FOOD STANDARDS Australia New Zealand
Te Mana Kounga Kai – Ahitereiria me Aotearoa

Supporting Document 2 (Approval)

Risk and technical assessment report – Application A1069

Irradiation of Tomatoes & Capsicums

Summary

FSANZ has previously assessed the toxicological hazard and nutritional adequacy of various irradiated tropical fruits 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.

The purpose of this risk assessment was to determine if tomatoes and capsicums irradiated at up to 1 kGy are as safe as non-irradiated tomatoes and capsicums. 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. This conclusion is based on the following considerations:

- Compounds potentially formed during food irradiation, such as 2-alkylcyclobutanones (2-ACBs), are found naturally in non-irradiated food.
- There is a low potential to generate 2-ACBs because of the low lipid content of capsicums and tomatoes.
- Furan, a genotoxic carcinogen, was not detected (Limit of Quantitation=1 ppb) in tomatoes and capsicums irradiated at 5 kGy.
- Available data indicate that the carbohydrate, fat, protein and mineral content of foods are unaffected by irradiation at doses up to 1 kGy.
- Differences in vitamin concentrations between irradiated and non-irradiated fruit are within the range of the vitamin losses that normally occur during the storage of non-irradiated fruit.
- Other food processing techniques have been demonstrated to have a larger impact on the vitamin content of fruits and vegetables than irradiation.
- Nevertheless, even assuming an upper estimate of vitamin A and C loss of 15% following irradiation from all fresh tomatoes, capsicums and tropical fruits (with existing irradiation permissions), estimated mean dietary intakes of these vitamins would decrease by 2% or less and remain above Estimated Average Requirements following irradiation at doses up to 1 kGy, with dietary intake typically derived from a wide range of foods.
- The safety of irradiated food has been extensively assessed by national regulators and international scientific bodies.
- There is a history of safe consumption of irradiated food in many countries.

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1. Introduction

Food Standards Australia New Zealand (FSANZ) received an Application from the Queensland Department of Employment, Economic Development and Innovation (DEEDI), in association with the New Zealand Fresh Produce Importers Association (NZFPIA), to permit the irradiation of tomatoes (*Lycopersicon esculentum*) and capsicums (*Capsicum annuum)* as a phytosanitary measure. Approval for an irradiation dose of up to 1000 Gray (1 kGy) is sought.

Standard 1.5.3 – Irradiation of Food prohibits the sale of irradiated foods unless the food is in the Standard. A pre-market assessment is required before irradiated tomatoes and capsicums can be sold in Australia or New Zealand.

FSANZ has previously undertaken risk assessments of irradiation of herbs, spices and herbal infusions and of a range of tropical fruits (Applications A413, A443 and A1038). These assessments concluded that there are no health and safety issues associated with the consumption of herbs and spices, and various tropical fruits (breadfruit, carambola, custard apple, lychee (or litchi), longan, mango, mangosteen, papaya, persimmons and rambutan), irradiated at 2-30 kGy and 150 Gy to 1 kGy, respectively, according to Good Manufacturing/Irradiation Practices (GMP and GRP, respectively) (FSANZ 2001, 2002 & 2011). The assessments also concluded that irradiation for these fruits, herbs and spices is unlikely to have a significant impact on the nutrient intake of the Australian and New Zealand populations as these fruits are minor contributors to the dietary intakes of nutrients when considered in the context of the total diet.

1.1 Objective of the Risk Assessment

The objective of this risk assessment is to assess the safety of irradiation of tomatoes and capsicums for Australian and New Zealand consumers.

To meet the objectives of this risk assessment, the following key questions have been posed:

1. Has the technological purpose for using irradiation as a quarantine measure for fresh tomatoes and capsicums been established?
2. Is the dose range requested by the Applicant consistent with quarantine requirements?
3. What is the risk to public health and safety for Australian and New Zealand consumers from any compounds formed following irradiation of fresh tomatoes and capsicums?
4. Does irradiation affect the nutrient composition of fresh tomatoes and capsicums?
5. If so, how does this compare to effects from other post-harvest and processing procedures?
6. Taking into account potential market share and trade of irradiated fresh tomatoes and capsicums, in both Australia and New Zealand, would any changes in the nutrient composition of fresh tomatoes and capsicums, following irradiation, have the potential to affect the nutritional adequacy of diets for Australian and New Zealand populations?
7. What are the combined cumulative nutritional effects on the nutritional adequacy of diets for Australian and New Zealand populations from irradiation of both the currently permitted irradiated foods and irradiated fresh tomatoes and capsicums?

The Risk Assessment report is structured to address each of these questions:

- Technological need assessment – which assessed whether irradiation at up to 1 kGy is effective as a phytosanitary measure and consistent with quarantine requirements (risk assessment questions 1 and 2)

- Hazard Assessment, which evaluated whether the irradiation of tomatoes and capsicums at the proposed level could generate hazardous compounds (risk assessment question 3)
- Nutrition Assessment, which evaluated whether irradiation at the proposed level would significantly alter the nutritional composition of tomatoes and capsicums, and examined the effect of other post-harvest and processing procedures on nutrient levels in tomatoes and capsicums (risk assessment questions 4 and 5)
- Dietary Intake Assessment, which examined whether there would be any nutritional disadvantages from consumption of irradiated tomatoes and capsicums (risk assessment questions 6 and 7).

Based on the hazard, nutrition and dietary intake assessment components, the risk to public health and safety has been characterised.

1.2 Risk Assessments by other agencies & scientific bodies

The safety of irradiated foods has been evaluated by regulatory agencies in other countries and international scientific bodies including the Joint FAO/IAEA/WHO Expert Committee on Food Irradiation (JECFI) (WHO 1977 & 1981), International Consultative Group on Food Irradiation (WHO 1994) and Study Group on High-Dose Irradiation (WHO 1999), Health Canada (2008) and the European Food Safety Authority (EFSA 2011). These reviews have examined the efficacy, safety and nutritional effects of irradiation on a wide range of foods. The weight of scientific opinion is that irradiated food is safe for consumption when irradiated at doses necessary to achieve the intended technological function and in accordance with GRP.

2. Technological need and quarantine requirements

2.1 Current status of food irradiation for phytosanitary purposes in Australia and New Zealand

To date, FSANZ has approved the irradiation of herbs, spices and herbal infusions and irradiation of a range of tropical fruits (mango, breadfruit, carambola, custard apple, litchi, longan, mangosteen, papaya and rambutan). Specific advice on technological need and appropriate dose ranges for phytosanitary purposes for both applications was sought at that time from the then Biosecurity Australia (BA) (now DAFF Biosecurity) and MAF Biosecurity (now New Zealand Ministry for Primary Industries).

Examples of previous approvals by the Australian and New Zealand authorities of irradiation for quarantine purposes are as follows:

Commodity	Date	Purpose	Dose
Fresh mangoes imported from India (BA)[1]	August 2008	Phytosanitary need for control of fruit flies, mealy bugs, red-banded mango caterpillar and mango weevils	400 Gy
Litchis exported from Australia (Biosecurity NZ[2])	September 2008	Control of Fruit fly and Hemiptera (bugs)	Minimum of 250 Gy
Mangoes and Papaya	2004 and 2006,	Control of Fruit fly and other	250 Gy

[1] http://www.daff.gov.au/__data/assets/pdf_file/0003/771906/Mangoes_from_India_Final_Report.pdf
[2] http://www.biosecurity.govt.nz/files/regs/imports/risk/aus-litchi-ra.pdf

Commodity	Date	Purpose	Dose
exported from Australia (Biosecurity NZ[3])	respectively	insect pests	

In 2011, the use of irradiation for phytosanitary purposes for domestic trade was approved by all states and territories in Australia. This treatment is available to businesses under the national Interstate Certification Assurance (ICA) Scheme as Operational Procedure Number 55 (i.e. ICA 55) and conforms to the principles of ISPM 18 and 28[4].

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 International evidence to support irradiation against fruit flies and other regulated pests

Irradiation is also a known effective treatment for fruit fly infestation. For fruits and vegetables that are hosts to the fruit fly the required treatment is applied in accordance with international requirements (under ISPM 18; 2003). The required treatment would specifically comply with *ISPM 28, Irradiation Treatment for Fruit Flies of the Family Tephritidae* (2007) within the dose range of 150 Gy to 1 kGy for prevention of the emergence of adult fruit flies for all fruits and vegetables. Further support for the efficacy of irradiation as a phytosanitary treatment for fruit fly exists in the US. In 2006, the US Animal and Plant Health Inspection Service (APHIS) approved generic irradiation doses of 150 Gy to reduce fruit fly infestation on specific fruits.

Currently, irradiation is an approved treatment to control quarantine pests in 17 fruits and seven vegetables for export from Hawaii to the USA mainland. There is also ongoing research to look at lower doses for phytosanitary needs, which will assist reducing costs, improving quality and increasing capacity due to shorter treatment times. As an example, the Mediterranean fruit fly is controlled in mandarins with a combination treatment of a radiation dose of 30 Gy and cold treatment (1 degree C for 2 days (Follett and Weinart, 2012)).

2.3 Australian and New Zealand quarantine agencies' support for irradiation against fruit flies and other regulated pests

DAFF Biosecurity has provided a letter of support indicating that irradiating fresh horticultural commodities at doses of 150 Gy to 1 kGy is an effective phytosanitary measure against fruit fly and other quarantine pests.

Similarly, the NZ Ministry for Primary Industries has recommended irradiation as an effective quarantine treatment for fruit fly and other pests of quarantine concern to New Zealand.

[3] http://www.hortaccess.com.au/page/plant_quarantine__food_safety.html
http://www.biosecurity.govt.nz/files/ihs/mango-au.pdf
http://www.biosecurity.govt.nz/files/biosec/policy-laws/intl/sps/transparency/notifications/nzl341-ft.pdf
[4] http://www.domesticquarantine.org.au/index.cfm?objectID=44F9C72D-A63D-3F2E-C127EE6E7389B7D8&action=detail&state=QLD&id=ICA-55

2.4 Conclusion

In summary, advice received by FSANZ from the relevant quarantine authorities is that irradiation of tomatoes and capsicums for the purpose of pest disinfestation would provide an effective alternative to currently used disinfestation methods. The proposed minimum dose of 150 Gy and maximum dose of 1 kGy will provide a dose range in order for quarantine agencies to consider irradiation as a treatment for pest disinfestation of tomatoes and capsicums. FSANZ understands that irradiation is viewed as an important pest reduction protocol for acceptance of Australian produce for interstate trade and in other countries.

However, both DAFF Biosecurity and the NZ Ministry for Primary Industries will still need to independently perform an import risk assessment (for quarantine purposes) on irradiation of tomatoes and capsicums, specifically for food imported into Australia or New Zealand. These assessments are separate from the approval processes in the food regulatory regime.

Response to Question 1: *Has the technological purpose for using irradiation as a quarantine measure for fresh tomatoes and capsicums been established?*

Irradiation is an internationally accepted quarantine measure for control of fruit fly and other insect pests.

Response to Question 2: *Is the dose range requested by the Applicant consistent with quarantine requirements?*

The dose range sought by the applicant (up to 1 kGy) is sufficient to meet domestic and international quarantine requirements.

3. Hazard assessment

3.1 Introduction

The scope of this hazard assessment was to evaluate supplementary data published since FSANZ's most recent evaluation of irradiated persimmons (in 2011)[5] covering the safety of food irradiation in general, and specifically, the potential hazard of radiolytic compounds generated by the irradiation of tomatoes and capsicums. The conclusion of this previous hazard assessment was that persimmons irradiated up to a maximum dose of 1 kGy are as safe to consume as non-irradiated persimmons on the basis of the following considerations:

- An evaluation of supplementary data published since 2002 raised no public health and safety issues associated with the consumption of irradiated foods.
- Compounds formed during food irradiation are found naturally in non-irradiated food.
- The safety of irradiated food has been extensively assessed by national regulators and international scientific bodies.
- The irradiation of a number of tropical fruits is already permitted in Australia and New Zealand. FSANZ has not previously identified any public health and safety issues associated with the consumption of these or other permitted irradiated foods.
- There is a history of safe consumption of irradiated foods in many countries.

[5] http://www.foodstandards.gov.au/foodstandards/applications/applicationa1038irra4655.cfm

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3.2 Evaluation

3.2.1 Compounds generated in irradiated foods

There are a number of compounds that may be generated during the irradiation of food (so-called radiolytic compounds) including free radicals, various hydrocarbons, formaldehyde, amines, furan and 2-alkylcyclobutanones (2-ACBs) (Sommers et al 2007; Vranova & Ciesarova 2009). However, the majority of these compounds are not unique to irradiated food and are naturally present at low levels in food or are generated via other processing treatments (e.g. thermal processing).

Compounds previously considered to be uniquely formed during food irradiation, namely the 2-ACBs, are detectable in some non-irradiated foods such as cashews and nutmeg (Variyar et al 2008). FSANZ evaluated the genotoxic potential of 2-ACBs as part of the risk assessment prepared in relation to Application A1038. The weight-of-evidence indicated that 2-ACBs are not genotoxic, with numerous laboratory animal studies demonstrating that long-term consumption of irradiated foodstuffs (that would contain low concentrations of 2-ACBs and other radiolytic compounds) is safe. Further, independent evaluations conducted by the European Commission's (EC) Scientific Committee on Food (2002), the WHO (2003), Health Canada (2008) and the European Food Safety Authority (EFSA 2011) have concluded that, based on the current scientific evidence, 2-ACBs in irradiated foods do not pose a health risk to consumers. It is worth noting that as the amount of 2-ACBs formed during irradiation is dependent on the lipid content of the food, and that the total lipid content of raw tomatoes (0.1%) and capsicum (0.1% for green and 0.2% for red capsicum) (FSANZ 2010) is very low and hence there is limited potential to generate 2-ACBs. Additionally, the total lipid content of tomatoes and capsicums is lower than that of custard apple (0.6%) and rambutan (0.4%), and comparable to that of lychee (0.1%), mango (0.2%) and papaya (0.1%) (FSANZ 2010). These fruits have previously been assessed by FSANZ as safe for consumers when irradiated up to 1 kGy.

Furan, a genotoxic carcinogen, can be formed at low concentrations in some thermally-processed and irradiated foods, and is derived predominantly from sugars (e.g. glucose, fructose and sucrose) and ascorbic acid (Fan 2005; Vranova & Ciesarova 2009). Fan and Sokorai (2008a) measured furan in freshly-cut tomatoes and green pepper (capsicum) that had been irradiated at 5 kGy (i.e. 5 times higher than that proposed in the current application). No quantifiable furan was detected in irradiated or non-irradiated tomatoes or capsicums [limit of quantitation (LOQ) = 1 parts per billion (ppb)].

3.2.3 Supplementary data

A search of the scientific literature published since FSANZ's most recent evaluation of irradiated persimmons (i.e. from 2011 to August 2012) did not identify any relevant supplementary data on the safety of irradiated food, or on the toxicity of 2ACBs or other radiolytic compounds.

3.2.4 Other relevant safety matters

FSANZ has previously considered reports of adverse neurological effects (leukoencephalomyelopathy) in specific pathogen free cats associated with the exclusive consumption of dry feed that had been irradiated in the range of 26-54 kGy (Cassidy et al 2007; Caulfield et al 2009). While the exact aetiology of the leukoencephalomyelopathy remains to be determined, Caulfield et al (2009) suggested that the long-term, exclusive consumption of highly irradiated feed with a reduced Vitamin A content and a high peroxide content may have been responsible.

Consumption of a specific brand of imported dry cat or dog food that had been irradiated at 50 kGy to comply with Australian Quarantine requirements also resulted in a neurological effects involving movement (ataxia) (Child et al 2009). The cause of the neurological effects for this one brand of dry pet food was not established but dogs consuming the same dried food were unaffected. This product is no longer imported into Australia.

The levels of irradiation used for these dry pet food incidents are 25 to 50 times greater than that being proposed for tomato and capsicum irradiation for phytosanitary purposes. At high doses of irradiation (25-50 kGy) Vitamin A was shown to be reduced and since this highly irradiated food was also the sole source of nutrition for cats a nutritional deficiency occurred. This situation is unlikely to be relevant for humans because a low level of irradiation (1 kGy) does not appreciably reduce vitamin levels and the likelihood that tomatoes and capsicums would ever be sole sources of nutrients in the diet is small.

These two studies (Cassidy et al 2007; Caulfield et al 2009) were also reviewed by EFSA in 2011 as part of its updated hazard assessment on the safety of irradiated foods. While EFSA expressed some uncertainty about the relevance of the observations in cats to humans and the need for additional data, it noted the lack of a similar effect in dogs fed the same irradiated diet or from observations in rodents or humans. EFSA's overall conclusion was that the weight-of-evidence was that the consumption of irradiated food was safe for humans.

FSANZ is also aware that the United States Food and Drug Administration (USFDA) is actively investigating the cause of illnesses reported in dogs which may be associated with the consumption of irradiated jerky pet treat products http://www.fda.gov/AnimalVeterinary/SafetyHealth/ProductSafetyInformation/ucm319463.htm

These pet treat products are also irradiated up to 50 kGy to control microbes. To date, extensive testing by the USFDA has not identified a contaminant which could account for the illnesses observed but further testing is still underway

In conclusion, FSANZ does not consider that these studies have implications for the safety of food irradiated at up to 1 kGy, and will continue to monitor any developments in this area and consider any related issues for irradiation of food for human consumption.

3.3 Conclusions

Capsicums and tomatoes irradiated up to a maximum dose of 1 kGy are as safe to consume as their non-irradiated counterparts on the basis of the following considerations:

- Compounds potentially formed during food irradiation, such as 2-ACBs, are found naturally in non-irradiated food.
- There is a low potential to generate 2-ACBs because of the low lipid content of capsicums and tomatoes.
- The weight-of-evidence indicates that 2-ACBs are not genotoxic.
- Furan, a genotoxic carcinogen, was not detected (LOQ=1 ppb) in tomatoes and capsicums irradiated at 5 kGy.

Response to Question 3: *What is the risk to public health and safety for Australian and New Zealand consumers from any compounds formed following irradiation of fresh tomatoes and capsicums?*

Since no hazard has been identified following irradiation of food at 1 kGy, the risk posed by consuming irradiated tomatoes and capsicums is considered to be negligible.

