FRANKENFOODS AND MUTANT RICE:

CONSUMERS AND FOOD BIOTECHNOLOGIES

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PREFACE

Introduction

Much has happened since American scientists first succeeded in splitting, sequencing, splicing and inserting genes in 1973, resulting in the first recombinant DNA construct. Since then, many setbacks have delayed the commercialisation of genetically modified organisms (GMOs), sometimes caused by stakeholder protests, sometimes by precautionary measures such as strict safety guidelines, lengthy approval processes, and even moratoria (e.g., the US moratorium 1974-1975, the EU moratorium 1999-2004, and the Swiss moratorium 2005-2010; see Scholderer, 2005).

In the EU, controversies over the technology declined after 2004 and in some periods even seemed to disappear from public attention. At the time of writing (August 2008), the debate appears to resurface as the current food crisis has forced the EU to look more positively on genetically modified (GM) crops and to reconsider them. EU member states are currently investigating how to simplify the approval procedure for GM crops, prompted by an official Commission communication (COM 2008 450/5, May 2008) stating that this might be a necessary measure to increase food security in the world. The change of attitude displayed by EU decision-makers reflects a general trend in public opinion. Eurobarometer results indicate that the majority of the general public regards biotechnology optimistically again (Gaskell, Allansdottir, Allum et al., 2006), suggesting that the "crisis of confidence" in the EU may be over (see Figure 1).

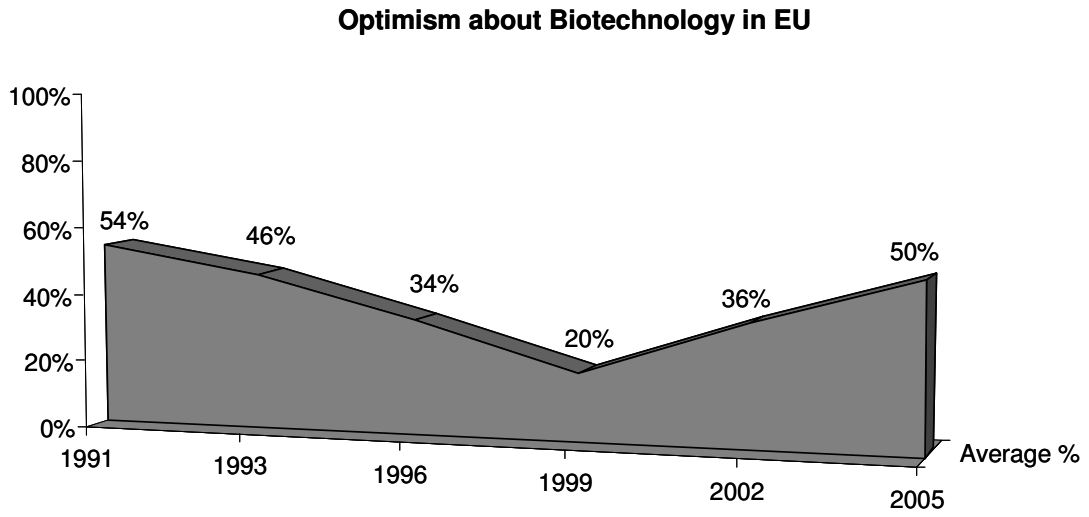

Figure 1. Optimism about biotechnology in EU-15 countries (% Eurobarometer respondents; source: Gaskell et al., 2006).

GM foods has since 2004 been regulated under a set of specific rules (Directive 2001/18/EC, Regulations (EC) 1829/2003, 1830/2003 and 641/2004) which clearly distinguish GM foods from other types of novel foods, particularly in terms of labelling requirements and environmental risk assessment (which is required for GMOs but not for other types of novel foods). In terms of the legal framework GM crops was regarded as different from other crops developed by biotechnologies such as mutation breeding, i.e. the development of new crop cultivars by means of mutagenesis, involving exposure of plant material to gamma radiation, thermal neutrons, or chemical agents. However, this directive brought along a number of problematic issues such as legal uncertainties concerning the definition of novel food, and the excessive length of the decentralised safety assessment and product authorisation procedure. The Commission proposed therefore in 2007 a revised regulation on novel

foods (COM[2007] 872 final; 2008/0002 COD) which was forwarded to the European Parliament in January 2008. The major proposed changes to the existing regulation were:

- Revised definitions of novel foods categories, including categories defined horizontally in terms of non-traditional breeding techniques and new production processes;
- Abolishment of national administrative procedures and replacement with a streamlined and centralised procedure for the assessment and authorisation of novel foods, with applications to be submitted to the Commission.
- Replacement of the applicant-linked procedure and the simplified notification procedure with a Community list of novel foods that grants authorisation as a general rule.
- A new notification procedure for traditional foods from third countries, with safety assessment and management based on the concept of a history of safe use;
- Provisions for integration into the planned common assessment and authorisation procedure for food additives, food enzymes, food flavourings and novel foods, enabling the submission of a substance or product for authorisation for several food uses through a single procedure.

The proposal caused considerable controversy among members of the parliaments, resulting in almost 200 suggested amendments concerning; disagreement over the basic objectives of the regulation, discussion over

the definition of novelty (not used in any member state before 1997, including recent accession countries, or only in the "old" member states?) and dispute over different interpretations of the concept of a history of safe use of traditional foods from third countries. Furthermore, did the dispute also include strong objections by the Parliament against the Commission's premature proposal to integrate the revised novel regulation into the common assessment and authorisation procedure for several food uses.

At present, the revision of Regulation 258/97 is in limbo. The Council of Europe has tabled its own suggestions for changes to the Commission's proposal in December 2008. The European Parliament is scheduled to vote over the revision in spring 2009. However, two member states (Denmark and Malta) have reserved parliamentary scrutiny, and the Commission has reserved general scrutiny. Hence, a finalisation of the regulation is not likely before the end of 2009.

According to the Council document from December 2008, the new novel food categories are:

- Food of animal origin, when to the animal is applied a non-traditional breeding technique not used for food production within the Community before 15 May 1997;
- Food of plant origin, when to the plant is applied a non-traditional breeding technique not used for food production within the Community before 15 May 1997, and where that production process gives rise to significant changes in the composition or structure of the food which affect its nutritional value, metabolism or level of undesirable substances;

- Food to which is applied a new production process, such as nanotechnology and nanoscience not used within the Community before 15 May 1997, where that production process gives rise to significant changes in the composition or structure of the food which affect its nutritional value, metabolism or level of undesirable substances;
- Food ingredients used exclusively in food supplements within the Community before 15 May 1997 if they are to be used in foods other than food supplements;
- Traditional food from a third country with a history of food use in a third country, where it has been, and continues to be, part of the normal diet for at least 25 years in a large part of the population of the country.

The revised regulation on novel foods (COM[2007] 872 final; 2008/0002 COD) proposed by the Commissions suggest that all novel foods are regulated under same legal framework. As food biotechnologies for many years have been synonymous with GM, it may from a consumer perspective seem logically to regulate all food biotechnologies in terms of the same legal framework. On other hand might other applications of foods biotechnologies that do not carry the "GM stigma" at the moment, inadvertently be structurally linked to GM and therefore rejected on assumptions originally linked to public debated gene technology. The aim of this thesis is therefore to investigate how different food biotechnologies are structurally linked in consumers mind. Specifically, will this thesis investigate the formation, structure and changeability of consumers' attitudes toward different applications of food biotechnologies.

The research presented is divided into three parts. The first part will investigate the belief basis of consumer attitudes towards two *different* food biotechnologies: one technology that has been at the centre of an intense public debate and can therefore be classified as relatively familiar to consumers (gene technology), and one that has never attracted a significant degree of public attention and can therefore be classified as relatively unfamiliar to consumers (mutation breeding). Part two will investigate the inter-attitudinal structures related to these attitudes (in particular, their relations to other attitude dimensions and their relation to each other), assessing the degree of commonality in these structures. Part three will analyse the changeability of such attitudes.

The three parts are associated with three overall research questions:

1. What is the content of the belief systems related to consumer attitudes towards different food biotechnologies and their applications?

2. Are attitudes towards different food biotechnologies embedded into a joint system of other attitudes that causes commonalities between them, or do their relationships to other attitudes differ?

3. Will repeated exposure to information lead to changes in consumer attitudes towards food biotechnologies?

Formation of attitudes toward food biotechnologies

The central construct in the research presented here is *attitude*. Eagly and Chaiken (1993, p.1) define attitude as "a psychological tendency that is expressed by evaluating a particular entity with some degree of favour or

disfavour." Tendency is sometimes used synonymous with disposition, which can be either acquired or genetically inherited, and sometimes even an impulse (Eagly & Chaiken, 1993). Attitudes cannot be observed through direct observation as they are not part of a person's physical characteristic. A person's attitude is believed to be latent, hypothetical characteristics only derived from measurable reactions. Social scientists assume that reactions expressing evaluations, thereby revealing attitudes, can be divided into three different categories: cognition, affect and behaviour, which is the most popular classification system of responses and which originates from Plato (Ajzen, 1988).

The cognitive category contains thoughts about an attitude object. Thoughts or ideas are also their cognitive reactions (called *beliefs*) being the associations that are established between the attitude object and its attributes (Fishbein & Ajzen, 1975). Affective reactions consist of feelings, moods, and emotions with regard to an attitude object. Affective reactions (often called *evaluation* by social psychologists) can push a person to an extreme such as being extremely positive or extremely negative toward an object. The final category, behaviour, deals with overt actions in connection with the attitude object. An attitude can be formed on the basis of three processes; cognitive, affective and behavioural processes. Cognitive processes take place when knowledge is acquired either direct through experience or indirect through a media, e.g. a TV commercial.

Affective processes take place when the attitude object elicits an affective reaction which could be regarded as a preference not mediated by thinking of the object's attributes. Behavioural processes take into account past behaviour as an antecedent for attitude. Typically, affective as well as cognitive processes will be involved in the evaluation of an object, and

both may in turn be associated with behavioural responses in the past, present, and future.

The first two studies (reported in Articles 1 and 2) which answer the first research question *"What is the content of the belief systems related to consumer attitudes towards different food biotechnologies and their applications?*" will focus on the cognitive aspects of consumer attitudes towards biotechnologies, specifically the belief systems that are linked to these attitudes. Belief-based models of attitude (Fishbein & Ajzen, 1975) have a long tradition in social psychology and have widely been applied in consumer research. All belief-based models assume that the overall evaluation of an object (the attitude) is formed based on the attributes of the object that are accessible at the time the evaluative judgment is made. Accessible attributes may be activated from memory (in case of prior experience with the attitude object), or they may be constructed via propositional reasoning at the time the judgment is made. Most belief-based models of attitude regard the beliefs themselves as given; the internal structure of an individual's belief system is considered highly domain-specific and in most cases even idiosyncratic, which are the point of interest when it comes to applied research.

Risk perception researchers (Morgan, Fischhoff, Bostrom & Atman, 2001) have developed an elaborate methodology for assessing the content and structure of belief systems. The underlying assumption is that an individual carries a network of beliefs that can be understood as a small-scale model

of reality, a "mental model"[1]. A mental model typically consists of a mixture of factual knowledge, value judgments, and considerations of uncertainty related to a risk issue (Fisher, Walker, Bostrom, Fischhoff, Haire-Joshu & Johnson, 2002).

Mental models methodology is qualitative but typically aims at a group-level representation. A group-level representation can either be achieved via aggregation of individual mental models (e.g., into a valued network representation), or through the use of consensual data collection methods (e.g., the Delphi method). Group-level representations facilitate group comparisons. Applications of mental models methodology in risk perception research have often benchmarked the mental models of laypersons against the mental models of technical experts, indentifying in which respect these groups differ in their understanding of a particular risk issue. Such comparisons can provide valuable input to the development of risk communication and conflict resolution strategies.

