*. 2013 evaluated the physicochemical and microbiological characteristics of 'Autumn Bliss' raspberries exposed to 0 (control), 0.5, 1.0 and 2.0 kGy. They showed low dose irradiation in general did not affect most fruit quality attributes, except firmness and weight loss; firmness was decreased with irradiation while percentage weight loss was reduced by irradiation. They found significant interactions between storage time and treatment in many quality variables. For vitamin C, phenolics and antioxidant activity significant effects of both treatment and time were observed plus significant interactions between time and dose. However, it should be noted that the effect was generally an increase rather than decrease in phenolics, ascorbic acid and total antioxidant activity levels; differences between treatments depended on the time post-treatment that measurements were made. Total soluble sugars (TSS) tended to increase over time but there was no interaction with irradiation dose. Titratable acidity decreased with time but there was no effect of treatment. For microbial control 2 kGy was determined to be the most effective dose but resulted in increased loss of fruit firmness.

Tezoto-Uliana *et al.* 2013, exposed raspberries to doses of 0.5, 1.0 and 2.0 kGy at stored the fruit at 0°C and 90%RH. They found that respiratory rate, ethylene production, flesh firmness, anthocyanins content and colour index were not altered by irradiation. They concluded that 1 kGy was the optimal dose to reduce decay and weight loss and resulted in the lowest reduction in ascorbic acid.

Cabo Verde *et al.* 2013 evaluated the effects of irradiation on raspberries at doses of 0.5, 1.0 and 1.5 kGy. They found that the total phenolic content and antioxidant capacity increased with irradiation dose and decreased with storage time. Irradiation induced a significant decrease in firmness compared to non-irradiated fruit. Irradiation at 1.5 kGy had 95% microbial inactivation efficiency. In general in this study the effect of storage was similar for both irradiated and non-irradiated raspberries.

For raspberry, NSW DPI found there were few changes in the nutritional content of raspberry fruit following irradiation and storage. The nutritional and proximate analysis (contents of ash, carbohydrate, dietary fibre, energy, moisture, protein, sodium, potassium, total sugar, fructose, glucose, anthocyanin) of treated fruit which had been stored for either two or seven days at 0°C were unaffected by irradiation. However the levels of some nutrients such as sucrose, ascorbic acid, citric and malic acid concentrations were significantly affected with irradiation treatment, but these differences, though statistically significant, were inconsistent and minor. For ascorbic acid, the mean concentration for fruit irradiated at 150 Gy was not significantly different from the untreated fruit (21.8 and 22.2 mg/100g respectively). The mean concentration of ascorbic acid for raspberries irradiated at 400 Gy and 1000Gy were not significantly different from each other (21.2 and 21.0 mg/100g respectively) though significantly lower than for the untreated and 150 Gy irradiated fruit. The lack of effect of irradiation on raspberry total monomeric anthocyanin levels should be noted. The length of time in storage had an effect on some fruit proximates and nutrients (ash, potassium, ascorbic acid, citric and malic acids). These declined with storage, with longer storage periods resulting in lower proximate contents. In addition, there was no interaction between irradiation treatment and storage time, indicating that irradiation did not alter the storage effects on raspberry fruit nutrient and proximate contents.

Irradiation as a quarantine treatment has been examined on a range of blueberries, but much of this work has been conducted on irradiation doses above 1.0 kGy (Miller *et al*. 1994b, Moreno *et al*. 2008) and studies have concentrated on fruit quality rather than nutrient composition of the fruit.

Miller *et al.* 1994b evaluated the postharvest quality of ‘Climax’ rabbiteye blueberries after exposure to dose of gamma irradiation ranging from 0.75 to 3.0 kGy and subsequent storage. They found no effect of irradiation on weight loss but a decrease in firmness as dose increased. Above 1.5 kGy berry quality was generally seriously reduced as demonstrated by berry softening, increased decay and reduces flavour acceptability. TSS and TA were not affected by treatment and pH remained constant except for fruit treated at doses above 1.5 kGy. They concluded that ‘Climax’ blueberries could tolerate irradiation levels up to about 0.75 kGy.

Miller and his co-workers published a study on the effect of electron beam irradiation on the quality of ‘Climax’ rabbiteye blueberry (Miller at al 1994a) and ‘Sharpblue’ southern highbush blueberry (Miller *et al.* 1995) at doses ranging from 0.25 to 1.0 kGy. They found that blueberry firmness decreased significantly with increasing dosage after 7 days storage post-treatment, though this decrease was only slight practically. Decay was not affected by treatment. Flavour and texture decreased with increasing irradiation dosage after storage but still remained acceptable. Weight loss, TSS, TA, pH and colour were not affected by dosage or storage over 7 days at 1°C.

Miller and McDonald (1996) gamma irradiated ‘Brightwell’ and ‘Tifblue’ rabbiteye blueberries at doses up to 1.0kGy with post-irradiation storage at 1°C for up to 7 days plus 2 days at 15°C. For ‘Brightwell’ blueberries, decay, % weight loss, TSS, TA, flavour, bloom, texture and colour were unaffected by irradiation but firmness did decrease with increasing dosage. For ‘Tifblue’ blueberries, there was no difference in any of the quality attributes evaluated between untreated and irradiated blueberries. They concluded that irradiation up to 1 kGy was a viable phytosanitary treatment for blueberries.

Moreno *et al*. 2006 used electron beam irradiation to treat blueberries (variety not documented) at doses above 1.0 kGy (1.1, 1.6 and 3.2 kGy) and stored them at 5°C for up to 14 days. Physico-chemical, textural, microstructural and sensory characteristics were evaluated at various times post-treatment. They found that that above 1.1 kGy the berries were softer throughout storage. Overall quality, texture and aroma were acceptable for all treatments except at 3.2 kGy. Berry density, pH, water activity, moisture content, acidity and juiciness were unaffected by irradiation at all dosages studies. They concluded that irradiation of blueberries up to 1.6 kGy was a feasible decontamination treatment that maintains overall fruit quality.

In a similar study Moreno *et al.* 2008 found that electron beam irradiation of highbush blueberries at 1.1 kGy had no significant effect on fruit quality with the exception of ascorbic acid which decreased by 17% after 14 days post-treatment storage. However this decrease in ascorbic acid levels 14 days post treatment at 1.1 and 1.6 k Gy was much less than for the control (untreated) blueberries and unchanged from levels at 3 days post treatment, so these treatments actually attenuated losses due to storage. They also found that irradiation enhanced total phenolic and tannin content by 10-20% by 14 days post-treatment. Again they concluded that electron beam irradiation of blueberries at doses up to 1.6 kGy would ensure shelf life for up to 14 days while maintaining specific quality attributes of the fruit.

NSW DPI (Golding *et al.* 2014a) showed for northern highbush 'Brigitta' blueberry, there was no effect of any irradiation treatment on the nutritional content. All nutritional and proximate analysis (contents of ash, carbohydrate, dietary fibre, energy, moisture, protein, sodium, potassium, total sugars, fructose, ascorbic acid, anthocyanin, citric and malic acid) of treated fruit which had been stored for either three or ten days at 0°C were unaffected by irradiation, except for the levels of one sugar, glucose. A statistically significant effect of irradiation on glucose concentration was detected, but these differences were small (mean glucose concentration being 6.28 g/100g and 5.85 g/100g at 0 Gy and 1000 Gy respectively) and not expected to be important. Indeed the other sugar types, total sugars and TSS were all unaffected by irradiation treatment. As expected, the length of time in storage had an effect on some proximates (dietary fibre, potassium, total sugars, glucose, ascorbic acid, citric and malic acids). These fruit proximates declined with storage, with longer storage periods resulting in lower proximate contents. However, no interaction between irradiation treatment and storage time (except glucose) was detected, indicating that irradiation did not influence the storage effects on blueberry nutritional and proximate contents. The lack of an effect of irradiation on blueberry ascorbic acid and total monomeric anthocyanin levels is particularly important to note; levels of ascorbic acid did decrease significantly with storage but without an interaction with irradiation level.

It can be concluded from these studies on blueberries carried out with electron beam irradiation as well as gamma irradiation in a number of blueberry varieties or cultivars, though some differences in responses to irradiation have been found between varieties, in general, blueberry quality and nutritional content are unaffected by irradiation at doses up to 1.0 kGy and low dose irradiation may ensure shelf life. Storage time has a major effect on blueberry quality and nutritional content and far exceeds any changes due to irradiation treatment.

From studies in the literature and those carried out by DPI NSW, it can be anticipated that irradiation of raspberry and blueberry under the same dose range and conditions applied for a disinfestation purpose would result in similar effects on vitamins, particularly Vitamin C, that would be no greater than with storage and therefore, would have minimal impact on the vitamin status of the fruit.

With the exception of potassium intake, fruits and vegetables generally are not major contributors to Australians' intake of six minerals including potassium, sodium, calcium, magnesium, iron and zinc (Cunningham *et al*. 2002).

The macronutrients, carbohydrate, protein and fat, are essentially low risk and unaffected by does of irradiation up to 4 kGy. The US FDA (2008) concluded that irradiation of iceberg lettuce and spinach up to a maximum dose of 4 kGy will not have an adverse impact on the nutritional adequacy of the overall diet. They concluded that few reaction products that would be generated from the small amounts of protein in iceberg lettuce (<1 %) and spinach (<3 %) and the amino acid composition would not be significantly changed when irradiated at doses up to 4 kGy.

The major components of raspberry and blueberry, as with most fruits and vegetables, are water (87% and 85% respectively) and carbohydrate (9% and 13% respectively), with protein (0.8% and 0.6% respectively) as a minor component and fat levels below detectable limits (Golding *et al.* 2014a). Therefore it is also likely that the nutritional quality of these fruits irradiated at 150-1000 Gy will not be adversely affected.

Many fruits and vegetables are good sources of provitamin A carotenoids. Provitamin A carotenoids have been identified as radiation-sensitive fat-soluble vitamins, however, the carotenoids in plant products are fairly radiation-tolerant. After careful review the US FDA concluded that while spinach is an excellent source of provitamin A, the small losses that might result from irradiating up to 4 kGy will have little impact on the dietary intake of Vitamin A. The treatment of raspberry and blueberry as requested are at doses ≤ 1KGy and provitamin A losses will be minimal, if any. Food irradiation is a non-thermal process; the loss of heat-sensitive vitamins is expected not to be greater than with conventional heat processing.

The primary sources of Vitamin A, carotenoids and other vitamins considered to be radiation-sensitive in the Australian and New Zealand diet are carrots, meats, dairy products, eggs, wholegrains and fortified processed cereals. In the context of total dietary intake, the vitamin levels and carotenoids in raspberry and blueberry are minor compared to that in the major food groups. For this reason provitamin A carotenoid levels were not reported in the NSW DPI study As noted above FSANZ has concluded that irradiation with up to 1 kGy did not adversely affect carotene levels, therefore requests for data on carotene levels in irradiated fruits and vegetables are not necessary. Also, importantly, the amount and variety of foods consumed by Australian and New Zealanders that contain vitamins is adequate to meet daily nutritional needs.

3.1.2 Nutritional value of Raspberry

Raspberries do not form a significant part of the nutrition of Australians and New Zealanders. For the Australian population, in 2013, the annual per capita consumption for fresh and processed raspberry was 0.28 kg of which only 0.04 kg is fresh (freshlogic 2014b). In the New Zealand 1997 National Nutrition Survey when looking at the most commonly consumed fruit, it was found that berry fruit, including strawberry and other berries or cherries including raspberries and blueberries, came in sixth with 39% of the population consuming at least one serve per week.

Sub-populations may have a higher than average levels of consumption of fresh raspberries and consumption levels are trending upwards with increased availability. Many health conscious consumers actively include fresh raspberries in their diet to obtain the health benefits they purportedly provide. While red raspberries contain a variety of beneficial compounds, such as dietary fibre, minerals, and vitamins, the most significant health promoting constituents are the polyphenolic phytochemicals, in particular anthocyanins and ellagitannins; these, along with the Vitamin C present, confer high antioxidant activity to raspberry and have been shown, mainly as separate compounds, to have anti-atherosclerotic, anti-cancer and anti-inflammatory activities. Anthocyanins have also been shown to have role in prevention of macular degeneration and in improving glucose control in diabetics. Because of this eating fresh raspberries may provide these health benefits, however very few human intervention studies have been carried out to study these proposed effects. Rao and Snyder (2010) provide a comprehensive review of the composition of raspberries and the bioactivity of the phytonutrients found in this fruit.

Nutritional data for fresh raspberry per 100g of edible portion obtained from the FSANZ NUTTAB Online 2010 Database, the USDA National Nutrient Database and the New Zealand Ministry of Health “The Concise New Zealand Food Composition Tables, 2009” and the mean for mean of the non-irradiated Assessment 1 samples from the NSW DPI study (Golding *et al*. 2014a, Golding *et al.* 2014b) are shown and compared in Table 33. There is some variation in the nutrient values between data sources which reflect variation due to variety, growing conditions, time of the season, postharvest handling and interlaboratory differences. Raspberries have high moisture content, being 84-88% of total weight, and so the energy-providing macronutrients are present in only low amounts resulting in relatively low total energy content of 225kJ/100g or below. In particular raspberries, by weight, consist of only about 1% protein and negligible to 0.7% fat, providing 7 to 13% and 0 to 16% of the total energy content of the fruit respectively (Table 35). Carbohydrate, mainly in the form of sugars (mainly fructose and glucose) is the major energy source in raspberry (Table 35), provide 57 to 80%, while dietary fibre provides 13 to 24% of the total energy content.

When the macronutrient content of raspberry is viewed in relation to the percentage of the recommended daily intake (%DI) (using the reference values set out in Food Standard 1.2.8) contained in a 150g standard serving (Table 34), it can be seen that a serving of raspberry would provide generally less than 4 % of the daily intake for total energy and protein, 1.3% or less of total fat and saturated fat, and less than 4.4% of carbohydrate. One serving would also contribute 8 to 12% of the daily intake of sugar. Beneficially however, one serving would contribute 12 to 31 % of the daily intake of dietary fibre making it, depending on the database used, anything ranging from a “source” to an “excellent source” of dietary fibre and is very low in sodium. It should be noted that the percentage daily intakes are based on an average adult diet of 8700kJ and an individual’s recommended daily intake will vary from this depending on their energy needs (influenced by factors such as gender, age, height, weight and activity level).

For vitamins and minerals (except for sodium and potassium) a food can be said to be a “source” of that vitamin or mineral if a serving contains >10% of the reference DI for that nutrient, and is a “good source” if a serving contains >25% of the reference DI (FSANZ Food Standard 1.2.7.). Food Standard 1.1.1 sets out the reference RDIs (or ESADDIs) for vitamins and minerals that are used to determine if a food is a “source” or “good source” of a specific vitamin or mineral. Table 36 shows the raspberry vitamin and mineral content in a 150g serving expressed as a percentage of the dietary reference values as per Food Standard 1.1.1 and as a percentage of the adult male reference value (RDI, AI or UL). Raspberry can be classified as a good source of Vitamin C and a source of folate and manganese. Levels of other vitamins and minerals are low and a serving of raspberry would not contribute significantly to their overall dietary intake.

A wide variety of fresh produce is available in Australia and New Zealand and fresh fruit and vegetables are a major source of many vitamins and minerals. As previously stated, the consumption of raspberry in the Australian and New Zealand population is low (total 0.28kg/capita/year), particularly the consumption of fresh raspberry (0.04kg/capita/year) (freshlogic, 2014b). From the available dietary consumption patterns (NZ MOH 1999) it is apparent that the major contribution to daily dietary intake of energy providing macronutrients and vitamins and minerals come from foods other than raspberries. The 1997 National Nutrition Survey in New Zealand (MOH 1999) found that in the New Zealand population aged 15 years and over, the five most commonly eaten fruits (percentage of the population consuming one serve at least once per week) were banana (82%), apples (73%), oranges (67%) stone fruit (56%) and pear (47%). Berry fruit, including strawberry and other berries (including raspberry) or cherries, came in sixth with 39% of the population consuming at least one serve per week. The most common types of vegetables consumed by New Zealanders at least once a week were potato (95%), carrots (83%), tomatoes (77%), lettuce (73%), onions/leeks (71%) and peas (68%). From Table 30 it can be seen that these more commonly consumed fruit and vegetables generally have similar levels of vitamins to raspberries but as they are consumed in greater quantities they would contribute to a greater extent to vitamin intakes. Carrot is a particularly good source of provitamin A carotenoids and peach, tomato, lettuce and peas also contain good levels. Peas also have good levels of thiamin, riboflavin, niacin and folate. Raspberry is low in provitamin A (probably due to the low fat content) and low in thiamin, riboflavin and niacin, but a source of folate.

Preformed Vitamin A can be found in organ meats, dairy products, eggs and ready-to-eat cereals. Green vegetables, grains and dairy and egg products are good sources of vitamin K, while nuts, seeds and vegetable oils and other fresh vegetables are sources of Vitamin E. Folate can be found in other fruit and vegetables, especially green leafy vegetables, however in Australia the major source of folate is folic acid-enriched or fortified bread. In Australia it is mandatory for millers to add folic acid to wheaten flour for bread-making purposes in an effort to prevent neural tube defect (NTD) in developing human foetuses. Many ready-to-eat breakfast cereals are also fortified with folic acid. In New Zealand folic acid fortification of bread is voluntary. So though raspberry is a source of folate its contribution to overall dietary intakes is very small in relation to other sources.

As noted above, a serving of raspberry is at least a source if not a good or an excellent source of dietary fibre (as defined in FSANZ Food Standard 1.2.7). However, the contribution of raspberry to the dietary fibre intake of the Australian and New Zealand populations must be viewed in context of the low consumption rate of this fruit and the other sources of fibre in the diets of these populations. The National Nutrition Survey of 1995 found that in Australia, 45% of dietary fibre comes from breads and other cereal foods, 30% from vegetables and 10% from fruit. Similarly in New Zealand, in the 1997 National Nutrition Survey it was found that 44% from breads and cereals, 28% from vegetables and13% from fruit ("Nutrient Reference Values for Australia and New Zealand".) Though no more recent data is available, it could be reasoned that raspberry is not a significant source of fibre in the overall diet.

Anthocyanins are phytonutrients which, although not essential for life, do have health promoting properties. Berry anthocyanins have been shown to have antioxidant properties important in human health and in prevention diseases such as cardiovascular disease, cancer, diabetes and age-related cognitive decline. The research in this area has been critically reviewed and summarised by Zafra-Stone *et al.* 2007, Rao and Snyder 2010 and Nile and Park 2014. Raspberry can be considered a functional food due to their anthocyanin content. Functional foods may have health benefits above and beyond the simply supply the macronutrients and micronutrients your body needs for normal biochemical reactions. The health benefit to be gained by eating raspberry is a reason why some people are including raspberry in their diet.

In Table 12 the anthocyanin contents of commonly consumed fruits and vegetables (adapted from Wu *et al*. 2006) are listed. It can be seen that red raspberry are listed as containing 92.1 mg/100g. In the NSW DPI study (Golding *et al*. 2014a, Golding *et al.* 2014b) the anthocyanin content of non-irradiated raspberries after 2 days storage was 24mg/100g which is lower than the value obtained by Wu *et al*. 2006. The web-based polyphenol database Phenol Explorer 3.0 (http://www.phenol-explorer.eu/) provides a compilation of anthocyanin values from 18 different samples for raw red raspberries obtained from 4 unique publications and calculated a mean value of 43.57 ± 43.64 mg/100g; the value obtained for the DPI NSW raspberries is within this range. The anthocyanin levels in raspberries is affected by factors such as variety, environmental, seasonal and genetic and these can result in large variations in values obtained from study to study, as well as variations due to differences in extraction and measurement method.

The contribution of raspberry to the intake of anthocyanins in the overall diet would depend very much on the level of consumption. In the Australian and New Zealand population raspberries would not contribute significantly as they have such a low consumption rate and more commonly consumed fruit such as cherries, stone fruit, strawberries, red grapes (including red wine) and red apples would have a greater contribution.

In relation to the mineral manganese, though raspberry can be claimed to be a source of manganese, the contribution of raspberry to the overall dietary intake of this mineral is not significant. Consumption of cereal products, particularly unrefined cereals, provides about one-third of the overall dietary intake of manganese and beverages, such as tea, and vegetables are the other major contributors (NRVANZ). Rich dietary sources of manganese include nuts and seeds, wheat germ and whole grains.

It can be concluded that raspberry, though a tasty and healthy food option, is not a significant part of the diet of the average Australian or New Zealander and the contribution of raspberry to overall micro- and macronutrient, fibre and anthocyanin dietary intakes is generally not significant.

Table 16. Nutritional data for fresh raspberry per 100g of edible portion from various sources.

Raspberry	Unit	[a]FSANZ / 100g	[b]USDA / 100g	[c]NZMOH / 100g	[d]DPI NSW/ 100g
Proximates					
Moisture	g	84.6	85.75	88	86.8
Energy, including dietary fibre	kJ	225	217	118	190.0
Protein	g	1.2	1.2	1.1	0.8
Fat	g	0.3	0.65	0.6	< 0.2
Carbohydrate, by difference			11.94		9.0
Available carbohydrate, with sugar alcohols	g	7.4		4.7	
Total sugars	g	7	4.42	4.6	6.5
Fructose	g	3.8			3.1
Glucose	g	3.1			2.6
Sucrose	g	0.1			0.9
Dietary fibre	g	6.1	6.5	2.4	3.1
Ash	g	0.4			0.4
Organic Acids					
Malic acid	g	0.1			0.22
Citric acid	g	2.4			1.7
Vitamins					
Vitamin C	mg	32	26.2	14	23.0
Thiamin (B1)	mg	0.037	0.032	Trace	
Riboflavin (B2)	mg	0.027	0.038	0.01	
Niacin (B3)	mg	0.36	0.598		
Niacin Equivalents	mg	0.56		0.5	
Total folates	ug	34		33	
Dietary folate equivalents	ug	34	21		
Alpha carotene	ug	0			
Beta carotene	ug	28			
Cryptoxanthin	ug	0			
Beta carotene equivalents	ug	28		0	
Retinol equivalents	ug	5	2	0	
Alpha tocopherol	mg	0.8			
Vitamin E	mg	0.77	0.87		
Vitamin K (phylloquinone)	ug		7.8		
Minerals					
Calcium (Ca)	mg	28	25	19	
Copper (Cu)	mg	0.104			
Iron (Fe)	mg	0.6	0.69	0.4	
Magnesium (Mg)	mg	22	22		
Manganese (Mn)	mg	0.565			
Phosphorus (P)	mg	37	29	20	
Potassium (K)	mg	169	151	170	116.7
Selenium (Se)	ug	1.2		0.1	
Sodium (Na)	mg	1	1	2	< 0.2
Zinc (Zn)	mg	0.36	0.42	0.4	
Other					
Total Monomeric Anthocyanins	mg				24.0

[a]FSANZ NUTTAB Online 2010 Database; [b]USDA National Nutrient Database; [c]New Zealand Ministry of Health "The Concise New Zealand Food Composition Tables, 8th Edition, 2009"; [d]mean for non-irradiated Assessment 1 samples from NSW DPI study (Golding *et al.* 2014a, Golding *et al.* 2014b).

Table 17. Nutritional information for Raspberry per 100g, per serve† (150g) and as % Daily Intake* (%DI).

Raspberry Nutrient	Average quantity per 100g [a]FSANZ	[b]NZMOH	[c]DPI NSW	Average quantity per serve[†] (150g) FSANZ	NZMOH	DPI NSW	% Daily Intake** (%DI) per serve FSANZ	NZMOH	DPI NSW	Reference value*
Water (g)	84.6	88	86.8	126.9	132	130.2				
Energy (kJ)	225	118	190	337.5	177	285	3.9	2.0	3.3	8700
Protein (g)	1.2	1.1	0.8	1.8	1.65	1.2	3.6	3.3	2.4	50
Fat (g)	0.3	0.6	< 0.2	0.45	0.9	<0.3	0.6	1.3	<0.4	70
Saturated fat (g)	0.1	<0.1		0.15	<0.15		0.6	<0.6		24
Carbohydrate (g)	7.4	4.7	9	11.1	7.05	13.5	3.6	2.3	4.4	310
Total sugars (g)	7	4.6	6.5	10.5	6.9	9.75	11.7	7.7	10.8	90
Dietary fibre (g)	6.1	2.4	3.1	9.15	3.6	4.65	30.5	12.0	15.5	30
Sodium (mg)	1	2	< 0.2	1.5	3	<0.3	0.1	0.1	<0.01	2300

[a]FSANZ NUTTAB Online 2010 Database (NUTTAB 2010b); [b]New Zealand Ministry of Health "The Concise New Zealand Food Composition Tables, 8[th] Edition, 2009" (MOH 2009); [d]mean for non-irradiated Assessment 1 triplicate samples from NSW DPI study (Golding *et al.* 2014a, Golding *et al.* 2014b); †One serve of fruit = 150g (http://www.gofor2and5.com.au/WhatisaServe/tabid/56/Default.aspx)
* from Table to subclause 7(3) FSANZ Food Standard 1.2.8 (Issue 138); **Percentage daily intakes are based on an average adult diet of 8700 kJ. A person's daily intakes may be higher or lower depending upon their energy needs. (FSANZ Food Standard Code 1.2.8)

Table 18: Calculation of the energy content of the macronutrients components of 100g of raspberry and their percentage (%) contribution to the total energy content of raspberry.

Raspberry Nutrient	Energy Factor*	Average quantity of nutrient per 100g raspberry [a]FSANZ	[b]NZMOH	[c]DPI NSW	Approx energy content (kJ) of nutrient per 100g raspberry [a]FSANZ	[b]NZMOH	[c]DPI NSW	% of total energy content [a]FSANZ	[b]NZMOH	[c]DPI NSW
Protein (g)	17	1.2	1.1	0.8	20.4	18.7	13.6	9.9	13.4	7.1
Fat (g)	37	0.3	0.6	< 0.2	11.1	22.2	<7.4	5.4	15.9	0.0
Carbohydrate (g)	17	7.4	4.7	9	125.8	79.9	153	61.0	57.1	79.9
Dietary fibre (g)	8	6.1	2.4	3.1	48.8	19.2	24.8	23.7	13.7	13.0
Approx Total Energy (kJ)					206.1	140.0	191.4	100.0	100.0	100.0

* from FSANZ Food Standard 1.2.8, Table 1 to subclause 2(2)
[a]FSANZ NUTTAB Online 2010 Database; [b]New Zealand Ministry of Health "The Concise New Zealand Food Composition Tables, 8[th] Edition, 2009"; [c]mean for non-irradiated Assessment 1 triplicate samples from NSW DPI study (Golding *et al.* 2014a, Golding *et al.* 2014b).