4. Nutrition Assessment

4.1 Introduction

4.1.1 Previous FSANZ considerations of the effect of irradiation on nutrients in food

FSANZ has previously evaluated the effect of low-dose irradiation on the nutrient profile of various fruits in relation to Applications A443 (Irradiation of tropical fruits – breadfruit, carambola, custard apple, lychee, longan, mango, mangosteen, papaya and rambutan) and A1038 (Irradiation of persimmons). These evaluations concluded that the macronutrient and mineral content of these foods was unaffected by irradiation up to a dose of 1 kGy, although the concentrations of certain water soluble vitamins (e.g. thiamin, vitamin C, folate or β-carotene) may potentially be reduced. However, any impact on vitamin content would be no greater than from other forms of food processing. As these particular fruits are not widely consumed in Australia and New Zealand, they contribute minimally to total dietary vitamin intake and hence there are unlikely to be any nutritional disadvantages from consuming these irradiated fruits.

4.1.2 Impact of irradiation on nutrients in food

Numerous independent reviews have been published on the effects of irradiation on food (WHO 1981; 1994 &1999; SCF 2003; Arvanitoyannis 2010; EFSA 2011). These reviews have examined the efficacy, safety and nutritional effects of irradiation on a wide range of foods. Irradiation can induce changes in nutrient content, depending on a variety of factors including the irradiation dose, composition of the food, packaging material, ambient temperature and atmospheric oxygen concentration (Diehl et al 1991; Kilcast 1994; WHO 1994). A relatively small proportion of nutrients are sensitive to irradiation, with their concentrations decreasing with irradiation dose (WHO 1999). Nutrient loss can be minimised by the use of appropriate processing techniques, such as low temperatures and oxygen-free conditions (WHO 1994; Diehl 1995).

There has been no demonstrated effect of irradiation up to 1 kGy on the amount and nutritional quality of carbohydrates, proteins or fats and no evidence to suggest that irradiation reduces the mineral content of food (Diehl et al 1991; WHO 1994). The concentrations of certain vitamins in some fruits and vegetables may be affected by irradiation but it is important to recognise that the natural variation in vitamin content in fruits and vegetables is very large, depending on the plant variety, growing conditions, maturity of the edible portion, post-harvest handling and storage conditions (WHO 1994). On this basis, changes in the concentrations of vitamins observed in individual studies must be interpreted in the context of this variation. Reductions in the vitamin content of a particular fruit or vegetable that has been irradiated may not be able to be extrapolated to other types of fruits or vegetables that differ in baseline nutrient composition.

Notwithstanding the variable effect that irradiation may have on the vitamin content of fruits and vegetables, experience to date suggests that there is a general hierarchy of vitamin sensitivity (Figure 4.1). Consequently, the majority of studies examining the effect of irradiation on fruit or vegetable quality have focussed on the analysis of vitamin C and the carotenoids because these represent the more sensitive nutrients found in fruits and vegetables.

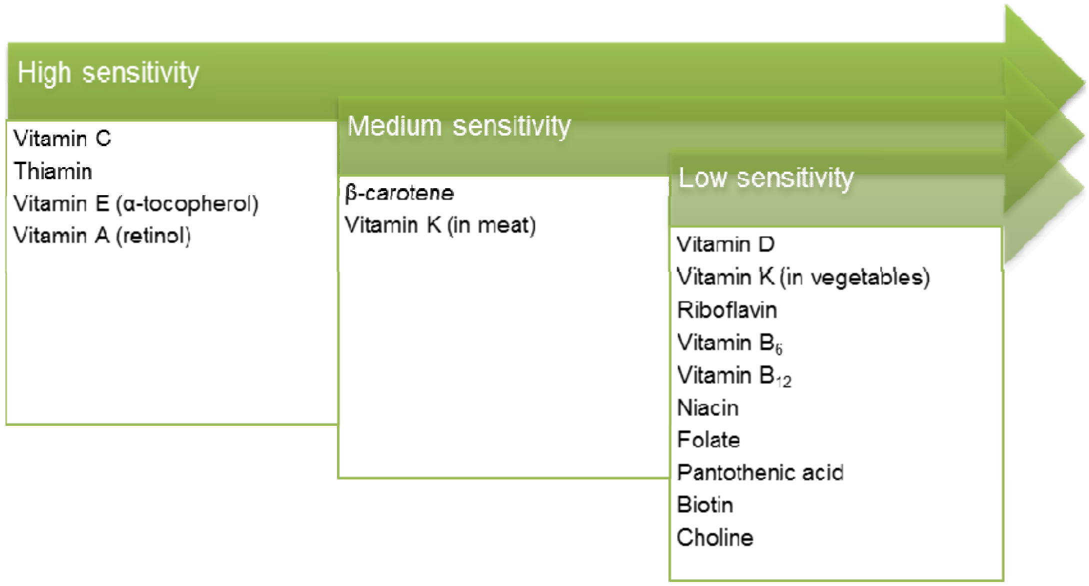

Figure 4.1: General sensitivity of vitamins in food to irradiation (modified from Kilcast 1994)

Ascorbic acid (vitamin C) is one of the most sensitive vitamins to irradiation, although this sensitivity varies due to exposure to oxygen, storage, temperature and pH (Kilcast 1994). Irradiation results in some ascorbic acid being converted to dehydroascorbic acid (Kilcast 1994), however both forms of vitamin C are biologically active (Tsujimura et al 2008). Therefore, when reviewing findings of irradiation studies, it is important to consider that losses due to irradiation may be overestimated if only ascorbic acid is reported. Hence, total ascorbic acid content is a more reliable indicator of post-irradiation vitamin C.

A review by Diehl et al (1991) concluded that the results of studies investigating the effect of irradiation on carotenoids vary considerably depending on the fruit or vegetable. Several studies assessing the total carotenoid, β-carotene and lycopene content of raw fruit and vegetables show inconsistent effects of irradiation at doses up to 1 kGy. Overall, the carotenoid content of irradiated fruit or vegetables is comparable to non-irradiated fruit or vegetables (Mitchell et al 1990; Farkas et al 1997; El-Samahy et al 2000; Boylston et al 2002; Patil et al 2004; Vanamala et al 2005; Moreno et al 2007; Reyes & Cisneros-Zevallos 2007; Girennavar et al 2008; Gomes et al 2008a; Gomes et al 2008b; Lester et al 2010).

In some fruit (e.g. mango and papaya), the carotenoid content increases during ripening, and irradiation can delay the ripening process (El-Samahy et al 2000; D'Innocenzo & Lajolo 2001; Reyes & Cisneros-Zevallos 2007; Singh & Pal 2009). This may account in part for lower total carotenoid concentrations after a period of post-irradiation storage because the comparisons between irradiated and non-irradiated samples are between samples at different stages of ripeness. In some instances, irradiation appears to result in a higher carotenoid content when analysis was conducted near to the time of irradiation. This higher carotenoid concentration post-irradiation may be attributable to increased extraction efficiency or conversion of vitamin precursors to other forms (Diehl et al 1991, Diehl 1992).

4.1.3 Aim of the nutrition assessment

The aim of this nutrition assessment is to evaluate the potential effect of the proposed irradiation of tomatoes and capsicums up to 1 kGy on the nutrient profile of these fruits.

4.2 Evaluation

The evaluation of the nutrient profile of irradiated tomatoes and capsicums is based on the following considerations:

- data on the normal range (i.e. variation) of nutrients in tomatoes and capsicums, including comparisons with other food processing techniques
- an unpublished study conducted by the Applicant on the effect of irradiation on the nutrient content of tomatoes and capsicums
- supplementary studies published in the scientific literature on the effect of irradiation on the nutrient content of tomatoes and capsicums.

4.2.1 Baseline nutrient profiles of tomatoes and capsicums

Tables 4.1 and 4.2 summarise the mean concentrations of nutrients in raw tomatoes and capsicums based on Australian and New Zealand data. The vitamin content of produce is highly variable, and can depend on a variety of factors including growing environment, variety and degree of ripeness. For example, a FSANZ survey of tomatoes collected at retail level nationwide in 2008 measured a mean β-carotene content of 150 µg/100 g but with a range of 25-400 µg/100 g. There was a similar large range in lycopene levels, from 240 to 1200 µg/100 g (FSANZ 2009a).

4.2.2 Temporal changes in nutrients during ripening

The concentrations of certain nutrients change during the ripening process. In the case of tomatoes, ripening involves the breakdown of chlorophylls and the concomitant increase in lycopene, phenolics, flavonoids and vitamin C; the concentration of folate decreases (Gautier et al 2008; Periago et al 2009). In a study by Periago et al (2009), the ascorbic acid content of three varieties of tomatoes ("Ronaldo", "Sienna" and "Copo") ranged from 5-8.2 mg/100 g for green tomatoes, 6-8.3 mg/100 g for pink tomatoes and 7.9-15.4 mg/100 g for red tomatoes. Similarly, up to a ~4-fold increase in lycopene occurred from the pink to red stage of ripening, with ~2.3-fold variation between the three cultivars. In the case of capsicums, ascorbic acid increased by ~1.5-fold during ripening from green mature to breaker to red (~107, 130 and 154 mg/100 g edible portion, respectively) (Martínez et al 2005).

Table 4.1: Nutrient content of raw ripe tomatoes per 100 g edible portion

Nutrient	Australia[a]	New Zealand[b]
Macronutrients		
Water	94.2 g	94 g
Energy	74 kJ	68 kJ
Protein	1.0 g	0.9 g
Nitrogen	0.16 g	Not analysed
Total lipid	0.1 g	0.2 g
Malic acid	0.1 g	Not analysed
Carbohydrate	2.4 g	2.7 g
Total dietary fibre	1.2 g	1.2 g
Ash	0.6 g	
Total sugars	2.3 g	2.7 g
Fructose	1.2 g	Not analysed
Glucose	1.1 g	Not analysed

Nutrient	Australia[a]	New Zealand[b]
Sucrose	0	Not analysed
Vitamins		
Vitamin C	18 mg	24 mg
Thiamin (vitamin B_1)	0.02 mg	0.02 mg
Riboflavin (vitamin B_2)	0.02 mg	0.01 mg
Niacin	Not analysed	Not analysed
Niacin equivalents	0.17 mg	0.6 mg
Vitamin B_6	0.03 mg	0.01 mg
Folate (total)	16 µg	14 µg
Vitamin A (retinol equivalents)	26 µg	92 µg
α-carotene	0 µg	Not analysed
β-carotene	153 µg	549 µg
Lycopene	537.5 µg	Not analysed
α-tocopherol (Vitamin E)	0.26 mg	Not analysed
Minerals		
Calcium	9 mg	11 mg
Iron	0.27 mg	0.1 mg
Magnesium	7 mg	Not analysed
Phosphorus	26 mg	23 mg
Potassium	214 mg	265 mg
Sodium	8 mg	4 mg
Zinc	0.31 mg	0.1 mg
Copper	0.042 mg	Not analysed
Manganese	0.092 mg	Not analysed
Selenium	0.4 µg	0.1 µg

[a] Data from NUTTAB 2010 online version (Food Standards Australia New Zealand 2010)

[b] Data from The Concise New Zealand Food Composition Tables (New Zealand Institute for Plant & Food Research and Ministry of Health 2009)

[c] β-carotene equivalents equals the amount of β-carotene plus half the quantity of other provitamin A carotenoids (α-carotene and β-cryptoxanthin)

Table 4.2: Nutrient content of raw red and green capsicums per 100 g edible portion

Nutrient	Australia[a]		New Zealand[b]	
	Red	Green	Red	Green
Macronutrients				
Water	92.2 g	93.2 g	91 g	94 g
Energy	106 kJ	92 kJ	146 kJ	66 kJ
Protein	1.5 g	1.6 g	1.7 g	0.9 g
Nitrogen	0.24 g	0.26 g	Not reported	Not reported
Total lipid	0.2 g	0.1 g	0.2 g	0.4 g
Malic acid	0.1 g	0.1 mg	Not analysed	Not analysed
Carbohydrate	3.5 g	2.5 g	6.7 g	2.2 g
Total dietary fibre	1.8 g	2.4 g	1.6 g	1.6 g
Ash	0.4 g	0.2 g	Not analysed	Not analysed
Total sugars	3.5 g	2.5 g	6.1 g	2.2 g
Fructose	1.9 g	1.0 g	Not analysed	Not analysed
Glucose	1.7 g	1.3 g	Not analysed	Not analysed
Sucrose	0 g	0.2 g	Not analysed	Not analysed
Vitamins				
Vitamin C	152 mg	98 mg	170 mg	100 mg
Thiamin (vitamin B_1)	0.035 mg	0.033 mg	0.04 mg	0.07 mg
Riboflavin (vitamin B_2)	0.044 mg	0.033 g	0.05 mg	0.03 g
Niacin	0.54 mg	0.88 mg	Not analysed	Not analysed
Niacin equivalents	1.13 mg	0.81 mg	Not analysed	Not analysed
Vitamin B_6	0.30 mg	0	0.36 mg	0.17 mg
Folate (total)	60 µg	10 µg	21 µg	11 µg
Vitamin A (retinol equivalents)	215 µg	29 µg	245 µg	33 µg
α-carotene	9 µg	16 µg	Not analysed	Not analysed
β-carotene	282 µg	161 µg	Not analysed	Not analysed
β-carotene equivalents	1292 µg	175 µg	Not analysed	Not analysed
α-tocopherol (Vitamin E)	4.03 mg	0.05 mg	Not analysed	Not analysed
Minerals				
Calcium	4 mg	9 mg	2 mg	9 mg
Iron	0.3 mg	0.58 mg	0.3 mg	0.4 mg
Magnesium	6 mg	10 mg	Not analysed	Not analysed
Phosphorus	28 mg	20 mg	34 mg	25 mg
Potassium	174 mg	165 mg	180 mg	210 mg
Sodium	2 mg	2 mg	1 mg	2 mg
Zinc	2 mg	0.19 mg	1 mg	0.2 mg
Copper	0.019 mg	0.072 mg	Not analysed	Not analysed
Manganese	0.139 mg	0.133 mg	Not analysed	Not analysed
Selenium	0.5 µg	0.4 µg	Not analysed	Not analysed

[a] Data from online version of NUTTAB 2010 (Food Standards Australia New Zealand 2010)
[b] Data from The Concise New Zealand Food Composition Tables (New Zealand Institute for Plant & Food Research and Ministry of Health 2009)
[c] β-carotene equivalents equals the amount of β-carotene plus half the quantity of other provitamin A carotenoids (α-carotene and β-cryptoxanthin)

4.2.3 Impact of other forms of handling and processing on the vitamin content of fruit and vegetables

Irradiated foods are considered nutritionally equivalent to counterpart foods processed by other accepted methods such as thermal heating, smoking, canning and freezing (WHO 1994; Crawford & Ruff 1996).

It is important to recognise that all food processing and handling practices are likely to lead to some changes in the vitamin content of fruits and vegetables. The major factors affecting the concentrations of vitamins in food include temperature, moisture, pH and light (Ottaway 2002). Table 4.3 summarises the effect that different processing methods have on the concentrations of vitamin C and carotenoids in tomatoes, capsicums and other vegetables. These data indicate that processes other than irradiation (including ripening) can lead to very large changes in vitamin content that overshadow any potential effects of irradiation.

A few studies have directly compared the effects of low-dose irradiation on the nutrient profile of fruit and vegetables with other forms of food processing. In one study, the retention of ascorbic acid and carotenoids in mango, papaya and litchi was greater after irradiation at 0.75-2 kGy (83-114%) than freezing (12-100%) or experimental canning (45-102%) (Beyers & Thomas 1979). Similarly in another study, the ascorbic acid, lycopene and β-carotene content of grapefruit irradiated at 0.3 kGy was similar to control samples, however freeze-dried samples tended to have lower ascorbic acid, lycopene and β-carotene than both irradiated and control samples (Vanamala et al 2005).

Table 4.3: Changes in vitamin C and carotenoids in capsicums, tomatoes and vegetables generally through a range of processes

Fruit/vegetable	Processing Step	% Change	Reference
Vitamin C			
Capsicum	Ripening from green to red	**+44**	Martínez et al (2005)
	Storage at 4ºC for 20 days, green fruit	**-11**	
	Storage at 4ºC for 20 days, red fruit	**-16**	
	Storage at 20ºC for 20 days, red fruit	**-25**	
	Water blanching	**-12**	
	Freezing	**-40**	
	Drying	**-88**	
Capsicum	Pressurisation, 200 MPa, 20 minutes, green fruit	**-20**	Castro et al. (2008)
	Pressurisation, 200 MPa, 20 minutes, red fruit	**+15**	
Tomato	Ripening from pink to red	**+60**	Periago et al (2009)
Vegetables (all types)	Frying	**-5 to -50**	Bell et al (2006)
	Baking	**-5 to -50**	
	Boiling	**-5 to -80**	
Carotenoids			
Tomatoes	Canning	**-13**	Rickman et al (2007)
Vegetables (all types)	Frying	**-10 to -15**	Bell et al (2006)
	Baking	**0 to -20**	
	Boiling	**-5 to -20**	

4.2.4 Unpublished studies

Chay P, Henriod R, Wright C & Leach P (2011) Effect of irradiation on the nutritional profile and postharvest quality of tomato and capsicum. Department of Employment, Economic Development and Innovation (DEEDI), Cairns, Queensland, Australia.

Firm ripe tomatoes (*Lycopersicon esculentum*, variety 'Gourmet Swanson') and fresh green capsicums (*Capsicum annuum*, variety 'Plato') were γ-irradiated at 0, 150, 600 or 1000 Gy at a temperature of 22.7-24.5ºC. These doses are consistent with those proposed in the current application. Fruit were sourced from a wholesale market on two occasions and were not graded or washed prior to irradiation. The concentrations of nutrients (Tables 4.4 and 4.5) were analysed following cold storage (10ºC) for 1 or 14 days for tomatoes, or 21 days for capsicums after irradiation. The reported nutrient concentrations are from three different composite samples with each consisting of 5 capsicums or 10 tomatoes per dose per assessment time.

The irradiation of tomatoes at doses up to 1000 Gy did not significantly alter the concentrations of various nutrients relative to the concurrent, non-irradiated fruit measured at 1 and 14 days after irradiation (Table 4.4). Of note was the absence of any difference in the concentration of those vitamins or provitamins known to be sensitive to irradiation (vitamin C, β-carotene (provitamin A)) in both tomatoes and capsicums (Figures 4.2 & 4.3).

No significant difference in the nutrient profile of irradiated green capsicums relative to the non-irradiated concurrent control was noted following storage for 1 day (Table 4.5). In capsicums irradiated at the highest dose and stored for 21 days, moisture was significantly lower ($p<0.05$) than the concurrent control, while fructose was significantly higher ($p<0.05$); neither of these differences have any specific nutritional relevance and are comparable to the moisture and fructose content of non-irradiated green and red capsicum previously published by FSANZ (Table 4.2). Significant differences in the concentration of carbohydrate, energy, moisture, sodium, total sugars, fructose or glucose were noted between capsicum analysed after 1 day of storage and fruit analysed after 21 days of cold storage across all groups (i.e. both irradiated and non-irradiated). The authors attributed these time-related changes to general senescence following ripening of the fruit.

