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10. Societal issues and public attitudes towards genetically modified foods

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10.1. Introduction

Public perceptions and attitudes about emerging biosciences and other new technologies are among the most important factors determining the likelihood of the successful development and implementation of technology. As well as considering the psychological determinants of people's perceptions and attitudes, it is necessary to consider public trust in institutions (both those concerned with regulatory matters and those concerned with the strategic development of science). Failure to do so may have a negative impact on genetic technology and its applications. While it is important to develop best practice in science communication about the risks and benefits of genetically modified food (GMF), this alone will not result in public confidence. Rather, it is becoming important to look at new ways to involve the public explicitly in the debate about technology innovation and commercialization, and to rethink the somewhat uneasy relationship between science and society.

The aim of this chapter is to consider how the public think about emerging biosciences, in particular genetic modification of foods, and to consider what implications public attitudes have for the development of best practice in regulation and how scientific innovation proceeds and develops. The intention is not to consider what is driving public concern *per se* but rather to consider how public attitudes impact on technology acceptance and their implications for institutional reform. Attention is paid to understanding why due account should be given to public perceptions and attitudes when considering innovation and the commercialization of the products of emerging technologies. Particular emphasis is given to discussion of public risk perception, and why public attitudes to risk may differ from those held by technical risk experts. This is particularly important as, while it is technical expertise that has driven regulatory processes, it is the non-expert public who decide the acceptability of both regulation and the consumer products associated with technology innovation processes. However, the discussion herein does not include any review of the wider debate about socio-economic issues, as may be promoted by non-governmental organizations (NGOs) and other such bodies.

Research investigating public opinion about emerging biosciences, such as genetic modification of foods, is reviewed, together with other empirical investigations into public attitudes relevant to predicting whether technology acceptance will occur. However, as few data are currently available on consumer attitudes in developing countries, this topic is not discussed extensively; this gap in knowledge should be addressed as a matter of urgency.

It is recognized that increased understanding of how best to introduce emerging technologies, such as genetic modification, has raised new issues in the complex relationship between science and society (Frewer & Salter, 2002). Increased public distrust (both in the processes of science and in scientific and regulatory institutions) has been identified as a key driver of public negativity towards different applications of biotechnology in general, and GMFs in particular.

Finally, the discussion focuses on the development of institutional mechanisms and structures that can be applied to integrate the 'values' held by members of wider society into the processes surrounding regulatory decision-making and scientific innovation. Some recommendations for policy, which follow on from this discussion, are provided. Whilst the focus of the chapter is on GMFs, the key issues raised and the conclusions drawn are likely to be generically applicable to other areas of science and technology policy.

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10.2. Attitudes

10.2.1. What is meant by the term 'attitude'?

A useful first stage for the purposes of the current discussion is to define what is meant by the term 'attitude', and to describe some of the theoretical contexts in which attitude research is embedded. The accepted definition of 'attitude' is 'a psychological tendency that is expressed by evaluating a particular entity with some degree of favour or disfavour' (Eagly & Chaiken, 1993). In this case, a 'psychological tendency' is defined as the internal psychological state of an individual. The cognitive, affective or behavioural responses that result from the attitude relate to the 'process of evaluation'. Thus psychological tendency might be thought of as a psychological bias that predisposes the individual towards positive or negative evaluative responses. Evaluative responses are those that express approval or disapproval, liking or disliking, approach or avoidance, attraction or aversion, and so forth.

Thus, an individual who holds a negative attitude towards GMFs, for example, may use cognitive, affective or behavioural responses to reject GMF products or may display other behaviours that are congruent with this attitude. An example of such a cognitive process might be selective processing of information about genetic modification such that only negative information is processed by the person receiving the information. An affective response might be a feeling of negativity or anger towards genetic modification and its proponents. A behavioural response might be avoidance of GM products through food choice. Conversely, an individual who holds a very positive attitude will exhibit very different evaluative responses consistent with such an attitude.

Attitudes have been used to explain why some people support particular social policies, ideologies, or technological advances, whilst others oppose them. A person who favours a particular policy is said to hold a positive attitude towards it, whereas someone who opposes it would hold a negative attitude. Attitudes are not directly observable but can be inferred from observable responses such as responses to questionnaires or interviewers (MacCorquodal & Meehl, 1948).

Evaluative responses and the psychological tendencies that are assumed to underlie them differ not only in terms of direction (positive or negative) but also intensity (a very positive evaluation is likely to have a very different impact on behaviour than is a slightly positive one). Thus social scientists usually measure attitudes along a bipolar continuum that ranges from extremely positive to extremely negative and includes a neutral reference point. In very broad terms, people who hold positive attitudes towards an object, event or situation are likely to associate it with positive attributes and are unlikely to associate it with negative attributes. In contrast, people who negatively evaluate an object, event or situation are more likely to associate it with negative attributes than positive ones (Eagly & Chaiken, 1993).

Social scientists have devoted much effort to the study of people's attitudes towards social and technological policies, such as racial harmony or the use of nuclear energy. Attitudes towards relatively abstract concepts (for example, the integrity of nature) have also been of interest and are normally termed 'values'. Both attitudes and values should be considered when investigating people's responses to different objects, events or situations, as both are likely to influence an individual's evaluative response.

10.2.2. Changes in attitudes

Attitude change may occur when an individual receives some additional information that will influence either the extent of the attitude's strength or its direction. There is some evidence that attitudes may be changed through direct exposure to an object, event or situation. In the case of foods produced with novel technologies, a person who has a very negative attitude towards the technology may develop a more positive attitude following experience with products made with the technology. Of course, the converse may be true: a positive attitude may become more negative if a person's experience with the object of the attitude is negative. In the case of food products, such a negative experience may include failure to deliver promised benefits. However, often attitude changes following direct exposure to the object of the attitude are difficult to detect because other contextual factors associated with the event mask the change. In the case of GMFs, such contextual factors may include, for example, an individual's interpretation of the information provided about a GM product or beliefs about the motives of information sources or societal actors, such as industry or regulators with responsibility for technology implementation. Exposure to a GM product in itself may provide information about the characteristics of the object; however, this will only produce attitude change if the new information is very different to what is already known about the product (Stroebe, Lenkert, & Jonas, 1988).

Theories of social influence provide a theoretical framework in which to examine an individual's attitude change following their receipt of 'persuasive' information. A position is advocated by an information source, and different messages are presented by the same information source to support this position. Persuasion frequently focuses on counter attitudinal-communication (advocating a position that is very different to those attitudes already held by the individual receiving the information). Theories of persuasion use the processes or variables that mediate the impact of communication on attitudes and beliefs. Hovland (1959) has argued that, if people do not attend a message (e.g. if they are not motivated to so do because the information is not useful

or interesting), attitude change will not occur. Similarly, if they are unable to comprehend the information, despite being highly motivated to do so, then their attitudes will not change.

People may also use two different routes to processing information (Petty & Cacioppo, 1986). The first is the central route to persuasion, in which people spend a considerable amount of effort on critically evaluating the message content. However, if people are loath to expend this amount of effort on processing message contents, they adopt peripheral routes to persuasion and do not process the information with any effort or in a critical way. For example, information sources that people trust or like may result in more positive evaluation of the message the source provides (Eagly & Chaiken, 1984). Petty and Cacioppo (1986) have proposed that attitude change will be the result of both the amount of thinking relevant to the message and the extent to which people agree with the information. For messages that elicit favourable thoughts, increased elaboration (i.e. increased thoughts about the message content) should increase persuasion. In contrast, if messages elicit mainly negative thoughts, increased processing should reduce persuasion. From this, it might seem that simply telling people that products are safe is unlikely to provide the reassurance that would result in public support of GMFs, unless such a belief is already strongly held by those people receiving the message or they trust the information source providing the information. Indeed, individuals who perceive that GMFs are risky may actually become more negative towards them if they receive information that they believe is biased in a particular direction (Frewer, Howard, Hedderley, & Shepherd, 1999).

