Extrapolating understanding of food risk perceptions to emerging food safety cases

*Gülbanu Kaptan, Ph.D., Food and Society Group, School of Agriculture, Food and Rural Development, Newcastle University, UK

Arnout R.H. Fischer, Ph.D., Assoc. Professor in Consumer Behaviour, Marketing and Consumer Behaviour Group, Wageningen University, NL

Lynn J. Frewer, Ph.D., Professor of Food and Society, Food and Society Group, School of Agriculture, Food and Rural Development, Newcastle University, UK

*Author to whom correspondence should be addressed.

gulbanu.kaptan@ncl.ac.uk

EXTRAPOLATING UNDERSTANDING OF FOOD RISK PERCEPTIONS TO EMERGING FOOD SAFETY CASES

Gülbanu Kaptan, Arnout R.H. Fischer, and Lynn J. Frewer

ABSTRACT

Important determinants of risk perceptions associated with foods are the extent to which the potential hazards are perceived to have *technological* or *naturally occurring* origins, together with the temporal dimension in which the potential hazard is presented (*acute* or *chronic*). This study presents a case study analysis to examine how these hazard characteristics affect people's risk and benefit perceptions, and associated attitudes and behaviours. The cases include *E.coli* incidences (outbreaks linked to fresh spinach and fenugreek sprouts), contamination of fish by environmental pollutants, (organochlorine contaminants in farmed salmon), radioactive contamination of food following a nuclear accident (the Fukushima accident in Japan), and GM salmon destined for the human food chain. The analysis of the cases over the temporal dimension suggests that longitudinal quantification of the relationship between risk perceptions and impacts is important for both acute and chronic food safety, but this has infrequently been applied to chronic hazards. Technologies applied to food production tend to potentially be associated with higher levels of risk perception, linked to perceptions that the risk is unnatural. However, for some risks (for example those involving biological irreversibility) moral or ethical concerns may be more important determinants of consumer responses than risk or benefit perceptions. (Lack of) trust has been highlighted in all of the cases suggesting transparent and honest risk-benefit communications following the occurrence of a food safety incident. Implications for optimising associated risk

communication strategies, additional research linking risk perception and other

quantitative measures, including comparisons in time and space, are suggested.

1. INTRODUCTION

It has been empirically demonstrated that people's responses to different risks, and their associated behaviours, are affected by how they perceive potential hazard characteristics, and that people's risk perceptions do not always align with technical risk estimates provided by experts (Fischhoff et al., 1978; Slovic, 2000). The term "risk perception" is normally defined as people's ability to understand hazards and hazard related choices, for example in relation to acceptability of institutional risk mitigation measures, or adoption of self-protective behaviours. Risk communication is described as a process that enhances or degrades people's decision making ability (Fischhoff, 2012). In the context of public health, effective risk communication aims to provide laypeople with the information they need to make informed, independent judgments (Morgan et al, 2001). Food safety is of particular interest in this context, as there is some evidence suggesting that food risks are perceived differently from non-food risks (FAO, in preparation). This is because complete avoidance of food risks is not possible, and because food has *cultural, symbolic, familial* and *religious* connotations which must be taken into account when developing risk messages (Frewer et al., in press). People's food choice decisions are often based on traditions, habits or well established behavioral patterns (Köster, 2009; Pollard et al; 2002) which people may be reluctant to change (Honkanen, 2005). It is important to take account of existing risk perceptions when developing risk communication about specific food hazards (Fischer & Frewer, 2009).

In addition, some types of determinants of risk perceptions seem to be specifically important in shaping people's responses to food risks. For example, an

important determinant of risk perceptions associated with foods is the extent to which the potential hazards are perceived to have "technological" or "naturally occurring" origins (Frewer et al, 2013; Rozin et al., 2004; Siegrist, 2008). Indeed, the application of any technology to food production may be perceived as hazardous in itself. Failing to take account of this negative starting point, and subsequent negligence of the needs and priorities of consumers during the process of technology development and implementation, has resulted in societal rejection of potentially useful emerging food technologies such as genetically modified (GM) foods (Frewer et al., 2011; Raley et al, submitted). Moreover, as a result of consumers' low levels of risk perception associated with naturally occurring food hazards (e.g., microbial contamination), risk communication has had limited success in improving public health associated with the adoption of self-protective measures associated with for example *Campylobacter* (Nauta et al., 2008).

