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# Does information on food safety affect consumers' acceptance of new food technologies? The case of irradiated beef in South Korea under a new labelling system and across different information regimes\*

Vincenzina Caputo <sup>†</sup>

Consumer aversion to new food technologies may be partly explained by the gap between the problem that the technology solves and what consumers actually understand about the food technology. This study assesses how accepting consumers are of food irradiation when exposed to prior information about food safety-related issues. Using a hypothetical discrete choice experiment, this study also explores consumer demand for a new food irradiation labelling system in South Korea under different information on food irradiation (positive, negative, and positive and negative). The results indicate that Korean consumers have a negative perception of irradiated foods and that they fail to link the use of food irradiation as a vehicle to solve food safety issues, even with the new version of the irradiated food label. However, providing consumers with information about food safety-related issues alongside with the benefits implied by the use of food irradiation resulted in more general acceptance of food irradiation. Furthermore, we conclude with a discussion of the relevant implications for policymakers, academics and food industry professionals.

**Key words:** food safety, new food technologies, food irradiation, information effects, consumer demand, South Korea.

## 1. Introduction

Although many countries have adopted a series of policies to strengthen food safety regulations, foodborne diseases remain a major problem in both developed and developing countries. Out of these countries, the African and South-East Asia regions are the most affected by foodborne diseases (WHO 2015). For example, more than 175,000 deaths occur from foodborne diseases every year in the South-East Asia region (e.g. Bangladesh, Bhutan, South Korea, India, Indonesia, Maldives, Myanmar, Nepal, Sri Lanka, Thailand

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and Timor-Leste), and about 51% of cases are caused by *Campylobacter*, *Salmonella*, Shiga toxin, *Escherichia coli*, *Brucella* or *Shigella* (WHO 2015). The increased demand for raw meat products and the emerging trend of diets containing exotic fruits and vegetables pose additional food safety challenges. These challenges require the adoption of high-quality and safety standards for food to minimise the risks of foodborne diseases.

Food irradiation (a technology that improves the safety standards of food products and extends their shelf life by reducing or eliminating insects and microorganisms) can minimise the occurrence of foodborne diseases. For example, food irradiation reduces the levels of harmful bacteria such as *E. coli* and *Salmonella* in meat and prevents premature spoilage in fresh and frozen raw ground beef. In the United States, irradiated food has been commercialised over the last 30 years with a consumption of 125,000 tonnes of irradiated food per year. In many Asian, European and Pacific countries (Wilcock *et al.* 2004), the lack of support for irradiated food among the public is still one of the major factors restraining the growth of the food irradiation market. Consumers have a poor level of knowledge and understanding of safety standards employed in food irradiation (Nayga 2003; Nayga *et al.* 2004); they erroneously fear that irradiation will make foods radioactive, alter nutritional quality and/or change flavour, odour, texture or appearance of foods. This study explores consumers' acceptance of food irradiation in South Korea under a new labelling system and under different information settings.

The acceptance of food irradiation and its impact on public health will be limited unless consumers consider food irradiation as a tool that increases the safety of food. To bridge the existing knowledge gap among consumers, irradiated food products are typically sold in retail stores using the international Radura logo. Additional explanatory statements such as 'Treated with radiation' or 'Treated by irradiation' are required to be displayed alongside the Radura logo. However, while these statements are intended to communicate additional information about the food irradiation process, consumers fail to differentiate their meaning with that of radioactive foods. As such, several countries have revised the actual food irradiation labelling system with the main goal of highlighting the food safety standards implied by the Radura logo. For instance, in the United States, the FDA now allows retailers (e.g. Schwans) to use new words such as 'Irradiated for Food Safety' or 'Irradiated to Protect Agriculture from Harmful Insect Pests' along with the Radura logo (Clemmons *et al.* 2015). In South Korea, the government introduced a new labelling system for irradiated food products, which established the use of the Radura logo followed by other statements describing the irradiation process in more detail such as 'Electron beam sterilization' or 'Gamma-ray sterilization of food'. Whether these new exploratory statements along with the Radura logo can communicate the potential benefits of food irradiation to enhance food safety to consumers still remains an open matter due to the lack of empirical studies investigating consumer acceptance of irradiated food under these new labelling systems.

Further, questions about whether consumers link the new Radura logo with food safety issues remain unanswered. In this regard, a much-debated question in the literature so far has focused on whether providing consumers with balanced information on the benefits and risks associated with the use of food irradiation technology alters consumer acceptance of irradiated food. However, the low acceptance of food irradiation has also been shown to be related to consumer unfamiliarity with food safety-related issues such as the main causes, incidence and prevention of foodborne diseases (Eustice and Bruhn 2013). This unfamiliarity comes from consumers failing to associate the use of food irradiation technology as a tool to reduce the incidence of foodborne diseases. Prior studies have shown that increasing the level of consumer awareness of food safety-related issues might be the key trigger to increase the acceptance of food safety standards (Dillaway *et al.* 2011). For example, consumers who are aware of potentially risky foods are also more likely to accept food irradiation (Eustice and Bruhn 2013) under various information regimes (positive, negative, and positive and negative). This in turn requires an understanding of whether delivering information about food safety-related issues affects the acceptability of irradiated food among consumers; an issue that has not been investigated yet.

To fill this gap in the literature, this study explores (i) consumer valuation for irradiated beef in South Korea under a new food irradiation labelling system and (ii) whether providing consumers with information on food safety-related issues increases their level of acceptance of irradiated foods under different information regimes. To explore the effect of information about food irradiation and food safety-related issues, we conducted a hypothetical choice experiment study on beef selection. The study is composed of a control and four treatments, and the respondents randomly participated in only one of the treatments. In the *Control* treatment, respondents were only faced with the choice questions. On the other hand, in the first treatment (named '*Video*') respondents were asked to watch a video clip on food safety-related issues prior to the choice questions. In the remaining three treatments, respondents were first exposed to information on food safety-related issues via the video clip and then randomly assigned to one of the following treatments: (i) *VideoPos*; (ii) *VideoNeg*; and (iii) *VideoPN*. The treatments differ in terms of the type of information on food irradiation that is provided to consumers via a statement: positive, negative and neutral information. The survey also included demographics and attitudinal questions, which were used to establish the relation between personal characteristics and food irradiation acceptability.

This study advances the literature in this field in three important ways. First, this study explores how food safety-related information delivered to consumers via a video clip affects their level of acceptance of food irradiation. Prior studies have looked at the how willing consumers are to accept new food technologies by exposing them to the range of benefits provided by food irradiation (Eustice and Bruhn 2013). Such approaches, however, have failed

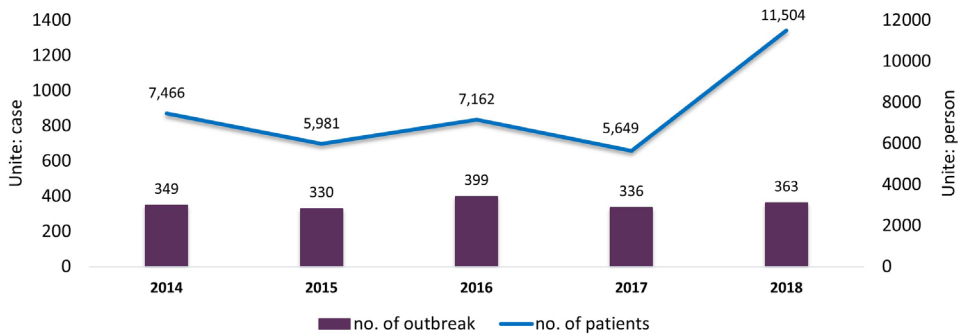
to address whether consumers are able to understand the link between the use of new food technologies and the benefit derived from food safety. Understanding this link is important for both food industry and policymakers. For instance, findings from this study can help the food industry and policymakers to understand whether educating consumers about food safety-related issues plays an important role in improving consumer acceptance of food irradiation. Second, previous studies on food irradiation have focused on irradiated food consumption by only using the Radura logo. Thus, this is the first study exploring consumer acceptance of irradiated food under the Radura logo followed by additional informational claims. Given the introduction of the new labelling system for irradiated food products and the discussion about introducing meat products to the list of allowed irradiated food types in South Korea, this study makes a unique contribution to the current debate about how to label irradiated food products in South Korea. Findings from this study can also be informative for policymakers from other countries where the food irradiation labelling system has been revised. For an example, the United States has been slowly implanting irradiated foods since the early 1990s; this study could provide insight on how to label foods that are already in supermarkets to increase consumer interest for irradiated foods (Bruhn 2017). Lastly, this study explores whether consumers respond to different types of information exposure differently depending on their socio-demographic and attitudinal factors such as knowledge and perceptions about the benefits implied by the food irradiation technology. Consumers' preferences and WTP for new food technologies including food irradiation may involve a complex decision-making process, which requires assessment of what factors explain the heterogeneous food preferences and drive food demand. Consequently, understanding how consumers respond to different information exposure is critically important to develop successful segmentation and marketing strategies, as well as designing effective labelling food policies.