In the present research, a similar approach will be adopted. Article 1 will identify the content and structure of consumers' beliefs about risks and benefits related to the genetic modification of food crops in general and a particular example application (a GM potato with altered levels of inherent toxicants). The mental model resulting from this analysis will be benchmarked against another mental model, based on the view of technical experts with a background in risk assessment. In Article 2, the research will

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[1] The term "mental models" should not be confused with its usage in cognitive psychology, where it refers to schema-driven but largely automatic processes involved in, for example, syllogistic reasoning.

be conceptually replicated, but with mutation breeding as the technology, and a mutation-bred rice with lower levels of an anti-nutrient as the example application.

The structure of attitude toward food biotechnologies

Attitudes towards complex socio-technical issues do not exist in isolation in an individual's mind. Rather, they tend to be linked to other attitudes in thematically consistent structures, comparable to ideologies (Eagly & Chaiken, 1993). Research on consumer attitudes towards gene technology has shed considerable light on the structure of the attitude system in which attitudes towards gene technology are embedded (e.g., Bredahl, 2001; Sjöberg, 2004; for reviews, see Bredahl, Grunert & Frewer, 1998; Frewer, Lassen, Kettlitz, Scholderer, Beekman & Berdal, 2004; Scholderer, 2005). Results suggest that attitudes towards gene technology are expressions of a system that consists of an interconnected structure of attitudes towards general socio-political issues such as environment and nature, technological progress, and trust in the socio-technical system from which technological innovations emerge.

No other food biotechnology has received comparable attention from public opinion and consumer researchers, possibly reflecting the low position that other food biotechnologies had on the public agenda. Public debates, too, have often implicitly connected biotechnology with gene technology during the last two decades, substantially narrowing the way biotechnology was portrayed in the media (see Brossard, Shanahan & Nesbitt, 2007). Theoretically, it can therefore be expected that European

citizens and consumers have acquired a cognitive representation of the concept "biotechnology" that consists mainly of the attributes of gene technology and associations between these attributes and other concepts, and only to a small degree of issues related to other food biotechnologies.

Partly, these questions will already be answered by Articles 1 and 2, where the content of consumers' belief systems will be investigated by means of qualitative methods. The degree of overlap the two belief systems (related to gene technology and mutation breeding, respectively) will be a first indication as to which degree generalisation occurs across consumer evaluations of different food biotechnologies. Yet while Articles 1 and 2 will approach the issue from an intra-attitudinal perspective and – due to the separate investigation of the two belief systems – only allow for a post-hoc assessment of the similarity between the two attitudes, Article 3 will approach the issue from an *inter*-attitudinal perspective and compare the two attitudes directly when answering the second research questions *"Are attitudes towards different food biotechnologies embedded into a joint system of other attitudes that causes commonalities between them, or do their relationships to other attitudes differ?"*

The earliest theoretical account of coherent inter-attitudinal structures is one of the cognitive consistency theories called balance theory (Heider, 1946, 1958). The underlying assumption is that people strive for consistency in their cognitions and call this equilibrium balance (Eagly & Chaiken, 1993). Lack of equilibrium, also called imbalance, produces an unpleasant sensation as the person will experience tension and therefore be motivated to restore equilibrium (Bohner & Wänke, 2002). Equilibrium can be restored either by changes through action or through cognitive

reorganization such as excuses or rationalizations, and the state of imbalance will steer towards a stable state of balance (Heider, 1946).

Heider's theory provides a symbolic language for describing the structures that represent attitudes and their relation to other attitudes. The symbolic language contains three elements: the person *P*, the attitude object *X*, and the "other" *O*. Classically, *O* stands for a significant other person or a reference group. Interpreted in a wider sense, however, the "other" may also stand for another attitude object *Y*. In the context of the present research, *P* will stand for a consumer, *X* for a particular food biotechnology the consumer is attempting to evaluate, and *Y* for another food biotechnology. When the entities *P*, *O*, and *X* are set into a relation to each other during the course of an evaluative judgment, "unit relations" are constituted. If a valence becomes associated with a unit relation, a "sentiment relation" is constituted. According to balance theory, a sentiment relation between a person and an object is an attitude.

According to Heider (1946), a balanced state exists either when all sentiment relations in the system are positive, or when the sum product of all sentiment relations has a positive sign, as illustrated in the example in Figure 2. The figure displays a balanced state: the consumer (*P*) evaluates gene technology (*X*) negatively, and if mutation breeding (*Y*) is perceived to be related to gene technology, the consumer is predicted to evaluate mutation breeding negatively, too. If, on the other hand, the consumer sees mutation breeding as a separate entity (without any connection to gene technology) she or he might evaluate the technology in a completely independent manner, i.e. either negatively, neutrally, or positively.

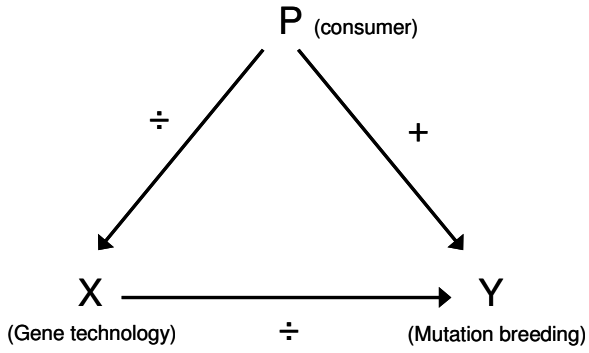

Figure 2. Balance theory example (adapted from Heider, 1946).

The logic of balance theory predictions for three-entity systems (as outlined above) can be extended to attitude systems containing more attitude objects. In addition to the two food biotechnologies (gene technology, mutation breeding), the system may contain more abstract attitude objects (e.g., environment and nature, technical progress, and the institutions constituting the socio-technical system from which technological innovations emerge). If these are symmetrically set into relation to the two food biotechnologies, and the food biotechnologies are set into relation to each other, a joint attitude system can be said to exist. If both attitudes are embedded into this joint system in a coherent manner, a balanced state is predicted: the sum product of the signs of the sentiment relations corresponding to the unit relations is expected to be positive, or equivalently, the signs of the correlations between attitude towards gene technology and a set of other relevant attitudes are expected to be equal to the signs of the correlations between attitude towards mutation breeding and the set of other attitudes. Furthermore, a high positive correlation between attitude towards gene technology and attitude towards mutation breeding is expected.

The predictions will be tested in Article 3. The methodology will be standardised and quantitative, based on representative survey data. Statistically, the predictions will be tested by means of confirmatory factor analysis and structural equation modelling.

Attitude change in relation to food biotechnologies

If attitudes towards food biotechnologies are indeed embedded into a coherent system of other attitudes, comparable to ideologies, they can be expected to be relatively resistant to change (Eagly & Chaiken, 1995). In line with this, previous studies that attempted to change consumer attitudes towards gene technology by means of communicative interventions, have had little success in doing so (e.g., Frewer, Howard & Sheppard, 1998; Peters, 2000; Frewer, Scholderer & Bredahl, 2003; Scholderer & Frewer, 2003; Wilson, Evans, Leppard & Syrette, 2004). However, all of these studies had a design aspect in common that may have been responsible for their lack of effect: all used relatively weak interventions, exposing consumers only once to the information that was supposed to influence their attitudes.

Single-exposure interventions may simply lack the persuasive power that would be necessary to influence an attitude which is embedded into a coherent, ideology-like system of other attitudes. Outside the laboratory, attitudes are in constant flux, evolving over time and in interaction with the multiple stimuli in a person's environment. Hence, more arguments may be necessary to change consumer attitudes towards food biotechnologies than can be communicated during a single exposure episode. Furthermore, the arguments may have to target multiple issues, matching the complexity of

the attitude system of which attitudes towards food biotechnologies are part.

Traditional as well as modern theories of attitude change (Petty & Cacioppo, 1986; Gawronski & Bodenhausen, 2006) predict that exposure to multiple messages will increase the number of evaluative associations to the attitude object. Peripheral (in traditional terminology) or implicit (in modern terminology) attitude change will then occur as a function of the number, valence and accessibility of the newly associated evaluations. Central (in traditional terminology) or explicit (in modern terminology) attitude change will occur when an individual engages in propositional reasoning about the arguments in the messages and decides that they have a bearing on the way she or he should feel about the object. The propositional evaluation may also influence future attitudinal responding, either when it becomes a part of the associative structure, or when a similar propositional reasoning process is triggered by the next confrontation with the attitude object.

If an individual is exposed to multiple messages of the same valence over time, implicit attitude change can be expected to occur in a gradual and cumulative manner as new evaluative associations with the attitude object are stored in memory. Explicit attitude change can be expected to follow a similar cumulative pattern, both because propositional reasoning about an attitude object always activates the associative representation of the attitude and is therefore confounded by it, and because the total time available for elaboration and propositional reasoning will necessarily increase with time. In this process, however, complex mediation patterns may have to be expected.

Social judgment theory predicts that persuasive arguments and other attitudinally relevant message properties – such as the trustworthiness of the source – will be processed relative to judgmental anchors set by individuals' prior attitudes (Sherif & Hovland, 1961; Sherif, Sherif & Nebergall, 1965; Mussweiler, Rüter & Epstude, 2004), resulting in assimilation or contrast effects. More specifically, when a person receives a persuasive argument that falls within the persons latitude of acceptance, the receiver often regards the message as more consistent with his/her position than with what is actually true. The person will therefore assimilate the position of the message toward the person's own attitude, which makes persuasion easier. The opposite effects occur when a message falls within the latitude of rejection and is seen as further away from the position than it actually is. In this case persuasion is said to be inhibited as the receiver contrasts the position of the message away from their own attitude (Eagly & Chaiken, 1993). Previous studies that investigated the changeability of consumer attitudes towards gene technology have indeed found such effects (Frewer et al., 1998, 2003): the degree to which a consumer trusts a source of information about gene technology appears to be a function of the degree to which information attributed to that source confirms the consumer's own prior attitude.

The third research question "*Does repeated exposure to information lead to changes in consumers' attitudes towards food biotechnologies"* will be studied in article 4 as the before mentioned predictions will be tested by means of a controlled attitude change experiment. Participants will be exposed to several messages over time. The messages will be evaluative consistent, but focus on different issues related to a food biotechnology example. In addition to attitude change effects, potential mediation

processes will be investigated. Statistically, the predictions will be tested by means of repeated-measures ANOVA and structural equation modelling.

ARTICLE 1

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Hot potato: Expert-consumer differences in the perception of a second-generation novel food

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Risk Analysis

Abstract

Novel foods have been the object of intense public debate in recent years. Despite widespread efforts to communicate the outcomes of risk assessments to consumers, public confidence in the management of potential risks has been low. Social scientists have identified various reasons for this; chiefly it is a question of disagreement between technical experts and consumers over the nature of the hazards which risk assessments should focus on. The aim of this study was to identify and compare how experts and consumers understand the benefits and risks associated with a genetically modified potato. Two qualitative studies were conducted. In Study 1, mental models were elicited by means of a three-wave Delphi procedure consisting of interviews with 24 international experts. In Study 2, mental models were elicited in in-depth interviews with 25 Danish consumers. As expected, the expert mental models were focused on the types of hazards for which risk assessments can be conducted under current regulatory frameworks, whereas consumers were more concerned about issues outside the scope of current legislation. Often, these concerned system-wide impacts on eco-systems and impacts on the broader consumption patterns, which are notoriously difficult to assess. Moreover, the experts defined risk and benefit in terms of detailed chains of cause-effect relationships between variables for which clear definitions and measurement rules exist. The concepts consumers used when reasoning about biological processes were very abstract, suggesting that most participants did not know anything about these processes beyond heuristic categorisations. In line with this, issues of uncertainty played a prominent role for consumers.

Introduction

Novel foods have been the object of intense public debate in recent years. Despite widespread efforts to communicate the outcomes of risk assessments to consumers, public confidence in the management of potential risks associated with these foods has been low (e.g., Van Kleef, Houghton, Krystallis, Pfenning, Rowe, Van Dijk, Van der Lans, & Frewer, 2007; Frewer, Lassen, Kettlitz, Scholderer, Beekman & Berdal, 2004; Frewer, Miles & Marsh, 2002). Social scientists have identified various reasons for the lack of public confidence, among these a disagreement between technical experts and consumers over the nature of the putative hazards on which risk assessments should focus, an absence of considerations of societal benefits in regulatory frameworks, and perceptions of insufficient openness about uncertainties in risk assessment.