Further complexity is provided by the temporal context in which the potential hazard is presented (Glik, 2007). Presenting even a naturally occurring risk in an acute or "crisis" context may increase risk perceptions (Pidgeon et al., 2003). Examples include foodborne outbreaks that may be difficult to predict in terms of which microbial hazard will occur when, and affect whom. In the case of chronically occurring food hazards, (e.g., heavy metal contamination in fish), more information regarding the potential for varied impacts across differentially vulnerable populations may become available as a consequence of the ongoing risk assessment process. The temporal context of the hazard may differentially influence people's perceptions of risks, and hence their behaviours. In order to understand the potential impacts of both acute and

chronic food safety incidents on public health and economic function of the food chain, it is important to quantify the relationships between food risk perceptions and impacts. However, new metrics may need to be proposed in order to assess this relationship (Konig et al, 2010; Dreyer et al, 2010).

Furthermore, food may simultaneously be associated with risks, such as inclusion of contaminants, and benefits, such as nutritional advantages (see, *inter alia*, van der Voet et al, 2007; Cohen et al, 2005), suggesting that both risk *and* benefit perceptions associated with foods need to be considered when developing risk communication strategies (Hooper et al., 2006; Saba and Messina, 2003; Verbeke et al., 2005; Van Dijk et al, 2011). If sustainable, healthy food choices are needed (for example, simultaneously targeting reduced obesity rates *and* consumer food waste), risk-benefit based decision-making becomes even more complicated. Both risk and benefit perceptions need to be considered across a range of short term negative outcomes (e.g. food induced illness) and long term consequences of food choices related to optimal nutrition, and sustainable consumption (Hamm and Bellows, 2003),

This paper presents a case study analysis to examine how food hazard characteristics affect people's risk and benefit perceptions, and associated attitudes and behaviours. Two "axes" frame the analysis. The first relates to the "risk origin" (*technological* or *natural*). The second relates to the "temporal dimension" of the food hazard (i.e., whether it is presented in an *acute* or *chronic* context).

2. METHODOLOGY

Use of case studies to understand a specific research question is a research strategy that focuses on understanding the dynamics present within a single or multiple

settings (Eisenhardt, 1989). In the comparative analysis of cases that follows, four food-related cases were presented where risk perceptions associated with the food hazards may lead consumers to behave in a way contrary to their own, and societal interests, where societal is understood to refer to a "common good." Thus it should be possible to derive *generic*, as well as *situation specific*, conclusions regarding risk perception and food choice. The cases selected have been subject to considerable attention among different stakeholders (e.g., the scientific community in general, regulatory agencies, media, and representatives of civic society such as non-governmental organisations). The cases include *E.coli* incidences, (outbreaks linked to fresh spinach and fenugreek sprouts), contamination of fish by environmental pollutants, (organochlorine contaminants in farmed salmon), radioactive contamination of food following a nuclear accident (the accident at the Fukushima Dai-ichi nuclear power plant), and the GM salmon destined for the human food chain

Each case is described with a brief explanation about the risk issue, information about the factors linked to increased consumer risk perceptions, the impact of the incident, a chronological overview from consumers' perspective, and where feasible, research reporting consumers' attitudes and behaviour during and/or after these incidents, and the metrics needed to quantify the relationship between risk perceptions and impacts. Classification of the cases according to risk origin and temporal dimension is provided in Table I.

Table I. Classification of the cases according to risk origin and temporal dimension

Case	Risk origin	Temporal dimension
- E. coli 0157:H7 outbreak linked to fresh spinach (North America, September 2006) - *E.coli* outbreak linked to fenugreek sprouts (Germany, May-June 2011)	Natural	Acute
- Organochlorine contaminants in farmed Atlantic salmon (United Kingdom, January 2004)	Technological	Chronic presented in a crisis context
- The accident at the Fukushima Dai-ichi nuclear power plant (Japan, March 2011)	Technological	Acute and chronic
- GM salmon destined for the human food chain	Technological	Chronic

3. CASE STUDIES

3.1. E. coli incidences

Some strains of *E. coli* bacteria (e.g., STEC including *E. coli* 0157:H7, *E. coli* O104:H4) are pathogenic resulting in diarrhea or serious conditions (eg., hemolytic uremic syndrome) that can be fatal (FSA, 2013). STEC are one of the most reported and monitored food pathogens in the EU and US because they frequently cause sporadic cases of illnesses and large foodborne outbreaks in these countries (CDC,

2013; EFSA, 2013). When presented in a "crisis" context, E. coli outbreaks have the potential to generate high level of public concern (Food Standards Agency, 2012).

Consumption of the particular food associated with the outbreak tends to decline during the course of the outbreak (McCullough et al., 2013; Mazzocchi, 2006; Oniki 2006). These effects are large enough to quantify the "acute" impacts of a food safety incident by examination of product specific sales data (Hooper et al., 2006; Saba & Messina, 2003; Verbeke et al., 2005). However, risk perceptions may have negative unintended consequences, such as not consuming the product or substitutes for a prolonged period after the crisis ends, in spite of their health benefits (Cuite et al., 2007). Such "stigmatization" of foods may therefore have negative long term health effects (Gregory et al, 1996).