In conclusion, this study indicated that irradiation up to a dose of 1000 Gy had no effect on the nutrient concentration, including irradiation sensitive vitamins and provitamins, or nutritional value (proximate, sodium) of fresh red tomatoes and green capsicums.

4.2.5 Published studies

FSANZ identified a number of published studies investigating the effect of irradiation on nutrients. These studies are viewed as supplementary to the preceding pivotal study by Chay et al (2011), which was conducted on fruit and conditions comparable to those proposed in the current application. The results of the published studies are summarised in Table 4.6.

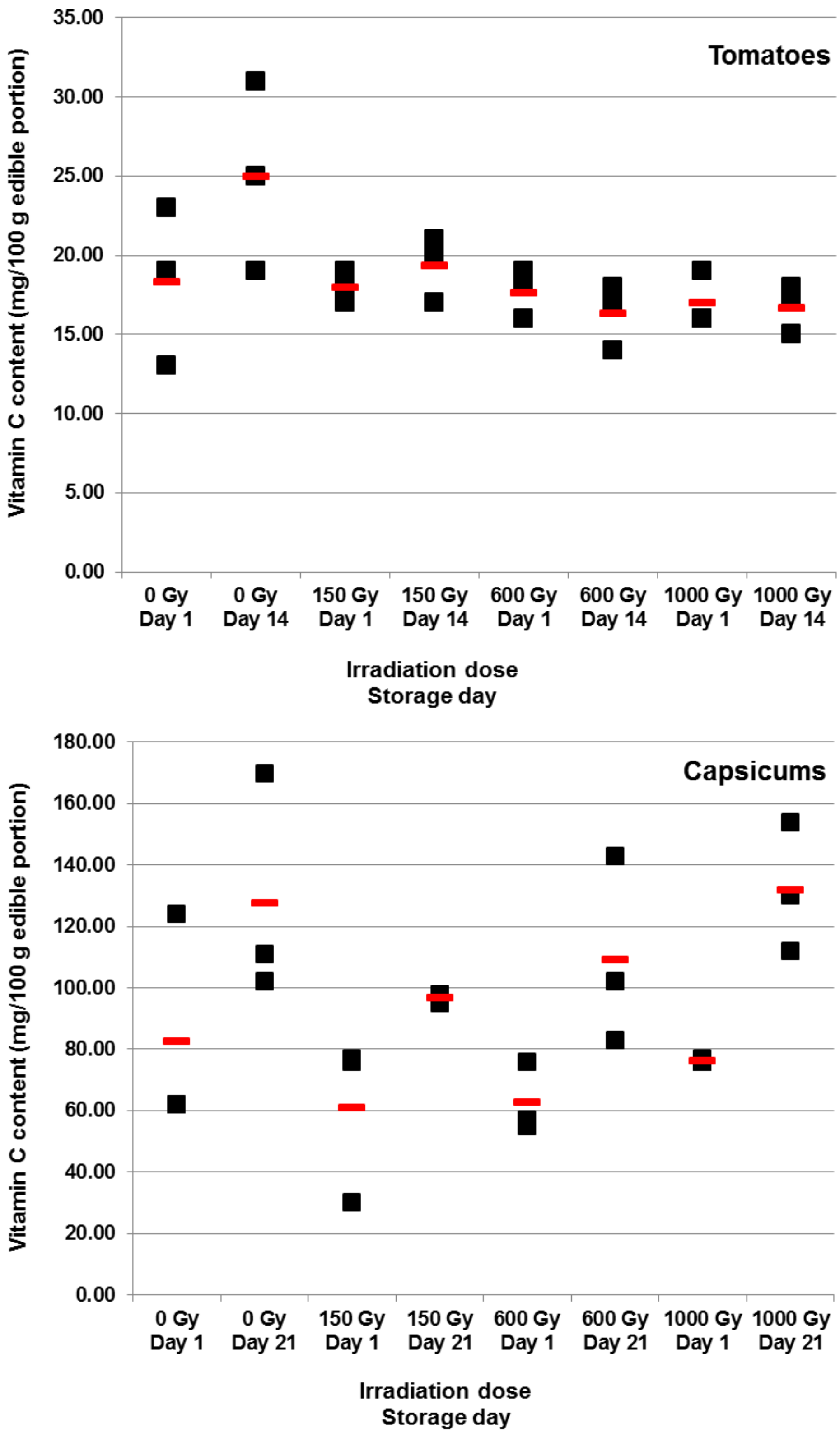

Figure 4.2: Vitamin C content of irradiated tomatoes (top panel) and capsicums (bottom panel). Each black square represents one of three replicates, with the red line representing the mean of these.

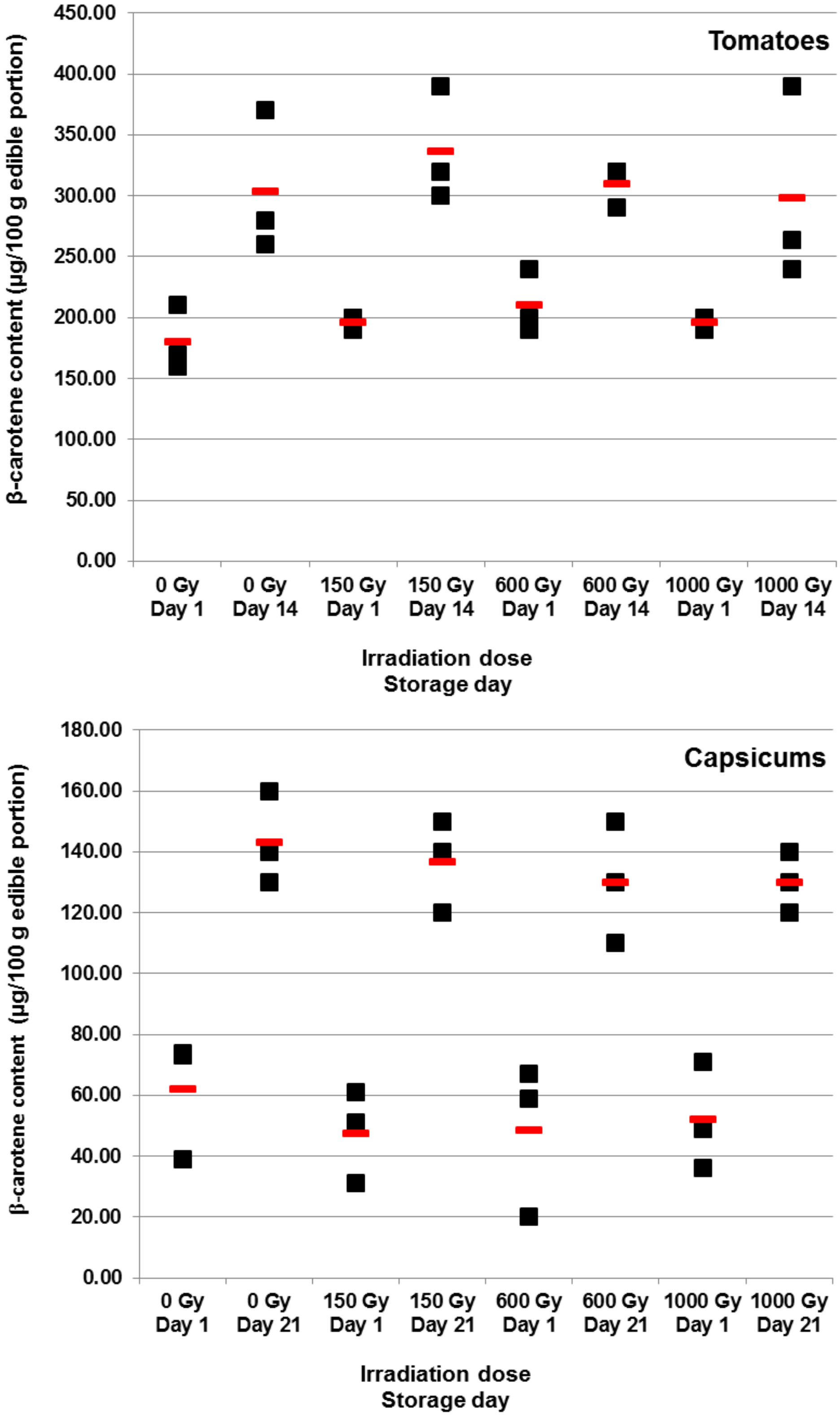

Figure 4.3: β-carotene content of tomatoes (top panel) and capsicums (bottom panel). Each black square represents one of three replicates, with the red line representing the mean of these.

Table 4.4: Nutrient content of irradiated tomatoes per 100 g edible portion (Chay et al, unpublished 2011)

Analyte	Irradiation dose (Gy)			
	0	**150**	**600**	**1000**
Ash (g)				
Day 1	0.57 (0.50-0.60)	0.57 (0.50-0.60)	0.50 (0.50)	0.53 (0.50-0.60)
Day 14	0.47 (0.40-0.50)	0.57 (0.40-0.70)	0.53 (0.50-0.60)	0.47 (0.40-0.50)
Carbohydrates (g)				
Day 1	3.27 (3.10-3.40)	3.07 (3.00-3.10)	3.23 (3.00-3.60)	3.40 (3.10-3.60)
Day 14	3.07 (3.00-3.10)	2.80 (2.60-2.90)	2.93 (2.40-3.20)	3.17 (3.00-3.40)
Fibre (g)				
Day 1	0.73 (0.50-0.90)	1.00 (0.80-1.10)	0.93 (0.80-1.00)	0.93 (0.80-1.10)
Day 14	0.90 (0.80-1.00)	0.90 (0.80-1.00)	0.70 (0.50-0.80)	0.77 (0.60-0.90)
Energy (kJ)				
Day 1	80.7 (77.0-83.0)	79.7 (75.0-86.0)	84.0 (80.0-89.0)	88.3 (86.0-90.0)
Day 14	84.3 (79.0-90.0)	85.7 (82.0-88.0)	77.3 (72.0-84.0)	77.7 (75.0-80.0)
Moisture (g)				
Day 1	94.43 (94.30-94.50)	94.43 (94.20-94.60)	94.27 (94.10-94.40)	94.07 (93.90-94.20)
Day 14	94.57 (94.4-94.7)	94.80 (94.6-95.2)	94.87 (94.3-95.4)	94.80 (94.7-100.7)
Protein (g)				
Day 1	0.83 (0.80-0.90)	0.80 (0.70-1.00)	0.83 (0.80-0.90)	0.93 (0.90-1.00)
Day 14	0.73 (0.70-0.80)	0.93 (0.80-1.30)	0.83 (0.80-0.90)	0.67 (0.60-0.80)
Sodium (g)				
Day 1	16.7 (15.0-20.0)	18.3 (15.0-20.0)	18.3 (15.0-20.0)	15.0 (10.0-20.0)
Day 14	18.3 (15.0-20.0)	21.7 (20.0-25.0)	18.3 (15.0-20.0)	20.0 (15.0-25.0)
Total sugars (g)				
Day 1	2.93 (2.90-3.00)	2.90 (2.80-3.10)	2.97 (2.90-3.00)	2.90 (2.80-3.10)
Day 14	2.87 (2.80-3.00)	2.70 (2.60-2.90)	2.70 (2.40-2.90)	2.90 (2.80-3.00)
Fructose (g)				
Day 1	1.57 (1.50-1.60)	1.53 (1.50-1.60)	1.60 (1.60)	1.53 (1.50-1.60)
Day 14	1.53 (1.50-1.60)	1.47 (1.40-1.60)	1.53 (1.40-1.60)	1.53 (1.50-1.60)
Glucose (g)				
Day 1	1.37 (1.30-1.40)	1.37 (1.30-1.50)	1.40 (1.40)	1.37 (1.30-1.50)
Day 14	1.30 (1.20-1.40)	1.23 (1.20-1.30)	1.20 (1.0-1.40)	1.33 (1.30-1.40)
Sucrose (kJ)	Not detected	Not detected	Not detected	Not detected
Maltose (g)	Not detected	Not detected	Not detected	Not detected
Fat (g)				
Day 1	0.12 (0.10-0.20)	0.17 (0.10-0.20)	0.20 (0.20)	0.20 (0.20)
Day 14	0.33 (0.20-0.50)	0.40 (0.20-0.50)	0.20 (0.10-0.30)	0.17 (0.10-0.20)
Monounsaturated fat (g)	Not detected	Not detected	Not detected	Not detected
Polyunsaturated fat (g)	Not detected	Not detected	Not detected	Not detected
Saturated fat (g)	Not detected	Not detected	Not detected	Not detected
Trans fat (g)	Not detected	Not detected	Not detected	Not detected

Results expressed as the mean of three replicate, with the range contained in parentheses

Table 4.5: Nutrient content of irradiated green capsicums (Chay et al, unpublished 2011)

Analyte	Irradiation dose (Gy)			
	0	150	600	1000
Ash (g)				
Day 1	0.37 (0.30-0.40)	0.50 (0.40-0.60)	0.47 (0.40-0.50)	0.50 (0.50)
Day 21	0.40	0.40±0.00	0.30	0.37
Carbohydrates (g)				
Day 1	3.43 (3.30-3.50)	3.30 (3.10-3.50)	3.33 (3.30-3.40)	3.20 (3.10-3.30)
Day 21	2.90$^{\#}$ (1.10-1.40)	3.07$^{\#}$ (2.90-3.20)	3.00$^{\#}$ (2.80-3.20)	3.23 (3.10-3.40)
Fibre (g)				
Day 1	1.60 (1.50-1.70)	1.57 (1.40-1.80)	1.57 (1.50-1.70)	1.43 (1.40-1.50)
Day 21	1.27 (1.10-1.40)	1.27 (1.20-1.30)	1.23 (1.0-1.40)	1.27 (1.20-1.30)
Energy (kJ)				
Day 1	95.3 (92.0-98.0)	91.7 (87.0-95.0)	92.7 (91.0-94.0)	88.0 (85.0-91.0)
Day 21	82.7$^{\#}$ (79.0-86.0)	84.3$^{\#}$ (84.0-85.0)	86.3$^{\#}$ (84.0-88.0)	89.7 (84.0-94.0)
Moisture (g)				
Day 1	93.43 (93.20-93.60)	93.47 (93.20-93.90)	93.50 (93.30-93.70)	93.77 (93.50-94.00)
Day 21	94.30$^{\#}$ (94.20-94.40)	94.20$^{\#}$ (94.10-94.30)	94.40$^{\#}$ (94.30-94.60)	93.97* (93.80-94.20)
Protein (g)				
Day 1	0.97 (0.90-1.00)	0.93 (0.90-1.00)	0.87 (0.80-1.00)	0.87 (0.90-0.90)
Day 21	0.90 (0.90)	0.80 (0.80)	0.83 (0.80-0.90)	0.87 (0.80-0.90)
Sodium (g)				
Day 1	8.3 (5.0-10.0)	16.7 (15.0-20.0)	16.7 (15.0-20.0)	15.0 (10.0-20.0)
Day 21	20.0$^{\#}$ (15.0-30.0)	7.3$^{\#}$ (5.0-10.0)	11.7 (10.0-15.0)	11.7 (10.0-15.0)
Total sugars (g)				
Day 1	2.93 (2.90-3.00)	2.83 (2.70-2.90)	2.73 (2.60-2.90)	2.60 (2.40-2.80)
Day 21	1.73$^{\#}$ (1.40-2.00)	2.37$^{\#}$ (2.30-2.40)	2.10$^{\#}$ (1.40-2.50)	2.70 (2.60-2.90)
Fructose (g)				
Day 1	1.43 (1.40-1.50)	1.40 (1.40)	1.40 (1.40)	1.30 (1.20-1.40)
Day 21	0.83$^{\#}$ (0.60-1.00)	1.27 (1.20-1.30)	1.13 (0.70-1.40)	1.53* (1.50-1.60)
Glucose (g)				
Day 1	1.47 (1.40-1.50)	1.40 (1.30-1.50)	1.37 (1.30-1.40)	1.30 (1.20-1.40)
Day 21	0.90$^{\#}$ (0.80-1.00)	1.10$^{\#}$ (1.10)	0.97$^{\#}$ (0.7-1.1)	1.23 (1.20-1.30)
Sucrose (kJ)	Not detected	Not detected	Not detected	Not detected
Maltose (g)	Not detected	Not detected	Not detected	Not detected
Fat (g)				
Day 1	0.20 (0.20)	0.20 (0.20)	0.22 (0.20-0.26)	0.20 (0.20-0.21)
Day 21	0.24 (0.21-0.28)	0.23 (0.21-0.26)	0.27 (0.25-0.29)	0.27 (0.23-0.30)
Monounsaturated fat (g)	Not detected	Not detected	Not detected	Not detected
Polyunsaturated fat (g)				
Day 1	0.10 (0.10)	0.13 (0.10-0.20)	0.12 (0.10-0.20)	0.10 (0.10)
Day 21	0.16 (0.10-0.20)	0.10 (0.10)	0.20 (0.20)	0.20 (0.20)
Saturated fat (g)	Not detected	Not detected	Not detected	Not detected
Trans fat (g)	Not detected	Not detected	Not detected	Not detected

Results expressed as the mean of 3 replicates, with the range contained in parentheses; *p<0.05 compared to the concurrent control; #p<0.05 compared to the corresponding day 1 value

Table 4.6: Results of published studies on the effect of irradiation on selected nutrients in tomatoes and capsicums