Previous research

Previous investigations of the way in which consumers understand and evaluate novel foods have almost exclusively focused on genetically modified foods. Hamstra and Feenstra (1989) were the first to conduct a detailed qualitative investigation of the contents of consumers' beliefs. The design of their study consisted of focus group-like workshops, involving altogether 34 lay participants. Judged with the benefit of hindsight, it is interesting to note that the issues uncovered in this early study are virtually identical to those uncovered in most subsequent qualitative studies. Aspects of uncertainty appeared prominently in consumers' responses, indicated by associations of biotechnology with ignorance, fear, control, and trust.

Also apparent in this early study was the persistent association of modern food production methods with losses in terms of taste, naturalness and

healthiness. Finally, a whole range of consumer policy issues was raised, which are still at the centre of the public debate, including freedom of choice, labelling, the trustworthiness of regulatory institutions, and allegations of purely economic motives underlying producers' choice of ingredients and processing methods. On the other hand, participants in this study also recognized the potential of modern biotechnology to provide advances in terms of convenience, prolonged shelf life of products, and lower prices for consumers. Hence, already at this early stage it could be expected that some degree of ambivalence would be present in consumers' belief systems.

In the initial study by Hamstra and Feenstra (1989), genetic modification was but one among a whole range of biotechnical processes which consumers were confronted with. Subsequent studies focused more narrowly on genetic modification, the biotechnical process that stakeholders regarded as most problematic in terms of consumer acceptance. Miles and Frewer (2001), for example, conducted individual laddering interviews with 130 UK consumers (in 1997) and obtained a hierarchical value map that was somewhat similar to the Hamstra and Feenstra (1989) results, albeit clearly biased towards negative associations.

Reflecting the research questions underlying early public opinion surveys (e.g., the Eurobarometer Series on Europeans and Modern Biotechnology), several studies investigated whether different beliefs were associated with different target organisms. Bredahl (1999; also see Scholderer, Balderjahn, Bredahl & Grunert, 1999) used laddering interviews to investigate the risks and benefits that European consumers associated with two different types of concrete product examples, including beer brewed from genetically modified yeast, and yoghurt produced with the help of genetically modified

starter cultures. Altogether 400 consumers from Denmark, Germany, Italy, and the UK participated in the study. The hierarchical value maps obtained from a content analysis of the interviews were relatively similar for both product examples. In connection with yoghurt as well as beer, the attribute "genetically modified" yielded more negative than positive association. In all four countries, the main focus was on beliefs relating to unhealthiness and low trustworthiness.

Notably, most of the associations did not relate to the particular type of genetic modification in the respective example product. Instead, they focused on somewhat fuzzy consequences that consumers perceived the general technology to have, including issues like the integrity of nature ("harms nature", "morally wrong"), uncertainty ("unfamiliar", "cannot trust product"), the power balance between different actors in the marketplace ("only benefits producer"), and a general expectation that modern food processing methods as such would render a product unhealthy ("unwholesome and artificial"). These consequences were generally seen to inhibit the attainment of individual life values such as happiness and inner harmony, a long healthy life, quality of life, security, and social values' responsibility for nature and responsibility for the welfare of other people.

Grunert, Lähteenmäki, Nielsen, Poulsen, Ueland and Åström (2001) report the results of another, very detailed laddering study involving approximately 300 consumers from Denmark, Finland, Norway and Sweden. Consumers received product descriptions of cheese, candy and salmon products representing different types of GM applications. The GM applications varied along a "psychological distance" dimension and a "what is modified" dimension; also they were presented along with conventionally produced product variants. In general, consumers appeared

to regard the absence of genetic modification as a value in itself and associated the use of the technology with a broad range of negative consequences, but mostly with uncertainty and unhealthiness. Benefits of the use of GM were regarded as relevant but could not compensate for the negative associations. For all three products, the major distinction respondents made was between GM and non-GM products. By design, the three products differed in terms of the particular risks and benefits attributed to them. In none of the cases were the benefits able to compensate for the negative associations with genetic modification. However, the degree to which the benefits appeared in respondents' perception varied.

Brüggemann and Jungermann (1998) report an interesting investigation into the level of abstraction on which consumer attitudes towards gene technology are represented. The level of representation was operationalised in their experiment in terms of the effects that different levels of abstraction in the description had on consumer evaluations of risks and benefits. Among other biotechnology applications, their stimuli included genetically modified foods. These were described to the same participants (100 German consumers) both on a high level of abstraction ("gene technology"), a medium level of abstraction ("gene technology in agriculture") and a low level of abstraction ("genetically modified tomatoes" and "genetically modified rape") whilst identical descriptions of risks and benefits were included in the texts. They found that consumers' evaluations of risks as well as benefits were significantly higher on higher levels of abstraction. The more concrete the descriptions, the less extreme the consumer evaluations, whilst trade-off values for risk versus benefit remained constant. The results point to an attenuation effect in the

concretization process: consumers appear to form their evaluation mainly on the abstract level of the general technology, whilst, when more concrete applications of the technology are to be evaluated, a variety of specific factors appear to be added, decreasing the extremity of the initial evaluation.

Schütz, Wiedemann and Gray (1999; also see Gray & Wiedemann, 1998) investigated a similar question. The target of their analysis, however, was not the level of abstraction on which the attitude object is represented, but the level of abstraction on which the consequences are represented that consumer associate with the object. They conducted focus groups and individual face-to-face interviews with altogether 110 German consumers, using a relatively unstructured protocol that gave participants the opportunity to elaborate their responses as much as they felt inclined to. The participants were asked to explain the risks and benefits they associated with a number of gene technology applications. After the interviews had been transcribed, the authors coded each response according to the level of specificity on which the belief had been stated. Their results suggest that consumers do not actually hold beliefs in the sense in which the concept of beliefs is commonly understood in consumer research. First of all, the statements the participants generated were largely evaluative rather than cognitive (a belief is commonly defined as cognitive). Moreover, the risk statements often did not have any specifications of causes or consequences, suggesting that the evaluative judgment was categorical and made on the level of the attitude object itself rather than on the level of the object's attributes, as a belief-based model of attitude structure would assume. Finally, even in those instances where attribute-like consequence specifications were made, these in many instances

referred to even more abstract entities ("the environment", "health") rather than more concrete ones, as a belief-based model would assume.

Taken together, the evidence gathered in qualitative studies suggests that consumers evaluate genetically modified foods on a heuristic level. The process of genetically modifying a living organism, rather than the results of that process, appears to be at the centre of consumers' concerns. Consumers appear to associate the process with potential threats to human health and the environment. The nature of these threats can usually not be specified by consumers. It seems to be uncertainty per se – rather than risk – that is the driving force behind their concerns, and this uncertainty is construed simultaneously in terms of environment, health, trustworthiness of risk assessments, and governance.

Overview of empirical work

The majority of the qualitative studies reviewed above are relatively old. Without exception, the interview material on which the studies were based was gathered in the 1990s, in most cases even before Regulation (EC) 258/97 on novel foods and novel food ingredients was implemented in the European Union member states where the respective studies had been conducted. Furthermore, the regulatory situation in the EU has changed considerably during the last five years. Genetically modified (GM) foods are now regulated under a set of specific rules (Directive 2001/18/EC, Regulations (EC) 1829/2003, 1830/2003 and 641/2004) that clearly distinguish them from other types of novel foods, particularly in terms of labelling requirements and environmental risk assessment (which is required for GMOs but not for other types of novel foods). The research presented in the following aims to provide a contemporary description of

the situation by investigating the example of a second-generation GM food (i.e., with a trait linked to functional consumer benefits, not just improved agronomic properties).

Example product

The research was conducted as part of a large, multi-disciplinary project on quantitative risk assessment strategies for novel foods. One of the example foods was a potato plant that had been genetically modified to achieve a changed balance of glycoalkaloids in their tubers (potato line SGT-9-2; see McCue, Allen, Shepherd, Blake, Whitworth, Maccree, Rockhold, Stewart, Davies & Belknap, 2006). Glycoalkaloids are compounds that are naturally occurring in potato tubers and can be toxic when present at high levels. Solanine and chaconine, the most important glycoalkaloids, have different toxicological properties. Normally, breeders work hard to ensure that low glycoalkaloid levels occur in marketed varieties. However, under certain types of stress (for example when tubers are exposed to light), the quantity of these compounds may increase significantly. The symptoms of glycoalkaloid poisoning in humans can range from nausea, vomiting, diarrhoea, abdominal cramps, headache, fever and rapid breathing to hallucinations and in extreme cases delirium, coma and death. The toxicity of glycoalkaloids to man is comparable to that of strychnine and arsenic. Zitnak & Johnston (1970) demonstrated that the initial decomposition temperature of solanine is 243°C and therefore glycoalkaloids would not be destroyed by home preparation or by most types of commercial processing (also see Woolfe, 1987; Nema et al., 2008).

Expert-consumer comparison

A key problem in past attempts to communicate the risks and benefits of novel foods to the public has been a substantial mismatch between expert and consumer understanding of the very nature of the issues. Specifically,

experts and consumers were found to differ in their conceptualisation of risk and benefit, in the way they thought risk and benefit should be assessed, and of their expectations regarding the overall process by which risk analysis should be governed (Scholderer et al., 1999; Frewer et al., 2004; Jensen & Sandøe, 2002). In the research presented below, we will explicitly compare expert and consumer understanding of the benefits and risks associated with the novel food investigated here.

Ideally, such a comparison should use identical research protocols for experts and consumers in order to maximise the validity of the comparison. However, for practical reasons (the experts who participated in Study 1 were based in a several countries) it was not possible to use identical protocols in both studies. A Delphi design will be used in Study 1 to explore experts' conceptualisation of the risks and benefits of the novel food investigated here. In Study 2, we use individual in-depth interviews to investigate consumers' conceptualisation of the risks and benefits of the novel food example. Differences between expert and consumer understanding of the different issues will then be assessed in the final sections of the article.

Mental models approach

In our research we utilise a particular methodology for the study of risk perception that focuses on the way people conceptualise hazardous processes. The theoretical underpinning of this research is that people bring to any risk a network of beliefs that can be understood as an idiosyncratic small-scale model of reality, a "mental model" of that risk. Mental models typically reflect a mix of factual knowledge, erroneous assumptions, value judgments, and uncertainty (Fisher, Walker, Bostrom, Fischhoff, Haire-

Joshu & Johnson, 2002). Morgan, Fischhoff, Bostrom and Atman (2002) have developed a systematic approach to analyse such mental models. This approach allows researchers to pit a "normative" analysis (mental models of experts) against a descriptive analysis (mental models of consumers). The procedure can be divided into four steps: (a) creating an expert mental model, (b) eliciting relevant beliefs from consumers, (c) mapping those beliefs into a consumer mental model, and (d) identifying differences between the expert and the consumer model. The great advantage of this approach is that it allows risk communicators to pinpoint their activities to the exact state of knowledge that already exists in the target audience. Specifically, differences between expert and consumer understanding of the issue at hand can serve as the starting point for communication activities. The usual goal of such communications is to fill knowledge gaps and correct misconceptions that might bias the processing of future information. The mental models approach can be regarded as a somewhat enlightened version of the "deficit model" (Hilgartner, 1990), acknowledging the legitimacy but still aiming to align them lay understanding with the understanding of technical experts.

A number of studies have applied the mental models approach to differences in the understanding of risk between experts and laypeople. The approach has typically been used in situations where the risks were highly personal, including health issues such as local complications for women with breast implants (Byram, Fischoff, Embrey, Bruin & Thorne, 2001), diabetes prevention (Fisher et al., 2002), vaccine risk (Bostrom, Stoto & Evans, 1998) and attitudes towards dietary supplements (Eggers & Fischhoff, 2004). Further use of the mental models approach has been made in the environmental area, for example in the context of climate

change (Bostrom, Morgan, Fischhoff & Read, 1994), geological radon (Bostrom, Fischhoff & Morgan, 1992) and nuclear energy (Barke & Jenkins-Smith, 1993).