## 2. Background

### 2.1 Foodborne diseases and the market opportunities for irradiated food

The occurrence of foodborne diseases is still one of the major concerns in Asian countries, and South Korea is not an exception. Recent statistics in South Korea indicate that the number of patients that have suffered from foodborne diseases has risen from 5,649 in 2017 to over 11,000 in 2018 (see Figure 1). Furthermore, Japan and China have both seen between 16,000 and 23,000 patients suffer from foodborne diseases between 2015 and 2018 (Ministry of Health, Labor and Welfare, Japan 2019; Wang *et al.* 2018).

The statistics associated with the number outbreaks occurring in public facilities are also alarming (especially in South Korea). For example, the cases of foodborne disease outbreaks in schools and restaurants providing meals



**Figure 1** Number of foodborne diseases and patients (2014–2018). Source: Food Poisoning Statistics, Food Safety Korea, Ministry of Food and Drug Safety, 2019. [Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

were 44 and 202, respectively, in 2018, with more than 5,400 patients involved (Food Poisoning Statistics, Food Safety Korea, Ministry of Food and Drug Safety 2019). The number of sick patients also has a significant effect on the economy. According to Lee *et al.* (2007), the annual socio-economic costs of foodborne diseases were about 1,600 billion won in 2005 and 1,954 billion won in 2008 (Shin *et al.* 2010). Prevention measures such as food irradiation are necessary to improve food safety and reduce the associated health and socio-economic annual costs. According to Lee *et al.* (2013), food irradiation could lower the socio-economic and healthcare costs of foodborne diseases by close to 88 billion won per year.

In South Korea, meat consumption accounts for many foodborne disease outbreaks, hospitalisation and deaths. For example, about 43% of foodborne disease are caused by beef consumption (Park *et al.* 2003). The projected increase in meat consumption as a result of the Korean consumers' westernised diet, development of the restaurant industry and increased contracted meat food service can further exacerbate the foodborne disease problem, thereby leading to higher socio-economic cost associated with foodborne disease outbreaks (Shin *et al.* 2009). The four main causes of food poisoning in South Korea are protozoa, *Escherichia coli*, *Salmonella* and norovirus. All of these pathogens can be effectively eliminated through the process of food irradiation. Despite so, except for dried meat, beef, pork and poultry products are not allowed to be irradiated in Korea<sup>1</sup> (Koutchma *et al.* 2018). The MFDS attempted to revise the food irradiation regulations in 2004 and 2006. For instance, the MFDS tried to extend the food irradiation

<sup>1</sup> Other products that are allowed to be irradiated in South Korea are as follows: potatoes, onions, garlic, chestnut, mushroom, powdered egg, grains and legumes, dry meat, powdered fish, shellfish, crustaceans, powdered soy sauce, soya bean paste, red pepper paste, drying vegetables, enzyme food, algae food, powdered aloes, ginseng or red ginseng, dry spice, composite seasoning food, sauces, leached tea and powdered tea.

allowances on red meat and other meat products as a method to prevent foodborne diseases, especially at schools. However, these efforts were shelved because of opposition from various consumer groups.

A change in irradiation regulations in Korea will not only reduce the economic losses due to foodborne disease outbreaks but also present significant opportunities for importers such as the United States and Australia who have the exporters of beef in South Korea and have the necessary infrastructure to supply large shares of the market. The irradiated food program in the United States is considered the most advanced program in the world with multiple irradiation facilities (Eustice 2017). A broad list of foods is allowed to be treated with irradiation, including certain meat products (Koutchma *et al.* 2018). Driven by consumer acceptance, the volume of irradiated food consumed in the United States amounts to approximately 125,000 tonnes per year, which is the second largest volume in the world following China (Eustice 2017). Around 10% of the consumed amount is made up of irradiated meat, poultry and live oysters. In Australia, on the other hand, food irradiation is currently only approved only for herbs and spices, herbal infusions and some tropical fruits. This minute approval list persists even though the government has deemed food irradiation a safe technology that does not cause a significant loss of nutrients in the food (Food Standards Australia New Zealand 2019). Knowledge among consumers in Australia about food irradiation is limited. A 2016 study found that two thirds of Australian respondents have never heard of food irradiation and the majority of respondents reported that they had never knowingly purchased irradiated food (Centre for Health Economics Research and Evaluation 2016). Nevertheless, the use of irradiation on approved commodities, particularly for exports, has been growing constantly.

Overall, food irradiation has an immense amount of benefits that can reduce the number of patients who suffer from diseases and allow countries to cut the amount that must be spent on socio-economic and healthcare cost. However, despite this truth, consumers still may be wary of products that have been irradiated.

## **2.2 Previous studies on consumer acceptance of food irradiation and information effects**

Despite the safety and efficacy of food irradiation that has been acknowledged in more than 40 published scientific articles (Johnson and Estes Reynolds 2004) and approved by several authorities including the WHO and Food and Agriculture Organization of the United Nations (FAO) (Morehouse 2002), several lines of evidence indicate that consumers perceive food irradiation as a risky technology. This negative perception is mainly associated with the lack of information and understanding of food irradiation; that is, the lower the level of consumer awareness about the irradiation process and the less the knowledge consumers possess about its benefits, then

the higher the perceived risk. In South Korea, for example, Choi *et al.* (2010) reported that 58.3% of consumers have never heard of irradiated food and 31.7% of those who have heard of food irradiation do not know what it means. Other research indicates that Korean consumers are unable to discern irradiated food products from those contaminated by radioactivity<sup>2</sup> (Kim and Kim 1998; Park and Kim 2001). Hence, they may generally perceive irradiated food as harmful, unsafe and dangerous for their health. Comparative data from other studies also indicate that the level of consumers' knowledge about the process of irradiation affects consumer acceptance of irradiated food. This means that the lower the level of consumers' knowledge, the lower the likelihood of purchasing irradiated food products over non-irradiated food products (Lusk *et al.* 1999; Nayga *et al.* 2005). Taken together, these findings suggest that the level of information about the process available in the market can play an important role in determining consumer's willingness to purchase irradiated food products.

In this regard, several studies demonstrated that the degree of consumer valuation and acceptance of irradiated food depends on the types of information (e.g. processed-based, favourable, unfavourable, and both favourable and unfavourable) provided to them. For instance, Bruhn (1995) argued that when consumers receive scientifically based information on food irradiation, they tend to prefer irradiated to non-irradiated food products. Similarly, Crawford and Ruff (1996) pointed out that when consumers are faced with the benefits of food irradiation, particularly as a means to prevent food contamination, their willingness to purchase such food products increases. Fox and Olson (1998) also reported that when consumers are exposed to unbiased science-based information about food irradiation, they are willing to purchase irradiated poultry products. Nayga *et al.* (2005), in an experimental auction study on irradiated ground beef, provided respondents with favourable information about food irradiation (nature and benefits), as well as two types of food irradiation processes: gamma rays; and electron beam. Their results generally suggest that consumers' willingness to purchase irradiated ground beef increased after the two sets of information were provided, this effect was especially large for habitual buyers.

Further studies documented that consumers' willingness to purchase irradiated food products varies when they are faced with balanced information. Hayes *et al.* (2002) and Fox *et al.* (2002), using experimental auctions in the United States, found that consumers' purchasing behaviour varies across favourable, unfavourable, and both favourable and unfavourable information<sup>3</sup>. To illustrate, Hayes *et al.* (2002) found that participants who received negative information decreased their bids for irradiated pork, with about

<sup>2</sup> The 2011 accident at a Japanese nuclear power plant exerted an influence on the awareness of consumers about the differences between irradiated and radiation-contaminated food (Seo 2012).

