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Review

Consumers and new food technologies

Fanny Rollin, Jean Kennedy and Josephine Wills*

European Food Information Council (EUFIC), Tassel House, Rue Paul-Emile Janson 6, 1000, Brussels, Belgium (Tel.: +32 2 506 89 89; fax: +32 2 506 89 80; e-mail: jo.wills@eufic.org)

This paper aims to describe the current landscape in Europe within which emerging food technologies are developed and applied, and to give insights from other parts of the world. Consumers' attitudes towards emerging food technologies are described, with a focus on five case-studies; nanotechnology, genetic modification, nutrigenomics, food irradiation and animal cloning. Stakeholders' opinions specifically on nanotechnology are also discussed taking into account a recent European consultation. The factors that shape consumers' views such as perceptions, knowledge and information, trust and socio-demographic attributes that influence consumers' views, are also included.

Introduction

The last two decades have seen considerable research and development efforts dedicated to new food technologies. The "Flavr Savr" tomato (the first genetically modified (GM) food developed in 1994) and the birth of Dolly the sheep (the first mammal to be cloned from an adult somatic cell developed in 1996) are some of the well-known examples that gave rise to much debate and controversy in the media when they were first developed. Nowadays, consumers are exposed to several applications of emerging technologies such as GM maize in Spain and irradiated poultry meat in the Netherlands. However, even if a variety of food ingredients and food contact materials derived from new food technologies are already available in some European countries, the application is at an early stage and is widely expected to grow.

One of the reasons for such interest in new food technologies is the anticipated range of benefits they can bring to the consumer and the food sector. The reported advantages include safer, healthier more nutritious foods using less energy, water and chemicals and producing less waste. However, the toxicological nature of hazard, likelihood of exposure and risk to consumers from some new food technologies are largely unknown (Chaudhry *et al.*, 2008).

The first part of this paper is concerned with consumers' awareness and attitudes towards new food technologies in general. Since consumers' reactions to new food technologies are not a one-dimensional relationship, several aspects of this relationship are also explored such as risk-benefit perceptions, knowledge and information, trust and socio-demographic attributes. The second part will focus on five case studies, namely nanotechnology, genetic modification, nutrigenomics, food irradiation and animal cloning. There is a particular emphasis on nanotechnology, and European stakeholders' opinions from a recent open consultation on nanotechnology are presented. This paper concludes with a discussion about the opportunity for stakeholders and policy-makers to involve the public in the new food technology debate and the potential for effective food risk/benefit communication. This paper should be considered as a general overview of the current research on this topic and not as an exhaustive literature review.

Emerging food technologies

In Europe, the use of novel foods or novel food ingredients and their placing on the market within the Community was first defined by the Regulation (EC) No 258/97. In this legislation, novel foods or food ingredients are defined as foods or ingredients containing or produced from genetically modified organisms (GMOs); with a new or intentionally modified primary molecular structure; consisting of or isolated from micro-organisms, fungi or algae, plants or animals not obtained by traditional propagating or breeding practices and having a history of safe food use; and foods and food ingredients to which has been applied a production process not currently used, where that process gives rise to significant changes in their composition or structure. A series of additional legislations completed the Regulation (EC) No 258/97; among them Regulation (EC) No 1852/2001 determines how certain information will be made accessible to the public. Since 2003, the authorisation and marketing of GMOs or products derived from GMOs doesn't fall under the Regulation (EC) No 258/97 anymore, but must be approved under Regulation EC No 1829/2003

* Corresponding author.

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concerning traceability and labelling. In January 2008, the European Commission published a proposal (COM(2007) 872) for a new Regulation to harmonise rules on novel foods and food ingredients (Aprea, 2009).

Consumers' attitudes

European consumers tend to be risk-adverse (Eurobarometer, 2006a; Nelson, 2001). In 1988, consumers were sensitised by the initial mismanagement of the BSE crisis, where they were wrongly reassured that beef was safe when it was not, and the subsequent mismanagement of the Belgian dioxin crisis in the same year further focused their attention food safety issues. It has been reported that past episodes of food safety incidents such as these have led to low public confidence in food safety systems (Curtis, McCluskey, & Wahl, 2004; Frewer & Salter, 2002; Verbeke, Viaene, & Guiot, 1999). However, since 1999, many measures have been taken to ensure food safety across EU Member States. For example, the European Food Safety Authority (EFSA) was set up in 2002 and an entire new raft of legislation known as the "hygiene package" was created to merge, harmonise and simplify the very detailed and complex hygiene requirements which were previously scattered over 17 EU Directives.