10.2.3. Risk perception and associated attitudes

The way in which a person perceives the risks associated with a particular hazard will have a direct impact on their attitudes towards that hazard. It has long been recognized that risk perception is socially constructed, and that it is the psychological representation of risk that defines people's responses to a particular hazard, rather than the technical risk estimates traditionally provided by experts. Research conducted by Slovic and co-workers has consistently demonstrated that factors such as whether a risk is perceived to be involuntary, potentially catastrophic or uncontrollable are more important determinants of public response than technical risk estimates (e.g. see Slovic, 1993; Slovic, Fischhoff, & Lichenstein, 1980). Understanding risk perceptions is probably the most important first step in the process of understanding public attitudes towards the different processes and technologies used in agriculture and food manufacturing.

It has been argued that the ways technical risk experts and lay people think about the risks associated with different hazards are very different (e.g. Barke & Jenkins-Smith, 1993; Lazo, Kinnell, & Fisher, 2000; Mertz, Slovic, & Purchase, 1998; Slovic, Malmfors, Mertz, Neil, & Purchase, 1997). It is generally acknowledged that expert communities drive risk communication processes and message content (FAO, 1998). It might be predicted that risk communication based on technical risk information alone would appear irrelevant to the general public, as it would not address their real concerns. For example, Sjöberg, Truedsson, Frewer, and Prades (2000) report that experts and the public have a similar attitudinal structure about estimation of the magnitude of a risk but differ considerably in their level of perceived risk. This assumption has been criticized. Rowe and Wright (2001) have identified what they describe as methodological weaknesses in the empirical research supporting the notion of differences between expert and lay representations of risk. Criticisms are related to the definition of who exactly is included in the 'expert' group and how the demographic profile of the expert group differs from the general population. For example, inspection of the literature indicates that more women may be allocated to 'non-expert' groups and that the expert groups may have a disproportionately high percentage of men. As women have been generally found to rate risks as being greater than do men (Kraus, Malmfors, & Slovic, 1992) this may explain differences in risk ratings between expert and non-expert groups. However, if gender differences actually do exist between the composition of expert groups relative to the general population and it is these expert groups that drive communication processes, then the demographic differences become irrelevant in terms of the how risk communication is practised, as it is driven by expert conceptualization of risk. It is those expert groups who decide what is communicated. In addition, gender differences have been found even within expert groups (Slovic *et al*., 1997).

There is some evidence that, in the area of technology innovation, people will tolerate risk if they perceive some direct benefit to themselves, rather than to other demographic groups, producers, or industry (Frewer, Howard, & Shepherd 1998a, 1998b). Indeed, there is evidence of an inverse relationship between perceived risk and perceived benefit associated with different hazards (Alkhami & Slovic, 1994). From this, it might be concluded that, as long as a risk is not so large as to be completely intolerable, an individual's acceptance of a particular technology will be driven by perceptions of personal benefit. There is some evidence that this occurs with GMFs (Frewer, 2000; Frewer *et al*., 1997), as well as other technologies (Da Costa, Deliza, Rosenthal, Hedderley, & Frewer, 2001), although the relationship is not straightforward. It is frequently argued that consumer rejection of GMFs was the result of the products initially introduced into the marketplace having very

small or no consumer benefits. Although this is likely to be a contributory factor to consumer rejection, it is probably an oversimplification to assume that the public will automatically be very positive towards products that do have a tangible consumer benefit. This argument fails to take account of people's risk perceptions and individual differences in perceptions of what actually constitutes a consumer benefit. Nonetheless, in the current climate it is unlikely that the public will be positive about a GMF product that does not have a consumer benefit of some type.

The issue of consumer benefit has been debated by policy makers. Policy documents (European Commission, 2000; OECD, 1994), expert consultations (European Federation of Biotechnology, 1997, 1998; Scholderer, Balderjahn, Bredahl, & Grunert, 1998; Scholderer, Balderjahn, & Will, 1998, 1999) and technology development reviews (Jongebreur, 2000; Tengerdy & Szakacs, 1998; Uzogara, 2000) have reported that two types of benefit are generally believed by the expert community to have the greatest potential to improve consumer acceptance of GMFs. These relate to sustainability claims (based on process innovations that enable reductions in energy expenditure or discharge of pollutants during primary production, manufacturing, or processing of foods or will benefit disadvantaged populations in some way, for example in developing countries) and health claims (based on the presence of functional ingredients or the absence of dysfunctional ingredients in the product and thus referring to innovations with direct consumer benefits in terms of improved health).

Scholderer and Frewer (in press) have demonstrated that neither type of benefit is persuasive for the acceptability of specific GMFs when consumers are presented with concrete product examples of genetic modification exhibiting these traits. This is almost certainly because consumers are not homogenous concerning what they regard as a personal benefit, and perceptions of what actually constitutes a benefit are likely to vary between individuals.

10.3. Perceptions and attitudes associated with GMFs

10.3.1. Research into public perceptions and attitudes associated with GMFs

Many opinion surveys have been conducted in Europe and elsewhere. These have attempted to pinpoint likely consumer responses to GM products (Zechendorf, 1994). Comparative analysis between different surveys conducted in different countries or at different times is problematic owing to the use of different methodological approaches in the different surveys. A further problem with consumer opinion polls is that they provide little information about the underlying attitudes and values that drive public reactions to genetic modification and its applications. Finally, it is difficult to predict from the results of such surveys what the impact of opinions on people's actual behaviours might be. Despite these problems, opinion polls have some value in charting very broad changes in public attitude in time and place.

One of the most extensive public opinion surveys conducted in Europe, in terms of the number of people surveyed, is the Eurobarometer survey, last conducted in 2001.[1] The Eurobarometer has been monitoring changes in attitude towards biotechnology in different European member states since the early 1990s (see, e.g., 1997 report[2]), although the Eurobarometer survey itself has been implemented since 1973. The 2001 Eurobarometer questioned over 16 000 Europeans about their opinions on biotechnology between 10 May and 15 June 2001. It was reported that, in general, Europeans had a positive view of science and technology, but no longer regarded scientific advance as a universal panacea for all problems. However, attitudes towards GMFs, specifically, were more negative. Of those sampled, 95% were concerned about the consumer's lack of choice about consuming GMFs, and 60% expressed the view that GM organisms had the potential to have negative effects on the environment. Furthermore, the survey found that, for some respondents, increased scientific knowledge about genetic modification was linked with preferences for greater regulatory control and safety analysis. The report notes that women perceived greater risks than men, and older respondents perceived more risks than younger respondents. It was thought that the latter observation might reflect differences in risk perception associated with increased risk aversion in the older group, rather than an effect that would mature as the youngest respondents got older. Differences between European member states had not been analyzed at the time of writing. However, an earlier Eurobarometer indicated that, in general (with the exception of Finland), consumers in northern Europe tend to express more concern about the risks of genetic modification of food than those in southern Europe. It is possible that northern Europeans are more risk adverse, whereas consumers in southern Europe may be more concerned about any potentially negative impact of food technology on food quality. Such broad generalizations almost certainly fail to take account of the value systems that drive consumer behaviour. For example, ethical concerns about GMFs appear to be

[1] European Commission (2001) *Europeans, Science and Technology* (Eurobarometer 55.2), Brussels, European Opinion Research Group, available (January 2003) at http://europa.eu.int/comm/research/public_opinion.

[2] European Commission (1997) *The Europeans and Modern Biotechnology: European Opinion on Modern Biotechnology* (Eurobarometer 46.1 Biotechnology), Bruxelles, European Commission, available (January 2003) at http://europa.eu.int/comm/public_opinion.

important in both Italy and the UK, and it is essential that assessment of consumer attitudes extends beyond the debate about risk in isolation to other cultural factors that are important in determining people's food choices (Saba, Moles, & Frewer, 1998).

