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Consumer response to irradiated food: purchase versus perception

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Purpose of review: Many successful experiences of commercialisation of irradiated foods call for a revision of the predominant negative views on their acceptance by consumers and an adaptation of strategies to encourage further commercialisation.
Findings: A significant number of consumers around the world have now purchased and re-purchased irradiated fresh produce, meat products and a few other products. The evidence is thus substantial that while a fraction of the public will not buy irradiated food, a much larger fraction will. Retailers have the key role since they decide whether or not they will offer irradiated food on their shelves. However, retailers generally still believe consumers will not purchase irradiated food. Communication on the products and on the benefits to consumers is more effective than providing technical details of the technology.
Directions for future research: Proponents of food irradiation should channel their efforts and resources towards convincing retailers that they can engage in food irradiation without the risk of disrepute. Building trust in the systems that will deliver and regulate food irradiation is essential. Governments must take a science-based stand and create the conditions whereby consumers can exercise their free choice of buying or not buying irradiated food. More effort should be put into addressing issues such as lack of irradiation capacity, optimising supply chain reliability, developing facilities to treat food where food is finally packaged and encouraging the use of non-radioactive, accelerator-based sources.

Keywords: food; irradiation; consumer; attitude; perception; purchase

Introduction

The early history of irradiation processing of food was discussed by Diehl [1**] including the first commercial application for spices in Germany in 1957. The General Standard for Irradiated Foods was first published by the Codex Alimentarius in 1983 [2**]. This essentially stated that any irradiated food was safe, nutritionally adequate and posed no special microbiological problems. The 2003 revision [3] stated that the maximum dose should not exceed 10kGy except when necessary to achieve a legitimate technological purpose.

Since the Standard was issued, a consistent message has been provided by scientists and science-based organizations that irradiation can contribute efficiently and effectively to increasing the safety and the security of food and to reducing the need for chemical treatments such as those used for fresh produce moving across borders [4*].

A 2009 survey led to an estimate of 405,000 tonnes of food being commercially irradiated world-wide [5**]. This was probably an underestimate due to a reluctance of some companies to reveal commercially-sensitive information. Given a recent rapid expansion in China of garlic and chicken products treated by irradiation, a reasonable estimate of the total amount of food being irradiated annually is approximately 750,000 tonnes. On a global scale, this is still a trivial amount given global food production and the apparent potential of irradiation to benefit consumers and industry.

This review examines cases of successful retailing of irradiated foods and considers the reasons for, and implications of, the most frequently cited reason behind the slow uptake of irradiation processing by the food industry, namely the belief that consumers will not purchase irradiated food.

Irradiated foods in the market place

The volume of spices, condiments and dried vegetables irradiated has for many years been higher than any other food class [5]. During the 1990s, France [6] soon followed by other European countries started irradiating thousands of tons of mechanically deboned poultry meat for incorporation into sausages or raviolis. However, except for spices in South Africa, these irradiated products were not sold directly to consumers but were blended and used as ingredients in processed foods. As is usual for compound foods, the consumer was not informed of any processing treatment of the constituents and the consumer was not making a voluntary choice to purchase an irradiated product.

There are now many examples of a whole food sold with a label clearly indicating irradiation, thereby presenting consumers with the opportunity to purchase or reject the product.

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Figure 1: Irradiated ground beef on sale in a US supermarket (with permission from Wegmans)

Pre-2000

Extensive market tests took place from the 1980s involving various types and quantities of irradiated food such as:

- Papaya, mango and poultry in the US [7, 8];
- Strawberries in France and South Africa [7, 9];
- Refrigerated shrimps in the Netherlands [10];
- Rehydrated dried fruit, chicken livers and gizzards in France.

These tests, in which information on irradiation was usually made available and in which irradiated and non-irradiated products were offered side by side, were considered positive in the sense that they all showed that consumers do buy irradiated food.

Long term retail sale of a variety of irradiated fresh produce supplied from a facility in Florida began in a small Chicago grocery store in 1992 and continued for over 10 years [11]. Between 1995 and 2000, 400 tonnes of Hawaiian papaya and other fruits were shipped to an irradiation facility in the Chicago area and sold in several US states [12**]. After 2000 an irradiation facility in Hawaii became available to treat the fruits prior to shipment.