Sample description	Experimental conditions	Results/Evaluation	Reference
Tomato			
Freshly harvested Early Pak No. 7 and/or Ace varieties. Fruits were graded based on maturity (mature-green, breaker stage, pinks & table-ripe).	100 fruits per treatment were irradiated within 36 hours of harvest at 0.5, 2, 3, 4 or 6 kGy then stored at 20ºC for up to 15 days. Ascorbic acid was analysed in 10 fruits per treatment, with at least two replicates. Data were not statistically analysed and standard deviations were not calculated.	Graphically-presented data illustrated variable declines in ascorbic acid in irradiated and non-irradiated fruit during storage; the overall pattern of decline was reasonably consistent across all treatments and fruit grade. However, the absence of standard deviations precludes a proper interpretation of the variability of the results. The study is considered to have limited regulatory value.	Abdel-Kader et al (1968)
Freshly harvested *Lutescent* tomato genetic line. Fruits were washed and graded according to size and maturity.	Fruits were irradiated at 0, 1, 3, 5, 7 or 10 kGy then stored at 24ºC for 0, 4, 10, 12 or 16 days. 5 fruits per treatment per time were analysed for carotenoids (phytoene, phytofluene, ξ-carotene, lycopene, β-zeacarotene, γ-carotene, β-carotene and total carotenoids).	Results were reported only for the 1 and 3 kGy doses and stage 1 & 2 fruits due to the occurrence of damage or mould infection at higher irradiation doses or in more mature fruit. There was no apparent difference in carotenoid content at day 0 (immediately after irradiation). Thereafter, all groups (i.e. irradiated and non-irradiated) showed a time-related increase in carotenoids attributable to ripening. In the absence of standard deviations, it is not possible to interpret the results in the context of the variability within and between groups. Stage 1 fruit (white, yellowish green around the stem end): The mean concentrations of all analysed carotenoids in tomatoes irradiated at 3 kGy were consistently lower (up to ~6-fold) than the control at every time point. The mean concentrations of most carotenoids in tomatoes irradiated at 1 kGy were comparable to the control; the exceptions were lycopene and β-carotene, which had ~half the concentration of the control. Stage 2 fruit (white, slightly yellow around the stem end): Fruit irradiated at 1 kGy had a comparable carotenoid content to the control. A similar pattern of lower carotenoid concentrations was noted in tomatoes irradiated at 3 kGy, although by the 12th day of storage concentrations were approaching that of the control. The lower carotenoids may be attributed to a delay in ripening in irradiated fruit (carotenoid synthesis) rather than to irradiation destroying existing carotenoids.	Villegas et al (1972)
Green-mature tomato fruits, variety Money maker.	Fruits were dipped in hot water (60ºC) for 2 minutes prior to irradiation at 0, 1, 2, 3 or 4 kGy. Fruits were stored at room temperature for an unspecified time prior to the analysis of ascorbic acid, total sugars and amino acids. Samples size unspecified.	In the absence of adequate reporting detail it is unclear how many samples were analysed, but it appears that only single point measurements were made. On this basis, the study is considered to have limited regulatory value. At 1 kGy, the concentration of ascorbic acid and total sugars was comparable to the non-irradiated control. At higher irradiation doses, ascorbic acid and total sugars were qualitatively lower than the control. Total amino acids were qualitatively higher than the control in irradiated fruit.	El-Sayed (1978)

Sample description	Experimental conditions	Results/Evaluation	Reference
Freshly harvested *Lycopersicon esculentum* L. variety Monte Carlo. Greenish-yellow or mature-green stage of ripening. Fruits were washed and graded prior to irradiation.	Irradiated at 24 or 48 hours after harvest at 0, 1, 2, 3 or 4 kGy (40 fruits per treatment). Fruits were stored illuminated at 25-27ºC for ~18 (green) or 22 (mature) days. Ascorbic acid and carotenoids (phytoene, phytofluene, β-carotene, lycopene, total) were analysed in composite/pooled samples.	The use of single point measurements from a pooled sample limits the value of this study, particularly in relation to determining normal variability in ascorbic acid and carotenoid content within and between fruits of differing maturity. The data do not allow a quantitative comparison to be made between irradiated and non-irradiated fruit. The study is viewed as a pilot study and cannot be used for regulatory purposes. Qualitatively, ascorbic acid concentrations were lower in irradiated tomatoes. There was no consistent, discernible, dose-related effect on carotenoids.	Al-Wandawi et al (1985)
***Lycopersicon esculentum* sourced from a local market.** Fruit was washed in water and cut into slices.	100 g portions of pre-cut fruits were irradiated at 0 or 1 kGy then stored refrigerated for 3 days prior to analysis. Samples (n=3) were analysed immediately after irradiation or following 3 days of refrigerated storage for ascorbic acid, total carotenoids and tocopherols (γ and α-tocopherol).	Graphically-presented data illustrated that there was no difference in total carotenoid or vitamin C content between irradiated and non-irradiated fruit. Graphically-presented data illustrated that the mean α-tocopherol concentration was ~40% lower than the control in irradiated fruit. In both irradiated and non-irradiated fruit, mean α-tocopherol concentrations increased following storage for 3 days (~13% increase in the control and ~36% in irradiated fruit).	Mohácsi-Farkas et al (2006)
Whole, mature *Lycopersicon esculentum*, variety Madanapally. Fruit was sourced from a local field, graded (based on size and ripeness), washed then dipped in benomyl.	Fruits (10 per bag) were irradiated at 0, 1, 2, 3 or 4 kGy then stored for 0, 7, 14 or 21 days at 12ºC. Total sugar, lycopene and ascorbic acid were analysed (n=3).	Data were only presented graphically without standard deviations. The lack of reporting detail limits the regulatory value of the study. There was no apparent difference in total sugar, lycopene or ascorbic acid on day 0. Temporal changes in these analytes were noted across all groups due to ripening. On day 21, the lycopene content of tomatoes irradiated at 4 kGy was significantly lower ($p<0.05$) than all other groups, which was attributed by the authors to delayed biosynthesis.	Mathew et al (2007)
***Lycopersicon esculentum* L.** **Source and maturity unreported.** Treated with 100 ppm chlorine solution for 2 minutes prior to slicing (0.3 cm thick).	175 g sliced tomato irradiated at 0 or 1 kGy then stored for 1 or 14 days at 4ºC. Ascorbic acid was measured in 4 replicates.	No significant difference in mean ascorbic acid content 1 day after irradiation (132.8 ± 16.1 *versus* 147.6 ± 16.1 µg/g fresh weight in the control). Significantly lower ($p<0.05$) mean ascorbic acid content 14 days after irradiation (111.4 ± 16.2 *versus* 144.9 ± 5.1 µg/g fresh weight in the control). Note: The ascorbic acid content of irradiated and non-irradiated tomatoes was ~30-50% lower than that published by FSANZ (Table 4.1).	Fan & Sokorai (2008b)
Capsicum			

Sample description	Experimental conditions	Results/Evaluation	Reference
Green and red *Capsicum annum*, Five Star variety (edible-ripe stage). Sourced from commercial suppliers in southeast Queensland, Australia. (minimum class 1 grade). Fruit dipped in approved fungicide and held in cool storage until irradiation.	Cartons of whole fruit were irradiated at 0, 75 or 300 Gy. Total vitamin C, dehydroascorbic acid, organic acids (citric, malic, tartaric & succinic) and sugars (fructose, glucose & sucrose) were analysed in 6 pieces of capsicum per treatment within 7 days prior to irradiation, immediately after irradiation and after storage for 3 weeks at 1-7ºC.	*Green capsicums*: Prior to (but not after) storage, significantly higher ($p<0.05$) citric acid was measured in capsicums irradiated at 75 Gy (but not 300 Gy) relative to the control (1.3 *versus* 1.0 mg/100 g, respectively). There were no other significant differences between irradiated and non-irradiated fruit. Increased total vitamin C (~2-fold) and decreased glucose and fructose (~40-50%) occurred during storage in both irradiated and non-irradiated fruit. *Red capsicums*: 20-25% increase ($p<0.05$) in the citric acid content of irradiated fruit (both 75 and 300 Gy) relative to the control. No changes in vitamin C or sugars during storage.	Mitchell et al (1992)
Yellow *Capsicum annum* purchased from a local market. The surface was wiped with a dry cloth and the fruit cut in to ~20 mm slices.	Fruit irradiated at 0 or 1 kGy then stored at 5, 10 or 15ºC for 2, 3 or 4 days Ascorbic acid, dehydroascorbic acid and β–carotene were analysed in an unspecified number of samples. Details of statistical analysis and standard deviations were unreported.	Time point comparisons between irradiated and non-irradiated fruit indicated no difference in mean ascorbic acid content following 3 days of storage at 10ºC, with lower mean ascorbic content in irradiated fruit following storage at 0, 2 and 4 days (13, 18 and 16% lower respectively). However, these differences were in the range of those time-related losses of ascorbic acid measured in non-irradiated fruit (up to a 23% loss). In contrast, the time-related loss in total ascorbic acid in irradiated fruit was smaller than the control (up to 9%). β-carotene in irradiated fruit was ~10-20% higher ($p<0.05$) than the control following 10 days of storage.	Farkas et al (1997)

Sample description	Experimental conditions	Results/Evaluation	Reference
Variety and maturity unspecified. Samples sourced from a local market, washed and sliced into rings.	200 g of sliced capsicum was irradiated at 0, 1, 2 or 3 kGy and stored at 5ºC or 10ºC for 0, 1, 2, 3 or 4 weeks (n=2). Ascorbic acid, chlorophyll and total carotenoids were analysed in triplicate.	Graphically-presented data illustrated no discernible difference in ascorbic acid, chlorophyll or total carotenoids between irradiated and non-irradiated fruit following storage at 5ºC or 10ºC for up to 4 weeks. Marginal to minimal losses of ascorbic acid, chlorophyll and total carotenoids occurred over time in all groups (i.e. irradiated and non-irradiated), apparently more so in the control and at 10ºC.	Ramamurthy et al (2004)

In some studies, analysis of other fruits and vegetables, fruit quality and other parameters was also undertaken but these results have not been included.

4.3 Discussion and conclusion

In this nutrition assessment, the effect of the proposed irradiation of tomatoes and capsicums up to a maximum of 1 kGy on irradiation sensitive vitamins or provitamins has been evaluated. Pivotal data for those nutrients most likely to be sensitive to irradiation and to be present in tomatoes and capsicums in nutritionally relevant amounts (vitamin C, β-carotene), came from an unpublished study submitted by the Applicant (Chay et al 2011). In this study, whole ripe tomatoes and capsicums were irradiated then stored under conditions comparable to those proposed to be used. The results of this study indicated that irradiation had no effect on the nutrient content of fresh red tomatoes and green capsicums, including on the vitamin C and β-carotene levels. Consistent with changes in nutrients during storage observed for other fruits and vegetables, storage of both irradiated and non-irradiated green capsicums resulted in changes in the carbohydrate, energy, moisture, sodium, total sugars, fructose or glucose content. These time-related changes are attributable to general senescence following ripening of the fruit.

Supplementary published studies (Table 4.6) were focussed predominantly on the effect of irradiation on the more sensitive vitamins including vitamin C, carotenoids and vitamin E. A number of these studies were of limited regulatory value because of poor experimental design and/or inadequate reporting detail (Abdel-Kader et al 1968; El-Sayed 1978; Al-Wandawi et al 1988; Mathew et al 2007). The remaining studies varied widely in terms of sample preparation (e.g. fruit variety, source, maturity and pre-irradiation processing such as slicing), irradiation conditions (e.g. temperature), post-irradiation storage conditions (e.g. temperature, duration) and methods of vitamin analysis. These factors are likely contributors to the variable nature of the results between the different studies.

Villegas et al (1972) found no immediate effect of irradiation up to 3 kGy on the carotenoid content of immature tomatoes. During storage, the carotenoid content of both irradiated and non-irradiated fruit increased, more so in the non-irradiated fruit. On this basis, irradiation appeared to delay the ripening process and consequent formation of carotenoids. A similar pattern of delayed ripening was described by Fan and Sokorai (2008b) who found no difference in the vitamin C content of tomatoes 1 day after irradiation relative to the control, but significantly reduced vitamin C after 14 days. Mohácsi-Farkas et al (2006) reported that α-tocopherol (but not γ-tocopherol, vitamin C or carotenoids) was lower in irradiated sliced tomato compared to the non-irradiated control but the data were not statistically analysed or compared with the normal range of tocopherols in non-irradiated tomatoes; storage resulted in an increase in tocopherols in both irradiated and non-irradiated fruit. These data suggest that irradiated immature tomatoes that have been stored may have a lower vitamin C, carotenoid or vitamin E content than non-irradiated fruit. This is likely to be attributable to a delay in ripening rather than the loss of pre-existing vitamins.

Time-related changes in nutrient levels occurred in irradiated and non-irradiated capsicums, consistent with the observations in tomatoes. Mitchell et al (1992) detected no effect of irradiation on vitamin C or sugars following the irradiation of green or red capsicums. However, citric acid was increased by ~25%. In another study, the vitamin C content of irradiated sliced green capsicums was ~15% lower than non-irradiated fruit, but this difference was less than the losses of vitamin C occurring in non-irradiated fruit during storage (up to 23%) (Farkas et al 1997). In this same study, irradiated capsicums had ~10-20% higher β-carotene following 10 days of storage. No discernible differences were identified in the levels of ascorbic acid, chlorophyll or total carotenoids between irradiated and non-irradiated fruit following storage at 5ºC or 10ºC for up to 4 weeks (Ramamurthy et al 2004).

No data were identified on the effect of irradiation on the thiamin, folate, riboflavin, niacin, vitamin B_6, vitamin B_{12}, pantothenic acid, biotin, choline, vitamin K and vitamin D content of tomatoes or capsicums. In addition, no data on the effect of irradiation on the vitamin E content of capsicums was found. However, given that tomatoes and capsicums contain low or negligible amounts of these vitamins, irradiation is unlikely to result in any nutritional impacts.

On the basis of the above considerations, the weight-of-evidence indicates that the irradiation of whole, ripe tomatoes or capsicums up to the proposed maximum irradiation dose of 1 kGy is unlikely to result in a discernible effect on nutrient content. There is limited evidence that the irradiation of immature and/or sliced fruit may result in lower concentrations of some vitamins compared to counterpart non-irradiated fruit, but these differences are within the range of the vitamin losses that normally occur during the storage of non-irradiated fruit. Further, other food processing techniques have been demonstrated to have a larger impact on the vitamin content of fruits and vegetables than irradiation.

Response to Question 4: *Does irradiation affect the nutrient composition of fresh tomatoes and capsicums?*

Irradiation at doses up to 1 kGy appears to have no consistent effect on the levels of irradiation sensitive vitamins or provitamins (ie. vitamin C and β-carotene) or the nutrient composition of tomatoes and capsicums. There is limited evidence that the irradiation of immature and/or sliced fruit may result in slightly lower concentrations of some vitamins compared to counterpart non-irradiated fruit, but these reported reductions fall well within the range of the vitamin losses that normally occur during the storage of non-irradiated fruit.

Response to Question 5: *If so, how does this effect compare to effects from other post-harvest and processing procedures?*

Other food processing techniques such as cooking, drying or freezing have been demonstrated to have a larger impact on the vitamin content of fruits and vegetables than irradiation.

5. Dietary intake assessment

5.1 Introduction

Although the weight of evidence indicates that irradiation up to 1 kGy is unlikely to have any discernible effect on the nutrient content of tomatoes and capsicums, a dietary intake assessment (DIA) was carried out to provide context on the contribution of tomatoes and capsicums to the nutrient intake of Australians and New Zealanders. It provides a 'worst case' estimate of the potential impact of irradiation on population nutrient intakes, assuming that irradiation could reduce nutrient levels in all fruits and vegetables currently, or proposed to be, permitted to be irradiated (tomatoes, capsicums and selected tropical fruits).

This DIA assesses the potential impact on population nutrient intakes of irradiation of tomatoes and capsicums up to the maximum dose proposed (1 kGy), and also includes any nutritional impact from those tropical fruits already permitted to be irradiated, in order to present a cumulative assessment of the potential effects of current and requested irradiation permissions on population nutrient intakes.

Herbs, spices and herbal infusions also have permissions for irradiation in the Code. However, as nutrient intakes from these foods are negligible, consideration of the nutritional impact of irradiation of these foods has not been included in this assessment.

As discussed in Section 4 – Nutrition Assessment, of this report, macronutrients and minerals are unlikely to be affected by irradiation. Therefore, this DIA is limited to consideration of the impact of irradiation on population intakes of those micronutrients identified as being irradiation-sensitive. These nutrients are water- and fat-soluble vitamins.

The overall nutritional status of Australians and New Zealanders is not being assessed.

5.2 Dietary Intake Assessment methodology

A DIA is the process of estimating how much of a nutrient a population, or population sub-group, consumes. Dietary intake of nutrients, or exposure to food chemicals, is estimated by combining food consumption data with nutrient content or food chemical concentration data. The process of doing this is called ‘dietary modelling’.

Dietary intake = nutrient concentration x food consumption

FSANZ’s approach to dietary modelling is based on internationally accepted procedures for estimating dietary exposure to food chemicals, including nutrients. Different dietary modelling approaches may be used depending on the assessment, the type of food chemical, the data available and the risk assessment questions to be answered. In the majority of assessments, FSANZ uses the food consumption data from each person in the most recent national nutrition surveys (NNSs) for Australia and New Zealand to estimate their individual dietary exposure to the food chemical of interest. Population summary statistics, such as the mean exposure or a high percentile exposure, are derived from each individual’s ranked exposure. Dietary intake assessments are conducted using FSANZ’s custom built dietary modelling program, DIAMOND.

For this assessment, FSANZ has used a ‘second day adjusted nutrient intake method’ which better estimates longer term population nutrient intakes when only one or two days of dietary data are available. Because nutrients are widespread in foods and almost all survey respondents will have a nutrient intake on any given day, it is possible to apply a statistical adjustment to estimate usual, longer-term nutrient intake, even when only a subset of respondents participated in more than one day of food recalls. Using adjusted intakes provides better information for risk characterisation purposes as it facilitates comparison with health based guidance values, which describe requirements over the long-term and are expressed as values per day for convenience only. To calculate usual daily nutrient intakes, more than one day of food consumption data is required for at least 10% of nutrition survey respondents, and population nutrient intake distributions should approximate normality.

Where results for per cent contributions of food groups to total nutrient intakes are presented, these are based on unadjusted day 1 data only.

Dietary intakes of nutrients presented by FSANZ are usually referred to as ‘estimated’. By the very nature of food composition and food consumption data, that have a degree of uncertainty, and use of dietary modelling methodologies, an exact intake value can never be determined, only estimated. Therefore, all of the dietary intakes presented in this report should be considered as the best estimates based on the data and methodologies available.

Estimated nutrient intakes calculated by FSANZ vary slightly from those reported in the publications for each Australian and New Zealand national nutrition surveys (NNS) due to variations in the statistical methodologies used to estimate longer term population nutrient intakes.

Further detailed information on the principles of conducting dietary exposure assessments at FSANZ is provided in *Principles and Practices of Dietary Exposure Assessment for Food Regulatory Purposes* (FSANZ 2009)[6].

5.2.1 Food consumption data

FSANZ uses food consumption data from the most recent NNSs to estimate dietary intake of nutrients for the Australian and New Zealand populations. The design of each of these surveys varies somewhat and key attributes of each are set out below.

2007 Australian Children's Nutrition and Physical Activity Survey (2007 ANCNPAS)

The 2007 ANCNPAS collected data on nutrition and physical activity for 4,487 children aged 2-16 years across Australia. The survey was conducted over a seven month time period, from February to August 2007. The results of the 2007 ANCNPAS were weighted to represent the overall population of Australian children because stratified sampling with non-proportional samples was used.