In 1997, the Eurobarometer survey was conducted in New Zealand, Japan and Canada, and data were compared with European data (Macer, Bezar, Richardson-Harman, Kamada, & Macer, 1997). The results of the survey indicated that New Zealanders were more positive about the use of agricultural applications of genetic modification in the context of specific applications (i.e. when they were asked to think about concrete and tangible applications as opposed to agricultural biotechnology in general) than some European countries or Japanese populations. Although statistically significant, the magnitude of the difference was not great. Of interest was the finding that New Zealanders, in common with most Europeans, tended to express doubts about the adequacy of risk management regulations. Even in Canada, where more people were convinced by the adequacy of regulatory practices, those supportive of current practices still were in the minority. A common finding across almost all of the countries surveyed was the belief that regulation was best developed and implemented at an international level by transnational bodies (for example, the World Health Organization or the United Nations) rather than by national regulatory institutions.

The received wisdom is that in comparison with other developed countries people in the USA are less concerned about GMFs although such assertions are often not backed by empirical evidence (see e.g. Braun, 2001). Furthermore, fewer data are available to compare the USA with other countries than, for example, are available to compare public opinion between different European Union Member States. However, a survey conducted in 2000 demonstrated that North American public opinion about the acceptability of GMFs is equivocal (Priest, 2000). While 53% of respondents believed genetic engineering would improve their quality of life over the next 20 years, 30% thought the technology would make things worse. When food biotechnology was considered specifically, a considerable degree of polarization was observed, such that most respondents either responded positively or negatively, but few responded neutrally or gave a 'don't know' response. A key finding was that many respondents did not appear to have confidence in US regulators concerning the safety of GMFs, although confidence in consumer groups and the food industry was generally high.

Aubert (2000) has noted that, with increasing consumer concern about GMFs in the developed world markets, multinational companies with interests in the novel food sector have turned to the developing countries, where there are greater requirements for increased food production. Presumably it is argued that these requirements may be met through genetic modification. Aubert has commented that resistance to the introduction of GMFs is growing in the developing world as well as in developed countries. This is attributed to international and national NGO activity that opposes the implementation of genetic technologies in agriculture. For example, in Brazil, at the request of consumer organizations, several states have signed a moratorium suspending the planting of GM crops. In India, various NGOs are questioning the argument that GMFs are an important weapon in the fight against hunger in developing countries, on the basis that India has a national food surplus although numerous local shortages. These groups are proposing that solutions to poverty are more likely to be related to increasing the effectiveness of distribution systems than increasing crop yields. At present, there is little information about the impact of NGO activity on local public opinion about technology implementation and GMFs, although this question is worthy of further investigation.

It is important to emphasize that public opinion about technology implementation is dynamic, and likely to change, as more information is made available about the benefits, risks, societal impacts and other factors relevant to acceptance of the technology in question. Thus it is difficult to generalize at a given point in time about the potential for long-term public acceptance (or otherwise) of a particular technology in different countries relative to each other. However, results from social research can help the formulation of clear recommendations for best practice in developing effective communication about a particular technology and its applications. It is important to understand what drives public concerns associated with a particular technology, and to address these concerns as an integral part of the communication process, as discussed below.

10.3.2. Specific public concerns about transgenic technologies

One problem in using opinion poll methodology to provide information for policy formulation is that questions may not reflect people's actual concerns, but rather may introduce people to what, to them, are irrelevant or unknown concepts, which are thought to be important by the researcher developing the study. In part, this is the result of the application of existing theoretical models of attitude, which constrains the selection of questions included in surveys (see e.g. Sparks, Shepherd, & Frewer, 1995). However, asking members of the public to rate items that are irrelevant to them is unlikely to provide information meaningful to questions about technology acceptance. Furthermore, Heijs, Midden, and Drabbe (1993) have criticized much previous research because it does not provide insight into the reasons underlying responses to questions.

The use of qualitative methodology provides the opportunity for respondents to express their concerns in their own words, which can them be developed into survey instruments used to assess larger, more representative populations. Frewer *et al.*, (1997) reported research results developed using semi-structured qualitative methodology, which completely relied on respondent generated responses. The research indicated that the extent to which people are concerned about genetic modification is dependent on many factors, each specific to the nature of the application. Minor modifications to food products were associated with moderate concern but, at the same time, the need for them and the advantages they offer were rated as low. Risk and high levels of ethical concern were associated with modifications involving animals or human beings, independent of whether they were related to food, agriculture or medical applications. Medical applications, such as pharmaceuticals and applications relevant to hereditary disease, were perceived to be the most important and necessary (Fig. 10. 1).

In a separate study, conducted in 1996, Miles and Frewer (2001) focused specifically on the use of genetic modification in food, using a semi-structured interview technique that permits the linkages between different concerns to be 'mapped' out diagrammatically. In broad terms, people's beliefs fell into three groups. The largest group of concerns (including long-term effects, unintended effects, and the potential to harm future generations) was linked to concerns about health. The concern that genetic modification represented 'tampering with nature', in some way, related to the potential for unintended effects not only on human health but also in animal welfare and the environment. A second group of beliefs related to perceptions that genetic modification of food was not under the control of the consumer. In particular, respondents expressed the view that consumers had no way to choose whether they ate GMFs or not, and that industry would put profit before safety. Linked to this was the notion that the technology in general was potentially unsafe when applied to food production. The third group of beliefs was linked to perceived benefits, including reduced costs and wastage, and increased shelf life.

When introducing any new, potentially controversial technology, it is extremely important to provide information that addresses the concerns of the public directly, rather than information that focuses on technical risk estimates alone. Information must be relevant and important to consumers if they are to read it and think in depth about the contents, in a way that will form the basis for informed choice. If, for example, consumers are very concerned about ethical issues, and the information does not address these, relevance is reduced and people do not read the information properly, nor think about its content (Frewer *et al.*, 1999). In

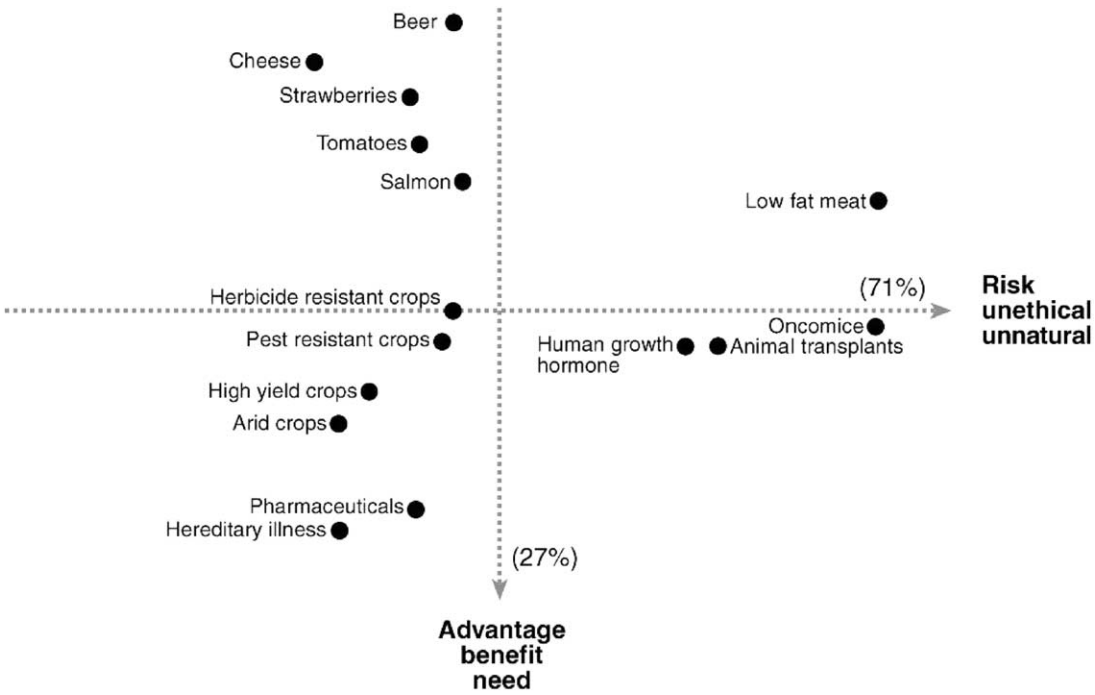

Fig. 10.1. Public concerns about different applications of genetically modified foods. Conceptually, people distinguish between applications involving plants and microorganisms against those involving animals and human genetic material. Perceptions of risk and ethical concern may be mediated by perceptions of need or benefit, particularly if those applications are related to medicine. Note that these data were collected before the recent debate about human cloning in 2001, which may have refocused attitudes towards the use of biotechnology in medicine for some individuals.

the past, communication activity associated with GMF has focused on the issue of substantial equivalence. If consumers are actually more concerned about the potential for negative environmental impact or other unintended effects associated with genetic technology, this information may have appeared, at best, irrelevant to consumers, and at worst may have seemed to be an attempt by the information source to hide from the public what the public perceived to be the 'real' risks of the technology.