Table 19: Raspberry vitamin and mineral content in a 150g serve expressed as a percentage (%) of the dietary reference intake as per Food Standard 1.1.1 and as a percentage of the dietary reference intake for an adult male

Raspberry		****Reference value as per Food Standard 1.1.1***	***Nutrient content as % of reference daily intake per 150g serve†***			*****Adult male reference value (per day)***	***Nutrient content as % of reference daily intake for adult male per 150g serve†***		
Nutrient	***Unit***	***RDI (unless stated otherwise)***	***[a]FSANZ***	***[b]NZ DOH***	***[c]NSW DPI***	***RDI (unless stated otherwise)***	***[a]FSANZ***	***[b]NZ DOH***	***[c]NSW DPI***
Vitamins									
Vitamin C	mg	40	80	35	57.5	45	71.1	31.1	51.1
Thiamin (B1)	mg	1.1	3.4			1.2	3.1		
Riboflavin (B2)	mg	1.7	1.6	0.6		1.3	2.1	0.8	
Niacin Equivalents	mg	10	5.6	5.0		16	3.5	3.1	
Dietary folate equivalents	ug	200	17	16.5		400	8.5	8.3	
Vitamin A (Retinol equivalents)	ug	750	0.7	0.0		900	0.6	0	
Vitamin E (α-tocopherol equivalents)	mg	10	8			10 (AI)	8		
Minerals									
Calcium (Ca)	mg	800	3.5	2.4		1000	2.8	1.9	
Copper (Cu)	mg	3 (ESADDI)	3.5			1.7 (AI)	6.1		
Iron (Fe)	mg	12	5.0	3.3		8	7.5	5.0	
Magnesium (Mg)	mg	320	6.9			400	5.5		
Manganese (Mn)	mg	5 (ESADDI)	11.3			5.5 (AI)	10.3		
Phosphorus (P)	mg	1000	3.7	2.0		1000	3.7	2.0	
Potassium (K)	mg					3800 (AI)	4.4	4.5	3.1
Selenium (Se)	ug	70	1.7	0.1		70	1.7	0.1	
Sodium (Na)	mg					2300 (UL)	0.04	0.09	<0.01
Zinc (Zn)	mg	12	3.0	3.3		14	2.6	2.9	

†One serve of fruit = 150g (http://www.gofor2and5.com.au/WhatisaServe/tabid/56/Default.aspx)
* from Schedule to FSANZ Food Standard 1.1.1
** from "Nutrient Reference Values for Australia and New Zealand" (2006)
[a]FSANZ NUTTAB Online 2010 Database; [b]New Zealand Ministry of Health "The Concise New Zealand Food Composition Tables, 8th Edition, 2009"; [c]mean for non-irradiated Assessment 1 triplicate samples from NSW DPI 2013 study (Golding *et al.* 2014a, Golding *et al.* 2014b).
RDI = Recommended dietary intake; ESADDI = Estimated Safe and Adequate Intake; AI = Adequate Intake; UL = Upper level of intake

3.1.3 Effects of irradiation on nutritional content and postharvest fruit quality of fresh raspberry

In at least 21 countries around the world, any fresh fruit or vegetable can be irradiated for disinfestation purposes at doses generally up to 1kGy (Irradiated Food Authorization (IFA) Database, http://nucleus.iaea.org/cir/cir/ficdb.html); hence in these countries raspberry can be subjected to the same low level irradiation for the purpose of disinfestation as requested in this application.

There have been no reported studies in the literature of the effects of low dose irradiation on the full proximate, nutritional and fruit quality aspects of low dose radiation of raspberry fruit following storage. However, a study of this has been carried out recently by the NSW Department of Primary Industries (NSW DPI) and is fully documented in Golding *et al*. 2014a and discussed below.

Two recent studies in the literature (Guimarães, *et. al*., 2013, and Tezotto-Uiliana, *et. al*., 2013) investigating the use of gamma-irradiation to extend the shelf-life of raspberries, irradiated the fruit at doses of 0, 0.5, 1.0 and 2.0 kGy. Post-treatment the raspberries were stored at 0-1°C at 90-95% RH and, at regular periods post-irradiation, fruit quality and ascorbic acid and total phenolics or anthocyanins were assessed as well as measures of microbial growth.

Guimarães, *et. al*., (2013) showed low dose irradiation of ‘Autumn Bliss’ raspberries in general did not affect most fruit quality attributes, except firmness and weight loss; firmness was decreased with irradiation while percentage weight loss was reduced by irradiation. They found a significant effect of storage on titratable acidity (decreased), pH (increased), total soluble solids (TSS, increased) and soluble pectin and percentage of pectin which was soluble (both increased with time in storage). They found significant interactions between storage time and treatment in many quality variables (TSS, firmness, total antioxidant activity, ascorbic acid, phenolics, weight loss and fungal growth). They looked at ascorbic acid and total phenolic levels (this includes anthocyanins) and the associated total antioxidant activity. During storage, ascorbic acid levels for the 1 and 2 kGy doses were observed remain constant for the first 9 days then increase at 12 days, while for 0 and 0.5kGy doses levels initially rose, remained constant from 3 till 9 days then decreased at 12 days. Total phenolic levels tended to rise with storage to similar levels for all irradiation doses except at 2 kGy for day 9 and 12 of storage which were higher than for the other doses. Antioxidant activity initially increased with storage for 0, 0.5 and 1 kGy doses then decreased slightly at 12 days while for the 2 kGy dose activity remained constant for the first 6 days then rose to be higher than other doses at 12 days. For vitamin C, phenolics and antioxidant activity significant effects of both treatment and time were observed plus significant interactions between time and dose. However, it should be noted that the effect was generally an increase rather than decrease in phenolics and ascorbic acid levels and in total antioxidant activity; differences between treatments depended on the time post-treatment that measurements were made. Total soluble sugars (TSS) tended to increase over time but there was no interaction with irradiation dose. Titratable acidity decreased with time but there was no effect of treatment. They concluded that over 12 days post treatment an irradiation dose of 2 kGy was highly effective in controlling microbial growth but it results in the most loss of fruit quality and at lesser doses irradiation was a viable technique for raspberry preservation.

Tezotto-Uiliana *et. al.* (2013) found no effect of irradiation on the respiratory rate, ethylene production, flesh firmness, anthocyanin content or colour index of the raspberries. Irradiation at 1 and 2 kGy extended the shelf life of the raspberries by 8 days with the non-irradiated and 0.5 kGy irradiated raspberries being discarded after 12 days due to excessive rots while the 1 kGy and 2 kGy fruit lasted till 20 days, the 2 kGy having the least decay. Weight loss increased with storage for all irradiation doses but the 1 kGy treated fruit had the lowest weight loss. Irradiation decreased pectin solubility. Titratable acidity decreased with storage and while the 0.5 and 1 kGy fruit did not differ from the 0 kGy controls, the 2.0 kGy fruit had the greatest decrease. .Ascorbic acid content decreased with storage for all treatments; the 0.5 and 1 kGy treatment fruit did not differ in rate of decrease but the 2 kGy treatment fruit had the biggest decrease in ascorbic acid levels. The two flavanoids, anthocyanins and quercetin, both increased with storage until day 12, then anthocyanins remained constant and quercetin decreased. Raspberries treated with 0.5kGy had the highest anthocyanins and quercetin. They concluded that the 1 kGy dose was the most useful to extend shelf life and allows the lowest reduction in ascorbic acid.

Cabo Verde *et al*. 2013 evaluated the effects of irradiation on raspberries at doses of 0.5, 1.0 and 1.5 kGy. They found that the total phenolic content and antioxidant capacity increased with irradiation dose and decreased with storage time. Irradiation induced a significant decrease in firmness compared to non-irradiated fruit. Irradiation at 1.5 kGy had 95% microbial inactivation efficiency. In general in this study the effect of storage was similar for both irradiated and non-irradiated raspberries.

To investigate the effects of irradiation on fresh raspberry, a NSW DPI study (Golding *et al.* 2014a, Golding *et al.* 2014b), recently conducted assessments of the nutritional content and postharvest fruit quality of raspberry (cv Maravilla) fruit 2 and 7 days after being treated with gamma irradiation (Golding *et al*. 2014a). The irradiation treatments doses tested were 0 (untreated controls), 150, 400 and 1000 Gy. Storage before and after treatment was at 0°C and >95% RH. This was replicated three times.

The statistical significance of the effects of irradiation level, storage times and their interaction on quality attributes and nutritional and proximate profile analytes were tested using ANOVA. The mean value for each quality parameter and all proximate and other nutrients assessed at 2 and 7 days post-irradiation at 0, 150, 400 and 1000 Gy are presented in Table 20. Table 21 lists the *P*-values for the effects of irradiation and storage and interaction between these two factors and those showing statistical significance ($P<0.05$) are shown in bold.

The results show that there was no effect of any irradiation treatment on raspberry fruit quality (overall fruit quality, fruit colour score and objective measures (Minolta ‘L’, ‘a’, ‘b’ and ‘hue angle’), fruit firmness (both subjective and objective), fruit weight loss, TSS, TA and TSS/TA ratio) after either two or seven days storage. Juice pH was affected by irradiation though this effect was very small (Table 22), maximum difference was pH 3.46 for 0 Gy and pH3.53 for 1000 Gy). However TA is a more useful measure of fruit acidity and was not affected by irradiation.

The main influence on raspberry fruit quality was time in storage (Table 21). Generally fruit quality declined with increasing cold storage post-treatment. Overall quality decreased, colour changed (colour score and Minolta ‘a’ and ‘b’), firmness decreased (both subjective and objective measures), weight loss increased, titratable acidity (TA) decreased and juice pH correspondingly increased, and TSS/TA ratio increased with longer storage. However the overall quality of the fruit over the entire trial was good. In addition, there was no significant interaction detected between irradiation treatment and storage time, indicating that irradiation did not influence these storage effects on raspberry fruit quality. It should also be noted that no rots or fruit physiological defects were observed in the raspberries in this trial indicating that irradiation treatment did not induce any pathogens or defects during storage.

There were few changes in the nutritional content of raspberry fruit following irradiation and storage. The nutritional and proximate analysis (contents of ash, carbohydrate, dietary fibre, energy, moisture, protein, sodium, potassium, total sugar, fructose, glucose, anthocyanin) of treated fruit which had been stored for either two or seven days were unaffected by irradiation. However the levels of some nutrients such as sucrose, ascorbic acid, citric and malic acid concentrations were significantly affected with irradiation treatment, but these differences were minor (Table 22).

The length of time in storage had an effect on some fruit proximates (ash, potassium, ascorbic acid, citric and malic acids). These fruit proximates declined with storage, with longer storage periods resulting in lower proximate contents (Table 23). In addition, there was no interaction between irradiation treatment and storage time, indicating that irradiation did not alter the storage effects on raspberry fruit nutrient and proximate contents.

Raspberries are eaten by health conscious consumers for their antioxidant content this includes ascorbic acid and anthocyanins. As the effect of irradiation on ascorbic acid levels are of particular interest, the values at each storage time for each treatment and the mean values for each treatment and storage time is shown in Table 24. The treatment with 150 Gy had no effect on the ascorbic acid levels but raspberries treated at 400 and 1000 Gy had significantly reduced levels though this reduction was only by about 5%. Storage had a greater effect on ascorbic acid levels, causing about 8% decrease between days 2 and 7 post treatment. Irradiation dosage did not influence the rate of decrease in ascorbic acid levels due to storage. Total monomeric anthocyanin level is a measure of the unoxidised anthocyanins, the anthocyanins that have antioxidant capacity. There was no effect of either storage time or treatment and no interaction between irradiation dose and storage time on total monomeric anthocyanin levels as shown in Table 25.

It can be concluded that an application of low dose irradiation treatment, up to 1 kGy, used as an effective phytosanitary method, will not result in any major detrimental damage to the nutritional and postharvest quality of raspberry. Any decreases in nutrient or vitamin levels are small and will not impact on their overall dietary intake by the average Australian and New Zealander.

Table 20. For 'Maravilla' raspberry, the mean values for fruit quality parameters and proximate and nutritional profile analytes after storage at $0^{o}C$ for 2 and 7 days post-irradiation treatment at 0, 150, 400 and 1000Gy and means for all fruit at each assessment. Means with different letters or cases within rows are significantly different (*P*<0.05)

Raspberry	**2 Days Storage**					**7 Days Storage**				
	0 Gy	**150 Gy**	**400 Gy**	**1000 Gy**	**2 Days mean**	**0 Gy**	**150 Gy**	**400 Gy**	**1000 Gy**	**7 Days mean**
Overall quality score	1.42	1.39	1.47	1.45	**1.43 a**	2.12	2.00	2.12	1.99	**2.06 b**
Weight loss (%)	0.54	0.47	0.71	0.69	**0.60 a**	1.18	1.01	1.15	1.05	**1.10 b**
Firmness (g)	51.17	52.37	51.20	49.94	**51.17 a**	48.84	50.43	47.48	46.12	**48.21 b**
‡Firmness Score	1.34	1.37	1.33	1.29	**1.33 a**	1.65	1.67	1.73	1.65	**1.67 b**
Minolta L*	25.47	25.88	24.74	25.37	**25.36**	25.39	25.62	24.95	25.47	**25.36**
Minolta_a*	24.82	24.98	24.48	24.80	**24.77 a**	25.95	26.30	25.66	26.14	**26.01 b**
Minolta_b*	11.09	11.47	11.21	11.49	**11.32 a**	11.70	11.96	11.43	11.78	**11.72 b**
Minolta hue angle	23.96	24.51	24.48	24.75	**24.43**	24.13	24.29	23.85	24.14	**24.10**
†Colour Score	2.02	1.89	1.91	1.83	**1.91 a**	1.99	1.91	2.10	2.01	**2.00 b**
Total soluble solids (TSS, Brix%)	9.81	10.04	10.03	9.97	**9.96**	9.71	9.67	10.20	9.88	**9.86**
Titratable acidity (TA, % citric acid)	1.58	1.57	1.51	1.53	**1.55 a**	1.35	1.19	1.22	1.20	**1.24 b**
TSS/TA ratio	6.29	6.48	6.74	6.60	**6.53 a**	7.22	8.28	8.42	8.25	**8.04 b**
Juice pH	**3.43**	**3.43**	**3.44**	**3.45**	**3.43 a**	**3.50**	**3.57**	**3.59**	**3.60**	**3.56 b**
Energy (kJ/100g)	190.0	190.0	183.3	176.7	**185.0**	190.0	190.0	203.3	193.3	**194.2**
Moisture (g/100g)	86.83	86.67	87.30	87.57	**87.09**	86.47	86.50	86.23	86.77	**86.49**
Protein (g/100g)	0.77	0.80	0.77	0.83	**0.79**	0.90	0.80	0.83	0.83	**0.84**
Fat (g/100g)	n.d.[1]				**n.d.**	n.d				**n.d.**
Total carbohydrates (g/100g)	9.00	9.00	8.67	8.33	**8.75**	8.33	8.33	9.67	8.67	**8.75**
Total sugars (g/100g)	6.50	6.90	6.93	6.17	**6.63**	6.77	6.47	6.73	6.77	**6.68**
Fructose (g/100g)	3.07	3.23	3.23	3.00	**3.13**	3.20	3.03	3.13	3.20	**3.14**
Glucose (g/100g)	2.57	2.67	2.73	2.47	**2.61**	2.67	2.50	2.63	2.70	**2.63**
Sucrose (g/100g)	0.87	1.00	0.97	0.70	**0.88**	0.90	0.93	0.97	0.87	**0.92**
Dietary fibre (g/100g)	3.13	3.07	2.80	2.73	**2.93 a**	3.90	3.63	2.97	3.53	**3.51 b**
Citric acid (mg/100g)	1700	1567	1567	1567	**1600 a**	1467	1400	1400	1367	**1408 b**
Malic acid (mg/100g)	223.3	226.7	220.0	193.3	**215.8 a**	220.0	206.7	196.7	186.7	**202.5 b**
Ash (g/100g)	0.40	0.40	0.37	0.37	**0.38 a**	0.30	0.33	0.37	0.33	**0.33 b**
Sodium (mg/100g)	n.d.[1]				**n.d**	n.d.				**n.d.**
Potassium (mg/100g)	116.67	116.67	116.67	116.67	**116.67 a**	98.67	106.33	90.33	98.00	**98.33 b**
Ascorbic acid (mg/100g)	23.00	23.00	22.00	22.00	**22.50 a**	21.33	20.67	20.33	20.00	**20.58 b**
Total anthocyanins (mg/100g)	24.0	23.0	23.0	22.0	**23.0**	23.3	23.7	23.3	21.3	**22.9**

[1]n.d. not detected. Levels below the limit of detection (<0.2 g/100g); †Colour score: 1 = bright light red-orange; 2 = bright red; 3 = dark red; 4 = dull dark red-purple; ‡Firmness Score: 1 = good - very firm; 2 = acceptable - slight softness; 3 = unacceptable – very soft; 4 = squashy

Table 21. P-values for the effects of irradiation, storage and the interaction of irradiation and storage treatments on fruit quality parameters and the nutritional and proximate analysis of raspberries. Effects are statistically significant if $P < 0.05$ (shown in bold).

Raspberry	Irradiation (I)	Storage (S)	Interaction (I X S)
Fruit quality			
Overall fruit quality	0.593	**<0.001**	0.884
% Weight loss	0.561	**0.001**	0.817
Firmness objective	0.066	**0.010**	0.834
Firmness subjective	0.631	**<0.001**	0.924
Colour 'L' value	0.054	0.927	0.879
Colour 'a' value	0.679	**<0.001**	0.971
Colour 'b' value	0.577	**0.032**	0.797
Colour 'hue angle'	0.339	0.059	0.247
Colour score	0.087	**0.040**	0.153
TSS	0.254	0.369	0.396
TA	0.091	**<0.001**	0.566
TSS/TA ratio	0.150	**<0.001**	0.451
Juice pH	**0.020**	**<0.001**	0.069
Fruit Nutritional and proximate analysis			
Energy	0.533	0.234	0.655
Moisture	0.269	0.082	0.719
Protein	0.617	0.067	0.219
Fat	n.d.		
Carbohydrate	0.263	1.000	0.596
Total sugar	0.321	0.661	0.080
Fructose	0.767	0.908	0.218
Glucose	0.580	0.754	0.084
Sucrose	**0.018**	0.679	0.758
Dietary fibre	0.073	**0.048**	0.791
Citric acid	**0.009**	**<0.001**	0.891
Malic acid	**0.012**	**0.015**	0.344
Ash	0.859	**0.028**	0.330
Sodium	n.d.		
Potassium	0.352	**<0.001**	0.519
Ascorbic acid	**0.006**	**0.005**	0.957
Anthocyanins	0.134	0.846	0.589

n.d. = Not detectable. Below the limits of detection

Table 22. For raspberry, mean values at each irradiation dose for the quality parameter, juice pH, and nutrients for which a significant effect of irradiation was found. Values in the same row which have the same letter (both a or both b) are statistically the same (*P*>0.05). Values in the same row with different letters are statistically different (*P*<0.05).

	Irradiation dose (Gy)			
	0	**150**	**400**	**1000**
Mean Juice pH	3.46 a	3.50 b	3.51 b	3.53 b
Mean sucrose concentration (g/100g)	0.88 ab	0.97 a	0.97 a	0.78 b
Mean citric acid concentration (mg/100g)	1,583 a	1,483 b	1,483 b	1,467 b
Mean malic acid concentration (mg/100g)	222 a	217 a	208 a	190 b
Mean ascorbic acid concentration (mg/100g)	22.2 a	21.8 a	21.2 b	21.0 b

Table 23. For raspberry, mean values at each storage time for nutrients for which a significant effect of length of storage was found. Values in the same row with different letters are statistically different (*P*<0.05).

	Storage time (days)	
	2	**7**
Mean total dietary fibre content (g/100g)	2.93 a	3.51 b
Mean citric acid concentration (mg/100g)	1,600 a	1,408 b
Mean malic acid concentration (mg/100g)	216 a	203 b
Mean ash content (g/100g)	0.38 a	0.33 b
Mean potassium content (mg/100g)	116.7 a	98.3 b
Mean ascorbic acid concentration (mg/100g)	22.5 a	20.6 b

Table 24. Effect of interaction of irradiation dose (Gy) and storage time (days) on mean raspberry ascorbic acid concentration (mg/100g) ($F_{3,8}$ =0.10, *P* =0.957).
*Effect of irradiation dose (Gy) on mean raspberry ascorbic acid concentration (mg/100g) ($F_{3,6}$ = 11.91, *P* = 0.006, l.s.d = 0.55).
†Effect of storage time (days) on mean raspberry ascorbic acid concentration (mg/100g) ($F_{1,8}$ = 14.69, *P* = 0.005, l.s.d. = 1.15)

Irradiation dose (Gy)	**Storage time (days)**		***Mean ascorbic acid conc'n (mg/100g)**
	2	**7**	
0	23.0	21.3	22.2 a
150	23.0	20.7	21.8 a
400	22.0	20.3	21.2 b
1000	22.0	20.0	21.0 b
†Mean ascorbic acid conc'n (mg/100g)	22.5 A	20.6 B	

Values with different letters, a or b, A or B, are statistically different (*P* <0.05).

Table 25. Effect of interaction of irradiation dose (Gy) and storage time (days) on mean raspberry total monomeric anthocyanins concentration (mg/100g) ($F_{3,8}$ =0.68, P = 0.589).
*Effect of irradiation dose (Gy) on mean raspberry total monomeric anthocyanins concentration (mg/100g) ($F_{3,6}$ = 2.76, P = 0.134).
†Effect of storage time (days) on mean raspberry total monomeric anthocyanins concentration (mg/100g).($F_{1,8}$ = 0.04, P = 0.846)

Irradiation dose (Gy)	Storage time (days)		*Mean total monomeric anthocyanins conc'n (mg/100g)
	2	7	
0	24.00	23.33	23.67
150	23.00	23.67	23.33
400	23.00	23.33	23.17
1000	22.00	21.33	21.67
†Mean total monomeric anthocyanins conc'n (mg/100g)	23.00	22.92	

3.1.4 Nutritional value of Blueberry

Blueberry is popularly known and often marketed as a "superfood". A superfood is defined as "a nutrient-rich food considered to be especially beneficial for health and well-being" (http://www.oxforddictionaries.com/definition/english/superfood). Blueberry is low in kilojoules and high in nutrients, including phenolic compounds, mainly anthocyanins, which have an antioxidant capacity significantly higher than vitamins C or E. The anthocyanins are responsible for the blue colour of blueberries. Consuming blueberries is claimed to help prevent cardiovascular disease, cancer and improve memory; these health benefits are mainly related to the anthocyanin content but more research is required to provide a conclusive link between eating blueberries and disease prevention (http://www.nhs.uk/livewell/superfoods/pages/are-blueberries-a-superfood.aspx). There are a number of good reviews of the research into the health benefits of eating berries, in particular blueberries: Nile *et al.* 2014: general health, anti-aging, antioxidant, anticancer, antimutagentic, antimicrobial, anti-inflammatory and neuroprotective properties; Basu *et al.* 2012: prevention of metabolic syndrome; Basu *et al.* 2010 improvement of cardiovascular health; Seeram 2008: cancer prevention. Yi *et al.* 2005 from his studies using extracts of blueberry containing the phenolic compounds concluded that blueberry intake may reduce colon cancer risk. Muraki *et al.* 2013, using data from the Nurses' Health Study (1984-2008), found that greater consumption of whole blueberries was most significantly associated with lower risk of type 2 diabetes, compared to other fruit. These health benefits to be gained by eating blueberry are a reason why some people are actively including them in their diet.

Growth in the consumption of blueberries in Australia has been significant for the last several years and is expect to continue to rise in the near future. In 2013 the total per capita consumption of blueberry in Australia was 363g of which 254g was fresh (freshlogic, 2014a). Australia is considered to be one of the highest per capita consumers of blueberry, though much lower than the USA with a per capita consumption of 570g in 2013 (freshlogic 2014a). However, blueberries do not form a significant part of the nutrition of Australians and New Zealanders. Their contribution to anthocyanin intake in these populations has not been estimated but Wu *et al.* 2006 estimated that blueberries contributed about 30% of the anthocyanin intake of the average US citizen. As noted previously, in the New Zealand 1997 National Nutrition Survey when looking at the most commonly consumed fruit, it was found that berry fruit, including strawberry and other berries or cherries as well as blueberries, came in sixth with 39% of the population consuming at least one serve per week. Sub-populations may have a higher than average levels of consumption of fresh blueberries and consumption levels are trending upwards with increased availability. However, blueberries are not a major part of the dietary intake of any subpopulation in Australia and New Zealand.

Nutritional data for fresh blueberry per 100g of edible portion obtained from the FSANZ NUTTAB Online 2010 Database, the USDA National Nutrient Database and the New Zealand Ministry of Health "The Concise New Zealand Food Composition Tables, 2009 and the mean for mean of the non-irradiated Assessment 1 samples from the NSW DPI (Golding *et al.* 2014a, Golding *et al.* 2014b) study are shown and compared in Table 26. There is some variation in the nutrient values between data sources which reflect variation due to variety, growing conditions, time of the season, postharvest handling and interlaboratory differences. Blueberries have high moisture content, being 83-87% of total weight, and so the energy providing macronutrients are present in only low amounts resulting in relatively low total energy content of 238kJ/100g or below. In particular blueberries, by weight, consist of less than 1% protein and negligible to 0.4% fat, providing 4 to 5% and 0 to 6% of the total energy content of the fruit respectively (Table 28). Carbohydrate, mainly in the form of sugars (fructose and glucose) is the major energy source in blueberry (Table 28), provide 84 to 89%, while dietary fibre provides 5.3 to 6.5% of the total energy content.

When the macronutrient content of a 150g standard serving of blueberry is viewed in relation to the percentage of the recommended daily intake (%DI) (using the reference values set out in Food Standard 1.2.8) it can be seen that a serving of blueberry would provide about 4 % of the daily intake for total energy, about 2% of protein, less than1% of total fat and 0% saturated fat, and about 6% of carbohydrate (Table 27). One serving would also contribute 18 to 20.5% of the daily intake of sugar and, beneficially, about 9% of the daily intake of dietary fibre. Blueberry is a source of fibre, providing more than 2g/serving. Blueberry is also very low in sodium (less than 0.4%DI). It should be noted that the percentage daily intakes are based on an average adult diet of 8700kJ and an individual's recommended daily intake will vary from this depending on their energy needs (influenced by factors including gender, age, height, weight and activity level).

Table 43 shows the blueberry vitamin and mineral content in a 150g serving expressed as a percentage of the dietary reference values as per Food Standard 1.1.1 and as a percentage of the adult male reference value (RDI, AI or UL). Blueberry, with 38-49%DI for Vitamin C, can claim to be a good source of Vitamin C. With 12% of the DI for copper, blueberry is a source of copper. Levels of other vitamins and minerals are low and a serving of blueberry would not contribute significantly to their overall dietary intake.

A wide variety of fresh produce is available in Australia and New Zealand and fresh fruit and vegetables are a major source of many vitamins and minerals. As previously stated, the consumption of blueberry in the Australian and New Zealand population is low (total 0.363kg/capita/year), with the consumption of fresh blueberry being 0.254kg/capita/year (freshlogic, 2014a). From the available dietary consumption patterns (NZ MOH 1999) it is apparent that the major contribution to daily dietary intake of energy-providing macronutrients and vitamins and minerals come from foods other than blueberries. The 1997 National Nutrition Survey in New Zealand (MOH 1999) found that in the New Zealand population aged 15 years and over, the five most commonly eaten fruits were 1: banana, 2:apples, 3: oranges, 4: stone fruit and 5:pear. Berry fruit, including strawberry and other berries (including blueberry) or cherries, came in sixth with 39% of the population consuming at least one serve per week. The most common types of vegetables consumed by New Zealanders at least once a week were 1: potato, 2: carrots, 3: tomatoes, 4: lettuce, 5: onions/leeks and 6: peas. From Table 13 it can be seen that these more commonly consumed fruit and vegetables generally have similar if not higher levels of vitamins to blueberries and as they are consumed in greater quantities they would contribute to a greater extent to vitamin intakes. Carrot is a particularly good source of provitamin A carotenoids and peach, tomato, lettuce and peas also contain good levels. Peas also have good levels of thiamin, riboflavin, niacin and folate. Blueberry is low in provitamin A and low in thiamin, riboflavin, niacin and folate and cannot be claimed to be a source of any vitamin except Vitamin C.

As noted above, a serving of blueberry is a source of dietary fibre (as defined in FSANZ Food Standard 1.2.7). However, the contribution of blueberry to the dietary fibre intake of the Australian and New Zealand populations must be viewed in context of the low consumption rate of this fruit and the other sources of fibre in the diets of these populations. The National Nutrition Survey of 1995 found that in Australia, 45% of dietary fibre comes from breads and other cereal foods, 30% from vegetables and 10% from fruit. Similarly in New Zealand, in the 1997 National Nutrition Survey it was found that 44% was from breads and cereals, 28% from vegetables and13% from fruit ("Nutrient Reference Values for Australia and New Zealand"). Though no more recent data is available, it could be reasoned that blueberry is not a significant source of fibre in the overall diet.