Several types of food were irradiated in European countries prior to an EU-wide Directive that restricted irradiation treatment to foods on a "positive' list which initially comprised only herbs and spices [13]. The Directive opened the possibility to extend the list to other products, but this has still not happened after more than 15 years. Given the positive conclusions of the European Food Safety Authority about the safety of irradiated food [14], the delay and barrier to authorising the irradiation treatment of more foods do not appear to be science based.

Japan was an early adopter of irradiation when, in 1973, a cooperative on its northernmost island treated potatoes to inhibit sprouting. Since then, Japan has consistently rejected extension of irradiation to any other foods. However, irradiated potatoes are still sold over 30 years later although the volumes have gradually reduced to less than half peak volumes, standing at approximately 6,000 tonnes per annum [5**].

Thai people enjoy *naem*, a fermented pork sausage eaten raw. The pathogens and parasites risk is significant and a safe irradiated option has been available in convenience stores and supermarkets since the mid-1980s [15]. Most Thai consumers do not recognize the health risk and the irradiated product has a higher price. As a result, the quantity of irradiated product sold yearly is only a few hundred tons.

Post-2000

Concerns about bacterial contamination (eg, *Campylobacter, Salmonella* and, particularly, *E coli H0157)* of ground beef and chicken have been steadily increasing in the USA since the 1990s due to the associated health costs [16*], potential liability issues and much publicised recalls of meat shipments that sometimes put companies out of business [17]. Small volumes of meat were irradiated pre-2000, but since then a steady market for irradiated ground beef has existed. The labelled product is sold through several mid-sized supermarket chains (Figure 1) and has totalled approximately 8000 tonnes per annum for several years [18**].

In 2000 an X-ray facility became available in Hawaii for phytosanitary treatment of fresh produce and irradiated sweet potato, papaya and other tropical fruits have been shipped for retail sale in mainland USA, a trade presently estimated at approximately 6000 tonnes per year [19**].

EU countries that permitted irradiation of foods other than spices and herbs prior to the 1999 Directive still maintain the right to use their existing national legislation. However, given the negative regulatory climate in the EU, it is unsurprising that volumes of irradiated food in the EU have continued to fall. Nevertheless, EU member states still irradiate approximately 7000 tonnes of food per annum [20*]. Almost half of the food treated comprises frog legs sold with suitable labelling in Belgium, France and the Netherlands.

China has leapt ahead in its use of irradiation for several foods such as garlic. Of special note is the disinfection of spicy pickled chicken feet and wings, a snack packed under vacuum and kept at room temperature, of which more than 120,000 tonnes of labelled product were sold in 2014 [Gao Mei Xu, personal communication 20 May 2015]. The market leader is building an in-house gamma irradiator in the region of Chongqing solely for their production.

In 2014, the total global volume of fresh produce irradiated for phytosanitary purpose was approximately 22,000 tonnes [21**, 22**]. New Zealand was the first country to accept irradiated fresh food from another country (Australia) in 2004. For over 10 years labelled mangoes and litchis irradiated to meet strict New Zealand import quarantine requirements have been available in shops and supermarkets. Volumes have grown steadily and since 2013, irradiated tomatoes and capsicums have also been available. The total volume of irradiated fresh product imports in 2014 was approximately 2000 tonnes [21**].

Consumers in the USA are also finding irradiated fruits imported from overseas in their supermarkets. Seven countries are sending a variety of fruits sold at retail into the US, totalling nearly 14,000 tonnes in 2014 [22**], adding to the 6,000 tonnes of irradiated Hawaiian produce.

Figure 2: Label on irradiated mango from Australia sold in New Zealand.

Australasian case study

The predominant interest in food irradiation in Australia and New Zealand is as a phytosanitary treatment to ensure viable insect pests are not exported along with fresh produce. Both countries conducted a government-led public enquiry into food irradiation at the height of public fears of any nuclear related technology following the Chernobyl accident and after New Zealand legislated to be a nuclear free zone.