Despite efforts to ensure public confidence in food safety, some new technologies, regardless of their potential benefits, can have difficulty in diffusing successfully into society (Ronteltap & van Trijp, 2007). In the past, several new food technologies faced unsupportive attitudes when they first appeared, such as canned food, pasteurised milk, artificial insemination of farm animals, microwave cooking (IFT, 2000). A recent review commissioned by the Food Standards Agency (FSA) in the UK (Fell, Wilkins, Kivinen, Austin, & Fernandez, 2009) confirmed that nowadays European consumers still tend to associate more negative than positive attributes to agro-biotechnology in general, such as wariness, unease and uncertainty. However, there are minorities with strongly positive or negative opinions, and a majority who are undecided or feel that they don't know enough to form a view.

Given the intimate relationship people have with food, education about the technical and rational aspects of emerging food technologies alone will not lead to consumer acceptance (Bruhn, 2008; Bruhn & Mason, 2002). Many factors can influence consumers' acceptance of food innovations. Understanding consumers' risk-benefit perceptions, socio-demographic attributes, knowledge and information, as well as trust in the source of information will be crucial to the realisation and success of technological advances.

Influencing factors

Risk-benefit perceptions

Consumer acceptance is driven by risk perception rather than the technical risk estimates provided by experts (Frewer, Howard, & Aaron, 1998) and food technologies typically possess many of the risk characteristics that engender greatest concern among consumers (Ronteltap, van Trijp, Renes, & Frewer, 2007). Research demonstrated that factors such as whether the risk is perceived to be involuntary, unnatural or potentially catastrophic, and whether the risk may affect health rather than the environment, drive public risk perception (Gaskell, 2000; Siegrist, Stampfli, Kastenholz, & Keller, 2008). Consumers also perceive a hazard as riskier when they believe that the consequences of the hazard are largely unknown to scientific experts (*e.g.* Slovic, 1987), particularly when the public perceives that the uncertainty is being "hidden" by regulatory institutions (van Kleef *et al.*, 2006).

Acceptance of a technology is also partly driven by the perception of the potential benefits (Ronteltap *et al.*, 2007). A lack of perceived benefits leads the majority of people to question the need for, and usefulness of, novel food technologies, and may even accentuate perceived risks and moral concerns (Gaskell, 2000).

Socio-demographic and economic factors

Women are more concerned, less positive, and likely to perceive fewer benefits of novel food technologies than men (Eurobarometer, 2005; Fell *et al.*, 2009). In general, students and young people have positive perceptions to biotechnologies (Eurobarometer, 2005).

According to two recent reviews, general attitudes may also be one of the key drivers of attitudes towards novel food technologies, which is pertinent in cases of uncertainty and low understanding (Fell *et al.*, 2009; Ronteltap *et al.*, 2007).

Moral and ethical worries can also affect the level of acceptance of new technologies. In relation to biotechnologies, they refer principally to technology "tampering with nature", making irreversible changes to nature and 'playing god' (Hallman & Condry, 2006). For one in three EU citizens, moral and ethical issues should be prioritised in decision-making regarding food technologies (Eurobarometer, 2005, 2006a). Europeans are likely to discount risk, if they perceive the technology to be both useful and morally acceptable.

Price, good taste and convenience are suggested to be key consumer benefits in today's marketplace (Bruhn, 2008; Fell *et al.*, 2009). A British study highlighted that a majority of UK consumers (74.5%) seems to be willing to purchase GM foods if they are cheaper than traditional foods (Spence & Townsend, 2006). A recent survey showed that almost two-thirds of US consumers (67%) indicated they would be likely to purchase a biotechnology modified product with improved flavour (Bruhn, 2008). Another American study underlined that over 80% of consumers indicate convenience is an important consideration in purchases (Food Marketing Institute, 2005).

Knowledge

New technologies often encounter a stumbling block in consumer acceptance. Will the consumers' acceptance

change if they receive more information about these technologies?

The evidence regarding the effects of new knowledge is mixed, with some studies finding that new information has no significant effect, and others finding positive or negative effects of new information. Among others, Bauer, Allum, and Miller (2007) pointed out that knowledge transfer to the public does not guarantee more positive attitudes towards technology and science. However, it has been shown that a lack of knowledge among consumers regarding innovative and emerging food technologies can serve as a major barrier to their acceptance (Cardello, Schutz, & Lesher, 2007). People are most suspicious of the least familiar technologies (Fell *et al*., 2009). A recent American study showed that greater self-rated knowledge of a technology is mostly associated with positive attitudes about that technology (Teisl, Fein, & Levy, 2009). In addition, it seems that educating consumers about new technologies may be critical to ensure that they will pay extra for such products (Costa-Font, Gil, & Traill, 2008; Hicks *et al*., 2009).

Over the last 5 years, there has been increased attention on new food technologies, particularly on GM food. From January 2005 to October 2009, European consumers have been exposed to more than 10,000 media articles dealing with GMOs (7300 articles), nanotechnologies (1531 articles), irradiation (634), nutrigenomics (220) or animal cloning (120) applications in the food sector (EUFIC study based on Factiva® database). Considering that media interest in these technologies has increased over the last 5 years, what is the impact on consumers' views?