Anthocyanins (a sub-class of polyphenols) are phytonutrients which, although not essential for life, do have health promoting properties. Berry anthocyanins have been shown to have antioxidant properties important in human health and in prevention diseases such as cardiovascular disease, cancer, diabetes and age-related cognitive decline. The research in this area has been critically reviewed and summarised by Zafra-Stone *et al.* 2007. As discussed earlier, the health benefits to be gained from eating blueberry are well recognised. Blueberries are particularly rich in anthocyanins and it is these phytonutrients that are considered to confer the health benefits. Blueberry can be considered a functional food due to their anthocyanin content. Functional foods may have health benefits above and beyond the simply supply the macronutrients and micronutrients your body needs for normal biochemical reactions. The health benefit to be gained by eating blueberry is a reason why some people are including blueberry in their diet.

In Table 12 the anthocyanin contents of commonly consumed fruits and vegetables (adapted from Wu *et al*. 2006) are listed. It can be seen that blueberry are listed as containing 386.6 mg/100g, the third highest of the fruit and vegetables containing anthocyanin. In the NSW DPI study (Golding *et al.* 2014a, Golding *et al.* 2014b) the anthocyanin content of non-irradiated blueberries after 3 days storage was 126.7 mg/100g which is lower than the value obtained by Wu *et al*. 2006. The web-based polyphenol database Phenol Explorer 3.0 (http://www.phenol-explorer.eu/) provides a compilation of anthocyanin values from 124 different samples for raw Highbush blueberry (*Vaccinium corymbosum* L., the same variety as used in the NSW DPI study) obtained from 7 different publications and calculated a mean value of 164.37 ± 62.97 mg/100g; the NSW DPI value is within this range. The anthocyanin levels in blueberries is affected by factors such as variety, environment, cultivation practices, season and genetics and these can result in large variations in values obtained from study to study, as well as variations due to differences in extraction and measurement methods, e.g. HPLC compared to pH differential method (Routray & Orsat, 2011).

The contribution of blueberry to the intake of anthocyanins in the overall diet would depend very much on the level of consumption. In the general Australian and New Zealand population blueberries would not contribute significantly as they have a low consumption rate and more commonly consumed fruit such as cherries, stone fruit, strawberries, red grapes and red apples would have a greater contribution. However, for those members of the population actively including blueberries in their diet for the health benefits, they may be a major contributor. Wu *et al*. 2006 calculated that blueberry was a major contributor to anthocyanin intake in the average US diet, but consumption of blueberry in Australia and New Zealand is lower than in the USA as mentioned earlier.

In relation to the mineral copper, though blueberry may be claimed to be a source of copper, this fruit is not a major contributor to the overall dietary intake of copper in the Australian and New Zealander population. Copper is widely distributed in foods commonly consumed with organ meats, seafood, nuts and seeds being major contributors of copper to the diet. Wheat bran cereals and whole grain products are also good sources of copper and very commonly consumed (NRVANZ).

It can be concluded that blueberry is not a significant part of the diet of the average Australian or New Zealander and the contribution of blueberry to overall micro- and macronutrient, fibre and anthocyanin dietary intakes is not significant. However for those actively including blueberry in their diet for the claimed health benefits to be gained, this fruit may be a major source of the phytonutrient, anthocyanin.

Table 26. Nutritional data for Blueberry per 100g of edible portion from various sources

Blueberries	Unit	[a]FSANZ per 100g	[b]USDA per 100g	[c]NZMOH per 100g	[d]DPI NSW per 100g
Proximates					
Moisture	g	87.3	84.21	83	85.5
Energy, including dietary fibre	kJ	218	238	224	230
Protein	g	0.6	0.74	0.7	0.6
Fat	g	0.1	0.33	0.4	<0.2
Available carbohydrate	g	11.3	14.49	12	12.3
Total sugars	g	10.8	9.96	11.8	12.3
Fructose	g	5.5			6.0
Glucose	g	5.3			6.5
Sucrose	g	0			<0.2
Starch	g	0.5		0.2	
Dietary fibre	g	1.8	2.4	1.6	1.7
Ash	g	0.1			0.2
Organic Acids					
Malic acid	g	0.2			0.29
Citric acid	g	0.6			0.56
Vitamins					
Vitamin C	mg	13	9.7	10	10.2
Thiamin (B1)	mg	0.02	0.037	0.02	
Riboflavin (B2)	mg	0.06	0.041	0.01	
Niacin (B3)	mg	0	0.418		
Niacin Equivalents	mg	0.1		0.6	
Total folates	ug	5		7	
Dietary folate equivalents	ug	5	6		
Alpha carotene	ug	0			
Beta carotene	ug	39			
Cryptoxanthin	ug	160			
Beta carotene equivalents	ug	119		204	
Retinol equivalents	ug	20	3	34	
Alpha tocopherol	mg	0.5	0.57		
Vitamin E	mg	0.47			
Vitamin K (phylloquinone)	µg		19.3		
Other					
Total Anthocyanins	mg				127
Minerals					
Calcium (Ca)	mg	4	6	11	
Copper (Cu)	mg	0.24			
Iron (Fe)	mg	0	0.28	0.5	
Magnesium (Mg)	mg	4	6		
Manganese (Mn)	mg	0.04			
Phosphorus (P)	mg	9	12	13	
Potassium (K)	mg	66	77	70	78
Selenium (Se)	ug	0		0.1	
Sodium (Na)	mg	0	1	6	0.7
Zinc (Zn)	mg	0.07	0.16	0.3	

[a]FSANZ NUTTAB Online 2010 Database; [b]USDA National Nutrient Database; [c]New Zealand Ministry of Health

Table 27. Nutritional information for Blueberry per 100g, per serve† (150g) and as % Daily Intake* (%DI).

Blueberry Nutrient	Average quantity per 100g [a]FSANZ	[b]NZMOH	[c]DPI NSW	Average quantity per serve† (150g) FSANZ	NZMOH	DPI NSW	% Daily Intake** (%DI) per serve FSANZ	NZMOH	DPI NSW	Reference value*
Water (g)	87.3	83	85.5							
Energy (kJ)	218	224	230	327	336	345	3.8	3.9	4.0	8700
Protein (g)	0.6	0.7	0.6	0.9	1.05	0.9	1.8	2.1	1.8	50
Fat (g)	0.1	0.4	<0.2	0.15	0.6	<0.3	0.2	0.9	<0.4	70
Saturated fat (g)	0	0		0	0		0.0	0.0		24
Carbohydrate (g)	11.3	12	12.3	16.95	18	18.45	5.5	5.8	6.0	310
Total sugars (g)	10.8	11.8	12.3	16.2	17.7	18.45	18.0	19.7	20.5	90
Dietary fibre (g)	1.8	1.6	1.7	2.7	2.4	2.55	9.0	8.0	8.5	30
Sodium (mg)	0	6	0.7	0	9	1.05	0.0	0.4	0.0	2300

[a]FSANZ NUTTAB Online 2010 Database (NUTTAB 2010a); [b]New Zealand Ministry of Health "The Concise New Zealand Food Composition Tables, 8th Edition, 2009" (MOH 2009); [c]mean for non-irradiated Assessment 1 samples from NSW DPI (Golding *et al.* 2014a, Golding *et al.* 2014b). †One serve of fruit = 150g (http://www.gofor2and5.com.au/WhatisaServe/tabid/56/Default.aspx)

* from Table to subclause 7(3) FSANZ Food Standard 1.2.8 (Issue 138); **Percentage daily intakes are based on an average adult diet of 8700 kJ. Your daily intakes may be higher or lower depending upon your energy needs. (FSANZ Food Standard Code 1.2.8)

Table 28. Calculation of the energy content of the macronutrients components of 100g of blueberry and their percentage (%) contribution to the total energy content of blueberry.

Blueberry Nutrient	Energy Factor*	Average quantity of nutrient per 100g blueberry [a]FSANZ	[b]NZMOH	[c]DPI NSW	Approx energy content (kJ) of nutrient per 100g blueberry [a]FSANZ	[b]NZMOH	[c]DPI NSW	% of total energy content [a]FSANZ	[b]NZMOH	[c]DPI NSW
Protein (g)	17	0.6	0.7	0.6	10.2	11.9	10.2	4.6	4.9	4.4
Fat (g)	37	0.1	0.4	<0.2	3.7	14.8	<7.4	1.7	6.1	0.0
Carbohydrate (g)	17	11.3	12	12.3	192.1	204.0	209.1	87.2	83.8	89.8
Dietary fibre (g)	8	1.8	1.6	1.7	14.4	12.8	13.6	6.5	5.3	5.8
Approx Total Energy (kJ)					220.4	243.5	232.9	100	100	100

* from FSANZ Food Standard 1.2.8, Table 1 to subclause 2(2)
[a]FSANZ NUTTAB Online 2010 Database (NUTTAB 2010a); [b]New Zealand Ministry of Health "The Concise New Zealand Food Composition Tables, 8th Edition, 2009" (MOH 2009); [c]mean for non-irradiated Assessment 1 triplicate samples from NSW DPI (Golding *et al.* 2014a, Golding *et al.* 2014b).

Table 29. Blueberry vitamin and mineral content in a 150g serve expressed as a percentage (%) of the dietary reference intake as per Food Standard 1.1.1 and as a percentage of the dietary reference intake for an adult male

Blueberry		*Reference value as per Food Standard 1.1.1	Nutrient content as % of reference daily intake per 150g serve†			**Adult male reference value (per day)	Nutrient content as % of reference daily intake for adult male per 150g serve†		
Nutrient	Unit	RDI (unless stated otherwise)	[a]FSANZ	[b]NZ DOH	[c]NSW DPI	RDI (unless stated otherwise)	[a]FSANZ	[b]NZ DOH	[c]NSW DPI
Vitamins									
Vitamin C	mg	40	48.8	37.5	38.1	45	43.3	33.3	33.9
Thiamin (B1)	mg	1.1	2.7	2.7		1.2	2.5	2.5	
Riboflavin (B2)	mg	1.7	5.3	0.9		1.3	6.9	1.2	
Niacin Equivalents	mg	10.0	1.5	9.0		16	0.9	5.6	
Dietary folate equivalents	ug	200	3.8			400	1.9		
Vitamin A (Retinol equivalents)	ug	750	4.0	6.8		900	3.3	5.7	
Vitamin E (α-tocopherol equivalents)	mg	10.0	7.5			10 (AI)	7.1		
Minerals									
Calcium (Ca)	mg	800	0.8	2.1		1000	0.6	1.7	
Copper (Cu)	mg	3 (ESADDI)	12.0			1.7 (AI)	21.2		
Iron (Fe)	mg	12	0.0	6.3		8	0.0	9.4	
Magnesium (Mg)	mg	320	1.9	0.0		400	1.5	0.0	
Manganese (Mn)	mg	5 (ESADDI)	1.2			5.5 (AI)	1.1		
Phosphorus (P)	mg	1000	1.4	2.0		1000	1.4	2.0	
Potassium (K)	mg					3800 (AI)	2.6	2.8	2.1
Selenium (Se)	ug	70	0.0	0.2		70	0.0	0.2	
Sodium (Na)	mg					2300 (UL)	0.0	0.4	0.03
Zinc (Zn)	mg	12	0.9	3.8		14	0.8	3.2	

†One serve of fruit = 150g (http://www.gofor2and5.com.au/WhatisaServe/tabid/56/Default.aspx)
* from Schedule to FSANZ Food Standard 1.1.1
** from "Nutrient Reference Values for Australia and New Zealand" (2006)
[a]FSANZ NUTTAB Online 2010 Database; [b]New Zealand Ministry of Health "The Concise New Zealand Food Composition Tables, 8th Edition, 2009"; [c]mean for non-irradiated Assessment 1 triplicate samples from NSW DPI (Golding *et al.* 2014a, Golding *et al.* 2014b).
RDI = Recommended dietary intake; ESADDI = Estimated Safe and Adequate Intake; AI = Adequate Intake; UL = Upper level of intake

3.1.5 Effects of irradiation on nutritional content and postharvest fruit quality of fresh blueberry

Blueberry can be irradiated for disinfestation purposes at doses generally up to 1kGy in at least 21 countries around the world; in these countries any fresh fruit and vegetables can be irradiated for this purpose (Irradiated Food Authorization (IFA) Database, http://nucleus.iaea.org/cir/cir/ficdb.html). There is limited data available in the literature on the impact of low dose irradiation (≤ 1kGy) for disinfestation purposes (Miller *et al.* 1994b, Miller *et al.* 1994a, Miller and McDonald 1996) or irradiation at higher doses (up to 3.2 kGy) for decontamination purposes and to increase shelf life (Miller *et al.* 1994a, Moreno *et al.* 2007, Moreno *et al.* 2008) on blueberry quality and nutrient content. Most studies have concentrated on the impact of irradiation on fruit quality but the effect of irradiation on the nutrient profile is important, as these berry fruit are often marketed for their health promoting capabilities. NSW DPI has carried out a study of the impact of low dose irradiation (≤ 1kGy) on a full range of fruit quality and proximate and nutrient content of 'Brigitta' Northern Highbush blueberry and a full report on this is available in Golding *et al*. 2014a.

There are three main species of blueberry which are commercially grown; highbush (*Vaccinium corymbosum*), lowbush (*Vaccinium angustifolium*), and rabbiteye (*Vaccinium ashei*). Lowbush blueberry is not grown in Australia's milder climate while it thrives in colder climates in the northern hemisphere. Highbush blueberry is the most common variety in Australia with the two most popular cultivars grown here being the Northern Highbush and the Southern Highbush. Northern Highbush varieties are the most commonly grown around the world. In Australia, Northern Highbush is grown in Victorian, Tasmania and Southern NSW, while the Southern Highbush is grown in milder regions like Northern NSW and Southern Queensland. Rabbiteye blueberry grows best in Northern NSW and Queensland (http://www.australianblueberries.com.au/is-good/berry-facts). 'Brigitta' is a Northern Highbush variety developed in Australia and is now being widely grown world wide. It is a favourite with exporters as it is probably the best keeping and shipping variety available (Australian Blueberry Growers Association http://www.abga.com.au/index.php?option=com_content&view=article&id=81&Itemid=109).

There are two main types of Blueberry grown in New Zealand. They are Northern Highbush (early season producer, fruiting from mid-November and continue through to mid-February) and Rabbiteye (the main producer of late season fruit, starting production early January and continuing to mid-April) (http://www.blueberriesnz.co.nz/HowTo/growingblueberries.htm). Southern Highbush is also grown in NZ in northern districts, north of Waikato.

The response of blueberries to irradiation may depend on the type and variety of the berries. In rabbiteye blueberries, low dose irradiation (≤1000 Gy) has been shown to have little commercial impact on fruit quality, although at higher irradiation doses, fruit firmness has been shown to deteriorate (Miller *et al.* 1994a, Miller *et al.* 1994b, Miller at al 1995, Miller and McDonald, 1996). Miller *et al*. 1994b looking at the quality of 'Climax' Rabbiteye blueberries after exposure to gamma-irradiation dosages up to 3 kGy found that irradiated berries were softer than non-treated berries and there was a trend to increased decay as dose increased. Also flavour decreased as dosage increased. They concluded that in 'Climax' blueberries quality (firmness, flavour and texture) was seriously reduced at doses above 1.5 kGy and that these berries could tolerate approximately 0.75 kGy of irradiation without affecting quality. In a follow up experiment the same group found that only 'Climax' blueberries treated with ≥1kGy were softer, had lower flavour and poorer texture (Miller *et al.* 1994a). Miller and McDonald (1996) looked at the post-irradiation quality of two more rabbiteye cultivars, 'Brightwell' and 'Tifblue', at doses of 0.5 kGy and 1kGy. 'Tifblue' quality was not affected by irradiation at these levels but 'Brightwell', though flavour and texture were not affected, quality tended to decrease with increasing dosage levels. For all studies, weight loss, TSS, TA, pH, surface colour and bloom were unaffected by irradiation.

Using electron beam irradiation Miller *et al*. 1994a and Moreno *et al*. 2008 showed the effects of irradiation on 'Sharpblue' Southern Highbush and an unspecified variety of Highbush blueberries respectively were comparable to those observed in Rabbiteye fruit. For the 'Sharpblue', the berries were irradiated up to 1kGy and in general berry flavour and texture declined with increasing dosage but neither the flavour nor texture were rated unacceptable by the sensory panel. In the study by Moreno *et al*. 2008 in terms of overall quality, texture and aroma, only the blueberries exposed to 3.2 kGy were found to be unacceptable by the sensory panel. They concluded that irradiation up to 1.6 kGy can be used without significant effect on quality and preserves shelf-life when stored at 5°C up to 14 days.

In 2008, the same research group (Moreno *et al*. 2008), once again looking at an unspecified variety of Highbush blueberries, using electron beam irradiation at medium levels (1.0 – 3.2 kGy), found that irradiation at 1.1 kGy had no significant effect on fruit quality. However ascorbic acid content was affected by irradiation with a mean reduction of 28% at day 3 after treatment. After 14 days storage, however, blueberries exposed to 1.1 kGy and 1.6 kGy had the highest ascorbic acid levels (above control levels) but those exposed to 3.2 kGy had the lowest. Interestingly they also found that the total phenolic (which includes anthocyanins) content of irradiated blueberries tended to be higher than for untreated berries particularly for doses 1.1 kGy and 1.6 kGy. The antioxidant activity in irradiated blueberries was correspondingly higher than untreated berries, with samples irradiated at 1.1kGy having the highest antioxidant activity. Tannin content also increased with irradiation dose. They also found that the production of volatile compounds that characterize the aroma of the blueberries also increased with irradiation. They concluded that electron beam irradiation at doses up to 1.6 kGy could be used to ensure and preserve the shelf life of blueberries for up to 14 days while maintaining specific quality attributes of the fruit.

NSW DPI in 2013 (see Golding *et al*. 2014a for full report) examined the effect of low dose gamma-irradiation (0, 150, 400 and 1000 Gy) treatment on fruit quality (overall fruit quality, colour, weight loss, fruit firmness, TSS, TA, pH), proximate content (ash, carbohydrate, fat, moisture, protein), and the nutritional profile (dietary fibre, energy, sodium, potassium, total sugars (fructose, glucose, sucrose), ascorbic acid, anthocyanin, and organic acids (citric and malic acid)) of the Northern Highbush blueberry variety, 'Brigitta'. These attributes and nutrient levels were assessed 3 and 10 days post-irradiation treatment with storage at 0°C and >95%RH. The mean values for fruit quality parameters and proximate and nutritional profile analytes when assessed after storage at 0^{o}C for 3 and 10 days post-irradiation treatment of 0, 150, 400 and 1000Gy are shown in Table 30.

A summary of the *P* values for the effects of irradiation treatment, storage time and the interaction between irradiation and storage time in blueberry fruit is presented in Table 31. There was no significant effect of irradiation detected on blueberry quality (weight loss, fruit firmness, overall quality, shrivel, TSS, TA or TSS/TA ratio), nor on the proximate or nutritional content (ash, carbohydrate, fat, moisture, protein, energy, dietary fibre, fructose, sucrose, total sugars, potassium, sodium, citric acid, malic acid, ascorbic acid and total anthocyanins).

With the exception of glucose, no significant interaction between the irradiation treatment and storage time was detected in either fruit quality or nutritional parameters. Although there was a significant statistical interaction between irradiation treatment and storage time for glucose, the differences between means were small (<1g/100g) and at day 10 the glucose content of irradiated blueberries was not statistically different to that of the control (0 Gy) blueberries (Table 32).

Table 30. For Northern Highbush 'Brigitta' blueberry, the mean values for fruit quality parameters and proximate and nutritional profile analytes 3 and 10 days post-irradiation treatment at 0, 150, 400 and 1000Gy with storage at 0oC. Means with different letters or cases within rows are significantly different (P<0.05)

Blueberry	**3 Days Storage**					**10 Days Storage**				
	0 Gy	**150 Gy**	**400 Gy**	**1000 Gy**	**3 Days mean**	**0 Gy**	**150 Gy**	**400 Gy**	**1000 Gy**	**10 Days mean**
Overall quality score	1.15	1.08	1.20	1.15	**1.14 a**	1.34	1.25	1.27	1.35	**1.30 b**
Weight loss (%)	0.32	0.30	0.30	0.21	**0.28 a**	0.50	0.35	0.32	0.38	**0.39 b**
Firmness (g)	149.8	149.8	150.0	147.5	**149.3 a**	159.7	156.7	156.4	151.6	**156.1 b**
Firmness subjective score	1.21	1.16	1.20	1.21	**1.19 a**	1.40	1.30	1.36	1.41	**1.37 b**
Colour score	1.06	1.08	1.04	1.06	**1.06**	1.08	1.09	1.08	1.06	**1.08**
Shrivel	1.01	1.04	1.03	1.02	**1.02**	1.05	1.02	1.06	1.04	**1.04**
Total soluble solids (TSS, Brix%)	12.69	12.87	13.03	12.82	**12.85**	12.80	12.46	12.53	12.51	**12.58**
Titratable acidity (TA, % citric acid)	0.61	0.61	0.61	0.60	**0.61**	0.58	0.59	0.59	0.58	**0.58**
TSS/TA ratio	21.27	21.04	21.40	21.48	**21.30**	22.36	21.35	21.47	21.80	**21.75**
Juice pH	3.57	3.53	3.54	3.54	**3.55 a**	3.62	3.60	3.61	3.65	**3.62 b**
Energy (kJ/100g)	230	240	227	227	**231 a**	247	237	230	240	**238 b**
Moisture (g/100g)	85.50	84.83	85.80	85.60	**85.40**	84.63	85.43	85.33	85.40	**85.2**
Protein (g/100g)	0.57	0.57	0.57	0.53	**0.56 a**	0.57	0.67	0.73	0.60	**0.64 b**
Fat (g/100g)	n.d[1]					n.d.				
Total carbohydrates (g/100g)	12.33	12.67	12.00	12.00	**12.25 a**	13.67	13.00	12.33	13.00	**13.00 b**
Total sugars (g/100g)	12.33	12.67	11.67	11.67	**12.08 a**	12.00	11.67	11.33	11.33	**11.58 b**
Fructose (g/100g)	6.00	6.03	5.53	5.47	**5.76**	5.87	5.63	5.53	5.53	**5.64**
Glucose (g/100g)	6.47 A	6.47 A	5.90 B	5.90 B	**6.18 a**	6.10 B	5.87 B	5.83 B	5.80 B	**5.90 b**
Sucrose (g/100g)	n.d.					n.d.				
Dietary fibre (g/100g)	1.73	1.97	1.57	1.67	**1.73 a**	1.07	0.83	1.23	0.97	**1.03 b**
Citric acid (mg/100g)	556.7	540.0	533.3	563.3	**548.3 a**	466.7	513.3	486.7	483.3	**487.5 b**
Malic acid (mg/100g)	293.3	290.0	286.7	290.0	**290.0 a**	276.7	276.7	273.3	273.3	**275.0 b**
Ash (g/100g)	0.17	0.17	0.23	0.20	**0.19**	0.23	0.20	0.20	0.20	**0.21**
Sodium (mg/100g)	0.69	0.67	0.67	0.70	**0.68**	0.68	0.58	0.63	0.60	**0.62**
Potassium (mg/100g)	78.00	87.33	82.67	85.00	**83.2 a**	79.00	76.33	77.00	73.67	**76.5 b**
Ascorbic acid (mg/100g)	10.17	9.67	9.97	10.03	**9.96 a**	7.30	6.93	7.40	7.33	**7.24 b**
Total anthocyanins (mg/100g)	126.7	123.3	130.0	123.3	**125.8**	133.3	126.7	123.3	116.3	**124.9**

[1]n.d. not detected. Levels below the limit of detection (<0.2 g/100g)

Table 31. P values for the effects of irradiation (F3,6), storage (F1,8) and the interaction of irradiation and storage treatments (F3,8) on fruit quality parameters and the nutritional and proximate analysis of Northern Highbush "Brigitta" blueberries. Effects with *P* values <0.05 were statistically significant at the 5% level.

Blueberry	Irradiation effect (I)	Storage effect (S)	Interaction effect (I x S)
Fruit quality			
Overall quality score	0.128	**<0.001**	0.319
Weight loss	0.609	**0.018**	0.329
Firmness objective	0.597	**0.024**	0.872
Firmness subjective	0.313	**<0.001**	0.776
Colour score	0.509	0.154	0.871
Shrivel	0.259	0.084	0.289
Total soluble solids (TSS)	0.872	0.122	0.573
Titratable acidity (TA)	0.934	0.079	0.998
TSS / TA ratio	0.900	0.331	0.850
Juice pH	0.868	**<0.001**	0.533
Fruit nutritional and proximate analysis			
Energy	0.407	**0.022**	0.093
Moisture	0.221	0.184	0.061
Protein	0.387	**0.008**	0.170
Fat	[1]n.d.		
Carbohydrate	0.211	**0.006**	0.287
Total sugars	0.179	**0.040**	0.596
Fructose	0.051	0.053	0.051
Glucose	**0.039**	**<0.001**	**0.020**
Sucrose	n.d.		
Dietary fibre	0.824	**<0.001**	0.194
Citric acid	0.866	**0.002**	0.394
Malic acid	0.625	**<0.001**	0.956
Ash	0.285	0.438	0.400
Sodium	0.823	0.233	0.902
Potassium	0.816	**0.029**	0.343
Ascorbic acid	0.458	**<0.001**	0.893
Anthocyanins	0.714	0.876	0.774

[1]n.d. Not detectable. Below the limits of detection

Table 32. Effect of interaction of irradiation dose (Gy) and storage time (days) on mean blueberry glucose concentration (mg/100g) ($F_{3,8}$ = 5.93, P = 0.020, l.s.d = 0.338). *Effect of irradiation dose (Gy) on mean blueberry glucose concentration (mg/100g) ($F_{3,6}$ = 5.40, P = 0.039, l.s.d = 0.323). †Effect of storage time (days) on mean blueberry glucose concentration (mg/100g) ($F_{1,8}$ = 30.42, P < 0.001, l.s.d. = 0.119)

Irradiation dose (Gy)	Storage time (days)		*Mean glucose conc'n (mg/100g)
	3	10	
0	6.47 a	6.10 b	6.28 A
150	6.47 a	5.87 b	6.17 AB
400	5.90 b	5.83 b	5.87 B
1000	5.90 b	5.80 b	5.85 B
†Mean glucose conc'n (mg/100g)	6.18 C	5.90 D	

Values with different letters, a or b, A or B, C or D are statistically different (P <0.05).

The length of time in cold storage had a significant effect on fruit quality regardless of whether the fruit had been irradiated. Overall subjective fruit quality, weight loss, fruit firmness and juice pH were all affected by time in storage (Table 30). Compared to when assessed at Day 3, after ten days storage blueberries were of lower overall quality, though still acceptable (Score: 1 = good/excellent, 2 = acceptable, 3 = unacceptable); the blueberries had lost more weight, however the untreated blueberries had lost more weight than the treated berries; by objective measure the blueberries were firmer though by subjective assessment they were softer; and juice pH had risen slightly. Time in storage also had a significant effect on several proximate and nutritional parameters. Energy content increased, protein content increased, total carbohydrates increased, total sugars decreased, glucose decreased, dietary fibre decreased, citric and malic acids both decreased, potassium decreased and ascorbic acid decreased (Table 30 and summarised in Table 33). Most changes though statistically significant were quite small and would have little impact on the nutritional content of blueberries. The biggest impact of length of storage was on dietary fibre which decreased by 40%. Though the Day 3 level of dietary fibre was < 2 g/100g, blueberries can be considered a source of fibre, so the impact of storage on this nutrient is significant as after storage for 10 days it cannot considered a source of fibre. However, as stated previously blueberry is not a major source of dietary fibre in the Australian or New Zealand diet. Citric acid decreased by 11%; this may affect flavour. The most significant change nutritionally was in the levels of ascorbic acid which decreased on average from 10.0 mg/100g after three days in cold storage to 7.2 mg/100g after ten days in cold storage.

