

**Supporting document 1**

Labelling Review Recommendation 34: Review of mandatory labelling of irradiated food

Literature review on the impacts of removing mandated food irradiation labelling on consumers



# Literature review on the impacts of removing mandated food irradiation labelling on consumers

Final Report

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**A report by the Centre for Health Economics Research and Evaluation**

**for Food Standards Australia New Zealand**



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#  Executive Summary

Food Standards Australia New Zealand (FSANZ) has commissioned the Centre for Health Economics and Research Evaluation (CHERE), University of Technology Sydney to undertake a comprehensive literature review of the available peer reviewed literature and relevant grey literature on the responses of consumers to food irradiation labelling.

Ten key questions to guide the review were developed. These questions were grouped into themes and research objectives. Including:

* consumer awareness and understanding towards food irradiation labelling,
* the purchasing impact of food irradiation labelling on consumer choice
* the economic impact of food irradiation labelling on consumer choice (including costs and benefits),
* the impact of removing mandatory food irradiation labelling information on consumer attitudes,
* other general points in relation to the population demographics and other attributes affecting or differentiating the literature, and

In addition to the above points, a general overview of potential means of providing information on food irradiation to consumers will be explored (i.e. consumer education).

**Main Findings**

The review demonstrates that consumers’ understanding and awareness of food irradiation varies significantly (1% to 72%). Consumer understanding of the food irradiation process is likely to be a key determining factor in understanding irradiation labelling. That said, no studies were identified that specifically discussed consumers’ understanding of the food irradiation labelling statements used in Australia and New Zealand. Awareness of food irradiation labelling was low. Only 1% of respondents had unprompted awareness of irradiation labelling; this rose slightly to 6% once the respondents had been prompted.

Given the low number of consumers that were aware of irradiation labelling, it was unsurprising that only 3% of respondents indicated that they used irradiated food labels at least occasionally to make purchasing decisions.

Consumers perceive food irradiation labelling in different ways. Many consider it an assurance of quality while some view it as a warning symbol. The way labelling information is presented (in terms of wording, presentation and use of the RADURA symbol) may directly impact the way that consumers form general opinions about irradiated food. It also suggests that different people will perceive the same label in a different way (positive or negative) depending on their knowledge and beliefs. Consumers may purchase products labelled with RADURA symbol without understanding its meaning, and being influenced by the green colour of the symbol.

Several studies suggest that aversion to irradiated foods has decreased over time. This may imply a more accepting attitude toward food irradiation and willingness-to-purchase irradiated food if sufficient information is provided from a reliable source. Indeed consumers value a label and information on irradiated food. This is measured by willingness-to-purchase and willingness-to-pay for food that has been irradiated. Several of these studies indicated that labelling information was important for consumers in their purchasing decision making.

Of the studies conducted in Australia and New Zealand, men or those aged 45-65 were more likely to be aware of irradiation in New Zealand. No differences in terms of demographic variables and irradiation awareness were noted in Australia. Studies conducted overseas demonstrated that consumers with higher educational attainment and income status were more likely to purchase, and be aware of, irradiated foods.

No studies compared the differences in consumer responses between voluntary and mandatory food irradiation labels. The review provides some evidence with regard to the differences between consumer attitudes towards mandatory and voluntary food labelling. The removal of mandatory labelling may impact consumers’ ability to make informed choices. Consumers averse to food irradiation may use other food labelling information as a proxy for irradiation status, or avoid food types that are known to be irradiated. However no data were retrieved to support this assertion.

The ‘right to know’ is a common theme raised in the literature. The cost to consumers (and therefore society) of removing irradiation labelling, is related to a number of factors: such as resistance to irradiated food, the proportion of individuals that choose food products based on their irradiation status (whether positive or negative) and the ease to obtain product information in the absence of a label. A label is intended to help consumers differentiate labelled product from otherwise similar products.

It is unclear if the price of irradiated food would increase, decrease or stay the same under a voluntary labelling permission. Some irradiated produce can be sold at parity to non-irradiated food (similar price) because irradiation effectively decreases product deterioration by increasing shelf-life (reduces wastage).

The main limitation of the review is the generalisability of the findings to the Australian and New Zealand context, since the majority of the data are obtained from international studies. Also the associated costs and benefits of mandatory and voluntary labels are derived from GM studies, since comparable studies are not available for irradiation labelling.

In conclusion, moving from mandatory irradiation food labelling, to voluntary (at the discretion of the producer) or no irradiation labelling, the following should be considered.

* Awareness of food irradiation in Australia and New Zealand is low and the general view is that very little is currently done to address the low level of awareness and understanding of the process of irradiation.
* Public education and information programs can increase public awareness of the benefits, costs and risks of food irradiation. Those studies that used a food irradiation benefits statement noted a significant change in acceptance and willingness-to-purchase irradiated foods.
* Point-of-purchase information and handling instructions also played a major role in changing consumer behaviour.
* In general, education has an important role to play, since the more acceptable the food technology, the lower the negative impact.

# Introduction

## Background for the review of mandatory food irradiation labelling requirements

In 2009, the then Australian and New Zealand Food Regulation Ministerial Council (now the COAG Australia New Zealand Ministerial Forum on Food Regulation) (Forum) agreed to a comprehensive independent review of food labelling law and policy. In January 2011, an expert panel, chaired by Dr Neal Blewett, AC, released a report entitled *Labelling Logic: Review of Food Labelling Law and Policy* that outlined 61 recommendations (Council, 2011). After the review of the Labelling Logic recommendations, the Forum referred a number of these recommendations to FSANZ.

In particular, Recommendation 34, “the requirement for mandatory labelling of irradiated food to be reviewed”.

The review panel identified that foods treated with ionising radiation have been in the food supply for at least a generation (i.e. 30 years’ experience) and there have been no problems for human health resulting from the consumption of food treated with irradiation.[[1]](#footnote-1)

Comment by the Forum[[2]](#footnote-2):

There is a significant body of evidence demonstrating that food processed using irradiation is both safe and nutritionally adequate. Irradiation, as with many other new technologies, provides significant benefits for consumers in terms of improved food safety and quality.

Irradiation also provides the food industry with a cost-effective approach to managing biosecurity threats and prolonging the shelf life of fresh produce. However, the uptake of irradiation in Australia and New Zealand, and therefore the realisation of these benefits, has been low.

It is timely that FSANZ review the need for mandatory labelling of irradiated food and assess whether there is a more effective approach to communicate the safety and benefits of irradiation to consumers. Improving consumer confidence in irradiation will reduce disincentives for increased uptake and broader application of the technology by industry.

This review will not encompass a broader assessment of the requirement for irradiated food to be subject to a pre-market safety assessment. Removal of the mandatory labelling requirement for irradiated food will not prevent the food industry from providing this information voluntarily to consumers. Evidence from other countries indicates that irradiation labelling is being used voluntarily to provide consumers with assurance of product safety and quality.[[3]](#footnote-3) Proposed action: The FoFR [Forum for Food Regulation] will request FSANZ to review Standard 1.5.3: Irradiation of Food, specifically with a view to assessing the need for the mandatory labelling requirement for all irradiated food to continue.

## Background on the food irradiation process and use in Australia and New Zealand

Food irradiation is used in more than 50 countries to destroy bacteria and pests and to extend the shelf life of food. Food irradiation technology is an alternative to chemical and heat treatment of food.

At low doses, irradiation extends a product’s shelf life. At higher doses, this process kills insects, moulds, bacteria and other potentially harmful micro-organisms.

Most modern day irradiation processes involve passing food through a radiation field. The radiation may be an electron beam or come from X-rays. The radiation may also consist of gamma rays, which are generated from the radioactive source Cobalt 60.

Current technology allows for a precise dose of radiation to be measured. The doses permitted range from a maximum of 1 kilogray (kGy) for tropical fruit; persimmons, tomatoes and capsicums, and up to 30 kGy for herbs and spices[[4]](#footnote-4). No radioactive energy remains in the food after irradiation.

Research has shown that food irradiation is safe and effective. The process has been examined thoroughly by the World Health Organization; the United Nations Food and Agriculture Organization; the European Community Scientific Committee for Food; the United States Food and Drug Administration, a United Kingdom House of Lords committee and by scientists at FSANZ.

FSANZ grants specific permission for the irradiation of food and requires these foods to be labelled, including food that has irradiated ingredients. Currently, FSANZ permission exists for the irradiation of herbs and spices, herbal teas, a number of tropical fruits (e.g. bread fruit, custard apples, mangoes and papaya), persimmons, tomatoes and capsicums.

FSANZ assesses each application for food irradiation by considering the following four aspects of the process and effect on the food: the technological need for the treatment; the safety of the treatment; effects on food composition; and any effects on the nutritional quality of the food.

FSANZ is currently assessing an application seeking permission to irradiate 12 specific fruit and vegetables (apples, apricots, cherries, nectarines, peaches, plums, honeydew, rockmelon, strawberries, table grapes, zucchini and scallopini (squash) for phytosanitary purposes.[[5]](#footnote-5)

## Labelling of irradiated food

Food that has been irradiated, or food that contains irradiated ingredients or components, must have a label or a mandatory labelling statement displayed close to the food with a statement that the food, ingredients or components have been treated with ionising radiation. The RADURA symbol (below) may be used in addition to the mandatory labelling. The RADURA symbol is the international symbol for irradiation, the petals represent the food, the central circle the radiation source, and the broken circle illustrates the rays from the energy source. In Australia and New Zealand it is not mandatory to include the RADURA symbol, however, a statement indicating that a food has been irradiated is mandatory.

 

Within Australia and New Zealand food irradiation was initially adopted in the 1980s. In 1990, due to consumer concerns a three year moratorium was set to further investigate the impact of irradiation on food. After three years, the moratorium was extended to last until 1999.

Under Standard 1.5.3 – Irradiation of Food of the Australia New Zealand Food Standards Code (The Code), food irradiation was initially permitted on 20 September 2001.[[6]](#footnote-6) Food irradiation in Australia is limited to a few items; herbs and spices were the first items permitted to be irradiated under the Code, some tropical fruit - permissions were added in 2003, and a few other fruit and vegetables were added a few years later.[[7]](#footnote-7)

Steritech has responsibility for food irradiation and other forms of irradiation in Australia with irradiation facilities in NSW, VIC and QLD. The only commercial food irradiation facility is in Queensland.[[8]](#footnote-8) New Zealand does not currently have the capacity to irradiate food products; therefore all irradiated food available in New Zealand is imported.

Currently, Australia supplies irradiated tomatoes, mangoes, papaya, and litchi to the New Zealand market. Table 1 summarises the current permissions for irradiated food in Australia and New Zealand, although the permissions do not reflect what is currently traded between these two countries. There is currently no importation of irradiated food products into Australia.

Table : Summary of Australia and New Zealand permissions for irradiated foods

|  |  |  |
| --- | --- | --- |
| **Food**  | **Purpose** | **Dose range (kGy)** |
| Herbs, spices and herbal infusions | disinfestation or decontamination | 2 to 30 |
| Tropical fruit (mangoes, breadfruit, carambola, custard apples, litchi, longan, mangosteen, papaya and rambutan), persimmons, tomatoes and capsicums | control pests of quarantine concern | 0.15 to 1 |

Source: <http://www.foodstandards.gov.au/code/applications/documents/A1069%20Irradiation%20of%20Tomatoes%20_%20Capsicums%20SD1%20Supp%20info.pdf>

#  Literature Review

## Aims and objectives

The objective of this review is to identify relevant literature on the impact on consumers of potential changes to the requirements of food irradiation labelling. In other words, ‘what will be the impact on consumer choice if the requirement for labelling of irradiated foods is no longer mandatory?’

The key questions and research methodology for the literature review of the available peer reviewed and grey literature on the response of consumers to food irradiation labelling are listed in Table 3. In consultation with FSANZ, ten key questions to guide the review were developed. These questions were grouped into themes and research objectives. Including:

* consumer awareness and understanding towards food irradiation labelling,
* the purchasing impact of food irradiation labelling on consumer choice
* the economic impact of food irradiation labelling on consumer choice (including costs and benefits),
* the impact of removing mandatory food irradiation labelling information on consumer attitudes,
* other general points in relation to the population demographics and other attributes affecting or differentiating the literature.

In addition to the above points, a general overview of the potential means of providing information on food irradiation to consumers will be explored (i.e. consumer education).

## Search Methodology

### Search strategy

The research questions were developed by FSANZ and form the basis of this literature review, these are presented in Table 3 along with the search terms used. Both search terms and databases used were determined in consultation with FSANZ.

There was overlap in the search terms used for the research questions. Where possible, MeSH (Medical Subject Headings) terms were used, whilst other search terms were included as keywords in the title and abstract or anywhere.

### Databases searched

The literature search aimed to focus on the Australian and New Zealand context whilst drawing on the international literature.

The electronic databases searched during the literature review included Medline, Embase and Biosis Previews via the Ovid interface. Pubmed via the US National Library of Medicine National Institutes of Health was used to identify papers in the health and medicine and biomedical fields.

To identify literature in the environmental field, the databases Academic Search Complete and Environment Complete and Business Source Complete via the Ebsco Host interface were searched. Econlit via this interface was searched to identify any economic papers that are not indexed in the health, medical, business and biomedical databases. SocINDEX was searched to identify additional social science references.

The search restriction was set to ‘humans’, but did not restrict any date. This broad approach minimised the risk of missing older publications, whilst avoiding a plethora of ‘animal’ studies.

The reference lists of relevant papers were hand searched to increase the number of papers that may have been missed in the search strategy.

### Non-peer reviewed literature

Grey literature was identified through searching the web sites of relevant Australian and New Zealand government departments and agencies. A number of national and international websites World Health Organisation (WHO) and US Food and Drug Administration (FDA) were searched to identify any ongoing studies or relevant literature. International websites were limited to these two because the focus of the report was on Australia and New Zealand. The FDA and WHO were deemed the most relevant (due to their role in setting phytosanitary standards) this was agreed upon with FSANZ during the scoping phase. The ‘Google’ search engine was used to identify reports from international agencies that may have been relevant.

Australian and New Zealand Entities:

1. Food Standards Australia and New Zealand

2. Australian Department of Health

3. New Zealand Department of Health

4. New Zealand Ministry for Primary Industries

5. Australian Department of Agriculture

6. CSIRO Animal Food and Health Sciences

7. Review of Food Labelling Law and Policy Committee (Australia)

State Entities:

1. Australian Capital Territory – ACT Health (Health Protection Service)

2. New South Wales – NSW Food Authority

3. Northern Territory – NT Department Health, Austlii Northern Territory Consolidated Acts

4. Queensland – Local Government, Public Health Units, Department of Health (Food Safety Standards and Regulation), Safe Food Production Queensland

5. South Australia – Local Government, Department of Primary Industries and Resources

6. Tasmania – Department of Health and Human Services, Local Government, Department of Primary Industries, Parks, Water and Environment

7. Victoria – Local Government, Department of Health (Food Safety and Regulation)

8. Western Australia – Local Government, Department of Health (Food Unit)

### Exclusion criteria

Articles that did not contribute any information on the consumer response to food irradiation, food irradiation labelling or food labelling, and the associated costs and benefits to consumers were excluded. This included papers that:

* focused on the science or safety of the technology that was not within the scope of the research questions.
* focused on other food technologies including functional foods, GMOs, etc, without any information that assisted with the research questions.
* focused on other food labelling including nutritional information, organic status and other information, without any information that would assist with the research questions.
* focused on food packaging.