<sup>3</sup> The favourable information used by the authors emphasised the safety and benefits of the food irradiation process, while the unfavourable information stressed the potential risks.



90% of them bidding zero at the end of the experiment. Conversely, participants facing favourable information increased their bids from \$0.25 up to \$0.55. Furthermore, while presenting participants with both unfavourable and favourable information, consumers had a significant reduction in their bids for the irradiated pork, with the median bid falling to zero. Similar results are also reported in Fox *et al.* (2002), who documented that in the treatment with both favourable and unfavourable information, negative information about food irradiation dominated positive information, with about 62% of participants bidding zero for pork treated by irradiation at the end of the experiment. Using the data of Hayes *et al.* (2002), Fox *et al.* (2002), and Rousu and Shogren (2006) assessed the value of pro-irradiation and anti-irradiation on food irradiation. Their findings indicate that 17% of participants switched from non-irradiated pork sandwich to irradiated pork sandwich after facing pro-irradiation information, with a value gain of \$0.65 per sandwich (value of the pro-irradiation information). On the contrary, only 5% of participants would purchase an irradiated pork sandwich after facing anti-irradiation information. Finally, about 20% of consumers who received both pro- and anti-irradiation information switched their purchase from the irradiated to the non-irradiated pork sandwich. This could be explained by consumers' tendency to give more weight to negative information than to positive ones (Levin *et al.* 1998; Rozin and Royzman 2001; Fox *et al.* 2002).

What we do know about the effects of information about food irradiation on consumer acceptance of irradiated food is largely based upon empirical studies conducted in the United States. In addition, in past studies, respondents were faced with information about food irradiation technology and its relative risk and benefits. However, as discussed earlier, consumers are unfamiliar with the main causes, incidence and prevention of foodborne diseases (Eustice and Bruhn 2013). Hence, they may fail to associate the use of food irradiation technology as a tool to prevent foodborne diseases. One method is exposing consumers to the relative risks and benefits of the food technologies. However, one drawback to this method comes from the uninformed consumer. Consumers who are not aware or knowledgeable about how the food technology works and what the technology intends to do may have perverse reactions to the new technology. This study extends the current literature on this research area by also exploring the effects of food safety-based information delivered by a video clip on consumer willingness to purchase beef. The food safety-related information was delivered to consumers using a video clip format because its effects are comparable to media coverage effects. A previous study suggests that the media coverage of biotechnology can shape public awareness, influence public perceptions and alter the public agenda on biotech foods in Europe and elsewhere (see Kalaitzandonakes *et al.* 2004 for a review).

### 3. Experimental procedures

#### 3.1 Product, attributes and attribute level selection

To assess consumer valuation for irradiated beef, this study uses a discrete choice experiment (DCE) approach. Since meat irradiation is still not allowed in South Korea<sup>4</sup>, we had to use a hypothetical DCE.

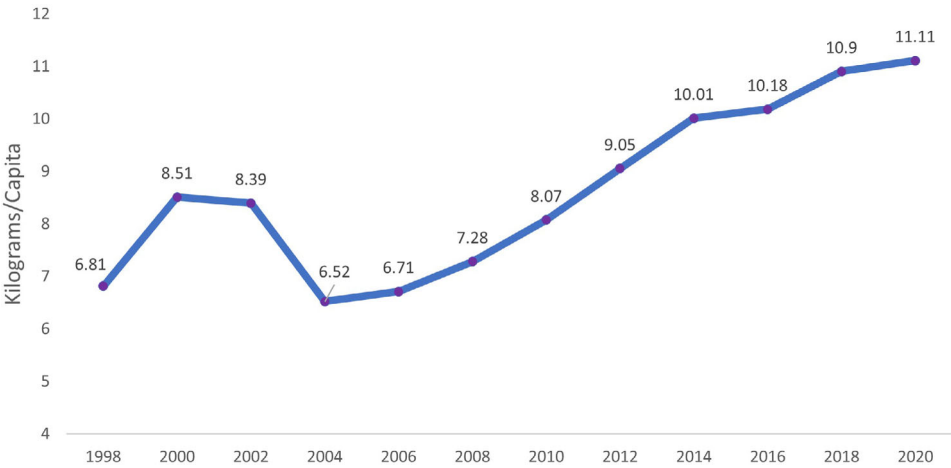
In addition to being one of the main causes of foodborne diseases, beef was selected as the product of analysis because Korean consumers have a strong preference for beef in general. This preference is reflected in the rise of beef consumption in the last years due to the development of the restaurant industry, the increased contracted meat food service and the Korean consumers' westernised diet. Figure 2 depicts the beef consumption per capita from 1998 to 2020 in South Korea. As can be seen, Korean per capita beef consumption has been steadily rising since 1998 (Ministry of Agriculture, Food and Rural Affairs 2015). There was only a drop of 8% in 2005 compared to the previous and the following years because of the mad cow disease that stemmed from US and Canada imports (Lee and Cho 2012).

In order to evaluate the importance ascribed to food safety and food irradiation in comparison with other beef quality features, the DCE was designed to incorporate multiple attributes and attribute levels that consumers typically encounter in actual food markets (see Table 1).

Price, country of origin and whether the beef is irradiated or not were selected. A number of Korean studies on consumer choices for beef found that consumers consider the price, country of origin and food safety attributes as the most important factors affecting their final purchase decisions (Lee *et al.* 2011; Cho *et al.* 2011; Chung *et al.* 2012). For instance, Cho *et al.* (2011) reported that the most important attributes for Korean consumers when selecting beef products are the price (20.2%), meat cuts (19.4%), country of origin (17.3%) and safety (15.9%). These attributes are then described by different levels. Four price levels were selected to mirror the actual market prices for 100 g of beef (1,900 won, 3,900 won, 5,900 won and 7,900 won). Irradiated and non-irradiated were selected as the attribute levels, where the Radura logo was used to describe the irradiated beef product profiles. Finally, three levels were considered for the country of origin attribute: domestic (from Korea), imported beef from the United States and imported beef from Australia<sup>5</sup>. As shown in Figure 3, the volume of beef imports into Korea has increased significantly in the last several years, with

<sup>4</sup> To date, meat products (e.g. beef, pork and poultry) are not allowed to be irradiated in South Korea. However, the MFDS attempted to revise the food irradiation laws and regulations, with particular attention on meat-based products. In 2004 and 2006, for instance, the MFDS attempted to extend the food irradiation allowances on red meat and other meat products as a method to prevent foodborne illness, especially at schools. However, these efforts were shelved because of opposition from various consumer groups.

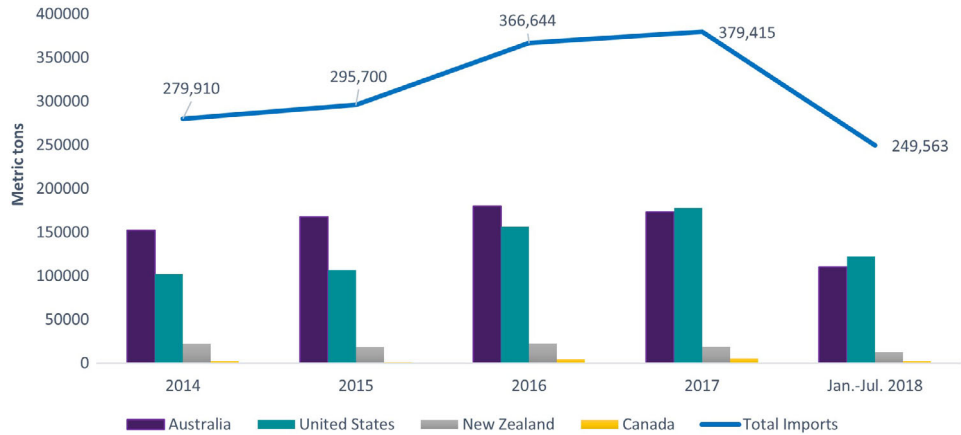
<sup>5</sup> The volume of domestic beef production (around 310,000 tonnes cwe in 2017) is much smaller than the total imports reported (OECD 2017) (see Figure 1).