Table 33. For blueberry, mean values at each storage time for nutrients for which a significant (P < 0.05) effect of length of storage was found.

	Storage time (days)	
	3	10
Energy content (kJ/100g)	231 a	238 b
Mean protein content (g/100g)	0.56 a	0.64 b
Mean total carbohydrate content (g/100g)	12.25 a	13.00 b
Mean total sugars (g/100g)	12.1 a	11.6 b
Mean glucose concentration (g/100g)	6.18 a	5.90 b
Mean total dietary fibre content (g/100g)	1.73 a	1.03 b
Mean citric acid concentration (mg/100g)	548.3 a	487.5 b
Mean malic acid concentration (mg/100g)	290 a	275 b
Mean potassium content (mg/100g)	83.2 a	76.5 b
Mean ascorbic acid concentration (mg/100g)	9.96 a	7.24 b

Values in the same row with different letters are statistically different (P<0.05).

As ascorbic acid is of concern when assessing changes to the nutritive value of foods upon irradiation, it must be emphasised that in this study irradiation had **no** effect on ascorbic acid content of Northern Highbush 'Brigitta" blueberries. Table 34 has the mean ascorbic acid values for all four irradiation levels at both post-irradiation assessment times, with the mean values for all fruit at each assessment and at each irradiation dosage level and indicates the statistically significantly different values. As can be seen, storage time was the only factor having a significant impact on total ascorbic acid content of the blueberries.

Table 34. Effect of interaction of irradiation dose (Gy) and storage time (days) on mean blueberry ascorbic acid concentration (mg/100g) ($F_{3,8}$ = 0.20, p = 0.893). *Effect of irradiation dose (Gy) on mean blueberry ascorbic acid concentration (mg/100g) ($F_{3,6}$ = 0.99, p = 0.458). †Effect of storage time (days) on mean blueberry ascorbic acid concentration (mg/100g) ($F_{1,8}$ = 389.3, p < 0.001, l.s.d. = 0.318)

Irradiation dose (Gy)	Storage time (days)		*Mean ascorbate conc'n (mg/100g)
	3	10	
0	10.17 a	7.30 b	8.73
150	9.67 a	6.93 b	8.30
400	9.97 a	7.40 b	8.68
1000	10.03 a	7.33 b	8.68
†Mean ascorbate conc'n (mg/100g)	9.96 a	7.24 b	

Values in the same row with different letters are statistically different (p<0.05).

Neither storage nor irradiation had any effect on the levels of total monomeric anthocyanins in the blueberries (Table 35). That anthocyanins, the main antioxidants present in blueberries, are unaffected by irradiation is very important; many people actively consume blueberries to benefit from the health promoting properties of anthocyanins, so if blueberries were to be irradiated it is important to know that these health benefits will not be negated.

Table 35. Effect of interaction of irradiation dose (Gy) and storage time (days) on mean blueberry total monomeric anthocyanin concentration (mg/100g). ($F_{3,8}$ = 0.37, p = 0.774). *Effect of irradiation dose (Gy) on mean blueberry total monomeric anthocyanin concentration (mg/100g). ($F_{3,6}$ = 0.47, p = 0.714). †Effect of storage time (days) on mean blueberry total anthocyanin concentration (mg/100g)($F_{1,8}$ = 0.03, p = 0.876)

Irradiation dose (Gy)	***Storage time (days)***		****Mean anthocyanin conc'n (mg/100g)***
	3	**10**	
0	126.7	133.3	**130.0**
150	123.3	126.7	**125.0**
400	130.0	123.3	**126.7**
1000	123.3	116.3	**119.8**
†Mean anthocyanin conc'n (mg/100g)	**125.8**	**124.9**	

So it can be concluded that in blueberry, while there are some possible variations in the response due to variety or cultivar, an application of up to 1kGy will not result in any significant detrimental damage to the nutritional and postharvest quality of blueberry fruit. Irradiation at doses up to 1.6 kGy could be used to ensure and preserve the shelf life of blueberries for up to 14 days maintaining many quality attributes and hence maintain nutrient levels. Importantly ascorbic acid levels and anthocyanin levels are not adversely affected. In one study phenolic compounds (including anthocyanins) and antioxidant activity were enhanced by irradiation. It should also be noted that any changes to the nutrient content of blueberry on irradiation will not have a significant impact on the dietary intake of those nutrients in the Australian or New Zealand diet due to the low consumption rate of blueberries and the provision of these nutrients by other foods in the diet. The findings of all studies carried out on irradiation of blueberries supports low dose gamma irradiation (≤ 1 kGy) of blueberry, as requested in this application, as a permissible effective routine phytosanitary treatment against quarantine pests.

3.2 Toxicological data

The position of the Food and Agriculture Organization (FAO)/ International Atomic Energy Agency (IAEA)/ World Health Organization (WHO) Joint Expert Committee on Food Irradiation (JECFI, 1981) on chemiclearance or chemical implications of irradiated foods affirmed that when foods of similar composition are similarly irradiated their chemical and microbiological responses are similar and they are accordingly toxicologically equivalent. When an irradiated food in a class of similar foods is cleared as safe and adequate for consumption, then other members of that class are, correspondingly, wholesome and safe.

The JECFI (1981) stated “irradiation of food up to an overall average dose of 10 kGy presents no toxicological hazard and introduces no special nutritional or microbiological changes”. Hence toxicological testing of foods so treated is no longer required.

Over many years, specialised diets for astronauts or for patients suffering immunological deficiencies have been irradiated at 25 kGy. No specific nutritional or toxicological adverse effects have been reported.

Fruits and vegetables contain mainly water and carbohydrates, with pectin and sugars being the main components. The application for fruit fly disinfestation is in the range of 150 Gy to 1 kGy. No adverse effects are expected. This is confirmed with numerous chemical analyses and vast amount of experimental data observed in the aroma, taste and colour of numerous tropical fruits (Thomas, 1986, 1988; Mitchell *et al*. 1992; Moy and Wong, 2002; Wall, 2008).

FSANZ, in 2003, approved the irradiation of breadfruit, carambola, custard apple, litchi, longan, mango, mangosteen, papaya and rambutan, and in 2013 approved tomato and capsicum for inclusion in the list of fruit and vegetables approved to be irradiated for phytosanitary purposes in *Standard 1.5.3*. In its assessment of the toxicological issues, the authority concluded that irradiation of tropical fruits up to a maximum of 1 kGy employing good manufacturing/irradiation practices is safe for Australian and New Zealand consumers. In the FSANZ Approval Report for tomatoes and capsicums, “The safety assessment concluded that irradiation of tomatoes and capsicums, as proposed, is unlikely to generate significant levels of radiolytic compounds. Furan was not detected following irradiation of tomatoes and capsicums at 5 kGy while 2-alkylcyclobutanones (2-ACBs) are not expected to be of concern because of the low lipid content of tomatoes and capsicums.” In the same Report FSANZ stated that “No toxicological hazards have been identified with the use of food irradiation up to a maximum of 1 Gy.”

As the food components in raspberry and blueberry fall within the range of these fruits (see Section 3.1 Nutritional data and Table 36), it would be safe to extrapolate the same findings that irradiated raspberry and blueberry treated under the same conditions for a phytosanitary purpose will not pose a toxicological problem.

There is an overwhelming body of research available assessing toxicological safety, where animals were fed with a variety of foods irradiated at different doses between 0.15 to 50 kGy. The majority of these studies showed no evidence of toxicity in irradiated foods.

Fernandez *et al*. 1984 evaluated the genetic risk of irradiated food consumption theoretically and experimentally. According to the model used in the study it predicted that if a man ingested 100 g of irradiated food daily for 30 years, the calculated probability of damage would be 100,000 times lower than the natural probability of genetic error. The model took into account the risk induced by consuming irradiated food directly and indirectly through an intermediate source.

Table 36. Proximate profiles (per 100g) for raspberry and blueberry and fruit presently approved by FSANZ for irradiation at up to a maximum of 1 kGy for phytosanitary purposes.

	Water	Energy	Protein	Fat	Carbo-hydrate	Total sugars	Fructose	Glucose	Sucrose	Starch	Dietary fibre	Ash
Unit/100g	g	kJ	g	g	g	g	g	g	g	g	g	g
Raspberry[a]	84.6	225	1.2	0.3	7.4	7.0	3.8	3.1	0.1	0.3	6.1	0.4
Blueberry[a]	87.3	218	0.6	0.1	11.3	10.8	5.5	5.3	0	0.5	1.8	0.1
Breadfruit[b]	70.7	431	1.1	0.2	27.1	11.0					4.9	
Red Capsicum[a]	92.2	106	1.5	0.2	3.5	3.5	1.9	1.7	0	0	1.8	0.4
Carambola[b]	91.4	130	1.0	0.3	6.7	4.0					2.8	
Custard Apple[a]	78.7	326	1.4	0.6	15.8	14.7	5.4	5.6	3.7	1.1	2.5	0.4
Longans[b]	82.8	251	1.3	0.1	15.1						1.1	
Lychee[a]	80.6	296	1.1	0.1	16.2	16.2	7.6	7.9	0.7	0	1.3	0.3
Mango[a]	84.1	230	0.9	0.2	11.6	11.2	2.7	0.8	7.7	0.5	1.5	0.4
Pawpaw (papaya) [a]	89.3	142	0.4	0.1	6.9	6.9	3.3	3.6	0	0	2.3	0.3
Persimmon[a]	79.7	298	0.6	0.2	16.1	16.1	7.8	7.8	0.5	0	2.6	0.3
Rambutan[a]	79.5	312	1.0	0.4	15.7	15.7	3.1	2.8	9.9	0	2.8	0.3
Tomato[a]	94.2	74	1.0	0.1	2.4	2.3	1.2	1.1	0	0.1	1.2	0.6

[a]From FSANZ food composition database, NUTTAB 2010 Online Database
[b]From USDA National food composition database (USDA National Nutrient Database for Standard Reference 26 Software v.1.3.1)

Schubert (1977) reviewed aspects of the toxicology and chemistry of irradiated foods and food components, the radiation chemical considerations, combined effects, mutagenicity testing and compared irradiation with other food processes such as cooking and food additives. It was estimated that an average daily diet that contained 10% irradiated foods would result in consumption of between 0.05–2 % of radiolytic products generated from conventional food processing in the form of food additives and other contaminants.

In a review on natural radioactivity and possible induced activity from consumption of irradiated food the authors concluded that the increase in radiation background dose from consuming irradiated food was insignificant and best characterised as zero (IAEA 2002).

In that recent and rigorous assessment by the US FDA, the conclusion that irradiation of iceberg lettuce and spinach at a dose up to 4.0 kGy for the control of food-borne pathogens and extension of shelf-life (FDA 2008, 21 CFR Part 179) does not present a toxicological hazard, is relevant to this application. In the assessment, the US FDA considered the basic principles of radiation chemistry which provides "the basis for the extrapolation and generalization from data obtained in specific foods irradiated under specific conditions to draw conclusions regarding foods of a similar type irradiated under different, yet related condition".

Although radiolytic products can be derived from lipids when exposed to irradiation treatment (Nawar, 1986; Diehl, 1995), many of these products are comparable to those observed during storage or with heat treatment (Nawar, 1986; WHO, 1994). The radiation chemistry and nature of the radiolytic products are described elsewhere (Raffi *et al*. 1981, Adam 1983, Thiery *et al*. 1990, Diehl 1995).

The quantity of radiolysis products formed from some fatty acids is related to the composition of fatty acids particularly to palmitic acid, and the concentrations are directly proportional to the radiation dose and the conditions of irradiation (Diehl 1995, JECFI 1999, Kim *et al*. 2004).

With foods such as chicken and ground beef that contain high total lipid and palmitic acid, 5–25% depending on the cut, minute amounts (<1 µg/ g lipid per kGy) of 2-ACB and 2-DCB have been detected when they were irradiated (Crone *et al*. 1992, Gadgil *et al*. 2002, Gadgil *et al*. 2005).

In 2003, the World Health Organisation concluded that 2-dodecylcyclobutanone (2-DCB) and 2-alkylcyclobutanones (2-ACBs) in general do not appear to pose a health risk to consumers based on scientific evidence at that time, including long-term feeding studies (WHO 2003), that irradiated foods are safe and nutritionally adequate. O'Bryan *et al*. 2008 provide a brief review of the impact of irradiation on the safety and quality of poultry and meat products.

Despite the fact that 2-DCB and 2- ACBs can be detected in trace quantities in irradiated foods (Boyd *et al*. 1991, Crone *et al*. 1992, European Committee for Standardization 2003, Gadgil *et al*. 2005), the available data do not suggest that irradiated food would be a toxicological concern and pose a significant risk to human health (Thayer *et al*. 1987, WHO 1994, European Commission 2002, Health Canada 2003, Sommers 2003, Sommers and Schiestl 2004, Sommers 2006).

Mutagenicity of 2-DCB was addressed using various mutagenicity tests. 2-DCB did not induce mutations in the *E. coli* tryptophan reverse mutation assay (Sommers 2003), nor in the *Salmonella* Mutagenicity Test or Intrachromosomal Recombination in *Saccharomyces cerevisiae* (Sommers and Schiestl 2004). Sommers 2006 found that no 2-DCB induced mutagenesis was observed in any of the four mutagenicity test systems investigated.

After consumption, minute amounts of pure synthetic 2-ACBs (Horvatovich *et al*. 2002) and 2-DCBs (Gadgil and Smith 2006) were detected in adipose tissue and faeces of rats. None was recovered from urine extracts (Gadgil and Smith 2006). The authors also suggested that the ingested 2-DCBs might have been metabolised in the animals and eliminated from the body or stored at sites other than adipose tissue as only 11% was recovered.

Hartwig *et al*. (2007) detected potential cytotoxic activity but no mutagenic activity when pure 2-ACBs were inoculated into bacterial cells. 2-ACB inoculated human colon tumour cells suggested genotoxicity. In another study (Marchioni *et al*. 2004) 2-ACBs demonstrated cytotoxic and genotoxic properties under experimental in-vitro conditions. However, these effects need further clarification as activity revealed here with pure synthetic 2-ACBs could very well differ when ingested as food.

In an earlier examination of the mutagenic potential and acute toxicity of 2-DCB using specific assays, Gadgil and Smith (2004) found 2-DCB to be non-mutagenic and that the toxicity was so low in the assay that the authors concluded from the evidence that the potential risk from 2-DCB consumption, if any, is very low.

The lipid content in plant products is very low compared to meat products. The lipid content of raspberry and blueberry (<0.2% in NSW DPI study (Golding *et al.* 2014a, Golding *et al.* 2014b) is considerably less than in iceberg lettuce (0.5%) and contains the same amount of palmitic acid (0.016g) as iceberg lettuce. It is anticipated that formation of alkylcyclobutanones, particularly 2-DCB, from irradiated raspberry and blueberry at doses up to 1 kGy would be appreciably lower if any and would not present a toxicological problem and deemed safe to eat as was iceberg lettuce and spinach irradiated up to 4kGy. Raspberry and blueberry represents a very small fraction in the context of a total human diet.

Ionising radiation is a safe and effective method for inactivating bacteria in food, and has been approved by the US Food and Drug Administration (US FDA). The American Medical Association (AMA) publicly supports food irradiation after it reviewed the toxicological data however; the purpose of this application is for a phytosanitary measure.

3.3 Products or ingredient

Not relevant to the request for a phytosanitary purpose.

3.4 Microbial data

Not relevant to the request for a phytosanitary purpose.

3.5 Assessment procedure

This application seeks a variation to the Food Standards Code, Standard 1.5.3 Irradiation of Food, Clause 4 Table by adding raspberry (*Rubus idaeus)* and blueberry (*Vaccinium corymbosum, V. strigosus, V. virgatum v ashei)* for market access.

Raspberries (*Rubus idaeus)* and blueberries (*Vaccinium corymbosum, V. strigosus, V. virgatum v ashei)* are hosts to fruit fly and are subject to phytosanitary regulatory treatments against fruit fly and other critical plant quarantine pests as a condition of their entry and/ or movement in certain plant quarantine jurisdictions.

The required treatment efficacy would comply with ISPM 28: Irradiation Treatment for Fruit Flies of the Family Tephritidae (Generic) (Annex 7) (2009). A ‘generic’ irradiation treatment at 150Gy minimum absorbed dose will prevent the emergence of adult fruit flies for all fruits and vegetables. The maximum absorbed dose is 1000Gy (1kGy). We anticipate that the assessment procedure applicable to the consideration of this application would be a General Procedure.

PART 4 – REGULATORY/ LEGISLATIVE IMPLICATIONS

4.1 International standards

The safety and benefits of food irradiation are supported and endorsed by the World Health Organisation and the Food and Agriculture Organisation of the United Nations. The internationally recognised standard-setting bodies for human and plant health are the Codex Alimentarius Commission (Codex) and the International Plant Protection Convention (IPPC).

International compliance with the Codex Alimentarius standards and codes of practices relating to the irradiation of food and food hygiene ensure the safety and nutritional goodness of irradiated food. The Codex Alimentarius represents the global standard for irradiation of food. Member states are free to convert or incorporate these standards into their national regulations. As a result regulations relating to irradiation of food differ from country to country. Most countries approve food irradiation on a case-by-case basis.

The International Plant Protection Convention (IPPC) endorse the International Standards for Phytosanitary Measures (ISPMs) that provide guidelines to achieve international harmonisation of phytosanitary measures and can help facilitate trade.

ASTM International maintains a number of current international voluntary consensus standards relating to the irradiation of food which, when used, can facilitate trade. They include standard guides for calibration and operation for radiation dosimetry, absorbed dose mapping (ASTM 20011, reporting and documentation of procedures, and selection and use of packaging materials for food irradiation. There is also an ASTM guide to procedures for radiation disinfestation of fresh agricultural procedures. Some of these standards are jointly published by ASTM and the International Standards Organisation (ISO).

Irradiation treatment of raspberry and blueberry for phytosanitary purposes (following approval) would comply with the relevant *Codex, IPPC and ASTM* International standards.

Codex Alimentrarius

The Codex Alimentarius, or the food code, is the global reference point for policies and procedures and legislation that ensure food is available, safe and of good quality worldwide. It is scientifically based and risk analysis has been applied and independent scientific advice relied upon for its development. The WHO in 1985 recognised the significance of the food code for consumer health protection by adopting guidelines advising:

> *“When formulating national policies and plans with regard to food, Governments should take into account the need of all consumers for food security and should support and, as far as possible, adopt standards from the Codex Alimentarius or, in their absence, other generally accepted international food standards”.*

In 1995 Codex standards, guidelines and codes of practice became a reference for food safety in the WTO Agreement on Sanitary and Phytosanitary Measures (SPS Agreement). Those of the World Organization for Animal Health (OIE) for animal health issues and the International Plant Protection Convention (IPPC) for plant health were also references.

Codex food standards are considered a vital component in promoting food control systems designed to protect consumer health, including issues related to international trade and the World Trade Organization (WTO) agreements on the Application of Sanitary and Phytosanitary Measures (SPS) and on Technical Barriers to Trade (TBT). Together with the FAO and WHO, Codex makes a substantial contribution internationally and to individual countries both in protecting their citizens and in benefiting from an increasingly globalised market in food.

The Codex Alimentarius represents the global standard for irradiation of food. The safety and nutritional aspects of irradiation of foods is ensured through compliance with the Codex *General Standard for Irradiated Foods CODEX STAN 106- 1983, REV.1-2003* (2003), which applies to foods processed by ionizing radiation.

The Codex *General Standard for Irradiated Foods*

The Codex *General Standard for Irradiated Foods CODEX STAN 106- 1983, REV.1-2003* (2003) can be found at:

http://www.codexalimentarius.net/download/standards/16/CXS_106e.pdf. It is used in

conjunction with applicable codes of practice relating to radiation processing of food and food hygiene, food standards, standard methods for detection of irradiated food and transportation codes. Table 37 lists Codex standards (CODEX STAN) and codes of practice (RCP) which underpin sections of the Codex *General Standard for Irradiated Foods.*

This standard makes it clear that irradiation of food is only justified if it fills a technological need (such as disinfestation) or public health need and it should not be used as a substitute for good agricultural practices, good hygienic or good manufacturing practices.

The types of ionizing radiation that may be used are listed; this includes gamma rays from ^{60}Co. It also sets out the minimum and maximum absorbed dose allowed:

> *"The minimum absorbed dose should be sufficient to achieve the technological purpose, and the maximum absorbed dose should be less than that which would compromise consumer safety, wholesomeness or would adversely affect structural integrity, functional properties, or sensory attributes. The maximum absorbed dose delivered to a food should not exceed 10kGy except when necessary to achieve a legitimate technological purpose".*

The standard sets out the requirements for the facilities that carry out the irradiation treatment. They must: be licensed and registered by the competent authority; be designed to meet the requirements of safety, efficacy and good hygienic practices of food processing; be adequately staffed with trained and competent personnel; keep adequate records of the control of the process including dosimetry; and be open to inspection by appropriate authorities.

Control of the food irradiation process should be carried out in accordance to *Recommended International Code of Practice for Radiation Processing of Food (CAC/RCP 19-1979, Rev. 2-2003* (2003). This code of practice covers the requirements of the irradiation process in a facility including: the pre-irradiation treatment of the food (primary production and/or harvesting, postharvest treatment, storage and shipment); packaging; the design and layout of the irradiation facilities and the radiation source; control of the operation including staffing and training[4], process control, control of applied dose and product and inventory control; the irradiation process, including dosimetry, dosimetry systems, process control, records of irradiation and control of hazards; post-irradiation storage and handling; and labelling. In Australia, the operation of the Steritech Narangba, Queensland, facility which presently irradiates tropical fruits, persimmon, tomatoes and capsicum for phytosanitary purposes conform to this Code of Practice.

[4] Codes of good irradiation practice and training manuals can be obtained from The International Consultative Group on Food Irradiation (ICGFI). Compilation of principles and international recommendations for regulatory control measures on food irradiation is published in *ICGFI Document 21*: Control of irradiated food in trade.

The purpose of Codex *Code of Practice for Radiation Processing of Food* is "to provide principles for the processing of food products with ionising radiation that are consistent with relevant Codex Standards and codes of hygiene practice." There is an emphasis is on food safety and it is stated that hygienic practice and practice of HACCP (Hazard Analysis and Critical Control Point) as described in *Recommended International Code of Practice General Principles of Food Hygiene* (*CAC/RCP 1-1969, Rev 4-2003* (2003) need to be carried out.

Irradiation is not a substitute procedure for good manufacturing practice and good agricultural practice which must be employed. The *Code of Hygienic Practice for Fresh Fruits and Vegetables, CAC/RCP 53-2003* (2003) addresses Good Agricultural Practices (GAPs) and Good Manufacturing Practices (GMPs) in the production of fresh fruits and vegetables from primary production to packing. Annex V of this Code covers specific guidance in relation to berries (including raspberries and blueberries).

Fruit and vegetables are often transported in bulk or semi-packed, that is in crates, bags or other containers where the food might come in direct contact with the food transportation container or the air. Codex *Code of Hygienic Practice for the Transportation of Food in Bulk and Semi-Packed Food CAC/RCP 47-2001* sets out the additional requirements of food hygiene applicable when fruit or vegetables are transported under these conditions.

In relation to post-irradiation verification of food having been irradiated, various methods have been developed and adopted by the Codex Alimentarius Commission for the detection of irradiated foods. These are listed in *General Methods for the Detection of Irradiated Foods, CODEX STAN 231e, Rev.1-2003* (2003). These analytical methods for the detection of irradiated foods were adopted from those have been standardised by the European Committee for Standardisation (CEN) (see Table 38); only method *EN 14569:2004, Microbiological screening for irradiated food using LAL/GNB procedures* was not adopted.

Section 5.2 of Codex *General Standard for the Labelling of Prepackaged Foods (CODEX STAN 1-1985, Rev. 7- 2010)* covers the labelling of irradiated food. There should be a written statement close to the name of the food indicating the food has been irradiated. The use of the international food symbol (the "Radura") is optional but if used should also be close the name of the food. Any food which contains an irradiated food must declare it in the list of ingredients.

Through Codex Australia, the Australian Department of Agriculture is involved in the work of the international Codex Alimentarius Commission. Codex coordinates the food standards that help protect the health of consumers and assist in ensuring fair trade. Further information on Australia's involvement and interaction with Codex can be found at http://www.daff.gov.au/agriculture-food/codex.

Table 37: CODEX Recommended Codes of Practice (RCP) and Standards (CODEX STAN) underpinning the CODEX General Standard for Irradiated Foods (CODEX STAN 106-1983, REV.1-2003)

Section of Standard (CODEX STAN 106-1983, REV.1-2003)	CODEX Codes of Practice / Standards
1 Scope	
2 General requirements for the process	
2.1 Radiation Sources	
2.2 Absorbed Dose	
2.3 Facilities and Control of the Process	Recommended International Code of Practice for Radiation Processing of Foods (CAC/RCP 19-1979, Rev.2-2003)
3 Hygiene of Irradiated Foods	General Principles of Food Hygiene (CAC/RCP 1-1969, Rev.4-2003) Code of Hygienic Practice for Fresh Fruits and Vegetables (CAC/RCP 53-2003) Code of Hygienic Practice for the Transport of Food in Bulk and Semi-Packed Food (CAC/RCP 47-2001)
4 Technological Requirements	
4.1 General Requirement	
4.2 Food Quality and Packaging Requirements	
5 Re-Irradiation	
6 Post Irradiation Verification	General Methods for the Detection of Irradiated Foods (CODEX STAN 231, Rev.1-2003)
7 Labelling	
7.1 Inventory Control	
7.2 Prepackaged Foods Intended for Direct Consumption	General Standard for the Labelling of Prepackaged Foods (CODEX STAN 1-1985, Rev.7-2010)
7.3 Foods in Bulk Containers	

4.1.2 International Plant Protection Convention (IPPC)

The main purpose of the International Plant Protection Convention (IPPC) and the responsibilities of the contracting parties are to prevent the introduction and spread of plant pests and promote appropriate measures for the control of regulated pests.

Guidelines regarding phytosanitary measures endorsed by the IPPC are written as International Standards for Phytosanitary Measures (ISPMs).

The ISPMs provide guidelines to achieve international harmonisation of phytosanitary measures and can help facilitate trade. The harmonisation of phytosanitary measures can help avoid the use of unjustifiable measures as barriers to trade.

ISPM No. 18 Guidelines for the Use of Irradiation as a Phytosanitary Measure (2003), of the International Plant Protection Convention, provides technical guidance on specific procedures for the application of ionizing radiation as a phytosanitary treatment for regulated pests. In Appendix 1 to this Guideline, the estimated minimum absorbed doses for certain responses for selected pest groups are listed. A minimum dose range of 50-250 Gy is given for fruit fly (Tephritidae) to “prevent adult emergence from 3rd instar”.