In contrast to other national nutrition surveys used to date by FSANZ (e.g. the 1995 NNS), in the 2007 ANCNPAS each respondent completed two 24-hour recalls on non-consecutive days. The availability of two days of food consumption data provides a more realistic estimate of long term consumption of infrequently consumed foods, because it takes account of those who may eat a food on one day of the survey but not on the other. Using only one 24-hour recall may capture an unusual eating occasion for an individual that does not describe how they normally eat.

Australian 1995 National Nutrition Survey (1995 NNS)

The 1995 NNS provides comprehensive information on dietary patterns of a sample of 13,858 Australians aged 2 years and above. The survey used a 24-hour recall method for all respondents, with 10% of respondents also completing a second 24-hour recall on another, non-consecutive day. The data were collected over a 13 month period. These data are used unweighted in DIAMOND. It is the most recent NNS for Australians aged 17 years and above. Only the data from respondents aged 17 years and above from this survey were used in this assessment.

New Zealand 2002 National Children's Nutrition Survey (2002 NCNS)

The 2002 NCNS provides comprehensive information on the dietary patterns of a nationally representative sample of 3,275 New Zealand children aged 5-14 years, including sufficient numbers of children in the Māori and Pacific groups to enable ethnic-specific analyses. The survey was conducted using a 24-hour recall methodology and collected data on dietary supplements as well as foods and beverages. A repeat 24-hour diet recall was obtained from a subsample of 15% of respondents. The results of the 2002 NCNS were weighted to represent the overall population of New Zealand children because stratified sampling with non-proportional samples was used in the survey.

[6] http://www.foodstandards.gov.au/scienceandeducation/scienceinfsanz/dietaryexposureassessmentsatfsanz/

New Zealand 1997 National Nutrition Survey (1997 NNS)

The 1997 NNS provides comprehensive information on the dietary patterns of a sample of 4,636 respondents aged from 15 years and above. The survey was conducted on a stratified sample over a 12 month period. The survey used a 24-hour recall methodology with 15% of respondents also completing a second 24-hour recall.

Further information on the National Nutrition Surveys used to conduct dietary exposure assessments is available on the FSANZ website[7].

5.2.2 Use of dietary supplement data

Both the 2002 NCNS and 2007 ANCNPAS collected detailed information on children's use of dietary supplements. These data have been excluded from this assessment in order to provide a more conservative 'worst case' estimate of children's baseline nutrient intakes and to determine percentage contribution of foods only to population irradiation-sensitive nutrient intakes.

5.2.3 Nutrient concentration data for Australian and New Zealand foods

FSANZ generates and compiles Australia's most comprehensive nutrient composition data using a range of methods including analytical programs, manufacturers' data, estimation and by using recipes. These nutrient composition data are publically available as electronic food composition databases and are available in two forms, the NUTTAB 'reference database' and the AUSNUT 'survey specific' databases.

Each AUSNUT database has been developed by FSANZ specifically to provide nutrient data for the relevant Australian NNS. Each AUSNUT database contains nutrient data for those foods and beverages reported as consumed in the survey and the nutrients of interest for the survey. They contain a complete dataset of reported nutrients for each food.

AUSNUT 2007 (FSANZ 2007) is FSANZ's most recent survey specific nutrient database developed for estimating nutrient intakes from foods, beverages and dietary supplements consumed as part of the 2007 ANCNPAS. The database contains 37 nutrient values for the 4225 foods, beverages and dietary supplements consumed during the 2007 ANCNPAS. It contains analytical data, as well as nutrient data taken from overseas food composition tables, food label information, data imputed from similar foods or data calculated using a recipe approach.

Similarly, AUSNUT 1999 (FSANZ 1999) was developed to provide nutrient data for the approximately 4,500 foods, including 1,300 recipe foods, reported as consumed in the 1995 NNS. Twenty eight nutrient values were originally reported for each food.

Nutrient composition data used in association with the New Zealand nutrition surveys was collected and compiled in the New Zealand Food Composition Database (NZFCD), jointly owned by the New Zealand Institute for Plant & Food Research Limited and the Ministry of Health. At the time the 2002 NCNS was conducted, the NZFCD contained the composition of approximately 2000 foods. If a direct match for a food in the NZFCD was not available for a food consumed in the New Zealand nutrition survey, and the frequency of consumption of that food was high relative to other foods, additional nutrient composition data were sought either from overseas databases (Australian, USA and British) if applicable, or the food item was recommended for analysis in New Zealand. The NZFCD is compiled and regularly updated by Plant and Food Research Limited.

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7 http://www.foodstandards.gov.au/scienceandeducation/scienceinfsanz/dietaryexposureassessmentsatfsanz/foodconsumptiondatau4440.cfm

The source of the concentration data and assumptions for specific nutrients relevant to irradiated foods used in the assessment are detailed below.

Vitamin B_6

There were no concentration data from AUSNUT 1999 for vitamin B_6 in Australian foods; therefore, data from the 1997 NZ NNS were matched with foods from the 1995 NNS. Vitamin B_6 was also not included in AUSNUT 2007. Therefore, data from the 1995 NNS were used for the assessment of the impact of irradiation of tomatoes and capsicum on vitamin B_6 intakes for Australian children.

β-carotene

For each Australian and New Zealand nutrition survey, concentration data for carotenes (provitamin A) are reported for each food consumed. β-carotene concentration data are not specifically reported. There are three carotenoids which can be converted to vitamin A: β-carotene, α-carotene and β-cryptoxanthin, of which the latter two have approximately half the vitamin A activity of β-carotene. For the purposes of this assessment, the modelling assumed that all pro-vitamin A carotenes concentrations in food were derived from β-carotene and the term 'carotenes' is used throughout the DIA.

Niacin

Niacin equivalents are reported for all nutrition surveys and population groups. This includes niacin and niacin derived from the amino acid tryptophan.

Vitamin E

Vitamin E is a group of eight naturally occurring isomers, of which α-tocopherol is the most biologically active and abundant form. Vitamin E is reported as α-tocopherol equivalents, in all nutrition surveys and population groups assessed.

Vitamin K

Vitamin K has not been included in this assessment as FSANZ does not hold composition data for this nutrient for foods consumed in any Australian or New Zealand nutrition survey. However, the impact of irradiation on population vitamin K intakes is expected to be minimal as vitamin K is the least sensitive to irradiation of the fat-soluble vitamins (see Nutrition Assessment, Section 4.1.2) and the major dietary sources of vitamin K are not the foods of interest to this application or which have current irradiation permissions. The main sources of Vitamin K are green leafy vegetables, such as kale, spinach, salad greens, cabbage, broccoli and Brussels sprouts, and certain plant oils such as soybean and canola oils and margarines and salad dressings made from them (NHMRC 2006).

Other nutrients

The available food composition data for pantothenic acid, biotin and choline were not sufficient to enable a dietary intake assessment to be conducted. Whilst there are small amounts of data available, these data were either not from Australian or New Zealand sources, were not extensive enough across the whole diet, were not in the correct format or had not been assessed for accuracy. Estimated Average Requirements[8] (EARs) have not been established for these substances and there is little or no evidence of deficiencies of these nutrients in the general population (NHMRC 2006).

[8] The EAR is defined as: 'A daily nutrient level estimated to meet the requirements of half the healthy individuals in a particular life stage and gender group' (NHMRC 2006).

5.2.4 Non-nutrient concentration data

Intakes of substances that do not have established nutrient roles, nor established health-based guidance values, have not been quantified in this DIA. This includes the carotenoids lycopene and lutein.

5.2.5 Population groups assessed

Population groups assessed were matched as closely as possible, within the limitations of the nutrition surveys and the DIAMOND dietary modelling program, to those age groups to which Nutrient Reference Values[9] (NRVs) (NHMRC 2006) apply (refer to Table 5.1).

Estimated Average Requirements (EAR) and Adequate Intakes (AI)[10] for some of the irradiation-sensitive nutrients vary by gender for some NRV age groups. However, even where EARs or AIs are the same for both genders in an NRV age group, dietary intakes were split by gender for all age groups as there were differences in foods consumed and therefore differences in nutrient intakes for males and females.

For some nutrients, specific NRVs are set for the population sub-groups of pregnant or lactating women. However, because the aim of this assessment is to compare intakes before and after irradiation, only general population intakes by age and gender have been assessed.

Table 5.1: NRV age groups and Australian and New Zealand population groups assessed

NRV Age Group	Australia		New Zealand	
	Age group assessed	National Nutrition Survey	Age group assessed	National Nutrition Survey
1-3 years	2-3 years	2007 ANCNPAS	-	-
4-8 years	4-8 years		5-8 years	2002 NCNS
9-13 years	9-13 years		9-13 years	
14-18 years*	14-16 years		14 years	
	17-18 years	1995 NNS	15-18 years	1997 NNS
19-30 years**	19-29 years		19-29 years	
31-50 years**	30-49 years		30-49 years	
51-70 years**	50-69 years		50-69 years	
>70 years**	70 years and above		70 years and above	

* The NRV age group of 14-18 years were assessed in two age ranges for both Australia and New Zealand as the food consumption data for this age group spans the two national nutrition surveys used in each country.

** There is a slight misalignment in relation to the NRV age group and the age groups that were reported in the 1995 NNS and subsequently used in DIAMOND (e.g. NRV age group = 31-50 years, NNS age group = 30-49 years). Nutrient intakes for the 1997 NNS are reported for the same age groups as for the 1995 NNS.

5.3 Tiered approach to the dietary intake assessment

A tiered approach to the DIA was used for this assessment, which is shown in Figure 5.1 and described below. Each nutrient identified as being irradiation-sensitive was assessed using this approach.

[9] Nutrient Reference Values (NRV) are health based guidance values that indicate the daily amount of nutrients required for good health, and for some nutrients safe intake levels.

[10] The AI is defined as: 'the average daily nutrient intake level based on observed or experimentally-determined approximations or estimates of nutrient intake by a group (or groups) of apparently healthy people that are assumed to be adequate' (NHMRC 2006).

5.3.1 Screening Step 1

Do the potentially irradiated fresh commodities contain more than a trace amount of the irradiation-sensitive nutrient at baseline?

Using Australian, New Zealand or, where no Australian or New Zealand data were available, international nutrient concentration data, the average concentration of each irradiation-sensitive nutrient was identified for each potentially irradiated food commodity. 'Potentially irradiated' refers to any commodity with irradiation permissions in the Code, as well as tomatoes and capsicums.

If the irradiation-sensitive nutrient was not present or present only in trace (i.e. unquantifiable) amounts in the potentially irradiated fruits and vegetables, then it was assumed that those fruits and vegetables would not be contributors to that nutrient's dietary intake for any population group assessed and no further assessment of that nutrient was required.

If the irradiation-sensitive nutrient was present in more than trace amounts in the potentially irradiated fruits and vegetables, then further assessment was required to determine if those fruit and vegetables were a significant contributor to any Australian and New Zealand population group's dietary intake of that nutrient.

5.3.2 Screening Step 2

Do food groups containing potentially irradiated fresh commodities contribute >5% to nutrient intake for any population group at baseline nutrient concentrations?

Foods identified as consumed in each Australian and New Zealand NNS are categorised, using traditional food groupings (e.g. meat, dairy, non-alcoholic beverages) and a numbered hierarchy, into major (2 digit, e.g. 'vegetables', 'fruit'), minor (3 or 4 digit, e.g. 'tomatoes and tomato products', and 'tropical fruit') and specific (4 or 5 digit, e.g. 'tomatoes', 'other tropical fruit') food groups. Food groupings and associated numbered codes vary slightly between each NNS as classification systems and methods of collecting food consumption data in Australia and New Zealand have evolved over time.

In screening step 2, major contributors to nutrient intakes for Australian and New Zealand population groups were evaluated at the major and minor food group levels. Consistent with FSANZ's dietary exposure assessment methodologies, major contributors to dietary intake are considered to be those food groups contributing 5% or more to a nutrient's dietary intake for one or more population groups.

A summary of the food grouping hierarchy for food groups containing the potentially irradiated foods is included at Appendix 1, Table A.1.

If any minor food group containing a potentially irradiated food commodity contributes 5% or more to any population group's irradiation-sensitive nutrient intake, then further assessment is required for that nutrient.

If all major or minor food groups containing a potentially irradiated food commodity contribute <5% to all population groups' irradiation-sensitive nutrient intake, then no further assessment is required for that nutrient.

5.3.3 Refined Assessment Step 3

Does maximum reduction of the irradiation-sensitive nutrient in potentially irradiated fresh commodities result in a decrease in mean or 5th percentile nutrient intakes of >5% for two or more population groups?

For each population group assessed, the intake of irradiation-sensitive nutrients was determined both at baseline (assuming no irradiation of any commodity) and using a 'worst case' scenario where a maximum nutrient loss due to irradiation of the fresh commodity was assumed.

This scenario assumed that commodities that are further processed, such as by juicing or canning, would not be irradiated prior to further processing and so only fresh versions of each of the potentially irradiated commodities were included in the assessment. Detailed food descriptors in each of the nutrition surveys allowed this differentiation to be made.

The change in nutrient concentration in mixed dishes where the fresh commodity was used as an ingredient (e.g. in fruit salad or in a sandwich) was also taken into account in the assessment by using a standard set of FSANZ developed recipes and the proportion of the recipe that the commodity represented.

Mean and 5th percentile nutrient intakes for baseline and the maximum nutrient loss scenario were compared to estimate the likely magnitude of any potential impact of irradiation.

Minimal nutritional impact was identified if a proportional reduction of the irradiation-sensitive nutrients from potentially irradiated fresh commodities, including where they are used in mixed dishes, resulted in decreases of mean nutrient intakes of >5% in no more than one population group.

Conversely, there may be some nutritional impact if two or more population groups had decreases of mean nutrient intakes of >5%, when a proportion of the irradiation-sensitive nutrients were reduced in potentially irradiated fresh commodities.

5.3.3.1 Irradiation-sensitive nutrient losses in tomatoes and capsicums

Section 4 of this report considered the impact of irradiation on nutrient content of tomatoes and capsicum and concluded that the irradiation of whole, ripe tomatoes or capsicums up to the proposed maximum irradiation dose of 1 kGy is unlikely to result in a discernible effect on nutrient content.

While reported vitamin C and carotenoid losses (or increases) varied in irradiated tomatoes and capsicums, for the purposes of the DIA a maximum nutrient loss of 15% for both vitamin C and carotenes in both tomatoes and capsicum has been identified as a potential worst case scenario. In the experimental data submitted by the Applicant (Chay et al 2011), average (although not statistically significant) ascorbic acid decrease across all irradiation doses and storage times was 17% for tomatoes and 15% for capsicums, and average (non-significant) β-carotene loss was 14% for capsicums and 0% for tomatoes.

The nutrition assessment only investigated the nutritional impact of irradiation on tomatoes and capsicum. However, as the DIA is considering the cumulative impact of irradiation on all potentially irradiated fruits and vegetables, the 15% nutrient loss was also applied to those tropical fruit commodities for which there is currently permission for irradiation for phytosanitary purposes, assuming that any losses would be similar in these commodities.

5.3.3.2 Potential market share of irradiated tomatoes and capsicums

There are currently no data available on the proportion of fresh tomatoes or capsicum that may potentially be irradiated. In Australia, approximately 60% of fresh tomato and 80% of capsicum production is from Queensland (ABS 2012). This may be assumed to represent a maximum proportion of fresh tomatoes and capsicums that may potentially be irradiated to control fruit fly. However, the proportion of fresh tomatoes and capsicums available for sale in Australia and New Zealand that would actually be irradiated is expected to be lower as:

- produce grown in fruit-fly controlled regions of Australia that does not cross a domestic quarantine barrier would not need to be irradiated for the purposes of domestic trade
- in New Zealand, only imported produce would need to be irradiated for fruit fly control, with domestic production unaffected
- fruit fly are more active and need to be controlled only in certain seasons
- home production of tomatoes is common in summer and home grown tomatoes would never be irradiated.

The proportion of irradiated fresh tomatoes and capsicum that are likely to be available in the New Zealand market is expected to be much less than for Australia, being limited to fresh tomatoes and capsicum imported to New Zealand, primarily from Australia.

Given the uncertainty around the proportion of fresh tomatoes and capsicums that may be irradiated, and in order to ensure that this assessment did not under-estimate the impact of irradiation on dietary intake of irradiation-sensitive nutrients for any population group assessed, market share was not factored into the refined assessment scenario.

Therefore, the refined assessment scenario (Step 3) is:

- '**15% nutrient loss**' scenario: assuming 15% nutrient loss in all potentially irradiated fresh foods and where they are used in mixed dishes, representing a worst case maximum nutrient loss, and assuming all potentially irradiated foods are actually irradiated.

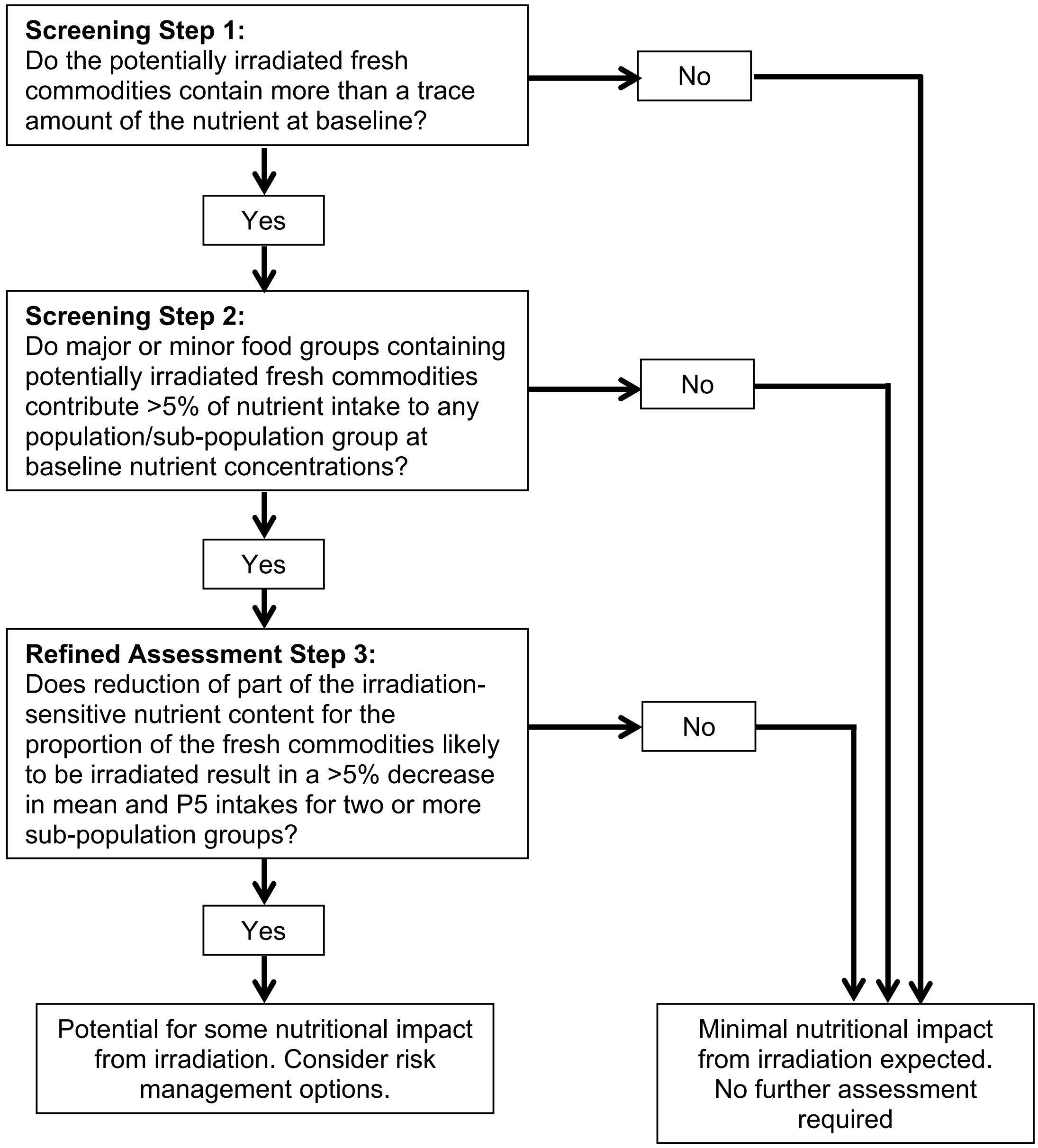

Figure 5.1: Tiered approach to the dietary intake assessment for potentially irradiated commodities

5.4 Limitations and assumptions of the dietary intake assessment

There are a number of limitations associated with estimating dietary intakes to nutrients and other food chemicals.