**Figure 2** Meat consumption: beef and veal, Kilograms/capita, 1998–2020(OECD 2020). [Colour figure can be viewed at [wileyonlinelibrary.com](#)]

**Table 1** Attributes and attribute levels

Product: Beef (100 g)	
Attributes	Attribute levels
Country of origin	United States, Australia, Korea
Price	1,900 won, 3,900 won, 5,900 won, 7,900 won
Radura logo	Present/Absent



**Figure 3** Volume of Beef Imports, Source: Gain Report 2018, Gain Report, 2016. Note: Product equivalent basis: Includes HS 0201 (fresh/chilled), HS 0202 (frozen), HS 021020 and 160250 (processed beef products). [Colour figure can be viewed at [wileyonlinelibrary.com](#)]



**Figure 4** Example of a choice question/choice task. [Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

the United States being the main importer of beef into Korea followed by Australia, who used to be the top importer after the BSE crisis in 2003 until 2017 (Chung 2018).

### 3.2 Experimental Design

The CE questions were designed following the approach introduced by Street and Burgess (2007). Two steps were undertaken. In the first step, we used the selected attributes and attribute levels described earlier to perform an orthogonal fractional factorial design, which resulted in 16 choice tasks only including the first alternative. In the second step, we generated the second alternative from the 16 alternatives obtained in the orthogonal design by using the generator (1, 1, 1). The 16 pairs were then randomly divided into two blocks to reduce fatigue effects. During the experiments, respondents were asked to respond to 8 choice questions, each represented by two product profiles and a no-purchase option (see Figure 4). Given the hypothetical nature of the experiments, the choice questions were framed using the inferred valuation approach suggested by Lusk and Norwood (2009).

The design employed in this study is defined as a D-optimal design since it assumes that all parameter priors are simultaneously equal to zero (e.g. null parameter prior hypothesis). Alternative approaches to generating experimental stated choice experimental designs exist, which involve selecting a design under the assumption that the parameter priors are non-zero (e.g. the non-null parameter prior hypothesis). These designs are known in the literature as efficient designs and can be generated using two different approaches. The first approach assumes that the parameter priors are non-zero and known with exact certainty by the researchers (e.g. Carlsson and Martinsson 2003; Scarpa and Rose 2008; Rose and Bliemer 2009). However, designs are efficient under the assumption of true parameter values. Hence, wrongly specified priors typically lead to a loss in efficiency. The second

approach relaxes the assumption of perfect a priori knowledge of the parameter priors and assumes prior parameters are estimated in a Bayesian-like fashion, where prior parameter distributions that might contain the true population parameter values are considered (Scarpa *et al.* 2007a). Findings from previous studies have shown that Bayesian efficient designs are able to produce greater precision in parameter estimates (smaller standard errors) with smaller sample sizes (Scarpa *et al.* 2007a; Scarpa and Rose 2008a). However, evidence from recent studies indicates that wrongly specified priors lead to a loss in efficiency even in Bayesian designs (Walker *et al.* 2018).

In the light of this, a D-optimal experimental design was used as the coefficient of the Radura logo is expected to vary in terms of both magnitude and signs across the CE treatments. Hence, neither of the two efficient designs would have been appropriated for this study. However, we evaluated the relative efficiency of our experimental design *ex post*, as described in Scarpa and Rose (2008). More specifically, following the authors, we compared the *ex post* statistics (e.g. D-error, A-error, B-estimate and S-estimate) of the used design (D-optimal) with the *ex ante* statistics of two efficient designs (certain priors and Bayesian priors) that we generated using the same number of attributes, attribute levels, alternatives, choice sets and blocks used in our design. Bliemer and Rose (2010) show that D-efficient MNL-based designs also perform well for mixed logit models despite the difference in the asymptotic variance–covariance estimator. Hence, the postdesign evaluation was conducted assuming a multinomial logit probability specification. The results that are reported in Table S1 (available as supplementary data at AJARE online) indicate that the efficient design appears to perform better in terms of D-error than the D-optimal design used in this study. However, the S-estimates for the designs that were used across treatments suggest that with less than 30 replicates of the design (i.e. with 22, 15, 54 and 33 respondents in the *Control*, *Video*, *VideoP* and *VideoN* treatments, since it took two respondents to complete one design), all coefficients would be significantly different from zero, except for the *VideoPN* treatment. Hence, the sample sizes compensate the lower efficiency in terms of D-error. The treatments used in this study are described in the following section.

### 3.3 Treatments and research hypotheses

To assess consumer acceptance of food irradiation under different information settings, we constructed a choice experiment study composed of five treatments. A between-sample approach was adopted, and respondents were randomly assigned to only one of the five treatments. As illustrated in Table 2, the five treatments are labelled as follows: *Control*, *Video*, *VideoP*, *VideoN* and *VideoPN*.

In the *Control*, respondents were just faced with the CE questions. In the *Video* treatment, before the CE questions respondents were provided with a video clip that we developed specifically for this study. The video clip shows,

**Table 2** Layout of the CE treatments

	Control	Video	VideoP	VideoN	VideoPN
Video clip – food safety-related issues		✓	✓	✓	✓
Basic information			✓	✓	✓
Positive information			✓		
Negative information				✓	
Positive and negative information					✓
Choice experiment questions	✓	✓	✓	✓	✓

first, the main causes and type of foodborne diseases and their symptoms. The video then displays some statistics about foodborne diseases in South Korea. Lastly, it informs consumers as to how they can prevent foodborne diseases and what the South Korean government does to prevent them (click here to watch the video clip<sup>6</sup>). In alignment with previous consumer studies on food irradiation, after the video clip respondents were exposed to a statement reporting different information on food irradiation. To illustrate, in the *VideoP* treatment, before the CE questions respondents were provided with the video clip, and then with positive information about food irradiation via a statement. In the ‘*VideoN*’ treatment, before the CE questions respondents were provided with the video clip and then with negative information about food irradiation via a statement. Finally, in the ‘*VideoPN*’ treatment, before the CE questions respondents were provided with the video clip and then with positive and negative information about food irradiation via a statement. The order of positive and negative information was randomised during the experiment. General information about the irradiation technology was also provided in all *VideoP*, *VideoN* and *VideoPN* treatments. Box 1–3 (available as supplementary data at AJARE online) report the set of information used in this study.

Using the data from these treatments, a set of hypotheses were built and tested to inform our research objectives. The first hypothesis pertains to how consumer values the new labelling system on food irradiation in South Korea. To this end, a marginal WTP value for the Radura logo will be estimated using data from the control treatment as it reflects how consumers would evaluate beef bearing the new Radura logo in an actual purchasing setting where no additional information is provided to consumers. It is expected that consumers evaluate the new Radura logo negatively, as the new additional information reported on the label may not be enough to bridge the consumer knowledge gap about how the food irradiation technology works (H1). The second hypothesis relates to the effects of information on food safety-related issues on consumer acceptance of food irradiation. It is expected that

<sup>6</sup> <https://www.dropbox.com/s/jsmh0hylk3735ql/Appendix%20E%20%22%80%93%20Priming%20effect%20%22%80%93%20movie%28English%29.mp4?dl=0>

consumers are unable to associate the use of food irradiation technology as a tool to reduce the incidence of foodborne diseases by just looking at the Radura logo. Hence, it can be anticipated that when no information about food irradiation is provided to consumers, the effect of information about food safety-related issues on consumer acceptance for food irradiation is null (H2). Therefore, no difference in consumer WTP for the Radura logo is expected between the *Control* and *Video* treatments.

The last set of hypotheses explores the effects of information on food safety-related issues on consumer acceptance of irradiated beef when they are accompanied by information on food irradiation. Findings from previous studies that provided consumers with only testing the effects of information about food irradiation on consumer acceptance of food irradiation (Fox *et al.* 2002) indicate that: (i) positive information increases WTP for irradiated food; (ii) negative information decreases WTP for irradiated food; and (iii) negative information dominates positive information and decreases WTP for irradiated food (Fox *et al.* 2002). Building on this, three additional research hypotheses are formulated in this study, all based on the effects of different types of information on consumer marginal WTP for irradiated beef when they are accompanied by information on food safety-related issues. First, consistent with previous studies it is hypothesised that providing consumers with information on food safety-related issues and positive information about food irradiation increases the consumers' WTP for irradiated beef (H3). To test this hypothesis, the marginal WTP for the Radura logo from the *Video* (only video) treatment was compared with the one from the *VideoP* (video plus positive information). Second, it is postulated that although consumer WTP for irradiated beef remains negative when consumers are provided with negative information about food irradiation, the provision of food safety information mitigates such effects as consumers may link the use of food irradiation to food safety concerns (H4). Hence, no difference in marginal WTP for the Radura logo is expected between the *Video* (only video on food safety issues) and the *VideoN* (only video on food safety issues plus negative information on food irradiation) treatments. Similarly, unlike findings from previous studies indicating that negative information about food irradiation dominates positive information, a reverse effect is expected in this study due to the provision of information regarding food safety-related issues (H5). Accordingly, an increase in marginal WTP for the Radura logo is expected between the *Video* (only video on food safety issues) and the *VideoPN* (video on food safety issues plus positive and negative information on food irradiation) treatments.