E. coli incidences may also occur sporadically where the risk is more likely to be presented in a "chronic" context, and in these cases risks may be perceived as relatively "low." In these cases, people are less motivated to change behavior not even towards appropriate self-protective behavior (Fischer et al., 2006), with subsequent negative impacts on public health. It is therefore relevant to compare perceptions of *E. coli* incidences across "acute" and "chronic" contexts.

Acute E. coli 0157:H7 *outbreak linked to fresh spinach.* In September, 2006, *E. coli* 0157:H7 infections associated with fresh spinach affected over 200 people in 26 North American states. More than 100 of these cases were hospitalized, and 31 developed a form of kidney failure called hemolytic uremic syndrome (HUS) that resulted in three deaths (CDC, 2006; Gelting et al., 2011). The source of the outbreak was identified as the processing and packaging plant of Natural Selection Foods, LLC in

San Juan Bautista, CA. The precise means by which the bacteria spread to the spinach remained unknown but US public health agencies were able to make predictions based on some field work (FDA, 2007a).

Following the outbreak, the lettuce safety initiative that had been launched in 2006 was expanded to include spinach (FDA, 2007b). This initiative aimed to reduce public health risks by focusing on the product, agents and areas of greatest concern and to alert consumers early and respond rapidly in the event of an outbreak.

During the outbreak, FDA's first advice to consumers was not to eat bagged fresh spinach (FDA, September 14, 2006) which was updated the next day to not eat fresh spinach or fresh spinach containing-products (FDA, September 15, 2006). The advice was updated again to confirm that spinach grown in non-implicated areas was safe to consume (FDA, September 22, 2006). One consequence of FDA's communication was that around 18% of American consumers surveyed reported that they had stopped buying other bagged vegetables (Cuite et al., 2007).

Bagged spinach expenditures were still 10% down at the end of 2007. In addition, over a period of 68 weeks, retail expenditures decreased 20% for bagged spinach, 1% for unbagged spinach and 1% for all leafy greens (Arnede et al., 2009).

Acute E. coli O104:H4 *outbreak linked to fenugreek sprouts.* Over 3800 cases of E. *coli* O104:H4 infections were reported in Germany between May and June 2011. More than 800 of those developed HUS that resulted in 54 deaths (Frank et al., 2011; Werber et al., 2012). In addition, several cases were reported in 12 other European countries, as well as the US and Canada (Bloch et al., 2012). Fenugreek seeds imported from Egypt were the most likely common link between the outbreak in

Germany and a related outbreak in France (EFSA, 2011). As a result, the European

Commission temporarily banned the import of fenugreek and certain seeds from Egypt

to the European Market on July 6 (EC, 2011). The relative rarity of the bacterial strain,

the associated serious health consequences, difficulties in tracing the bacteria back to

the food source, and communication failures on the part of authorities resulted in global

media attention.

The German public health authorities provided information about the outbreak

initially on May 24, 2011, without a reference to the affected crop. Consumers were

advised the next day to be careful when eating raw tomatoes, lettuce, and cucumbers,

in particular in Northern Germany as these vegetables were believed to be the potential

causes of the outbreak. On May 26, German authorities informed that three cucumbers

from Spain were identified as the potential cause of the outbreak. On June 1, however,

the Spanish cucumbers were cleared. Finally, on June 10, consumers were advised not

to eat raw sprouts as contaminated sprouts of a Lower Saxony producer were identified

as the vehicle for the outbreak. Soon after on June 23, an international investigation

concluded that fenugreek sprouts were the common link between the German outbreak

and a related outbreak in France (Werber et al., 2012). On July 5th, consumers were

informed that the outbreak had been ended but still advised not to eat raw sprouts.

Consumer advisories during the outbreak have been criticized in terms of

implicating a broad scope of unaffected produce as potential sources (cucumbers,

tomatoes, and lettuce while the actual source was fenugreek sprouts), and implicating

foreign production (Spain) while the problem occurred domestically (in Germany itself),

thus misleading consumers (e.g., Poudelet, 2012; WHO, 2011). As a consequence,

consumer demand for a range of fresh produce, in particular, produce grown locally and in Spain declined considerably (BBC, 2011a; die Welt, 2011). For example, German institutional kitchens (e.g., Stuttgart's youth hostels) stopped serving fresh salad. As well as having potentially negative impacts on the nutritional quality of diets, the negative economic impacts on Spanish producers were severe, with concomitant impacts on the broader local communities (BBC, 2011a).