Bauer, Kohring, Gutteling, and Allansdottir (2001) consider that media can have a "direct effect" on consumer risk perceptions and attitudes and influence people's negative emotions and perception of risks by dramatising the reality. This can result from selective information processing, whereby individuals seek out and confer greater value to information reporting risks. Although the content of media reporting is important, the quantity of coverage can also have an impact. A European review focusing on the UK and Sweden underlined that public acceptance to controversial technologies varies in accordance with the volume of reporting, even if the overall tone is mostly positive (Rowe, Frewer, & Sjöberg, 2000).

Trust in the source of information

In Europe, the most trusted sources of information are health professionals, university scientists, and consumer organisations, followed by scientists working in industry, and media (Eurobarometer, 2006a). Consumer trust towards industry has consistently increased over the period 1999–2005. A specificity of the European community is that European Union government is more trusted than national government on regulation (Eurobarometer, 2006a). However, a recent Eurobarometer study on risk issues (Eurobarometer, 2006b) showed that European consumers have different trusted sources when asked who they would trust the most to inform you about a serious food risk (Table 1). In general, the 10 new EU members included in 2005 have greater trust in actors and institutions involved in science and technology. Compared to European consumers, US and Chinese population have higher levels of trust in their regulator (Curtis *et al*., 2004; Gaskell, Ten Eyck, Jackson, & Veltri, 2005; Hicks *et al*., 2009).

Labelling

Labelling aims to provide additional information about the technology and its benefits to raise awareness and improve transparency. Labelling can also assist in increasing individual perception of personal control over the consumption of new food products (Costa-Font *et al*., 2008). When asked about the need of labelling on food products derived from an emerging food technology, recent studies highlight that consumers and stakeholders support the presence of more and clearer labels (Curtis *et al*., 2004; Eurobarometer, 2008; Frewer *et al*., 2004; Landmark Europe, 2009). People are inclined to accept the risk of consuming new food products, if it is under their own control. This may explain why they prefer clear labelling and increased regulation.

However, labelling of GMO content in foods can negatively impact on the intention to purchase a product. In particular, extensive GMO information on the label does not have a positive influence on consumers' intentions to buy. The consumers most likely to be willing to buy GM foods are those who desire the lowest level of information on the label possibly because there is a lack of awareness behind consumers willingness to purchase GM products (according to the attitude activation model). Consumers with lower awareness of GM foods may be less concerned about GMO content of food products, but negatively influenced by extensive label information (O'Fallon, Gursoy, & Swanger, 2007).

Case studies

The acceptance of emerging food technology varies depending on the technology and across the EU Member States (Gaskell, 2000), so that in-depth understanding of the relationship between the consumer and one specific technology should be tackled on a case-by-case basis. In

Table 1. Most trusted source of information for European consumers (Eurobarometer, 2006b). Question: Who would you trust the most to inform you about a serious food risk in fish or chicken?

Most trusted source	Countries
Physician or doctor	Belgium, France, Malta, Spain
Consumer groups	Germany, Hungary, Luxembourg, The Netherlands
Scientists	Cyprus, Czech Republic, Greece, Poland, Slovakia, Sweden
Media	Ireland, Slovenia

Case study 1: Nanotechnologies

Up to now, there are no generally accepted definitions of nanomaterials and no specific overarching regulation about nanotechnology, as the current legislation covers in principle the potential health, safety and environmental risks in relation to nanomaterials. Despite that, a number of studies have been performed on attitudes towards nanotechnology, considering the generally accepted definition; "the term nanomaterials is used here to indicate engineered materials which contain structures of less than 100 nm for at least one dimension. These materials include free nanoparticles as well as nanomaterials that are attached to or incorporated into the matrix of larger structures. Naturally occurring and unintentionally produced nanomaterials are not included in this definition" (Dekkers *et al*., 2006).

A series of communications from the European institutions have been published on nanotechnologies to propose an integrated strategy in Europe (COM(2004)338), to define an action plan for 2005–2009 (COM(2008)366) and to outline the potential food safety risks related to nanotechnology (EFSA opinion on the Potential Risks Arising from Nanoscience and Nanotechnologies on Food and Feed Safety).

i. Stakeholders opinions

A broad stakeholders survey (Landmark Europe, 2009) evaluated the opinion of industry representatives, scientific experts, policy makers, consumer groups, NGO representatives and journalists. This study suggested that stakeholder awareness of nanotechnology is relatively high (62% of the respondents reported having heard 'a lot' or 'some' about nanotechnology), while the actual knowledge of nanotechnology is modest (70% claimed to know 'little' or 'less than little' about nanotechnology). Similar to consumers, nanotechnology is not yet 'top of mind', but is a growing consumer policy concern. Stakeholders display a high level of concern (60%) about nanotechnology, in particular about the adequacy of current risk assessment requirements for nanotechnology, and 43% believe that the overall potential risks of nanotechnology will outweigh the benefits.