ISPM No. 28 Phytosanitary Treatments for Regulated Pests (2007) considers harmonising efficient phytosanitary treatments for fruits and vegetables, particularly in international trade, which may also facilitate trade. Appendix 1 of this standard has a list of adopted annexes to the standard which contain the phytosanitary treatments for regulated pests that have been adopted by the Commission of Phytosanitary Measures. For all except one target regulated pest, the treatment type is irradiation at minimum absorbed dose levels varying from of 60Gy to 232Gy. *Bactrocera cucurbitae* is the exception with Vapour Heat as the adopted treatment. Annex 7 is *“Irradiation treatment for fruit flies of the family Tephritidae (generic)” (ISPM 28. 2007: Annex 7 (2009)*).The treatment schedule is a “minimum absorbed dose of 150 Gy to prevent the emergence of adults of fruit flies” to be “applied in accordance with the requirements of ISPM 18 (*Guidelines for the Use of Irradiation as a Phytosanitary Measure).*”

Viable phytosanitary treatments are those that are economically and technically feasible, and meet *ISPM No. 24 Guidelines for the Determination and Recognition of Equivalence of Phytosanitary Measures* (2005). This standard considers equivalent phytosanitary measures that achieve appropriate level of protection for the regulated pest(s) and accounts for the changing phytosanitary situations in exporting countries. It *“describes the principles and requirements that apply for the determination and recognition of equivalence of phytosanitary measures. It also describes a procedure for the equivalence determinations in international trade.”*

The ICCP Commission on Phytosanitary Measures (CPM) Recommendation CPM-3/2008 - Replacement or Reduction of the Use of Bromide as a Phytosanitary Measure (2008) provides guidance to National Plant Protection Organisations on the replacement of or reduction in the use of methyl bromide as a phytosanitary measure towards reducing emissions of methyl bromide (an ozone depleting substance). In Appendix 1, irradiation is listed as one of the potential phytosanitary treatments to be considered to replace or reduce methyl bromide for fresh fruit and vegetables.

4.1.3 ASTM International

ASTM International, formerly known as the American Society for Testing and Materials (ASTM), is recognised world leader in the development and provision of international voluntary consensus standards (ASTM 1996). ASTM standards are used around the world to improve product quality, enhance safety, facilitate market access and trade, and build consumer confidence. ASTM test methods, specifications, guides and practices are used worldwide by industries and governments.

ASTM standards are developed in accordance with the guiding principles of the World Trade

Organization, and due to the global recognition and acceptance of these standards, practices and methods, their application allows for facilitation of trade.

Current and equivalent ASTM International standards regarding food irradiation are:

ASTM F1355-06 Standard Guide for Irradiation of Fresh Agricultural Produce as a Phytosanitary Treatment (ASTM 2006) considers irradiation as a phytosanitary treatment to minimize the pest risk and to maximize the safety associated with the movement and use of fresh agricultural produce. The guide provides procedures for radiation disinfestation to control regulated pests. The typical absorbed dose range is between 150 Gy and 600 Gy, for the control of certain insect pests of fresh fruits. It does specify a limitation to the use of irradiation as a phytosanitary treatment:

> *"If the minimum effective dose necessary to achieve the desired phytosanitary effect is greater than the radiation tolerance of the produce, then irradiation is not an appropriate treatment."*

ASTM F1640-09 Standard Guide for Packaging Materials for Foods to be Irradiated (ASTM 2009), provides a guide and parameters for selection and use of packaging materials for holding food during irradiation. It also examines criteria for their fitness for use.

ASTM E2303 – 11e1 Standard Guide for Absorbed-Dose Mapping in Radiation Processing Facilities (ASTM 2011) provides guidance in determining absorbed-dose distributions in products that are irradiated and describes methods of analysing dose map data. ISO/ASTM52628-13 *Standard Practice for Dosimetry in Radiation Processing* is used in conjunction with ASTM E2303.

Other food irradiation associated ASTM standards include *ISO / ASTM51702 – 13 Standard Practice for Dosimetry in Gamma Irradiation Facilities for Food Processing* (ASTM 2013) and *ISO / ASTM51431 - 05 Standard Practice for Dosimetry in Electron Beam and X-Ray (Bremsstrahlung) Irradiation Facilities for Food Processing* (ASTM 2005). These standards outline the installation qualification program for an irradiator and routine processing in the facilities that irradiate food from gamma sources in the former and with high-energy electrons and X-rays in the second, to ensure that product has been treated within a predetermined range of absorbed dose. These standards are jointly published by ASTM and the International Standards Organisation (ISO).

4.2 National standards or regulations

4.2.1 Australia and New Zealand

FSANZ Standard 1.5.3 *Irradiation of Food*

FSANZ *Standard 1.5.3 Irradiation of Food* provides permission for the irradiation of specified foods where this method of processing fulfils a technological need. The absorbed dose applied should be the minimum required for the technological purpose to be achieved and conforms to good radiation processing practice. The irradiation must be carried out in appropriately licensed and registered facilities according to the relevant Codex Alimentarius codes of practice. The Standard also considers the packaging materials used, labelling and record keeping in relation to the irradiation of food. It prohibits irradiation of food that has not expressly been given permission or for purposes other than those specified in the Standard.

Currently, the Standard allows for the irradiation of specified fruits and vegetables - apple, apricot, breadfruit, capsicum, carambola, cherry, custard apple, honeydew, litchi (lychee), longan, mango, mangosteen, nectarine, papaya, peach, persimmon, plum, rambutan, rockmelon, strawberry, table grape, tomato, zucchini and scallopini / summer squash - for phytosanitary purposes The minimum and maximum doses for these produce are specified in the standard and are 150 Gy and 1 kGy respectively.

This current application to FSANZ is to amend Standard 1.5.3 to give permission for the irradiation of raspberry and blueberry for phytosanitary purposes at the same minimum and maximum doses as specified for the fruit and vegetables already listed in the Standard.

MAF Biosecurity New Zealand Standard 152.02: *Importation and Clearance of Fresh Fruit and Vegetables into New Zealand* and *Import Health Standard Sub-class: Fresh Fruit/Vegetables*

In 2004 the first international shipment of irradiated food occurred; this was of gamma irradiated mangoes from Australia to New Zealand. This was possible as a result of the New Zealand Minister for Primary Industries (MPI), using the principles and guidelines set out in ISPM 18, approving irradiation as a pre-export phytosanitary measure in 2004 for fresh mango exports from Australia, for treatment against Queensland fruit fly Bactrocera tryoni. The MPI has subsequently approved irradiation of fresh lychee, papaya, capsicums and tomatoes from Australia and lychee, papaya and mango from additional countries.

MAF Biosecurity New Zealand Standard 152.02: Importation and Clearance of Fresh Fruit and Vegetables into New Zealand (2014), and the associated *Import Health Standard Sub-class: Fresh Fruit/Vegetables* (commodity specific hyperlinks are provided in Standard 152.02) specifically provide for the import of irradiated mango, papaya, lychee, tomato and capsicum from Australia, mango from Vietnam, lychee and longan from Thailand and papaya from Hawaii as a pre-export phytosanitary measure. The irradiation must be carried out in accordance with ISPM 18: *Guidelines for the use of irradiation as a phytosanitary measure (2011)*. For Risk Group 3 (RG3) regulated pests, which includes *Bactrocera tryoni* (Qff) and *Ceratitis capitata* (Medfly), NZ MPI approves a minimum dose rate of 150 Gy; for other IHS regulated arthropod pests, a minimum dose rate of 400 Gy is required.

At present MAF Biosecurity New Zealand Standard 152.02 does not list raspberry or blueberry among the list of commodities approved to be imported into New Zealand from Australia regardless of phytosanitary treatment or if sourced from a fruit fly free area. This means Australia presently does not have market access to New Zealand for raspberry and blueberry. The treatments allowed for each fruit or vegetable approved for import into New Zealand from Australia has been agreed to and is supported as part of a NZ MAF/DAFF Bilateral Quarantine Arrangement. DAFF would have to negotiate with NZ MAF to allow market access for irradiated raspberry and blueberry into New Zealand.

FSANZ Standard 1.4.3 *Articles and materials in contact with food*

The packaging material for use during irradiation of raspberry and blueberry would conform to FSANZ Standard 1.4.3 *Articles and materials in contact with food.* This Standard provides permission for materials and articles to be in contact with food. The Standard however does not specify the details of the materials used in manufacturing the packaging and places this on the responsibility of the manufacturers. Manufacturers must comply with Australian Standard AS2070-1999.

Australian Standard *Plastics Materials for Food Contact Use, AS2070 –1999*

Australian Standard for *Plastics Materials for Food Contact Use, AS2070 –1999* (1999) specifies materials (resins, granules and powders and colorants) and the procedures in the production of plastics materials, coating and printing of plastics items for food contact use and its subsequent use. This includes such items as packages, domestic containers, wrapping materials, utensils or any other plastics items intended for food contact applications. This revised standard harmonises with the international Standards – US FDA regulations and EEC Directives. It recommends and establishes the references of international Standards for use in Australia. Two such referenced documents are US FDA 21 CFR Parts 170-199, and the European Commission Directive 90/128/EEC *Directive relating to plastics materials and articles intended to come in contact with foodstuffs* and its amending directives 92/39/EEC, 93/9/EEc, 95/3/EC and 96/11/EC.

Australian Interstate Certification Assurance (ICA) Scheme

Australia has a national system of plant health certification based on quality management principles and agreed to by the quarantine agencies of all States and Territories. Interstate Certification Assurance Scheme Operational Procedure Number 55 (ICA 55) was adopted in 2011 (ICA 2011) and is accepted by all states and territories of Australia. ICA 55 is an operational procedure for irradiation treatment as a quarantine entry requirement and applies to all insects excluding only Lepidoptera that pupate internally, and to all fruits and vegetables for which FSANZ has approved the use of irradiation. The irradiation procedure conforms to the principles of ISPM 18 and is accepted by Biosecurity Australia. ICA 55 also sets the minimum doses required as follows –

- 150 Gy for fruit flies of the family Tephritidae
- 300 Gy for the mango seed weevil.
- 400 Gy for all pests of the phylum Arthropoda (excluding Lepidopteron that pupate internally).

The ICA 55 procedure covers all certification of irradiated product by a business operating under an ICA arrangement in Queensland. At present the only facility capable of irradiating fruit and vegetables in Australia is located in Queensland.

Regulation of Irradiation facilities

Irradiation facilities in Australia are regulated by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) or by the respective state and territory authorities. The National Radiation Laboratory (NRL) under delegated authority from the Ministry of Health regulates all radiation facilities and radioactive substances and apparatus in New Zealand.

Australia has a Gamma Irradiation Offshore Treatment Providers Scheme with a list of Approved Offshore Treatment Facilities http://www.daff.gov.au/biosecurity/import/general-info/pre-border/gamma. The Department of Agriculture accredits facilities as approved offshore treatment providers for gamma irradiation treatment. Through an evaluation process approved facilities have demonstrated their capacity to irradiate commodities as listed on the Import Conditions database (ICON) (http://apps.daff.gov.au/icon32/asp/ex_querycontent.asp). However the foodstuffs that can be irradiated are restricted to those listed in Food Standard 1.5.3. Approved offshore facilities are in Germany, Israel, Netherlands, New Zealand and United Kingdom.

4.2.2 United States of America

The safety and benefits of food irradiation in the US are upheld by authorities including; the US Surgeon General, the Food & Drug Administration (FDA), the Centres for Disease Control, the US Dept. Health & Human Services, the US Department of Agriculture (USDA), the American Dietetic Association (ADA) and the American Medical Association.

In the USA, the Food & Drug Administration (FDA) is responsible for regulating the use of irradiation in the treatment of food and food packaging as it is classified as a food additive and not a food process; a food is adulterated (that is, it cannot be marketed legally) if it has been irradiated, unless the irradiation is carried out in conformity with a regulation prescribing safe conditions of use. Thus, FDA regulates the lawful use of irradiation through the food additive petition process. The United States Department of Agriculture amends the FDA regulations for the use of irradiation with meat, poultry and fresh fruit.

The FDA Irradiated Food and Packaging website (http://www.fda.gov/Food/IngredientsPackagingLabeling/IrradiatedFoodPackaging/default.htm) is a good source of general as well as more specific regulatory and scientific information about the irradiation of food and packaging for consumers, representatives from industry, and other stakeholders in the USA.

The FDA regulations relating to irradiation of food are found in Code of Federal Regulations (CFR) *Title 21: Food and Drugs, Part 179 Irradiation in the production, processing and handling of food*, *21 CFR 179* (2009). Subparts relevant to gamma irradiation of food are listed below in Table 38.

The US FDA has approved the use of ionising radiation on various foodstuffs under defined conditions. These are specified in the Federal Register at *21 CFR Part 179 Irradiation in the Production, Processing and Handling of Food § 179.26 Ionizing Radiation for the Treatment of Food*, including meats such as pork, poultry, and packaged meats used solely in space flight programs, culinary herbs, spices, seeds, seasonings, wheat, fruits, and vegetables like lettuce and spinach. For disinfestation of arthropod pests in food is one of the uses specified.

Table 38. Sub-parts of 21 CFR 179 that are relevant to gamma irradiation in the production, processing and handling of food.

Code	Description
179.21	Sources of radiation used for inspection of food, for inspection of packaged food, and for controlling food processing.
179.25	General provisions for food irradiation.
179.26	Ionising radiation for the treatment of food.
179.45	Packaging materials for use during the irradiation of prepackaged foods.

Source: http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&sid=911a36a52aad0759b094cf95b467782e&rgn=div5&view=text&node=21:3.0.1.1.10&idno=21

APHIS regulates the use of irradiation to meet quarantine requirements of products entering the USA and the interstate movement of horticultural produce from Hawaii and US territories into the mainland. In October 2002, US Department of Agriculture, Animal and Plant Health Inspection Service (APHIS) *Irradiation Phytosanitary Treatment of Imported Fruits and Vegetables,* (APHIS 2002) approved the use of irradiation against 11 major species of tropical and sub-tropical fruit fly and one species of seed weevil, regardless of commodities and countries of origin, thus opening up trade. In 7 CFR Parts 305 and 319 the dose specified for Medfly is 225 Gy and for Qff, 150 Gy.

Rule 7 CFR Parts 305 and 319 (e-CFR Data 2009) *Irradiation Phytosanitary Treatment of Imported Fruits and Vegetables*, APHIS, provides for the use of irradiation as a phytosanitary treatment for fruits and vegetables imported into the USA. The treatment provides an alternative to other currently approved treatments (fumigation, cold and heat treatments) against fruit flies and the mango seed weevil in fruits and vegetables. It should be noted that in 7 CFR Part 319, Foreign Quarantine Notices, Sub-Part Fruit and Vegetables, 319.56, litchi and mangoes imported from Australia must be irradiated as specified in 7 CFR Part 305. Raspberry and blueberry are not specifically mentioned.

The *USDA Fresh Fruits and Vegetables Import Manual* (2008) provides background, procedures, and reference tables for regulating imported articles of fresh fruits and vegetables. The manual also contains the procedures for regulating foreign produce that is transiting the United States. This may be accessed at

http://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/fv.pdf

In addition to USDA requirements, the FDA and Department of Homeland Security's Customs and Border Group have specific requirements for importing fresh fruits.

4.2.3 European Union/European Commission (EC)

Currently regulations on food irradiation among member states in the European Union (EU) are not fully harmonised. In 1999 the European Parliament and the Council of the European Union adopted Directive 1999/2/EC (EU 1999a) as the "framework Directive" to take into account (or "approximate") the differences between national laws relating to the irradiation of food and the manufacture, marketing and importation of foods and food ingredients treated with ionising radiation. This was necessary to allow free movement (market access) of irradiated foods across national borders within the and allow for the importation of irradiated food from non-EU countries. *Framework Directive 1999/2/EC* (EU 1999a) establishes a framework for controlling irradiated foods, labelling and importation.

The "framework" Directive legislates for development of a list of foods that can be irradiated; this list is in the "implementing" *Directive 1999/3/EC* (EU 1999b). The only category of foodstuff permitted across European Community boundaries, and so on this list, is dried aromatic herbs, spices and vegetable seasonings which are to be irradiated at a maximum dose of 10kGy.

The "framework" Directive sets out the conditions for authorising food irradiation – reasonable technological need, not a health hazard, to be carried out under the conditions proposed, benefits the consumer and is not a substitute hygiene or health practices or good manufacturing or agricultural practices. It also sets out the purposes for which irradiation can be used; these include to rid the food of organisms harmful to plant and plant products and to reduce spoilage.

The provisions relating to the labelling of irradiated are also set out in Directive 1999/2/EC (must be labelled "irradiated" or "treated with ionising radiation"), as are regulations relating to the creation of a list of foodstuffs that are authorised for irradiation by the member states, the approval of irradiation facilities, the creation of a list of approved facilities within the EU, record keeping of food irradiated and the conditions under which irradiated food can be imported from non-EU countries, including the creation of a list of approved irradiation facilities in non-EU countries.

Member States maintain existing national authorisations for the irradiation of certain foodstuffs in their own countries. The list of member states' authorisations of foodstuffs which may be irradiated in addition to dried aromatic herbs, spices and vegetable seasonings according to *Article 4(6) of Directive 1999/2/EC*, and their associated maximum authorised radiation dose is in *2009/C 283/02* (EU 2009b). Seven member states (Belgium, the Czech Republic, France, Italy, the Netherlands, Poland and the UK) are listed, among which only Belgium, the Czech Republic and the UK authorise the irradiation of fruit and the maximum dose authorised for fruit is 2 kGy. Grains, potatoes, onions, vegetables, pulses, strawberries, dried fruits and vegetables, seafood and other meat products are other foods authorised by certain member states.

The current list of approved food irradiation facilities in the member states is in a Notice from Member States *2012/C 20/04* (EU 2012). These facilities are in Belgium, Bulgaria, Czech Republic, Germany, Estonia, Spain, France, Hungary, Italy, Netherlands, Poland, Romania and the UK.

Imports of irradiated foods into the EU from a non-EU country are only possible if the irradiation facility has been inspected and approved by the EC and the treatment is legal within the EC or some Member state. The list of approved facilities in non-EU countries for the irradiation of foods is in Commission Decision 2002/840/EC (amended in Commission Decision 2004/691/EC) (EU 2004). The latest consolidated version of this document is dated 24/05/2012 and contains three facilities in South Africa, one in Turkey, one in Switzerland, two in Thailand and three in India. At present no Australian facility is approved for irradiation of food for importation into the EU.

Analytical methods for the detection of irradiated foods have been standardised by the European

Committee for Standardisation (CEN) and can be viewed at:

http://ec.europa.eu/food/food/biosafety/irradiation/anal_methods_en.htm (Table 39) (EU 2009a). All these standards, with the exception of EN14569:2004, have been adopted by the Codex Alimentarius Commission as General Methods for the detection of irradiated foods in *CODEX STAN 231-2001*and are referred to in the Codex General Standard for Irradiated Foods (*CODEX STAN 231e, Rev.1-2003*) in section 6.4 on 'Post-irradiation verification'.

Table 39. European standard analytical methods for the detection of irradiated foods, its use and source

Code	Purpose
EN 1784:2003	Detection of irradiated food containing fat - Gas chromatographic analysis of hydrocarbons http://ec.europa.eu/food/food/biosafety/irradiation/1784-1996_en.pdf
EN 1785:2003	Detection of irradiated food containing fat - Gas chromatographic/mass spectrometric analysis of 2-alkylcyclobutanones http://ec.europa.eu/food/food/biosafety/irradiation/1785-2003_en.pdf
EN 1786:1996	Detection of irradiated food containing bone - Method by (electron spin resonance) ESR spectroscopy http://ec.europa.eu/food/food/biosafety/irradiation/1786-1996_en.pdf
EN 1787:2000	Detection of irradiated food containing cellulose by ESR spectroscopy http://ec.europa.eu/food/food/biosafety/irradiation/1787-2000_en.pdf
EN 1788:2001	Thermoluminescence detection of irradiated food from which silicate minerals can be isolated http://ec.europa.eu/food/food/biosafety/irradiation/1788-2001_en.pdf
EN 13708:2001	Detection of irradiated food containing crystalline sugar by ESR spectroscopy http://ec.europa.eu/food/food/biosafety/irradiation/13708-2001_en.pdf
EN 13751:2002	Detection of irradiated food using photostimulated luminescence http://ec.europa.eu/food/food/biosafety/irradiation/13751-2002_en.pdf
EN 13783:2001	Detection of irradiated food using Direct Epifluorescent Filter Technique/Aerobic Plate Count (DEFT/APC) - Screening method http://ec.europa.eu/food/food/biosafety/irradiation/13783-2001_en.pdf
EN 13784:2001	DNA comet assay for the detection of irradiated foodstuffs - Screening method http://ec.europa.eu/food/food/biosafety/irradiation/13784-2001_en.pdf
EN 14569:2004	Microbiological screening for irradiated food using LAL/GNB procedures http://ec.europa.eu/food/food/biosafety/irradiation/14569_2004_en.pdf

The Official Journal of the European Union publishes annual reports on irradiation of food in the EU. These reports are requested by Article 7(4) of the 'framework" Directive 1999/2/EC. They are compilations of the information forwarded to the Commission by the 27 Member States as required by Article 7(3) of the 'framework" Directive. Results of checks carried out in irradiation facilities, in particular the categories and quantities of foodstuffs treated and the doses administered, and the results of checks carried out at the product marketing stage and the methods used to detect treatment with ionising radiation. Details of approved irradiation facilities and any change of status and a report on information provided by the national supervisory authorities are also included in the report.

The most recent annual report is for 2012 (EC 2014). It shows that 7972.1 tonnes of foodstuffs were irradiated of which 5157.7 tonnes were irradiated in Belgium. Frogs legs (36%) and poultry (35%) and dried aromatic herbs (15%) and spices were the three biggest commodities irradiated.

Of the almost 5000 samples tested at marketing stage 96.1% were compliant with the “framework” Directive. The two main reasons for non-compliance were incorrect labelling and forbidden irradiation. Non-compliance was also due to irradiation in facilities not approved by the EU. These annual reports, freely available to the public, result in transparency of the food irradiation process in the EU.

4.2.4 Canada

Canada has a regulatory approach similar to Australia and New Zealand. The Canadian *Food and Drug Regulations (2014) Part B Foods, Division 26 Food Irradiation* provides for the treatment of foods with ionizing radiation. This provides a table of foods that may be irradiated, the permitted source(s) of ionizing radiation, the purpose of the treatment and the permitted absorbed dose. It also sets out the records that must be kept by the manufacturer and importers of irradiated food, and details how a food may be added or a change made to the table of permitted foods.

The Food and Drug Regulations apply to foods offered for sale in Canada, no matter where they were produced or, in this case, where they were irradiated. It is the responsibility of the Canadian Food Inspection Agency (CFIA) to enforce the regulations.

The foods currently approved for irradiation and the approved purposes are potatoes and onions to inhibit sprouting during storage; wheat, flour, and whole wheat flour to control insect infestation during storage; whole and ground spices, and dehydrated seasoning preparations to reduce microbial load. Currently, the technology is not used widely on food commodities in Canada. So far, the main use of irradiation in Canada has been on spices.

The labelling of irradiated foods is regulated by *Food and Drug Regulations (2014) Section B.01.035* (CFDR 2014). Other related regulations are Canadian Food Inspection Agency (CFIA) *Reference Listing of Accepted Construction Materials, Packaging Materials and Non-Food Chemical, Food contact q1* (CFIA 2014).

Any imported irradiated food must also be approved for irradiation in Canada and must comply with all relevant regulations, including labelling requirements. Canadian government regulations require all foods processed by irradiation be labelled with an international symbol for irradiation and the words "treated by irradiation", "treated with radiation" or "irradiated"

4.2.5 Other nations and global use of food irradiation

Today over 50 countries approve at least one type of application of food irradiation, usually through their Ministry of Health or equivalent. Approximately 35 types of food have been approved across those countries and there are well over 100 facilities for food irradiation worldwide. Details can be obtained from IAEA databases (IAEA 2012a, b).

The Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture maintains the Irradiated Food Authorizations (IFA) database (IAEA 2012a, b). This is a compilation of information provided by countries on the types of food that can be irradiated for human consumption in the countries specified. The information includes country, food class and recommended dose limit. Table 40 lists the countries which allow irradiation of fresh fruit and vegetables for phytosanitary purposes. The list of commodities allowed to be irradiated for Australia is not complete and India, which also allows irradiation for phytosanitary purposes, is not listed, so the database needs updating.

Table 40. Countries listed in the FAO/IAEA Irradiated Food Authorizations (IFA) database that allow irradiation of fresh fruit and vegetables for phytosanitary purposes.

Country	Food Class	Food	Dose (kGy)
Australia	Fresh fruit & vegetables	breadfruit	0.15(min)-1.0(max)
		longan	
		litchi	
		mango	
		mangosteen	
Algeria	Fresh fruit & vegetables	any	10.0 (medium)
Bangladesh	Fresh fruit & vegetables	any	1.0 (max)
Belgium	Fresh fruit & vegetables	any	1.0 (max)
Brazil	Fresh fruit & vegetables	any	depends on purpose
Croatia	Fresh fruit & vegetables	any	3.0 (max)
Czech Republic	Fresh fruit & vegetables	any	1.0 (max)
Ghana	Fresh fruit & vegetables	any	1.0 (max)
New Zealand	Fresh fruit & vegetables	Carambola	0.15(min)-1.0(max)
		Custard apple	
		longan	
		mango	
		mangosteen	
		papaya	
		rambutan	
Mexico	Fresh fruit & vegetables	any	10.0 (max)
Paraguay	Fresh fruit & vegetables	any	1.0 (max)
Peru	Fresh fruit & vegetables	any	1.0 (max)
Russian Republic	Fresh fruit & vegetables	any	0.03 (max)
Phillipines	Fresh fruit & vegetables	any	1.0 (max)
Saudi Arabia	Fresh fruit & vegetables	any	depends on purpose
South Africa	Fresh fruit & vegetables	any	
Turkey	Fresh fruit & vegetables	any	1.0 (max)
Syria	Fresh fruit & vegetables	any	1.0 (max)
Ukraine	Fresh fruit & vegetables	any	0.03 (max)
USA	Fresh fruit & vegetables	any (imported)	1.0 (max)
Vietnam	Fresh fruit & vegetables	any	1.0 (max)
Zambia	Fresh fruit & vegetables	any	1.0 (max)

Other countries continue to irradiate significant volumes of food, including spices, vegetables, fruit, grains, potatoes and meats. The purposes for irradiation include prevention of seeds sprouting, extension of shelf-life, to delay ripening or physiological growth, disinfestation and for phytosanitary purposes.

In India, the Ministry for Agriculture, Directorate of Plant Protection, Quarantine & Storage standard *NSPM-21 Guidelines for Certification of Irradiation Treatment Facilities to meet the Phytosanitary Requirements* (NSPM 2006) provides technical guidance on the specific procedures for the application of ionizing radiation as a phytosanitary treatment for regulated pests. It also provides guidance for the approval or recognition of irradiation facilities for the performance of appropriate phytosanitary treatment to mitigate the pest risk associated with international trade in agricultural commodities. It references the appropriate ISPM standard guidelines such as *ISPM 18 Guidelines for the use of irradiation as a phytosanitary measure.*NSPM-21 provides, as an appendix, a list of agricultural products approved for irradiation; these include onion, potato, ginger, garlic and shallots for the purpose of inhibition of sprouting, mango, rice, semolina, wheat flour, raisins, figs, dries dates and pulses for the purpose of disinfestation, and spices for microbial decontamination.

Large differences exist between the regulatory requirements concerning food irradiation in the Asia Pacific and the nations have begun to harmonise food irradiation regulations based on conformance with Codex requirements.

Globally, China is currently the biggest user of irradiation (Kume 2009).; it has a over 100 irradiation facilities and a regulatory framework (Bustos-Griffin (2012). Other countries with approval of food irradiation include Bangladesh, India, Indonesia, Iran, Israel, Japan, Korea, Pakistan, Philippines, Russia, Syria, Thailand in Asia; Costa Rica, Cuba, Mexico in North America; the South American countries of Argentina, Brazil, Chile, Peru, and Uruguay; and South Africa and Algeria in Africa (IAEA). Japan allows irradiation of potatoes but to date has not provided clearance for any other commodity.