In contrast to acute outbreaks, chronic E. coli incidents affecting only one or very few people occur relatively frequent (Tariq, Haagsma & Havelaar 2011). These incidents tend not to receive much media attention and are not the focus of acute risk communication, although the consequences of affected individuals can be as severe as those for someone who was infected during an outbreak. Food safety practice by consumers can mitigate such chronic incidents. Optimistic bias (where people do not perceive they are personally vulnera to a specific food risk) appears to militate against the adoption of safe domestic food hygiene practices associated with the prevention of foodborne illness (Miles & Scaife, 2003; Redmond & Griffith, 2004; Verbeke et al., 2007). An additional perception, that engaging in safe food preparation practices is too difficult or otherwise costly or inconvenient considering the perception that there are only few risks may also result in public health problems linked to microbial contamination of foods (Fischer et al, 2006). In the case of foodborne illness, the temporal presentation of the risk as acute or chronic has profound implications for public health, which are shaped by differences in risk perceptions.

3.2. Contamination of fish by environmental pollutants

Seafood, in particular fish, is an important supplier of omega-3 fatty acids, and a significant source of protein, vitamins, and minerals that are essential to maintain good health. Research has suggested that fish consumption may contribute to prevention of certain illnesses such as cardio-vascular disease (Kris-Ethorton et al, 2003), and some cancers (Hirose et al., 2003; Norat et al., 2005), and is beneficial to fetal neurodevelopment (IOM, 2006). Increased fish consumption is frequently targeted as a public health nutrition goal (Ruxton et al, 2004). However, fish is also associated with environmental contaminants such as methyl mercury and organochlorine compounds (e.g., PCB). Methylmercury might have adverse effects on developing fetuses (IOM, 2006), while PCB's might adversely affect liver, kidney, and central nervous system (Sirot, 2012). Vulnerabilities to risk also vary across the population (for example, pregnant women and immuno-compromised individuals are more at risk from negative effects), and it is important to examine risk-benefit perceptions across different population groups (van Dijk et al., 2012a).

The source of contamination in fish may be perceived as technological in origin. Both negative and positive consequences of changes in fish consumption may be perceived to be delayed, as health impacts (both toxicity effects and positive effects of omega-3 consumption) are long term. Communicating risks and benefits of fish consumption presents a challenge for experts to target the information to the appropriate audience and to help differentially vulnerable consumers make informed decisions to optimise their own health protection (Engelberth et al., 2013; Verbeke et al., 2008).

Organochlorine contaminants in farmed Atlantic salmon. An article published in the January 9, 2004, issue of Science reported that farmed Atlantic salmon (particularly from Scotland and the Faroe Islands) contained higher levels of organochlorine contaminants than wild Pacific salmon. The authors suggested that consumption of this particular fish should be limited to less than one and a half portions per month and concluded that consumption of farmed Atlantic salmon may pose risks that limit the beneficial effects of fish consumption. In response to this article, UK Food Standards Agency immediately issued a press release, pointing out that the levels of dioxins and PCB's found in this study were in line with those previously found by the FSA, and are within safety levels set by the World Health Organisation (FSA, 2004a). On January 9, the FSA issued a more detailed response highlighting that there is no reason to avoid eating Scottish farmed salmon or any other salmon (FSA, 2004b). Later in 2004, an inter-committee subgroup consisting of experts from the British Scientific Advisory Committee on Nutrition (SACN) and Committee on Toxicity (COT) issued a report weighing nutritional benefits against possible risks of consumption of fish, in particular oily fish. It was suggested that the UK population should be encouraged to increase its oily fish consumption to one portion a week to confer significant public health benefits without appreciable risk from the contaminants in fish (SACN, 2004).The Science article and subsequent responses from the Scottish Salmon Industry, and FSA received substantial media attention in the UK (eg., BBC, 2004; The Telegraph, 2004).

In a cross-national European study conducted with 206 participants from Germany, Greece, Norway, and UK (Van Kleef et al., 2009), participants were interviewed about recent food safety incidents in their home countries. Fifty-two

participants from the UK were interviewed about their opinions regarding contaminated farmed Atlantic salmon incident. The results suggest that UK participants were generally confused about the conflicting information provided by the media reporting the Science article and FSA's response. They required more information about how guidelines on contaminants are developed and reviewed and wanted to be updated about follow-up activities such as investigations. They also reported that they do not trust the salmon industry because the industry is more concerned about economic motivations rather than the safety of fish. Lack of trust in the farmed salmon industry was also found in more recent studies (Schlag & Ystgaard, 2013) but was reported as not predicting consumption choices for salmon (Hall et al., 2013). In studies on other food safety incidents (eg., BSE), consumption behaviours have been found to be affected by lack of trust (Pieniak et al.,2008; Rosati & Saba, 2004)..