Influence diagrams can be used for visualising mental models. An influence diagram is a directed graph with influences (edges) connecting concepts (nodes). An influence diagram may involve many nodes, including uncertain outcomes in situations where the outcome is unknown until the process has terminated (for a general overview of such techniques, see Newman, 2003; Dawid, 2002).

Study 1: Mental models of experts

Method

Participants and procedure. Altogether 24 experts participated in the study, consisting of a three-wave Delphi design. In the first Delphi wave (April 2004), individual face-to-face interviews were conducted with two food safety experts from the Danish Institute for Food and Veterinary Research. In the individual face-to-face interviews, the experts were asked to identify all potential risks and benefits related to the novel food in question and elaborate on their potential consequences. The results were transcribed, content-analysed and illustrated in an influence diagram. In the second Delphi wave (two months after the first), the influence diagram generated in the first wave was sent to twenty additional experts with backgrounds in human toxicology, nutrition, epidemiology, plant genetics, and food science. The purpose of the second wave was to validate the results found in the first wave as experts have deep but very fragmented knowledge and therefore only in-depth knowledge within a limited area. The diagram was

therefore send to additional experts for elaboration and comments with the intent to verify the results of the initial diagram. Before evaluating the diagrams the experts received a shorts written description regarding the purpose of the study, how to read the diagrams and the main results from the first wave. The responses for this stage were collected as written statements. The statements were content-analysed and integrated into the influence diagram. In the third Delphi wave (two months after the second wave), the updated influence diagram was forwarded to two additional experts with a background in environmental risk assessment. Again, the written responses were content-analysed and integrated into the influence diagram, resulting in final versions of the influence diagram. Despite the fact that all twenty experts carefully reviewed the influence diagram it did not change significantly from the first to the second wave (only one additional node was added). However, based on the results of the third wave several new nodes were integrated into the diagram, reflecting the different areas of expertise of the experts who had been consulted.

Analysis. The content analysis was conducted in three steps. In a first step, key concepts were identified in the interview transcripts (e.g., “genetically modified potato”, “chaconine”). Whenever explicit or implicit qualifications of these concepts had been given by participants, these qualifications were linked directly to the concepts (e.g., “increased level of chaconine”, “lower level of solanine”). In a second step, relationships between pairs of key concepts were identified, including class-inclusion relationships (e.g., “risk of human diseases” is part of “risk associated with genetically modified potatoes”), cause-effect relationships (e.g., “use of resistance gene” may lead to “risk of transfer to soil bacteria”) as well as social relationships (“national authorities” exert influence on “legislation”).

In a third step, the responses were aggregated over respondents and transformed into an influence diagram. The strength of the relationships between the concepts was not quantified. The results should therefore be understood in a purely qualitative way.

Results

Altogether 29 concepts could be distinguished in participants' responses. In Figure 1, the concepts are represented as nodes of an influence diagram. Relationships between concepts are represented as edges. Given that all participants were active scientists involved in risk assessment (as opposed to risk management or communication), it is not surprising that the influence diagram is dominated by risk assessment issues. Management and communication issues were by no means neglected; however, the concepts were of a much less detailed nature than the concepts participants used when they referred to risk assessment issues.

Food safety issues and environmental issues were equally represented. In almost all cases, these referred to relatively well-defined, measurable phenomena. The experts identified potential benefits as well as hazards that might result from a change in the glycoalkaloid content of the potato plant and its tubers. Lowering the level of solanine would decrease the toxicity of the tubers and strengthen the plant's immune system. At the same time, a lower solanine level would trigger an increase in the other main glycoalkaloid, chaconine, which could weaken the plant's immune system and result in increased toxicity of its tubers. A weakened immune system could in turn increase the need for plant protection, leading to a higher need for pesticides. Furthermore, the experts expected a loss of the trait after a certain number of generations. Obviously, this would lead to an increase in

the level of solanine, making the tubers more toxic again, posing a greater risk to humans. Another potential environmental hazard was linked to the use of a resistance marker gene, which could theoretically be transferred to soil bacteria. These bacteria might accumulate in sewage treatment plants and eventually change the composition of the bacterial community.

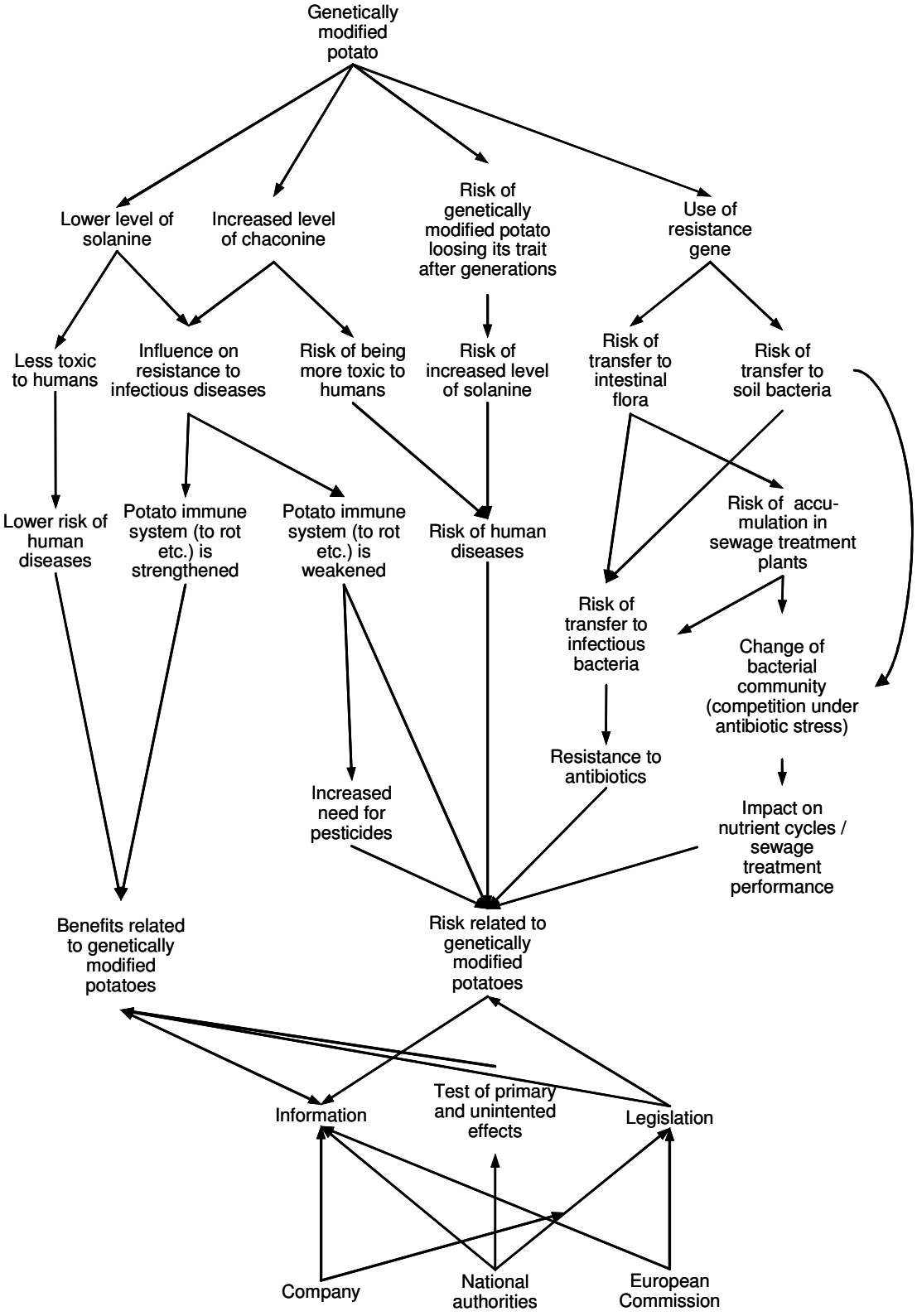

Figure 1. Expert model for GM potato with altered levels of inherent toxicants

The use of a resistance gene could theoretically also influence human health via transfer into the intestinal flora, possibly leading to antibiotic resistance in gut bacteria.

Among the food safety issues, potential risks and benefits were equally represented, whilst among environmental issues, potential risks were clearly dominant. Although we did not include uncertainty as such as a concept in the influence diagram, several participants noted that the validity of the model as a representation of potential risks and benefits associated with the genetically modified potato depended on the assumption that all effects were included in the diagram. This of course indicates that other effects might exist but they are not included in the diagrams because they are unknown to the experts today, but may re-surface in the future.

Furthermore, the environmental risk experts noted that farm-scale or even higher-level system changes might occur, for example changes in the types of crops that are grown and traded, with further consequences for rural economies and biological diversity. However, they also noted that there was currently no regulatory framework under which an environmental risk assessment could address such changes, either on European or on national level. Hence, the experts declined to elaborate further on this.

Study 2: Mental models of consumers

Method

Participants. In-depth interviews were conducted with altogether 25 consumers (13 men and 12 women). Their age was between 20 and 61 years, with an average of 35.48 years (*SD* = 12.97). Levels of education ranged from primary school to university level. 36% of the respondents

were married or cohabitating. Of these, 88% had one or more children. 28% of the respondents lived in rural areas.

Procedure. All participants were recruited at a shopping centre in Denmark. At the recruitment stage, participants were only informed that the interview would be about new food products. Participants received a gift certificate (EUR 25) as an appreciation of their time. In the first part of the interview, an open technique was used. Each interview began with an icebreaker question ("Which novel foods are you familiar with?"), followed by a short description of the potato example ("A new potato variety is being developed in which the concentration of a toxin called glycoalkaloid has been reduced by means of genetic modification. In the new potato variety, the level of this toxin has been reduced so that the potato can be regarded as healthier. Participants were then asked to explain what they thought about the potato example ("What do you think about this?") and elaborate on the reasons for their opinion. In the analysis, the responses from this part of the interview were categorised as unaided responses.

In the second part of the interview, a structured elicitation technique was used. The purpose of was to elicit consumer responses to the concepts that had been used by scientific experts in Study 1. We began with a card-sorting task. Participants were confronted with altogether 40 stimulus cards. Half of these contained the key concepts that had been used by the experts in Study 1, half contained unrelated concepts (distracters). Participants were first asked to sort the cards into two piles. This first pile should contain the concepts they could relate to the GM potato, whilst the second pile should contain those that they could not relate to it. The unrelated concepts were discarded. Then, participants were then asked sort

the concepts they could related to the GM potato into benefit and risks and explaining why they did so. All interviews were electronically recorded for later transcription. At the end of the interview, all participants were fully debriefed and received a gift certificate in compensation.

Analysis. A two-level category system was constructed by the authors. The categories were developed inductively, based on a qualitative analysis of the transcripts of the first five interviews. On a first level, risk and benefit domains were coded (governance issues, human health issues, environmental issues, evolutionary issues, production and economic issues). On a second level, the actual responses were coded (within the governance domain, for example, the categories were risk assessment, labelling and information, public authorities, European Union, legislation, farm subsidies).

Furthermore, participants' evaluations were coded (either as risk or as benefit) and whether the response had been given spontaneously during the first part of the interview (unaided) or upon confrontation with a concept card during the second part of the interview (aided). Responses that could not be fitted into the category system were coded as "miscellaneous" and were excluded from further analysis. No more than 0.7% of all statements were coded as miscellaneous (e.g., the response "potato peel is good compost for my vegetable garden" was judged to be unrelated to the issue of the interview and was therefore excluded). All transcripts were coded by the lead author of the present paper

After short quantitative summaries of complexity, accessibility, and valence indicators, the results of the in-depth analysis will be presented. In addition to the narrative interpretation, the interrelationships between the

content analysis categories will be visualised by means of influence diagrams. As in Study 1, the categories will be represented as nodes of a directed graph. The relative position of the categories to each other will be defined by their association frequencies (mapped into two dimensions by means of multidimensional scaling). Associations between categories will be represented as edges connecting the respective pairs of category nodes.