Limitations relating to this assessment include:

- Age of the adult food consumption data - the 1995 and 1997 NNSs are the most recent comprehensive sets of quantitative data on food consumption patterns for Australian and New Zealand adults and older teenagers currently available to FSANZ. While the older NNSs may not include information regarding food products that are now available in the market, for staple foods such as vegetables, the data derived from the these surveys are likely to be still representative today (Cook et al 2001).

However, there is greater uncertainty when assessing consumption of foods that have been introduced to the market since the 1995 and 1997 NNSs were conducted, or for which there may have been changes in food consumption patterns over time.

- Estimating usual consumption – estimating consumption from one or two days of dietary data tends to overestimate the average amounts eaten of less frequently consumed foods. This may impact estimated consumption amounts for some of the food groups assessed, such as some tropical fruits, as they are relatively infrequently consumed foods.

- Lack of market share information – there is no identification of foods by factors such as brand, production method or treatment process in DIAMOND, so only broad market share assumptions, relating to the overall proportion of each fruit and vegetable category that may be irradiated in Australia and New Zealand, can be made.

Assumptions made in undertaking this assessment include:

- Where a commodity is permitted to be irradiated for phytosanitary purposes, only the commodity reported in the nutrition surveys as consumed fresh, and where it is used in recipes as a fresh ingredient, is irradiated. Processed foods (for example canned tomatoes, tomato paste, fruit juice, canned mango etc.) are assumed not to be irradiated.

- Nutrient losses from other forms of food processing, food handling, preparation and cooking have been taken into account in this assessment in as much as these factors are incorporated into the food composition data for each food consumed in the Australian and New Zealand nutrition surveys.

Further detailed discussion on the limitations and assumptions associated with dietary intake assessments is provided in FSANZ (2009b).

5.5 Results

5.5.1 Screening Step 1

NUTTAB 2010 (FSANZ 2010), FSANZ's most recent release of nutrient analytical data for a range of Australian foods, was used as the data source to determine levels of irradiation-sensitive nutrients in the potentially irradiated fruits and vegetables. Where Australian analytical data were not available, international data were used, including New Zealand data if available. A summary of the mean concentrations of irradiation-sensitive nutrients in those food commodities currently, or potentially, permitted to be irradiated is provided at Table 5.2.

Outcome of Screening Step 1

Three nutrients, vitamin B_{12}, vitamin D and pre-formed vitamin A (retinol) are not present in the food commodities under consideration for treatment with irradiation in quantifiable amounts. These three vitamins are found largely, or exclusively, in animal foods (NHRMC 2006) and therefore tomatoes, capsicums and tropical fruits are not dietary sources of them. Population dietary intakes of these nutrients will therefore not be affected by irradiation treatment of the commodities of interest. No further assessment of these nutrients is required.

Requires further assessment	Does not require further assessment
Carotenes Folate Niacin Riboflavin Thiamin Vitamin B_6 Vitamin C Vitamin E	Vitamin B_{12} Vitamin D Retinol

Table 5.2 Mean analysed concentrations of irradiation-sensitive nutrients in fresh (raw) foods currently permitted or proposed to be irradiated

	Units/ 100 g Edible portion	A1069		Tropical fruits									A1038
		Tomato (hydroponic, cherry, common)	Capsicum (green, red)	Bread fruit	Carambola (starfruit)	Custard apple	Longan	Litchi (lychee)	Mango	Mangosteen	Papaya (paw paw)	Rambutan	Persimmon
Water soluble vitamins													
Folate	µg	12-18	10-60	14*	12*	-	-	14*	43-71◊	0+	1-58^	-	7-8^
Niacin, (preformed)	mg	0.5-1	0.54-0.88	0.9*	0.367-0.4^	0.8	0.3*	0.5	0.56	0.3+	0.3	0.79	0.5
Riboflavin	mg	0.02-0.04	0.033-0.044	0.03*	0.016-0.03^	0.08	0.014*	0.07	0.037	0.01+	0.03	0.065	0.1
Thiamin	mg	0.03-0.06	0.033-0.035	0.11*	0.014-0.03^	0.05	0.013*	0.05	0.018	0.05+	0.03	0.015	0.01
Vitamin B_6	mg	0.03-0.04	0-0.3	0.1*	0.017*	0.22-0.221#	-	0.1*	0	-	0.019-.038^	-	0.03-0.1
Vitamin B_{12}	µg	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vitamin C	mg	16-28	98-152	29*	31-34.4^	43	84*	49	26	3+	60	70	14
Fat soluble vitamins													
β-carotene	µg	60-460	161-282	0*	25#	0	-	0	1433	-	240	0	200
Retinol	µg	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vitamin D	µg	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vitamin E (α-tocopherol equivalents)	mg	0.3-0.7	0.1-4	0.1*	0.15*	-	-	0.07*	1.3	-	0.3*	-	0.73-1.8◊

* USA mean value
+ UK mean value
^ range of mean UK, USA and Danish values
# range of mean UK and USA values
◊ range of mean Danish and USA values
N/A nutrient concentration data not available as not found in potentially irradiated fruits and vegetables- nutrient concentration analytical data unavailable from any source

5.5.2 Screening Step 2

As described under Section 5.3.2, Step 2 of the screening process identified the percentage contribution of the food groups containing potentially irradiated foods to dietary intakes. This step was carried out for each irradiation-sensitive nutrient and for each Australian and New Zealand population and NRV age/gender group. This screening step was conducted in two stages; first at the major food group level, and second at the minor food group level. Where fruit or vegetable categories were considered major contributors (i.e. contributed >5%) to total nutrient intake in the first stage, the second stage was undertaken.

A summary, setting out percentage contribution to nutrient intakes of those major and minor food groups containing potentially irradiated foods is provided in Appendix 1, Tables A1.2 and A1.3. A high level summary identifying those population groups for which any food group containing potentially irradiated foods contributes >5% is set out below in Table 5.3 at the major food group level and

Table **5.4** at the minor food group level.

5.5.2.1 Carotenes

For carotenes, vegetables contributed >5% of intake for all population groups assessed and fruits contributed >5% of intake for most population groups, hence contributions from individual minor food groups were assessed.

The minor food group ‘other fruiting vegetables’ (or ‘other vegetables’ for New Zealand NNSs) contributed >5% to carotenes intake for all Australians aged 17 years and above (ranging from 9% for females aged 17-18 years and males aged 19-29 years, to 18% for females aged 70 years and above). This high contribution to carotenes intake for Australian population groups, but not for New Zealanders, is due to pumpkin being included in the ‘other fruiting vegetable’ food group for Australian nutrition surveys, whereas pumpkin is included in the ‘orange vegetables’ food group in the New Zealand nutrition surveys. The food group ‘tomato and tomato products’ was also a minor food group but contributed >5% to three population groups’ intake of carotenes. ‘Other fruit’ contributed >5% of Australian boys’ (2-8 years) carotenes intake but was not a major contributor to carotenes intake in any other groups.

In Australia the minor food group ‘carrots and similar root vegetables’ was the major dietary source of carotenes; whereas, in New Zealand, it was the minor food group ‘orange vegetables’ (including carrots and pumpkin).

5.5.2.2 Vitamin C

For vitamin C, at the major food group level, both ‘fruit products and dishes’ and ‘vegetable products and dishes’ were major contributors (>5%) to intakes for all population groups assessed, hence contributions from individual minor food groups were considered.

The minor food group ‘tomato and tomato products’ contributed >5% of adults’ vitamin C intake in both Australia and New Zealand, but was not a major contributor to children’s intakes in either country. ‘Other fruiting vegetables’ was also a major contributor to adult vitamin C intake in Australia but not for any other Australian or New Zealand population groups. Both ‘tropical fruit’ and/or ‘other fruit’ food groups were major contributors to vitamin C intake in some older adult groups. For children, none of the relevant minor food groups were major contributors to vitamin C intake, other than for Australian children 2-3 years and New Zealand girls aged 4-8 years and 14 years.

Major contributors to vitamin C intakes for Australian children were fruit and vegetable juices and drinks and citrus fruit; for New Zealand children, powdered drinks, citrus fruit, fruit juices and cordials and fruit drinks were the main sources of vitamin C intake. For Australians aged 17 years and above, the major contributor to vitamin C intake was fruit and vegetable juices, followed by potatoes; and, for the New Zealand population aged 15 years and above, cordials and fruit drinks, citrus and fruit juices.

5.5.2.3 Vitamin B6

The minor food group ‘tropical fruit’ contributed >5% to vitamin B_6 intakes for the majority of population groups assessed in both Australia and New Zealand. However, as can be seen in Table 5.5, this was due to the contribution to this food group made by bananas, which are a more frequently consumed tropical fruit, and which have a higher vitamin B_6 concentration (average of approximately 0.2 mg/100 g) than many other tropical fruits (see Table 5.2).

5.5.2.4 Other nutrients

For the remaining nutrients (thiamin, riboflavin, niacin, folate and vitamin E), the contribution to intake by the major food groups, fruits and vegetables, varied across the groups assessed. Generally, vegetables contributed more to irradiation-sensitive nutrient intakes than fruits. At the major food group level, both fruits and vegetables contributed <5% to thiamin, riboflavin and niacin intakes for all New Zealand children. Similarly, both fruits and vegetables contributed <5% to riboflavin intakes for all Australian children. Therefore, no further compilation of major contributors at the minor food group level was undertaken for these population groups and nutrients. For adults in both countries, fruits and vegetables were major contributors to intakes of all nutrients of interest and therefore the contribution of minor food groups was assessed.

At the minor food group level, the food groups containing potentially irradiated foods all contributed <5% to intakes of thiamin, riboflavin, niacin, folate and vitamin E for all population groups assessed. Therefore, no further assessment of these nutrients was required.

Summary of outcome of Screening Step 2

At the major food group level, the food categories ‘vegetable products and dishes’ and/or ‘fruit products and dishes’ were not major contributors (<5%) to thiamin, riboflavin or niacin intakes for any New Zealand children’s population groups assessed. These food groups were also not major contributors (<5%) to riboflavin intakes for Australian children. No further assessment of these nutrients and population groups was conducted at the minor food group level.

At the minor food group level, one or more of the food groups ‘tomato and tomato products’, ‘other fruiting vegetables’, ‘tropical fruit’ and ‘other fruit’ contributed >5% of estimated intake, for at least one population group assessed, for carotenes and vitamin C and therefore required further assessment. These minor food groups contributed <5% to thiamin, riboflavin, niacin, folate or vitamin E intake for all Australian or New Zealand population group assessed, therefore, no further assessment was required for these nutrients. Within the minor food group ‘tropical fruit’, bananas were identified as the major contributor to vitamin B_6 intakes, therefore, no further assessment of vitamin B_6 was undertaken.

Requires further assessment	Does not require further assessment
Carotenes Vitamin C	Folate Niacin Riboflavin Thiamin Vitamin B_6 Vitamin E

Table 5.3: **Australian and New Zealand population groups for which any major food group containing a potentially irradiated food contributes >5% to estimated irradiation-sensitive nutrient intakes**

Country	Age	Gender	Carotenes	Vitamin C	Thiamin	Riboflavin	Niacin	Folate	Vitamin E	Vitamin B6
Australia	2-3 years	Male	✓	✓				✓	✓	✓
		Female	✓	✓				✓	✓	✓
	4-8 years	Male	✓	✓				✓	✓	✓
		Female	✓	✓			✓	✓	✓	✓
	9-13 years	Male	✓	✓	✓		✓	✓	✓	✓
		Female	✓	✓	✓		✓	✓	✓	✓
	14-16 years	Male	✓	✓	✓		✓	✓	✓	✓
		Female	✓	✓	✓		✓	✓	✓	✓
	17-18 years	Male	✓	✓	✓	✓	✓	✓	✓	✓
		Female	✓	✓	✓	✓	✓	✓	✓	✓
	19-29 years	Male	✓	✓	✓	✓	✓	✓	✓	✓
		Female	✓	✓	✓	✓	✓	✓	✓	✓
	30-49 years	Male	✓	✓	✓	✓	✓	✓	✓	✓
		Female	✓	✓	✓	✓	✓	✓	✓	✓
	50-69 years	Male	✓	✓	✓	✓	✓	✓	✓	✓
		Female	✓	✓	✓	✓	✓	✓	✓	✓
	70 years & above	Male	✓	✓	✓	✓	✓	✓	✓	✓
		Female	✓	✓	✓	✓	✓	✓	✓	✓
New Zealand	5-8 years	Male	✓	✓				✓	✓	✓
		Female	✓	✓				✓	✓	✓
	9-13 years	Male	✓	✓				✓	✓	✓
		Female	✓	✓				✓	✓	✓
	14 years	Male	✓	✓				✓	✓	✓
		Female	✓	✓				✓	✓	✓
	15-18 years	Male	✓	✓	✓		✓	✓	✓	✓
		Female	✓	✓	✓		✓	✓	✓	✓
	19-29 years	Male	✓	✓	✓		✓	✓	✓	✓
		Female	✓	✓	✓		✓	✓	✓	✓
	30-49 years	Male	✓	✓	✓			✓	✓	✓
		Female	✓	✓	✓			✓	✓	✓
	50-69 years	Male	✓	✓	✓		✓	✓	✓	✓
		Female	✓	✓	✓	✓		✓	✓	✓
	70 years & above	Male	✓	✓	✓	✓	✓	✓	✓	✓
		Female	✓	✓	✓	✓		✓	✓	✓

Table 5.4: Australian and New Zealand population groups for which any minor food group containing a potentially irradiated food contributes >5% to estimated irradiation-sensitive nutrient intakes

Country	Age	Gender	Carotenes	Vitamin C	Thiamin	Riboflavin	Niacin	Folate	Vitamin E	Vitamin B6
Australia	2-3 years	Male	✓	✓						✓
		Female		✓						✓
	4-8 years	Male	✓							✓
		Female		✓						✓
	9-13 years	Male								
		Female								✓
	14-16 years	Male	✓							
		Female								
	17-18 years	Male	✓							
		Female	✓							
	19-29 years	Male	✓							✓
		Female	✓	✓						✓
	30-49 years	Male	✓	✓						✓
		Female	✓	✓						✓
	50-69 years	Male	✓	✓						✓
		Female	✓	✓						✓
	70 years & above	Male	✓	✓						✓
		Female	✓	✓						✓
New Zealand	5-8 years	Male								✓
		Female								✓
	9-13 years	Male								✓
		Female								✓
	14 years	Male								✓
		Female	✓	✓						
	15-18 years	Male								✓
		Female	✓							✓
	19-29 years	Male								✓
		Female								✓
	30-49 years	Male		✓						✓
		Female		✓						✓
	50-69 years	Male		✓						✓
		Female		✓						✓
	70 years & above	Male		✓						✓
		Female		✓						✓

Table 5.5: Per cent contribution of the specific food groups 'bananas' and 'other tropical fruit' to Vitamin B6 intakes for Australian and New Zealand population groups

			Minor food group: Tropical fruit	
Country	**Age**	**Gender**	**Specific food group: Bananas**	**Specific food group: Other tropical fruit**
Australia	**2-3 years**	Male	12	<1
		Female	11	<1
	4-8 years	Male	8	<1
		Female	9	<1
	9-13 years	Male	5	<1
		Female	6	<1
	14-18 years	Male	2	<1
		Female	3	-
	19-29 years	Male	5	<1
		Female	7	<1
	30-49 years	Male	7	<1
		Female	9	<1
	50-69 years	Male	8	<1
		Female	11	<1
	70 years & above	Male	10	<1
		Female	14	<1
New Zealand	**5-8 years**	Male	9	<1
		Female	13	<1
	9-13 years	Male	8	<1
		Female	8	<1
	14 years	Male	6	-
		Female	5	<1
	15-18 years	Male	6	<1
		Female	8	<1
	19-29 years	Male	8	<1
		Female	9	<1
	30-49 years	Male	8	<1
		Female	11	<1
	50-69 years	Male	10	<1
		Female	14	1
	70 years & above	Male	11	<1
		Female	18	2

5.5.3 Refined Assessment Step 3

Screening Step 3 estimated the nutritional impact of a 'worst case' nutrient loss scenario, loss of 15% of the irradiation-sensitive nutrient from all foods currently, or proposed to be, permitted to be irradiated. Each Australian and New Zealand population group's dietary intake of the irradiation-sensitive nutrient was calculated at baseline (no irradiation of any fruits or vegetables). This was then repeated assuming 15% irradiation-sensitive nutrient loss in all potentially irradiated fresh commodities and where these commodities were used in recipes, referred to as the '15% nutrient loss' scenario. The decrease in mean and 5th percentile intakes between baseline and the 15% nutrient loss scenario were calculated.