Chronic contamination of salmon resulted in reduced levels of trust in food industry (Schlag & Ystgaard, 2013; Van Kleef et al., 2009). However, in order to metricise this, research is needed to map the long-term impacts of the incident in relation to consumer risk-benefit perceptions and fish consumption. As part of this, it is important to segregate risk perceptions associated with farmed salmon from those associated with fish in general, in order to establish the extent to which risk perceptions have generalised to other fish or seafood species. Thus, without further analysis, the long term public health impacts of this chronic food safety incident are unknown.

3.3. Radioactive contamination of food following a nuclear accident

Nuclear power has long been perceived as unacceptably risky by some members of the public. Incidents such as the Chernobyl accident have highlighted the potentially

negative effects of a nuclear accident to human and environmental health in general (Drotz-Sjoberg & Sjoberg, 1990; Renn, 1990), and the human food chain in particular (BBC, 2011b; Beach, 1990). In the early 2000's nuclear power has been repositioned as a solution to mitigate climate change because it has the potential to contribute to the growing demand for energy without emitting carbon dioxide to the atmosphere (e.g. IAEA, 2012; Sailor et al, 2000; Whitfield et al., 2009; Department of Energy, 2005), although its adoption in this regard is controversial (Sovacol et al, 2008). Accordingly, research has suggested people's attitude toward nuclear power as becoming less negative (Brook, 2012; Goodfellow et al., 2011). However, the catastrophic Fukushima nuclear accident that occurred, following a tsunami, in Japan in March 2011 may have nullified the change towards more positive attitudes (Kanda, et al., 2012; Poortinga et al., 2013).

Although not strictly a "technological food production" related hazard, this case represents the occurrence of an acute food hazard with technological origins, where perceptions (based on those learned from previous examples of similar incidents) are formed rapidly under conditions of uncertainty, are linked to unintended and uncontrollable effects of technology, and shaped by uncertainties associated with the geographic and temporal "spread" of impacts, in particular immediately after the crisis has occurred (Hamada & Ogino, 2012).

The accident at the Fukushima Dai-ichi nuclear power plant (NPP). On March 11, 2011, an earthquake of 9.0 magnitude created a powerful tsunami that flooded the Fukushima *Dai-ichi* NPP in Japan. As the flooding cut off power for cooling and created malfunction of all backup systems, reactors overheated, and a marked amount of

radiation was released to the environment, including the ocean. According to the review of an independent investigation panel established by the Rebuild Japan Initiative Foundation, the accident could have been prevented despite the earthquake and associated tsunami, but this did not occur due to ignorance and human error (Funabashi & Kitazawa, 2012).

The Japanese authorities evacuated citizens living within 20 km radius and suggested that people living in the radius of 20-30 km of the plant remain indoors. On March 17, provisional standards for radioactivity in foods were established as radioactive contamination of food was observed in areas far from the NPP. However, they were revised and lowered in April 2011 (Baba, 2013).

There were no initial deaths or serious exposures to radiation at the NPP. However, the evacuation resulted in 60 immediate deaths of patients or elderly people in nursing homes and health care facilities due to deterioration of serious medical conditions (Gonzalez et al., 2013). On December 16 2011, more than 9 months after the accident, the Japanese authorities declared the plant to be stable, although acknowledging that it would take decades to decontaminate the surrounding areas (BBC, 2011c).

The Japanese government announced a comprehensive review of its energy policy to emphasize renewable sources. In addition, all NPP's in Japan have either been closed or had their operations suspended for safety inspections and maintenance. The accident has also affected other countries' future energy plans. In response to German citizens' rising concerns about nuclear energy as a result of the Fukushima accident, Germany announced plans to shut down all its nuclear reactors by 2022.

Similarly, Switzerland agreed to phase out its five aging power reactors, and Italy decided to exclude nuclear energy from its future energy mix.

Communication efforts by the Japanese authorities to the public during and aftermath of the disaster have been widely criticized due to lack of transparency, downplaying the extent of the disaster, and failure to warn about likely events as raising concerns, as well as shedding doubt on credibility of the government (Figueroa, 2013; Funabashi & Kitazawa, 2012; Gonzalez et al., 2012; Ng & Lean, 2012; Poortinga et al., 2013; Srinivasan & Rethinaraj, 2012). There is evidence from within Japan that public support for nuclear power, which was not high before the incident, has further reduced (Figueroa, 2013; Kato et al, 2013; Poortinga et al, 2013).