A recent European stakeholder consultation (DG Health and Consumers, 2009) showed the views of 16 NGOs on nanotechnologies, which complemented those of consumers. Indeed, NGOs recommend public participation in decision-making. As the public is sceptical regarding nanotechnologies, NGOs suggest that the risks and benefits must be communicated to the public and not only to the scientists. NGOs asked for more transparency (*e.g*. mandatory reporting scheme, public inventory of all current and forthcoming nanomaterials used in products on the market), more precautionary risk management of products with nanotechnology elements (from no further market introduction management to a ban/moratorium on production and marketing of these products), and case-by-case risk evaluation and a labelling system to indicate the presence of manufactured nanomaterials/particles. Moreover, some NGOs called for a standard definition and new regulation of nanotechnologies. Concerning research and risk assessment studies, standard methods and the ban of animal testing were suggested.

ii. Consumers attitudes

Consumers awareness of nanotechnology specifically is low (Chaudhry *et al*., 2008; EORG, 2001; Siegrist *et al*., 2008). In 2005, 44% of Europeans had heard about nanotechnology (Eurobarometer, 2006a). European acceptance seems to be increasing. In 2002, only 29% agreed on the future positive impact of nanotechnology, and 53% answered 'don't know' (Gaskell *et al*., 2005), while in 2005, almost half (48%) considered that nanotechnology will have positive effects on their way of life in the next 20 years (Eurobarometer, 2005). Over half of Europeans (55%) support the development of nanotechnology as they perceived this technology as useful to society and morally acceptable (Eurobarometer, 2006a). In particular, the use of nanotechnology in packaging seems to be more acceptable than the use of nanotechnology in food (Siegrist, Cousin, Kastenholz, & Wiek, 2007; Siegrist *et al*., 2008).

In 2002, US consumers were more optimistic about nanotechnology (50% optimistic) than Europeans (29% optimistic). However, by 2005, European, US and Canadian citizens were equally optimistic about nanotechnology. Europeans were more concerned about the impact of nanotechnology on the environment and were less confident in regulation than North Americans (Gaskell *et al*., 2005).

iii. Risk-benefit perceptions

Among consumers, the main perceived risks seem to be the fear of the unknown (Landmark Europe, 2009) and of playing god (Macoubrie, 2005), as well as the ability of regulators and others to ensure safety and the general public benefits (Smallman & Nieman, 2006).

iv. Socio-demographic factors

Women are less optimistic than men (33% *vs* 49%), and slightly less supportive (53% *vs* 59%) (Eurobarometer, 2006a). However, these conclusions should be addressed cautiously as the proportion of 'don't know' answers is always higher for women than it is for men, reaching almost half of those women surveyed about their optimism (up to 49% in some cases, *e.g.* Eurobarometer, 2005). One exception is that males are not inclined to have a genetic test for personalised nutrition (Stewart-Knox *et al.*, 2009).

In a Eurobarometer survey, respondents are categorised into four age groups: 15–25 years, 26–45 years, 46–65 years, and 66 years and above. The oldest group seem to be less supportive (only 14% of the 66 years and above group totally agree to support nanotechnology, *versus* 21%, 20% and 22% for the 15–25 years, 26–45 years, 46–65 years groups, respectively) about nanotechnologies (Eurobarometer, 2006a). Siegrist *et al.* (2008) suggested that age is not a significant influencing factor of risk perception of the nanotechnology applications in food and packaging, but older people are more likely than other age groups to perceive nanotechnologies used in food packaging as beneficial.

It seems that religion may play a role in influencing consumer behaviour and in a 2005 study, it was found that religious people were less likely to think that benefits of nanotechnology outweigh the risks (Fam, Waller, & Erdogan, 2004; Lee, Scheufele, & Lewenstein, 2005).

v. Labelling

Most European stakeholders (70%) ask for the labelling of food products derived from nanotechnology and it has been reported that acceptance of nanotechnology could benefit from the provision of more consumer information and awareness-raising (Landmark Europe, 2009). However, labelling of food products derived from nanotechnology remains difficult, as no consensus has been established on the definition of nanoparticles. Furthermore, with the multiplicity of labels on food products, it remains unknown how consumers will make sense of them, and how they will make trade-offs with other information on label.

this section, five novel food technologies are considered; nanotechnology, genetic modification, nutrigenomics, food irradiation, animal cloning. It should be noted that there is not the same amount of material available for the five technologies; this can be partly explained by the fact that more studies were performed on the less recent technologies and on the technologies with applications available on the market.

Conclusion & recommendations

This paper shows that many factors affect consumer attitudes and acceptance of novel food technologies and their applications. Whilst waiting for a full understanding of these technologies, some actions can be taken to increase public awareness and acceptance. Understanding consumer perceptions and the role of socio-demographic attributes on the acceptance of new technologies are key for policy-makers to formulate meaningful regulations, particularly in Europe where opinions vary considerably across countries. Stakeholders also need to explore more deeply what affects public trust in food sectors, government, and in related policy-influencers like industry, scientists, NGOs, and journalists (Houghton, Van Kleef, Rowe, & Frewer, 2006; Ten Eyck & Gaskell, 2003). Furthermore, public confidence in food safety has important economic and political consequences at a national and international level (Houghton *et al.*, 2006).