Results

Complexity of mental models and accessibility of cognitive representations. As expected, participants generated a relatively small number of unaided responses in connection with the genetically modified potato with altered glycoalkaloid levels (61 unaided responses, 475 aided responses). This ratio of unaided to aided responses can be interpreted as an indicator of the accessibility or salience of consumers' mental models, that is, how "active" or "top of the mind" the underlying cognitive representations are. The low amount of unaided responses suggests a relatively low overall degree of accessibility or salience in the cognitive representations of the risks and benefits of the novel foods. Even though Danish consumers in general posses knowledge about genetically modification (Gaskell et al, 2003) and a majority of participants also knew the danger of green potatoes (green potatoes have a high amount of glycoalkoloids) this is not something that are active in participants minds and they do not use this knowledge in their daily lives. The complexity of participants mental models in relation to the potato varied as amount of responses (both prompted and unprompted) varied from 10 to 30 per respondent with an average of 21 responses.

Dominant valence and risk-benefit domain. The ratio of responses classified as risk evaluations to responses classified as benefit evaluations

is an indicator of the overall evaluative valence dominating consumers' mental models. In consumers' responses, risk evaluations had a slight dominance over benefit evaluations (55% of responses classified as risks, 45 % as benefits; $\chi^2 = 6.28$, df = 1, $p < .05$). Considering only the unaided responses (61 in total), environmental issues clearly dominated (43%), followed by human health issues (21%), governance issues (16%) and production and economic issues (16%), and finally evolutionary issues (3%).

Environmental issues. Some participants saw a potential benefit for the environment if the potato plant could lead to reductions in fertiliser and pesticide expenditure. Some respondents further believed that such reductions would also lower the amount of toxins in the groundwater and that the potato would therefore have several beneficial consequences for the environment. On the other hand, many participants saw a risk in the cultivation of the GM potato plant, believing that its genes might cross out and spread in an uncontrollable way to other plants, which would in turn result in genetic pollution of the environment. Furthermore, some respondents believed that the cultivation of GM potato plants might influence the balance of the wider ecosystem, leading to unpredictable adaptation processes by other parts of the ecosystem.

Human health issues. Some participants believed that the potato could be beneficial because it contained fewer toxins. However, many participants relied on their long personal history of apparently safe potato consumption and were therefore unconvinced of the need for a low-toxin potato. Others believed a GM potato would somehow pose a health risk. When asked to elaborate on the nature of the supposed health risk, participants could not state anything more concrete than a vague notion of unknown long-term

effects, suggesting that their worries were motivated by uncertainty as such, rather than specific risk. Even though opinions differed somewhat, the majority of the participants agreed that the potato could be beneficial in terms of food security in developing countries[2] even though this is not a feature related to the potato example used in this study. Finally, some participants believed that GM potatoes can change human DNA.

Animal health issues. Participants voiced some concern that the GM potato might affect animal health when used as feed. One participant argued that the potato's balance of toxins was changed and that therefore it might develop a higher overall toxicity to animals. Other respondents believed that the feeding of farm animals with GM potatoes might have an indirect effect on human health when humans consumed meat from these animals.

Governance issues. Participants generally believed that public authorities, rather than commercial actors, should develop guidelines for the cultivation, processing and marketing of GM potatoes. Participants saw it as essential that authorities on the national as well as the EU level ensured proper labelling of the potatoes and also provided more detailed information to the public. Existence of and adherence to such guidelines was regarded as a benefit. Lack of adequate risk assessments and potential violation of labelling rules were at the same time evaluated as risks by participants. Furthermore, some participants voiced suspicions that

[2] In the content analysis, consumer acknowledgements of the potential value of the crop to developing countries were coded in terms of the value dimension they referred to, i.e. either as "economic incentives", "lower risk of diseases", or "increased yield".

legislation might lag behind the rapid pace of development in the technological area.

Production and economic issues. Some participants were worried about system-wide changes in agricultural production that might be prompted by the availability of high-yield GM plant species. The availability of such species might provide incentives to producers to increase outputs to unsustainable levels, possibly leading to escalating competition that might be impossible to control. Interestingly, the participants saw the same incentives as beneficial when interpreted as opportunities for a second "green revolution" in developing countries. Unlike in the industrialised world, where increases in crop yield were seen as a risk to the environment, increases in crop yield in the developing world were seen as instrumental in achieving food security.

Broader evolutionary issues. Some participants referred to the film "Jurassic Park" as an illustration of why they regarded uncertainty as a risk unto itself. Although the nature of unintended consequences might not be known, they argued, uncontrollable and unnatural developments do not automatically have a zero risk. One respondent argued that although mutation is a natural process, occurring permanently and without human interference in the natural environment, the results of artificial modifications of plant genomes are only monitored over a very short time period and should therefore be regarded as inherently risky because slow changes would remain outside the temporal scope of current risk assessment practices.

Mental models. Interrelationships between participants' responses to the GM potato with altered glycoalkaloid levels are visually represented in Figure 2.

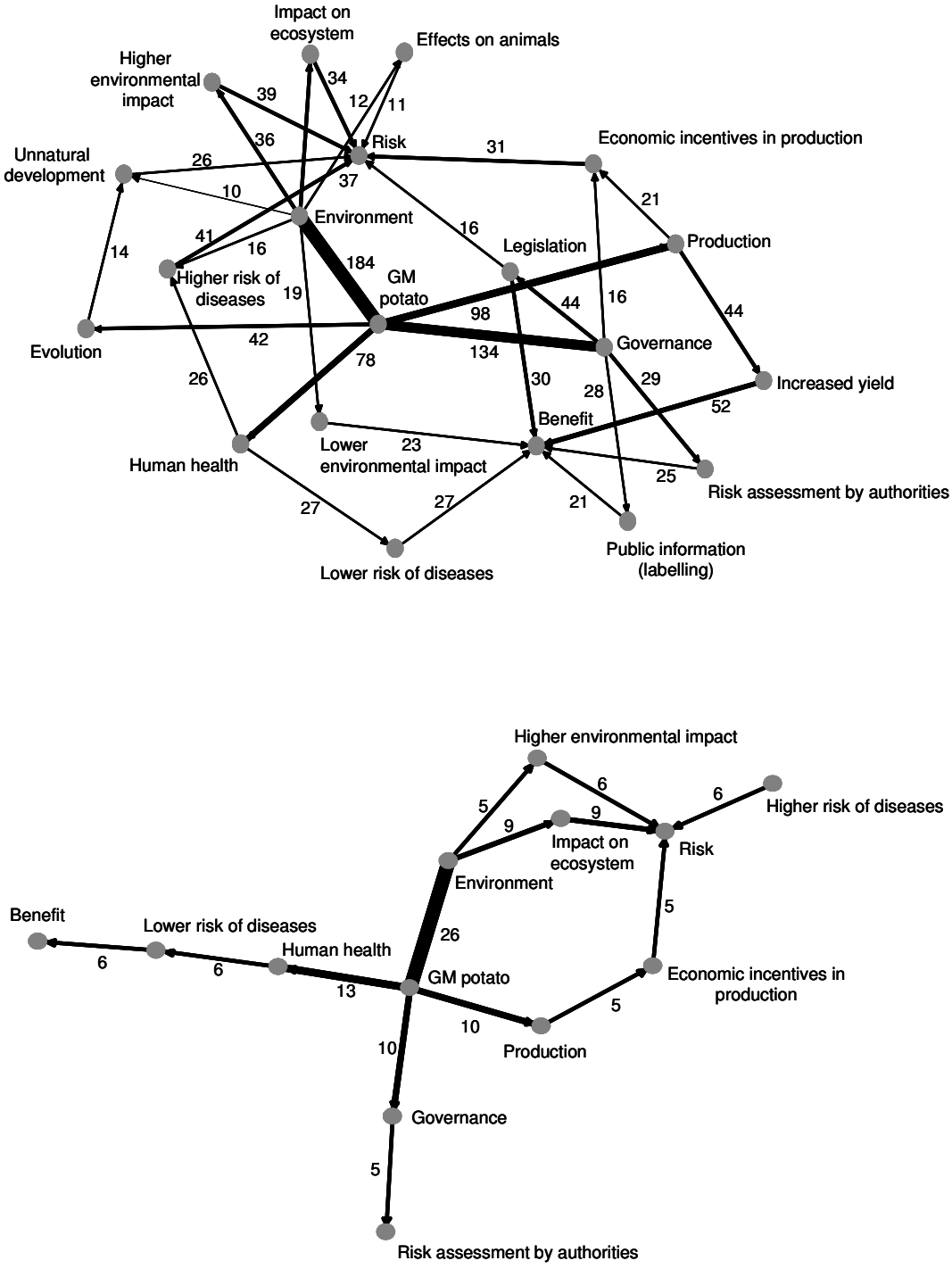

Figure 2. Consumer mental models for GM potato with altered levels of inherent toxicants. Upper figure: unaided and aided responses (only edges with association

frequencies ≥ 10 shown). Lower figure: only unaided responses (only edges with association frequencies ≥ 5 shown).

The categories of the content analysis system are represented as nodes of a directed graph (with node size proportional to category frequency e.g. minor nodes such as "legislation" and "evolution" in the model are mentioned less frequent by the participant than larger nodes such as "environment"), and associations between them are represented as edges (with line strength proportional to association frequency). The lower figure was generated from unaided responses only and is therefore substantially less complex; it can be interpreted as containing only the "active", directly accessible parts of consumers' mental models. Edges based on association frequencies below 5 were omitted for the purpose of clarity. The upper figure was generated from unaided as well as aided responses and is therefore substantially more complex. For purposes of clarity, edges based on association frequencies below 10 were omitted.

General discussion and conclusions

The aim of the research presented here was to identify and compare experts and consumers' mental models of the benefits and risks associated with a novel food example, a genetically modified potato with altered levels of the glycoalkaloids solanine and chaconine. To this end, two qualitative studies were conducted. In Study 1, mental models were elicited by means of a three-wave Delphi procedure from altogether 24 international experts with professional responsibilities in food safety risk assessment and environmental risk assessment. In Study 2, mental models were elicited in in-depth interviews with altogether 25 Danish consumers. In both studies,

detailed content analyses were conducted on the data, resulting in network visualisations of the mental models of experts and consumers.

In the following sections, we first discuss key differences between experts and consumers. Then, consumer misconceptions that are likely to have an impact on their response to future communication activities will be discussed. Following this, issues of particular criticality will be discussed. Finally, we will discuss limitations of the present research outline implications for further research.

Expert-consumer differences

The most obvious difference between expert and consumer mental models was their scope. All participants in the expert study were active scientists with professional responsibilities in risk assessment. Hence, it came as no surprise that the mental models elicited from the expert participants were very focused on the types of hazards for which risk assessments can reasonably be conducted under current legal European frameworks such as Regulation (EC) 258/97 concerning novel foods and novel food ingredients, Directive 2001/18/EC on the deliberate release into the environment of GMOs, and Regulation (EC) 1829/2003 on GM food and feed.

Consumers, on the other hand, were often much more concerned about the very issues that lay outside the scope of current legislation than they were about issues within the scope of current legislation. Often, these concerned system-wide impacts on eco-systems that are notoriously difficult to identify and assess, but also impacts on the broader consumption patterns in the industrialised world. In addition, consumers tended to raise normative ethical or governance issues in relation to almost every aspect of

risk assessment, management, and communication, a notion scientists usually shy away from because it tends to conflict with their role as impartial assessors or consultants to a process that is governed by others.