Papers that did not explicitly refer to food irradiation labelling were included if parallels could be drawn with other types of labelling including GMOs or other methods to provide information (for instance, consumer education).

## Search results

The search of Medline, Embase, Biosis Previews, PubMed, Academic Search Complete, Environment Complete, Business Source Complete and EconLit returned 1800 papers after the removal of duplicates. The Round 1 exclusion refers to papers being excluded on the basis of title alone, these papers were of MRI technologies, ultrasound and X-rays. The review (Round 2 exclusion) of the articles involved a title and abstract scan, the excluded articles included papers on medical imaging, other medical technologies, other labelling uses not relating to consumer response (organic, allergies, animal welfare, food miles, nutrition to reduce obesity, private and branded goods), other food irradiation safety topics (safety, packaging), other food processing techniques (pulsed electric field, ozone-treated whole shell eggs), non-human studies and food marketing techniques.

After the review of the title and abstracts, 111 articles were identified to potentially have either direct relevance or may have helped to address to research questions. A number of studies were provided by FSANZ, manually searched for and extracted from reference lists of review papers leading to an additional 12 papers (grey literature and peer-reviewed articles) after removing those already found in the literature search.

### Full-text review of articles

The full articles were retrieved and hand searched according to the inclusion criteria developed by the reviewers. Papers were given a 0,1 ranking to determine if they addressed any of the research questions, articles that returned a sum of 0 were excluded from the review.

Figure 1 summarises the process used to identify and select the studies included in the literature review.

Figure : Summary of the process used to identify and select studies included in the literature review

Studies included in the literature review (n = 46). Of these:

Peer-reviewed literature search

(n = 26)

Peer-reviewed other sources (n=16)

Grey literature (n = 4)

Potentially relevant studies identified in the literature searches (n =1,905)

Studies assessed for eligibility based on citation information (n = 1,800)

Duplicates excluded (n =105)

Studies assessed for eligibility based on citation information (n = 1,261)

Round 1 exclusion (title) (n = 539)

Studies retrieved for full-text examination (n = 111)

Round 2 exclusion (title and abstract) (n = 1,150)

Studies excluded (n = 85). Of these:

Food irradiation safety or use (n=27)

GMO (n = 37)

Nutrition labelling (n = 9)

Organic labelling (n = 2)

Other labelling (COOL, traceability) (n=7)

Other (n=3)

Other literature Peer-reviewed from other sources (n=16)

Grey literature (n=4)

Table 4 (In the Appendix) lists the included studies from the main literature search. From the literature search 26 articles were included in the literature review. Table 5 lists the included studies from other sources, and includes 16 peer-reviewed papers and four studies from the grey literature.

### Reasons for exclusion

The major reason studies were excluded was that they were relating to genetically modified food technology (37), or labelling for other purposes including organic food (2) and nutrition labelling (9). Studies that related to food irradiation were excluded if they only referred to the safety of the process or its use (27), these studies did not address the pre-specified research questions. The list of excluded studies and the reason for exclusion for the main literature search is shown in Table 6 of the Appendix.

## Critical appraisal of the literature

The papers were critically appraised using peer-reviewed checklists, namely STROBE (von Elm, 2007) [[9]](#footnote-9) for observational studies and MOOSE (Stroup, 2000) [[10]](#footnote-10) for reviews. No systematic literature reviews or meta-analyses were found in the peer-reviewed literature, so the MOOSE checklist was used only as a guide to evaluate the quality of the reviews. Table 7 in the Appendix summarises the generalisability issues of the sample and potential biases of the original surveys. Full critical appraisals of both the original surveys and review articles are provided as part of the supporting electronic documents. (Microsoft Excel spread sheet, titled: Food Irradiation-Lit Review\_List of references\_Final for FSANZ).

Eleven review articles were identified during the literature review, however only one was a systematic literature review and it was found in the grey literature (Lyndhurst, 2009).

The quality of the included studies is discussed in a narrative fashion, with important issues (e.g, bias, generalisability and limitations) being highlighted in the discussion of outcomes.

### Quality of the studies

The majority of studies identified were questionnaire based surveys. The sampling methodology was not always explained in detail; therefore the potential for sampling/selection bias was high. In fact, the samples were frequently not representative of the population which would lead to issues of generalisability to the broader population. Given the potential for selection bias and the fact that many of the papers were based in the US, the external validity of most papers is questionable to the Australian and New Zealand context.

# Summary of findings and discussion

Non-randomised studies were analysed and discussed separately, following the approach recommended by Deeks *et al* (2003) and Audigé *et al* (2004). The findings of these studies were interpreted with caution.

Due to the limited number of food permitted to be irradiated by FSANZ, and the lack of recent surveys and studies specific to the Australian and New Zealand context, findings from the international literature have been drawn on, in particular, the United States where irradiated food has been on the market for a number of decades.

## Are consumers aware of food irradiation labelling?

Most of the studies identified asked survey respondents if they were aware of the food irradiation process, rather than food irradiation labelling.

Of the 15 surveys that addressed the question of food irradiation awareness, one asked respondents if they had heard of a specific irradiated food (e.g. irradiated beef) and 13 asked if they heard of the term ‘food irradiation’. (Table 8, in the Appendix) Only one survey in the grey literature, asked respondents about food irradiation labels specifically (FSANZ, 2003), this survey measured unprompted awareness of food irradiation labelling by asking:

*“firstly, thinking about all of the different types of food products available to buy, can you tell me what kinds of information can be found on packaged food and drink products?”*

and then prompted awareness of label elements (including one of irradiated label) were measured:

*“…[t]hese pictures show 16 different types of information found on labels. Which of these do you recognise?”*

In this study, awareness of irradiation labelling was low. Less than 1% of 1940 Australian and New Zealand respondents, were aware of food irradiation (unprompted (FSANZ, 2003). This increased slightly to 6% once prompted. It is possible that awareness of irradiation labelling may have increased in recent years, but no recent surveys were published to justify this in relation to Australia and New Zealand.

One explanation of the low awareness of food irradiation labelling in Australia and New Zealand is the fact that there is a limited number of food products irradiated (therefore limited exposure) on the market compared to other countries. For instance, irradiated foods have been on the market for longer and a wider variety of food products are irradiated in the United States (spices, fruit and vegetables and meat and poultry)[[11]](#footnote-11) and other countries (China, Brazil, France and Thailand). In Australia, there is no importation of irradiated food products from other countries. There is some small scale trade between Australian states, however this would have been limited to mangoes at the time of the survey in 2003, as most irradiated tropical fruit grown in Australia are exported to other countries (e.g. dragon fruit to Vietnam). At the time of the survey the only irradiated products available in New Zealand were imported from Australia (mangoes, litchi).

There are few studies that have explored consumer understanding of food irradiation in the Australian and New Zealand context; therefore findings have been drawn from the international literature.

### Are consumers aware of food irradiation?

Table 8 in the Appendix lists the papers identified in the literature search that addressed consumer awareness of food irradiation. The proportion of respondents who were aware of food irradiation ranged from less than 1% to 85%, this depended on the sample chosen and whether they were representative of the population. The generalisability of these findings is limited by the selection bias associated with the descriptive studies. Five out of 15 surveys used somewhat representative samples and found the following levels of awareness; less than 1% (FSANZ, 2003), Australia and New Zealand, 25% (Malone, 1990), USA, 34% (Prior *et al.*, 2013), UK, 49% (Frenzen *et al.*, 2001), USA and 72% (Resurreccion *et al.*, 1995), USA) These results suggest that there is a country-effect associated with food irradiation awareness. In addition, the way the irradiation question was framed also limits the generalisability across different countries.

The surveys that were conducted in Australia and New Zealand reported considerably different levels of consumer awareness. Gamble *et al* (2002) reported an irradiation awareness of between 60-68%, whereas the FSANZ Report (2003) reported an awareness of less than 1% and 6%, although the latter related specifically to labelling rather than a general question on food irradiation. The different results in these two studies can be explained by how the question of awareness was asked. The former asked respondents if they had heard of the term irradiation, whilst the latter required respondents to recall what labels they used when making purchasing decisions. It is noteworthy that these studies were carried out over a decade ago, and consequently these figures may not reflect current food irradiation label awareness levels in Australia and New Zealand.

To illustrate this point, a recent large survey (n=3,231) conducted by the UK Food Standards Agency in 2012 (Prior *et al.*, 2013), demonstrated that 34% of the representative sample had heard of irradiation in relation to food production. However, relative to Australia, whether the increased awareness is related to a time-effect or country-effect is difficult to disentangle. In the UK, only dried aromatic herbs, spices and vegetable seasonings can be irradiated; however, approved irradiated foods can be imported[[12]](#footnote-12).

The surveys identified during the review were published over a 20 year period ranging from 1993 to 2013. They were also performed in a number of countries including USA, Argentina, Turkey, China, Brazil, UK, Australia and New Zealand. Since the number of allowed irradiated products is limited in the Australian and New Zealand markets, it is understandable that awareness is low compared to other countries with both high use of irradiation and sale of irradiated products. Further, these countries have different labelling requirements compared to Australia and New Zealand.

A review for the Food Standards Agency (UK) (Lyndhurst, 2009) identified a number of studies that considered the public’s views on irradiation (awareness, understanding, concern and acceptance). All quoted studies related to the research questions have been included in this report; including Frenzen *et al* (2001), Gunes and Tekin *et al* (2006) and Rimal *et al* (2004).

## Do consumers understand the meaning of food irradiation labels?

Ten articles discussed consumer understanding of food irradiation. All of these studies measured knowledge subjectively, using a self-reported measure of knowledge, as opposed to being objectively tested. These articles are listed in Table 9 in the Appendix.

The results of the review showed that the level of understanding about food irradiation ranged from 0% to 72% in these surveys. Flores *et al* (2008), found 0% of Argentinian secondary (high-school) and non-student adults stated that they had ‘a lot’ of knowledge regarding food irradiation, whilst 8% of food science university students and 4% of non-food science students sampled did. These findings are likely to be biased as the sample is not representative and food science students are likely to have greater knowledge of food processes than the general population. However, this indicates that formal education may play a role in consumer understanding of food irradiation process.

Six out of seven surveys measured both consumer awareness and understanding of food irradiation. In all these studies, a lower proportion of respondents stated that they understood what food irradiation was compared to the proportion that stated they were aware of the process. For instance, the survey of a US consumer database identified that 72% of respondents were aware of food irradiation, but only 63% stated that they understood food irradiation (Resurreccion *et al.*, 1995). Similarly, 34% of the respondents in a random sample of UK households stated that they were aware of food irradiation, but only 31% of respondents agreed to the statement *“I feel knowledgeable about the use of irradiation in food production”* (Prior *et al.*, 2013). In Chile a survey conducted on the streets of Santiago showed that 23.5% of consumers were aware of irradiation, and 45.9% of respondents associated irradiated food with radioactive food (Junqueira-Gonçalves *et al.*, 2011).

Knowledge of the RADURA symbol was tested in four surveys. Terry *et al* (1988), found only 2.8% of respondents knew the RADURA symbol; while Nayga *et al* (2005) reported only 10.3% of respondents did not recognise the symbol; Ornellas *et al* (2006) found 92% did not know the meaning of RADURA symbol; and Junqueira-Goncalves *et al* (2011) reported that 95.8% of the respondents were unfamiliar with the symbol. The first two surveys were conducted in the US, while the other two were conducted in Chile and Brazil, respectively. There are considerable differences in recognising the international sign for food irradiation both across and within a country.

These results demonstrate that consumers’ self-reported understanding of food irradiation varies significantly. It is reasonable to assume that consumers’ understanding of the food irradiation process is likely to be a key determining factor in understanding food irradiation labelling. The literature search did not find studies that specifically identified consumer understanding of the food irradiation labelling statements used in Australia and New Zealand:

* ‘*Treated with ionising radiation’ or* *Irradiated (name of food)’* [[13]](#footnote-13)

## Do consumers find the food irradiation labelling useful and why?

A number of studies were identified that explored the usefulness of nutrition labelling of food products, but only four papers directly addressed the usefulness of food irradiation labelling (Nayga *et al.*, 2005; Ornellas, 2006; Resurreccion *et al.*, 1995; Terry, 1988).

Labelling of irradiated whole product is mandatory in the US, Canada and European countries, as well as in Australia and New Zealand (Kume, 2009). There is none, or very limited, information on the labelling requirements in other major users of food irradiation, such as China and the Ukraine.

In Australia, one survey addressed the question of whether consumers actually used food irradiation labels (FSANZ, 2003). In this survey 3% of respondents indicated that they used irradiated food labels at least occasionally when asked if they used any of the 15 label elements presented (one of which was for food irradiation) to make purchasing decisions[[14]](#footnote-14).

Consumers may also perceive food irradiation labels as a warning (Nayga *et al.*, 2005). In this study, conducted with shoppers at several stores in major cities in Texas, US, 484 respondents were asked their opinion toward the RADURA symbol. The results demonstrated that: 67.1% considered it an assurance of quality, 5.5% considered it a warning symbol, 17.1% indicated that it does not affect their buying decision and 10.3% did not recognise the symbol. The findings from this study suggest that the way labelling information is presented (in terms of wording, presentation and the RADURA symbol) may directly impact the way that consumers form general opinions about irradiated food. It also suggests that people perceive the same label in a different way (positive or negative) depending on their knowledge and beliefs.

Similarly, in survey conducted in Chile, 55.8% indicated willingness-to-purchase irradiated food because of the RADURA symbol which ‘transmits the sensation of confidence and safety’ (Junqueira-Gonçalves *et al.*, 2011).

A US study of consumer attitudes towards labelling of irradiated meat and poultry, reported that an ‘irradiation’ label was important to 81% of respondents (Resurreccion *et al.*, 1995). In this study 50% of the respondents considered the RADURA symbol and statements such as “Treated with/by Irradiation” to be insufficient to inform consumers that the food was irradiated (Resurreccion *et al.*, 1995). The findings of this study suggest that effective labelling and education, if successful, would result in 75-81% of consumers preferring irradiated meat and poultry to the non-irradiated.

In addition, in a survey of 218 consumers, conducted in Brazil, the study concluded that consumers respond favourably to the additional information on food irradiation label (Ornellas, 2006).

However, due to country-effect it is uncertain whether the magnitude of these positive preferences would translate to the Australian and New Zealand setting.

Apart from the studies discussed in this section, there is a gap in the literature on studies objectively testing consumers’ understanding and use of food irradiation labelling (for instance, some nutrition labelling studies ask respondents to decipher elements of the nutrition label).

All of these studies measured knowledge subjectively, that is, they used self-reported levels of knowledge, as opposed to being objectively tested. However, it is unlikely that consumers would understand and use food irradiation labelling (and the RADURA symbol) appropriately, if they are unfamiliar with the concept of food irradiation in the first place.

## Do consumers use food irradiation labels in selecting products to purchase or consume? Do consumers trade off information on food irradiation against other food attributes?

There were 18 studies identified where respondents were asked if they would purchase irradiated food. The positive responses ranged from 19% to 94% (Table 10 of the Appendix).The study designs varied with regard to the amount of prior irradiation information that was provided to respondents.

* *No prior information* - In eleven studies, respondents were asked if they would purchase or consume irradiated food - no information regarding irradiation was provided. In these studies between 19% and 75% indicated they would purchase irradiated food.
* *Response conditional of prior knowledge of irradiation* – In two studies respondents that understood the irradiation process were asked if they would purchase irradiated food. Between 50% and 89.75% gave a positive response.
* *Food irradiation information provided* - When information about food irradiation was included in the survey, between 48% and 94% of respondents indicated they would purchase irradiated foods.