It is difficult to obtain an exact estimate of the amount of food being irradiated globally, partly due to commercial sensitivity. A minimum estimate of the amount of food irradiated world-wide in 2005 was 405,000 tonnes (Kume 2009). Herbs, spices and dried vegetables comprised the greatest amount treated (46%), followed by garlic and potatoes (22%), grain and fruit (22%), meat and seafood (8%). There has significant growth in the number of food irradiation plants operating in developing countries such as China, India and Vietnam.

Bustos-Griffin *et al*. 2012 in their study of the current status of trade in horticultural products irradiated for phytosanitary purposes found that only seven countries were involved in export/import of irradiated commodities. New Zealand and the USA are importing countries and Australia, India, Thailand, Vietnam and Mexico are exporting countries. They noted that Chile was considering importing irradiated fruit from Vietnam and Mexico was considering importing irradiated peaches from the USA from mid-2012. They noted that Mexico is the world’s largest exporter of irradiated fruit at 10,298 tons of mainly guava but also grapefruit, mango, sweet lime, and manzano pepper. Thailand was the next largest with 4080 tons of Longan, Mango, mangosteen and rambutan. Australia was next with 756 tons of mango (to NZ and Malaysia), longan and papaya. Vietnam exported 500 ton of irradiated dragonfruit and India 272 ton of irradiated mango.

4.3 Labelling

Packages containing treated blueberries and/ or raspberries will be unambiguously labelled in accordance with the labelling requirement as stated in FSANZ Code *Standard 1.5.3*. There is no application to vary the labelling requirement.

Standard 1.5.3 states that
(1) The label on the package of irradiated food must include a statement to the effect that the irradiated food has been treated with ionising radiation.

Examples include:

'TREATED WITH IONISING ELECTRONS'
‘TREATED WITH IONISING RADIATION’
‘IRRADIATED BLUEBERRIES/ RASPBERRIES

Right: The **Radura** logo, used to show a food has been treated with ionizing radiation (international version)

(2) The label on a package of food containing an irradiated food as an ingredient or component, must include a statement that the ingredient or component has been treated with ionising radiation, either as part of the declaration of that ingredient or component in an ingredient list or elsewhere on the label.

(3) Where an irradiated food, or a food containing an irradiated food as an ingredient or component, is not required to bear a label pursuant to clause 2 of *Standard 1.2.1*, there must be displayed on or in connection with the display of the food a statement that the food has been treated with ionising radiation, or that it contains an ingredient or component that has been treated with ionising radiation, as the case may be.

(4) Notwithstanding clause 3 of *Standard 1.2.1*, the label on a package of irradiated food which is sold other than for retail sale must include –

(a) a statement that the food has been irradiated; and
(b) the minimum and maximum dose of the irradiation; and
(c) the identity of the facility where the food was irradiated; and
(d) the date or dates of irradiation.

Usual carton marking and labelling is a requirement under the Trade Measurement Act 1989 (National Measurement Institute, 2007). Labelling is an important means of identifying fruit treated by irradiation. Labelling will ensure that consumers are not misinformed. Correct labelling can enhance consumer confidence so that they are able to make informed choices.

4.4 Irradiation facilities

The safety of operations of irradiation facilities is regulated separately. Extensive worker training, supervision and regulatory oversight are required.

The irradiation facility will be a licensed and prescribed radiation facility. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) regulates all Australian Government entities and the activities of non-Australian Government entities are regulated by the respective state and territory authorities.

The National Radiation Laboratory (NRL) under delegated authority from the Ministry of Health regulates all radiation facilities and radioactive substances and apparatus in New Zealand.

The radiation facilities are licensed in accordance with any relevant State, and Territory, and New Zealand law governing radiation control and operation. Currently in Australia, this responsibility is under the jurisdiction of the relevant state departments:

- ACT Health, Radiation Safety Section
- NSW Department of Environment and Climate Change
- NT Department of Health and Community Services (DHCS)
- Qld Department of Health
- SA Environment Protection Authority
- Tas Dept of Health and Human Services
- Vic Department of Human Services
- WA Radiological Council, Department of Health.

All matters including occupational health safety and welfare regulations are regulated by the relevant regulatory authorities, i.e. all national, state, territory and local government authorities.

Irradiation treatment facilities will need to abide by requirements of good manufacturing practice and act in accordance with the Codex Alimentarius *General Standard for Irradiated Foods* (2003) and its associated *Code of Practice for the Operation of Irradiation Facilities Used for the Treatment of Foods* (1983).

The *General Standard for Irradiated Foods CODEX Standard 106-1983, REV.1-2003* applies to foods processed by ionizing radiation that is used in conjunction with applicable hygienic codes, food standards and transportation codes. It does not apply to foods exposed to doses imparted by measuring instruments used for inspection purposes.

Any treatments for blueberries and/ or raspberries to be exported from Australia would be required to meet importing country requirements.

Gamma-radiation is a proven and sound technique for insect disinfestation in a range of tropical fruits (Moy, 1985; Moy and Wong, 2002; Moy, 2005).

There are currently three commercial irradiation facilities operating in Australia. All three are nuclear irradiation facilities, using gamma radiation from radioactive Cobalt-60. The facility at Narangba is the only facility currently accredited by AQIS for treatment of fruits (Table 41). (See: Application to amend the F*ood Standards Code, Standard 1.5.3 - Irradiation of Food* 35).

Table 41. Steritech sites in Australia

Company name	Address	Contact details
Steritech Pty Ltd	5 Widemere Road Wetherill Park NSW 2164	Tel: 02 9609 5566 Fax: 02 9604 4396
Steritech Pty Ltd Australian Quarantine Inspection Service (AQIS) Accredited for fresh fruits and vegetable	180-186 Potassium Street Narangba QLD 4504	Tel: 07 3293 1566 Fax: 07 3293 1544 http://www.steritech.com.au/
The Trustee for [redacted] Family Settlement T/A Steritech	160 South Gippsland Highway Dandenong VIC 3175	Tel: 03 9793 5566 Fax: 03 9701 3158

The Certificates of Registration for the Steritech facility are attached.

There is an AQIS approved treatment facility in New Zealand – Schering Plough Animal Health Ltd., 33 Whakatiki Street, Upper Hutt, New Zealand.

4.5 Dosimetry

Proper dosimetry systems will ensure compliance in accordance with the desired dose for each treatment that is required for approval by regulatory agencies and for developing quality control procedures. It is also important to ensure compliance of trade in irradiated food with national and international standards.

Jordan (2007) effectively demonstrated differentiation in absorbed dose variations and distributions in the irradiated prepackaged persimmons. Fruit were packed into telescopic board cartons, with external dimensions of 445 mm X 355 mm X 195 mm which typically holds 10–11 kg of fruit in three layers, placed on plastic inserts.

Dosimetry and dose mapping to establish treatment parameters conducted in the study (Jordan, 2007) provides an accurate estimation of maximum and minimum irradiation doses given during the fruit flies pupae sterilization process.

The applied doses took account of the commercial situation, where whole pallets of fruit would be treated, with the effective dose range related to the density of the product stack. A special stack was used for achieving a low maximum/minimum dose ratio.

CERTIFICATE OF ACCREDITATION

FOR AN

INTERSTATE CERTIFICATION ASSURANCE (ICA) ARRANGEMENT

Queensland Government

Department of Agriculture, Fisheries and Forestry

BUSINESS DETAILS

NAME OF ACCREDITED PERSON

Steritech Pty Ltd

TRADING NAME/S OF ACCREDITED PERSON

Steritech

POSTAL ADDRESS OF ACCREDITED PERSON

PO BOX 376
BURPENGARY QLD 4505

STREET ADDRESS OF ACCREDITED FACILITY

180-186 Potassium St
NARANGBA

INTERSTATE PRODUCE (IP) NUMBER

Q 1067

ICA ARRANGEMENT (CAA) NUMBER

Q 1067-01-ICA55

PERIOD OF ACCREDITATION

From 31 May 2014 to 31 May 2015

SCOPE OF ACCREDITATION

The business is accredited under the Plant Protection Act 1989 for an Interstate Certification Assurance arrangement for the following Operational Procedure. The scope of the accreditation covers the produce types, chemicals and other restrictions listed under Restrictions on Accreditation. Accreditation is subject to the conditions specified on the application form.

PROCEDURE CODE	OPERATIONAL PROCEDURE TITLE
ICA55	Irradiation Treatment

RESTRICTIONS ON ACCREDITATION

Produce	Chemical	Other Restrictions
Food approved by FSANZ for Irradiation	Chemical Not Specified	Not Applicable

AUTHORISATION [redacted] [redacted]

Official Stamp

Plate 1. Certificate of Accreditation for an Interstate Certification Assurance (ICA) Agreement

Australian Government

Department of Agriculture, Fisheries and Forestry
Australian Quarantine and Inspection Service

Certificate of Registration

of an Export Registered Establishment

Registration Number 2997

Name of Occupier

STERITECH PTY LTD

ACN 007 308 027

ABN 30 451 935 502

Location of Premises or Name of Ship and Home Port

180 - 186 POTASSIUM ST
NARANGBA QLD 4504

Alternate Trading Names

Registered Operations

Producing	:	fish products under appvd arrangement, fish products (irradiated), game meat (irradiated), meat products (irradiated)
Packing	:	plants products, prescribed grains
Inspecting	:	fresh fruit, fresh vegetables, plants products, prescribed grains
Load in	:	game meat commodity, meat commodity
Load out	:	game meat commodity, meat commodity
Holding	:	game meat commodity (frozen)
Storing	:	fish commodity (frozen)

Country Listing

Persons who manage and control

[redacted]

Registered subject to the following conditions (if any)

This certificate is issued in accordance the *Export Control Act 1982* and its subordinate Orders and Regulations

Date of Effect 11 Nov 2014

[redacted]

[redacted]

Secretary or Delegate

13 Nov 2014

Date

Department Seal

[redacted]

✻ denotes a suspended Registered Operation or Country Eligibility

EX23A - 11/03

Plate 2. Certificate of Registration of an Export Registered Establishment

Licence No.: 805582-P002855712

Queensland Government

Radiation Safety Act 1999

Possession Licence

Steritech Pty Ltd

ACN: 007 308 027

is, subject to any conditions mentioned in the Act or herein imposed by the Chief Executive, allowed to possess:

Radiation Source	For the radiation practice	Approved Plans RSPP	SP	TSP	Condition
Cs137 - Sealed radioactive substance	Calibration/reference	72099			-
Co60 - Sealed radioactive substance in a MDS Nordion Irradiator, including security enhanced sources	Irradiation of things for disinfestation, decontamination, sterilisation and related purposes	72099	375089		-

Approved Radiation Safety and Protection Plan (RSPP):

RSPP ID	RSPP Title	Date of Plan
72099	Radiation Safety and Protection Plan for Steritech Narangba	10/06/2003

Approved Security Plan (SP):

SP ID	SP Title	Nominated Person	Date of Plan
375089	Source Security Plan Steritech Pty Ltd	[redacted]	31/01/2012

[redacted]
Delegate of the Chief Executive

24/4/2015
Date

12 Apr 2016
Expiry Date

Page 1 of 1

Form 11 Version 3-Possession Licence
Document Id: 904419

Plate 3. Radiation Safety Act 1999 Possession Licence

Australian Government

Department of Health and Ageing
Therapeutic Goods Administration

Quality Management System Certificate
ISO 13485:2003

Issued to:

Steritech Pty Ltd

This is to certify that the Quality Management System for the manufacture of the devices described below conforms to the relevant provisions of ISO13485:2003.

TGA File Number:	2011/001850
Manufacturer Name:	Steritech Pty Ltd
Manufacturer Address:	180-186 Potassium St Narangba QLD 4504 AUSTRALIA
Scope of Certification:	Provision of contract gamma irradiation services, in accordance with ISO11135:2007 and ISO11137:2006.
Special Conditions:	Nil

Effective Date: 15 November 2012

Expiry Date: 10 May 2015

This Certificate is valid for the period indicated subject to periodic and satisfactory surveillance.

[redacted]

15 November 12

Inspection Group Manager
Office of Manufacturing Quality
Therapeutic Goods Administration
PO Box 100, Woden ACT 2606 Australia
Phone: +61 (0)2 6232 8790
Fax: +61 (0)2 6232 8426

MI-2011-LI-03848-3

This Certificate is the property of the Office of Manufacturing Quality, TGA, and must be returned upon demand.

Plate 4. Quality Management System Certificate – ISO 13485:2003

USDA

United States
Department of
Agriculture

Animal and
Plant Health
Inspection
Service

Plant Protection
and Quarantine

Certificate of Approval

For: **Irradiation**
Type of Facility

This treatment facility and associated equipment have been examined and found acceptable for use in the treatment of articles regulated under the provisions of quarantines and regulations administered by Plant Protection and Quarantine.

Steritech Pty Ltd
Name of Facility

[redacted]
Operator

180-186 Potassium Street, Narangba Queensland 4504 Australia
Location

Conditions of Approval:
1. The facility must operate under the conditions in the compliance agreement, operational work plan, and addenda.
2. Treatments must follow approved process configurations.
3. See compliance agreement for conditions under which recertification is required.

January 8, 2015
Date Approved

[redacted]

none
Expiration Date

Pest Exclusion Specialist
Title

PPQ Form 482 (Feb. 2011)

Plate 5. USDA Certificate of Approval for Irradiation

4.6 Records

Compliance by the approved radiation facility with accurate records as specified by the relevant radiation licensing authorities and relevant plant quarantine authorities, regulated at the national, state and local government authority, in establishing traceability will be fully documented. The treatment facility must keep all dosimetry and treatment records. A copy of the kind of records that are taken and kept by Steritech Pty Ltd is shown in Plate 6. Steritech routinely irradiate mango, papaya and litchi for export to New Zealand.

Records will be maintained to track the irradiated food product from receiving through shipping.

All records must identify the irradiated product and be retained in accordance with requirements by phytosanitary authorities /NPPOs and good manufacturing practices are employed. Irradiation treatment however, will not replace good agricultural production practices and the supply chain practices currently in place and employed by Australian (and New Zealand) growers.

Food irradiation may be incorporated as part of a Hazard Analysis and Critical Control Point (HACCP)–plan where applicable but a HACCP–plan is not required for the use of radiation processing of food processed for purposes other than for food safety. The provisions of this Code will provide guidance to the radiation processor to apply the HACCP (1997) system, as recommended in the *Recommended International Code of Practice General Principles of Food Hygiene (CAC/RCP 1-1969, Rev 4-2003, Amd. 1-999*), where applicable for food safety purposes to foods processed by ionizing radiation.

There will be compliance with record keeping requirements, as established in FSANZ *Standard 1.5.3*:

(1) Records must be kept at a facility where food is irradiated in relation to
- (a) the nature and quantity of the food treated
- (b) lot identification
- (c) the minimum durable life of the food treated
- (d) the process used
- (e) compliance with the process used
- (f) the minimum and maximum dose absorbed by the food
- (g) an indication whether or not the product has been irradiated previously and if so, details of such treatment
- (h) date of irradiation.

(2) The records required to be kept by subclause (1) must be kept for a period of time that exceeds the minimum durable life of the irradiated food by 1 year.

Facilities that are used for food irradiation must comply with plant and worker safety and training record requirements of the radiation regulatory authority and the occupational safety and health agency. The safety of operations of irradiation facilities is regulated by the respective state and territory authorities in Australia, and in New Zealand by the National Radiation Laboratory (NRL).

The relevant regulatory entities ensure that commercial irradiation facilities are properly designed and operate according to federal and state or territory regulations. The facilities have multiple fail–safe measures and have established extensive and well-documented safety procedures. This will ensure that the irradiation facility operates safely and without posing any significant radiation risk to personnel or the public.

Accurate records permit tracking and tracing in addition to meeting regulatory compliance. Retail distribution channels are able to respond to needs from their suppliers about the status of production, manufacturing and shipping. Since irradiation treatment does not need to kill the pest immediately to provide quarantine security, but may render pests sterile, live (but sterile) pests may accompany shipments. This would make inspection for the target pests redundant as confirmation of treatment application and efficacy (IPPC, 2006 - ISPM 18; Hallman, 2008). As a

Steritech

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Quality System
Quality Endorsed Company
ISO9001:2000
QEC11523
Standards Australia

Facility Records and Traceability

On receipt of each delivery check number of pallets and tray count matches documentation. Hold pallets in designated area to prevent cross contamination.
Product is then booked-in to our system and given an identification/lot number, with the following information:

- Identification of Grower.
- Identification of Exporter.
- Identification of Facility.
- Number of trays per pallet.
- Number of pallets.
- Must be noted "Irradiated for Export".
- Dose range; (eg. 250Gy – 1000Gy).
- Fruit variety.
- Date of Treatment.

A process indicator is placed on the outside of the pallet and all pallets must have top and bottom sheet and then shrink wrapped.
Ensure trays/ctns have mandatory labelling, as outlined by FSANZ.

Treatment Load Station Log Requires:

- The date of processing and the signature of the operator.
- The sequential pallet number (log-in number).
- The customer's name (usually abbreviated) and the product lot number.

This information identifies back to the Lot Number and Booking-in System.

Routine Dosimeter Placement and Records:

- Dosimeter to be placed in the routine position, on every pallet of each consignment. Results to be recorded on the Certificate of Irradiation - Customer Copy, Warehouse Copy and Office Copy.
- Results are also recorded in the Processing Log Book and on an Electronic Perspex file.

***Steritech maintains records for a minimum of seven years.**

The following attachments are for grower/exporter to fill in prior to processing (mandatory).
Attachments:

1.1 Gamma Irradiation Agreement.
1.2 Request for Irradiation of Tropical Fruit – Purchase Order.
1.3 Acknowledgement of Treatment and Loading Services.

Information Sheet

1.4 Pallet stacking instructions.

Steritech Pty Ltd A.C.N 007 308 027 www.steritech.com.au

Plate 6. Facility records and traceability documentation taken at Steritech Pty Ltd.

result, this places an added level of importance on the certification procedures for irradiation facilities, treatment monitoring, proper documentation and system integrity.

Irradiation of blueberries and raspberries is carried out together with good agricultural and good manufacturing practices that comply with specific quality assurances and record keeping requirements.

4.7 Packaging used for specified fruit

Irradiation for disinfestation takes place after packaging. Fruits treated with irradiation are shipped in the same cartons in which they are treated. The packaging is important in maintaining hygiene and be appropriate for irradiation.

Fresh persimmon fruit destined for irradiation treatment in the study by Jordan (2007) were packed into telescopic 3-layer fibre board cartons, with external dimensions 445 mm X 355 mm X 195 mm, that holds 10 to 11 kg of fruit in three layers. Fruit were placed on plastic inserts. The packaging used did not discolour, lose strength or become brittle when irradiated at the recommended doses. These types of packaging material are used, also, for marketing and shipping of blueberries and raspberries.

In a commercial simulation of the domestic supply chain incorporating irradiation treatment (Campbell, 2009) persimmon, packaged in either persimmon fruit or summerfruit trays and bulk fibre-board cartons were used. The cartons are insect-proof with no openings that will allow the entry of fruit flies and the cartons will be sealed with seals or polywrapped that will visually indicate if the cartons have been opened. Alternatively, each pallet of cartons must be completely enclosed in polyethylene, shrink-wrap, or another solid or netting covering that completely precludes access to the cartons by fruit flies before leaving the room.

The identity of treated lots is preserved by wrapping each pallet with polyethylene shrink wrap, net wrapping, or strapping so that each carton on the outside row is constrained, before leaving the irradiation facility.

Australia New Zealand Food Standards *Code 1.4.3* provides permission for articles and materials to be in contact with food in accordance with conditions set out in the Application to amend the *Food Standards Code, Standard 1.5.3 - Irradiation of Food* 46 Standard. However, the Code does not specify the details of materials and places this on the responsibility of the manufacturers.

Australia New Zealand Food Standards *Code 1.5.3 Irradiation of Food*, provides permission for the irradiation of a range of tropical fruits, including carambola, which has edible peel. The packages and packing materials should be of suitable quality and in an acceptable hygienic condition appropriate to this form of processing. Currently, mango, papaya and lychee that are treated with ionizing radiation are packed and irradiated in standard fibre board fruit and produce packages. Amcor, Carter Holt Harvey and Visy are the main manufacturers and suppliers of the fibre board fruit and produce packages in Australia. These fibre board packages are standard fruit boxes that are sized according to the dimensions of the particular fruit in question.

The corrugated or fibre board fruit boxes used for packing most fruit for market are made from components consisting of kraft and recycled papers, inks, adhesives and various other coatings. The components used by Amcor, Carter Holt Harvey and Visy are listed in the Tables 42, 43 and 44, respectively. Material details are present individually or in combination.

The materials used in manufacturing the fibre board packages and the plastic inserts are radiation-resistant at the disinfestation dose applied (150 Gy–1 kGy) and are currently approved for use in irradiating fruits and vegetables, under US FDA *21 CFR § 179.45 Packaging materials for use during the irradiation of prepackaged foods*, Subpart C (Table 45, see section below).

Corrugated fibre board packaging

Table 42. Amcor Fibre packaging components used in the manufacture of fruit and produce packaging.

Component	Description
Kraft Liners	Manufactured from a blend of pine and eucalypt fibre incorporating a neutral sulphite semi-chemical pulp and Rosin sizing. Liners may include functional coatings i.e. polyethylene terephthalate (PET) and medium density polyethylene (MDPE).
Recycled Liners and Medium	Manufactured from various sources of paper stock including that provided by kerbside collection systems. In addition alkenylsuccinic anhydride (ASA) sizing and starch based filling agents are used in manufacture.
Inks	Water based pigments incorporating amine binding agents.
Hot Melt Adhesive	Ethylene-vinyl acetate (EVA) or metallocene based
Cold Adhesive	EVA based
Corrugator Starch	Manufactured from wheat starch and incorporating the following additives - Borax, Sodium Hydroxide, and natural polymer water proofing agents
Wax	Blend of microcrystalline and paraffin waxes with hydrogenated palm oil also being present in the formulation.

Table 43. Materials used by Carter Holt Harvey Corrugated Australia in the manufacture of fruit and produce packages

Component	Description
Papers: Kraft paperboard NSSC paperboard (semi-chem) Recycled paperboard	
Adhesives	Non-hazardous emulsion polymer to laminate and glue papers together. Wheat starch-based adhesive to glue the papers into corrugated board. Hotmelt adhesive - comprising rosin and alum, for assembling boxes.
Inks	Non-hazardous Acrylic Emulsion w/non-hazardous waterbased pigment dispersions.

Table 44. The components used in the manufacture of the fruit boxes by Visy from corrugated board grades produced from recycled and kraft papers

VISY BOARD
INNOVATIVE PACKAGING SOLUTIONS.

Technical Data Sheet – Cardboard Products
Issue Date: 2nd May, 2008.
Issued By: [redacted] Technical Supervisor

To Whom it May Concern:

Visy Board Queensland manufactures cardboard products comprising of:

Paper:
- Recycled Papers manufactured in conformance with FDA.176.260
  - No hazardous substances are used within the manufacturing process
- Kraft Papers.
  - Raw materials sourced from sustainable Australian sources

Starch:
- Tapioca Starch

Inks:
- Water based Inks

Adhesive:
- PVA adhesive

Suitability for Food Use:
Visy Cardboard Products are suitable for food use.
Microbial & analytical testing, including heavy metals testing meeting the requirement of EC Packaging & Packaging Waste legislation is carried out routinely.

Contact Information
[redacted]

Certification:
CODEX HACCP, GMP, ISO9001:2000.
SAI Global.
License Number: HAC20003. Certified: 25/8/1993.

Plastic inserts

The fruit skin is the contact area with the irradiation beam and very little of the fruit surface is in contact with the packaging. The plastic inserts are made from the most common polymers used in food packaging materials that can be irradiated up to 10 kGy.

The two PVC films used in the manufacture of the plastic inserts for food contact use were tested by Consulchem Australia and they comply with Australian Standard AS2070/2, 1992 Plastics Materials for Food Contact Use Part 2, Polyvinyl chloride (PVC) compound. A copy of the laboratory report shown in Plate 7.

The test report of the PVC plastic film used in manufacturing the plastic insert is provided in Plate 8.The laboratory certifying the test is SGS-CSTC Standards Technical Services Co., Ltd.

The material complies with the overall migration requirements stated in European Commission Directive 2007/19/EC (2007; 2002/72/EC (Directive 2002/72/EC has been last amended by Directive 2008/39/EC)) relating to plastic materials that come into contact with foodstuffs.

The packaging used will provide an effective barrier to re-contamination and reinfestation. Packaging must also meet the requirements of the importing region or country. Packaging will take into consideration the *Codex General Standard for Irradiated Foods (CODEX-STAN 106-1983, Rev. 1-2003)* and the *Recommended International Code of Practice for Radiation Processing of Food (CAC/RCP 19-1979, Rev. 2-2003)*.

06 Feb 09 09:32a John Stevenson [redacted] p.
From:NETWORK MARKETING [redacted] 04/04/2006 11:10 #065 P.001/003

Approved Analysts (Food Act)
A.B.N. 61 005 377 613

CONSULCHEM PTY. LTD.

Analytical & Consultant Chemists & Microbiologists
A.C.N. 005 377 613

Reference: C3995/1-2 NT:yh
20th October, 2004

CGPC Group,
Suite 4, Level 3,
694 Burke Road,
CAMBERWELL VIC. 3124

[redacted]

[redacted]

LABORATORY REPORT

Sample:
Two PVC samples, identified below, as received on the 27th July, 2004 for food grade testing.

Method of Analysis:
The sample was tested as per the Australian Standard AS2070.2, 1992 – Plastics Materials for Food Contact Use, Part 2. Polyvinyl chloride (PVC) compound.

Results:
Expressed in mg/Kg.

Test parameter	Hi Impact – Black	Silicone – Clear	AS specifications
Vinyl chloride:	<2	<2	5
Cadmium:	<50	<50	100
Mercury:	<0.1	<0.1	50
Barium:	<50	<50	100
Selenium:	<50	<50	100
Chromium:	<50	<50	1,000
Lead:	<10	<10	100
Antimony:	<10	<10	500
Arsenic:	<2	<2	100

CONSULCHEM PTY LTD

[redacted]

Chemist
Title

ISO 17025 NATA

NRA

Unit 1, 7-11 Rocco Drive, Scoresby, Vic. 3179, Australia. Tel: (03) 9764 8881 Fax: (03) 9764 8892
E-mail: conchem@consulchem.com.au Web Page: www.consulchem.com.au

'04

Plate 7. Test report for two PVC films used in the manufacture of plastic liners for fruit

06 Feb 09 09:32a
From:network marketing [redacted] [redacted] 02/10/2008 17:00 #769 P.002/003 p.8

19/09 2008 11:44 FAX 001

SGS

Test Report No.: GLHGR080606068CM Date: JULY 10, 2008 Page 1 of 2

HAN RIGID PLASTICS CORP. (GUANGZHOU)
1, YUN PU 1ST ROAD, YUN PU INDUSTRIAL ZONE, GUANGZHOU CHINA

The following sample(s) was/were submitted and identified on behalf of the applicant as :

Product Description	: PVC PLASTICS FILM
SGS Ref No.	: GZ0806110265/CHEM
Style/ Item No.	: RIGID PVC PLASTICS FILM
Test Performed	: Selected test(s) as requested by applicant
Sample Receiving Date	: JUNE 20, 2008
Testing Period	: JUNE 20, 2008 TO JULY 09, 2008
Test Results	: Please refer to the next page

Test Requested : To determine the Overall Migration in accordance with European Commission Directive 2007/19/EC (2002/72/EC amendment) relating to plastic materials and articles intended to come into contact with foodstuffs.

Test Method : With reference to EN 1186-1:2002 for selection of conditions and test methods; EN 1186-3:2002 aqueous food simulants by total immersion method; EN 1186-2:2002 olive oil by total immersion method.