5.5.3.1 Carotenes

The NRVs relevant to carotenes are for vitamin A expressed as retinol equivalents, which is a calculated value derived from preformed vitamin A (retinol) and carotenes (provitamin A) concentrations using the following equation (NHMRC 2006):

$$\text{Vitamin A (retinol equivalents) } (\mu g) = \text{preformed vitamin A } (\mu g) + (\text{provitamin A } (\mu g)/6)$$

Equation 5.1: Calculation of vitamin A as retinol equivalents

Mean and 5th percentile intakes of vitamin A (expressed as retinol equivalents) were assessed to determine what impact the 15% carotenes loss scenario had compared to baseline vitamin A intakes. As can be seen in Table 5.6, the impact on vitamin A intakes was minimal. All Australian and New Zealand population groups assessed had a reduction in vitamin A intake of <1% at both the mean and 5th percentile as a result of the 15% carotenes loss scenario. For all population groups, mean intakes remained above the EAR. Major contributors to vitamin A for Australian children were carrots and similar root vegetables and milk, and for New Zealand children: orange vegetables and milk. For Australian adults aged 17 years and above, carrots and similar root vegetables were the major contributor to vitamin A intake, with the contribution from organ meats and offal increasing as age increased. For the New Zealand population aged 15 years and above, orange vegetables were the major contributor to vitamin A intakes with smaller contributions from milk, butter, polyunsaturated margarine and offal meats.

Table 5.6: Mean and 5th percentile dietary intake of vitamin A (as retinol equivalents/day) at baseline and 15% carotenes loss scenario, for Australian and New Zealand population groups

					15% carotenes loss scenario			
Country	Age	Gender	Baseline		Mean		P5	
			Mean intake (RE/day)	P5 intake (RE/day)	Intake (RE/day)	% decrease from baseline	Intake (RE/day)	% decrease from baseline
Australia	**2-3 years**	Male	692	454	690	<1	453	<1
		Female	623	390	621	<1	390	<1
	4-8 years	Male	691	480	689	<1	478	<1
		Female	685	502	683	<1	502	<1
	9-13 years	Male	777	488	774	<1	487	<1
		Female	711	419	708	<1	416	<1
	14-16 years	Male	928	500	924	<1	497	<1
		Female	741	444	738	<1	442	<1
	17-18 years	Male	1139	994	1136	<1	992	<1
		Female	901	429	898	<1	427	<1
	19-29 years	Male	1167	996	1162	<1	993	<1
		Female	962	454	958	<1	452	<1
	30-49 years	Male	1280	1035	1274	<1	1032	<1
		Female	1054	579	1049	<1	577	<1
	50-69 years	Male	1343	1132	1337	<1	1127	<1
		Female	1093	996	1087	<1	991	<1
	70 years & above	Male	1337	1136	1332	<1	1131	<1
		Female	1079	996	1073	<1	991	<1
New Zealand	**5-8 years**	Male	644	313	642	<1	311	<1
		Female	569	454	567	<1	452	<1
	9-13 years	Male	733	375	730	<1	374	<1
		Female	613	380	610	<1	379	<1

					15% carotenes loss scenario			
Country	Age	Gender	Baseline		Mean		P5	
			Mean intake (RE/day)	P5 intake (RE/day)	Intake (RE/day)	% decrease from baseline	Intake (RE/day)	% decrease from baseline
	14 years	Male	775	403	772	<1	401	<1
		Female	637	345	635	<1	344	<1
	15-18 years	Male	1244	1206	1239	<1	1203	<1
		Female	963	873	958	<1	869	<1
	19-29 years	Male	1243	1204	1238	<1	1200	<1
		Female	988	856	983	<1	852	<1
	30-49 years	Male	1258	1208	1253	<1	1205	<1
		Female	990	863	985	<1	859	<1
	50-69 years	Male	1255	1208	1250	<1	1205	<1
		Female	1021	874	1016	<1	870	<1
	70 years & above	Male	1253	1213	1248	<1	1210	<1
		Female	1018	876	1013	<1	871	<1

5.5.3.2 Vitamin C

Estimated mean and 5th percentile baseline vitamin C intakes were compared to 15% vitamin C loss scenario intakes for Australian and New Zealand population groups (Table 5.7).

The maximum reduction in mean vitamin C intakes was 2%, for a number of older Australian and New Zealand population groups (Australian males and females aged 30-49 years and 50-69 years, Australian females aged 70 years and above, New Zealand females aged 50-69 years and New Zealand males aged 70 years and above). All other population groups assessed had a reduction in mean intakes of 1% or less as a result of the 15% vitamin C loss scenario. Mean intakes remained above the EAR in all population groups.

At 5th percentile intakes, the maximum reduction in vitamin C intake was 3%, for three population groups, Australian females aged 30-49 years, 50-69 years and 70 years and above. All other Australian and New Zealand population groups assessed had reductions in 5th percentile intakes of 2% or less.

Table 5.7: Mean and 5th percentile dietary intake of vitamin C (mg/day) at baseline and 15% vitamin C loss scenario, for Australian and New Zealand population groups

					15% vitamin C loss scenario			
			Baseline		Mean		P5	
Country	**Age**	**Gender**	Mean intake (mg/day)	P5 intake (mg/day)	intake (mg/day)	% decrease from baseline	intake (mg/day)	% decrease from baseline
Australia	**2-3 years**	Male	86	42	85	<1	42	<1
		Female	80	36	79	<1	35	<1
	4-8 years	Male	103	44	102	<1	44	<1
		Female	89	43	88	<1	43	<1
	9-13 years	Male	120	62	118	1	61	1
		Female	113	57	112	<1	56	2
	14-16 years	Male	147	70	146	1	68	2
		Female	127	66	126	1	65	<1
	17-18 years	Male	147	65	145	1	65	<1
		Female	127	62	125	1	61	1
	19-29 years	Male	145	63	143	1	62	1
		Female	117	61	115	1	60	1
	30-49 years	Male	133	59	131	2	58	1
		Female	112	53	110	2	51	3
	50-69 years	Male	135	61	133	2	60	1

Country	Age	Gender	Baseline		15% vitamin C loss scenario			
					Mean		P5	
			Mean intake (mg/day)	P5 intake (mg/day)	intake (mg/day)	% decrease from baseline	intake (mg/day)	% decrease from baseline
		Female	117	51	115	2	49	3
	70 years & above	Male	127	61	125	1	60	1
		Female	112	50	110	2	49	3
New Zealand	5-8 years	Male	95	57	94	<1	56	<1
		Female	98	69	98	<1	68	1
	9-13 years	Male	108	49	107	<1	48	2
		Female	101	59	100	<1	59	<1
	14 years	Male	104	47	103	1	46	2
		Female	106	57	105	<1	58	<1
	15-18 years	Male	137	80	136	<1	80	<1
		Female	114	68	112	1	67	1
	19-29 years	Male	130	81	129	<1	81	<1
		Female	112	68	110	1	67	<1
	30-49 years	Male	121	60	119	1	59	2
		Female	101	48	99	1	47	1
	50-69 years	Male	111	60	109	1	59	2
		Female	106	51	104	2	51	1
	70 years & above	Male	104	64	102	2	62	2
		Female	97	49	96	1	48	2

Summary of outcome of Refined Assessment Step 3

Following a maximum reduction of the irradiation-sensitive nutrient in potentially irradiated fresh commodities, the 15% nutrient loss scenario, reductions in estimated mean and 5th percentile vitamin A and vitamin C intakes, compared to baseline, were <5% for all Australian or New Zealand population group assessed.

Potential for some nutritional impact	Minimal potential for nutritional impact
	Carotenes Vitamin C

5.6 Conclusion

A tiered screening approach to the DIA was used to determine the potential impact of irradiation of fresh fruits and vegetables with current or proposed irradiation permissions (the potentially irradiated foods) on irradiation-sensitive nutrient intakes for Australian and New Zealand populations. A summary of the outcomes of the screening assessment is provided in Table 5.8.

The conclusion of the DIA is that irradiation of tomatoes, capsicums and certain tropical fruit at up to 1 kGy, even using the 'worst case' assumption of 15% nutrient loss applied to all fresh tomatoes, capsicums, and those tropical fruits with existing irradiation permissions, is likely to have no impact on population nutrient intakes for any irradiation-sensitive nutrient considered.

Table 5.8: Summary of outcomes of the tiered screening approach to the DIA

Step	Yes – Requires further assessment	No – Does not require further assessment
Screening Step 1: Do the potentially irradiated fresh commodities contain more than trace amounts of irradiation sensitive nutrient?	Carotenes Vitamin C Thiamin Riboflavin Niacin Folate Vitamin E Vitamin B_6	Vitamin B_{12} Vitamin D Retinol
Screening Step 2. Do food groups containing the potentially irradiated fresh commodities contribute >5% to irradiation-sensitive nutrient intake?	Carotenes Vitamin C	Thiamin Riboflavin Niacin Folate Vitamin B_6 Vitamin E
Refined Assessment Step 3. Does maximum reduction of the irradiation-sensitive nutrient in the potentially irradiated fresh commodities have an impact on population nutrient intakes?		Carotenes Vitamin C

Response to Question 6: *Taking into account potential market share and trade of irradiated fresh tomatoes and capsicums, in both Australia and New Zealand, would any changes in the nutrient composition of fresh tomatoes and capsicums, following irradiation, have the potential to affect the nutritional adequacy of diets for Australian and New Zealand populations?*

There is minimal potential for irradiation of fresh tomatoes and capsicums, at doses up to 1 kGy, to affect the nutritional adequacy of Australian and New Zealand diets.

Response to Question 7: *What are the combined cumulative nutritional effects on the nutritional adequacy of diets for Australian and New Zealand populations from irradiation of both the currently permitted irradiated foods and irradiated fresh tomatoes and capsicums?*

Mean population intakes of vitamin A and C are estimated to decrease by 2% or less if all fresh tomatoes, capsicums and tropical fruits for which irradiation is already permitted were to be irradiated such that vitamin concentrations declined by 15%. As not all of these foods would be irradiated, any decrease in intakes would be less than this.

6. Risk characterisation

Irradiation of fruits and vegetables is an internationally-accepted means of disinfesting produce. For Australian produce, the critical pest for which irradiation is effective is the fruit fly. Irradiation doses below 1 kGy are sufficient to control fruit fly for quarantine purposes.

There are negligible risks associated with the formation of radiolytic compounds in tomatoes and capsicums. The low lipid content of capsicums and tomatoes (0.2 g/100 g or less) means there is a low potential to generate 2-ACBs. Furan formation in irradiated tomatoes and capsicums is negligible.

Irradiated fruits and vegetables have been consumed in a number of countries, including the USA, for many years without any human health and safety issues being identified.

Data submitted by the Applicant on levels of a range of nutrients in tomatoes and capsicums irradiated at doses up to and including 1 kGy, and at two storage times, showed no significant effects of irradiation on nutrient levels. The Applicant's data are the most relevant available to the consideration of this Application as they are generated from fruit and conditions comparable to those proposed in the current application.

Most vitamins are labile and levels in fresh produce are highly variable, being affected by parameters such as variety, ripeness, storage time and exposure to light. Any potential effects of irradiation on vitamin levels are smaller than effects associated with other handling or processing steps, such as storage time, ripeness and heating.

Of those vitamins possibly affected by irradiation, vitamin C and vitamin A (from pro-vitamin A carotenoids such as β-carotene) are the only ones present in tomatoes, capsicums and tropical fruits at nutritionally relevant levels. Using a worst case estimate of 15% loss of vitamin C and carotenes across all fresh tomatoes, capsicums and tropical fruits (where irradiation is already permitted), mean population intakes of vitamin A would decline by no more than 1% and of vitamin C by no more than 2% in all Australian and New Zealand population groups assessed. In all these groups, mean intakes of vitamins A and C would remain above the Estimated Average Requirements.

There is no appreciable risk to public health and safety from irradiation of tomatoes and capsicums at up to 1 kGy.

7. References

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Appendix 1

Table A1.1: Major, minor and specific food group categories to which potentially irradiated commodities belong, for each Australian and New Zealand nutrition survey

Nutrition Survey	Major food group		Minor food group		Specific food group		Commodities included
	Food Code	**Food group name**	**Food Code**	**Food group name**	**Food Code**	**Food group name**	
2007 ANCNPAS	16	Fruit products and dishes	165	Tropical fruit	16504	Other tropical fruit	Guava, **mango**, **pawpaw** (papaya) and **rambutan**; raw
			166	Other fruit	16601	Other fruit	Feijoa, fig, grape, kiwifruit, **lychee**, honeydew melon, rockmelon, watermelon, **persimmon**, passionfruit, pomegranate, rhubarb and fruit not elsewhere specified: raw.
	24	Vegetable products and dishes	246	Tomato and tomato products	24601	Tomato	**Cherry, common tomato; raw, boiled with salt or stir-fried.**
			247	Other fruiting vegetables	24703	Other fruiting vegetables	Avocado, **capsicum (green, red, not specified as to colour)**, chilli, choko, cucumber, eggplant, melon (bitter) and okra; raw, cooked (baked, steamed, stir-fried, boiled).
1995 NNS	16	Fruit products and dishes	165	Tropical fruit	1653	Other tropical fruit	**Carambola (starfruit)**, **custard apple**, guava, jackfruit, **mango**, **pawpaw**, pepino **rambutan** and tamarillo, raw, stewed, canned.
			166	Other fruit	1661	Other fruit	Dates, feijoa, figs, grapes (raw only), honeydew melon, kiwifruit, loquat, **lychee**, passionfruit, **persimmon**, rhubarb, rockmelon, watermelon, and fruit not specified as to type, raw, stewed or canned.
	23	Vegetable products and dishes	236	Tomato and tomato products	2361	Tomato	**Tomato and cherry tomato; raw, grilled, fried, stewed, not specified as to cooking method.**
			237	Other fruiting vegetables	2373	Other fruiting vegetables	Avocado, **capsicum (green, red, not specified as to colour)**, chili, choko, cucumber, eggplant, melon (bitter), okra, plantain; raw, cooked, canned.
2002 NCNS	32	Vegetables	3203	Tomatoes and tomato products	32033	Raw tomatoes	**Tomato, raw, uncooked, from fresh**, raw, not further specified
			3207	Other vegetables	32071	Other vegetables - includes parsnip, marrow/courgettes and eggplant etc	Cumquat; chives; celery; seed sprouts; mushrooms; okra; herbs, fresh; spices, fresh; chilli; radish; **capsicum (peppers), green, red/yellow, raw, baked, cooked other method**; seaweed; gherkin; cucumber; asparagus; cassava tuber; courgette; parsnip; bamboo; eggplant; beetroot; incl. raw, cooked (baked, boiled, grilled, steamed etc) canned, pickled etc.
	35	Fruit	3505		35053	Other tropical fruits	**Lychee**; **mango**; passionfruit; rockmelon; watermelon; guava; **breadfruit, papaya**.
			3506		35061	Other fruit	Feijoa; kiwifruit; **persimmon**; rhubarb; grapes, fresh; tamarillo, raw; avocado; olives, plain, stuffed; fruit, raw, not further specified.
1997 NNS	22	Vegetables	223	Tomatoes and tomato products	2233	Raw tomatoes	**Tomato from fresh, raw, salad**, not specified as to form.

Nutrition Survey	Major food group		Minor food group		Specific food group		Commodities included
	Food Code	Food group name	Food Code	Food group name	Food Code	Food group name	
			227	Other vegetables	2271	Other vegetables - includes parsnip, marrow/courgettes and eggplant etc	Chives; celery; seed sprouts; mushrooms; okra; herbs, fresh; spices, fresh; chilli; radish; **capsicum (peppers), green, red/yellow, raw, baked, cooked other method**; seaweed; gherkin; cucumber; asparagus; cassava tuber; courgette; parsnip; bamboo; eggplant; beetroot; okra; vineleaf; artichoke; horseradish; radish; taro root; choko; witloof; incl. raw, cooked (baked, boiled, grilled, steamed etc) canned, pickled etc.
	25	Fruit	255	Tropical fruits	2553	Other tropical fruits	**Lychee**; **mango**; passionfruit; rockmelon; watermelon; honeydew melon; guava; **breadfruit**; **papaya**; tamarillo; olives, plain, stuffed.
			256	Other fruit	2561	Other fruit	Feijoa; kiwifruit; gooseberry; **persimmon**; rhubarb; **jackfruit**; pepino; babaco; **breadfruit**, avocado; fruit, raw, not further specified.

Table A1.2: Percentage contribution of fruit and vegetables at the major food group level to estimated irradiation-sensitive nutrient intakes for Australian and New Zealand population groups

Nutrition Survey	Age	Gender	Carotenes		Vitamin C		Thiamin		Riboflavin	
			Vegetable products & dishes	Fruit products & dishes	Vegetable products & dishes	Fruit products & dishes	Vegetable products & dishes	Fruit products & dishes	Vegetable products & dishes	Fruit products & dishes
Australia	2-3 years	Male	60	14	19	34	<5	<5	<5	<5
		Female	60	11	21	33	<5	<5	<5	<5
	4-8 years	Male	60	10	19	26	<5	<5	<5	<5
		Female	62	10	21	32	<5	<5	<5	<5
	9-13 years	Male	59	9	23	21	6	<5	<5	<5
		Female	59	7	23	22	6	<5	<5	<5
	14-16 years	Male	63	5	23	15	6	<5	<5	<5
		Female	64	5	24	18	7	<5	<5	<5
	17-18 years	Male	68	<5	37	12	11	<5	5	<5
		Female	64	<5	28	10	9	<5	6	<5
	19-29 years	Male	66	5	35	12	9	<5	6	<5
		Female	69	<5	34	14	10	<5	7	<5
	30-49 years	Male	71	<5	40	16	9	<5	7	<5
		Female	67	7	42	20	11	<5	8	<5
	50-69 years	Male	72	7	46	20	12	<5	8	<5
		Female	71	8	44	26	12	<5	8	<5
	70 years & above	Male	71	7	46	22	11	<5	8	<5
		Female	74	7	45	25	12	<5	8	<5
New Zealand	5-8 years	Male	66	9	12	30	<5	<5	<5	<5
		Female	66	9	10	31	<5	<5	<5	<5
	9-13 years	Male	65	8	13	23	<5	<5	<5	<5
		Female	61	8	11	30	<5	<5	<5	<5
	14 years	Male	65	<5	17	16	<5	<5	<5	<5
		Female	61	<5	12	26	<5	<5	<5	<5
	15-18 years	Male	66	6	15	15	<5	7	<5	<5

Nutrition Survey	Age	Gender	Carotenes		Vitamin C		Thiamin		Riboflavin	
			Vegetable products & dishes	Fruit products & dishes	Vegetable products & dishes	Fruit products & dishes	Vegetable products & dishes	Fruit products & dishes	Vegetable products & dishes	Fruit products & dishes
		Female	62	8	18	18	***<5***	6	***<5***	***<5***
	19-29 years	Male	67	***<5***	20	20	***<5***	6	***<5***	***<5***
		Female	68	10	21	21	6	***<5***	***<5***	***<5***
	30-49 years	Male	73	7	29	29	7	***<5***	***<5***	***<5***
		Female	71	8	28	28	6	***<5***	***<5***	***<5***
	50-69 years	Male	76	5	34	34	7	***<5***	***<5***	***<5***
		Female	73	10	34	34	8	***<5***	6	***<5***
	70 years & above	Male	80	5	35	35	7	***<5***	5	***<5***
		Female	78	7	32	32	7	***<5***	5	***<5***

Figures in red indicate that no further assessment is required for that nutrient and population group combination.
Figures in bold (<5) indicate that the major food group is not a major contributor to nutrient intakes for that population group
The categories ‘vegetable products and dishes’ and ‘fruit products and dishes’ do not include vegetable or fruit juices, respectively.