People's risk perceptions associated with nuclear contamination are extremely high, both in terms of general environmental contamination (Slovic, 2012), and in relation to the food supply (Burger, 2012). Thus even a low level of radioactive contamination of foods may result in consumer rejection, even if the level of contamination is similar in magnitude to naturally occurring background levels of radiation. As a consequence, in the short term, foods which are technically safe to consume may be rejected by consumers (IAEA, 2012). This is particular concern in a crisis situation, for example, following a nuclear accident, where it may be difficult to provide adequate food supplies to the effected population as other crisis management activities (e.g., evacuation, provision of medical aid) may have higher priorities in terms of resource allocation. Given that contamination is likely to be perceived as ubiquitous within the region, short-term problems associated with under nutrition may occur (Spirichev, et al., 2006). Thus risk perceptions may result in acute nutritional

deficiencies in a population which is dealing with multiple potential health concerns associated with the aftermath of the earthquake such as tsunami and the nuclear accident. In the long term, there is the potential for all foods produced or stored within the vicinity of the nuclear accident to be "stigmatised" or rejected. Consumer rejection of food produced in the affected region may have negative impacts on the local economy as it has already been compromised by food produced in non-affected regions. This may extend beyond local consumers and effect export markets. National food production, unaffected by the nuclear incident itself, may be stigmatised, which will further impact on the national or even regional economy. In summary, such incidents may cause consumers to act rapidly to protect themselves from harm, but in the long term, their risk perceptions may "stigmatize" foods produced within local production systems, with concomitant negative socio-economic impacts. In a crisis, when food availability is potentially an issue, health problems associated with malnutrition may result from the perception that all local food supplies have been contaminated by radiation (WHO, in preparation). In order to quantify these relationships, it is important to measure risk perceptions and dietary choices immediately after the incident has occurred, as economic measures are unlikely to be reliable owing to multiple perturbances. Longitudinal analysis might usefully correlate economic data associated with local food production (both in terms of price and volume) with risk perceptions of local consumers, and consumers in export markets for local and national products.

3.4. GM animals applied to food production

GM technology has been applied to various crops, including those intended for food and animal feed, and to production animals (Cowan, 2010; Frewer et al, 2013b). However, food products derived from GM animals have not yet entered the US and European market, although regulatory approval appears imminent for some applications (FDA, 2012; Nature, 2012; Vàzquez-Salat et al, 2012). Medical applications based on pharmaceuticals derived from GM animals are more widespread internationally (Houdebine 2009, 2011; in particular in relation to disease models (Prather et a, 2008; Laible, 2009). The use of GM animals in food production systems potentially confers benefits in terms of food safety, enhanced nutrition, and improved food security (Niemann, and Kues 2007). Consumer perceptions of risk are higher for GM animal related food applications than plant related applications, and may militate against their use in food production. Other areas of application such as medical applications appear more acceptable to the public, primarily because the benefits are perceived to outweigh the risks (Frewer et al, 2013a; Frewer et al, submitted). Particular concerns are associated with animal welfare issues, and perceptions that negative environmental impacts may be associated with intended or unintended environmental releases of GM animals (Eisendel, 2005). What distinguishes the case of GM animals applied to agriculture to the other cases presented here is that it is associated not only with high levels of risk perception, but also moral or ethical concerns on the part of the public (Frewer et al, 2013a).

GM *salmon destined for the human food chain.* At the time of writing, a GM salmon destined for human consumption is undergoing the approval process by the US

Food and Drug Administration (FDA, 2013). The genetic modification increases growth rate (Aerni, 2004), anticipating increased demand for fish and fish products over the coming decade (OECD-FAO, 2013). Accordingly, GM fish has been considered as a sustainable solution in terms of food security. Atlantic salmon is one of the food species that has been subjected to GM (Menozzi et al., 2012). It has been argued that GM salmon offers nutritional advantages, including resistance to environmental stressors and pathogens, and increased availability of omega three fatty acids (Aerni, 2004). Disadvantages may be associated with the need to ensure allergens are not introduced into the human food chain (Nakamuraet al, 2009), and less than 100% sterility resulting in potential cross-breeding with wild varieties of salmon (Le Curieux-Belfond et al, 2009). The advantage for consumers may be economic (retail price reduction), or nutritional (increased availability of foods rich in heath promoting components) (Mora et al., 2012). Against this, the issue of environmental impact (for example, unintended release of animals into the environment and animal welfare concerns) remain a potential source of controversy (Frewer et al, in press). The primary drivers of risk perceptions, at least in Europe, appear to be perceptions that the application of GM technologies to animals is risky and is not associated with consumer benefits. Consumers in North America and South East Asia tend to be more concerned about moral and ethical issues (Frewer et al, 2013a).The lack of equity of distribution of benefits across different countries and across populations is regarded as a potential issue militating against the development of such production animals. Perceptions leading to consumer rejection are not linked to the use of GM animals *per se*, but rather focused on their use in the food supply chain.