Australia imposed a moratorium on food irradiation and New Zealand put in place a policy of not permitting irradiated foods to be produced, sold or exported. This situation lasted over a decade until 1999 by which time the two countries had established Food Standards Australia New Zealand (FSANZ), a joint body to set food standards. FSANZ Standard 1.5.3 (Irradiation of Food) [23] was established to permit food irradiation subject to application and approval on a case-by-case basis. Adoption of the Standard ensured consistency with the strong support of both countries for trade rules to be based on science and the recommendations of the recognized international bodies for food (Codex and the International Plant Protection Commission, IPPC).

In 2003 FSANZ approved 9 tropical fruits that could be irradiated up to 1 kGy for a phytosanitary purpose. As of May 2015, 23 fresh produce items have FSANZ approval. The strong original (1980-1990s) opposition to irradiated food was significantly reduced when it was made clear that labelling would ensure that consumers would have the choice whether or not to purchase.

Irradiated mangoes have been imported into New Zealand since 2004 and litchis since 2006 [21**]. Adverse public reaction was limited to some initial letters to newspapers and on-line comment. Objections during the public comment period conducted by FSANZ on applications to irradiate fresh produce have fallen from several hundred for the first series of applications in 2003 to a handful for the latest applications in 2014.

New Zealand's two major supermarket chains did not stock irradiated mangoes during the first year they were available but watched the reaction to display in smaller independent stores. Since then irradiated labelled mangoes (Figure 2) have been available in both major and independent stores.

Approximately 1,000 tonnes of imported mangoes and litchis have been available at retail in recent years and the figure reached 1,500 tonnes in the 2014-15 season [21**]. The mangoes are presented as premium products and are purchased despite a cost from two to three times the cost of mangoes imported from other countries treated with other phytosanitary treatments.

In 2013 and 2014 over 400 tonnes of irradiated tomatoes were imported. However these were only sold in the independent stores. There has been opposition to the importation but it has come from local tomato growers, not from consumers. Arguments have been based on whether imports are needed and on the adequacy of the labelling requirements not on the safety of irradiated tomatoes.

Australia has strict quarantine rules on fresh produce moving across the borders of its States and Territories. Queensland fruit fly is the pest of greatest significance but there are many others. Queensland also is the site of Australia's sole facility licensed to irradiate food. In 2011 a protocol accepting the phytosanitary use of irradiation was agreed by all States and Territories [24]. There is a slowly growing trade in Queensland mangoes, tomatoes and capsicums being sold at retail in Western Australia and trialled in South Australia [21**].

Summary of retail experience

There is now sufficient experience to show that when labelled irradiated foods are offered for retail sale, consumers will purchase and re-purchase it, implying that irradiated foods may be marketed profitably and without risk to reputation. The experience has been gained in several countries including those with sophisticated, well-informed consumers with active lobby groups who favour 'natural' and minimally processed foods, such as the USA and New Zealand.

Though vocal at times, opposition seems to have little impact on most consumers who at the moment of purchase make decisions on the basis of what they see in front of them and price. This does not imply unanimous acceptance of irradiated food. No food is purchased or wanted by all consumers. Also, consumers do not decide the new products that are offered to them. This decision is made by the retailers who assess afterwards if the sales are acceptable or not.

Understanding consumer attitudes

It is not hard to conceive why it was originally thought that consumer resistance was the major barrier to the uptake of food irradiation. Post-Chernobyl uptake was slow, and anti-food irradiation lobbyists declared that irradiated products were neither wanted nor needed, a position seemingly justified by the slow uptake. The public may often equate irradiated food with radioactive food and any new technology involving radiation or radioactivity has been mistrusted despite the long term use of such technologies in medicine and industry.

The question is why, in view of the significant examples of successful retail sale that now exist, the belief in consumer re-

sistance persists among food producers and retailers? The answer probably lies in the early surveys of consumer opinion about food irradiation, an overly simplistic interpretation of the results and their use by anti-nuclear and anti-irradiation lobbies.

The literature on surveys of consumer opinions on food irradiation has become extensive. Articles on the US consumers' perception of food irradiation and irradiated meat pre-dominate [25] and have been reviewed by Eustice and Bruhn [18**]. There are now data from the EU, Canada, Brazil, Australia, New Zealand and a few developing countries [26-33]. The methodologies, the size of the studies and the rigour of the analyses vary widely but there are some clear trends.