10.4. Public and ethical concern about genetic modification

Just as public risk perceptions are now regarded as providing legitimate inputs into the strategic development of the new biosciences, it is also important to understand the ethical concerns that the public may have about GMFs. It is essential to understand how the public think about and conceptualize important elements of the ethical issues associated with biotechnology, in order to foster consensus building regarding its long-term application. For example, the philosophical distinction between ethics and morality may not be meaningful to non-experts and thus may not contribute to public discourse about issues of concern. Cross-cultural differences are also important, particularly in the light of the globalizing economy. What is considered ethically problematic in one culture may be acceptable in another. Public opposition to genetic modification may focus on arguments that genetic modification is intrinsically wrong when applied to food-related applications; however, when genetic modification technology is used in a medical context, ethical concerns may arise only in the cases of specific applications (Frewer & Shepherd, 1995).

Demarcating different 'publics' according to how they think about ethical concerns is also important, if the continuing process of the democratisation of scientific development is to involve the European population as a whole. Such demarcation must go beyond religious issues and identify the way in which ethical concerns have evolved within particular interest groups (Hoban, Woodrum, & Czaja, 1992). The debate about cloning, for example, is of great importance to many religious groups, and Maori groups are particularly concerned about the potential for scientific practice to impact on the natural environment, which they consider sacred, whereas, at the same time, Miles and Frewer (2001), for example, report that many members of the public express loosely defined ethical concerns about genetic modification that are not necessarily religious in origin (e.g. people state that they believe that the technology is 'interfering with nature' or that they 'don't agree' with genetic modification).

The way in which the public understand and articulate ethical concerns related to emerging technologies is an area worthy of further research. Whilst there is evidence that ethical concerns are extremely important in determining whether an individual will accept genetic modification technologies or not, it is likely that the value systems which drive ethical worries of the public might be very different to those identified by professional philosophers. Public conceptualization of the ethical debate associated with all of the biosciences might usefully be incorporated into the regulatory framework in which the technology is contained. By so doing, public trust in regulation and biotechnology, itself, is likely to be increased.

Of course, the value systems that people have that drive risk perceptions and associated attitudes are also subject to temporal change. For example, it has been assumed that people's concern about the potential for negative environmental impact is an important determinant of consumer negativity associated with a particular food production technology. Although this was certainly true in the early 1990s, it appears to be of lesser importance now. This may be an oversimplification of how societal values influence technology acceptance (Von Avelsleben, 2001).

Newholm (2000) has suggested that relatively small changes in buying patterns may be indicative of new ethical dilemmas or concerns emerging within society, and may be useful indicators of emerging and changing attitudes to technology innovation. However, monitoring economic changes in consumer behaviour does little to inform regulators and science policy unless there is also a qualitative analysis of why these changes are occurring.

10.5. The importance of trust

10.5.1. Considering the politics of technology acceptance when developing new products and processes

> "Risk managers have become keenly aware that in democratic countries (public) perceptions of a technology's risks and benefits are important components of the... political decision process, from initial decisions to developing a technology or product, to the acceptance of management approaches to risk mitigation" (Siegrist, Cvetkovich, & Roth, 2000).

Siegrist (1999, 2000) has demonstrated that trust in companies and scientists conducting research in the area of gene technologies has a strong effect on the risks and benefits perceived to be associated with those technologies. It is reasoned that the more an individual trusts the biotechnology industry and scientists conducting research within biotechnology to have the interests of the general population and environment at the forefront of their activities, the less risk and more benefit is perceived

by the public to be associated with their scientific endeavours, if the public trust is high.

It is important to distinguish between the concepts of 'social trust' (which has origins in sociopolitical analysis) and 'source credibility' (which is derived from empirical work within applied social psychology), reviewed by Johnson (1999) and Renn and Levine (1991). 'Social trust' refers to people's willingness to rely on experts and institutions in the management of risks and technologies (Cvetkovich & Lofstedt, 1999). 'Source credibility' refers to people's perceptions of the motivations of institutions or individuals providing information to the public.

10.5.2. Social trust

In the field of biotechnology, as in other areas of science, public trust is a statement about the legitimacy of processes of scientific investigation as well as the technical applications of a particular technology. It is currently recognized that public trust and confidence in a particular scientific activity, as well as in regulators and regulatory institutions, are likely to be important determinants of technology acceptance. If regulatory institutions fail to convince the public that their interests and those of the environment are being protected, it is likely that public confidence in a particular arena of science and technology will decline. This will produce a negative impact on the regulatory institutions involved, an increase in the economic vulnerability of the industrial sector associated with the particular technology, and potential for the escalation of critical media interest (Frewer & Salter, 2002). Scientific authority has lost much of its past credibility, at least in the UK (Office of Science and Technology, 1998). People no longer trust scientific endeavour to be legitimized by reference to the technical estimates about risk that scientific institutions themselves produce (Cabinet Office, & Office of Science and Technology, 1999). However, there is some evidence that differences in trust exist between different European countries, with the Scandinavian public being more likely to trust government than do people from the UK and southern Europe[3] (Miles & Frewer, 2002; Sjöberg, 1999).

It is arguable that, without public trust, long-term development of the biotechnological industry will be problematic, whether in the agriculture, food or health sectors. Increasing public distrust in science and scientific institutions has been of concern to regulators and politicians, who depend to some extent on the development of a successful interface between science and wider society. Frewer and Salter (2002) have commented that trust has historically been less of a concern to the research community who, in the debate about biotechnology, appear to have been the most unprepared for the public reaction against the use of genetic engineering in agriculture and food production.

At present, individual governments decide how to integrate international agreements within their own national systems of biotechnology regulation and legislative frameworks (Wheale, 1999). Obviously there is scope for one country to offer a more sympathetic regulatory environment than another, in order to attract inward investment from multinational biotechnological concerns. However, increased disharmony between national regulatory systems might be predicted to increase public distrust in biotechnology, as what is considered 'safe' within one regulatory framework may fail to meet more stringent safety regulations in another. This indeed seems to have been the case in the agrofood sector in the past (Frewer, 1999), and perhaps indicates the need to develop a system of governance to be implemented at a global, rather than a national level. However, demand for public inputs into local regulatory activity may militate against global governance (Royal Commission on Genetic Modification, 2001).

10.5.3. Trust in information sources

Theoretical perspectives on the potential impact of source credibility on reactions to information have a long tradition in social psychological research, and the importance of source characteristics is recognized in models of communication and attitude change (McGuire, 1985). In contrast to the concept of social trust, source credibility is usually assumed to be multidimensional and specifically dependent on both the information source and the subject under consideration. Two major dimensions have emerged as being important in determining trust, namely 'competence', the expertise held by the communicator and the extent to which they are able to pass on information about a particular subject area, and 'honesty', the extent to which a communicator will be truthful in communication of information. Hovland, Janis, and Kelley (1953) have identified two similar dimensions that have been distinguished in the literature, namely 'expertise' and 'trustworthiness'. Here, expertise refers to the extent to which a speaker is perceived to be capable of making correct assertions, whilst trustworthiness refers to the degree to which an audience perceives the assertions made by a communicator to be ones that the speaker considers valid and truthful.