Information on irradiation technology and food safety-related issues can also influence how consumers value domestic beef vis-à-vis with imported beef. Previous research indicates that country of origin is perceived by consumers as a quality cue as it can embed other quality features (Gao and Schroeder 2009; Caputo *et al.* 2017). For example, Asian consumers may prefer domestic beef as they perceive it safer than imported beef, especially

the beef imported from the United States due to the BSE disease outbreak. Ortega *et al.* (2017) found that Chinese consumers prefer domestic pork to pork imported from the United States unless the pork is marketed food safety claims. Thus, it is conjectured that when food safety-related information is provided to the Asian consumers, that their marginal WTP for imported US beef goes up. This can be because consumers' trust for the US food system increases due to the effects of food safety information.

#### 4. Econometric analysis

To test the research hypotheses, the data from each treatment were analysed using a mixed logit model with error component (MXL-EC) for panel data (see Scarpa *et al.* 2005; Scarpa *et al.* 2007b; Train 2009). The MXL-EC captures potential heterogeneity in taste intensities, which is a pattern commonly observed in food choice studies, by allowing the coefficients in the model to vary across decision-makers. It also accounts for correlation across utilities due to the extra variance shared by the experimentally designed attributes as compared to the opt-out option (Scarpa *et al.* 2005; Scarpa *et al.* 2007b). The utilities were specified in WTP space (see Train and Weeks 2005; Scarpa *et al.* 2008) rather than in preference space to allow for heterogeneity in the cost coefficient and to impose a finite variance in the distribution of marginal WTP values (Scarpa *et al.* 2008; Daly *et al.* 2012). Using this theoretical approach, two empirical strategies were followed. The first empirical strategy relates to the use of data from each treatment (segmented data) and the specification of the following indirect utility function per treatment:

$$U_{njt} = \theta_n [ASC - PRICE_{jt} + \omega_{1n} KOREA_{jt} + \omega_{2n} US_{jt} + \omega_{3n} RADURA_{jt} + 1_j(\eta_{nt})] + \varepsilon_{njt} \quad (1)$$

where  $U_{njt}$  is the utility that individual  $n$  obtains from alternative  $j$  at choice situation  $t$ ;  $\theta$  is the price scale parameter equal to  $\alpha/\lambda$ , where  $\alpha$  is the price coefficient, and  $\lambda$  is the Gumbel scale parameter (see Scarpa *et al.* 2008 for details); ASC is the alternative specific constant of the no-purchase alternative; PRICE is the price for 100 g of beef; KOREA and US are variables indicating the country of origin of the beef: from Korea and the United States, respectively. RADURA is a variable indicating the presence or absence of the Radura logo, and thus, it indicates whether beef is irradiated or not;  $\omega_{kn}$  is the coefficient of the estimated WTP values and represents the effect of one unit increase in total WTP;  $1_j(\cdot)$  is an indicator function that takes the value of 1 for experimentally designed food profiles, while  $\eta_{nt}$  is the respondent-specific idiosyncratic error component associated only with the two experimentally designed product profiles. Finally,  $\varepsilon_{njt}$  is the distributed extreme value type I error term. The variable PRICE entered in the models as a continuous variable, while the KOREA, US and RADURA variables are included in the



model as dummy coded variables. Hence, they take the value of 1 if the beef comes from Korea and the United States, and is irradiated, and take on zero otherwise. Beef from Australia and not irradiated are the baselines. The coefficients of the price are distributed log normal. The elements of  $\omega_n$  (marginal WTP values) associated with the KOREA, US and RADURA attributes are normal. The ASC is assumed invariant in the population due to model specifications with all random coefficients can be empirically unidentifiable (Ruud 1996). Further, Burton (2019) indicates that mixed logit models require full correlation to ensure invariance of estimates. Thus, all models were estimated using full correlated random parameters. For each treatment, the correlation coefficient matrix was derived from the Cholesky matrix (the Cholesky matrix and correlation matrix are available upon request). A total of five models were specified, one for each treatment or segmented sample.

Because of the use of various treatments and thus consumer samples, the second empirical strategy relies on the use of a pooled sample approach to explore WTP-based hypotheses. First, a joint model was estimated to test the null hypothesis of joint equality of marginal WTP values using a log-likelihood (LR) test. The joint model restricts the beef marginal WTP values for all attributes (Radura, Korea and US) to be equal across all treatments<sup>7</sup> (*Control*, *Video*, *VideoP*, *VideoN* and *VideoPN*). As shown in Louviere, Hensher, and Swait (2000), the test is based on the log-likelihood values of the segmented and joint models; it is calculated as  $-2 * [L_{Pooled} - (L_{Control} + L_{Video} + L_{VideoP} + L_{VideoN} + L_{VideoPN})]$ , which is chi-square-distributed with degree of freedom equal to  $K(M - 1)$ , where  $K$  is the number of restrictions and  $M$  the number of treatments. A rejection of the null hypothesis of equality across the likelihood values of joint and segmented models suggests that that information on food irradiation and food safety-related issues significantly affected the parameter estimates (marginal WTPs) and thus indicates the need to explore the significance of attribute-specific effects across treatments.

Models with WTP-space specifications offer a natural and intuitive way to test whether differences in WTPs for specific attributes are statistically significant across treatments (Caputo *et al.* 2017), as they estimate directly marginal WTP values (Scarpa *et al.* 2008; Scarpa and Willis 2010). For example, WTP-based hypotheses can be accommodated using a pooled data approach and extended utility functions with treatment interaction terms

<sup>7</sup> Differences in consumer valuation for the Radura logo can be because of differences in marginal WTPs, differences in the scale factors or both. In this application, for example, the scale factor can be higher in the information treatments relative to the *Control* group because the information on food irradiation and food safety-related issues might make the product profiles easier to evaluate. To investigate this issue, I also estimated a joint model that in addition to restricting the beef marginal WTP values for all attributes to be equal across treatment also allowed for estimation of the relative scale parameters for *Video*, *VideoP*, *VideoN* and *VideoNP* treatments. Results from this model indicate that the scale factors (choice determinism) do vary across information treatments. Therefore, the joint model was estimated without accounting for difference in scales.

between the attributes of interest and the treatments under evaluation (De Magistris *et al.*, 2013; Bazzani *et al.* 2016; Matthews *et al.* 2017; Gilmour *et al.* 2019). As discussed in Matthews *et al.* (2017), different pooled models can be specified depending on the assumptions underlying the scale factor<sup>8</sup> and the expected shifts in WTP across treatments. In this application, we expect the marginal WTP for irradiated beef to be the same in the *Control* and *Video* treatments (H2), higher in the *VideoP* and *VideoN* treatments as compared to the *Video* treatment (H3 and H5), and lower in the *VideoN* treatment as compared to the *Video* treatment (H4). Therefore, based on these research hypotheses, the data sets from all treatment were pooled and the indirect utility function was specified as follows:

$$\begin{aligned}
 U_{njt} = & \theta_n[ASC - PRICE_{jt} + \omega_{1n}KOREA_{jt} + \omega_{2n}US_{jt} + \omega_{3n}RADURA_{jt} \\
 & + \delta_{KO}(KOREA_{jt} * dTreat) + \delta_{US}(USA * dTreat) \\
 & + \delta_{RA}(RADURA_{jt} * dTreat) + 1_j(\eta_{nt})] + \varepsilon_{njt}
 \end{aligned}
 \tag{2}$$

where *dTreat* is a binary variable identifying the treatments of interest, while the significance of the estimated  $\delta$  and their signs establish the effect of the treatment on the marginal WTP estimate of the beef attributes. The *Video* treatment was used as baseline for identification purpose. The rest of the elements in (2) are specified as in (1). As can be noted, in addition to the effects of information on food irradiation, Equation (2) also explores differences in marginal WTP values for Korea and US attributes as food safety and food irradiation information can also influence the way consumers perceive domestic versus imported beef. All models were estimated in R, using the 'gmn1' package developed by Sarrias and Daziano (2017).