Although there is significant heterogeneity in the above responses, these data suggest that resistance to irradiated food products could be lessened by providing better information regarding the food irradiation process. This is also evident from a survey conducted by Terry *et al* (1988) that included three stages of food irradiation information presented to respondents. Each stage revealed additional information about the irradiation label or food irradiation technology. In the final stage, the results indicated that 48% of consumers were willing to buy irradiated produce that was US$0.03 per pound more expensive than non-irradiated produce (an increase from about 15% when only the RADURA symbol and the label ‘irradiated’ were presented) (Terry, 1988).

Most of the studies used stated preference techniques to understand consumer attitude and five studies presented revealed consumer preferences. These are discussed below (Deliza *et al.*, 2010; Fox, 1998; Hashim *et al.*, 2001; Hashim *et al.*, 1995; Rimal *et al.*, 2004).

An experiment that collected consumer (N=240) purchasing information on irradiated beef used three sources of data, a simulated supermarket experiment (included two rounds), a questionnaire and an exit survey. In the data obtained from the exit survey for preferences for irradiated beef, 60% of participants reported their intention to purchase irradiated beef (Rimal *et al.*, 2004). These results are somewhat contradicted by the revealed data from the simulated supermarket experiment, which showed that only 21.7% actually purchased irradiated beef during the experiment. However, of those who reported that intended to purchase irradiated beef only 11.1% actually purchased all irradiated packages, while 10.2% of participants who reported that they would never purchase irradiated beef subsequently did so. This study suggests that there may be inconsistencies between what consumers say they will do and what they actually do when presented with real-life choices, and this infers that The product choice was affected by product attributes (appearance of the product and safety information and handling instruction on the package labels).

However, the simulated supermarket experiment was conducted in two rounds; for the second round display posters were set up with information on ‘food irradiation technology’, including stated facts about the use of food irradiation and the FDA approval. The purchasing results of irradiated beef from the second round were statistically different from the first round. In conclusion the point-of-purchase information at the store had a significant effect on the choice of purchasing irradiated beef.

Similarly, Fox *et al* (1998), investigated a potential market for irradiated chicken breasts by conducting a mail survey with complete response from 229 households, two retail trials in grocery stores, and a simulated market experiment from a random sample of 250 households with 98 subjects were selected to participate in the experiment on the willingness-to-purchase irradiated poultry in the US. The survey, which included information about food irradiation, showed that 81% would choose irradiated poultry, however in the retail trial phase only 43% of consumers bought irradiated poultry (the researchers observed that only a small percentage of shoppers read the readily available information about food irradiation). The market experiment indicated that 80% of participants bought irradiated poultry, a similar result was found for the 10% discounted irradiated product, with 84% purchasing in the experiment compared to 87% in the mail survey. The results also indicated that around 30% of all participants in the study were willing to pay a 10% premium for the irradiated product. The paper suggested that ‘*shoppers’ unawareness of the benefits of food irradiation was a major factor accounting for the difference between mail survey and retail experiment results*’ (Fox, 1998).

In another simulated experiment consumers were presented with an option to select two packages from non-irradiated and irradiated beef (Hashim *et al.*, 2001). About 30% of consumers purchased all irradiated packages, while 40% of consumers selected at least one irradiated package and 30% purchased non-irradiated beef. The experiment showed that there was no difference between the variety of product on the impact of consumer choice with different cuts of beef (that is, choice of ground beef, ground chuck, top round or rib eye steak) in selecting irradiated packages.

Using a simulated supermarket setting, tested whether consumers (n=126) would purchase irradiated poultry products, and the effects of marketing strategies on consumer choices (Hashim *et al.*, 1995). Following an education program the number of participants that purchased irradiated chicken breasts increased from 59.5% to 83.3% (61.9% to 85.7% for chicken thighs). Fifty-eight percent of the participants stated they would always buy irradiated chicken if available, and an additional 27% stated they would purchase it sometimes. Approximately 44% were willing to pay the same price for irradiated chicken as non-irradiated chicken, and 42% were willing to pay a 5% premium for irradiated chicken.

Huang *et al* (2007) also demonstrated that consumers were willing to pay a price premium for irradiated poultry products (average US$1.34/lb). In this US study of 303 adults interviewed by telephone, 65% of responders indicated a willingness-to-buy irradiated chicken products.

At the point-of-purchase consumers base their purchasing decisions on a variety of factors including the appearance of the food (Deliza *et al.*, 2010; Rimal *et al.*, 2004). Some studies reported that consumers indicated that the positive attributes of food irradiation, such as killing bacteria 70.9% (Malone, 1990); 47.1% (raw meats and poultry, 48.4% (pork) (Resurreccion *et al.*, 1995); 85% and 65.8% (Spaulding *et al.*, 2007; Spaulding *et al.*, 2006), respectively) and extended shelf-life (35% and 15.2% (Spaulding *et al.*, 2007; Spaulding *et al.*, 2006) respectively) were important. The food irradiation label and food attributes (such as appearance) were used interchangeably (and traded-off) by consumers during purchasing decision making. This suggests that consumers value food irradiation labels as additional information relating to the products.

The peer reviewed literature indicated that consumers use irradiation information when purchasing food products in these experiments, and there is an effect on willingness-to-buy when information about irradiation is provided at the point-of-purchase. Although, as indicated by Fox *et al* (1998) in a retail setting, few consumers read the information on food irradiation, which resulted in half of the expected number of shoppers buying irradiated poultry. In addition, information on the benefits of, and reasons for, food irradiation may reduce some of the perceived negative effects of food irradiation in general.

## Do consumers use food irradiation labels in avoiding products to purchase or consume?

Eleven papers contain information on consumer preferences to avoid, or not buy, food that has been irradiated (Table 11, in the Appendix). Most studies suggest that some consumers would use food irradiation labels to avoid irradiated food.

As discussed in section 3.3, the study by Nayga *et al* (2005) asked participants about their perception of the RADURA symbol. Most respondents (67%) viewed it as an assurance of quality and indicated a willingness-to-purchase irradiated food, 17% were indifferent to the presence of the symbol, 5.5% considered it a warning and would not be willing to buy irradiated food. Only 10% of the participants were unaware of the symbol or its meaning (Nayga *et al.*, 2005).

A list of studies that discuss consumers’ attitudes towards buying irradiated food is presented in Table 11. In the reviewed literature there was no evidence regarding whether consumers would behave differently if irradiation labels were removed. This is because countries with available data require mandatory irradiation labelling; therefore this option had not been explored (Kim, 2012).

In a number of US studies conducted from the late 80s to the mid-90s the levels of reported aversion to irradiated food varied from 19% (Resurreccion *et al.*, 1995) to 54% (Malone, 1990). During the same period, two studies reported an aversion to irradiated foods in the UK that ranged from 43% (Donaldson *et al.*, 1996) to 81% (Jack and Sanderson, 1995).

In more recent surveys, the results indicated that consumer perceptions have changed and consumers were willing to be educated about food irradiation. The rate of avoidance of irradiated food in the USA varied from 31% (Hashim *et al.*, 2001), 29.8% (Rimal *et al.*, 2004) to 5.7% (Nayga *et al.*, 2005). The largest and most representative sample (n=10,780) indicated a 32% avoidance of food irradiation (Frenzen *et al.*, 2001). These studies suggest that aversion to irradiated foods has decreased over time. This may imply that consumers have a more accepting attitude toward food irradiation and willingness-to-purchase irradiated food if sufficient information (on food irradiation) is provided from a reliable source. Although this should be interpreted with caution since the data used is cross-sectional rather than longitudinal.

This trend is supported by a UK study, which revealed a small decrease in the percentage of consumers claiming to avoid irradiated food, from previous years. In this study, 39% of respondents indicated they were not willing to buy irradiated food (Gruber *et al.*, 2003).

In contrast to the data obtained from the US and UK, studies conducted in other countries have shown a higher acceptance of irradiated food. A study conducted in Turkey showed than only 13% of respondents were not willing to buy irradiated food (Gunes and Tekin, 2006). In a shopping experiment conducted in China, less than 3% of participants were unwilling to buy irradiated food, after tasting irradiated apples (Xu *et al.*, 1993). The low aversion to irradiated food in China may be due to the study design (i.e. a taste test). But it is worth noting that China irradiates the largest amount of food in the world (Kim, 2012; Kume, 2013), therefore the low level of aversion to food irradiation may be, in part, due to exposure to large quantities and varieties of irradiated food over a long period of time (country-effect and time-effect).

Although, no literature was available regarding recent education campaigns in countries like China, the US and the UK, food industries in these countries have continued to expand the supply of irradiated foods. This may suggest that they are less concerned about negative attitudes to food irradiation.

## Do consumers value food irradiation labels while not using them to make selection or avoidance decisions (i.e. is there a perceived ‘right to know’ that a product is irradiated or not). How can the ‘right to know’ be included in assessments of benefits and costs in the context of food labelling?

A number of studies indicated that consumers value a label on irradiated food. This is measured by willingness-to-purchase and willingness-to-pay for irradiated food. Consumers considered the label information important when purchasing a food product and that food irradiation label was important for acceptance of irradiation foods. The use of labels by consumers to buy or avoid irradiated foods was discussed in sections 3.4 and 3.5.

The ‘right to know’ is a common theme that relates to different types of processed foods, such as irradiated foods and genetically modified (GM) foods.

The review identified one study that provided data on the use and value of food irradiation by consumers (Marcotte and Kunstadt, 1993) and 13 studies on consumer willingness-to-purchase irradiated food (as discussed previously). These studies reported that consumers value the presence of labels and irradiation information at the point-of-purchase. In many cases, this information may change consumers’ purchasing attitudes.

The food label conveys information about the product and allows consumers the ability to easily choose between products. Without a clear label, additional burden and cost may be placed on the consumer. For example a motivated consumer would need to read additional product information or contact the producer in the absence of a suitable label, as demonstrated with GM foods:

*“Labeling theoretically allows those consumers who have qualms and concerns about [genetically engineered (GE)] foods to withhold consent and exit the GE food market altogether. In this way, labeling protects what is commonly known as exit rights, the ability of consumers to avoid the market if they desire to do so (Thompson 1997; Burgess and Walsh 1999; Thompson 2000)”* (Berenji, 2007)*.*

The cost to consumers (and therefore to society) of removing irradiation labelling, is related to a number of factors, such as the resistance to irradiated food, the proportion of individuals that choose food products based on their irradiation status (whether positive or negative), and the ease of obtaining product information in the absence of the label.

Todt *et al* (2010) conducted a survey asking consumers the reasons they favoured mandatory labelling (GM foods). Half of respondents (48%) indicated that the principal reason (chosen out of a list of pre-specified choices) was ‘the right of consumers to know’. In this study, respondents were more concerned with general consumer rights, rather than the safety of the product (19%). This survey was conducted in Spain, where GM food is still being produced and sold in higher amounts than in other parts of the EU, after the EU mandatory labelling laws were passed in 2004 (Marchant and Cardineau, 2013).

In October 2001, FSANZ (formally known as ANZFA) commissioned a consultant group the NFO Donovan Research to undertake qualitative research to determine consumer response to food irradiation labelling. It should be noted that permission to first irradiate food (herbs, herbal infusions and spices) in Australia and New Zealand was announced in September 2001. This may indicate the minimal consumer exposure to irradiated foods in the market and the results should be interpreted with caution (FSANZ, 2001). The report found that *“the general consensus was that even though the word [irradiation] was alarming and off-putting, that it should be used on packaging rather than a symbol, again because people had a right to know what has been done to their food, and a symbol was seen as way of hiding this. (page 62)”(FSANZ, 2001).*

Although there is rich literature regarding the ‘right to know’ in the food labelling literature, it is difficult to quantify and value it. The consumers’ ‘right to know’ is also part of the discussion on mandatory versus voluntary label policies in section 3.10.

## Are there other benefits and costs that consumers may derive from food irradiation labelling?

### Costs of food irradiation labelling

There were no identified studies that specifically explored the cost of food irradiation labelling or the potential savings of removing irradiation labels. Several articles discussed that the potential impact of irradiation (labelled items) in terms of price increase to the consumer is minimal or may be absorbed by additional attributes of irradiation (DeRuiter and Dwyer, 2002; Spaulding *et al.*, 2006).

DeRuiter *et al* (2002) argued that:

*“Some irradiated produce is sold at prices that are comparable to non‑irradiated produce because losses were decreased and shelf life was increased by irradiation.”(DeRuiter and Dwyer, 2002).*

It is suggested that the cost of irradiated food may be on par with non-irradiated food due to the savings incurred by the seller through extended shelf-life (DeRuiter and Dwyer, 2002). It is also rational to assume that irradiation of some foods (such as fresh food) will replace other types of post-harvest treatments; therefore there is a possibility for cost-offset. Other cost-savings that may lower the price of irradiated food were discussed in the literature:

*“Overall, savings from decreased foodborne illness are calculated to be much greater than the small increase in food costs, although costs and benefits do not necessarily accrue to the same individuals.”(DeRuiter and Dwyer, 2002).*

Although, the additional cost of food irradiation treatment was not discussed in the literature, it was mentioned that the cost of separation and pre-irradiation packaging would add to the cost of the product. In relation to labelling costs in general, the research involving GM foods provides some relevant information.

In Australia, the non-GM producers are currently required to take precaution not to cross contaminate with GM produce, thus there is added cost to GM producers on product segregation (ACCC 2002)[[15]](#footnote-15). Although this is the case in the GM industry, the food irradiation industry in Australia and New Zealand may be subject to different procedures, with the irradiated food supplier and retailer required to keep their produce segregated from non-irradiated foods at additional cost.

It is important to note that GM cross contamination of foods may occur naturally (pollination, water supply). In contrast, food irradiation is a controlled technology where the segregation of irradiated produce is innately different from segregation of GM foods, therefore the cost of segregating irradiated food may be attributed to the producer.

In Marchant *et al* (2010), the authors discussed a potential mandatory labelling of GM foods in the US and they suggested that the increased cost of additional food labelling by the producer/supplier may be passed onto the consumer.

*“The major cost of GM labeling is the cost of segregating GM from non GM foods from farm to fork….Failure to carefully segregate GM ingredients at the farm level, during transportation and storage, during food processing, and during distribution can result in enormous penalties under proposed GM labeling programs…there are few consumers who are willing to pay this price for labeling of GM foods.” (Marchant and Cardineau, 2013).*

In Australia and New Zealand such penalties (costs) may be placed upon the users of food irradiation technology and the costs passed onto consumers.

In the GM context, there is a difference in the cost of the product depending whether the GM ingredient is a component of a processed food or a whole GM food (Carter and Gruere, 2003). The authors argue that under mandatory GM labelling schemes (such as in the EU and Japan), GM ingredients in highly processed foods that account for a small share of the cost of the final product did not cause a large monetary impact on the producers of processed foods during switching to non-GM foods. However, this would be different for producers of a whole product, as the presence of a label may increase the cost of the product, this represents a financial cost. There is a potential cost to consumer choice as well, mandatory labelling may drive the GM labelled product out of the market, as the case in the EU and Japan, and thus decrease consumer choice. It is likely that the same would apply to irradiated foods.