Conclusion : When tested as specified, the submitted sample(s) comply with the overall migration requirements stated in European Commission Directive 2007/19/EC (2002/72/EC amendment) relating to plastic materials and articles intended to come into contact with foodstuffs.

Signed for and on behalf of
SGS-CSTC Ltd.

[redacted]
Engineer

242307

[redacted] ... 510663 ... (86-20) 82155555 | (86-20) 82075191 www.cn.sgs.com
中国·广州·经济技术开发区科学城科珠路198号 邮编: 510663 ... sgs.china@sgs.com
Member of the SGS Group (SGS SA)

Plate 8. SGS Test report of PVC plastic film intended for use in plastic materials and articles intended to come into contact with foodstuffs

General packaging

Most modern packaging materials have been shown to be resistant to irradiation changes (Kilcast, 1990). Cartons are constructed of material that prevents the entry of fruit flies and prevents oviposition by fruit flies into the articles in the carton. The materials used for the packaging of blueberries and raspberries are general packaging materials that are resistant to ionising radiation with respect to their physical properties, and not altered in a fashion that causes a chemical change in the packaging to be added indirectly to the food.

Both the USA and the EU have complex regulations to control migration from food packaging materials. The selection and control of maximum migration levels of monomers in plastics and other materials used in the manufacture of food packaging in Australia and New Zealand has been based on what is permitted in some overseas legislation.

The irradiation dose requested for insect disinfestation in this application is not expected to affect packaging integrity. The packaging materials are consistent with the provisions listed in *21 Code of Federal Regulations (CFR) 179.45* (US FDA) and, do not present any concerns for safety of irradiated blueberries and raspberries.

Safe packaging materials is addressed in *21 (CFR) 179.21* and specifically allows the use of wax-coated paperboard, which are common carton type for packaging fruit and vegetables. Most of the packaging materials will withstand higher doses, up to 10 kGy of radiation.

These materials are radiation-resistant at the disinfestation dose applied for blueberries and raspberries.

Table 45. Packaging materials and maximum dose levels authorized under 21 CFR 179

21 CFR Reference	Packaging materials (Maximum dose in kGy)
Section 179.45 (b)	• nitrocellulose-coated cellophane 10 • glassine paper 10 • wax-coated paperboard 10 • polyolefin film[1] 10 • Kraft paper 0.5 • polyethylene terephthalate film (basic polymer) 10 • polystyrene film[1] 10 • rubber hydrochloride[1] 10 • vinylidene chloride-vinyl chloride copolymer film 10 • nylon 11 (polyamide-11) 10
Section 179.45 (c)	• ethylene-vinyl acetate copolymer 30
Section 179.45 (d)	• vegetable parchment[1] 60 • polyethylene film (basic polymer) [2] 60 • polyethylene terephthalate film[2] 60 • nylon 6[2] (polyamide-6) 60 • vinyl chloride - vinyl acetate copolymer film[2] 60

Source website: http://www.fda.gov/Food/IngredientsPackagingLabeling/IrradiatedFoodPackaging/ucm074764.htm (Accessed June 2014);
1 containing various adjuvant substances and coatings
2 with or without added substances

Some of the plastics described above may be amended with various adjuvants and other preservatives. The Code also addresses the adjuvants substances and coatings. Various commercial adhesives and inks used for labelling are commonly used inks that are safe and generally resistant to irradiation. The inks contain pigments and dyes that are stable under visible and ultra-violet light. Adhesives are made from the polymers and plastics that are resistant to irradiation.

ASTM Standard Guide F1640-09 Standard Guide for Packaging Materials for Foods to Be Irradiated (2003), written by the American Society for Testing and Materials (ASTM) Subcommittee E10.06 on Food Irradiation Processing and Packaging, addresses issues in the selection and use of packaging materials for food and agricultural products to be irradiated.

New Zealand MAF Biosecurity *Standard: 152.02 Importation and Clearance of Fresh Fruit and Vegetables into New Zealand* (2008) approves the importation of mango (2004), papaya (2006), and litchi (2008) from Australia using irradiation as a phytosanitary treatment in accordance with the NZ MAF/AQIS Bilateral Quarantine Arrangement. Standard fruit and produce packages used for packing fresh blueberries and raspberries fruits are similar to those currently used for packing mango, papaya and litchi destined for irradiation, albeit the specific dimensions to suit the particular fruit type vary with fruit size.

Standard 152.02 also states that fruit fly host material shall be shipped in pest-proof packages. All packages shall be sealed with a destructible sticker/label identifying the authority in the exporting country and directly traceable to the phytosanitary certificate. In Canada, the safety of materials used for the packaging of foods that are irradiated is controlled under Division 23 of Part B of the *Food and Drug Regulations* (Canada Food and Drugs Act, 2009). The Canadian Food Inspection Agency (CFIA) *Reference Listing of Accepted Construction Materials, Packaging Materials and Non-Food Chemical* (updated 2007), provides a listing (database) of materials that are suitable for packaging food to be irradiated.

4.8 Methods for verification for irradiated foods

There is not yet one simple and cost effective method developed for detecting whether food has been irradiated and particularly reflecting the very small, often undetectable chemical changes that occur.

Post irradiation analytical methods exist but they are generally not practical or reliable particularly for rapid verification at the low phytosanitary doses (<1kGy) requested in this application.

Detection methods (European Standards, 2009 (see Table 39); Codex Alimetarius Commission, 2003) are listed in Table 13. Detection tests however, can assist to enforce labelling requirements for identifying the irradiated fruit.

The currently available techniques include electron spin resonance (ESR), thermoluminescence, lipid-derived volatiles, viscometry, electrical impedance and DNAComet assay. These purpose-detection methods are limited either to foods containing bone, fat-containing foods or light emission. The techniques will require further development to have general applicability.

Detection of irradiated food containing cellulose by ESR spectroscopy (*EN 1787:2000*) may have practical application in fruit and vegetables; however, the technique is limited to about three weeks after treatment.

Currently, countries permitting the use of irradiation for phytosanitary disinfestation, e.g. USA, Australia, New Zealand, South Africa and India have selected record keeping for its management of irradiation as a phytosanitary treatment. Strict adherence to the guidelines by all stakeholders will serve to uphold the current position within the principles on good manufacturing practice, good irradiation practice and food safety.

Accurate record keeping provides the most reliable and practical method of tracking fruits that have been treated, to date.

PART 5 – OTHER IMPLICATIONS

5.1 Cost considerations

In both domestic and international agricultural markets, expanding the use of irradiation can help to reduce the need for methyl bromide for postharvest control of insect pests. Unlike other fruit and vegetables, blueberry and raspberry have been unaffected by the restriction or cancellation of the use of dimethoate and fenthion for phytosanitary purposes, as these chemicals were not used on these fruits as a postharvest phytosanitary treatment. However methyl bromide fumigation continues to be used in Australia for postharvest phytosanitary purposes.

Methyl bromide is an ozone depleting substance and as such its use is controlled under the Montreal Protocol. However, quarantine and pre-shipment (QPS) use of methyl bromide (for pest control) is not controlled under the Montreal Protocol. Though its use is allowed, methyl bromide does have a detrimental effect on blueberry and raspberry fruit quality, shortening shelf-life, and so an alternative non-chemical phytosanitary treatment is required. The phytosanitary treatments evaluated and adopted by the Commission on Phytosanitary Measures (CPM) of the IPPC primarily for the purposes of international trade are set out in *ISPM 28 Phytosanitary treatments for regulated pests (2007)*. The treatment adopted for both *Bactrocera tryoni* (Qff) and *Ceratitis capitata* (Medfly), the two pests of economic significance in relation to Australian blueberry and raspberry, is irradiation with a minimum absorbed dose of 100Gy. So this is the international standard postharvest phytosanitary treatment for these pests and the future export of Qff and Medfly hosts, such as raspberry and blueberry, to fruit fly sensitive markets may depend on the fruit having been irradiated pre-export. The future potential economic cost to these industries if this treatment is not available is difficult to predict but could be considerable.

In 2008 the IPPC Commission on Phytosanitary Measures (CPM) issued a Recommendation providing guidance to National Plant Protection Organisations (NPPOs) on the replacement of or reduction in the use of methyl bromide as a phytosanitary measure in order to reduce emissions of methyl bromide (Recommendation CPM-3/2008 – Replacement or reduction of the use of methyl bromide as a phytosanitary measure. https://www.ippc.int/core-activities/governance/cpm-recommendations/replacement-or-reduction-of-the-use-of-methyl-bromide-as-a-phytosanitary-measure). As well as promoting appropriate measures to control regulated plant pests, contracting parties to the IPPC must take into account "internationally approved principles governing the protection of plant, human and animal health and the environment. Following from this, contracting parties are encouraged to promote best fumigation practices, recapture technology and development and use of alternatives to methyl bromide in phytosanitary measures where this is technically and economically feasible. By reducing methyl bromide emissions environmental concerns relating to the protection of the ozone layer are being accounted for. For fresh fruit and vegetables the potential replacement phytosanitary treatments listed are "cold treatment, high-temperature forced air, hot water, irradiation, quick freeze, vapour heat treatment, chemical dip, phosphine, combination of treatments". Cold treatment is possible for blueberry but the time required is inhibitory. For both raspberry and blueberry only irradiation is a potential alternative, so this should be promoted and supported by the Australian authorities.

The structure and production for the raspberry and blueberry industries were discussed previously in Section 2.5 and costs and benefits discussed in Section 2.4. They are both growing industries with high value fruits. Their worth is substantial and they are important to the economies of the regional communities that they support. At present raspberries are not being exported but blueberries are (see Section 2.3.2). In the past a large proportion of the Australian blueberry production was exported; now, due to factors including market concerns relating to the regulated pests Qff and Medfly, exports have been disrupted and less than 10% is currently exported.

Phytosanitary protocols currently apply to the interstate movement of fresh produce that are hosts of fruit fly to fruit fly sensitive areas in Australia (see Section 2.3.1). Approval for irradiation could alleviate the market access situation as it is an efficacious, selective, less disruptive and economic alternative to methyl bromide fumigation. Treatment time is considerably less than alternative cold treatment which can only be considered for blueberry.

Asia remains the biggest market for Australian fruit and vegetable exports, the main vegetable products primarily exported to Japan, Malaysia and United Arab Emirates, and fresh fruit lines included apples, grapes and oranges, mainly to USA, Hong Kong and Malaysia. Irradiated mangos, papaya, litchi, tomato and capsicum are exported to New Zealand. China and India are recently opened markets for citrus, apple and mangoes. While the key markets are in Hong Kong, Japan, Malaysia and Singapore, there are opportunities in New Zealand, the USA and the European Union. Recent free-trade, bilateral and regional agreements such as those with South Korea, Malaysia, Japan, China, Singapore, US, Thailand, the Gulf States and India could open up export markets for Australian fresh produce if phytosanitary access can be negotiated. Australian fresh blueberries are currently exported mainly to Hong Kong, Singapore and China with smaller volumes exported to England, Russia, Malaysia, Indonesia and Thailand.

The presence of various pests and diseases in Australia means potential Asian markets would require phytosanitary measures to be undertaken before market access is granted. The major export markets in Asia currently do not require quarantine treatment for our fresh produce however the status is expected to change. For example, in 2009, Malaysia advised Biosecurity Australia that from 1 March 2009 all fresh mango fruit must be irradiated prior to export (AQIS, 2009). The relevant authorities in our trading partners are reviewing the quarantine status of fruit fly products and it is expected that phytosanitary requirements and measures will be introduced. Given that irradiation is the phytosanitary treatment adopted by the IPPC for both Bactrocera tryoni (Qff) and Ceratitis capitata (Medfly) (the two pests of economic significance in relation to Australian blueberry and raspberry), it could be expected that irradiation will be required in the future by our trading partners.

The potential loss of access to export markets will be costly to the blueberry industry which is growing rapidly and it is often challenging and complex to re-enter, as these are very competitive markets. Though raspberries are not presently exported, mainly due to the highly perishable nature of the fruit, their export should not be limited by a lack of an appropriate phytosanitary treatment.

Irradiation shows great potential for increasing both market access and profitability for Australian and New Zealand growers and industry cannot afford to depend on markets with low phytosanitary requirements as these markets are generally volume sensitive and lower returning markets.

Any additional processing will add cost to the food; however, it will also add value to the treated product. Benefits include fruit quality, quantity, availability, convenience and quarantine safety. In general, the cost of irradiation is expected to be competitive compared to other treatments that achieve a phytosanitary purpose. In the US, the cost of irradiation to meet quarantine requirements is about 10-20% of that of vapour heat treatment (Loaharanu, 2003). The current cost of irradiation of fresh produce in Australia at the Steritech Narangba facility ranges from $90 - $120 per tonne/pallet and is dependent on the minimum dose required e.g. 150Gy – 400Gy. This equates to $0.01 - $0.015 per 125 g punnet which is a minimal cost increase.

Although methyl bromide fumigation may be less expensive than irradiation, the cost of irradiation may be offset by reduced damage to the fruit and an extended shelf life. Also, irradiation can be carried out on prepackaged fruit, so this may reduce handling costs and further reduce damage to the fruit. There will potentially be savings due to less waste resulting from damage due to handling. The percentage contribution of irradiation treatment is relatively insignificant when compared to the value of the fruit. Raspberry and blueberry are high value fruits; blueberries have a market value of about $30/kg and raspberry about $50/kg. Other cost related to the marketing of fruit, for example, harvesting, packaging, storage and transportation costs, further reduce the percentage contribution of irradiation treatments. The costs associated with any changes required to packaging, transport and warehousing are difficult to assess.

Since irradiation gives the added economic benefits of prolonged shelf life (for some commodities), decreased waste and increased market potential of the food, these factors need to be considered in any cost-benefit analysis.

5.2 Profit implications

Approval for the use of irradiation as a phytosanitary measure for raspberry and blueberry will potentially maintain access for these industries for both domestic and export markets where fruit fly is a pest of concern. This should ensure continued access, and in the longer term, could lead to increase in production with increasing demand and improved market outlook.

At present raspberry and blueberry production in Australia is insignificant compared to other world production areas (Tables 46 and 47) for these fruits. In 2012, by volume of production, Australia was ranked 42 with 750 tonnes, with the Russia ranked 1 (133,000 tonnes), Poland ranked 2 (127,055 tonnes) and USA ranked 3 (100,775 tonnes) (FAO Stat Agricultural Database (FAO 2014)). The estimate of Australian production volume used in this ranking is lower than other estimates available such as for 2012/13, 2000 tonnes (HAL, private communication July 2014) and 1448 tonnes (freshlogic 2014a, freshlogic 2014b). This production volume is only 1-2% of those of each of the top 3 ranked countries.

For blueberry, by volume, in 2012, the USA was ranked 1 (214,708 tonnes), Canada was ranked 2 (120,929 tonnes) and Poland was ranked 3 (11251 tonnes) (FAO Stat Agricultural Database (FAO 2014)). Australia was unlisted in these rankings though New Zealand was ranked 10 with production of 2526 tonnes which would be less than Australia's volume of production; in 2011/12 Australia's production was estimated at 3780 tonnes in data collected by NSW DPI (Table 9, P. Wilk, personal communication). Another estimate for Australian blueberry production for 2012 is 5916 tonnes (freshlogic 2014a) which is similar to that of the Netherlands ranked number 7, but still 5% of the production of Canada and 3% of the production of the USA.

The countries in the northern hemisphere and Asia could provide significant market opportunities and improve profit for the Australian and New Zealand industry, particularly during the counter-season. The export of raspberries over long distances may be restricted by the perishable nature of the fruit but this is not so for blueberries being more resilient and having a longer shelf-life. At present New Zealand has limited production seasons for these fruit and Australian fruit could supplement their production to provide year-round supply of fresh blueberries and raspberries.

Approval of irradiation as an appropriate phytosanitary treatment can potentially assist in accessing additional and previously challenging markets. This, along with continued and increasing domestic markets, will allow increased production volume and business ensuring that growers and industry service providers gain economies of size and scale and hence, increased profits.

Table 46. World Raspberry production estimates for 2012 - FAOSTAT

Rank	Area	Production (Int $1000)	Production (MT)
1	Russian Federation	257354	133000
2	Poland	245850	127055
3	United States of America	194999	100775
4	Serbia	185910	96078
5	Ukraine	58630	30300
6	Mexico	32912	17009
7	United Kingdom	29218	15100
8	Spain	25348	13100
9	Azerbaijan	22445	11600
10	Canada	21033	10870
11	Bosnia and Herzegovina	13575	7016
12	Germany	10147	5244
13	Bulgaria	9384	4850
14	France	6186	3197
15	Kyrgyzstan	5030	2600
16	Portugal	4837	2500
17	Norway	4376	2262
18	Switzerland	4371	2259
19	Lithuania	4063	2100
20	Hungary	3893	2012

Source: FAOSTAT | © FAO Statistics Division 2013 | 13 June 2013 http://faostat3.fao.org/download/Q/QC/E
may include official, semi-official or estimated data

Table 47. World Blueberry production estimates for 2012 FAOSTAT

Rank	Area	Production (Int $1000)	Production (MT)
1	United States of America	543530	214708
2	Canada	306130	120929
3	Poland	28481	11251
4	Germany	22385	8843
5	France	20836	8231
6	Mexico	18203	7191
7	Netherlands	15188	6000
8	Spain	12657	5000
9	Sweden	7594	3000
10	New Zealand	6394	2526
11	Lithuania	6328	2500
11	Romania	6328	2500
13	Russian Federation	6075	2400
14	Italy	3037	1200
14	Ukraine	3037	1200
16	Uzbekistan	2278	900
17	Switzerland	837	331
18	Portugal	645	255
19	Bulgaria	253	100
20	Latvia	217	86

Source: FAOSTAT | © FAO Statistics Division 2013 | 13 June 2013 http://faostat3.fao.org/download/Q/QC/E
may include official, semi-official or estimated data

5.3 Market share implications

The industry structure and production and consumption of raspberry and blueberry can be found in Section 2.5. Discussion of the export trade in these fruits can be found in Section 2.3.2.

The raspberry and blueberry industries in Australia are focussed on the domestic market, though this has not always been the case for the blueberry industry. The majority of raspberries (81%) and blueberries (90%) are sold fresh on the domestic market (freshlogic 2014b, freshlogic 2014a). No fresh raspberries are exported or imported due to the highly perishable nature of the fruit and biosecurity concerns. Imports of processed and frozen raspberry product are considerable; in 2012/13, 5105 tonnes of processed raspberries were imported, mainly from Chile (53%), China (20%) and Serbia (10%) (freshlogic 2014b).

Though raspberries are not exported at present, the future possibility of export to nearby nations such as New Zealand should not be ruled out by the lack of an internationally recognised method of phytosanitary postharvest treatment for regulated pests such as Qff and Medfly; low dose irradiation is the treatment of choice (IPPC 2007). New Zealand produces raspberry but in much smaller volumes than Australia; 2011 raspberry production volumes were 797 tonnes for Australia and 141 tonnes for New Zealand (FAO 2014b). In 1988 Australia, which was New Zealand's biggest market for raspberry, stopped accepting New Zealand's fresh raspberries due to the risk of raspberry bud moth (*Heterocrossa rubaphaga*) which is endemic to New Zealand. The New Zealand industry subsequently went into decline and does not produce enough to satisfy the domestic market and NZ has imported raspberries, mainly from Chile, since1995 (Scarrow 2012). New Zealand could be an export market for Australian fresh raspberries if an acceptable phytosanitary treatment was available.

HAL statistics for raspberry for 2011/12 estimate that NSW produced 32% of national total production, Victoria 36%, Tasmania 18.5% and Queensland 13.5% (HAL 2012). With the exception of Tasmania and Victorian Yarra Valley PFPP, all raspberry production is in fruit fly affected areas. Tasmania and the Yarra Valley do not produce enough or produce year-round to satisfy the Australian market. There has been an expansion of the raspberry growing area into northern NSW and southern Queensland driven by the need to extend the seasonal availability of raspberry. Irradiation as a phytosanitary measure will provide producers in fruit fly affected areas with an alternate treatment if current treatments are deemed insufficient and hence they would not lose market access and market share. As seen by the NZ example, lack of market access can decimate the industry and imports must be relied upon. Alternative fruits, such as strawberries, may also replace them in the diet.

The current blueberry export trade is variably estimated at between 1% and 10% of production, having fallen from about 30% of production in 2010/2011 (HAL 2012). Reasons for this drop include an increase in the Australian dollar ($A) and phytosanitary concerns relating to Qff and Medfly particularly in the Japanese market. Irradiation as a phytosanitary measure will provide growers with an alternative treatment which, as set out in *ISPM 28 Phytosanitary treatments for regulated pests (2007)*, has been adopted for phytosanitary purposes against both Qff and Medfly for the purpose of international trade. This would facilitate gaining access to fruit fly sensitive markets and increase the market share. New Zealand produces blueberries on a seasonal basis and mainly for frozen and processed product. Access to the New Zealand market for Australian fresh blueberries would allow for year-round availability of fresh fruit and this may stimulate the fresh blueberry market for New Zealand growers as market penetration increases.

Australia does import fresh blueberries from New Zealand – 817 tonnes in 2012 (freshlogic 2014a) - but this is only during the New Zealand production season and peaks January to March. These imports supplement the Australian grown supply, mainly from Tasmania, during the peak consumption period. These imports have grown on the back of growing consumption and should not be affected by changes to available phytosanitary treatments.

At present the blueberry industry in Australia is mainly centred around Coffs Harbour on the NSW Mid-North Coast with 88% of the national GVP coming from NSW (83% for the Mid-North Coast region) in 2010/11(Tables 10 and 11, ABS 2012). This is in the Qff endemic zone. Victoria, which accounted for 8% of the GVP in 2010/11, is no longer a fruit fly free area. Tasmania, a fruit fly free zone, accounted for only 3% of the GVP and Queensland, SA and WA produced only small or negligible volumes of blueberry. Blueberries are not grown in the Northern Territory. More recently there has been expansion of the blueberry growing regions into southern and northern Queensland to further extend the seasonal availability of this fruit; once again this is in the Qff endemic zone. Irradiation as a phytosanitary measure will provide growers in the endemic Qff zone with an alternative phytosanitary treatment in the event that current treatments are restricted. This will allow the industry to maintain their market share against competitor and substitute products. Tasmanian production is seasonal and at present not large enough to meet the needs of the Australian market.

HAL statistics indicate that nationally the household penetration for raspberries in 2010/11 was only 7.04% and 29.77% for blueberries (HAL, 2012). So for both fruit, and particularly for raspberries, there is considerable scope for increasing the domestic market size consumption with increased household penetration. Year-round availability of these berries has and will further increase the household penetration and per capita consumption by increasing the market share of these berries against alternative fruits. This growth can only be assured if market access through availability of appropriate phytosanitary measures is ensured. Irradiation would provide this assurance.

Irradiation as a phytosanitary measure will provide growers with an alternative phytosanitary treatment in the event that current treatments are restricted. This will allow the industry to maintain their market share against competitor and substitute products.

The biggest economic challenge lies in predicting market demand for irradiated fresh produce. At present 80-90% of Australian raspberry and blueberry production is sold domestically, and the quantities in relation to total domestic supply are increasing. Furthermore, not all produce destined for the domestic markets will need to be irradiated, and the volumes will also depend on the production areas and destinations which may or may not require a phytosanitary treatment. In addition, imports of fresh produce and substitute fresh produce also add to the equation.

While there is potential to increase the domestic market, the volumes traded represent only a small percentage in comparison to other fruit substitute commodities and competition for market share from other well organised fruit industries within the country and overseas. Existing DAFF quarantine requirements permits the importation of fresh blueberries (*Vaccinium angustifolium* and *Vaccinium corymbosum*) from New Zealand only; fresh raspberries are prohibited entry into Australia due to insufficient information being available on its risk status (DAFF ICON 2014). Specific detail and import conditions for all fruit can be accessed from the Australian Government Department of Agriculture, Fisheries and Forestry (DAFF) ICON Database portal http://apps.daff.gov.au/icon32/asp/ex_querycontent.asp.

5.4 Price implications

It is anticipated that approval for the use of irradiation as a phytosanitary measure will lead to increased competition in the market place. The competition will be with untreated fruit and with other varieties of fruits. Some consumers may prefer irradiated fruit to chemically treated fruit with resulting residue.

While the price of irradiated produce cannot be predicted it seems likely that irradiated produce may cost a little more than non-irradiated fruit, but how much more is unclear. Prices could also decrease. Decreased waste, extended shelf-life and increased economies of size and scale as access to markets increase could all lead to lower prices.

However, pricing of any fresh fruit is subject to the variables of seasonal supply and demand conditions. Prices in all major Australian cities can vary, reflecting the variability in quality and supply. At present raspberry and blueberry peak in wholesale price in July and are lowest in January. For raspberry peak growing seasons are summer and autumn and during this time volumes are higher and prices lower. Raspberries from northern NSW and south-western Queensland provide supplies in winter and spring and are higher priced (freshlogic 2014b). However, with greater production now coming from NSW and Queensland, prices during winter and spring are decreasing. For blueberries, peak growing season for the Mid-North coast region of NSW is July to February and prices are high at the beginning of the season and decrease until January. Between December and June blueberries are supplied by growers in Tasmania, southern NSW, Victoria and small volumes from South Australia and Western Australia. During this period imported fresh New Zealand blueberries supplement supplies.

Blueberry exports could expect strong price competition from New Zealand exports targeting the same Southeast Asian countries. For markets in Europe and North America there is increasing competition from countries like Chile that have lower labour costs in a very labour intensive industry. China, Japan and New Zealand also have their own blueberry industry against which to compete. In many cases bilateral trade agreements, a number of which have recently been signed between Australia and other countries, may assist in opening up markets if phytosanitary access can be negotiated. Under these agreements tariffs are removed or decreased on commodities and they become more price competitive. However, countries like Chile have their own bilateral trade agreements which may result in different tariff environments, and phytosanitary requirements for their produce may be different to that for Australian produce. So, the price competitiveness of Australian blueberry and raspberry (if exported in future) in off-shore markets is dependent on a number of factors unrelated to whether they are irradiated or not. Permission to export irradiated fruit to other countries is the first step that needs to be overcome and this is also dependent on the legislative and regulatory environment of these countries as well as Australia.

A major factor affecting market prices is fruit quality. Australian blueberries and raspberries are high quality and, as shown in Part 3 of this document, irradiation does not affect fruit quality with storage under commercial conditions. Methyl bromide fumigation, which irradiation would replace as a phytosanitary treatment has deleterious effects on fruit quality and decreases shelf-life.

5.5 Trade implications

Food import and exports are important to the health and economies of nations and people. However, pests, diseases and food safety issues continually threaten and inhibit trade. Irradiation is a technology that can assist to improve trade by overcoming trade barriers.

In 2011/12, Australia had an overall “trade deficit” for fresh and processed fruit, nuts and vegetables of $863 million because of high imports in the processed, frozen and other sectors (Table 48).

Table 48. Value (millions of dollars) of imports and exports of horticultural commodities

Imports	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
Fruit & Nuts	846	928	991	943	1022	1194
Vegetables	621	731	842	744	786	908
Total	**1467**	**1659**	**1833**	**1687**	**1808**	**2102**
Exports	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
Fruit & Nuts	774	760	898	778	651	734
Vegetables	410	384	397	372	460	505
Total	**1184**	**1144**	**1295**	**1150**	**1111**	**1239**

Source: DAFF 2013 “Horticulture Fact Sheet”,

http://www.agriculture.gov.au/ag-farm-food/food/publications/hort-fact-sheet

Australia has a trade surplus in fresh vegetables, exporting more than it imports. However, export of fresh produce (particularly fruit) is limited by quarantine restrictions in a number of countries including Japan, USA, mainland China, South Korea and Taiwan (DAFF ICON 2014). On the other hand a wide range of fresh produce is prohibited from entering Australia on the basis of quarantine restrictions. Fresh produce is imported into Australia during out of season periods or during periods of domestic shortage due to production failures, an inability to produce the commodity and/or production shortfalls relative to demand (DAFF 2013).