In the past, the public was perceived as a passive receiver of risk and benefit information and was considered to often misunderstand or misinterpret messages. It is now recognised that risk and benefit communication should involve a process of exchange of information among all stakeholders (Rogers-Hayden, Mohr, & Pidgeon, 2007). Indeed, these technologies are complex concepts for the public to grasp. Without a serious communication effort, these innovations could face a negative public reception. European consumers are risk-averse and demand transparency. Increased communication and early involvement of end-users may contribute significantly to an increased transparency of the decision-making process and a higher level of trust in public authorities (WHO, 2006), as well as the likelihood of market success (Frewer *et al.*, 2004).

However, food risk communication is a highly complex field, where no single set of recommendations can suit all situations. Many factors may affect its success, including trust in the source of information, scientific uncertainty, interaction with the public, cultural variation, as well as how the message is developed in terms of language, style and pre-testing with target audiences (*e.g.* choice of appropriate channels for reaching target audiences) (van Dijk *et al.*, 2008; van Kleef *et al.*, 2007; Smillie & Blissett, 2010). A recent report on the results of two workshops with international experts and an open web-based consultation on

Case study 2: GMOs

The World Health Organisation defines genetically modified organisms (GMOs) as "organisms in which the genetic material (DNA) has been altered in a way that does not occur naturally. It allows selected individual genes to be transferred from one organism into another, also between non-related species." (WHO, 2009).

The European Union maintained a long "de facto" moratorium against the importation of GM food that ended in 2005. At present, Regulation (EC) No 1829/2003 on GM food and feed lays down the general framework for regulating GM food and feed in the Community. The Regulation is complemented by Regulations (EC) No 1830/2003 and 65/2004 that ensures trace ability and labelling of GMOs at all stages of placing on the market, including the possibility of establishing thresholds. In summer 2009, an evaluation of the EU legislative framework in the field of GM food and feed is in progress and the results are expected for summer 2010. Among others, the socio-economic impact of GMOs (food and feed prices/consumer perception), consumer acceptance as well as the overall impact of the current labelling system and the GM free labelling schemes are some of the key issues that will be assessed.

i. Consumer attitudes

The levels of awareness of novel food technologies are generally low for consumers in Europe, except for GMOs. In a recent Eurobarometer study on public attitudes to various aspects of biotechnology (Eurobarometer, 2005), 80% of consumers in Europe reported that they were familiar with GM foods.

Despite this high level of awareness, the same Eurobarometer survey revealed that 73% of EU citizens were not favourably disposed to GM (Eurobarometer, 2005). The acceptance of GM technology varies depending on their application (Eurobarometer, 2006a). Although GM medicines are widely accepted, there is apprehension about both GM crops and GM foods. Moreover, consumers have been found to be less likely to accept genetic modification to food products that they considered to be natural or healthy (Costa-Font *et al*., 2008) and more accepting of GM technologies using plant based products rather than animal based products (Onyango & Rodolfo, 2004).

According to Costa-Font *et al.* (2008), the European population is found to be broadly more tolerant to GM food in Southern European countries, such as Spain, Malta, Portugal and Italy, as compared to France or the Nordic population. French consumers are considered to be resistant to change and in Nordic countries, consumers find benefits associated with GM food as insufficient to overcome their associated (perceived) risk. The results about the optimistic countries are in line with a previous Eurobarometer survey on biotechnology; and to a lesser extent for the Nordic countries (Eurobarometer, 2006a).

US consumers exhibit a more favourable and trusting attitude towards GM technology than Europeans. US consumers consider GM products that exhibit clear-cut benefits are acceptable and they are less willing to pay a premium for non-GM food than Europeans (Costa-Font *et al*., 2008). Although US consumers preferred non-GM products, they have recently voted against proposals that would prohibit the use of genetically modified inputs, and so did the company stakeholders (House, Morrow, Lusk & Moore, 2001).

Developing countries tend to have positive attitudes to novel food technologies, in particular towards GM (Hoban, 2004). For example, Chinese consumers are willing to pay a premium for GM foods (McCluskey, Grimsrud, & Wahl, 2006). This positive attitude can be explained by greater perceived benefits (due to more urgent needs in terms of food availability and nutritional content, and the opportunity to be competitive in world markets), and lower perceived levels of risk (due to trust in government regulation, positive perceptions of scientific discovery, and positive media influences) (Curtis *et al*., 2004; Huang, Qiu, Bai, & Pray, 2006; McCluskey *et al*., 2006).

ii. Risk-benefit perception of GMOs

The perception of risks and benefits of GMOs vary across Europe. According to a Eurobarometer study, 62% of Europeans convey that they are worried about GM products in food and drinks (very worried: 25% and fairly worried: 37%) but Greece (81%), Italy (77%) and Cyprus (76%) have the highest concerns about genetically modified products in food or drinks. The only three countries where less than half of consumers report that they are worried are; the Netherlands (42%), Finland and Sweden (46% in both) (Eurobarometer, 2006b).