Expertise without honesty is unlikely to result in long-term changes in attitude. The psychological determinants of trust may be very different to determinants of distrust (Frewer *et al.*, 1996). Trust appears to be linked to perceptions of accuracy, knowledge and concern with public welfare. Distrust is associated with perceptions

[3] European Commission (1997) *The Europeans and Modern Biotechnology* (Eurobarometer 46.1 Biotechnology), Bruxelles, European Commission, available (January 2003) at http://europa.eu.int/comm/public_opinion.

that an information source is deliberately distorting information, is promoting a biased view of reality, and has been proven wrong in the past. Sources that are perceived to be over-accountable or protecting a vested interest are not trusted to the same extent as sources that are not associated with such attributes. However, perceptions that a source is not accountable at all may also lead to distrust. In the UK, government and industry sources are distrusted, NGOs and environmental pressure groups and the quality media are highly trusted. The effect of trust in information sources providing risk information about a specific potential hazard (as opposed to institutions responsible for public protection) on perceived risk is less well understood (Frewer *et al.*, 1998a, 1998b). It might be that trust in an information source providing information about a particular risk may be a particularly important determinant of public responses to that information. The evidence to support this hypothesis has been equivocal. An alternative prediction might be that trust in an information source is unlikely to be very influential for potential hazards where people already hold very extreme attitudes about a particular hazard. Under these circumstances, people are more likely to assess the information with which they are presented, to see if it aligns with the view that they already hold. If it does not, they change their opinion about the information source rather than change their attitudes towards the hazard (Frewer *et al.*, 1998a, 1998b; Frewer, Scholderer, & Bredahl, in press).

Trust in information sources has been specifically examined in the context of GMF products by Frewer, Scholderer, and Bredahl (in press). It was hypothesised that public attitudes towards emerging technologies are driven by trust in institutions responsible for regulating genetic engineering. A second hypothesis, that trust is actually a consequence of people's responses to information about GMF, was also tested. The empirical work (conducted in Denmark, Germany, Italy and the UK) suggested that the extent to which people trusted information sources appeared to be driven by people's attitudes to GMFs. Trust in information sources did not drive people's reactions to the information. However, it was thought that people's attitudes to genetic modification technology might be informing perceptions of the motivation of the source providing the information. Thus providing information about risk and benefit associated with GMFs alone is not a sufficient condition to promote attitudinal change within the public.

Scholderer and Frewer (in press) suggest that, in the past, communication strategies aimed at facilitating consumer acceptance of GMFs have focused on 'technology-driven, top-down' practices. That is, communication has been driven by technical risk assessments rather than information salient to the wider, non-expert public. Providing information about the benefits of GMFs has failed to convince consumers of the merits of such products. In brief, the information strategies used in the research were based on expert views of what would convince the public of the merits of GMFs. Such communication tends to promote the idea that people need to be 'educated' about the benefits of a technology (Doubleday, 2001). As a result, information tends to focus on the benefits alone, which may not be relevant or important to consumers or convince them that the sender of the message does not possess a vested interest in promoting the technology.

In the past, it has been assumed that people's reactions to risk information will depend on their level of trust in the institution or individual providing that information, although this is not necessarily the case (Eiser, Miles, & Frewer, 2002). Information from a trusted information source, which reassures people of the safety of a potential hazard, will reduce perceived risk. The same information from a distrusted source may increase perceived risk. It has also been assumed that alarming information will not influence risk perceptions if the information is from a distrusted source. However, empirical analysis (Eiser *et al.*, 2002) indicated that trust did not directly influence risk perception. Trust and perceived risk independently influenced people's attitudes towards gene technology. The research provided support for the notion that the prior attitudes people hold about a hazard might also influence people's interpretation of risk communication information. These processes create a positive feedback cycle that helps explain the stability and resistance to change of people's attitudes to particular hazards, under circumstances where these attitudes have 'strength' and are well established.

10.6. Communication

10.6.1. Communicating uncertainty

There is some evidence that people may be concerned that there is the potential for genetic modification of food and crops to be associated with unintended effects on either human health or the environment.

Uncertainty associated with scientific and technological endeavours exists when the communicator does not have perfect knowledge about a risk (or benefit) associated with that technology (Viscusi, Magat, & Huber, 1991; Johnson & Slovic, 1995, 1998), and consideration of uncertainties forms part of risk management practices. It has been argued that a better understanding of uncertainty in risk and how people deal with uncertainty (both analytically and as part of their everyday lives) is a prerequisite for better decision-making in situations involving uncertainty (Rowe, 1994). Failure to disclose uncertainty information may have a negative effect on public confidence (Anand & Forshner, 1995). There are various types and causes of uncertainty (Haimes, Barry, & Lambert, 1994; Peterman & Anderson, 1999; Woodward

& Bishop, 1997). Some research has indicated that there is a negative impact of scientific disagreement on public risk perception, although 'negative' in this context indicated increased concern about the consequences of the risk should it occur (reported in Pidgeon & Beattie, 1997). There does appear to be a public preference for information about risk uncertainty (Eldridge *et al.*, 1998; Jasanoff, 1997). Wynne (1992) argues that 'scientific knowledge' deals with a restricted agenda of defined uncertainties, with a range of other uncertainties left unspecified. Wynne refers to these unspecified uncertainties as representing 'scientific ignorance' (perhaps equitable to unintended effects in the case of gene technology applied to food production and agriculture) and notes that scientific ignorance becomes a problem when scientific knowledge is misunderstood and policy language

> "falsely reduces the full range of uncertainties to the more comforting illusion of controllable, probabilistic but deterministic processes."

Wynne further notes that the scientific uncertainties inherent in decisions about many potentially hazardous events can be accentuated by the social context in which they occur, for example public trust in or conflict between risk regulators and other actors in the debate (e.g. NGOs). Examination of the literature indicates that there are various arguments as to why communicating uncertainty is a positive activity, as well as why uncertainty should not be communicated (Johnson & Slovic, 1995, 1998). However, it has been suggested that presentation of uncertainty information could enhance the credibility and trustworthiness of the source presenting the information. Acknowledging uncertainty associated with different hazards may improve public confidence in the quality of scientific output. In addition, presenting uncertainty information may allow the public to make more informed decisions (Johnson & Slovic, 1995). These authors suggest that people expect regulatory action to mitigate the risks of potential hazards, even under conditions of uncertainty, and they may suspect that the topic of uncertainty is being raised merely to justify inaction, particularly in cases where the uncertainty refers to whether there is a risk present or not (Johnson & Slovic, 1998).

The effects of information about uncertainty on public perceptions of the motives of information sources are equivocal. Fessenden-Raden, Fitchen, and Heath (1987) found that admissions of uncertainty might be perceived by the public as ignorance, evasiveness or an attempt to hide the 'truth' about risk. Against this, Frewer *et al.* (1998a, 1998b) found that reference to uncertainty by both well and poorly trusted sources reduced rejection of different applications of genetic modification technologies, perhaps because recipients of the information were already aware of the public discourse about unintended effects and GMFs.

In general, scientific experts and the general public have very different views about how the public might react to information about scientific uncertainty. Scientific experts in food safety (drawn from scientific institutions, industry, and government) were interviewed about how they thought the general public might handle information about uncertainty. There appeared to be a widespread belief that the public were unable to conceptualise uncertainties associated with risk management processes. Many scientists thought that providing the public with information about uncertainty would increase distrust in science and scientific institutions, as well as cause panic and confusion about the extent and impact of a particular hazard (Frewer, Scholderer, & Bredhal, in press). However, a series of focus groups, using members of the public drawn from different social milieus, demonstrated that the general public were very familiar with the concept of uncertainty (perhaps through exposure to conflicting scientific opinion in the media). Contrary to the assumption above, their distrust in scientific and regulatory institutions increased (Kuznesof, 2001) with any tendency within the scientific community to deny that uncertainties exist, when in fact scientific uncertainty had been identified.

Communication about GMFs should include discussion of potential uncertainties associated with risk management (whether related to unintended effects on human health or the environment). Failure to do so may increase public distrust in information sources and regulators, although risk perceptions themselves may be unaffected. Indeed, increased transparency in risk management and regulatory decision-making will mean that information dissemination activities must focus on uncertainties and what is not known, as much as the purported benefits and what is known about any innovative technology.