In the case of GM animals used in food production, it is difficult to argue that consumer *risk perceptions* militate against their own interests. It could be argued that lower prices for animal proteins high in beneficial nutrients represents a considerable consumer benefit which will deliver advantages to public health, although this may not be such an important benefit given that early innovations are destined for more affluent countries (Menozzi et al., 2012).Rejection of pharmaceutical production where alternative technologies are not available, would go against end-user benefit, but in pharmaceutical use GM is much more acceptable to end-users. Of potentially greater importance regarding consumer adoption is the issue of how moral and ethical concerns (Kaiser et al, 2007) contribute to rejection of GM animals in food. It is suggested that the principle of informed choice, through adoption and implementation of an effective traceability and labelling policy, will prove beneficial if and when products are released into the market. Even if consumers perceive that adequate risk assessment procedures are introduced, that animal welfare standards are met, and that governance structures are adequate, perceived benefits may not outweigh even very small perceived risks. Attempting to predict the relationship between consumer attitudes and beliefs, and potential future purchasing activities, must take account of both consumer risk and benefit perceptions.

4. DISCUSSION

Four food safety cases where risk perceptions associated with the food hazards have been presented. In three of these (*E.coli* outbreaks, linked to fresh spinach and fenugreek sprouts, organochlorine contaminants in farmed salmon, and the radioactive contamination following the Fukushima accident), it was concluded that risk perceptions

may lead consumers to behave in a way contrary to their own, and societal interests. In the fourth (GM salmon destined for the human food chain), moral concerns may influence consumer behaviour to a greater extent than risk perceptions. In relation to these cases, the acute *versus* chronic (temporal axis) nature of food hazards and how technological *versus* natural (risk origin) hazards affected people's risk and benefit perceptions, and associated attitudes and behaviours, has been examined.

An initial starting point to examine the temporal axis is that more is known about the acute effects of a food safety incident compared to long terms impacts, in particular when examining (changes in) risk perceptions and subsequent consumption behaviours. In the case of the E. coli outbreaks, and the reporting of contamination of Atlantic salmon, short term impacts can be "metricised" through analysis of changes in risk perceptions and consumption and sales patterns. The long term impacts on dietary choices have not, to our knowledge, been analysed, and it is not clear how risk and benefit perceptions affect dietary choices in the long term. These chronic effects are particularly complex because vulnerabilities to the risk change through the lifecycle of consumers (for example, with respect to age and immune status) (Ma & Fang, 2013; Wada et al., 2013) and also vary between different demographic groups (for example, with respect to gender) (Yan et al., 2010; McCombe et al., 2009). In addition, improved scientific knowledge, for example about toxicology may result in food choice dilemmas in the future. A recent example is that of inorganic arsenic in the food supply (Llorente-Mirandes, T., 2014), where reports of relatively high levels in vegetables may fuel consumer risk perceptions, with the consequence of reduced vegetable consumption. This reduction may lead to net negative impact on long term public health.

The analysis of the cases over the second axis (technological *versus* natural food hazard origins) presented support for the contention that technologies applied to food production are associated with higher levels of risk perception, potentially because they are perceived to be unnatural. However, the available evidence suggests that intrinsic (or intuitive) consumer concerns about ethical or moral issues are closely associated with the introduction of GM animals applied to food production, more than "objective" hazards like health risks. The issue of whether alternative, less controversial, technological approaches may be available to deliver the same benefits may also need to be considered, as this is an issue influencing consumer acceptance (Gupta et al, 2012). In contrast, whilst it is possible to construct extrinsic ethical arguments regarding the risks of nuclear power (for example, the potential for environmental harm), this would relate to risks of a nuclear accident, rather than a concern located in the development and application of the (enabling) technology itself. Again, longitudinal assessment of the relationship between risk perceptions and consumer choices is required. Linking these data with economic assessment would be useful in order to determine the socio-economic impacts (for example, to local producers in the case of Fukushima). In the case of GM Salmon, such analysis would need to be projected at present, as approval is pending. If approval is given to commercialise GM salmon in the human food chain, there may be ample opportunity to assess the relative influence of consumer risk perceptions and moral and ethical concerns, on purchasing and consumption. Analysis of external changes (for example, societal debate about synthetic biology and food production) might further crystallise public opinion regarding the biological sciences in general (Torgersen, 2009; Torgersen & Schmidt, 2013).