The main perceived risks about GM food are development of super-weeds, unintended effects on human health and the environment ("tampering with nature"), the potential irreversibility of any negative impact, unnaturalness, and the lack of animal welfare (CONSUMERCHOICE, 2008; Frewer *et al*., 2004; Uzogara, 2000).

The highest valued GM-associated benefits are the improvement in shelf-life and nutritional quality, the enhanced flavour modification followed by enhanced nutritional value and pesticide reduction (Loureiro & Bugbee, 2005; Uzogara, 2000). However, consumers make a distinction between the direct benefits for the individual consumers, such as health benefits, and benefits to society more broadly such as environmental benefits (Ronteltap *et al*., 2007). Despite the reported benefits of GM crops to farmers and the environment, these benefits are not perceived by most consumers as being advantageous to them (Batista & Oliveira, 2009) and overall the perceived risks outweigh the perceived benefits (Eurobarometer, 2006a).

iii. Socio-demographic factors

Mixed results were found on the impact of socio-demographic attributes on consumers' acceptance to GM foods (Costa-Font *et al*., 2008). In general, it seems that women and older people are less likely to accept GM foods in Europe and in the US, but not in Canada (Eurobarometer, 2006a; Grimsrud, McCluskey, Loureiro, & Wahl, 2002; McCluskey *et al*., 2006).

According to a recent review, there is no consensus on the role of religion and moral and ethical considerations on consumers' acceptance of nanotechnologies (Costa-Font *et al*., 2008).

iv. Knowledge

Education was demonstrated to have a positive impact on consumers' willingness to purchase GM food in Norway, but a negative impact in Canada, Japan and China, and no effect in the US (McCluskey *et al*., 2006). On the other hand, providing information on the benefits of these technologies was suggested to have a direct and positive influence on consumer perception and helped to reduce public perception of risk from GM applications (Costa-Font *et al*., 2008).

v. Trust

Consumer organisations, environmental groups and scientists seem to be more trustworthy than the biotech industry and government about GMOs, across Europe (Bredahl, Grunert, & Frewer, 1998), the US (Onyango, Ferdaus, Hallman, Schilling, & Adelajan, 2003; Savadori *et al*., 2004) and Canada (Veeman, Adamowicz & Hu, 2005).

vi. Labelling

Over the world, consumers would like to see more labels on GM products (Curtis *et al*., 2004; Frewer *et al*., 2004). In Europe, the European Union has imposed mandatory labelling on GM foods to ensure trace ability and labelling of GMOs at all stages of placing on the market (Regulation (EC) No 1830/2003). A "GM-free" label is quite common in some countries (*e.g*. Poland, Germany) but prohibited in others (*e.g*. The Netherlands). Even if labelling is demanded by consumers, few of them actually look at the labels when buying food and most shoppers do not actively avoid GM-labelled products (CONSUMERCHOICE, 2008).

communication outreach in nanotechnology, highlighted several recommendations to improve communication on nanotechnology (Burnet *et al*., 2008). First, population and stakeholders should be divided into different groups (young people, scientists, journalists, NGOs, business/industry and policy-marker) and targeted with tailored messages. Then, a hands-on approach should be developed, based on for example the cooperation model of school-science museum-labs. Different channels and methods (*e.g*. website, festivals, exhibition, commercialisation-like techniques), should be used to generate dialogue and guarantee the engagement of policy makers. Any promoting intervention should involve passionate people to develop imaginative ways to allow citizens to experience nanotechnology and foster communication from applications, benefits and risks.

Effective communication should also highlight what has been done to mitigate risks. Providing information about enforcement of food risk control, food safety laws and regulations is likely to increase perceptions of control, which in turn may decrease negative risk perceptions (van Dijk *et al*., 2008). Moreover, public perception that authorities

Case study 3: Nutrigenomics

Emerging in 2000 as a new field of research, scientists predict that nutrigenomics could bring about big changes in how food is grown, processed and consumed. Nutrigenomics has been defined as 'understanding how nutrition influences metabolism and maintenance of the internal equilibrium in the body, how this regulation is disturbed in the early phase of a diet related disease, and to what extent the individual genotype contributes to such diseases' (Müller & Kersten, 2003). It is usually based on genetic tests and may also be called personalised nutrition.

i. Consumers' attitudes

A survey performed in six European countries showed that a majority of respondents (66.6%) reported that they would be willing to undergo genetic testing and 27% to follow a personalised diet. Willingness to undergo genetic testing was lower in Germany and higher in the UK. Individuals who answered positively were more likely to report a history of health problems (*e.g.* high blood cholesterol levels, central obesity, metabolic syndrome) (Stewart-Knox *et al.*, 2009). These results may encourage stakeholders to target specific population groups for the development of nutrigenomics applications. In the US, 21% of the population would be unwilling to undergo a genetic test for any reason (Wang, Fridinger, Sheedy, & Khoury, 2001).