The second obvious difference between expert and consumer mental models was their depth. In line with what was expected, given their professional background, the participants in the expert study tended to define risk and benefit in terms of detailed chains of cause-effect relationships between variables for which clear definitions and measurement rules exist. The participants in the consumer study, usually not having a professional background in the biosciences, tended to define risk and benefit by target domain (e.g., health), and often elaborated on this in terms of mere class-inclusion relationships (e.g., animal health, human health) when asked by the interviewers what exactly they meant. Cause-effect relationships for biological processes could only rarely be identified in consumers' reasoning, and even then only in data collected in interviews with highly educated participants. Overall, the concepts that our consumer participants used when they reasoned about biological processes were very abstract, suggesting that most participants did not actually know anything about these processes beyond heuristic categorisations such as "toxins are unhealthy".

The third difference between expert and consumer understanding of risk was the enormous role which outcome uncertainty played in consumers' thinking. In contrast to the expert participants, who often declined to elaborate on consequences that were undefined in terms of their very nature, such states of ignorance appeared to be the main drivers behind consumers' concerns. Outcome uncertainty was generally regarded as a risk unto itself. This also explains the high importance that many

consumers attach to long-term risk assessments in the way of the farm-scale trials of GM crops conducted in the UK in recent years. In their view, the nature of unintended effects might only become apparent when a longer time window is applied to risk assessment than is currently the case.

At present, it is doubtful as to whether such consumer concerns will be taken up in agricultural and environmental policy in the near future. Two major factors in this are the prohibitive cost and the constraint on innovation that such a broadened approach to pre-market assessment would entail. Current government thinking in most OECD countries leans toward a reduction of the regulatory burden faced by innovators, rather than an increase, hence it is doubtful whether a broadened approach would find the necessary political backing. Furthermore, the discussions following the farm-scale trials in the UK (e.g., DEFRA, 2007) have demonstrated that consistent implementation of such an approach would need to resolve some issues beforehand that can arguably be regarded as even thornier (e.g., the formulation of quantitative protection goals, the ecological significance of changes detected in available endpoints, the question of proper baselines to which novel systems should be compared, the inclusion of benefits in the assessment, and the possible extension of such assessment to all crops and crop systems).

Consumer misconceptions

Several types of misconceptions became apparent in the qualitative analysis of the consumer data. The first type is an interesting form of over-generalisation. The information consumers received about our novel food example was limited to health issues; we did not provide any information regarding the agronomic properties of the crop. Nevertheless, many

consumers implicitly assumed that the crop had substantially improved agronomic properties. This we found peculiar; one explanation would be that consumers (quite plausibly) assume agribusiness companies to concentrate their R&D efforts on the development of crop varieties with improved agronomic properties. Another explanation would be that consumers automatically assumed any GM crop to have properties comparable to the "first generation" of GM crops, which have dominated the public debate during the last two decades. Either way, both explanations would suggest that consumers think about novel foods in terms of a prototype concept, unaware that the regulatory concept of novel foods does not have any meaning beyond the novelty of a product or process relative to what is currently available in the particular geographical market for which authorisation is sought.

The second type of misconception was related to an apparent unfamiliarity with regulatory procedures. The current legislation in the EU governing novel foods is not monadic; rather, it consists of a whole network of interlinked regulations and directives. In consumers' evaluations of what they assumed to be current risk assessment practices, it became apparent that a number of them assumed that all novel foods were governed by the same body of legislation bin the EU that applies to genetically modified foods. This is reflected even more clearly in findings by Hagemann and Scholderer (2007), who obtained the same result in a similar study as the present one that focused on a mutation-bred rice example (which would not be classified as a novel food under EU law).

Both misconceptions may become relevant for future communication activities. The common problem is that consumers appear to regard GM crops as the prototype of all novel foods. Given the way the concept of

novel foods has been discussed in popular media up until now, focusing almost exclusively on GM foods, this is only what could be expected. The consequence is, however, that consumers are likely to over-generalise the negative as well as the positive specificities of GM foods to all foods that are framed in communications as being "novel foods". A particular problem may occur when it becomes apparent to consumers that novel foods other than GM foods do not have to undergo environmental risk assessment. If consumers regard the technologies involved in the development of such novel foods as potentially dangerous (which is likely for all processes involving irradiation, for example), communications that run counter to consumers' expectations may shake their confidence in what they previously regarded a proper regulatory process.

Furthermore, most consumers appeared to assume that all stages in the risk assessment of novel foods were exclusively conducted by public authorities. This they judged as a trustworthy process. However, consumers' expectations are not quite correct at this point – toxicity data, for example, are usually supplied by the applicant or collated from published sources. If it became apparent in communications to consumers that commercial actors have collected the data on which a risk assessment is based, the trustworthiness of the assessment might be tainted. In general, consumers are relatively sceptical as to the motives and honesty of commercial actors in the food chain.

Critical issues

The low amount of aided responses generated by the participants indicates that a majority of risk and benefit associations appear to be "dormant" in consumers' thinking. They would not normally enter consumers' active

deliberations; however, as we demonstrated in previous research (Scholderer & Frewer, 2003; Frewer, Scholderer & Bredahl, 2003), normally inaccessible associations can be activated by unwise communications and cause serious boomerang effects. Blatant attempts to convince consumers of the benefits of novel technologies are particularly likely to yield such results; if these run counter to consumers' pre-existing attitudes towards a technology – be they dormant or not – such communications are likely to prompt a reaction in consumers and lead to behavioural avoidance reactions and decreases in the perceived trustworthiness of the communicator that would not normally occur. Hence, communications should be designed very carefully to avoid triggering dormant risk associations.

The issues consumers were most concerned about are somewhat problematic for risk communicators to handle. In many cases, the concerns consumers had about environmental consequences of the cultivation of plant species with altered genomes were related to complex, system-wide effects that cannot realistically be addressed in environmental risk assessments, at least as they are currently stipulated by legislative frameworks. In a similar way, consumers often reasoned about the rather complex influences that foods with altered health characteristics might have on whole patterns of consumption behaviour in the population. Again, this issue is extremely difficult to address under current risk assessment guidelines. Further research is needed here; at present, no models exist that would allow the necessary predictions.

Equally problematic are the issues consumers were not concerned about as they did not derive their public health potential from the fact that inherent toxicants are overall reduced (solanine has been reduced). Many of the

consumers we interviewed in our study simply ignored these health benefits or re-interpreted the product descriptions, for example assuming that only green potatoes were toxic and that we had somehow made a mistake in its description.

Besides the fact that consumers usually do not have the necessary background knowledge to make sense of the biological effects of solanine or chaconine, a subjectively safe history of personal use turned out to be the main barrier. Consumers actively defended their personal eating history, maintaining the security offered by lifelong habits. Arguments along the line of "I have eaten potatoes all my life and I am still not dead" demonstrated that consumers found it utterly unconvincing that, all of a sudden, they should regard their everyday foods as highly toxic. We do not think that it will be possible to communicate the health benefits of the potato example effectively to consumers. If the public health potential of this product (or similar ones) is to be realised, other mechanisms than consumer choice may have to be relied upon.

Limitations

The research presented in this article was qualitative. Due to the small sample sizes we used in the two studies presented here, the results are preliminary and should not be over-generalised. Our pragmatic aim was to identify, on a qualitative, content-oriented level, key issues in the expert and consumer understanding of risks and benefits associated with a novel food, a genetically modified potato.

Some more specific limitations should be noted. The participants in our expert study were professionally concerned with risk assessment. We did not involve experts with professional responsibilities in legislation, risk

management, or risk communication. Therefore, the perfunctory discussion of legislative, managerial and communicative aspects by our expert participants is only natural. In addition, it should be noted that the potential hazards identified by our experts are by no means completely established yet. Their answers are working hypotheses, partly based on previous research, partly derived by analogy from related research, partly based on considerations of biological plausibility.

Furthermore, we investigated only one example of second-generation novel foods. It is not possible to conclude from the results what experts or consumers would regard as risks or benefits in relation to other types of novel foods. The results point in certain directions, but will always require detailed case-specific assessments before the results can be considered valid.

Finally, the consumer study reported here involved only Danish consumers. In several respects, our compatriots are "outliers" when compared to the average EU citizen. Danish consumers tend to trust public authorities, favour command-and-control regulation over voluntary codes of conduct, and are much less likely than consumers in other EU member states or the US to think about or choose their foods based on nutrient considerations (Gaskell, Allum & Stares, 2003; INRA Europe, 1998; Lappalainen, Kearney & Gibney, 1998). If the same methodology had been applied in other countries, the results might have been somewhat different.

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ARTICLE 2

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Consumer versus expert hazard identification: A mental models study of mutation-bred rice

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Abstract

Novel foods have been the object of intense public debate in recent years. Despite efforts to communicate the outcomes of risk assessments to consumers, public confidence in the management of potential risks has been low. Various reasons behind this have been identified, chiefly a disagreement between technical experts and consumers over the nature of the hazards on which risk assessments should focus, and perceptions of insufficient openness about uncertainties in risk assessment. Whilst previous research has almost exclusively focused on genetically modified foods, the present paper investigates plant varieties developed by means of mutation breeding, a less-debated class of novel foods. Two studies that investigated the mental models of experts and laypeople were conducted. The results revealed that the mental models of both groups differed in terms of scope, depth and the role of uncertainty. Furthermore, a number of misconceptions became apparent in the study of laypeople's mental models, often related to the regulatory system governing risk assessments of novel foods. Critical issues are outlined and communication needs are discussed.

Introduction

In European food law, the term "novel foods" stands for foods and food ingredients that have never been used for human consumption in Europe to a significant degree (Regulation EC 258/97). The definition can be subdivided into three subclasses: products never used as foods in Europe (e.g., new types of fruits and vegetables), foods that are genetically modified, and foods produced with the help of novel and emergent technologies not previously used in agriculture, food manufacturing and

processing. A classic example of the second subclass is Golden Rice, a genetically modified rice variety that promotes bioavailability of nutrients by means of genetically increased beta-carotene levels (Potrykus, 2001; Zimmermann & Qaim, 2004). The rice is designed to improve nutrition among people in developing countries, whose daily diet does not cover the needs for almost 50 different nutrients.

Increasing the level of nutrients is one way to improve the nutritional properties of plants; lowering the levels of anti-nutrients is another way. The present study will focus on expert and consumer perceptions of one such novel food, a rice seed which has been developed by mutation breeding to contain a lower amount of phytic acid. Mutation breeding is a non-GM approach which has been used to develop a number of plant varieties. Phytic acid can act as an anti-nutritional compound by influencing the bioavailability of minerals but it is also claimed to have some benefits in humans. Interestingly, current regulatory frameworks do not define mutation breeding as a novel technique that would make risk assessment under the terms of Regulation (EC) 258/97 mandatory. Although mutation breeding has never been an issue of public debate in Europe, previous research on consumer concerns related to *other* uses of ionizing radiation (see below) suggests that public opinion may turn out to be rather critical once it actually is investigated. The present study aims to provide first insights into public perceptions of the risks and benefits of mutation-bred plant varieties, taking the above-mentioned rice as a case in point.

Consumer perceptions of food irradiation

Previous research on consumer perceptions of food irradiation has concentrated on post-production uses of the technology (Sigurbjornsson & Loaharanu, 1989; Bruhn, 1995; 1998; Furuta, Hayashi, Hosokawa, Kakefu & Nishihara, 1998; Frenzen, DeBess, Hechemy, Kassenborg, Kenney, McCombs, McNess & the Foodnet Working Group, 2001; Wilcock, Pun, Khanona & Aung, 2004) where the food is exposed to ionizing radiation with the intent to kill harmful bacteria, extending the shelf-life of the food and preventing food-borne diseases such as salmonella (Loaharanu, 2003). Even though irradiation was used for the first time in 1905 by Appleby and Banks (see Diehl, 1993) and has been used widely in the last 50 years, many consumers regard it as a novel and unfamiliar technology. Consumer concerns about post-production uses of food irradiation focus on safety, nutritional adequacy, potential harm to employees and the danger of living close to production facilities (Weaver & Marcotte, 1988; Bruhn, 1995; Wilcock, Pun, Khanona & Aung, 2004). Several US studies have suggested that providing consumers with scientific information would have a positive influence on their knowledge about and willingness to pay for irradiated foods (Bruhn, 1995; 1998; Furuta, Hayashi, Hosokawa, Kakefu & Nishihara, 1998). Research indicates that Europeans share the general concerns of US consumers but are much more reluctant to actually accept food irradiation (Wilcock, Pun, Khanona & Aung, 2004). Reflecting this, European regulators have kept a ban on the post-production irradiation of foods, with no signs that the ban will be lifted in the near future.