The importance of developing trust has been highlighted in all of the cases, although this may have greatest impact in terms of long–term consumer responses to risk–benefit communications (e.g., Berg, 2004; Frewer et al, in press). Communicating risk uncertainty to the public has emerged as an important issue. Therefore communicating transparent and honest information, in particular telling the consumers what the authorities know and do not know, with clear recommendations for actionable behaviour changes if relevant, may increase trust in information following the occurrence of a food safety incident (Kaptan & Fischhoff, 2010; Frewer et al, in press). Communication of uncertainties associated with the scientific assessment of risks and benefits may also be relevant where these exist, and need to be communicated to consumers in terms of consumer protection or the generation of consumer confidence in information (Beck and Kropp, 2011; Thompson, 2002). In the case of both acute and chronic risks, it is noticeable that transparency about the internal decision-making processes of regulatory agencies and about new scientific information (e.g., contamination in fish) and novel technologies (e.g., GM technology) rises as an important determinant affecting risk perceptions.

The Fukushima accident case exemplifies the importance of prior attitudes and value orientations towards nuclear power in risk information, which seem to some extent similar to experimental studies involving prior attitudes towards food (Fischer & Frewer, 2009; Van Dijk, et al., 2012b). There is no single "public" with regard to energy preferences and corresponding risk beliefs but rather there are multiple populations with different viewpoints (Greenberg &Truelove, 2011; Whitfield et al, 2009).

In all the cases presented here, consumers needed to make informed decisions by understanding and balancing their decisions regarding both risks and benefits associated with associated food choice behaviours. If relevant risk-*benefit* information is not available, people may rely on judgmental heuristics, or rules of thumb such as availability heuristic (Gilovich, 2003; Kahneman et al., 1982). Because availability heuristic may explain why foods are rejected when only risk information is provided, the risk attitude will be the most available and most influential one in consumer decisions Other inferences are derived from people's existing mental models allowing them a framework to interpret issues in the news media, participate in discussion, feel competent to make decisions, and generate options (Fischhoff, 2012). Mental models can provide essential structure in understanding risk communication, but also produce incorrect conclusions if they contain incorrect beliefs and/or misconception. Therefore communications need to be tested before (and evaluated after) communicating because mental models of risk communicators and the target audience may be different, thus leading to unexpected impacts of the communication.

Based on the findings of the analysis of four cases, it should be possible to extrapolate to emerging fo risks, where there is little existing data regarding risk perceptions, such as synthetic biology, in general and as applied to food production, (Pauwels, 2013), and increased mycotoxin levels in the global food supply (Wu, 2006), or inorganic arsenic in food and water (Moreno-Jimanez, et al., 2012; Smith & Steinmaus, 2009). The case studies highlight an important research need in the context of examining the relationship between risk perceptions and impacts (whether on health or socio-economic functioning of affected societies). Whilst there is some evidence to

assess the impact of chronic events (for example, in relation to sales volumes of foods and food commodities associated with a food risk incident), the long term impacts are not understood. Developing metrics to assess this would not enable greater understanding of the relationship between risk perceptions and consumer behaviours, but also allow mapping of the broader "stigmatisation" of foods and food products in affected food chains or regions. As part of this, methods to quantify risk perceptions, psychological impacts, impacts on local and regional economies are needed, which have to be utilised in conjunction with assessments of public health and environmental impacts, possibly in the same models. Methodologies which can harmonise natural and social science data sets are needed to generate predictive power in this respect.

5. CONCLUSIONS

In this study, two axes, risk origin (natural or technological) and temporal context (acute or chronic) have framed the analysis of four different food safety incidents. In the case of the "naturally" occurring incidents, it was concluded that there is potential for risk perceptions to override consumer best interests from the perspective of optimal nutrition (in particular relative to under consumption of health promoting nutrients). In the case of technological potential hazards, consumers own interests may be harmed in the short term (for example, in the case of a food safety incident linked to a nuclear accident), and therefore developing a comprehensive understanding of consumer perceptions as well as technical risk estimates is needed to develop effective communication. In the case of GM animals applied to food production, other concerns, which are potentially moral or ethical in nature, may be more relevant to consumer acceptance than their risk perceptions. In this case it is difficult to argue that consumer

risk perceptions are operating "contrary to their own interests," and therefore an effective traceability and labelling policy for GM animal food products is needed. However, long term analysis linking perceptions to robust measures of impact is infrequent, and future research should attempt to quantify the links between risk perceptions, behaviours economic effects, and public health and environmental risk indicators.

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