In the food irradiation context, due to the different nature of food processing, the irradiation process does not leave any residues and hence cannot ‘contaminate’ non-irradiated products or ingredients. Therefore, segregation would not be necessary for ‘contamination’ purposes, however, segregation may still be important (at the final point-of-purchase) for those consumers who would want to know if their food is irradiated (regardless of whether a label is present).

### Benefits of food irradiation labelling

Several studies have investigated the willingness-to-pay for irradiated food based on the personal benefits to consumers from food irradiation (Deliza *et al.*, 2010; Malone, 1990; Nayga *et al.*, 2005; Terry, 1988). However, there were no identified specific studies that evaluated willingness-to-pay for food irradiation labels. The willingness-to-pay studies presented irradiated food that was clearly labelled.

In several studies consumers were presented with data of the potential danger of food-borne illnesses from consuming meat and poultry. Consumer willingness‑to‑pay for food that has been irradiated to reduce the incidence of food-borne illnesses depended on the level of food safety it provided (Malone, 1990). A review by Cottee (2005) identified an increase in consumers’ willingness-to-purchase irradiated poultry from 20% to 45-54% after receiving information of the benefits of irradiation in eliminating food-borne bacteria. Poultry and meat are currently not irradiated in Australia or New Zealand, therefore the relevance of these findings to non-meat products may be limited.

In Nayga *et al* (2005), consumers were presented information about benefits of food irradiation (‘irradiation has been shown to destroy at least 99.9% of common foodborne pathogens (salmonella, E.coli, listeria)’). After the initial survey the ‘strong buyer segment’ for irradiated food increased from 8.4% to 28.3%. These results indicate that within stated preferences, consumers respond to information about benefits of labelled irradiated food. Although it should be noted that the benefits were predicated on consumers’ understanding the health benefits associated with irradiation (rather than the label per se).

Nayga *et al* (2005) surveyed consumers about their preferences based on the type of irradiation source. The study provided a second set of information to the consumers regarding the type of irradiation (gamma ray and electron beam irradiation), willingness-to-buy of irradiated beef using electron beam process increased from 89% to 94.3%. The ‘strong buyer’ population segment increased to 42.2%, these results indicated that about 24% of the ‘doubter’ population segment and 41% of the ‘rejecters’ population segment had switched to ‘strong buyer’.

Food safety is a main concern for many consumers (Spaulding *et al.*, 2006) and (FSANZ, 2008). It is possible to assume that in populations or regions where food-borne diseases are common, and can lead to severe outcomes, including fatalities, consumers would be more willing to purchase food that has an ‘irradiated’ label attached. Malone *et al* (2007) reported that consumers perceived the use of irradiation to treat food as a signal of quality through improved food safety

It was reported that all consumers may want their food to be safe, but will differ in their risk perception and risk preferences (Golan *et al.*, 2001). Several studies reported consumers being risk averse[[16]](#footnote-16) to food-borne diseases (Malone, 1990; Nayga *et al.*, 2005; Spaulding *et al.*, 2007; Spaulding *et al.*, 2006). These studies also reported positive results in relation to consumer awareness and understanding of food irradiation providing a benefit of eliminating bacteria-causing diseases. A labelled irradiated product may provide consumer confidence of being bacteria free and safe for consumption regardless of the consumer’s purchasing intention. Parallels can be drawn from the GM labelling context.

In a comment from Streiffer *et al* (2003) to the article “Mandatory Labelling of Genetically Modified Foods: Does It Really Provide Consumer Choice?” by Carter *et al* (2003), labelling represented consumer autonomy as an ‘underlying value of both choice and informed choice’. The authors argued, that although mandatory labelling may decrease consumer options to buy GM free food, the label will protect autonomy by providing information about the product that consumers may regard important.

## Are there differences across age, gender and socio-economic status in the response to these questions? Are there differences between Australian and New Zealand consumers?

The original studies identified in the review (surveys, willingness-to-purchase (WTP) studies, simulated supermarket experiments) collected demographic information including gender, age, income and education levels.

There were two studies that investigated Australian and New Zealand consumers’ awareness or understanding towards irradiated food. FSANZ (2003) found no differences in demographic variables in relation to the research questions. Whilst Gamble *et al* (2002) found that in Australia there was no difference in demographic variables, however in the New Zealand sample, men or those aged 45-64 were more likely to be aware of irradiation.

Higher educational attainment and income status are correlated with WTP and awareness of irradiated foods. However, not all studies provided evidence of whether demographic variables correlated with their findings.

Deliza *et al* (2010) reported a marginally significant correlation between income and preference for irradiated food, where low-income earners preferred non-irradiated food. The study also reported that the appearance of the food demonstrated a statistically significant correlation with age, showing that consumers over the age of 36 were more willing to buy ‘good looking’ irradiated food (i.e. papaya with no blemishes).

The study by Nayga *et al* (2005) demonstrated significant correlation between education, income, age and willingness-to buy irradiated food. Consumers with lower education or higher income or those over 50 years were less willing to buy irradiated ground beef.

Malone *et al* (2007) reported a positive correlation between level of education and income status and willingness or intention to purchase irradiated foods.

Terry *et al* (1988), found that at lower prices, both males and females had a similar willingness-to-pay for irradiated products, however males indicated a higher willingness-to-pay for irradiated products that cost the same or higher than those that were non-irradiated. At US$0.10 lower price per pound only 62% of females, compared to 76% of males, were willing to buy irradiated produce. The study concludes that males were more inclined to accept irradiated produce. There was also an increase in willingness-to-purchase in the lowest income group when the prices were lower, while 66% of the high income group were willing to pay at the US$0.03 higher price per pound of irradiated food.

Huang *et al* (2007), found being married or being the primary shopper of the household increased the probability of purchasing irradiated poultry by 27%. However, the presence of children under the age of 18 had a significant and negative impact on the probability of purchasing irradiated poultry products by 21%. Similar results were presented for age and household income, although with small marginal effects. The endorsement by the US Food and Drug Administration had a positive and significant effect on the probability of purchasing irradiated poultry; however, endorsement by the WHO had a negative effect.

The study also concluded that consumers who were willing to purchase irradiated poultry were also willing to pay a higher price. In addition, households with children under the age of 18, and willing to buy irradiated poultry, had a positive and significant effect on willingness-to-pay at around US$0.57 more per pound of irradiated chicken breast (Huang, 2007).The researchers concluded that the benefits of food irradiation outweigh the perceived hazards associated with irradiation technology.

In another survey, the WTP for irradiated food by chefs varied significantly (Crowley *et al.*, 2002). There were statistically significant results for a positive relationship between age and awareness, and willingness-to-purchase irradiated food, while level of education had a negative relationship with these variables. There were no differences found for gender preferences.

It is important to note that some surveys sampled shoppers and that the majority of respondents were women, parents and older populations.

## Are there differences in the consumer response to food irradiation labelling that is mandated compared to that which is voluntarily provided?

The review did not identify any studies that compared the differences in consumer responses between voluntary and mandatory food irradiation labels. This is in line with the findings, that most countries, for which data were available, apply a mandatory policy on labelling irradiated food; therefore, a voluntary permission was not considered in the design of the studies.

## What are the general categories of costs and benefits to consumers from the removal of previously mandated information or where they are no longer able to access information from food labels?

### Costs to consumers from the removal of previously mandated information

The review provides some evidence with regard to the differences between consumer attitudes towards mandatory and voluntary food labelling.

The literature available on genetically modified (GM) foods indicated that removal of mandatory labelling may impact on consumers’ ability to make informed choices, under the assumptions that consumers are aware of and understand GM as a technology. The literature from European and US studies differs due to the difference in consumer attitudes and policies on GM foods.

In general, the literature argues that consumers are most affected by the removal of mandatory labelling, since they lose the ability to make informed choices.

In the literature it is unclear if the price of irradiated food would increase, decrease or stay the same under a voluntary labelling permission. DeRuiter *et al* (2002) reviewed food irradiation in the USA and reported that the increased cost of irradiated food could sometimes be attributed to the need for improved packaging materials, but some irradiated produce could be sold at parity to non-irradiated food because irradiation effectively decreases product deterioration by increasing shelf-life, or replacement of other types of treatment

Under a voluntary label setting, in Australia and New Zealand, product price for irradiated food may not be higher than for non-irradiated food, as food transportation savings inter-state and overseas would offset the higher cost of irradiation.

A Canadian study (Gunes and Tekin, 2006) conducted a welfare analysis of different labelling policies for GM products. In this study the willingness-to-pay for GM foods was higher with mandatory labelling, which also leads to an increased magnitude of consumer welfare, as more products are affected by the labelling policy.

*‘Consumers’ tolerance for potential price increases under the mandatory labelling regime is much higher than that under the voluntary labelling regime.’ (Gunes and Tekin, 2006). It is anticipated that mandatory labelling is likely to incur more costs than is the case for voluntary labelling. However, the analysis shows that on average consumers do place higher values on the information obtained from mandatory labelling.’*

The study also indicated that there was a difference in consumer treatment of information under mandatory and voluntary policies. Consumers treated loss and gain of information according to an asymmetric value curve, as the study referred to Kahneman and Tversky (1979). Under a voluntary policy the loss of a label can hold a higher value, which can include additional time to search for information, uncertainty regarding the product and mistrust of negative statements (e.g. ‘non-GM product’), that can be considered as a marketing tool. The study concluded that:

*‘Overall, however, the asymmetric impacts of welfare measures from*

*different labelling policies may be deeply rooted in social, economic, and psychological influences on consumer behaviour.’*

Further research is necessary to investigate the reasons behind the asymmetric effects of mandatory and voluntary policies.

Under a voluntary labelling regime, some products may continue to use irradiation labels (e.g. as a sign of quality). However some products may exclude the irradiation information, especially if the irradiated product is a small component of the ingredients. In these cases consumers with an aversion to food irradiation have a number of options. They may use the food origin as a proxy for non-irradiation status (e.g. imported Australian tropical fruit in New Zealand). Alternatively they could use other food labelling information as a proxy for irradiation status. For example, food labelled as ‘organic’ cannot be irradiated (according to the certification process). Finally, they could avoid food types that are known to be irradiated. The latter would be more difficult for consumers if the number (and scope) of irradiated products increased under a voluntary labelling scheme.

A report by FSANZ (2008) indicated that “*consumer trust in food labelling was at a lower level, with Australian consumers significantly less likely to trust the information provided on food labels than New Zealanders*.” (FSANZ, 2008). On a scale of one to seven, where one represents ‘cannot trust at all’ and seven represents ‘can trust completely’, Australian consumers reported a mean score of 4.31 (S.D. 1.32) compared with 4.52 (S.D. 1.27) for New Zealand consumers (page 60, FSANZ 2008). Removing mandatory labelling of irradiation status could impact consumer confidence further.

### Benefits to consumers from the removal of previously mandated information

As discussed previously, Rimal *et al* (2004) demonstrated that consumers’ stated preferences differed markedly from their revealed behaviour. This study suggested that caution is required when interpreting the impact of removing mandatory information. That said, limited evidence, specifically relating to irradiated food products, is available regarding the benefits to consumers of removing mandatory labelling information. Therefore, studies that have investigated the benefits of voluntary labelling of GM foods have been included in this review, since potential parallels may be drawn. These are summarised below:

* Increased choice – Carter *et al* (2003) argued that one of the main benefits of voluntary labelling would be an increased product choice due to the availability of (irradiated) food products that would no longer require mandatory labelling. Another study argued that mandatory labelling would decrease ‘consumer choice’, due to the higher costs of segregation, tracking and labelling, stigma and potential liability for using GM foods, which will drive GM foods out of the market (Marchant and Cardineau, 2013). Under a mandatory policy, consumers may interpret the label as a warning, which is a misguidance that will affect demand for the product (Marchant and Cardineau, 2013). The paper pointed to voluntary labelling policy as promoting consumer choice, especially as alternatives exist for consumers to be able to avoid GM foods (non-GM voluntary labelling, organic food).
* Increased net benefit – Loureiro *et al* (2004) reported that there is a net benefit associated with removing mandatory labelling. Although the willingness-to-pay for a mandatory labelling policy was higher than a voluntary labelling policy, the price increase per household per year for a mandatory labelling policy was larger than the willingness-to-pay (i.e. it is insufficient to compensate for the increased WTP). Under these conditions, the study concluded that only a small proportion of the population would be willing to pay the premium to have mandatory labelling for GM foods.

# Education

This section provides a summary of the evidence regarding the role of consumer education and information on food irradiation treatment. A general view in the literature is that very little is currently done across the countries that allow food irradiation to address the low level of awareness and understanding of the process of food irradiation. That said, the policies in countries (e.g. the US), allow for a variety of statements (claims) to be placed on the food irradiation label, such as ‘irradiated to treat bacteria’ (on meat and poultry products), which may inform the consumer of the purpose of product irradiation.

Qualitative research was commissioned, by FSANZ in 2001, to determine consumer response to food irradiation, as a response the granting of permission to irradiate certain foods was announced in September 2001 (FSANZ, 2001). A concern raised by these participants was the perceived contamination with radioactivity and reduced nutritional quality of food. These findings highlight the need to better educate the public on the process of food irradiation.

Two review articles were found that address the role of education on food irradiation. Young *et al* (2003), concluded that public education and information programs could increase public awareness of the benefits, costs and risks of food irradiation. The authors suggested a unified approach by the government and national agencies, such as scientific and academic involvement, were required. A second review by Rodrigues *et al* (2007), suggested providing consumers with irradiation information using a combination of traditional and social media. This was due to the high level of access and usage by consumers, it also allows consumers to participate in forums and engage in discussions about food irradiation (Rodriguez, 2007).

Table 2, below, provides a list of the papers that evaluated or suggested educational strategies available to governments, industries and communities to increase consumers’ knowledge and awareness of food irradiation processes. These original studies were identified during the literature search but were not included in the search strategy, hence, these studies may be more indicative of the literature on education methods as opposed to exhaustive.

The studies listed below indicate that there is a major need to inform and educate consumers on the factual use, process and impact of food irradiation. Those studies that used a food irradiation benefit statement noted a significant change in acceptance and willingness-to-purchase irradiated foods (Gunes and Tekin, 2006; Hashim *et al.*, 1995; Marcotte and Kunstadt, 1993; Resurreccion *et al.*, 1995).

Point-of-purchase information and handling instructions also played a major role in changing consumer behaviour. These results coincide with the low levels of consumer awareness and understanding of food irradiation (Bruhn *et al.*, 1986; Cottee *et al.*, 1995; Hashim *et al.*, 2001; Marcotte and Kunstadt, 1993; Nayga *et al.*, 2005; Resurreccion *et al.*, 1995; Rimal *et al.*, 2004).

Furuta *et al* (1998) suggested a review of education policy and curriculum to educate future consumers about food irradiation and radiation in general. The study suggested that a positive image of the food irradiation process could be created by addressing the topic at an early age and presenting scientific information at schools through school programs. The study stated that incorrect information could be presented and be misleading, thus an engagement with the scientific and academic community was essential to prepare the education material.

As mentioned above (section 3.10), the survey conducted by FSANZ in 2008 showed lower levels of trust in food labels by Australian and New Zealand consumers, which is another supporting factor for better education and information campaigns for consumers.(FSANZ, 2008) Low levels of trust in food labels is a cost to consumers in general, but involving a relatively unknown and not well understood food processing technology, may decrease trust levels further. This may deter consumers from buying the product that is irradiated – thus decreasing consumer choice and participation in the market.