First, most respondents have never seen irradiated food. Their opinion is sought about an abstract concept. Generally it is found that:

- The majority of respondents have not heard of irradiation or know no very little about the process.
- The initial reaction of most consumers asked if they would purchase irradiated food is negative.
- When provided with factual evidence, the number of respondents willing to consider purchasing irradiated food increases, often then comprising a majority of consumers even if asked to consider paying a premium. Providing negative information at the same time as positive information offsets the increase in acceptance.
- For fresh produce, irradiation is viewed more favourably than chemical treatments when a similar level of information is provided about the technologies [31, 33].
- Irradiation is viewed much less favourably than other physical processes such as cold storage with which the respondents feel they are familiar.

Social scientists have now examined consumer reactions to novel technologies in greater depth through studies in which genetic modification, nanotechnologies or high pressure are assessed together with irradiation [34**, 35*-37]. These studies show that irradiation is not unique in engendering both general and organized opposition. A full discussion of these important recent findings is beyond the scope of this review but the studies show clearly that:

- The issue of acceptance of a new food technology has much to do with trust in the systems in place to regulate and deliver the technology. The issues are greater than risk perception *per se.*
- Technologies that are not perceived as "natural' or which are thought to alter the character of the food generate greater opposition than technologies that are familiar or perceived as more "natural".
- Labelling can help to provide some degree of control, although one-third of respondents in a US survey would consider the word "irradiated" on a label to be a warning [37].
- Information can be valuable in increasing positive responses to novel technologies, but the information must be focussed on the benefits to consumers. Technical details of the process often lead to consumers feeling they cannot understand the process and that it will be out of their control. New technologies which are perceived as being of benefit mainly to the food industry tend to be distrusted.

Future directions

Food irradiation should contribute appropriately to safer food, a more secure food supply and facilitated trade in fresh produce. As a result of the early marketing trials of irradiated food, several authors noted that the willingness of consumers to purchase irradiated food may be greater than indicated by their initial response to a general survey when irradiated food was not actually available [7, 8, 38**]. Nevertheless, an unsubstantiated belief in massive consumer resistance to irradiated food continues to the present day and has discouraged efforts to interest key sectors of the food trade in the technology. The response of irradiation advocates has often been to stress the need to provide consumers with more information about the process.

The now overwhelming success of actual retail of irradiated foods and the evidence from sophisticated studies of consumer attitudes to novel food technologies suggest future strategies for increasing the commercial uptake of food irradiation. Elements of a future strategy should include:

- Taking every opportunity to place in front of food producers and retailers the evidence of successful, long-term retailing of labelled irradiated foods.
- Increasing the amount of irradiated food on retail shelves through seeking the cooperation of entrepreneurial retailers, who are likely to be small or medium-sized.
- Developing coalitions of stakeholders that believe in the value of food irradiation and that would have the trust of consumers. Food producers and retailers will be seen by consumers as less biased than irradiation processors.
- Providing information and support to producers and retailers on a technology that is very unfamiliar to them. This must come from regulatory authorities, academics and, despite the caution above, the irradiation industry. The role of regulatory authorities is crucial. The US and New Zealand cases benefited from the attitude of food authorities that make science-based rules. Wherever food irradiation is considered too sensitive an issue to make science-based decisions, the public debate is dominated by vocal opponents.
- Stressing the benefits of irradiation that are focussed on the food and the consumer rather than the technicalities of the process. For example, in the case of meat, giving consumers a guarantee that they will not be poisoned by a pathogen is what will matter most. Consumers can relate to a non-chemical phytosanitary treatment that protects local agriculture and the environment as well as providing produce that is exotic or out-of season. However, extension of shelf-life of fresh produce is not necessarily seen as a benefit by consumers who have become used to the notion of fresh (meaning just harvested) produce.
- Taking into consideration that both positive and negative points of view will coexist in any public debate on food irradiation.
- Ensuring that labelling of irradiated food is both consistent and fair. Labelling is a very difficult issue to balance. Consumers see mandatory labelling as empowering them and providing greater control over what they buy. An assurance that irradiated foods would be labelled played a significant

role in decreasing opposition to irradiated foods in Australia and New Zealand. The food industry, however, sees labelling as a barrier to irradiation since consumers are likely to perceive it as a warning given that competing technologies are often not required to label (for example, competing phytosanitary treatments) and it carries some extra costs.