10.6.2. The role of the media

Regulatory institutions and the scientific community have associated the media with promotion of distrust in science regulation. What institutions (including those responsible for regulation) are signalling when they refer to what is described as the 'hysteria' of the press and the need for 'a more temperate climate in which to build public confidence',[4] is the loss of control over the public

[4] Defra (1999) The Government's Response to the Fifth Report of the Select Committee on Environmental Audit — Genetically Modified Organisms and the Environment: Co-ordination of Government Policy, London, UK, Department for Environment, Food and Rural Affairs, available [January 2003] at http://www.defra.gov.uk/environment/gm/.

discourse about biotechnology and the lack of impact that the authority of scientific institutions has on public opinion. It is important to examine, through systematic empirical investigation, whether extensive reporting about the potential negative effects of any scientific event or process does, indeed, have the postulated impact on public opinion about the development and implementation of that same event or process. It is essential that members of the scientific community provide to journalists accurate and balanced information, which duly acknowledges scientific uncertainties.

Information about risk and risk events reaches individuals through two primary communication networks—the news media and informal personal networks (Kasperson *et al.*, 1988). Sometimes a particular risk event will result in the media coverage necessary to trigger public fears about a particular risk or to provide sufficient cues to mobilize collective fears and increase perceived risk. Of particular interest to those concerned with food crisis management are the cases of BSE in cattle in 1996 and, more recently, the increased attention associated with GMFs in the spring of 1999 (Frewer, Miles, & Marsh, 2002).

It has been argued that the course of a food scare may be influenced by a number of attributes of the information provided about a risk event, resulting in increased public concern about risks. The 1999 media reporting of the risks of genetic modification of foods in the UK was characterized by several factors: a large volume of information, which may serve as a risk amplifier (which increases public perceptions of risk), independent of the accuracy and actual content of the information; disagreement between various actors in the risk debate; dramatization of risk information (e.g. through presentation of risk 'scenarios' and examples); and the symbolic connotations of terms or concepts used in messages.

Genetic modification of food has been associated with a great deal of media attention, both in the UK and more generally in Europe. GM soya was first imported into Europe, from the USA, in 1996; however, it was not until 1998 that media attention really began to increase. Laboratory research claiming the potential for adverse health effects, as a result of the consumption of GM potato, was reported (later published by Pusztai and co-workers). Later that year, the media reported the findings of an independent analysis, conducted by The Royal Society (1999), which criticized the research as flawed and argued that no conclusion should be drawn from the work. Nonetheless, the spring of 1999 was associated with extensive media reporting about potential risks to humans from GMFs.

It is not clear whether increased discussion of the risks of GMFs has a long-term impact on people's risk perceptions. Frewer, Miles, *et al.* (in press) report that perceived risk temporarily increased during the media reporting but had returned to previous levels by the following spring. However, perceived benefit appeared to be permanently depressed by negative reporting about GMFs. Trust in regulatory institutions with responsibility for protecting the public was not affected, possibly because of a 'floor' effect (people's trust in government and industry had reached such a low point that it could not subsequently be further influenced downwards). Taken together, these results suggest that the media does have an effect on people's risk perception, although the effect is neither great nor enduring. Associating public negativity about emerging technologies with so-called 'press hysteria' is probably overstating the case. In addition, whether any attempt to control the press is desirable in democratic societies must be open to question.

It is also important to remember that the public are not homogenous with regard to their risk perceptions. For example, Frewer, Miles *et al.* (2002) report that there are large inter-individual differences in the extent to which people are likely to accept or reject GMFs. Similarly there are differences in their trust in institutions. These differences appear to be greater within national populations than are cross-cultural differences. That there are such differences in risk perception is probably an argument for maintaining diversity in production methods, and ensuring that consumers are able to make informed choices about consumption.

10.7. Science and society: emerging issues

Frewer and Salter (in press) note that there is increasing emphasis on developing new ways of negotiating the relationship between the scientific community and the wider society. The new relationship has implications for the development of all forms of science policy, including genetic modification applied to food and agriculture.

At the present time the regulatory environment is changing its relationship with society. The emphasis for public acceptance or rejection of technologies is no longer on 'top-down' risk communication models (where information is developed by experts who expect the general public to attend to what they have communicated). Instead, the focus has been on the development and use of more inclusive and transparent institutional processes, particularly during early stages of technology development and implementation. These changes reflect the rapid decline in public trust in science that is widely regarded as having compromized the perceived legitimacy of governance in technology development. Societal values are likely to contribute to consumer acceptance (or otherwise) of GMFs and need to be explicitly included in the debate about regulation of products and in associated communication strategies. For example, questions of need, concerns about emerging bioethical issues, and so forth are likely be the

focus of public discourse about technology implementation, and this should be acknowledged by regulatory bodies and interested stakeholders when developing discussion about strategic development of bioscience applications. It is arguable that models of information dissemination driven by science and technology (described as 'elite' models) rather than public need are probably of limited utility in the current climate. Simply providing the public with information about science, in whatever form, will not result in technology acceptance.

Levidow and Marris (2001) have noted

> "public distrust or opposition to new technologies is often attributed to "extra-scientific" concerns, and in particular to "ethical issues""

(possibly here used implicitly to include the value systems that people hold and use to make judgments about events in the world around them). The authors suggest that such rhetoric is used to create 'firewalls' between 'value-free' scientific knowledge and 'value-laden' public discourse about technology implementation. More recent activity within, for example, the European Commission has emphasized the need to introduce 'new institutional relationships and forms' reinforcing the process of mutual learning between the public and the scientific community[5]. How such a strategy might best be implemented is currently the subject of conjecture. However, the concept of transdisciplinary research appears to be on the agendas of many research strategists and funding bodies. Such programmes encourage the development of integrated research projects, which harmonise natural and social science activity in order to dissipate the supposed division between 'science and society'. Similarly industrial interests are beginning to focus on developing consumer research at the product development (as opposed to product marketing) stage in order to maximise consumer uptake of resultant products.

The 'science and society' agenda identifies the need to change institutional terms of reference and procedures, including the development of a broader base of public consultation and dialogue on risk issues. There are a variety of practical and ethical reasons for policy-making bodies to involve lay people in decision-making on issues in which the public has a stake. Political theorists and ethicists discuss concepts such as democracy, procedural justice, and human rights, in providing the moral basis for involvement; but it is now recognized that, in a practical and expedient sense, making decisions without public support is liable to lead to confrontation, dispute, disruption, boycott, unrest, distrust, and public dissatisfaction in science and technology. The need for public involvement would seem particularly apparent in the food domain, as food is of fundamental, unavoidable and everyday interest to all members of society. A plethora of different consultation processes have been developed (Rowe & Frewer, 2000). However, it is also important to evaluate systematically whether consultation processes are effective, whether the outputs facilitate policy decision-making and whether public consultation has a substantial impact on public confidence in science and technology (Jasanoff, 1993).

10.8. Conclusions

In the case of GMFs, consumer attitudes are dependent, in part, on an analytical assessment of risk and benefit and on communication about such analysis. Other factors such as ethical and moral considerations, uncertainties and concerns about the potential for unintended effects as well as trust in the regulatory system are also important determinants of consumer acceptance or rejection of emerging technologies and their products. Trust in information sources is also important. An important issue, therefore, is exactly how to include societal values when making decisions about regulation and innovation. A key factor is regaining public confidence in regulatory institutions, science and scientific practices, and industry.

Increased transparency in regulation means that any lack of consensus about risk management processes and associated uncertainties is open to public scrutiny. However, increased transparency in itself does not mean that regulation will be influenced by broader social concerns. An institutional shift away from a position in which scientific knowledge is the authoritative source for risk regulation to one in which the general public have an increased voice, as one of the constituent elements of the political discourse influencing government decisions, appears to be the basis for current institutional reform. This implies that there should be greater consultation with the general public as well as stakeholder groups.