Table : Education methods

| **Article** | **Education method used or suggested** |
| --- | --- |
| Cottee, *et al*. (2005) | The US study concluded that there is a need to use marketing promotions such as point-of-sale information and newspaper advertising. In the study the consumers were offered samples of irradiated chicken wings and strawberries. Education statements were presented: "a) killed Salmonella in chicken, (or \_E. coli in hamburger meat) and, b) was approved by the US Food and Drug Administration and the US Department of Agriculture" |
| Furuta*, et al*. (1998) | The Japanese survey's results strongly suggest that school activity is a good medium as a recognition route of "radiation", as well as the mass media. Transfer of the correct information about radiation science and technology at the right stage of education, could improve consumers’ image of food irradiation from negative to positive especially for consumers who have vague concerns about irradiated foods. The survey found that the "Radiation fair" was shown to be very helpful as an introduction of radiation science and radiation-related technology to elementary school children. The study suggested a change in education curriculum and overarching education policy to check and plan an effective inclusion of radiation-related information transfer to schools. |
| Gunes, *et al*. (1997) | This study was conducted in Turkey. The study used benefits statements: ‘‘raw red meat and poultry products may contain pathogenic microorganisms. These food products can cause diseases if not properly cooked. Irradiation can eliminate these pathogens from raw red meat and poultry product." The conclusion indicated that lack of knowledge about food irradiation in a country with little exposure to irradiated foods also impacts on acceptability levels. These conclusions change substantially when scientific information on food irradiation treatment is provided. Gunes suggested pathways for information exposure: schools, media, conferences and educational fairs.  |
| Hashim, *et al*. (1995) | The US study used several point-of-purchase and store level information displays on food irradiation including slide programs, posters and labels. These had a statistically significant effect on changing consumer behaviour towards buying irradiated product, however the paper concludes that the “..beef industry may need to employ other means to educate consumers about the benefits of irradiation; more information is needed to prevent the negative effect of not providing enough information.”  |
| Marcotte, *et al*. (1992) | In-store information was provided with an irradiation label indicating “Strawberries irradiated to improve freshness and quality”, additionally newsletters with factual information on food irradiation were provided at point-of-purchase. The US study concluded that food irradiation treatment is likely to be accepted if marked properly (labelled) and positive statements and factual information is provided. |
| Resurreccion, *et al*. (1995) | This US study identified that media campaigns provided the best reach to the largest number of consumers (Radio, TV and magazines). Using effective labelling by stating the purpose of the irradiation gives consumers understanding of the reasons for the treatment. Awareness of federal regulation on food irradiation treatment plays a role in consumer awareness and acceptance of food irradiation. |
| Xu, *et al*. (1992) | This Chinese study outlined the existing need to strengthen the education of consumers on the benefits of food irradiation technology (improved quality and safety, longer shelf-life, wide product availability or good price value). It also suggested means of education such as: newspapers, magazines, radio, TV broadcasting, exhibitions and other forms. |
| Bord, *et al*. (2007) | This US study concluded that effective risk communication, history of safe use and industry regulation information are likely to change consumer attitudes towards food irradiation treatment, compared to technical information about food irradiation. |
| Bruhn, *et al*. (1986) | This US study exposed consumers to information regarding irradiation via posters and leaflets and measured their irradiation concerns post exposure to information. Both leaflets and posters were found to be effective in generating change in attitudes towards food irradiation. The conclusion indicated that an educational program which addresses and responds to consumer concerns could result in increased acceptance of irradiated food, although may not have an effect on those already opposed to the process. |
| Deliza, *et al*. (2010) | The results of this study in Brazil indicated that consumers with no prior knowledge or awareness of food irradiation were less in favour of irradiated produce (papaya). The authors concluded that consumer education regarding the technology is a key factor to its acceptance and will lead to alternative methods of food preservation by producers to produce safer goods. |
| Hashim, *et al*. (2001) | This US study used both food irradiation labels and an information poster at point-of-purchase to test consumer willingness-to-buy irradiated meat. The results indicate that store level information was sufficient to motivate some consumers to shift towards irradiated products. Although some consumers were discouraged from purchasing irradiated products. The net-effect was minimal. The conclusion for the beef industry was to employ other means to educate consumers about the benefits of food irradiation (such as irradiation promoting programmes). |
| Malone, J. W. (2007) | This US study addressed the low levels of population awareness of food irradiation and indicated that government agencies or related food industry have not taken action to provide information to consumers. Further, the consumer groups, or other groups for or against food irradiation have not been effectively reaching large numbers of consumers. |
| Nayga,*et al*. (2005) | This US study presented consumers with a poster and a slide-show on food irradiation at the point-of-purchase. The results indicated that information had a strong impact on the respondents’ willingness-to-purchase irradiated product (beef). The conclusion indicated the importance of scientific information on consumers’ decisions to buy food treated by irradiation. The study also indicated that consumers ‘search’ their memory to make a purchasing decision and easily accessible (recent) information can counteract information from long-term memory.  |
| Rimal*, et al*. (2004) | This US study used a supermarket simulated session, with food irradiation information provided on posters (RADURA symbol, irradiation benefits statements, government approval, and scientific references). The conclusion was that point-of-purchase information significantly affected buyers’ selection process of the irradiated product (meat). The study identified that information regarding ‘safety concerns’ had the biggest impact on change in behaviour. Thus information regarding irradiation safety plays an important role in changing consumer acceptance of food irradiation treatment. |
| Spaulding, *et al*. (1997) | This US study concluded that additional information is needed to educate consumers about food irradiation. The consumers need to be reassured about the safety and the process of treatment. Medical professionals and food scientists are considered trust worthy and reliable sources of information. |
| Spaulding, *et al*. (2007) | The conclusion of this study was the same as in Spaulding (1997).  |

Source: compiled during the review

# Conclusions

The review demonstrates that consumers’ understanding and awareness of food irradiation varies significantly (1% to 72%). Consumer understanding of the food irradiation process is likely to be a key determining factor in understanding irradiation labelling. That said, no studies were identified that specifically discussed consumers’ understanding of the food irradiation labelling statements used in Australia and New Zealand. Awareness of food irradiation labelling was low. Only 1% of respondents recognised the RADURA label, this rose slightly to 6% once the respondents had been prompted (Gruber *et al.*, 2003).

Given the low number of consumers that recognise the RADURA label, it was unsurprising that only 3% of respondents indicated that they used irradiated food labels at least occasionally to make purchasing decisions (Gruber *et al.*, 2003).

Consumers perceive food irradiation labelling in different ways. Many consider it an assurance of quality, some view it a warning symbol. The way labelling information is presented (in terms of wording, presentation and the RADURA symbol) may directly impact on the way that consumers form general opinions about irradiated food. It also suggests that different people will perceive the same label in a different way (positive or negative) depending on their knowledge and beliefs.

Several studies suggested that aversion to irradiated foods has decreased over time. This may imply a more accepting attitude toward food irradiation and willingness-to-purchase irradiated food if sufficient information is provided from a reliable source. Indeed consumers value a label on irradiated food. This was measured by willingness-to-purchase and willingness-to-pay for food that has been irradiated. Several studies indicated that label information was important for consumers in their purchasing decision making.

Of the studies conducted in Australia and New Zealand, men or those aged 45-65 were more likely to be aware of irradiation in New Zealand. No differences in terms of demographic variables and irradiation awareness were noted in Australia (Gamble *et al.*, 2002). Studies conducted overseas demonstrated that consumers with higher educational attainment and income status were more likely to purchase, and be aware of, irradiated foods.

No studies compared the differences in consumer responses between voluntary and mandatory food irradiation labels. The review provides some evidence with regard to the differences between consumer attitudes towards mandatory and voluntary food labelling. Removal of mandatory labelling may impact on the ability of consumers to make informed choices. Consumers averse to food irradiation may use other food labelling information as a proxy for irradiation status, or avoid food types that are known to be irradiated.

The ‘right to know’ is a common theme raised. The cost to consumers (and therefore society) of removing irradiation labelling, is related to a number of factors; such as the resistance to irradiated food, the proportion of individuals that choose food products based on their irradiation status (whether positive or negative) and the ease of obtaining product information in the absence of the label.

It is unclear if the price of irradiated food would increase, decrease or stay the same under a voluntary labelling permission. Some irradiated produce can be sold at parity to non-irradiated foods because irradiation effectively decreases product deterioration by increasing shelf-life, or substitute for other types of product treatment

The main limitation of the review is the generalisability of the findings to the Australian and New Zealand context, since the majority of the data are obtained from international studies and the costs and benefits of mandatory and voluntary labels are derived from GM studies.

In conclusion, moving from mandatory irradiation food labelling, to voluntary (at the discretion of the producer) or no irradiation labelling, the following should be considered.

* Awareness of food irradiation in Australia and New Zealand is low and a general view is that very little is currently done to address the low level of awareness and understanding of the process of irradiation.
* Public education and information programs can increase public awareness of the benefits, costs and risks of food irradiation. Those studies that used a food irradiation benefits statement noted a significant change in acceptance and willingness-to-purchase irradiated foods.
* Point-of-purchase information and handling instructions also played a major role in changing consumer behaviour.
* In general, education has an important role to play, since the more acceptable the food technology, the lower the negative impact.

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# Appendix

Table : Research questions and search terms used

|  | Research question | Search terms |
| --- | --- | --- |
| 1 | Are consumers aware of food irradiation labelling?  | Consumer response:consumer attitude\* or consumer perception\* or consumer acceptance or consumer response\* or consumer awareness or consumer view\* or consumer choice or consumer preference\*or consumer movements or consumer organi?ations or consumer behavior or consumer opinion or purchaser\* or consumer safety or consumer confidence or consumer acceptance or purchasing decisions or consumer understanding or Food irradiation:exp food irradiation/, food irradiation or ioni?ed food radiation or food ioni?ation or raduri?ed food or treated with ioni?ing electrons or irradiated food or ioni?ing radiation or electronic pasteuri?ed or cold pasteuri?edFood labelling:Exp food labeling or food label\* or RADURA or exp food labeling |
| 2 | Do consumers understand the meaning of food irradiation labels? |
| 3 | Do consumers find the food irradiation labelling useful and why? |
| 4 | Do consumers use food irradiation labels in selecting products to purchase or consume? Do consumers trade off information on food irradiation against other food attributes? | As above.Economic evaluation:economic evaluation or cost benefit analysis or cost utility analysis or cost effectiveness analysis or cost\* or price or benefit-cost analysis or risk aversion or endowment effect or Costs and Cost Analysis or the following MESH terms: economic evaluation/ or cost benefit analysis/ or cost benefit analysis/ or cost utility analysis/ or “costs and cost analysis” |
| 5 | Do consumers use food irradiation labels in avoiding products to purchase or consume? |
| 6 | Do consumers value food irradiation labels while not using them to make selection or avoidance decisions (i.e. is there a perceived ‘right to know’ that a product is irradiated or not). How can the ‘right to know’ be included in assessments of benefits and costs in the context of food labelling | As above.Willingness-to-pay:willingness-to-pay or wtp or willingness to accept or contingent valuation or consumer-individual demand or endowment effect or utility or willingness-to-purchaseFood labelling:mandatory label\* or voluntary label\* |
| 7 | Are there other benefits and costs that consumers may derive from food irradiation labelling? |
| 8 | Are there differences across age, gender and socio-economic status in the response to these questions? Are there differences between Australian and New Zealand consumers |
| 9 | Are there differences in the consumer response to food irradiation labelling that is mandated compared to that which is voluntarily provided? |
| 10 | What are the general categories of costs and benefits to consumers from the removal of previously mandated information or where they are no longer able to access information from food labels? |

\*=wildcard to account for alternative endings,? = to account for alternative spelling, exp = explode for MeSH terms

Source: compiled by CHERE

Table : Included studies from the literature search

| **Article year** | **Article** | **Type of food technology** | **Type of article or research method (n)** |
| --- | --- | --- | --- |
| 2007 | Berenji, S. (2007). “Consumers and the Case for Labeling Genfoods”. Journal of Research for Consumers13, 1-7. | GM | Review |
| 1999 | Burgess, J. A., & Walsh, A. J. (1999). “Consumer Sovereignty, Rationality and the Mandatory Labelling of Genetically Modified Food”. Business & Professional Ethics Journal, 18, 3/4, 7.  | GM | Review |
| 2003 | Carter, C. A. and G. P. Gruere (2003). "Mandatory Labeling of Genetically Modified Foods: Does It Really Provide Consumer Choice?" AgBioForum 6(1-2): 68-70. | GM | Review/commentary |
| 1995 | Cottee, J., P. Kunstadt, *et al*. (1995). "Consumer acceptance of irradiated chicken and produce in the U.S.A." Radiation Physics and Chemistry 46(4-6 I): 673-676. | Irradiation | Review |
| 2002 | Crowley, M. L., D. J. Gaboury, *et al*. (2002). "Chefs’ attitudes in North-Eastern US toward irradiated beef, Olestra, rBST and genetically engineered tomatoes." Food Service Technology 2(4): 173-181. | Irradiation | Original survey (n=115) |
| 2002 | DeRuiter, F. E. and J. Dwyer (2002). "Consumer acceptance of irradiated foods: dawn of a new era?" Food Service Technology 2(2): 47-58. | Irradiation | Review |
| 1996 | Donaldson, C., T. Mapp, *et al*. (1996). "Estimating the economic benefits of avoiding food-borne risk: Is 'willingness-to-pay' feasible?" Epidemiology and Infection 116(3): 285-294. | Irradiation | Original / WTP (n=134) |
| 2005 | Ekici, A. (2005). “Consumers' View of Food Biotechnology: A Proactive Approach to Marketing and Public Policy.” Advances in Consumer Research, 32, 1, 670-677. | GM | Original qualitative study |
| 2008 | Flores, A. and G. Hough (2008). "Perception Of Irradiated Foods Among Students (Secondary, University [Food Science And Nonfood Science]) And Adults In Argentina." Journal of Food Processing & Preservation 32(3): 361-377. | Irradiation | Original survey (n=400) |
| 2001 | Frenzen, P. D., DeBess, E. E., Hechemy, K. E., Kassenborg, H., Kennedy, M., McCombs, K., *et al*. (2001). “Consumer acceptance of irradiated meat and poultry in the United States”. Journal of food protection, 64, 12, 2020-2026.  | Irradiation | Review cites survey (n= 10 780) |
| 1998 | Furuta, M., Hayashi, T., Hosokawa, Y., Kakefu, T., & Nishihara, H. (1998). “Consumer attitudes to radiation and irradiated potatoes at 'Radiation fair' in Osaka, Japan”. Radiation Physics and Chemistry, 52, 1-6, 67-71.  | Irradiation | Original survey (n=3568) |
| 2006 | Gunes, G., & Tekin, M. D. (2006). “Consumer awareness and acceptance of irradiated foods: Results of a survey conducted on Turkish consumers”. LWT Food Science & Technology, 39, 4, 444-448.  | Irradiation | Original survey (n=444) |
| 2005 | Harrison, R. W., & Jae-Hwan, H. (2005). “The Effects of Urban Consumer Perceptions on Attitudes for Labeling of Genetically Modified Foods”. Journal of Food Distribution Research, 36, 2, 29-38.  | GM | Original survey (n=509) |
| 1995 | Hashim, I. B., Resurreccion, A. V., & McWatters, K. H. (1995). “Consumer acceptance of irradiated poultry”. Poultry Science, 74, 8, 1287-1294.  | Irradiation | Original survey (n=126) |
| 2005 | Hu, W., Veeman, M. M., & Adamowicz, W. L. (2005). “Labelling Genetically Modified Food: Heterogeneous Consumer Preferences and the Value of Information”. Canadian Journal of Agricultural Economics, 53, 1, 83-102.  | GM | Original DCE (n=437) |
| 2003 | Huffman, W., Rousu, M., Shogren, J. F., & Tegene, A. (2003). “The Welfare of Implementing Mandatory GM Labeling in the United States”. Iowa State University, Department of Economics, Staff General Research Papers.  | GM | Original simulated experiment (n=142) |
| 2011 | Junqueira-Gonçalves, M. P., Galotto, M. J., Valenzuela, X., Dinten, C. M., Aguirre, P., & Miltz, J. (2011). “Perception and view of consumers on food irradiation and the RADURA symbol.” Radiation Physics & Chemistry, 80, 1, 119-122. | irradiation | Food irradiation, radura symbol |
| 2004 | Loureiro, M. L., & Hine, S. (2004). “Preferences and willingness-to-pay for GM labeling policies”. Food Policy, 29, 5, 467-483. doi: 10.1016/j.foodpol.2004.07.001 | GM | Original survey (n=334) |
| 2013 | Marchant, G. E., & Cardineau, G. A. (2013). “The labeling debate in the United States”. GM Crops & Food, 4, 3, 1-9. doi: 10.4161/gmcr.26163 | GM | review |
| 1993 | Marcotte, M., & Kunstadt, P. (1993). “Acceptance of irradiated food by North American consumers”. Radiation Physics and Chemistry, 42 (1-3 -3 pt 1), 307-311.  | Irradiation | review |
| 2006 | Nayga, R. M., Jr., M. Gillett Fisher, *et al*. (2006). "Acceptance of Genetically Modified Food: Comparing Consumer Perspectives in the United States and South Korea." Agricultural Economics 34(3): 331-341. | GM | Original survey (n=1201 (USA) and n=1054 (South Korea)) |
| 1995 | Resurreccion, A. V. A., Galvez, F. C. F., Fletcher, S. M., & Misra, S. K. (1995). “Consumer attitudes toward irradiated food: Results of a new study”. Journal of Food Protection, 58, 2, 193-196.  | Irradiation | Original survey (n=918) |
| 2009 | Todt, O., Muoz, E., Gonzalez, M., Ponce, G., & Estevez, B. (2009). “Consumer attitudes and the governance of food safety”. Public Understanding of Science, 18, 1, 103-114.  | GM | Original survey (n=1002) |
| 2003 | van der Pol, M., Ryan, M., & Donaldson, C. (2003). “Valuing food safety improvements using willingness-to-pay”. Applied Health Economics And Health Policy, 2, 2, 99-107.  | irradiation | Original survey (n=200) |
| 1993 | Xu, Z., Cai, D., He, F., & Zhao, D. (1993). “Radiation preservation and test marketing of fruits and vegetables”. Radiation Physics and Chemistry, 42 (1-3 -3 pt 1), 253-257.  | irradiation | Original survey (n=634) |
| 2013 | Zhao, L., Gu, H., Yue, C., & Ahlstrom, D. (2013). “Consumer welfare and GM food labeling: A simulation using an adjusted Kumaraswamy distribution”. Food Policy, 42, 58-70. | GM | Original experiment (n=216) |