ii. Risk-benefit perception

Nutrigenomics may raise consumer concerns regarding the impact of human genetics on the integrity of nature, control over sensitive information to avoid risks of improper use of information (*e.g.* loss of privacy, employment or insurance, commercial exploitation of both the information and the technology) (Ronteltap *et al.*, 2007; Stewart-Knox *et al.*, 2009), and the potential high cost of new functional foods. Canadian research also highlighted that nutrigenomics evoked strong associations with GMOs (Burgess, 2003), so that nutrigenomics requires specific attention and careful communication to consumers.

On the other hand, the benefits of nutrigenomics may be potentially high: maintenance of health (adding health to years), improving performance (*e.g.* in sports) and ultimately longevity (adding years to life). Nutrigenomics may contribute to healthier food consumption and reduction in health-care costs (Ronteltap *et al.*, 2007). However, nutrigenomics will only contribute to the quality of life of end-users if they are motivated and follow their personalised recommendations on food intake (Ronteltap & van Trijp, 2007).

iii. Socio-demographic factors

The willingness to undergo genetic testing seems to be lowest among the 55–64 years age group and highest in the over 65 years age group among the European population (Stewart-Knox *et al.*, 2009).

direct their efforts towards preventing the occurrence of a food safety incident has a greater impact on public trust in authorities than only managing risks (van Kleef *et al.*, 2006).

The role of marketing and advertising in communication strategies for novel food technologies seems to be unexplored. Scepticism among consumers towards use of emerging food technology is probably one reason for this; industry is reluctant to communicate any messages that could provoke negative attitudes towards their products. For example, it has been shown that consumers' flavour ratings of a product decrease if they are told the product is produced by a novel technology. Another example is the use of statements such as "minimally processed" and with "fewer preservatives", which have been reported to be negatively viewed by some consumers (Bruhn, 2007).

Naturalness of foods and their processing methods is recognised to be highly valued by consumers and this is widely used in advertising campaigns and is considered to be a determinant for acceptance of new food technologies (Siegrist, 2008). The most negative effect on perceived naturalness is seen for GM foods. The least negative effect is seen for physical transformations.

It has been suggested that tangible consumer benefits may increase consumers' purchase intentions to buy products produced by technologies towards which there is scepticism (Frewer, Howard, Hedderley, & Shepherd, 1997; Siegrist, 2008). Taste, naturalness, convenience, healthiness, price, environmental and welfare concerns all have a role to play in consumer food choices and can be emphasised in marketing and advertising campaigns as appropriate. Technologies with apparent industry

Case study 4: Food irradiation

Food irradiation is a processing technique that exposes food to ionising radiation (electron beams, X-rays or gamma rays), to kill bacteria that cause food poisoning, to control insect infestation, to delay fruit ripening and to help stop vegetables from sprouting (FSA, 2009). Irradiation is sometimes referred to as "cold pasteurisation" since the result achieved is similar to heat-based pasteurisation, but without the heat. Low to medium doses of radiation successfully reduces bacterial contamination but are not sufficient to affect viruses or toxins. Higher radiation doses are needed to kill all living contaminants creating sterile foods. Such foods are necessary for people with impaired immunity such as patients suffering from AIDS or cancer. Food irradiation is used on more than 60 food types in over 40 countries worldwide (FSAI, 2006).

In terms of legislation, there are two EU Directives (1999/2/EC and 1999/3/EC) relating to irradiated food. Six Member States have notified that they maintain national authorisations for certain foods (*e.g.* fish, meat or eggs). In 1986, 1992 and 1998 the EU Scientific Committee on Food (SCF) issued favourable opinions on irradiation of a range of foods as long as the process was not used to mask a food's unsuitability for consumption or to cover poor handling practices. A joint World Health Organisation (WHO), Food and Agriculture Organisation (FAO) and the International Atomic Energy Agency (IAEA) study group convened in 1997 concluded that food irradiated to any dose appropriate to achieve the intended technological objective was both safe to consume and nutritionally adequate. However, the EU SCF, in an opinion issued in April 2003, recommended that maximum doses of irradiation should continue to be considered for foods on a case by case basis.