- Ensuring consistency in national regulations on the labelling of food in which an irradiated ingredient is only a minor constituent. Requiring that the tiniest quantity of irradiated ingredient in a processed food be mentioned on the label is extreme.
- Adjusting promotional strategies to recognize that irradiated food can appear to run counter to some recent shifts in consumer opinion, specifically towards minimal processing, attraction to naturalness and 'organic' and for locally produced food.

We have made the point that for too long the food trade has believed that consumers will not purchase irradiated foods. Equally, food irradiation advocates may have concentrated on consumer acceptance for too long at the expense of other barriers that need to be addressed. Briefly, these include:

- Producers do not relate easily to irradiation processing. Contrast the likely reaction of a fruit grower who for years has used hot water treatment in the packing shed or an insecticide spray in the field with a new requirement to send his fruit to a distant facility that requires special authorization and has hazard signs. The sterilization of health-care products can be a useful analogy for growers.
- At present irradiation requires the shipment of products to a specialised contractor during which time they are out of the control of the producer with a transportation time and a cost that comes on top of the price charged by the irradiation company. Food generally being a perishable commodity, smooth operation of supply chain logistics is even more essential than for health-care products.
- Affordable irradiation devices that could be placed on-line in, for example, a fruit packing house or meat processing chain would go a long way to encourage the adoption of the process. Such equipment is a research concept at present but would be the ideal answer for the final step in a HACCP or quarantine system; it would also empower the user.
- The number of irradiation facilities is limited and since most are located to capture non-food products, they are not necessarily in the right place for food manufacturers or traders. Also these facilities are often optimized to treat at much higher doses than those required for food. These factors result in a lack of capacity to treat food at present and keep commercial volumes low. The result is to feed doubts about the potential for food irradiation to expand.
- Food generally involves high volumes. If only a fraction of a specific food can be treated this creates problems for the trade. These include practical issues of having two production streams and can include perception issues. For example, meat produced under GMP is rightly regarded as safe, but what would be the issues for a dual market, one with safe meat and one for irradiated meat that is even safer?
- Gamma irradiation is currently the predominant technology for food irradiation. Gamma facilities are safe and able to irradiate up to pallet size of products of high densities. They will undoubtedly continue to have an important role for many years. However, accelerator facilities producing electron and X-ray beams have several advantages. These include independence from the supply of cobalt-60 and the ability to 'switch-off' the emission of radiation. This can result in greater ease of obtaining permission to build traditional centralized facilities and opportunities to develop the on-line, in-house treatment systems that would excite the interest of food producers and, as they do not involve radioactive material, probably improve public perceptions of the technology.

Conclusions

Evidence from several countries shows that labelled irradiated foods (fresh and processed meats, fresh produce) have now been sold over a long period by food retailers without disruptive opposition. There is no record of any irradiated food having been withdrawn from a market simply because it has been irradiated. Although there are some consumers who choose not to purchase irradiated food, a sufficient market has existed for retailers to have continuously stocked irradiated products for years.

The long-standing belief among food producers and retailers that consumer resistance is the major barrier is no longer justified and there are lessons to be learned from the successful experiences. Provision of factual, positive information on the benefits of food irradiation to consumers and the food trade is still necessary. However, strategies to increase retail sales of irradiated foods should be modified in light of recent studies on consumer attitudes to novel food technologies generally.

Studies show that it is trust in the systems and institutions rather than perceptions of risk that dictate consumer attitudes and govern the adoption of a new technology. Retailers play an essential role in communicating the benefits of new products to consumers and it is likely that positive messages on irradiated food from retailers and food producers will generate the most favourable response from consumers.

Historically, the large retail food chains have only engaged to a limited extent with food irradiation experts. It is vital to ensure that the message about successful retailing of irradiated food is continuously presented to leading retail stakeholders, and to take every opportunity to put irradiated food on retail shelves.

If food irradiation proponents are persuaded that trying to convince consumers directly to accept the process should not be their sole strategy, then more effort can be put into working collaboratively with the food trade to address issues such as lack of irradiation capacity, optimising supply chain reliability, developing facilities to treat food where food is finally packaged and to encourage the use of non-radioactive, accelerator-based sources.

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