Finally, the estimated coefficients from models in WTPs were used to derive 'individual-specific' WTPs (see Train 2009). These 'individual-specific' marginal WTPs were then used to estimate an ordinary least square regression to determine how marginal WTPs for the Radura logo vary with demographic and attitudinal characteristics within each treatment.

## 5. Data

We conducted an online DCE survey in South Korea and outsourced it to a research service agency, Qualtrics. Respondents were invited via email. They were excluded a priori if they did not buy beef within the past three months preceding the survey, and if they were younger than 18 years old. A total of

<sup>8</sup> As for the joint model, I estimated a pooled model with both the interaction terms between the attributes of interest and the treatments, and the scale parameters for *Control*, *VideoP*, *VideoN*, and *VideoNP* treatments. The results indicate that the scale factors do not vary across information treatments. Therefore, the pooled model was estimated without accounting for difference in scales.

803 respondents participated in the study, with about 100 respondents participating in each treatment. The respondents' socio-demographic and beef consumption characteristics are reported in Table 3.

In all treatments, the majority of respondents were female and more than 60% of them have graduated from college. In addition, most of respondents were also aged between 35 and 39 and earn between 30,000,000 and 59,999,000 won annually. Further, near 56% of consumers purchase beef in agricultural and livestock cooperatives markets and supermarkets, purchase beef once a week or every two weeks, and consume more than 100 g per meal occasion. For each of the demographics and purchasing habits, the results from the chi-square tests or ANOVA confirm that there are not statistically significant differences across treatments.

Table 4 reports summary statistics related to consumer concerns about new food technologies and consumer knowledge and attitudes towards food irradiation. Regarding consumer concerns about the use of new food technologies, following Teisl *et al.* (2003), participants were asked to indicate their level of concern (a scale from 1 to 5 was used, where 1 is not concerned at all and 5 is very concerned) for eight different food production and processing techniques, whereas, to ascertain consumers' subjective level of knowledge, the consumers were asked whether they heard about food irradiation or whether they have seen the Radura logo. The consumers were also asked how knowledgeable they were about food irradiation using a scale from 1 to 4, where 1 is very unknowledgeable and 4 is very knowledgeable. Further, respondents were provided with a list of five potential benefits of using food irradiation and asked them to indicate their level of agreement using a 5-point scale (where 1 indicates totally disagree at all and 5 indicates totally agree).

The results indicate that the use of genetically modified ingredients (GMO) and food irradiation is the two main consumer concerns, while the use of artificial flavours and pasteurisation is the lowest consumer concerns. Only about 21 per cent of the respondents had heard of food irradiation before receiving the survey. Only 1.18 per cent of consumers claimed they were very knowledgeable about the Radura logo, 6.71 per cent indicated they were somewhat knowledgeable, and about 43.59 and 48.58 per cent claimed they were somewhat unknowledgeable and very unknowledgeable about the meaning of the Radura logo. As for the potential benefits of using food irradiation, reduced foodborne diseases and increased shelf life were the most important to consumers. On the other hand, increased nutritional values and increased taste were the less important benefits.

## 6. Results from the econometric analysis

Table 5 presents the likelihood values for segmented and the joint models, along with the LR tests statistic. The joint model restricts the marginal WTPs for all beef attributes to be equal across treatments. Results from the LR test indicate that null is rejected at the  $P < 0.001$  level (chi-square = 124.9),

**Table 3** Socio-demographics and beef consumption characteristics of the sample

	Pooled	Control	Video	VideoP	VideoN	VideoNP
No. of respondents	507	104	101	100	100	102
Demographics						
Gender (mean)						
Female	0.53	0.56	0.52	0.54	0.51	0.53
	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)
<i>P</i> -value*				0.9620		
Age (mean)						
	37.62	39.10	37.84	37.09	38.39	35.68
	(12.35)	(11.93)	(11.81)	(13.01)	(13.12)	(11.82)
<i>P</i> -value				0.3314		
Education (%)						
High school or lower	22.09	24.04	21.78	22.00	21.00	21.57
Graduated from college	66.86	66.35	66.34	69.00	63.00	69.61
Masters, PhD, etc.	11.05	9.62	11.88	9.00	16.00	8.82
<i>P</i> -value				0.859		
Income (% won)						
<29,999,000 won	20.71	18.27	11.88	26	25	22.55
30,000,000–59,999,000	43.00	47.12	50.50	34	38	45.10
60,000,000–89,999,000	24.85	26.92	24.74	26	23	23.53
>90,000,000	11.44	7.69	12.87	14	14	8.82
<i>P</i> -value				0.272		
Beef purchasing characteristics (%)						
Beef purchase location						
Department store	1.18	0.96	1.98	0.00	1.00	1.96
Burcher	14.00	11.54	14.85	10.00	15.00	18.63
Discount market	6.90	5.77	5.94	7.00	8.00	7.84
Agricultural and livestock cooperatives markets	36.29	35.58	36.65	39.00	37.00	32.29
Supermarket	19.72	24.04	17.82	21.00	18.00	17.65
Online	4.73	4.81	6.93	2.00	6.00	3.92
Others	17.16	17.31	17.82	21.00	15.00	14.71
<i>P</i> -value				0.969		
Beef purchase frequency (%)						
Once a week	24.65	24.04	32.67	18.00	24.00	24.51
Once every two weeks	27.22	30.77	21.78	24.00	30.00	29.41
Once every three weeks	12.23	10.58	13.86	15.00	12.00	9.80
Once a month	22.88	25.00	16.83	28.00	22.00	22.55
Once every two months	9.66	8.65	10.89	11.00	9.00	8.82
Other	3.35	0.96	3.96	4.00	3.00	4.90
<i>P</i> -value				0.787		
Beef amount per meal occasion (grams) (%)						
<100 g	3.94	3.85	6.93	2.00	4.00	2.94
Between 100 g and 150 g	20.23	21.15	25.74	17.00	16.00	21.57
Between 151 g and 200 g	23.27	23.08	18.81	27.00	27.00	20.59
Between 201 g and 250 g	14.99	17.31	14.58	15.00	16.00	11.76
More than 250 g	37.48	34.62	33.66	39.00	37.00	43.14
<i>P</i> -value				0.769		

\**P*-values from F-tests/chi-square tests testing the null hypothesis of equality of means/frequencies between demographics and beef purchasing characteristics across treatments.

suggesting that marginal WTP estimates differ across treatments (the results of the joint model are available as supplementary data at AJARE online; Table S2).