Abbreviations: DCE = discrete choice experiment, GM = genetically modified

Source: compiled by CHERE

Table : Included studies from other sources

| **Article year** | **Article** | **Type of food technology** | **Type of article or research method (n)** |
| --- | --- | --- | --- |
| **Peer-reviewed papers from other sources** |
| 1990 | Bord, R. J. and R. E. O'Connor (1990). "Risk Communication, Knowledge, and Attitudes: Explaining Reactions to a Technology Perceived as Risky." Risk Analysis 10(4): 499-506 | irradiation | Original survey (n=195) |
| 1986 | Bruhn, C. M., R. Sommer, *et al*. (1986). "Effect of an educational pamphlet and posters on attitude toward food irradiation." Journal of Industrial Irradiation Technology 4(1): 1-20. | irradiation | Original survey (n=78) |
| 2010 | Deliza, R., A. Rosenthal, *et al*. (2010). "Consumer perception of irradiated fruit: a case study using choice-based conjoint analysis." Journal of Sensory Studies 25(2): 184-200.  | irradiation | Original DCE (n=168) |
| 1998 | Fox, J.A. and Olson, D.G. 1998. Market trials of irradiated chicken. *Radiation Physics & Chemistry* **52**: 63-66. | irradiation | Survey (n=229), consumer experiment (n = 98) |
| 2001 | Golan, E., F. Kuchler, *et al*. (2001). "Economics of Food Labeling." Journal of Consumer Policy 24(2): 117-184. | irradiation and other food labelling | Review |
| 2001 | Hashim, I. B., K. H. McWatters, *et al*. (2001). "Consumer purchase behaviour of irradiated beef products: a simulated supermarket setting." International Journal of Consumer Studies 25(1): 53-61. | irradiation | Original survey (n=240) |
| 2007 | Huang, C.L., Wolfe, K. and McKissick, J. (2007) “Consumers' willingness to pay for irradiated poultry products”, Journal of International Food & Agribusiness Marketing, 19 (2-3), pp. 77-95. | irradiation | Original survey (n=303) |
| 1995 | Jack, F. R. and D. C. W. Sanderson (1995). "Radiophobia: Will fear of irradiation impede its future in food processing?" British Food Journal 97(5): 32 | irradiation | Original survey (n=200) |
| 1990 | Malone, J. W. (1990). "Consumer willingness to purchase and to pay more for potential benefits of irradiated fresh food products." Agribusiness 6(2): 163-178.  | irradiation | Original survey (n=800) |
| 2005 | Nayga, R. M., Jr., A. Wipon, *et al*. (2005). "Information Effects on Consumers' Willingness to Purchase Irradiated Food Products." Review of Agricultural Economics 27(1): 37-48.  | irradiation | Original survey (n=484) |
| 2006 | Ornellas C.B.D., Junqueira-Goncalves, M.P., Silva, P.R., and Martins, R.T. (2006). Attitude do consumidor frente a irradiacao de alimentos. *Cienc. Technol. Aliment.* **26**: 211-213 | Irradiation  | Survey (n=218) |
| 2004 | Rimal, A. P., K. H. McWatters, *et al*. (2004). "Intended vs. Actual Purchase Behavior for Irradiated Beef." Journal of Food Products Marketing 10(4): 1-15. | irradiation | Original survey/experiment (n=240) |
| 2006 | Spaulding, A. D., B. R. Wiegand, *et al*. (2006). "Consumer Knowledge and Perceptions of Food Irradiation: Ground Beef Study." Journal of Food Distribution Research 37(1): 161-167.  | irradiation | Original survey (n=119) |
| 2007 | Spaulding, A. D., B. R. Wiegand, *et al*. (2007). "College—Age Consumers' Knowledge and Perceptions of Food Irradiation." Journal of Food Products Marketing 13(4): 99-113. Abstract | irradiation | Original survey (n=159) |
| 2003 | Streiffer, R. and Rubel (2003). "Choice versus autonomy in the GM food labeling debate." AgBioForum 6(3): 141-142. | GM | review |
| 1988 | Terry, D.E., and Tabor, R.L. 1988. Consumer acceptance of irradiated produce: A value added approach. *Journal of Food Distribution Research*: 73-89. | Food irradiation | Surveys (n=436) |
| **Grey literature** |
| 2003 | Food Standards Australia New Zealand (2003). “Food labelling Issues:Quantitative Issues with consumers, Evaluation Report Series No. 4”. Canberra, Food Standards Australia New Zealand. | irradiation and other food labelling | Original survey (n=1940) |
| 2002 | Gamble, J., Harker, R. and Gunson, A. (2002) “New Zealand and Australian perceptions of irradiated food. Report to the Horticulture and Food Research Institute of NZ Ltd and Horticulture Australia Ltd.” HortResearch Client Report No. 2003/42, Horticulture Australia Ltd, Sydney. | irradiation | Original survey (n=401(Australia) and n=404 (New Zealand) |
| 2009 | Lyndhurst, B. (2009). “An Evidence Review of Public Attitudes to Emerging Food Technologies.” UK, Social Science Research Unit Food Standards Agency. | irradiation and other food technology | review |
| 2013 | Prior, G., L. Taylor, *et al*. (2013). “Exploring food attitudes and behaviours in the UK: Findings from the Food and You Survey 2012. Unit Report 20.” United Kingdom, Policy Studies Institute and University of Westminster  | irradiation and other food technology | Original survey (n=3231 for awareness and n=1059 for understanding) |

Source: compiled by CHERE. Abbreviations: DCE = discrete choice experiment, GM = genetically modified.