Such an approach does require some formalisation of the development of ground rules for best practice in public consultation and public involvement (Rowe & Frewer, 2000). The need to involve the public in policy development must be made explicit. If it is to become a standard part of the policy development process, information should be available about how public involvement should be conducted and evaluated, so that standardized procedures can be used and the outputs can be comparable in time and place. Public acceptance of GMFs is likely to increase if people perceive that products and associated regulatory frameworks are not imposed upon them by institutions perceived to be untrustworthy and uninterested in public concerns and values.

[5] EC DG-RTD & ED-JRC (2000) *Science and Governance in a Knowledge Society: The Challenge for Europe*, Brussels, European Commission, available (January 2003) at http://www.jrc.es/sci-gov/.

10.9. References

Alhakmi, A. S., & Slovic, P. (1994). A psychological study of the inverse relationships between perceived risk and perceived benefit. *Risk Analysis*, 1085–1096.

Anand, P., & Forshner, C. (1995). Of mad cows and marmosets: from rational choice to organisation behaviour in crisis management. *British Journal of Management*, *6*, 221–233.

Aubert, J. E. (2000). NGOs on GMOs: the reasons for resistance. *OECD Observer*, *220*

Barke, R. P., & Jenkins-Smith, H. C. (1993). Politics and scientific expertise: scientists, risk perception and nuclear waste policy. *Risk Analysis*, *13*, 425–439.

Braun, R. (2001). Why are Europeans scared of biotech food. *Agro-Food Industry Hi-Tech.*, *5*, 32–34.

Cabinet Office, & Office of Science and Technology. (1999). *The advisory and regulatory framework for biotechnology: report from the government's review*. London: The Stationery Office.

Cvetkovich, G., Löfstedt, R. E. (Eds.). (1999). *Social trust and the management of risk*. London: Earthscan Publications.

Da Costa, M. C., Deliza, R., Rosenthal, A., Hedderley, D., & Frewer, L. J. (2001). Non-conventional technologies and impact on consumer behaviour. *Trends in Food Science and Technology*, *11*, 188–193.

Doubleday, R. (2001). Knowledge and the governance of biotechnology. *Politeia*, *17*, 22–33.

Eagly, A.H., & Chaiken, S. (1984). Cognitive theories of persuasion. In L. Berkowitz (Ed.), *Advances in experimental social psychology* (pp. 297–359).

Eagly, A. H., & Chaiken, S. (1993). *The psychology of attitudes*. Forth Worth, TX: Harcourt Brace Jovanovitch.

EC DG-RTD, & EC-JRC. (2000). Conference conclusions. In *science and governance in a knowledge society: the challenge for Europe, 16–17 October, 2000, Brussels*. Sevilla, Spain: Institute for Prospective Technology Studies, JRC Sevilla European Commission.

Eiser, R.J., Miles, S., & Frewer, L.J. (2002). Trust, perceived risk and attitudes toward food technologies. *Journal of Applied Social Psychology, 32(11)*, 2423.

Eldridge, J., Kitzinger, J., Philo, G., Reilly, J., Macintyre, S., & Miller, D. (1998). The re-emergence of BSE: the impact of public beliefs and behaviour. *Risk and Human Behaviour Newsletter*, *3*, 6–10.

European Federation of Biotechnology. (1998). *How can biotechnology benefit the environment?* The Hague: European Federation of Biotechnology.

FAO. (1998). *The application of risk communication to food standards and safety matters* (Food and Nutrition Paper 70). Rome: Food and Agriculture Organization.

Fessenden-Raden, J., Fitchen, J. M., & Heath, J. S. (1987). Providing risk information in communities: factors influencing what is heard and accepted. *Science, Technology and Human Values*, *12*, 94–101.

Frewer, L. J., & Shepherd, R. (1995). Ethical concerns and risk perceptions associated with different applications of genetic engineering: interrelationships with the perceived need for regulation of the technology. *Agriculture and Human Values*, *12*, 48–57.

Frewer, L. J., Howard, C., Hedderley, D., & Shepherd, R. (1996). What determines trust in information about food-related risks? Underlying psychological constructs. *Risk Analysis*, *16*, 473–486.

Frewer, L. J., Howard, C., & Shepherd, R. (1997). Public concerns about general and specific applications of genetic engineering: risk, benefit and ethics. *Science, Technology and Human Values*, *22*, 98–124.

Frewer, L. J., Howard, C., & Shepherd, R. (1998a). The importance of initial attitudes on responses to communication about genetic engineering in food production. *Agriculture and Human Values*, *15*, 15–30.

Frewer, L. J., Howard, C., & Shepherd, R. (1998b). Understanding public attitudes to technology. *Journal of Risk Research*, *1*, 221–237.

Frewer, L. J., Howard, C., Hedderley, D., & Shepherd, R. (1999). Reactions to information about genetic engineering: impact of source credibility, perceived risk immediacy and persuasive content. *Public Understanding of Science*, *8*, 35–50.

Frewer, L. J. (1999). Risk perception, social trust and public participation into strategic decision-making — implications for emerging technologies. *Ambio*, *28*, 569–574.

Frewer, L. J. (2000). Risk perception and risk communication about food safety issues. *British Nutrition Foundation Nutrition Bulletin*, *25*, 10–14.

Frewer, L.J., Scholderer, J., Bredahl, L. (in press). Communicating about the risks, benefits of genetically modified foods: effects of different information strategies. *Risk Analysis*.

Frewer, L.J., Miles, S., & Marsh, R. (2002). The GM foods controversy. A test of the social amplification of risk model. *Risk Analysis, 22(4)*, 713–723.

Frewer, L.J., Salter, B. (in press). Public attitudes, scientific advice and the politics of regulating policy: the ease of BSE. *Science and Public Policy*, *29*, 137–145.

Haimes, Y. Y., Barry, T., & Lambert, J. H. (1994). When and how can you specify a probability distribution when you don't know much? *Risk Analysis*, *14*, 661–706.

Heijs, W. J. M., Midden, C. J. H., & Drabbe, R. A. J. (1993). *Biotechnology: attitudes and influencing factors*. Eindhoven: Eindhoven University of Technology.

Hoban, T., Woodrum, E., & Czaja, R. (1992). Public opposition to genetic engineering. *Rural Sociology*, *57*, 476–493.

Hovland, C. I., Janis, I. L., & Kelly, H. H. (1953). *Communication and persuasion: psychological studies of opinion change*. New Haven CT: Yale University Press.

Hovland, C. I. (1959). Reconciling conflicting results derived from experimental and survey studies of attitude change. *American Psychologist*, *14*, 8–17.

Jasanoff, S. (1993). *The fifth branch: scientific advisors as policy makers*. New Haven CT: Harvard University Press.

Jasanoff, S. (1997). Civilization and madness: the great BSE scare of 1996. *Public Understanding of Science*, *6*, 221–232.

Johnson, B. (1999). Exploring dimensionality in the origins of hazard-related trust. *Journal of Risk Research*, *2*, 325–354.

Johnson, B. B., & Slovic, P. (1995). Presenting uncertainty in health risk assessment: initial studies of its effects on risk perception and trust. *Risk Analysis*, *15*, 485–494.

Johnson, B. B., & Slovic, P. (1998). Lay views on uncertainty in environmental health risk assessment. *Journal of Risk Research*, *1*, 261–279.

Jongebreur, A. A. (2000). Strategic themes in agricultural and bioresource engineering in the 21st century. *Journal of Agricultural Engineering Research*, *76*, 227–236.

Kasperson, R. E., Renn, O., Slovic, P., Brown, S., Emel, J., Goble, R., Kasperson, J. X., & Ratick, S. (1988). The social amplification of risk: a conceptual framework. *Risk Analysis*, *8*, 177–187.

Kraus, N., Malmfors, T., & Slovic, P. (1992). Intuitive toxicology: expert and lay judgements of chemical risks. *Risk Analysis*, *12*, 215–232.

Kuznesof, S. (2001). *Understanding lay conceptualisations of scientific uncertainty* (Report to the UK Food Standards Agency). Newcastle: University of Newcastle.