Any irradiated food, or food containing an irradiated ingredient within the EU must carry the word "irradiated" in a prominent position either as part of the main label or next to the ingredient that has been irradiated. It may also (optionally) show the international icon for irradiated food called the "Radura" symbol.

i. Consumers' attitude

Public attitudes towards food irradiation are negative (He, Fletcher, & Rimal, 2005a; Cardello *et al*., 2007). Despite the fact that the scientific community recognises food irradiation as a safe and effective process, and extensive education efforts and endorsements given by many health-related organisations worldwide, significant consumer resistance has slowed down the application of the technology in Europe and in the USA (DeRuiter & Dwyer, 2002; Henson, 1995).

ii. Knowledge

A recent analysis suggested that information about the nature and benefits of food irradiation leads to positive changes in consumers' perceptions and buying decisions (Nayga, Aiew, & Nichols, 2005).

iii. Labelling

Any irradiated food or any irradiated food ingredient of a compound food must be labelled with the words 'irradiated' or 'treated with ionising radiation' (Directive 1999/2/EC) (European Commission, 2007). One in three people stated that they would consider an 'irradiated food' label to be a warning and so would try to avoid the product (He, Fletcher, & Rimal, 2005b).

benefits, but with no obvious benefits for consumers, do not show any positive effect on purchase intention (Frewer *et al*., 1997; Søndergaard, Grunert, & Scholderer, 2005). Taste is the factor consistently rated highest amongst consumers as a driver for consumption and repeated purchase of foods. Indeed, improved flavour was the driving factor behind the introduction of the GM tomato Flavr Savr. It has been reported that more than 50% of US consumers are willing to purchase GM foods with improved flavour (Bruhn, 2007). Besides naturalness, flavour was the strongest factor for willingness to buy for nanotechnology-processed foods (Siegrist, Stampfli, & Kastenholz, 2009) and GM cheese (Frewer *et al*., 1997). Convenience is another important driver for purchase of foods in general, and it has been described as the most important motivation for buying minimally processed vegetables (Bruhn, 2007). The effect of price on consumer attitudes towards foods produced by means of new technologies appears to be of limited importance. For willingness to buy nanotechnology-produced foods, naturalness and possible health benefits are in comparison much stronger factors (Siegrist *et al*., 2009). Price is however not a negligible factor for acceptance of novel food technologies. For example, it has been reported that a majority of

Case study 5: Animal cloning

Although it has not been banned, cloning is not a commercial practice in Europe. The European Parliament is calling for prohibiting the cloning of animals for food supply purposes (RSP 2008/259). If the EU were to legislate for a ban on food from cloned animals or to introduce labelling for cloned food, it would have to justify measures to the World Trade Organisation because the European Food Safety Authority has not identified a food safety risk associated with it. In the US there has been a voluntary moratorium on the sale of such products since July 2001.

i. Consumers' attitude

Animal cloning shares some similarities with GM technology in terms of consumers' awareness and acceptance. The knowledge of European citizens on this technology is good, on average (Eurobarometer, 2008; Fell *et al*., 2009) whilst their acceptance is low. While the cloning of human cells and tissues is supported, animal cloning is considered as morally wrong and only one third of European citizens considered it as acceptable, if animal cloning helps to solve worldwide food problems (Eurobarometer, 2008; Gaskell, 2000).

ii. Trust

Even if no commercial applications are available on the European market, the most trusted source of information on the safety of cloned animals from a European perspective are scientists (Eurobarometer, 2005).

iii. Labelling

A Eurobarometer survey dedicated to animal cloning showed that eight out of 10 EU citizens (average 83%, from 71% in Estonia to 94% in Greece) ask for labels if food products from the offspring of cloned animals become available in the shops (Eurobarometer, 2008).

British consumers are willing to purchase a GM product at a certain price (Siegrist, 2008).

Irrespective of its merits, it also seems that even the best intentioned communication can actually have the perverse effect of creating consumer resistance because it increases awareness to what might be previously unknown risks (see for instance Scholderer & Frewer, 2003). One explanation that has been suggested is that the information activates already existing attitudes, rather than changes them. This is then manifested in the choice situation. Labels simply stating "genetically modified" are unlikely to trigger existing attitudes to any large extent. However, classically designed information material, *i.e*. material providing pieces of information selected by experts according to what they think consumers should know, may differ from what the consumers want to know or have concerns about, according to the "deficit model". Thus, an alternative approach could be to develop information material based on consumer needs and wishes, and thereby increase the chances to convey a message which positively impacts on attitudes and product choice (Scholderer & Frewer, 2003). For example, increased knowledge about food safety, as well as label information on safety and handling, has been shown to increase consumers' intention to purchase irradiated meat products (Rimal, McWatters, Hashim, & Fletcher, 2004).

In conclusion, stakeholders and policy-makers should adopt a proactive approach towards consumers, combining appropriate stakeholder forums aimed at tackling the issues head-on by informing, and public consultation at the early stage of development (Chaudhry *et al*., 2008; European Commission, 2004). Keeping in mind that extensive worldwide debate over GM foods and related issues hasn't resulted in consensus over GMOs yet (Batista & Oliveira, 2009), the increase in public acceptance in new technologies may be a long-term process. When it comes to advertising and marketing to consumers about new technologies, campaigns that incorporate improved, convenience, naturalness, taste and benefit for the consumer could have a positive impact on consumers food choice, particularly when the message is concise and from trusted sources.

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