Table : Excluded studies and reason for exclusion

| **Article**  | **Reason for exclusion** |
| --- | --- |
| “Executive Summaries.” (2004). International Food & Agribusiness Management Review, 7, 3, 1-6.  | GMO |
| Abbott,A (1997). "Europe outlines labelling rules for genetic modification seeds." Nature 386(6625): 532. | GMO |
| Akgüngör, S., B. Miran, *et al*. (2001). "Consumer Willingness-to-pay for Food Safety Labels in Urban Turkey: A Case Study of Pesticide Residues in Tomatoes." Journal of International Food & Agribusiness Marketing 12(1): 91. | organic labelling |
| Andrews, L. S., M. Ahmedna, *et al*. (1998). "Food preservation using ionizing radiation." Reviews of environmental contamination and toxicology 154: 1-53. | safety |
| Angulo, A. M., & Gil, J. M. (2007). “Risk perception and consumer willingness-to-pay for certified beef in Spain”. Food Quality & Preference, 18, 8, 1106-1117.  | safety |
| Arvanitoyannis, I. S. (2010). “Consumer Behavior toward Irradiated Food.” Irradiation of Food Commodities: Techniques, Applications, Detection, Legislation, Safety and Consumer Opinion:673-698, 2010. | safety |
| Bansal, S., Chakravarty, S., & Ramaswami, B. (2013). “The informational and signaling impacts of labels: experimental evidence from India on GM foods.” Environment & Development Economics, 18, 6, 701-722.  | GMO |
| Bender, A. E. (1986). "Food irradiation." Journal of the Royal Society of Health 106(3): 80-81. | safety |
| Berenji, S. (2007). “Consumers and the Case for Labeling Genfoods.” Journal of Research for Consumers13, 1-7.  | GMO |
| Boschert, K., & Gill, B. (2005). “Germany's agri-biotechnology policy: precaution for choice and alternatives.” Science & Public Policy (SPP), 32, 4, 285-292.  | GMO |
| Brown, J. L., & Ping, Y. (2003). “Consumer perception of risk associated with eating genetically engineered soybeans is less in the presence of a perceived consumer benefit.” Journal of the American Dietetic Association, 103, 2, 208-214.  | Use of irradiation |
| Bruhn, C. M. (1995). "Consumer attitudes and market response to irradiated food." Journal of Food Protection 58(2): 175-181. | Use of irradiation |
| Bruhn, C. M. (1998). "Consumer acceptance of irradiated food: Theory and reality." Radiation Physics and Chemistry 52(1-6): 129-133. | Use of irradiation |
| Bruhn, C. M. (1999). “Consumer perceptions and concerns about food contaminants.” Kluwer Academic/Plenum Publishers: 1-7. | GMO |
| Bukenya, J. O. and N. R. Wright (2007). "Determinants of Consumer Attitudes and Purchase Intentions with Regard to Genetically Modified Tomatoes." Agribusiness 23(1): 117-130. | Other labelling |
| Capps, O., Jr. (1992). “Consumer Response to Changes in Food Labeling: Discussion.” American Journal of Agricultural Economics, 74, 5, 1215-1216.  | GMO |
| Carter, C. A. and G. P. Gruere (2003). "Mandatory versus Voluntary Labeling of Genetically Modified Food, Consumer Choice, and Autonomy: Reply." AgBioForum 6(3): 143-144. | GMO |
| Chakraborty, K. (2011). “Consumers' Attitude and Product Labeling for GM Food in China and Hormone Induced Milk in the United States.” International Journal of Economics and Finance, 3, 2, 3-11.  | nutrition labelling |
| Curran, M. A. (2002). “Nutrition labelling: perspectives of a bi-national agency for Australia and New Zealand.” Asia Pacific Journal of Clinical Nutrition, 11, 2, S72-76.  | GMO |
| Dannenberg, A., S. Scatasta, *et al*. (2011). "Mandatory versus voluntary labelling of genetically modified food: evidence from an economic experiment." Agricultural Economics 42(3): 373-386. | GMO |
| D'Souza, C., Rugimbana, R., Quazi, A., & Nanere, M. G. (2008). “Investing in consumer confidence through genetically modified labelling: an evaluation of compliance options and their marketing challenges for Australian firms.” Journal of Marketing Management, 24, 5/6, 621-635.  | GMO |
| Einsiedel, E. F. (2002). "GM Food Labeling." Science Communication 24(2): 209. | safety |
| Fan, X. and K. J. Sokorai (2011). "Changes in quality, liking, and purchase intent of irradiated fresh-cut spinach during storage." Journal of Food Science 76(6): S363-S368. | GMO |
| Federici, V. (2010). "Genetically Modified food and informed consumer choice: comparing U.S. and E.U. labelling laws." Brooklyn Journal of International Law 35(2): 515-561. | Use of irradiation |
| Ferrier, P. (2010). "Irradiation as a quarantine treatment." Food Policy 35(6): 548-555. | Use of irradiation |
| Follett, P. A. and E. D. Weinert (2012). "Phytosanitary irradiation of fresh tropical commodities in Hawaii: Generic treatments, commercial adoption, and current issues." Radiation Physics and Chemistry 81(8): 1064-1067. | safety |
| Food and Drug Administration, H. H. S. (2012). “Irradiation in the production, processing and handling of food. Final rule.” Federal register, 77, 231, 71316-71320.  | organic labelling |
| Giannakas, K. (2002). “Information Asymmetries and Consumption Decisions in Organic Food Product Markets.” Canadian Journal of Agricultural Economics, 50, 1, 35.  | GMO |
| Giannakas, K., & Fulton, M. (2002). “Consumption effects of genetic modification: what if consumers are right?” Agricultural Economics, 27, 2, 97.  | safety |
| Gordon, L. J. (1999). “From Nuclear Bombs to Food Safety: A Personal Odyssey.” Journal of Public Health Policy, 20, 4, 389-393.  | GMO |
| Grobe, D. and C. Raab (2004). "Voters' Response to Labeling Genetically Engineered Foods: Oregon's Experience." Journal of Consumer Affairs 38(2): 320-331. | Other labelling |
| Gruber, J., Brooke-Taylor, S., Goodchap, J., & McCullum, D. (2003). “Regulation of food commodities in Australia and New Zealand.” Food Control, 14, 6, 367.  | GMO |
| Gruere, G. P., & Rao, S. R. (2007). “A Review of International Labeling Policies of Genetically Modified Food to Evaluate India's Proposed Rule.” AgBioForum, 10, 1, 51-64.  | GMO |
| Gruere, G. P., Carter, C. A., & Farzin, Y. H. (2008). “What Labelling Policy for Consumer Choice? The Case of Genetically Modified Food in Canada and Europe.” Canadian Journal of Economics, 41, 4, 1472-1497 | Other labelling |
| Haghiri, M., & Simchi, A. (2012). “Consumer Attitudes Toward Mandatory Traceability and Labeling Systems for Farmed Atlantic Salmon.” Journal of International Food & Agribusiness Marketing, 24, 2, 121-136.  | GMO |
| Harrison, R. W., & McLennon, E. (2004). “Analysis of Consumer Preferences for Biotech Labeling Formats.” Journal of Agricultural and Applied Economics, 36, 1, 159-171. | GMO |
| Heslop, L. A. (2006). “If We Label It, Will They Care? The Effect of GM-Ingredient Labelling on Consumer Responses.” Journal of Consumer Policy, 29, 2, 203-228.  | nutrition labelling |
| Hoefkens, C., Verbeke, W., & Van Camp, J. (2011). “Consumer perception and behaviour related to food labelling.” Communications in agricultural and applied biological sciences, 76, 1, 89-92.  | Other labelling |
| Holdershaw, J., Gendall, P., & Case, P. (2013). “Country of origin labelling of fresh produce: consumer preferences and policy implications.” Market & Social Research, 21, 2, 22-31.  | GMO |
| Huffman, W. E. (2003). "Consumers' Acceptance of (and Resistance to) Genetically Modified Foods in High-Income Countries: Effects of Labels and Information in an Uncertain Environment." American Journal of Agricultural Economics 85(5): 1112-1118. | GMO |
| Huffman, W. E. (2010). “Consumer Acceptance of Genetically Modified Foods: Traits, Labels and Diverse Information.” Iowa State University, Department of Economics, Staff General Research Papers. Retrieved from  | GMO |
| Hyun Soon Park, Y., & Sun Young, L. (2003). “Genetically Engineered Food Labels, Information or Warning to Consumers?” Journal of Food Products Marketing, 9, 1, 49-62.  | Use of irradiation |
| Ibarra, A. A., Vargas, A. S., & Nayga, R. M. (2010). “Water quality concerns and acceptance of irradiated food: A pilot study on Mexican consumers.” Journal of the Science of Food and Agriculture, 90, 13, 2342-2344.  | safety |
| Kaferstein, F. K. (2000). “Food irradiation dialogue.” International Journal of Infectious Diseases, 4, 3, 178.  | safety |
| Kaferstein, F. K., & Moy, G. G. (1993). “Public Health Aspects of Food Irradiation.” Journal of Public Health Policy, 14, 2, 149-164.  | GMO |
| Kalaitzandonakes, N., & Bijman, J. (2003). “Who is driving biotechnology acceptance?” Nature Biotechnology, 21, 4, 366-369.  | nutrition labelling |
| Kiesel, K., & Villas-Boas, S. B. (2009). “Can Information Costs Confuse Consumer Choice?--Nutritional Labels in a Supermarket Experiment.” Department of Agricultural & Resource Economics, UC Berkeley, Department of Agricultural & Resource Economics, UC Berkeley, Working Paper Series.  | nutrition labelling |
| Kiesel, K., & Villas-Boas, S. B. (2013). “Can Information Costs Affect Consumer Choice? Nutritional Labels in a Supermarket Experiment.” International Journal of Industrial Organization, 31, 2, 153-163. | GMO |
| Kiesel, K., Buschena, D., & Smith, V. (2005). “Do Voluntary Biotechnology Labels Matter to the Consumer? Evidence from the Fluid Milk Market.” American Journal of Agricultural Economics, 87, 2, 378-392.  | GMO |
| Kim, R. and M. Boyd (2006). "Japanese Consumers' Acceptance of Genetically Modified (GM) Food: An Ordered Probit Analysis." Journal of Food Products Marketing 12(3): 45-57. | GMO |
| Kim, R. B. (2012). “Consumer Attitude of Risk and Benefits toward Genetically Modified (GM) Foods in South Korea: Implications for Food Policy.” Rizikos ir naudos vartotojo požiūris į genetiškai modifikuotus (GM) maisto produktus Pietų Korėjoje: reikšmė maisto pramonės politikai., 23, 2, 189-199.  | GMO |
| Kume,T.,Furuta, M., Todoriki, S., Uenoyama, N. and Kobayashi, Y. (2009). "Status of food irradiation in the world." Radiation Physics and Chemistry 78 (2009): 222-226 | nutrition labelling |
| Kume,T. and Todoriki, S. (2013). "Food Irradiation in Asia, the European Union, and the United States: A Status Update. Radioisotopes 62 (2013): 291-299 | Other labelling |
| Lassoued, R., & Giannakas, K. (2010). “Economic Effects of the Consumer-oriented Genetically Modified Products in Markets with a Labelling Regime.” Journal of Agricultural Economics, 61, 3, 499-526.  | safety |
| Lenhart, J., Kendall, P., Medeiros, L., Doorn, J., Schroeder, M., & Sofos, J. (2008). “Consumer Assessment of Safety and Date Labeling Statements on Ready-to-Eat Meat and Poultry Products Designed To Minimize Risk of Listeriosis.” Journal of Food Protection, 71, 1, 70-76.  | safety |
| Lim, K. H., Hu, W., Maynard, L. J., & Goddard, E. (2013). U.S. “Consumers' Preference and Willingness-to-pay for Country-of-Origin-Labeled Beef Steak and Food Safety Enhancements.” Canadian Journal of Agricultural Economics, 61, 1, 93-118.  | safety |
| Louria, D. B. (2000). “Counterpoint on food irradiation.” International Journal of Infectious Diseases, 4, 2, 67-69.  | nutrition labelling |
| Louria, D. B. (2000). “Food irradiation, vitamin loss, and needed American studies.” International Journal of Infectious Diseases, 4, 4, 234-235.  | safety |
| Lutter, R. (1999). “Policy forum: food safety. Food irradiation--the neglected solution to food-borne illness.” Science, 286, 5448, 2275-2276.  | GMO |
| Mathios, A. D. (2000). “The Impact of Mandatory Disclosure Laws on Product Choices: An Analysis of the Salad Dressing Market.” Journal of Law and Economics, 43, 2, 651-677. doi:  | nutrition labelling |
| McCally, M., Donohoe, M., Osterholm, M. T., Norgan, A. P., & Thayer, D. W. (2004). “Irradiation of food [5] (multiple letters).” New England Journal of Medicine, 351, 4, 402-403.  | GMO |
| McCann-Hiltz, D., Veeman, M., Adamowicz, W., & Wuyang, H. (2004). “Agricultural Biotechnology: A Comparison of Consumers' Preferences for Selected Policy Options.” Canadian Journal of Agricultural Economics, 52, 3, 333-350.  | nutrition labelling |
| McCullough, J., & Best, R. (1980). “Consumer Preferences for Food Label Information: A Basic Segmentation.” Journal of Consumer Affairs, 14, 1, 180.  | GMO |
| McFadden, B. R., & Lusk, J. L. (2013). “Effects of Cost and Campaign Advertising on Support for California's Proposition 37.” Journal of Agricultural and Resource Economics, 38, 2, 174-186.  | nutrition labelling |
| Mhurchu, C. N., & Gorton, D. (2007). “Nutrition labels and claims in New Zealand and Australia: a review of use and understanding.” Australian & New Zealand Journal of Public Health, 31, 2, 105-112. | Other labelling |
| Moon, W. and S. K. Balasubramanian (2003). "Is There a Market for Genetically Modified Foods in Europe? Contingent Valuation of GM and Non-GM Breakfast Cereals in the United Kingdom." AgBioForum 6(3): 128-133. | safety |
| Moorman, C., R. Ferraro, *et al*. (2012). "From Consumer Information Regulation to Nutrition Competition: A Response." Marketing Science 31(5): 747-755. | GMO |
| Mullins, M. (2010). “Not COOL: the consequesnces of mandatory country of origin labelling.” Journal of Food Law & Policy, 6, 1, 89-102.  | GMO |
| Nayga, R. M., Jr. (2003). “Food Safety through Food Irradiation: Should It Be Adopted More by the EU?” EuroChoices, 2, 3, 36-39.  | Use of irradiation |
| Nestle, M. (1998). "Food biotechnology: Labeling will benefit industry as well as consumers." Nutrition Today 33(1): 6.Offers a look at food biotechnology while focusing on product labeling. Criticisms of food biotechnology; Results of a survey conducted on consumer attitudes towards food biotechnology; What the findings of the survey suggested. | GMO |
| Onyango, B., *et al*. (2006). "U.S. Consumers' Willingness-to-pay for Food Labeled 'Genetically Modified'." Agricultural and Resource Economics Review 35(2): 299-310. | safety |
| Over, K. F., Hettiarachchy, N. S., Perumalla, A. V. S., Johnson, M. G., Meullenet, J. F., Dickson, J. S., . (2010). “Antilisterial activity and consumer acceptance of irradiated chicken breast meat vacuum-infused with grape seed and green tea extracts and tartaric acid.” Journal of Food Science, 75, 7, M455-M461.  | GMO |
| Phillips, P. W. B. and D. Corkindale (2002). "Marketing GM Foods: The Way Forward." AgBioForum 5(3): 113-121. | Other |
| Preston, F. S. (1988). “Food irradiation and airline catering.” Aviation Space & Environmental Medicine, 59, 4, 363-366.  | Other labelling |
| Rimal, A., Moon, W., & Balasubramanian, S. (2007). “Labelling genetically modified food products: consumers’ concern in the United Kingdom.” International Journal of Consumer Studies, 31, 4, 436-442.  | GMO |
| Roberts, T. M. (2013). “The Rise of Rule Four Institutions: Voluntary Standards, Certification and Labeling Systems.” Ecology Law Quarterly, 40, 1, 107-156.  | Other |
| Roosen, J., J. L. Lusk, *et al*. (2003). "Consumer Demand for and Attitudes toward Alternative Beef Labeling Strategies in France, Germany, and the UK." Agribusiness 19(1): 77-90. | safety |
| Rousu, M. C., & Corrigan, J. R. (2008). “Estimating the Welfare Loss to Consumers When Food Labels Do Not Adequately Inform: An Application to Fair Trade Certification.” Journal of Agricultural & Food Industrial Organization, 6, 1, 1-26.  | GMO |
| Schnettler, B., *et al*. (2013). "Food neophobia, nanotechnology and satisfaction with life." Appetite 69: 71-79. | GMO |
| Shea, K. M. (2000). “Technical report: irradiation of food. Committee on Environmental Health.” Pediatrics, 106, 6, 1505-1510.  | GMO |
| Siipi, H. and S. Uusitalo (2008). "Consumer autonomy and sufficiency of GMF labelling." Journal of Agricultural & Environmental Ethics 21(4): 353-369. | Other |
| Sleenhoff, S., & Osseweijer, P. (2013). “Consumer choice.” GM Crops & Food, 4, 3, 1-6. doi: 10.4161/gmcr.26519 | safety |
| Soregaroli, C., *et al*. (2003). "Consumer's Attitude Towards Labeled and Unlabeled GM Food Products in Italy." International Food & Agribusiness Management Review 6(2): 111-127. | safety |
| Wim, V. (2005). "Agriculture and the food industry in the information age." European Review of Agricultural Economics 32(3): 347-368. | safety |
| Wood, O. B., & Bruhn, C. M. (2000). “Position of the American Dietetic Association: food irradiation.” Journal of the American Dietetic Association, 100, 2, 246-253.  | safety |
| Yan, H. J., Lee, E. J., Nam, K. C., Min, B. R., & Ahn, D. U. (2006). “Effects of dietary functional ingredients and packaging methods on sensory characteristics and consumer acceptance of irradiated turkey breast meat.” Poultry science, 85, 8, 1482-1489.  | GMO |
| Young, A. L. (2003). “Food irradiation: After 35 years, have we made progress: A government perspective.” Environmental Science and Pollution Research, 10, 2, 82-88.  | GMO |
| Yulianti, F., Reitmeier, C. A., & Boylston, T. D. (2004). “Consumer Sensory Evaluation and Flavor Analyses of Pasteurized and Irradiated Apple Cider with Potassium Sorbate.” Journal of Food Science, 69, 5, S193-S197.  | organic labelling |

Table : Summary of generalisability issues and potential bias in the original studies

| **Article** | **n** | **Representativeness of sample and potential bias** |
| --- | --- | --- |
| **Peer-reviewed literature from search**  |
| Crowley, *et al*. (2002) | 115 | small, unrepresentative sample of chefs |
| Donaldson, *et al*. (1996) | 134 | unrepresentative sample |
| Flores, A. and G. Hough (2008) | 400 | food science students may not be representative, only average age given, overall, the groups are specific and results may not be generalisable to the whole Argentinian population |
| Furuta, *et al*. (1998) | 3568 | sample of fairgoers, may be unrepresentative of Japanese population |
| Gunes, G., and Tekin, M. D. (2006)  | 444 | unrepresentative sample (convenience sample) |
| Harrison, R. W., and Jae-Hwan, H. (2005) | 509 | May not be representative, highly educated from metropolitan regions |
| Hashim, *et al.* (1995) | 126 | May not be representative, from consumer database but predominantly, female and caucasian |
| Hu, *et al* (2005) | 437 | used consumer database in Canada, may be representative |
| Huffman *et al* (2003) | 142 | unsure how sample was selected, but it is small but may be representative if the independent agency contacted them randomly |
| Loureiro, M. L., and Hine, S. (2004) | 334 | Sample may not be representative |
| Nayga, *et al*. (2006) | 2255 (1202 US and 1054 SK) | representative sample in both the US and South Korean groups |
| Resurreccion, *et al* (1995) | 918 | may be a representative sample in US |
| Todt, *et al* (2009) | 1002 | representative sample in Spain |
| van der Pol *et al* (2003)  | 200 | maybe representative due to similarities in the participants with the total population contingent review200 - shoppers in 2 supermarkets post purchases (Aberdeen - Scotland)provides comparison with regional data of Scotland for the same characteristics |
| Xu, *et al*. (1993) | 634 | not representative, doubtfulfunded by irradiation centre - shoppers in one supermarket in Shanghai with mainly women and the elderly |
| Zhao, *et al*. (2013) | 216 | more for Mandatory vs. voluntary labelling discussion |
| **Other peer-reviewed studies** |
| Bord, R. J. and R. E. O'Connor (1990).  | 195 | not representative, limited to women only, can only have an indicative result |
| Bruhn, *et al*. (1986) | 78 | support from Nuclear Science Fund |
| Deliza, *et al*. (2010) | 168 | representative sample of Brazilian shoppers (but those for those who consumed papaya) |
| Hashim, *et al*. (2001) | 240 | somewhat representative however, beef industry funding |
| Jack, F. R. and D. C. W. Sanderson (1995) | 200 | representative sample of shoppers in Scotland |
| Malone, J. W. (1990) | 800 | representative sample |
| Nayga, *et al*. (2005) | 484 | representative sample |
| Rimal, *et al*. (2004) | 240 | representative for the selected population |
| Spaulding, *et al*. (2006) | 119 | not representative |
| Spaulding, *et al*. (2007) | 159 | somewhat representative - university survey |
| **Grey literature** |
| Food Standards Australia New Zealand (2003) | 1940 | representative sample |
| Gamble, *et al*. (2002)  | 805 (401 AU and 404 NZ) | representative |
| Prior, *et al*. (2013) | 3231 for the awareness question (2220 England & Wales, 507 Scotland, 504 Northern Ireland) and 1059 for the understanding question | representative |