Market access restrictions and intense import competition facing some horticultural industries work against the development of an export culture. The task of complying with phytosanitary aspects of market access including the completion of research to prepare pest treatment protocols has become a major one for an increasing number of horticultural industries and industries are unduly locked out of the export arena.

Most commodities treated with phytosanitary irradiation use generic treatments carried out in accordance with *ISPM No 18: Guidelines for the Use of Irradiation as a Phytosanitary Treatment*. For example, the generic dose of 150 Gy for Tephritidae is used for citrus fruit, manzano pepper and mango exported from Mexico to the US. For exports of several fruits and curry leaf from Hawaii, several fruits from Thailand, mango from India and Pakistan, guava from Mexico and dragon fruit from Vietnam to the US, the 400 Gy generic dose is used. South Africa gained permission to irradiate and export persimmon to the US in 2011(APHIS 2011); a minimum absorbed dose 400Gy is required.

Other examples are: for mangoes exported from Australia to New Zealand the minimum dose to eliminate the risk of fruit fly is 150 Gy and for other regulated arthropods, 250 Gy (IHS 2010); for capsicum exported from Australia to New Zealand, a minimum dose of 150 Gy for RG3 regulated pests including fruit fly, 400Gy for other regulated arthropod pests and for *Conogethes punctiferalis* requires 250 Gy (IHS 2014a); for tomatoes the minimum dose for RG3 regulated pests is 150 Gy and for other regulated pests it is 400 Gy (IHS 2013); for mangoes exported for Vietnam to New Zealand a minimum absorbed dose of 400 Gy is required ((IHS 2014b); for papaya exported from Hawaii to New Zealand a minimum dose of 150 Gy is required (IHS 2006).

Before markets can be accessed, an acceptable phytosanitary treatment for fruit flies must first be approved. This is an opportunity for Australian and New Zealand industries to supply high quality fruit outside the normal northern hemisphere season.

Whilst the main focus of phytosanitary requirements is on protocols that minimise risk of delivering pests with imported product and maximising delivered product safety (in relation to applied chemicals and treatments), the area is complex and does not readily allow streamlining. Increasingly growers are being required to find solutions and demonstrate an audit trail that complies with market access and phytosanitary regulation. It comes back to overcoming impediments to market access over the long run that helps to underpin export market commitment, for domestic or export markets.

The Australian marketing season for blueberry and raspberry would generally be counter-seasonal to export markets. The competition will come mainly from within the country and from countries in the southern hemisphere.

There are international standards and agreements governing trade in agricultural commodities established by the WTO. Governments who belong to the WTO including Australia and New Zealand are bound by rules of all multilateral trade agreements, particularly the WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) (WTO 2014) and Agreement on Technical Barriers to Trade (TBT) (WTO 1995).

A model protocol using irradiation as a quarantine treatment was developed for ASEAN nations to access the fresh fruits and vegetables market in the US, EU and inter-ASEAN trade (ASEAN (undated) No. 2). A Harmonized Regulation on Food Irradiation for ASEAN, Food Handling Publication Series No.3 (ASEAN (undated) No. 3), in *Annex 1 Class 2 food: fresh fruits and vegetables, for quarantine control*, provides for the treatment of food by ionizing radiation with technological dose limits, minimum 0.15 kGy and maximum 1.0 kGy. One of the objectives of the harmonised regulation is to overcome quarantine barriers to trade.

Irradiation treatment will open a number of Asian markets to Australian fruit by providing a cost effective treatment for their pests of concern. It is anticipated that irradiation treatment will meet Thailand and Malaysian requirements in the event that phytosanitary disinfestation becomes an import health standard. The Ministry of Health Malaysia, advised Biosecurity Australia that on 1

March 2009 all mango (*Mangifera indica*) fruit must be irradiated prior to export with a minimum irradiation dose of 300 Gy. Irradiation also meets NZMAF Biosecurity requirements, thus facilitating trade between Australia and New Zealand.

Irradiation is an effective technology to resolve many of the technical problems in trade, and this is clearly illustrated as a positive step in the US where a range of irradiated fresh fruits imports have been approved by APHIS for entry into the US.

Australia has exported increasing amounts of irradiated fresh mango and litchi to New Zealand (Table 49). In the past occasionally, live insects have been found in irradiated shipments and this delayed clearance of the early shipments to New Zealand however the issue is not proving a practical barrier. Irradiation below 1 kGy guarantees insect sterility, not mortality.

Table 49: Australian irradiated fruits for export to New Zealand (tonnes)

Season	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11*	2011/12
Mango	19	129	201	346	589	1095	620	918
Litchi	-	5	10	20	57	110	15	32
Total	**19**	**134**	**223**	**367**	**642**	**1205**	**635**	**950**

Source: Richards, P. (2012)
*reduced cop volumes due to severe damaging weather conditions

The effect of international trade and export and import prices on the price paid by consumers for fresh fruit and vegetables is well documented for New Zealand on the Statistics New Zealand website "Fresh fruit and vegetable prices – our global connection" (http://www.stats.govt.nz/tools_and_services/newsletters/price-index-news/jan-14-fruit-and-vege.aspx). This website also shows how imports can stabilise prices of fresh fruits and vegetables over the year as well as resulting in the year-round availability of these commodities. In regard to the case of tomatoes and capsicum and the impact of the prohibition of the use of dimethoate in Australia, the following is stated:

> *"In October 2011, the Australian Pesticides and Veterinary Medicines Authority suspended the use of dimethoate on a number of food crops, due to potential health risks. Using this pesticide was an import requirement for Australian tomatoes and capsicum coming into New Zealand – to protect domestic crops from the Queensland fruit fly.*
>
> *While the import restriction was in place (until July 2013) we did not import Australian tomatoes or capsicum. The result of this was a significantly higher New Zealand domestic price over the period. In July 2010, the average price of tomatoes was $8.70. This compares with an average July price of $10.43 for 2011–13.*
>
> *As the Ministry for Primary Industries has approved Australia's new form of pest control (irradiation), the import restriction has been lifted. All imports of Australian tomatoes and capsicum are now irradiated. As Australian imports increase and return to normal levels, this may influence tomato and capsicum prices in New Zealand."*

This demonstrates the importance of viable non-chemical phytosanitary measures for exported and imported fresh fruit and vegetables; irradiation does provide an effective, economical and sustainable export treatment.

History of Irradiated Export Produce (Tonnes/Pallets)

Season	2004-05	2005-06	2006-07	2007-08	2008-90	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15
Mangoes (NZ/U.S/Malaysia)	19	129	201	346	585	1095	620	918	1018	866	1480
Tomatoes (NZ)										413	430
Capsicums (NZ)										58	28
Lychees (NZ)		5	10	20	57	110	15	132	76	29	34
Papaya (NZ)			12	1						22	
Plums (Indonesia)											2
Table Grapes (Indonesia)											28
TOTALS:	**19**	**134**	**223**	**367**	**642**	**1205**	**635**	**1050**	**1094**	**1388**	**2002**

Table 50: Australian irradiated fruits for export (tonnes) (Steritech, 2015)

5.6 Environmental implications

Fresh mango, papaya, lychee, tomato and capsicum fruit are currently irradiated at the Steritech Narangba facility. The facility is AQIS accredited.

The irradiation facilities that are licensed to carry out the phytosanitary disinfestation do not become radioactive and do not create radioactive waste. The facilities that use radioactive sources are regulated and licensed by the relevant federal, state and local authorities. The facility is designed with multiple fail-safe measures, and must establish extensive and well-documented safety procedures, occupational health and extensive worker training.

The approval of irradiation as an alternative phytosanitary measure for blueberry and raspberry will result in a reduction in the use of methyl bromide. Methyl bromide is an ozone-depleting substance and banned under the Montreal protocol however it was granted a critical use exemption for use as a phytosanitary treatment for agricultural commodities. In IPPC Recommendation CPM-3/2008 (IPPC 2008) NPPOs are encouraged to reduce or replace the use of methyl bromide as a phytosanitary measure in order to reduce emissions of this substance and to replace the use of methyl bromide with an appropriate alternative treatment including irradiation as the adopted appropriate phytosanitary treatment. ISPM 28 adopts irradiation at a minimum dose of 150Gy as the phytosanitary treatment to prevent the emergence of adult fruit flies (IPPC 2009).

With irradiation there is no chemical residue left on the fruit surface from the treatment and no emissions or waste stream.

The USDA prepared “Irradiation for Phytosanitary Regulatory Treatment Environmental Assessment” (APHIS 1997) found that there was no need for an environmental impact statement. Potential environmental consequences were analysed, and no significant impact on the quality of the human environment was found for irradiation for phytosanitary regulatory treatment of fruits and vegetables and it would not present a risk of introducing or disseminating plant pests. There were no adverse impacts to threatened or endangered species or their habitats from this regulatory action anticipated, and there were no disproportionate effects on any minority and low-income populations found. It concluded “The overall effect from the use of irradiation treatments, therefore, is regarded as positive.”

In the USA in 2002 in examining the environmental issues related to the Rule on “Irradiation Phytosanitary Treatment of Imported Fruits and Vegetables” the following was concluded:

> *“An environmental assessment and finding of no significant impact have been prepared for this rule. The assessment provides a basis for the conclusion that the irradiation methods in this rule would not present a risk of introducing or disseminating plant pests and would not have a significant impact on the quality of the human environment. Based on the finding of no significant impact, the Administrator of the Animal and Plant Health Inspection Service has determined that an environmental impact statement need not be prepared.”* (https://federalregister.gov/a/02-27027)

It can be concluded that the use of irradiation as a phytosanitary measure in itself would have an insignificant environmental impact but by decreasing the use of methyl bromide would have a positive effect.

5.7 Consumer acceptance

Despite over 50 years of food irradiation being proved to be safe and useful tool for reducing or eliminating pathogenic bacteria in food, for disinfestation, for phytosanitary purposes, controlling sprouting and extending shelf life of food, it is still perceived to be a controversial treatment. As noted by Eustice & Bruhn (2013) in their review of “Consumer Acceptance and Marketing of Irradiated Foods”, food irradiation has been described as the “most extensively studied food processing technology in the history of mankind", approved of in more than 50 countries for a wide variety of food products (including fresh fruit) and endorsed or supported by governments, high level medical and scientific organisations. In spite of this it is viewed as a "new" or ''emerging" technology and it is human nature to resist change and to fear the unknown.

Prior *et al*. 2013 in a British study and Lyndhurst 2009 in a review of public attitudes to emerging food technologies found that consumer attitude to and knowledge of food irradiation was similar to that for other new food technologies such as genetically modified food and nanotechnology. In fact the arguments against food irradiation are very similar to those against pasteurisation when it was first introduced; these include it will change the properties of the food, dangerous substances will be formed, the process could be carelessly done and accidents could happen, it will increase the price of the product, and it is not necessary. It was only through the insistence of medical and scientific groups and government regulators that pasteurisation was eventually embraced as a lifesaving technology (Eustice & Bruhn 2013).

Consumer acceptance of a new technology is based on a complex decision-making process with actual and perceived risks and benefits considered and compared to existing options. Knowledge about the risks and benefits and comparison to existing options for new food technologies often relies on the consumer seeking out this information from various reliable and unreliable sources or being exposed to fact and opinion through social interaction. In relation to food irradiation their acceptance of the information provided was shown by Sapp 2003 in a study in the US to be most dependent on the consumer's trust in government and industry.

Responsible educational material can help consumers make better-informed choices regarding irradiated fruit. FSANZ has produced communication factsheets to assist consumer, industry and government understanding regarding food irradiation and irradiation of fruit in general (FSANZ 2013). Queensland Health has a consumer factsheet about food irradiation (QH 2011) as does Victoria Better Health (VBHC 2014). The International Consultative Group on Food Irradiation has produced numerous publications and other information sheets about food irradiation to help address various aspects of concern. They may be retrieved from their website www.iaea.org.

Consumers seeking information regarding food irradiation in this day and age would be likely to "google" the topic "food irradiation factsheets". Such a search carried out in September 2014 gave the sites listed in Table 39. These include Australian and New Zealand sites supporting food irradiation and giving the scientific facts relating to it, often in a "question and answer" format addressing common concerns. There are also international sites supporting it and giving factual information (including the popular "Wikipedia'' site). There are also anti-food irradiation sites set up by "independent consumer" groups. Food Irradiation Watch contains Australian relevant articles and says "Food Irradiation Watch are an independant [sic] consumer watchdog, advocating clean, nuclear-free food. We receive no government funding." On its Home page it states "Irradiation changes food in ways that have not been adequately tested for safety. Irradiation depletes food or [sic] vitamins and causes the formation of "radiolytic products" whose effect on human health is not known." So in some sections of the community these fears still persist (and stated as facts) despite many years of scientific research to the contrary and despite government legislation ensuring that adequate testing is done on foods irradiated in Australia in relation to it being safe for human consumption.

5.7.1 Studies on Consumer Acceptance

There have been many studies on the acceptance of irradiated food by consumers; on their knowledge of the process, their attitudes to food irradiation and their willingness to buy irradiated food. These have mainly been carried out in the USA but also in the UK, Europe, Japan, Chile and Argentina. These generally relate to foods, usually raw meat and chicken, that have been irradiated for food safety purposes at levels of up to 10kGy rather than to fruit or vegetables irradiated at levels between 150Gy and 1kGy for phytosanitary purposes, as is the case for the raspberry and blueberry in this application. The main finding of all these studies has been that there was uncertainty and concern regarding food irradiation, however education of the consumer about the process of irradiation and its safety, reasons for irradiating the food, the benefits, the safety and nutritional adequacy of the food and the quality of irradiated food resulted in greater acceptance and willingness to buy irradiated food.

As these studies generally relate to irradiation of food for food safety purposes, their relevance to the present case of raspberry and blueberry for phytosanitary purposes could be questioned. Also, some studies were carried out up to 20 years ago and in countries with different culture to Australia; however these countries may be importers of irradiated Australian fruit in the future.

It can be said that food irradiation is controversial and there will always be people who are opposed to it for a variety of reasons and will never buy irradiated foods. Whether these people are the “vocal minority” or do in fact express the opinion of the community at large is the reason for the large number of studies carried out on this subject.

A seminal document in food irradiation in Australia is the report on “The Australian Consumers’ Association Inquiry into Food Irradiation” (ACA 1987) which was undertaken between October 1986 and April 1987, before food irradiation was occurring in Australia and before the present regulatory regime was in place in Australia and New Zealand. Hence it can be seen as a baseline for Australian consumer concerns about food irradiation. The inquiry was commissioned by the then Commonwealth Minister of Health, Dr N. Blewett, who recognised that this “technological advance was of major concern to consumers” and that it was “vital that the public should be made fully aware of the implications of irradiation and that the issue should be widely discussed”. This inquiry resulted in sixteen recommendations being put forward for the structure and conditions under which food irradiation could (and now does) operate in Australia, these being federal legislation (now Food Standard 1.5.3) and regulations addressing the issues raised during the inquiry.

In looking at consumer attitudes to food irradiation, this inquiry did not conduct a survey into consumer acceptance of food irradiation but invited submissions, as well as consulting widely and collecting “a large amount of literature expressing doubts, concerns and fears about the introduction of food irradiation”. They noted that “the opponents of food irradiation do get heard” and “the anti-food irradiation movements have a high profile”. However they noted that “it is very difficult to find out how representative these views are” as “there is not a visible or audible pressure group from the community or from consumers extolling the virtues of food irradiation”.

Of the 86 submissions received expressing a point of view 83 were opposed to irradiation and 3 were in favour of irradiation; the three in favour were not consumers but Horticultural Holdings Limited (Victoria), the Australian Atomic Energy Commission and the National Farmers Federation. Many submissions expressed a strong objection to food irradiation. Submissions from individuals most commonly (55%) were concerned with the nutritional quality of irradiated foods, especially loss of vitamins. Concern about radiolytic and toxic chemicals formed in the food on irradiation was a concern of 47% of individuals and 44% were concerned about labelling. Concerns were expressed regarding: (i) the health of the consumer (including fear the food will be become radioactive, formation of toxic substances, the possibility that irradiation will be used to clean up unacceptably contaminated food, and reduction of vitamin levels); (ii) the environment (including the development of irradiation resistant micro-organisms, radioactive contamination of the environment due to accidents, natural disasters and system failures); (iii) cost to the consumer and economic gain going to large companies and small primary producers and companies being “squeezed out”; (iv) other issues including the taste, smell and texture of irradiated food, that irradiation was unnecessary, the need for item by item approval rather than blanket approval at up to 10kGy, distrust of the research, scientists and industry, concern that food irradiation is being promoted as a way of using nuclear waste or justifying the nuclear industry, enforcement of labelling and the right to purchase food which has not been irradiated.

Following this government commissioned review, researchers from the CSIRO conducted a rigorously designed survey of the Australian community’s awareness and the perceived benefits and problems associated with food irradiation (Crawford and Baghurst, 1990). In 1988 they surveyed 1500 adults randomly selected from major urban centres of the five mainland states. There was a 67% response rate (916 subjects). They found that 48% of participants had not heard of food irradiation, 17% did not understand the issue, 5% had no opinion, 4% were pro-food irradiation and the remaining 27% were against it. The perceived major benefits were “preserves food/increases shelf life” (18%) and “bacterial or pest control” (5%); the perceived main problems were “uncertainty of the long term health benefits”(8%), “causes health problems"(6%) and "residual radiation in the food", "reduces nutritional value" and "artificial/unnatural"(all 5%). Of those who had heard of food irradiation, most had become aware of it via the media (television and radio – 52%) and other media (22%). When asked whether they felt the issue had been adequately explained to them by the media, health authorities, the food industry, consumer groups and by the health food movement, 75% of all respondents felt it had not been adequately explained and a further 20% were uncertain. So this indicates that the community was generally poorly informed or ignorant of the process of food irradiation and of the "pros and cons" and so their perception of food irradiation was generally uninformed opinion. Perception is important in the acceptance of a new technology and adequate appropriate education about the issues involved is important in changing perceptions and gaining acceptance.

Irradiation of food was effectively banned in Australia and New Zealand until, on 2 December 1999, an amendment to the ANZFA (now FSANZ) food standards code was gazetted which allowed applications to be made to give permission for specified foods to be irradiated for specified purposes. At that time an irradiation plant was being built in Australia, but due to a strong anti-nuclear stance in NZ permission for one there could not be obtained. To gain more knowledge about the public perception in these countries of the irradiation process and irradiated foods The Horticulture and Food Research Institute of New Zealand Ltd (HFRINZ) and HAL commissioned a study to explore consumer opinion in the two countries. This was carried out through the use of 8 focus groups (four in New Zealand and four in Australia) with a total of 36 New Zealanders and 37 Australians of various age groups, gender and ethnicity. Consumer opinions were explored before and after viewing of an American produced video on the irradiation process and irradiated food, using moderated discussions and a series of questionnaires. Industry opinion was also obtained in a series of one-on-one interviews.

The results were reported in "Perceptions of food irradiation in New Zealand and Australia (Year 1 Final Report) (Harker *et al.* 2001, reported by Gamble *et al.* 2002). They found that the consumers had little knowledge of irradiated foods and many were suspicious of the technology and expected it to be dangerous. Their fears were the same as found in other studies: exposure to radiation, reduction in nutrients and wholesomeness of the food, damage to the environment and workers' safety, that it would be used as a substitute for safe food production and they did not want extended shelf life. After viewing the informational video they developed a consensus that irradiation was only a minor issue and that spray chemicals, food spoilage and fumigation were more of a concern than irradiation. Their initial views had been based on ignorance. Their willingness to buy irradiated products was much lower than in the USA being only 20 to 25% for strawberries and 50 to 55% for sterilised foods for the immune-compromised; in the US studies purchase intent ranged from 30-38% to 70%.

The study also highlighted the need for public education on food irradiation that is present in a balanced manner by trusted sources; these Australian and New Zealand consumers tended to distrust organisations not specific to their own country, such as the American Medical Association and US FDA. They were open to the need for food exporters to have access to food irradiation to retain and gain market access. Both exporters and importers feared a backlash from anti-irradiation activists and, while exporters were prepared to contribute to public education in order to speed up establishment of facilities and the technology, importers expected the government to have the major role in educating the public about food irradiation. It was seen that consumer perceptions of risk associated with a product are strongly influenced by the extent of their knowledge of the process used to produce it.

A follow up study also commissioned by HFRINZ and HAL entitled "New Zealand and Australian perceptions of irradiated food" by Gamble *et al*. 2002 was a quantitative investigation of Australian and New Zealand consumers. A survey was administered to 401 Australians and 404 New Zealanders. As a 10% response rate had been obtained in the recruitment of these subjects the results were acknowledged to be more indicative than representative of the populations of the two countries though there was a very diverse demographic in the sample.

This study found that a third of respondents in both countries were unaware of the term "irradiation" and of those who were familiar with it, many had negative perceptions of the technology particularly in Australia. The main negative reaction was the belief that irradiation is harmful to human health and that it will reduce the nutritional content of the food. About 25%

believed that irradiated foods will be radioactive. There was a low level of awareness of infestation problems with imported fruit and microbial contamination problems with herbs and spices and so the consumers did not understand the need for what they see as a little understood and risky technology. When made aware of the need for treatments of fruit and herbs and spices and the reason why irradiation may be a viable alternative, nearly half the respondents chose irradiation over the alternatives. Over half the respondents preferred to continue current food handling practices to control microbial contamination as they perceived home food hygiene to be high, though many saw irradiation as an appropriate food safety treatment for food served in hospitals, delicatessens and fast-food outlets. A greater percentage of respondents in both NZ and Australia were comfortable with the importation of products irradiated for phytosanitary purposes compared to having an irradiation plant in their own country.

The study generally confirmed the findings of the earlier more qualitative study (Harker *et al*. 2001, reported by Gamble *et al.* 2002) that a lack of knowledge about irradiation and suspicions surrounding the use of the technology influenced the intention of those surveyed to purchase irradiated products. Overall, when respondents became aware of the purpose or need for the disinfestation treatment in fruits, they were more positive in supporting the use of the technology over other chemical alternatives. Consumers were more concerned about pesticide residues, preservatives and microbiological contamination than irradiation. Irradiation with adequate product labelling was also seen as important as it will give consumers informed choices for purchases of irradiated fruits as well as the benefits from possible greater seasonal availability of fruits. This study also supported the need for appropriate public education about food irradiation so that consumers could make a reasoned assessment of the risks and benefits of the technology and the product.

The results obtained in Australia and New Zealand in these studies in 2001 and 2002 are consistent with that found in previous consumer and market research on irradiated foods in the USA and other countries (Bord and O'Connor 1989, Bruhn 1995, 1999). Interviews with consumers and marketing tests showed that those who knew something about irradiation responded more positively about the technology. When consumers were informed about the technology and the purpose of the treatment, they were more willing to buy irradiated food products after having tried the irradiated food item.

There is considerable survey information elsewhere particularly in the USA but, as stated earlier, these are mainly for meats (Bruhn *et al*. 1986, DeRuiter and Dwyer 2002, Nayga *et al*. 2005, Gunes and Tekin 2006). All studies revealed that accurate information about food irradiation could determine consumer choice in purchasing irradiated food products, hence expanding the market for these products. In essence, availability of irradiated foods in the marketplace is itself an endorsement of product quality and safety (Bruhn 1999).

Consumer education and market development activities in several ASEAN countries (IAEA 2001) have cleared the way for public acceptance and commercialization of food irradiation and trade development for irradiated food. This could help in marketing and acceptance of irradiated raspberry and blueberry in export countries, including developing educational and promotional material to help inform consumers about irradiation and its purpose in both domestic and export markets.

The most recent study done in Australia involving customers perceptions of food irradiation was commissioned by AUSVEG and carried out in 2012 (TKP Market Research Consultants, AUSVEG Study #4158, March 2012 (TKP 2012)). This survey came about due to the phasing out of dimethoate and fenthion, the two chemicals used on produce to control Qff and the need to gauge consumer perceptions of alternate methods including irradiation; chemical dips, cold disinfestation and fumigation were the other alternative methods. As discussed earlier in this document, dimethoate and fenthion are not used on raspberry and blueberry for phytosanitary purposes and irradiation is the only alternative treatment to the presently-used methyl bromide for raspberry and blueberry.

The study found that there was generally low awareness of the problem of fruit fly and of the methods of control. The use of chemicals was seen as a fact of life but, given the choice, consumers would minimise chemical use. Education was found to create discomfort; when consumers were provided information about treatment methods and then asked to consider these treatments they had to consider something they don't usually think about. A little exposure to names and method can create suspicion and when people claimed they will not purchase fruit or vegetables treated in a particular way it is likely to be overstated. Targeted information was recommended and the use of scientific name and terminology may be alarming.

In this study the overwhelming response to irradiation was a lack of understanding and attitudes to it were mixed from positive to negative to "not sure what to think". The lack of need to use chemicals and lack of residues was seen as a positive however the perception that vitamins and nutrients would be depleted and the perceived possible ingestion of toxic substances were major concerns. For some subjects the elimination or eradication of microorganisms and bacteria was an advantage with the benefit that the produce would have a longer shelf life. Overall cold disinfestation (at 63% preferred) was the most strongly preferred phytosanitary method with irradiation (11% preferred) being preferred at a similar rate to chemical dips and sprays (10%) fumigation (6%) or no treatment (10%). . It should be noted that they found that the use of methyl bromide was seen as unacceptable due to its ozone depleting activity. A systems approach was seen as "good practice" but time consuming and expensive. The fact that food irradiation has been used overseas for many years was generally seen as having a positive effect as it demonstrated a track-record of safe use. The name "irradiation" caused concern but no more than the chemical options. The requirement to label irradiated foods causes suspicion especially as it is the only treatment method the consumer is made aware of. The study recommended the need for a public education program about food irradiation to inform the public of the issues and increase the acceptance rate of this phytosanitary method.

Compared to the US and countries where irradiated food products have been available for the past decade, much would need to be done by Australian and New Zealand government agencies and suppliers to educate people about irradiation technology, and how irradiated foods compare nutritionally and safety-wise to similar products preserved in other ways.

A consumer attitudes survey revealed that Australians (13.4%) and New Zealanders (10.6%) were less concerned about irradiation of food or food ingredients than they were with food poisoning and food safety (FSANZ 2008).

The best gauge of consumer acceptance of irradiated foods is the amount being sold in the marketplace. After the approval by FSANZ permitting the irradiation of selected tropical fruits, 256 tonnes of fresh mango and 3 tonnes of fresh papaya grown and irradiated in Australia were imported into New Zealand between 2004 and 2006 (Biosecurity New Zealand, 2008). In the 2009-2010 season more than 1000 tonnes of Australian mangoes (25% of the total Australian mango exports) were sold in New Zealand. There have been increasing volumes of irradiated tropical fruit being sold in New Zealand

PART 6 – FOOD IRRADIATION CLEARANCES DATABASE

At present, over 55 countries use irradiation for ensuring safety and quality of foods and for fulfilling quarantine requirements in trade, as set out in the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) of the World Trade Organisation.

A database is developed and maintained by the Food and Environmental Subprogramme of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture and is available on the International Atomic Energy Agency (IAEA) website, http://nucleus.iaea.org/ifa/FoodAuthorisationDisplay.aspx

The database provides information on country approvals of irradiated foods for consumption, and includes selections for country, food class, product, objective of irradiation, date of approval and the recommended dose limit. It should be noted that this database appears not to be up to date as the list of food commodities allowed to be irradiated in Australia is incomplete and India is not listed as irradiating food for phytosanitary purposes. India is however listed as irradiating food for purposes of disinfestation, inhibition of sprouting and to delay ripening/physiological growth.

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