Table A1.2: Percentage contribution of fruit and vegetables at the major food group level to estimated irradiation-sensitive nutrient intakes for Australian and New Zealand population groups (continued)

Country	Age	Gender	Niacin		Folate		Vitamin E		Vitamin B_6	
			Vegetable products & dishes	Fruit products & dishes	Vegetable products & dishes	Fruit products & dishes	Vegetable products & dishes	Fruit products & dishes	Vegetable products & dishes	Fruit products & dishes
Australia	2-3 years	Male	***<5***	***<5***	6	14	10	11	5*	6*
		Female	***<5***	***<5***	6	14	10	11	6*	5*
	4-8 years	Male	***<5***	***<5***	6	13	9	8	8*	***<5****
		Female	5	***<5***	7	13	9	9	7*	6*
	9-13 years	Male	5	***<5***	8	10	10	6	7*	***<5****
		Female	6	***<5***	9	12	10	7	9*	***<5****
	14-16 years	Male	5	***<1***	9	8	10	***<5***	*	*
		Female	7	***<5***	10	9	12	6	*	*
	17-18 years	Male	10	***<1***	23	***<5***	11	***<5***	9*	***<5****
		Female	9	***<5***	23	***<5***	13	6	10*	***<5****
	19-29 years	Male	8	***<1***	21	***<5***	12	***<5***	10	***<5***
		Female	9	***<5***	24	***<5***	13	5	8	***<5***
	30-49 years	Male	8	***<5***	23	***<5***	13	***<5***	8	***<5***
		Female	9	***<5***	27	***<5***	15	7	7	***<5***
	50-69 years	Male	9	***<5***	27	***<5***	14	7	6	***<5***
		Female	10	***<5***	29	5	16	9	6	***<5***
	70+ years	Male	10	***<5***	25	***<5***	14	8	5	***<5***
		Female	11	***<5***	28	6	16	9	5	***<5***
New Zealand	5-8 years	Male	*<5*	*<5*	7	***<5***	7	9	***<5***	13
		Female	*<5*	*<5*	9	7	7	10	6	17
	9-13 years	Male	*<5*	*<5*	9	***<5***	7	7	***<5***	11
		Female	*<5*	*<5*	9	7	8	9	***<5***	13
	14 years	Male	*<5*	*<5*	8	***<5***	9	***<5***	***<5***	8
		Female	*<5*	*<5*	11	***<5***	9	7	5	9
	15-18 years	Male	6	***<5***	12	7	7	***<5***	***<5***	9

Country	Age	Gender	Niacin		Folate		Vitamin E		Vitamin B_6	
			Vegetable products & dishes	Fruit products & dishes	Vegetable products & dishes	Fruit products & dishes	Vegetable products & dishes	Fruit products & dishes	Vegetable products & dishes	Fruit products & dishes
		Female	6	***<5***	14	8	9	7	7	11
	19-29 years	Male	5	***<5***	15	6	8	***<5***	6	10
		Female	6	***<5***	18	9	11	8	9	13
	30-49 years	Male	***<5***	***<5***	19	7	13	6	9	12
		Female	***<5***	***<5***	19	9	12	9	9	16
	50-69 years	Male	5	***<5***	21	6	14	6	10	14
		Female	***<5***	***<5***	23	11	14	9	12	20
	70+ years	Male	6	***<5***	21	7	14	6	11	16
		Female	***<5***	***<5***	23	11	14	11	11	25

* Percentage contribution of fruits and vegetables to vitamin B_6 intakes for Australian children population groups were derived from the 1995 NNS. The percentage contribution of vegetables and fruits for the Australian population aged 17-18 years (1995 NNS) also includes Australian children aged 14-16 years, for this nutrient only.
Figures in red indicate that no further assessment is required for that nutrient and population group combination.
Figures in bold (<5) indicate that the major food group is not a major contributor to nutrient intakes for that population group
The categories 'vegetable products and dishes' and 'fruit products and dishes' do not include vegetable or fruit juices, respectively.

Table A1.3: Percentage contribution of <u>minor</u> food groups containing potentially irradiated foods to estimated irradiation-sensitive nutrient intakes for Australian and New Zealand population groups

			Carotenes				Vitamin C				Thiamin			
			Vegetable products & dishes		Fruit products & dishes		Vegetable products & dishes		Fruit products & dishes		Vegetable products & dishes		Fruit products & dishes	
Country	**Age**	**Gender**	**Tomato & tomato products**	**Other fruiting vegetables**	**Tropical Fruit**	**Other Fruit**	**Tomato & tomato products**	**Other fruiting vegetables**	**Tropical Fruit**	**Other Fruit**	**Tomato & tomato products**	**Other fruiting vegetables**	**Tropical Fruit**	**Other Fruit**
Australia	2-3 years	Male	<5	<5	<5	***7***	<5	<5	<5	***6***	<1	<1	<1	<1
		Female	<5	<5	<5	<5	<5	<5	***6***	***5***	<1	<1	<1	<1
	4-8 years	Male	<5	<5	<5	***5***	<5	<5	<5	<5	<1	<1	<1	<1
		Female	<5	<5	<5	<5	<5	<5	<5	***5***	<1	<1	<1	<1
	9-13 years	Male	<5	<5	<5	<5	<5	<5	<5	<5	<1	<1	<1	<1
		Female	<5	<5	<1	<5	<5	<5	<5	<5	<1	<1	<1	<1
	14-16 years	Male	***5***	<5	<5	<5	<5	<5	<5	<5	<1	<1	<1	<1
		Female	<5	<5	<1	<5	<5	<5	<5	<5	<1	<1	<1	<1
	17-18 years	Male	<5	***11***	<1	<5	<5	<5	<1	<5	<1	<1	<1	<1
		Female	<5	***9***	<1	<5	<5	<5	<1	<5	<1	<1	<1	<1
	19-29 years	Male	<5	***9***	<5	<5	<5	<5	<5	<5	<1	<1	<1	<1
		Female	<5	***10***	<5	<5	<5	***6***	<5	<5	<1	<1	<1	<1
	30-49 years	Male	<5	***10***	<5	<5	***5***	***5***	<5	<5	<1	<1	<1	<1
		Female	<5	***12***	<5	<5	***6***	***6***	<5	<5	<5	<1	<5	<1
	50-69 years	Male	<5	***12***	<5	<5	***5***	***5***	<5	<5	<1	<1	<1	<1
		Female	<5	***13***	<5	<5	***6***	***5***	***6***	<5	<5	<5	<5	<1
	70 years & above	Male	<5	***17***	<5	<5	<5	***5***	***5***	<5	<1	<1	<5	<1
		Female	<5	***18***	<5	<5	***5***	***5***	***6***	<5	<5	<5	<5	<1
New Zealand	5-8 years	Male	<5	<1	<1	<1	<5	<5	<5	<5	-	-	-	-
		Female	<5	<5	<5	<1	<5	<1	<5	<5	-	-	-	-
	9-13 years	Male	<5	<1	<5	<5	<5	<5	<5	<5	-	-	-	-
		Female	<5	<1	<5	<1	<5	<5	<5	<5	-	-	-	-
	14 years	Male	<5	<1	<1	<1	<5	<5	<5	<5	-	-	-	-

Country	Age	Gender	Carotenes				Vitamin C				Thiamin			
			Vegetable products & dishes		Fruit products & dishes		Vegetable products & dishes		Fruit products & dishes		Vegetable products & dishes		Fruit products & dishes	
			Tomato & tomato products	Other fruiting vegetables	Tropical Fruit	Other Fruit	Tomato & tomato products	Other fruiting vegetables	Tropical Fruit	Other Fruit	Tomato & tomato products	Other fruiting vegetables	Tropical Fruit	Other Fruit
		Female	***6***	<5	<1	<1	<5	<1	<5	***7***	-	-	-	-
	15-18 years	Male	<5	<1	<1	<5	<5	<1	<5	<5	<1	<1	<1	<1
		Female	***5***	<5	<1	<1	<5	<5	<5	<5	<1	<1	<5	<1
	19-29 years	Male	<5	<1	<1	<1	<5	<5	<5	<5	<1	<1	<1	<1
		Female	<5	<1	<5	<1	<5	<5	<5	<5	<1	<1	<5	<1
	30-49 years	Male	<5	<5	<5	<1	***6***	<5	<5	<5	<1	<1	<1	<1
		Female	<5	<5	<5	<1	***6***	<5	<5	<5	<1	<1	<5	<1
	50-69 years	Male	<5	<5	<5	<1	***6***	<5	<5	<5	<1	<1	<1	<1
		Female	<5	<5	<5	<1	***8***	<5	***5***	***6***	<1	<1	<5	<1
	70 years & above	Male	<5	<1	<5	<1	***8***	<5	<5	<5	<1	<1	<5	<1
		Female	<5	<1	<1	<1	***8***	<5	***6***	***9***	<1	<1	<5	<1

- indicates that no further assessment was conducted for these nutrients and population groups as the major (2 digit code) food groups ‘fruits’ and ‘vegetables’ contributed <5% to the nutrient intakes.

Figures contributing 5% or more to nutrient intake for a population group indicated in ***bold italics***.

Table A1.3: Percentage contribution of <u>minor</u> food groups containing potentially irradiated foods to estimated irradiation-sensitive nutrient intakes for Australian and New Zealand population groups (continued)

			Riboflavin				Niacin				Folate			
			Vegetable products & dishes		Fruit products & dishes		Vegetable products & dishes		Fruit products & dishes		Vegetable products & dishes		Fruit products & dishes	
Country	**Age**	**Gender**	**Tomato & tomato products**	**Other fruiting vegetables**	**Tropical Fruit**	**Other Fruit**	**Tomato & tomato products**	**Other fruiting vegetables**	**Tropical Fruit**	**Other Fruit**	**Tomato & tomato products**	**Other fruiting vegetables**	**Tropical Fruit**	**Other Fruit**
Australia	2-3 years	Male	-	-	-	-	<1	<1	<1	<1	<1	<1	<5	<1
		Female	-	-	-	-	<1	<1	<1	<1	<1	<5	<5	<1
	4-8 years	Male	-	-	-	-	<1	<1	<1	<1	<1	<1	<5	<1
		Female	-	-	-	-	<1	<1	<1	<1	<1	<1	<5	<1
	9-13 years	Male	-	-	-	-	<1	<1	<1	<1	<1	<1	<5	<1
		Female	-	-	-	-	<1	<1	<1	<1	<1	<5	<5	<1
	14-16 years	Male	-	-	-	-	<1	<1	<1	<1	<5	<1	<5	<1
		Female	-	-	-	-	<1	<1	<1	<1	<1	<5	<5	<1
	17-18 years	Male	<1	<1	<1	<1	<1	<1	<1	<1	<1	<5	<1	<1
		Female	<1	<1	<1	<1	<1	<1	<1	<1	<5	<5	<1	<1
	19-29 years	Male	<1	<1	<1	<1	<1	<1	<1	<1	<5	<5	<1	<1
		Female	<1	<1	<5	<1	<1	<1	<1	<1	<5	<5	<5	<1
	30-49 years	Male	<1	<1	<5	<1	<1	<1	<1	<1	<5	<5	<5	<1
		Female	<1	<5	<5	<1	<1	<1	<1	<1	<5	<5	<5	<1
	50-69 years	Male	<1	<1	<5	<1	<1	<1	<1	<1	<5	<5	<5	<1
		Female	<1	<5	<5	<1	<1	<1	<1	<1	<5	<5	<5	<1
	70 years & above	Male	<1	<5	<5	<1	<1	<1	<1	<1	<5	<5	<5	<1
		Female	<1	<5	<5	<1	<1	<5	<5	<1	<5	<5	<5	<1
New Zealand	5-8 years	Male	-	-	-	-	-	-	-	-	<1	<1	<1	<1
		Female	-	-	-	-	-	-	-	-	<1	<1	<5	<1
	9-13 years	Male	-	-	-	-	-	-	-	-	<1	<1	<1	<1
		Female	-	-	-	-	-	-	-	-	<1	<1	<1	<1
	14 years	Male	-	-	-	-	-	-	-	-	<1	<1	<1	<1

Country	Age	Gender	Riboflavin				Niacin				Folate			
			Vegetable products & dishes		Fruit products & dishes		Vegetable products & dishes		Fruit products & dishes		Vegetable products & dishes		Fruit products & dishes	
			Tomato & tomato products	Other fruiting vegetables	Tropical Fruit	Other Fruit	Tomato & tomato products	Other fruiting vegetables	Tropical Fruit	Other Fruit	Tomato & tomato products	Other fruiting vegetables	Tropical Fruit	Other Fruit
		Female	-	-	-	-	-	-	-	-	<5	<5	<1	<1
	15-18 years	Male	<1	<1	<1	<1	<1	<1	<1	<1	<1	<5	<5	<1
		Female	<1	<1	<5	<1	<1	<1	<1	<1	<5	<5	<5	<1
	19-29 years	Male	<1	<1	<5	<1	<1	<1	<1	<1	<1	<1	<5	<1
		Female	<1	<5	<5	<1	<1	<1	<1	<1	<5	<5	<5	<1
	30-49 years	Male	<1	<5	<5	<1	<1	<1	<1	<1	<5	<5	<5	<1
		Female	<1	<5	<5	<1	<1	<1	<1	<1	<5	<5	<5	<5
	50-69 years	Male	<1	<1	<5	<1	<1	<1	<1	<1	<5	<5	<5	<1
		Female	<1	<5	<5	<1	<1	<1	<5	<1	<5	<5	<5	<5
	70 years & above	Male	<1	<1	<5	<1	<1	<1	<1	<1	<5	<5	<5	<1
		Female	<1	<5	<5	<1	<1	<1	<5	<1	<5	<5	<5	<5

- indicates that no further assessment was conducted for these nutrients and population groups as the major (2 digit code) food groups 'fruits' and 'vegetables' contributed <5% to the nutrient intakes.
Figures contributing 5% or more to nutrient intake for a population group indicated in ***bold italics***.

Table A1.3: Percentage contribution of minor food groups containing potentially irradiated foods to estimated irradiation-sensitive nutrient intakes for Australian and New Zealand population groups (continued)

Country	Age	Gender	Vitamin E				Vitamin B_6			
			Vegetable products & dishes		Fruit products & dishes		Vegetable products & dishes		Fruit products & dishes	
			Tomato & tomato products	Other fruiting vegetables	Tropical Fruit	Other Fruit	Tomato & tomato products	Other fruiting vegetables	Tropical Fruit	Other Fruit
Australia	2-3 years	Male	<5	<5	<5	<5	<1*	<1*	***12****	<5*
		Female	<5	<5	<5	<5	<1*	<1*	***11****	<5*
	4-8 years	Male	<5	<5	<1	<1	<1*	<1*	***8****	<5*
		Female	<5	<5	<1	<5	<1*	<1*	***9****	<1*
	9-13 years	Male	<5	<5	<1	<1	<1*	<1*	<5*	<1*
		Female	<5	<5	<1	<1	<1*	<1*	***6****	<5*
	14-16 years	Male	<5	<5	<1	<1	*	*	*	*
		Female	<5	<5	<1	<1	*	*	*	*
	17-18 years	Male	<5	<5	<1	<1	<1*	<1*	<5*	<1*
		Female	<5	<5	<1	<1	<1*	<5*	<5*	<5*
	19-29 years	Male	<5	<5	<1	<1	<1	<5	***5***	<1
		Female	<5	<5	<1	<1	<1	<5	***7***	<1
	30-49 years	Male	<5	<5	<1	<1	<1	<5	***7***	<1
		Female	<5	<5	<5	<1	<1	<5	***10***	<5
	50-69 years	Male	<5	<5	<5	<1	<1	<5	***8***	<5
		Female	<5	<5	<5	<5	<1	<5	***11***	<5
	70 years & above	Male	<5	<5	<5	<1	<1	<5	***10***	<1
		Female	<5	<5	<5	<1	<1	<5	***15***	<5
New Zealand	5-8 years	Male	<5	<1	<1	<5	<1	<1	***9***	<1
		Female	<5	<1	<1	<5	<1	<1	***13***	<1
	9-13 years	Male	<5	<1	<1	<5	<1	<1	***8***	<1
		Female	<5	<1	<1	<5	<1	<1	***9***	<1
	14 years	Male	<5	<1	<1	<1	<1	<1	***6***	<1

Country	Age	Gender	Vitamin E				Vitamin B_6			
			Vegetable products & dishes		Fruit products & dishes		Vegetable products & dishes		Fruit products & dishes	
			Tomato & tomato products	Other fruiting vegetables	Tropical Fruit	Other Fruit	Tomato & tomato products	Other fruiting vegetables	Tropical Fruit	Other Fruit
		Female	<5	<1	<1	<5	<1	<5	<5	<5
	15-18 years	Male	<1	<5	<1	<1	<1	<1	***7***	<1
		Female	<5	<1	<5	<1	<1	<5	***8***	<1
	19-29 years	Male	<5	<1	<5	<1	<1	<1	***8***	<1
		Female	<5	<5	<5	<5	<1	<5	***10***	<1
	30-49 years	Male	<5	<5	<5	<5	<1	<5	***9***	<1
		Female	<5	<5	<5	<5	<1	<5	***12***	<5
	50-69 years	Male	<5	<5	<5	<5	<1	<5	***11***	<1
		Female	<5	<5	<5	<5	<1	<5	***15***	<5
	70 years & above	Male	<5	<1	<5	<1	<1	<5	***12***	<1
		Female	<5	<1	<5	<5	<1	<5	***19***	<5

Figures contributing 5% or more to nutrient intake for a population group indicated in ***bold italics***.
* Percentage contributions to vitamin B_6 intakes for Australian children population groups were derived from the 1995 NNS. The percentage contribution of minor food groups for the Australian population aged 17-18 years (1995 NNS) also includes Australian children aged 14-16 years, for this nutrient only.