Table : Literature on consumer awareness of food irradiation

| **Reference** | **Question** | **Results (%)** | **Sample size (n) and description** | **Country** |
| --- | --- | --- | --- | --- |
| **Papers from Literature search** |
| Crowley, 2002 | Are you aware of irradiated ground beef? | 85 | 115 chefs | USA |
| Flores, 2008 | Knowledge about food irradiation ('yes') | Secondary students 6, Food science university students 71, Nonfood science university students 22, Nonstudent adults 16 | 400 (Secondary students 100, Food science university students 100, Nonfood science university students 100, Nonstudent adults 100) | Argentina |
| Frenzen, 2001 | ..had ever heard of “irradiation”as a process for treating food.. | 49 | 10 780 from 7 different sites in both rural and urban centres | USA |
| Gunes, 2006 | …indicated that they had heard food irradiation before.. | 29 | 444 range of customers and employees at local businesses | Turkey |
| Junqueira-Goncalves, 2011 | …food preservation methods…impression from Radura symbol… | 23.5 | 497 respondents to a survey, randomly selected people at supermarkets, metro stations, offices, malls and university campuses | Chile |
| Resureccion, 1995 | …heard about irradiation… | 72 | 446 from consumer database, representative  | USA |
| Xu, 1993 | …have you heard of irradiated food before? | 59 | 634 shoppers at a store | China |
| **Peer-reviewed from other sources** |
| Deliza, 2010 | Do you know anything about food irradiation? | 40 | 168 shoppers | Brazil |
| Jack, 1995 | Was the consumer aware that irradiated food could legally be sold in this country? | 36 | 200 shoppers | Scotland |
| Malone, 1990 | had heard about the process of irradiation | 25 | 800 households from national sample | USA |
| Nayga, 2005 | What is your perception of the RADURA symbol | 10.3% did not recognise the symbol | 484 shoppers in 4 sites  | USA |
| Spaulding, 2006 | heard of irradiation | 68 | 119 convenience sample | USA |
| Spaulding, 2007 | heard of irradiation | 65 | 159 college students | USA |
| Terry, 1988 | Recognition of RADURA symbol | 2.8% | 436 household interviews | USA |
| **Grey literature** |
| FSANZ, 2003 | Unprompted awareness of irradiated food (exact mentions of label element). Prompted awareness of irradiated food (label elements) | Unprompted awareness <1 and prompted awareness 6 | 1940 representative sample | Australia and New Zealand |
| Gamble, 2002 | Have you heard of the term 'irradiation'? | 60 (Australian sample) and 68 (New Zealand sample) | 401 (Australian sample) and 404 (New Zealand sample), quota sampled based on census figures | Australia and New Zealand |
| Lyndhurst, 2009 |  | Review, variety of articles cited (Frenzen, 2001) |  |  |
| Prior, 2013 | Which of the following have you heard of in relation to food production? [Irradiation] | 34 | 3231 (2220 England & Wales, 507 Scotland, 504 Northern Ireland) representative sample | UK (England, Wales, Scotland, Northern Ireland) |

Source: Compiled by CHERE

Table : Literature on consumer understanding of food irradiation

| **Reference** | **Question** | **Results (%)** | **Sample size (n)** | **Country** |
| --- | --- | --- | --- | --- |
| **Papers from literature search** |
| Flores, 2008 | Level of knowledge about food irradiation ('a lot' vs.'neither little nor a lot' vs. 'a little') | Secondary students (0, 37, 63), Food science university students (8, 54, 38), Non-food science university students (4, 11, 85), Nonstudent adults (0, 37, 63) | 400 (Secondary students 100, Food science university students 100, Non-food science university students 100, Nonstudent adults 100) | Argentina |
| Furuta, 1998 | Did the respondent understand the display and description of irradiated potatoes | 57 | 3568 visitors to a science fair | Japan |
| Junqueira-Goncalves, 2011 | Do you know about gamma irradiation for food preservation?…RADURA symbol | 23.5 | 497 respondents to a questionnaire, randomly selected people at supermarkets, metro stations, offices, malls and university campuses | Chile |
| Resurreccion, 1995 | …understood irradiation… | 63 | 446 from consumer database | USA |
| Xu, 1993 | Have you understood irradiated food before? | 33 | 634 shoppers | China |
| **Peer-reviewed from other sources** |
| Jack, 1995  | Consumer has knowledgeof process, Irradiation | 28 | 200 shoppers | Scotland |
| Nayga, 2005 | What is your perception of the RADURA symbol | 10.3% did not recognise the symbol | 484 shoppers in 4 sites  | USA |
| Ornellas, 2006 | Observe irradiate food labels | 45% | 218 Interviewees in several neighbourhoods in Belo Horizonte | Brazil |
| Terry, 1988 | Recognition of RADURA symbol | 2.8% | 436 household interviews | USA |
| **Grey literature** |
| Prior, 2013 | How much do you agree or disagree with the following statement? I feel knowledgeable about the use of irradiation in food production  | 31 | 1059 representative sample | UK (England, Wales, Scotland, Northern Ireland) |

Source: Compiled by CHERE

Table : Consumer stated or revealed preference to consumer or purchase irradiated food and other food attributes that determine selection of irradiated food

| **Article** | **Survey question**  | **Result (%) of respondents that responded positively** | **n and sample** | **Other food attributes** | **Country** |
| --- | --- | --- | --- | --- | --- |
| Papers from Literature search |
| Crowley, 2002 | Willingness-to-purchase irradiated ground beef? | 74 | 115 chefs | Readily available. Price. | USA |
| Donaldson, 1996 | Willingness-to-buy irradiated poultry meat? | 57 | 134 random sample from elector rolls in Aberdeen | Price | Scotland |
| Frenzen, 2001 | Whether respondents would buy meat or poultry that had been irradiated if it was available where they shopped. | 50 | 10,780 from 7 different sites, in both rural and urban centers | Price and food safety | USA |
| Gunes, 2006 | ‘Raw red meat andpoultry products may contain pathogenic microorganisms.These food products can cause diseases if notproperly cooked. Irradiation can eliminate these pathogensfrom raw red meat and poultry products’’, withthese given information would you buy irradiatedfoods? | 62 | 444 range of customers and employees at local businesses | Price, Purchase intent for irradiated food was greatest (44%) if the price would be same as unirradiated foods | Turkey |
| Hashim, 1995 | Purchase of irradiated poultry (revealed preference study) | For irradiated chicken breast OR thighs before and after the slide program (59.5 vs 83.3) and (61.9 vs. 85.7), respectively. For irradiated chicken breast OR thighs before and after the poster (47.3 vs 63.9) and (61.1 vs 66.7), respectively. For irradiated chicken breast OR thighs before and after the label (33.3 vs. 50) and (60.4 vs 60.4, no change), respectively. Willingness-to-pay for raw irradiated chicken compared to the price of nonirradiated chicken = 43.5% if price is the same | 126 consumer database | Price | USA |
| Resurreccion, 1995 | a choice of : buy irradiated, buy non-irradiate, uncertain and neither | 45 | 446 from consumer database | Food safety. Type of irradiated product, there is a higher preference to buy irradiated meat, poultry and fish (32-44%) and 50% of respondents consider irradiation of fruits and vegetables unnecessary. | USA |
| van der Pol, 2003 | Willingness-to-buy irradiated poultry?  | 61 | 200 shoppers | Prevention of food borne diseases | UK |
| Xu, 1993 | Would you buy irradiated food again, if you understand the irradiated food?  | 89.75 | 634 shoppers | Organoleptic qualities (taste) of apples and shelf life | China |
| **Papers from other sources** |
| Deliza, 2010 | Purchase of irradiated papaya (revealed preference study) | if the papaya had been irradiated, the probabilityof the good-appearance papaya being chosen was five times that ofnonirradiated regular-appearance fruit (0.15/0.03 = 5). | 168 shoppers | Sensory attributes (for papaya blemishes, size, colour) | Brazil |
| Fox, 1998 | Stated and revealed preferences. One questionnaire, one retail trial and one market experiment, in purchasing irradiated chicken breast | Survey: 81% indicated they will purchase irradiated chicken at equal price to non-irradiated chicken, and 87% at discounted price.; first retail trial: 43% purchased irradiated chicken at equal price and 62% purchased irradiated chicken at discounted price; market experiment: 80% purchased irradiated chicken (at equal price), and 84% (at discounted price. | 229 – survey98 subjects in market experimentNumber of participants in the retail trial was not reported. | Price and discount | USA |
| Hashim, 2001 | Purchase of irradiated beef (revealed preference study)Simulated supermarket setting | 68-71% purchased either ground chuck or ground beef | 207 consumer database | Type of beef cut (ground beef, ground chuck, top round steak and rib eye steak) | USA |
| Huang, 2007 | Online survey on intention to purchase irradiated poultry products | 65% were somewhat likely | 212 consumers | Price | USA |
| Jack, 1995 | Consumer would buy foodsthat had been treated inthis way (irradiated) | 19 | 200 shoppers |  | Scotland |
| Malone, 1990 | Willingness-to-purchase irradiated products | 36 | 800 households from national sample | Food-safety and shelf-life | USA |
| Nayga, 2005 | Willing to buy irradiated beef (stated preferences study, in rounds after information on irradiation was provided) | Before information: 49.99%;After Round I information (eradicating harmful bacteria) : 89.04%;After Round II information (all electron beam irradiation): 94.3% | 484 consumers of selected regional (random selection of consumers buy the interviewer) supermarkets chains in Texas. | Information: Food irradiation by electron beam not gamma rays. | USA |
| Rimal, 2004 | Purchase or not purchase irradiated beef (stated and revealed preferences study) | reported: 60%bought: 11.1% | 240 consumer database via simulated supermarket setting sessions) | appearance of the product (such as marbling and fat content of beef) had significant influence on product selection.  | USA |
| Spaulding, 2006 | Would you buy irradiated ground beef products? | 71 | 119 convenience sample | 85% indicated killing bacteria as important;35% indicated extended shelf-life as important, if the taste of the ground beef product was unchanged, then 75% of the participants said they would buy irradiated ground beef. | USA |
| Spaulding, 2007 | Would buy irradiated ground beef products? | 75 | 159 college students | 65.8% indicated killing harmful bacteria important reason to buy irradiated beef; 15.2% - longer shelf-life 80% were willing tobuy if the taste was unchanged. | USA |

Table : Consumer stated or revealed preference to avoid irradiated food

| **Article** | **Survey question**  | **Result (%)** | **n and sample** | **Country** |
| --- | --- | --- | --- | --- |
| **Peer reviewed literature from literature search** |
| Donaldson, 1996 | Willingness-to buy irradiated poultry meat?**Response:** said that they would not buy poultry, meat processed by irradiation. | 43 | 134 random sample from elector rolls in Aberdeen | UK (Scotland) |
| Frenzen, 2001 | Adults unwilling to buy these products (meat or poultry that had been irradiated) | 32 | 10,780 from 7 different sites, in both rural and urban centers | USA |
| Gunes, 2006 | **Response**: not buying irradiated food after the benefit statement was made available. | 13 | 444 range of customers and employees at local businesses | Turkey |
| Resurreccion, 1995 | **Response:** would not buy irradiated food. | 19 | 446 from consumer database | USA |
| van der Pol, 2003 | Willingness-to-pay for irradiated poultry? **Response:** would not buy irradiated poultry. | 39 | 200 shoppers | UK |
| Xu, 1993 | **Question**: Would you buy irradiated food again, if you understand the irradiated food? **Response:** Not willing to buy | 2.68 | 634 shoppers in Shanghai | China |
| **Peer-reviewed literature from other sources** |
| Hashim, 2001 | **Response**: Purchase traditional beef (revealed preference study) | 31 | 207 consumer database | USA |
| Jack, 1995 | Consumer would not buy food that had been treated in this way | 81 | 200 shoppers | UK (Scotland) |
| Malone, 1990 | 'Willingness to purchase irradiated products’ Consumers not willing to purchase | 54.4 | 800 households from national sample | USA |
| Nayga, 2005 | **Response**: Not willing to buy irradiated beef (stated preferences study, in Rounds) | Before information: 50.01;After Round I information : 10.96;After Round II information: 5.7 | 484 consumers of selected regional (random selection of consumers buy the interviewer) supermarkets chains in Texas. | USA |
| Rimal, 2004 | **Response**: Will not purchase irradiated beef | Stated: 40Revealed: 29.8 | 240 consumer database | USA |

1. Legislative and Governance Forum on (convening as the Australia and New Zealand Food Regulation Ministerial Council) Food Regulation and response to the Recommendations of Labelling Logic: Review of Food Labelling Law and Policy (2011). [↑](#footnote-ref-1)
2. Source: The Forum provided responses and actions in December 2011 (referred to as the Government Response) to each of the labelling review panel’s recommendations [http:/www.foodlabellingreview.gov.au/internet/foodlabelling/publishing.nsf/Content/home](http://www.foodlabellingreview.gov.au/internet/foodlabelling/publishing.nsf/Content/home) ).

 [↑](#footnote-ref-2)
3. The CHERE Report did not find any discussion on the use of voluntary labels, it is assumed that under a voluntary labelling scheme, food irradiation labels would not be seen in the market. [↑](#footnote-ref-3)
4. Radiation is measured in kilograys (kGy). 1kGy = 1000 Gray (Gy). It indicates the absolution of 1 Joule (watt per second) of ionising radiation by one kilogram of matter (mass). [↑](#footnote-ref-4)
5. <http://www.foodstandards.gov.au/consumer/foodtech/irradiation/Pages/default.aspx>, accessed 23 June 2013 [↑](#footnote-ref-5)
6. Amendment 56 to the Food Standards Code. [↑](#footnote-ref-6)
7. Kume, T. Furuta, M. *et al*. (2009), “Status of food irradiation in the world”, Radiation Physics & Chemistry, 78, 222-226 [↑](#footnote-ref-7)
8. <http://www.steritech.com.au/>, accessed 23 June 2014 [↑](#footnote-ref-8)
9. The STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) checklist was developed for researchers to provide guidance on how to report observational research (cohort, case-control and cross-sectional studies) well. [↑](#footnote-ref-9)
10. The Meta-analysis Of Observational Studies in Epidemiology (MOOSE) checklist was developed for researchers to provide guidance on how to report meta-analyses in observational studies. [↑](#footnote-ref-10)
11. In the US, the 2005 quantities of irradiated food were 80 000 tonnes of spices, 4000 tonnes of fruit and vegetables and 8000 tonnes of meat and poultry, representing a wider range of food groups (Kume, 2009). [↑](#footnote-ref-11)
12. It is unclear what the range and quantity of irradiated food is imported and how this influences the population exposure and awareness of food irradiation <http://food.gov.uk/science/irradfoodqa/#.U6drT_mSyCk>, accessed 23 June 2014 [↑](#footnote-ref-12)
13. FSANZ, Standard 1.5.3 Irradiation of Food. Note: these are only examples provided by FSANZ, sellers of irradiated food may use other wording in their labels including the use of a benefit statement. [↑](#footnote-ref-13)
14. It was not specified whether this was for selection or avoidance decisions. It should be noted that compared to other label elements such as date mark and ingredients list which are mandatory on all food packaging, irradiation labelling is only required on packaging that contains those products, hence, awareness and use is expected to be lower than for other label elements. [↑](#footnote-ref-14)
15. Australian Competition & Consumer Commission, ‘ACCC watches new labelling of GM foods’, media release, 18 January 2002, <http://www.accc.gov.au/media-release/accc-watches-new-labelling-of-gm-foods>, accessed 23 June 2014 [↑](#footnote-ref-15)
16. The degree to which a certain product is preferred (lower risk of contracting food-borne disease) to a risky alternative (higher risk of contracting a food-borne disease) with the same expected value. [↑](#footnote-ref-16)