Ionizing radiation can also be used in plant breeding to induce mutations. Mutation breeding is a non-GM approach which has been used to develop numerous plant varieties including maize, barley, wheat and rice lines

(Falk, Chassy, Harlander, Hoban, McGloughlin & Akhlaghi, 2002). Mutation breeding involves the altering of plant genomes by "artificial" means. Hence, it is often suspected that consumers would perceive mutation breeding as similar to genetic modification if mutation breeding was to become an issue of public debate. Existing studies concerning novel foods have more or less exclusively focused on genetically modified foods, neglecting other types of novel foods that may provide more tangible consumer benefits and do not bear the "stigma" of being genetically modified. The research presented in this paper aims to fill this gap.

Overview of empirical work

A key problem in past attempts to communicate the risks and benefits of novel foods to the public has been a substantial mismatch between expert and consumer understanding of the nature of the issues (Scholderer, Balderjahn, Bredahl & Grunert, 1999; Jensen & Sandøe, 2002; Frewer, Lassen, Kettlitz, Scholderer, Beekman & Berdal, 2004). In order to avoid such problems, we will investigate and explicitly compare expert and consumer understanding of the benefits and risks of the novel rice. However, studies with experts and studies with consumers require different research protocols. Therefore, we used a Delphi design to investigate expert conceptualisations of the risks and benefits and individual in-depth interviews with consumers to investigate their conceptualisations of the risks and benefits of the novel food. Differences between expert and consumer understanding of the various issues will then be assessed in the final sections of the paper.

We will employ a methodology that focuses on the way people conceptualise hazardous processes. The theoretical underpinning of this

research is that consumers bring to any risk a network of beliefs that can be understood as an idiosyncratic small-scale model of reality, a "mental model" of that risk (e.g., Fisher, Walker, Bostrom, Fischhoff, Haire-Joshu & Johnson, 2002). A systematic approach to analyse such mental models has been developed by Morgan, Fischhoff, Bostrom and Atman (2001). The procedure can be divided into four steps: (1) creating an expert mental model, (2) eliciting relevant beliefs from consumers, (3) mapping those beliefs into a consumer mental model, and (4) identifying differences between the expert and the consumer model.

A number of recent studies have applied the mental models approach to differences in how experts and laypeople perceive risk. The approach has typically been used in situations where the risks evaluated are highly personal, including health issues such as local complications for women with breast implants (Byram, Fischhoff, Embrey, Bruin & Thorne, 2001), diabetes prevention (Fisher, Walker, Bostrom, Fischhoff, Haire-Joshu & Johnson, 2002), and vaccine risk (Bostrom, Stoto & Evans, 1998). The mental models approach has furthermore been used in the environmental area, for example in the context of climate change (Bostrom, Morgan, Fischhoff & Read, 1994) and geological radon (Bostrom, Fischhoff & Morgan, 1992).

The advantage of this approach is that it allows risk communicators to pinpoint their activities to the exact state of knowledge that already exists in the target audience. Specifically, differences between expert and consumer understanding of the issue at hand can serve as the starting point for communication activities. It must be noted, though, that the mental models approach can be seen as an instance of what has been identified as the "deficit model" in the public understanding of science literature. The

model refers to technocratic elites adopting the perspective that the public is in some way ignorant of the scientific "truth" about risk and probability, and that therefore risk communicators should attempt to rectify the knowledge gap between the originators of scientific information and its recipients (Hilgartner, 1990). The authors of the present paper do not subscribe to such a view; however, differences between technical experts and laypeople are often responsible for communication failures. Therefore, a more dialogue-oriented approach to risk communication needs to be aware of such differences as well.

Study 1: Mental models of experts

Method

Participants and procedure. Altogether 24 experts participated in the study. A three-wave Delphi design was used. In the first Delphi wave (April 2004), individual face-to-face interviews were conducted with two food safety experts from the Danish Institute for Food and Veterinary Research. In the second Delphi wave (June 2004), the influence diagrams generated in the first wave were forwarded to twenty additional experts with backgrounds in human toxicology, nutrition, epidemiology, plant genetics and food science for validation. In the third Delphi wave (August 2004), the updated influence diagrams were then forwarded to two additional experts with backgrounds in eco-toxicology and applied ecology for additional comments. All responses were transcribed, content-analysed and integrated into influence diagrams, resulting in the final versions of the influence diagrams.

Analysis. A three-step content analysis of participants' responses was conducted. In the first step, key concepts were identified in the interview transcripts (e.g., "mutated rice", "phytic acid"). Whenever explicit or implicit qualifications of these concepts had been given by participants, these qualifications were linked directly to the concepts (e.g., "lower level of phytic acid"). In the second step, relationships between pairs of key concepts were identified, including class-inclusion relationships (e.g., "risk of human diseases" is part of "risk associated with mutation-bred rice"), cause-effect relationships (e.g., "lower level of anticancerogenous agent" may lead to "no impediment of cancer development") as well as social relationships ("national authorities" exert influence on "legislation"). In the third step, the responses were aggregated over respondents and transformed into influence diagrams separately for the three novel food examples under study. The strength of relationships between the concepts was not quantified in any way and the results should therefore be understood in a purely qualitative way.

Results

Altogether 25 concepts were identified in participants' responses that were related to the mutation-bred rice with lowered levels of phytic acid. Given that all participants were active scientists, as opposed to risk managers or communicators, it is not surprising that the influence diagram is dominated by risk and benefit assessment issues. Risk management and communication issues were not actually neglected but were relatively unspecific. Human health issues, animal health issues, environmental issues as well as economic aspects were represented in the model, usually in the form of clear and detailed cause-effect relationships. The final influence diagram is depicted in figure 1.

Several experts pointed to the fact that, even though there were potential eco-system consequences associated with widespread use of the rice seed in question as a crop plant, current regulatory frameworks did not provide for ecological risk assessment. Unlike GM crop plants, mutation-bred varieties were not legally defined as a class of crops that warranted such assessment. Strictly speaking, there would not even be the legal requirement of performing a rigorous food safety risk assessment under the terms of Regulation (EC) 258/97. Mutation-breeding is not regarded as a novel technique under current regulatory frameworks; hence there is no special status for varieties such as the rice line investigated here that would go beyond general food law.

Study 2: Mental models of consumers

Method

Participants. In-depth interviews were conducted with altogether 25 consumers: 13 men and 12 women. Their average age was 35.48 years (*SD* = 12.97). A wide variety of occupations were represented, including craftsmen, public employees, students and unemployed persons. Levels of education ranged from primary school to university level. 36% of the respondents were married or cohabitating. Of these, 88% had one or more children.

Procedure. All participants were recruited at a shopping centre in Denmark. To ensure that major segments of the population were covered, the following demographic variables were checked: age, gender, education, occupation, marital status, and children in the household. Participants were then invited to take part in an in-depth interview lasting up to two hours

and were offered a gift certificate (EUR 25) as an appreciation of their time. A relatively open technique was used in the interviews, avoiding the imposition of scientific perspectives on participants' answers. Simple open-ended introductory questions were used, followed by questions directing participants towards specific topics identified in Study 1, and follow-up prompts. The follow-up prompts began with approximately 40 stimulus cards containing 20 concepts extracted from the expert models constructed in Study 1 and 20 cards with concepts that did not relate to the mutation-bred rice. Participants were asked first to divide the cards into two piles; one containing only those concepts that they could relate to the novel food, and the other those that they could not relate to it. The unrelated concepts were discarded. The participants were then asked to divide the concepts that participants evaluated as benefits, whilst the second pile should contain concepts that participants evaluated as risks associated with the novel food. As expected, participants reported a number of risks and benefits not included in the expert models. Therefore, we allowed the first five respondents to add new concepts as stimulus cards to the two piles.

Analysis. Content analysis of participants' responses was conducted in three steps. In the first step, key concepts were identified from the transcripts of the first five interviews. In the second step, the relationships between these concepts were identified, again from the transcripts of the first five interviews. Unlike in Study 1, where the expert participants predominantly related their concepts in terms of cause-effect relationships, we found that consumers related their concepts mainly in terms of semantic associations, class-inclusion relationships, and social influences, but not at any great associative depth.

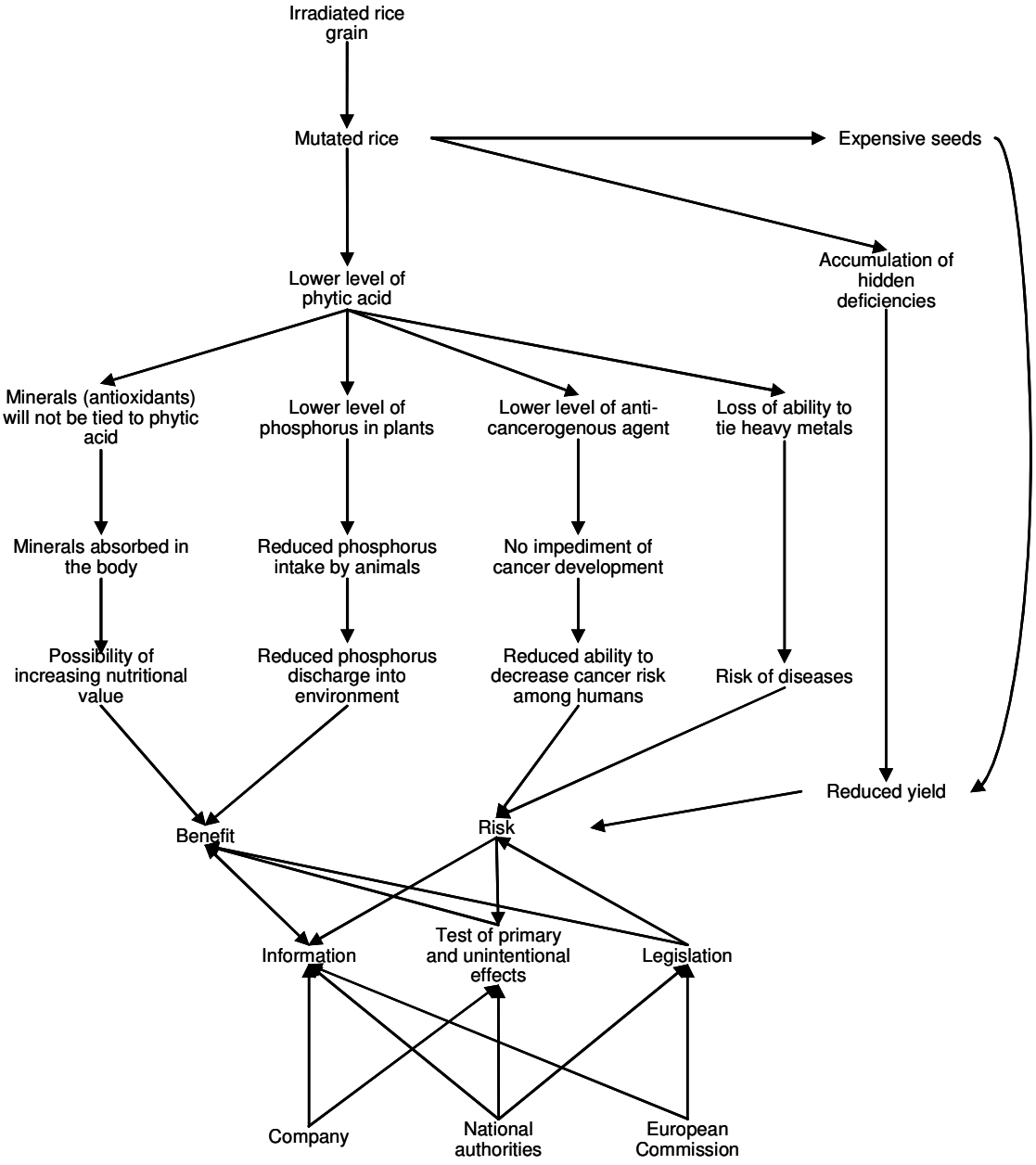

Figure 1. Expert model for mutation-bred rice

After short, quantitative summaries of complexity, accessibility and valence indicators, the results of the in-depth analysis will be presented; first the qualitative results on a purely content-oriented level will be presented. These will be summaries of the main points and arguments that were raised spontaneously by the participants during the interviews. Then,

we will present quantitative summaries of the structural relationships in the content-analysed data.