Lazo, J. K., Kinnell, J. C., & Fisher, A. (2000). Expert and layperson perceptions of ecosystem risk. *Risk Analysis*, *20*, 179–193.

Levidow, L., & Marris, C. (2001). Science and governance in Europe. Lessons from the case of agricultural biotechnology. *Science and Public Policy*, 345–360.

MacCorquodal, K., & Meehl, P. E. (1948). On a distinction between hypothetical constructs and intervening variables. *Psychological Review*, *55*, 95–107.

Macer, D., Bezar, H., Richardson-Harman, N., Kamada, H., & Macer, N. (1997). Attitudes to biotechnology in Japan and New Zealand in 1997, with international comparisons. *Eubios Journal of Asian and International Bioethics*, *7*, 137–143.

McGuire, W. J. (1985). Attitudes and attitude change. In G. Lindzey, & E. Aronson (Eds.), *The handbook of social psychology* (pp. 233–346). New York: Random House.

Mertz, C. K., Slovic, P., & Purchase, I. F. H. (1998). Judgements of chemical risks: comparisons among senior managers, toxicologists and the public. *Risk Analysis*, *18*, 391–404.

Miles, S., & Frewer, L. J. (2001). Investigating specific concerns about different food hazards — higher and lower order attributes. *Food Quality and Preference*, *12*, 47–61.

Miles, S., Frewer, L.J. (2002). *Traceability of genetically modified ingredients. consumer response in Italy, Norway and the UK (report)*. Norwich: European Commission, Institute of Food Research

Newholm, T. (2000). Consumer exit, voice and loyalty: indicative, legitimation and the regulatory role in agricultural and food ethics. *Journal of Agriculture and Food Ethics*, *12*, 153–164.

OECD. (1994). *Biotechnology for a clean environment: prevention, detection, remediation*. Paris: Organization for Economic Co-operation and Development.

Office of Science and Technology. (1998). *Memorandum to the scientific advisory system: genetically modified foods inquiry by the Science and Technology Committee*. London: Office of Science and Technology.

Peterman, R. M., & Anderson, J. L. (1999). Decision analysis: a method for taking uncertainties into account in risk-based decision making. *Human and Ecological Risk Assessment*, *5*, 231–244.

Petty, R. E., & Cacioppo, J. T. (1986). *Communication and persuasion: central and peripheral routes to attitude change*. New York: Springer.

Pidgeon, N. F., & Beattie, J. (1997). The psychology of risk and uncertainty. In P. Calow (Ed.), *The handbook of environmental risk assessment and management* (pp. 289–318). London: Blackwell Science.

Priest, S. H. (2000). U.S. public opinion divided over biotechnology. *Nature Biotechnology*, *18*, 939–942.

Renn, O., & Levine, D. (1991). Credibility and trust in risk communication. In R. E. Kasperson, & P. J. M. Stallen (Eds.), *Communicating risks to the public* (pp. 175–218). Dordrecht: Kluwer.

Rowe, G., & Frewer, L. J. (2000). Public participation methods: an evaluation review of the literature. *Science, Technology and Human Values*, *25*, 3–29.

Rowe, G., & Wright, G. (2001). Differences in expert and lay judgements of risk: myth or reality? *Risk Analysis*, *21*, 345–356.

Rowe, W. D. (1994). Understanding uncertainty. *Risk Analysis*, *14*, 743–750.

Royal Commission on Genetic Modification. (2001). *Report of the Royal Commission on Genetic Modification*. Wellington, New Zealand: Department of Internal Affairs.

Saba, A., Moles, A., & Frewer, L. J. (1998). Public concerns about general and specific applications of genetic engineering: a comparative study between the UK and Italy. *Journal of Nutrition and Food Science*, *28*, 119–129.

Scholderer, J., Balderjahn, I., & Will, S. (1998). *Communicating the risks and benefits of genetically modified food products to the public: the view of experts from four European countries (MAPP Working Paper No. 57)*. Aarhus: The Aarhus School of Business.

Scholderer, J., Balderjahn, I., Bredahl, L., & Grunert, K. G. (1999). The perceived risks and benefits of genetically modified food products: experts *versus* consumers. *European Advances in Consumer Research*, *4*, 123–129.

Scholderer, J., Frewer, L.J. (in Press). The biotechnology communication paradox: experimental evidence, the need for a new strategy. *Journal of Consumer Policy*.

Siegrist, M. (1999). A causal model explaining the acceptance and rejection of genetic engineering. *Journal of Applied Social Psychology*, 2093–2106.

Siegrist, M., Cvetkovich, G., & Roth, C. (2000). Salient value similarity, social trust and risk/benefit perception. *Risk Analysis*, *20*, 323–361.

Siegrist, M. (2000). The influence of trust and perceptions of risks and benefits on the acceptance of gene technology. *Risk Analysis*, *20*, 195–204.

Sjöberg, L. (1999). Risk perception in Western Europe. *Ambio*, *28*, 555–568.

Sjöberg, L., Truedsson, J., Frewer, L., & Prades, A. (2000). Through a glass darkly: experts' and the public's mutual risk perception. In M.P. Cottam, D.W. Harvey, R.P. Pape, & R.J. Tate (Eds.), *Foresight and precaution: proceedings of ESREL 2000, SARS and SRA-Europe Annual Conference, Edinburgh, UK, 14–17 May 2000* (pp. 1157–1162). Rotterdam: Balkerna.

Slovic, P., Fishhoff, B., & Lichenstein, S. (1980). Facts and fears: understanding perceived risk. In R. C. Schwing, & J. Albers (Eds.), *Societal risk assessment: how safe is safe enough?* (pp. 181–216). New York: Plenum.

Slovic, P. (1993). Perceived risk, trust and democracy. *Risk Analysis*, *13*, 675–682.

Slovic, P., Malmfors, T., Mertz, C. K., Neil, N., & Purchase, I. F. H. (1997). Evaluating chemical risks: results of a survey of the British Toxicology Society. *Human and Experimental Toxicology*, *16*, 289–304.

Sparks, P., Shepherd, R., & Frewer, L. J. (1995). Assessing and structuring attitudes towards the use of gene technology in food production: the role of perceived ethical obligation. *Journal of Basic and Applied Social Psychology*, *16*, 267–285.

Stroebbe, W., Lenkert, A., & Jonas, K. (1998). Familiarity may breed contempt: the impact of student exchange on national stereotypes and attitudes. In A. Kruglanski, D. Bar-Tal, & M. Hewstone (Eds.), *The social psychology of intergroup conflict: theory, research and applications* (pp. 189–218). New York: Springer.

The Royal Society. (1999). *Review of data on possible toxicity of GM potatoes*. London: Royal Society Press Office.

Tengerdy, R. P., & Szakacs, G. (1998). Perspectives in agrobiotechnology. *Journal of Biotechnology*, *66*, 91–99.

Uzogara, S. G. (2000). The impact of genetic modification of human foods in the 21st century: a review. *Biotechnology Advances*, *18*, 179–206.

Viscusi, W. K., Magat, W. A., & Huber, J. (1991). Communication of ambiguous risk information. *Theory and Decision*, *31*, 159–173.

Von Avelsleben, R. (2001). Beliefs Associated with Food Production Methods. In L. J. Frewer, E. Risvik, & H. Schifferstein (Eds.), *Food, people and society: a European perspective of consumers' food choices* (pp. 381–397). Munich: Springer Verlag.

Wheale, P. R. (1999). The social management of modern biotechnology and the new industrial divide. *New Genetics and Society*, *18*, 23–44.

Woodward, R. T., & Bishop, R. C. (1997). How to decide when experts disagree: uncertainty-based choice rules in environmental policy. *Land Economics*, *73*, 492–507.

Wynne, B. (1992). Uncertainty and environmental learning: reconceiving science and policy in the preventive paradigm. *Global Environmental Change*, 111–127.

Zechendorf, B. (1994). What the public think about biotechnology. *Bio-Technology*, *12*, 870–875.