**Table 4** Consumer concerns about new food technologies, knowledge and attitudes towards food irradiation

Treatment	Pooled	Control	Video	VideoP	VideoN	VideoNP	P-value*
No. of respondents	507	104	101	100	100	102	
Concerns about new food technologies (means)							
Use of antibiotics	4.22 (0.80)	4.20 (0.83)	4.22 (0.77)	4.17 (0.84)	4.30 (0.80)	4.20 (0.76)	0.8214
Use of pesticides	4.17 (0.84)	4.18 (0.88)	4.16 (0.88)	4.15 (0.81)	4.24 (0.78)	4.12 (0.86)	0.8808
Use of growth hormone	4.18 (0.87)	4.19 (0.87)	4.27 (0.80)	4.18 (0.88)	4.17 (0.87)	4.09 (0.93)	0.7027
Use of GMO ingredients	4.30 (0.83)	4.31 (0.81)	4.22 (0.89)	4.33 (0.80)	4.41 (0.79)	4.23 (0.85)	0.4509
Use of food irradiation	4.23 (0.86)	4.17 (0.91)	4.21 (0.89)	4.31 (0.83)	4.24 (0.87)	4.25 (0.80)	0.8402
Use of artificial flavours/colours	3.70 (0.94)	3.62 (0.91)	3.71 (0.92)	3.64 (1.09)	3.85 (0.90)	3.70 (0.90)	0.4655
Use of pasteurisation	3.15 (0.96)	3.18 (0.89)	3.23 (0.97)	3.07 (1.01)	3.16 (1.01)	3.12 (0.92)	0.8078
Use of preservatives	4.11 (0.85)	4.08 (0.88)	4.15 (0.82)	4.03 (0.93)	4.20 (0.77)	4.12 (0.85)	0.6676
Knowledge (%)							
Heard/food irradiation							
Yes	20.71	14.42	24.75	23.00	26.00	15.69	
No	56.21	66.35	52.48	53.00	52.00	56.86	
I don't know	23.08	19.23	22.77	24.00	22.00	27.45	
P-value				0.273			
Seen/Radura logo (%)							
Yes	81.07	82.69	81.19	79.00	17.00	20.59	
No	18.93	17.31	18.81	21.00	83.00	79.41	
P-value				0.927			
Subjective knowledge/Radura logo (%)							
Very unknownledgeable	48.52	48.08	53.47	46.00	44.00	50.98	
Somewhat unknownledgeable	43.59	47.12	36.63	47.00	47.00	40.20	
Somewhat knowledgeable	6.71	3.85	8.91	7.00	7.00	6.86	
Very knowledgeable	1.18	0.96	0.99	0.00	2.00	1.96	
P-value				0.8020			
Perceptions/Benefits (mean)							
Increased safety	2.93 (1.05)	2.98 (0.93)	2.81 (1.04)	2.81 (1.12)	2.95 (1.16)	3.06 (1.01)	0.3312
Reduced foodborne diseases	3.27 (0.99)	3.28 (0.99)	3.24 (0.95)	3.17 (1.03)	3.29 (1.02)	3.36 (0.96)	0.7223
Increased nutritional values	2.67 (0.96)	2.76 (0.86)	2.65 (0.95)	2.67 (1.02)	2.61 (1.05)	2.68 (0.90)	0.8575
Increased shelf life	3.16 (0.92)	3.05 (0.84)	3.20 (0.87)	3.17 (0.93)	3.21 (0.98)	3.16 (0.96)	0.7323
Increased taste	2.67 (0.87)	2.59 (0.80)	2.68 (0.88)	2.67 (0.78)	2.69 (0.95)	2.73 (0.94)	0.163

\* P-values from F-tests/chi-square tests testing the null hypothesis of equality of means/frequencies between demographics/beef purchasing characteristics across treatments.

Table 6 reports the WTP-space estimates for the segmented models (first five columns) and pooled model (last column).

Looking at the results of the segmented models, it can be noted that the ASC coefficients are all negative and statistically significant suggesting that respondents preferred one of the experimental product profiles to the no-purchase option. Also, in all treatments the standard deviations of the error component associated with the two product profiles are statistically significant, indicating that utility variance is larger for purchase than for no-purchase alternatives. In addition, consistently across treatments, the estimates of population means for the marginal WTP coefficients of the Korea attribute (domestic beef) are found positive and statistically significant at the 1% level (range 2,981–4,963 won), while the ones of the US attribute are found negative and statistically significant at the 1% level (range –6,792 ~ –2,658 won). This suggests that respondents are willing to pay a price premium for domestic and Australian beef as compared to American beef. A higher consumer price premium for Australian beef products over the United States has been reported in previous consumer studies conducted in other Asian countries such as China (Ortega *et al.* 2016).

Further, as expected, the population mean values of the marginal WTP estimates for the Radura logo vary across treatments in terms of sign, magnitude and significance. To illustrate, the coefficient of the Radura logo is found to be: (i) negative and statistically significant in the *Control* (–2,867 won), *Video* (–2,739 won) and *VideoN* (–3,373 won) treatments; (ii) positive and statistically significant in the *VideoP* treatment (868 won); and (iii) negative but not statistically significant in the *VideoPN* treatment (–375 won). Looking at the results more closely, two striking observations emerge: first, the marginal WTP estimates for the Radura logo in the *Control* are negative and statistically significant. This confirms the first research hypothesis; namely, consumers marginal WTP for the new labelling system is negative, suggesting that adding new statements about the food irradiation process is not enough to bridging the consumer knowledge gap about how the food irradiation technology works (H1). Second, the share of consumers with positive WTP<sup>9</sup> for irradiated beef varies across treatments as indicated by the magnitude of the population mean and standard deviation coefficients of the Radura logo. To illustrate, the share of the population with positive WTP is 32% and 38% in the *Control*<sup>10</sup> and

<sup>9</sup> The MXL-EC model provides distributional information that can be used to predict the fraction of consumers with positive and negative preferences or WTP values, depending on whether models are specified in preference space or WTP space. For computation details, see Train 2009.

<sup>10</sup> Although in the *Control* treatment 32% on consumers exhibit positive WTP for beef bearing the Radura logo, there is no evidence of a strong opportunity for the introduction of irradiation of beef. Indeed, the sign and magnitude of the population mean WTP for irradiated beef suggest that the share of consumers with positive preferences would not be willing to pay enough to cover additional adoption costs. Yet, consumer WTP for irradiated beef remains negative in all other treatments unless positive information on food irradiation technology and on food safety-related issues is provided to consumers.

**Table 5** Log-likelihood ratio test

Treatments	<i>N</i>	Log likelihood
Control	832	−528
Video	808	−544
VideoP	800	−550
VideoN	800	−577
VideoPN	816	−562
All treatments	4,056	−2,822
Hypothesis test of equality		
LR test statistic		124.9
Degree of freedom		64
<i>P</i> -value		<0.001

*Video* treatments, respectively. The percentages go up to 55% and 46% in the *VideoP* and *VideoPN* treatments, respectively, and it goes down to 32% in the *VideoN* treatment. Taken together, these results indicate that providing positive information about food irradiation alongside with information on food safety-related issues increases the proportion of consumers with a positive marginal WTP for the Radura logo. This evidence is also confirmed in the *VideoPN*, indicating that positive information tends to dominate negative information when consumers are informed on food safety-related issues and food irradiation.

The last column of Table 6 reports the results of the pooled model. The pooled model was estimated to determine whether the differences in marginal WTP for the Radura logo across treatments are statistically significant and thus explore the remaining research hypotheses. Practically, the data from all treatments (*Control*, *Video*, *VideoP*, *VideoN* and *VideoPN*) were pooled and the treatment effects estimated through interaction variables for *Control*, *VideoP*, *VideoN* and *VideoPN* treatments with Radura logo. Treatment effects on the other attributes (Korea and United States) were also estimated as food safety information can also influence the way consumers perceive domestic versus imported beef. The *Video* treatment is the baseline.

Looking at coefficient estimates for the interaction *Control*, it can be noted that the second hypothesis is confirmed, as demonstrated by the insignificance of the estimated coefficient of the interaction term between the *Control* treatment and the Radura logo (H2). This implies that when no information about food irradiation is provided to consumers, the effect of information about food safety-related issues on consumer acceptance for food irradiation is null. This might be because consumers fail to associate the use of food irradiation technology as a tool to reduce the incidence of foodborne diseases, an evidence that corroborates earlier findings (Eustice and Bruhn 2013).

Turning now to the third hypothesis, the significance and the positive sign of the estimated coefficient of the interaction terms between the *VideoP* treatment and the Radura logo (2,633 won) indicate that providing consumers with positive information about food irradiation and information

Table 6 Results from the MXL-EC model in WTP space, segmented and pooled sample

	Segmented models				Pooled model with interactions	
	Control	Video	VideoP	VideoN	VideoPN	
WTP parameters						
Radura						
Mean	-2,867*(398)	-2,739* (510)	868** (360)	-3,373* (515)	-375 (264)	-2,118* (319)
St. dev.	3,139* (608)	9,076* (1027)	6,361* (715)	7,113* (842)	3,958* (406)	6,126* (324)
Korea						
Mean	3,012* (384)	4,963* (603)	3,640* (457)	2,981* (449)	4,050* (393)	3,990* (422)
St. dev.	5,341* (637)	4,079* (618)	3,030* (759)	3,381* (680)	3,973* (526)	2,687* (267)
United States						
Mean	-3,424* (462)	-6,792* (805)	-2,658* (501)	-4,137* (654)	-3,005* (442)	-4,688* (426)
St. dev.	3,825* (524)	5,175* (760)	4,094* (719)	5,456* (893)	3,375* (559)	3,932* (319)
Price scale parameter						
Mean	-328* (166)	-557* (133)	-931* (91)	-663* (117)	-419* (154)	-742* (45)
St. dev.	1,698* (424)	1,340* (248)	909* (221)	1,174* (300)	1,559* (312)	1,015* (114)
NO-BUY						
Mean	-11.54* (0.79)	-12.49* (1.34)	-12.11* (1.50)	-9.18* (0.68)	-9.91* (0.84)	-11.15* (0.49)
ERC						
St. Dev.	5,780* (703)	7,469* (939)	6,054* (1037)	4,594* (760)	6,809* (568)	5,877* (406)
Treatment effects						
Control vs. Video						
Control * Radura	-	-	-	-	-	241 (405)
Control * Korea	-	-	-	-	-	151 (553)
Control * United States	-	-	-	-	-	1102* (531)
VideoP vs Video						
VideoP * Radura	-	-	-	-	-	2,633* (416)
VideoP * Korea	-	-	-	-	-	91 (545)
VideoP * United States	-	-	-	-	-	1,860* (527)
VideoN vs Video						
VideoN * Radura	-	-	-	-	-	808 (415)
VideoN * Korea	-	-	-	-	-	-195 (577)



Table 6 (Continued)

	Segmented models				Pooled model with interactions
	Control	Video	VideoP	VideoN	VideoPN
VideoN * United States	–	–	–	–	–
VideoPN vs Video					1,974* (538)
VideoPN * Radura	–	–	–	–	–
VideoPN * Korea	–	–	–	–	–
VideoPN * United States	–	–	–	–	–
Model statistics					
Log likelihood	–528.30	–543.50	–549.64	576.61	–562.21
No. of individuals	104	101	100	100	102
No. of observations	832	808	800	800	816
No. of parameters	16	16	16	16	16
AIC/N	1.399	1.478	1.508	1.575	1.509
					1.405

Number in parentheses is standard error; \* indicates statistical significance at 5% level or higher.

on food safety-related issues increases WTP for irradiated beef. This confirms our third hypothesis (H3). On the other hand, contrary to expectations, the fourth hypothesis is not confirmed as the estimated coefficient of the interaction term between *VideoN* and the Radura logo is found to be not statistically significant. This evidence does not support the notion that providing consumers with negative information about food irradiation resulted in lower stated marginal WTPs as hypothesised in this study (H4) and found in previous research (Fox 2002; Hayes *et al.* 2002; Rousu and Shogren, 2006). This result might be explained by the fact that in all treatments, including the *VideoN* treatment, participant received basic information on how the food irradiation technology works. This together with providing the participants with information on food safety-related issues might have mitigated the effects of negative information on consumer valuation for irradiated beef. Finally, consistent with our last research hypothesis when consumers receive both positive and negative information their marginal WTP for the Radura logo increases (as indicated by the positive sign of the interaction term between *VideoPN* and Radura logo), although the total effect remains negative and of low magnitude<sup>11</sup> (H5). This finding partly contradicts previous studies, which showed that negative information generally tends to overcome positive information in consumer valuation for irradiated food products (Fox 2002; Hayes *et al.* 2002; Rousu and Shogren 2006).

Further, closer inspection of the estimates also shows that information on food irradiation and food safety-related issues influences the way consumers value imported beef, while this same information does not impact the way consumers value domestic beef products. For example, the coefficients of the interaction terms between US beef and *VideoP* and *VideoN* treatments are both positive and statistically significant. This indicates that information on food safety-related issues increases consumer acceptance of irradiated beef only if accompanied by additional information on food irradiation. Interestingly, the coefficient of the interaction term between the *Control* and US beef is also positive and statistically significant (1,102 won). This result suggests that consumers' perception and therefore value of US beef decline when consumers are provided with information on food safety issues (*Video* treatment). This result is likely to be related to the distrust of the US food safety system among Korean consumers.

Table 7 reports the relationship between demographics/attitudinal variables and 'individual-specific' marginal WTP for the Radura logo.

Except for age and education, none of the demographics has significant effect on the individual marginal WTP for irradiated beef. As for age, results indicate that young consumers are less averse to anti-food irradiation, while

<sup>11</sup> As shown in Table 6, the coefficient of the interaction term between the Radura logo and the *VideoPN* treatment is 1,431, while the coefficient of the Radura logo is -2118. Thus, the net effect is -777 Won (-2,118 won + 1,431 won).

**Table 7** Relationship between demographics/attitudinal variables and WTPs for the Radura logo

Variable	Mean	St. Errors	P-value
Intercept	−7,534.96	3,716.15	0.043
Gender	−659.41	619.44	0.288
Age	−545.08	167.78	0.001
Age2	6.44	2.081	0.002
Education	940.43	569.01	0.099
Income	−63.59	259.44	0.806
Hear	347.07	473.88	0.464
Seen	386.42	867.01	0.656
Subjective knowledge	2,046.76	1,267.03	0.107
Increased safety	2,453.96	432.53	0.000
Reduced foodborne diseases	−631.42	393.87	0.110
Increased nutritional values	1,352.91	487.09	0.006
Increased shelf life	1,044.78	383.98	0.347
Increased taste	1,044.78	487.83	0.033
Video	−188.20	935.29	0.841
VideoPos	3,720.88	939.38	0.000
VideoNeg	−987.37	944.20	0.296
VideoPosNeg	2,020.96	936.14	0.018
R <sup>2</sup>	0.2948		

mid-age consumers are the most averse to the technology. The results also indicate that benefits implied by increased food safety, taste and nutritional values are more likely to increase the price premium consumers are willing to pay for irradiated beef. Providing consumers with information on food safety alongside with positive and both positive and negative information about food irradiation produces a positive effect on consumer valuation for food irradiation. Knowledge had no significant effect on the individual WTP for irradiated beef.

## 7. Final Remarks

This study investigated: (i) consumer acceptance of irradiated beef under a new food irradiation labelling system; and (ii) whether providing consumers with information on food safety-related issues increases their level of acceptance of irradiated foods under different information settings. The study was conducted in South Korea as the incidence of foodborne diseases is on the rise every year despite the implementation of a new labelling system on food irradiation.

Overall, the results from this study show that Korean consumers have a negative perception of irradiated foods, even with the new version of the irradiated food label. However, consumer valuation for the Radura logo varied across information treatments. More specifically, our results indicate that consumers fail to link the use of food irradiation as a vehicle to alleviate foodborne diseases and solve food safety issues. However, providing

consumers with information about food safety-related issues alongside with the benefits implied by the use of food irradiation resulted in more general acceptance of food irradiation. Unlike previous studies, we found that positive sentiment had a more profound impact than negative sentiment. This impact may come from how the consumers were informed about food safety throughout the survey. Since the consumers were more informed about the relevant food safety issues, then they may be more likely to adapt and accept technologies that address the relevant issues. Furthermore, results indicate that consumers' marginal WTP for irradiated beef is higher among young people and well educated, as well as among people who link the benefits implied by the technology with increased food safety, taste and nutritional standards.

The findings of this paper will be of interest to academics, food industry and policymakers. Academics have particular interest in this paper as they are interested in evaluating how the information about a new technology may affect the degree of acceptance for consumers. Furthermore, academics remain interested in the ability of consumers to create a linkage between food technologies and food safety. This paper informs food industry professionals by showing them that a new labelling system alone will not be sufficient to extinguish the existing knowledge gap among consumers. To close the gap, the food industry must provide additional information to consumers. This information should sensitise consumers to current and prevalent food safety issues in order to make them more accepting and knowledgeable about new food technologies. Policymakers can help alleviate this lack of knowledge by enacting policies that enhance the consumers' food and food safety education. These policies could be in the form of advertising campaigns or additional food safety classes within schools. Furthermore, these food safety courses would be especially effective within public schools where the food knowledge and food quality consumed by the students are lacking.

Prior studies have attempted to link emerging food issues with changes in consumer demand (Piggott and Marsh 2004; Tonsor and Olynk 2011). In this regard, further work needs to be done to establish whether the information about current issues obtained and utilised by consumers affects the degree of acceptance for new food technologies. This is not only limited to the irradiation of food but can also be extended to other technologies such as gene editing or even the labelling of food.

### **Data availability statement**

The data that support the findings of this study are available in the Supporting information (Appendix S3) of this article.

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### Supporting Information

Additional Supporting Information may be found in the online version of this article:

**Table S1.** Ex-post experimental design evaluation.

**Table S2.** Estimates from the joint model.

**Data S1.** Data and Codes.