The structural relationships will be visualised by association frequencies using network analysis. Association frequencies between categories can be interpreted as proximity indicators. These will first be transformed into geodesic distances between categories and then rescaled into two-dimensional representations by means of metric multi-dimensional scaling (MDS). In the visualisations, the categories will be represented as nodes of a directed graph. The relative position of the categories to each other will be defined by their MDS-rescaled distances. Associations between categories will be represented as edges connecting the respective pairs of category nodes. The network visualisations can be understood as aggregate representations of consumers' mental models of the benefits and risks associated with the novel food.

Results

Accessibility of cognitive representations. The ratio of unaided to aided responses can be interpreted as an indicator of the accessibility or salience of consumers' mental models, that is, how "active" or "top of the mind" the underlying cognitive representations are. Unaided responses accounted for only 12% of all responses (53 unaided and 381 aided responses), suggesting a relatively low overall degree of accessibility or salience in the cognitive representations of the risks and benefits associated with mutation-bred rice.

Dominant valence. The ratio of responses classified as either risk or benefit evaluations is an indicator of the overall evaluative valence dominating consumers' mental models. The evaluations in connection with the mutated

rice were more or less equally represented (47% of responses classified as risks, 53% as benefits). Together the risk-benefit domains covered five issues, where human health issues were most frequent (31%), followed by environmental issues (25%), governance issues (22%), production and economic issues (16%), and evolutionary issues (6%).

Aided and unaided responses to mutation-bred rice. Interrelationships between participants' responses to the mutation-bred rice are visually represented as in figure 2. This complex figure contains the "active", directly accessible parts of consumers' mental models (identified by the unaided responses) as well as those which can temporarily be made accessible through communications or some other form of external activation (identified by the aided responses).

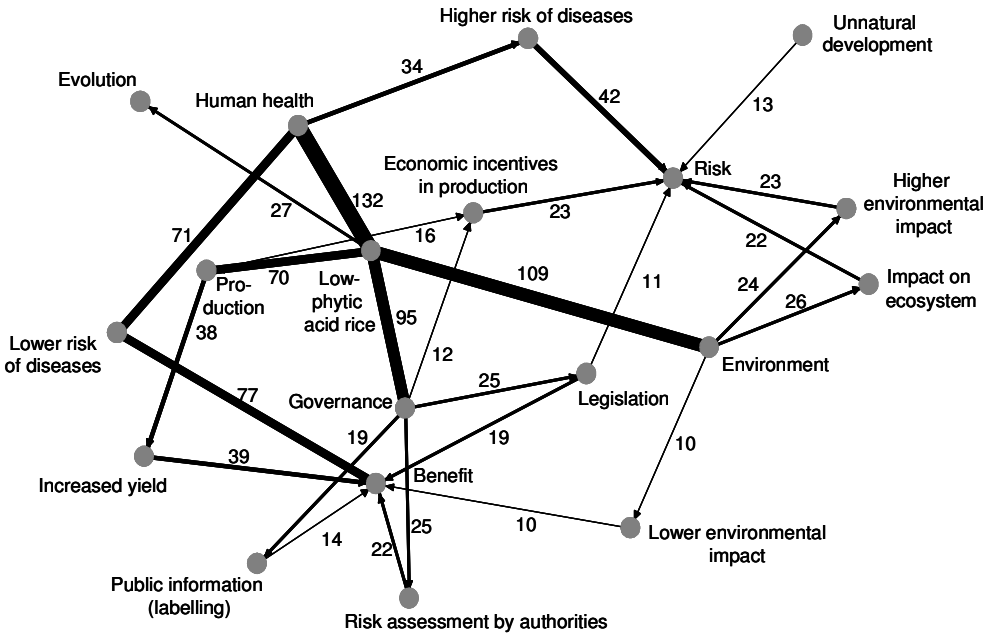

Figure 2. Consumer mental models for mutation-bred rice (both unaided and aided responses; only edges with association frequencies ≥ 10 shown).

The categories of the content analysis system are represented as nodes, and associations between them are represented as edges of a directed graph. Numbers attached to the edges are raw association frequencies. For purposes of clarity, edges based on association frequencies below 10 were omitted.

Unaided responses to mutation-bred rice. In this section, we will present in-depth analyses of consumers' responses to the mutation-bred rice and only considering unaided responses given spontaneously by consumers without further prompting by the interviewer, see figure 3. Out of the 46% *unaided* responses, human health issues clearly dominated (40%), followed by environmental issues (23%), governance issues (17%), evolutionary issues (11%) and production and economic issues (9%).

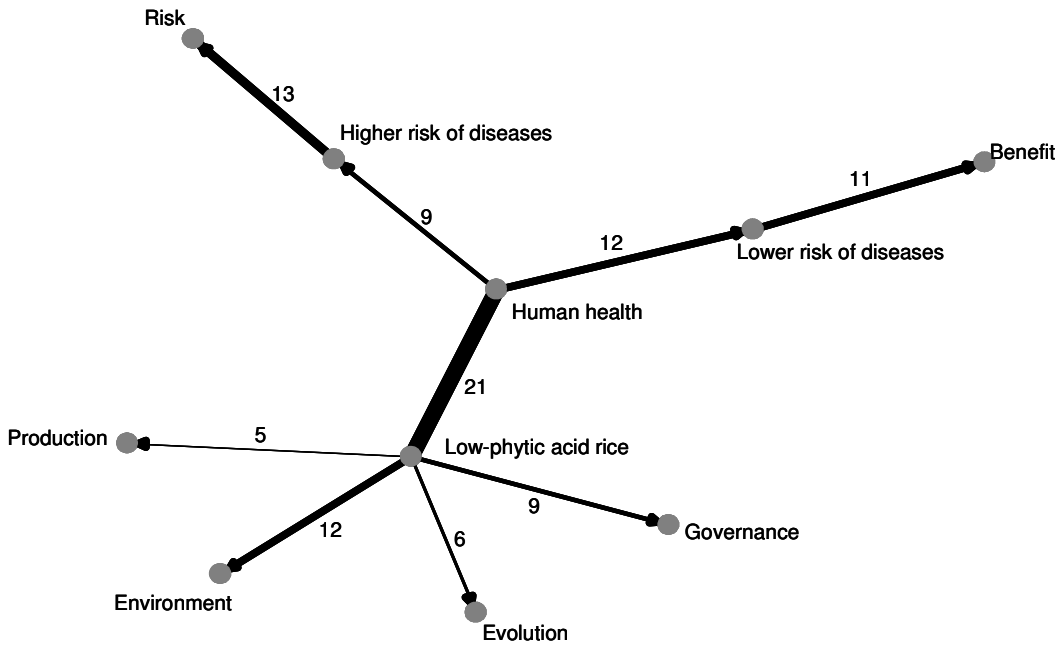

Figure 3. Consumer mental models for mutation-bred rice (only unaided responses, only edges with association frequencies ≥ 5 shown)

Figure 3 was generated solely from unaided responses and therefore only contains the "active", directly accessible parts of consumers' mental models. The unaided model was substantially less complex than the full model (figure 2). Here, edges based on association frequencies below five were omitted for purposes of clarity. Again, association strength is represented in terms of distances between nodes as well as the strength of the edge connecting any given pair of nodes.

Human health issues were seen in a rather balanced way by the participants as better nutrition due to the provision of essential minerals from the rice was perceived as a health benefit. But the majority of participants thought mutation-bred rice in connection with human health to be a risk, believing that consumption of the rice could lead to excessive intake of vitamins and minerals, which might have toxic effects. Another risk issue raised was the possibility that the rice would be used as a convenient "pretext for doing nothing" by people with questionable nutritional habits. In continuation of this assumption participants believed that the rice would lead to increased consumption of other foods with undesirable nutritional profiles because consumers might think that the mutation-bred rice would cover all needs for minerals. The same mechanism might even increase the risk of obesity. Interestingly, the issues that were understood as risks to human health in the industrialised world were interpreted as benefits for human health in the developing world[3]. Several participants thought the rice could alleviate

3 In the content analysis, consumer acknowledgements of the potential value of the crop to developing countries were coded in terms of the value dimension they referred to, i.e. either as "economic incentives", "lower risk of diseases", or "increased yield".

malnutrition problems and contribute to higher food security in developing countries.

Concerning environmental issues, potential risk was stated by several participants. In particular, some believed that the mutated rice line might require higher levels of plant protection thereby leading to increases in pesticide expenditure. The concerns about the environment were strongly connected to some evolutionary concerns as participants feared that the mutation might spread to other plants causing system-wide environmental changes.

Participants voiced considerably less concern about governance issues in connection with the rice than expected. Participants believed that long-term risk assessments, governed by public authorities, and the opportunity to examine potential effects of the mutated rice line more closely would be beneficial. However, labelling and information provision were of some concern as participants thought it absolutely necessary that the process be governed by legitimate public authorities.

Economic motives were regarded as inherently problematic by a few politically-minded participants. These participants were mainly worried about overproduction, and some respondents feared that companies with a commercial stake in the mutated rice line might disregard adverse consequences.

General discussion and conclusion

The aim of the research presented here was to identify and compare mental models of experts and consumers and their perceptions of benefits and risks associated with mutation-bred rice with a reduced level of an inherent

toxicant, phytic acid. Two qualitative studies were conducted. In Study 1, mental models were elicited by means of a three-wave Delphi procedure from altogether 24 international experts with professional responsibilities in food safety risk assessment and environmental risk assessment. In Study 2, mental models were elicited in in-depth interviews with altogether 25 Danish consumers with wide variations in socio-demographic characteristics and education. In both studies, detailed content analyses were conducted, resulting in network visualisations of the mental models of experts and consumers. In the following sections, we will first discuss key differences between experts and consumers. Then, consumers' mis-conceptions that are likely to have an impact on their response to future communication activities will be discussed. Following this, issues of particular criticality will be discussed. Finally a discussion of limitations of the present research will outline implications for further research.

Expert-consumer differences

The most obvious difference between the expert and consumer mental models was their scope. All participants in the expert study were active scientists with professional responsibilities in risk assessment. Hence, it came as no surprise that the mental models elicited from the expert participants were very focused on the types of hazards for which risk assessments can reasonably be conducted under current legal frameworks concerning novel foods and novel food ingredients. Hazards beyond the scope of current legislation were acknowledged by the experts but not further elaborated on, which is a known disadvantage in experts' risk assessments. Consumers were often much more concerned about the issues that lay outside the scope of current legislation and these concerns often involved system-wide impacts on eco-systems or impacts on the broader

consumption patterns, which are notoriously difficult to identify and assess. In addition, consumers tended to raise normative ethical or governance issues in relation to almost every aspect of risk assessment, management, and communication.

The second obvious difference between expert and consumer mental models was their depth. Due to their professional background, experts tended to define risk and benefit in terms of detailed chains of cause-effect relationships between variables for which clear definitions and measurement rules exist. The participants in the consumer study tended to define risk and benefit by target domain (e.g., health), and when they were told to elaborate they defined risk only in terms of mere class-inclusion relationships (e.g., animal health, human health). Overall, the concepts which our consumer participants used when they reasoned about biological processes were very abstract, suggesting that most participants did not have any knowledge about these processes beyond heuristic categorisations such as “toxins are unhealthy”.

The third difference between expert and consumer understanding of risk was the enormous role of outcome uncertainty in consumers’ thinking. In contrast to the expert participants, who often declined to elaborate on consequences that were undefined in terms of their very nature, such states of ignorance appeared to be the main drivers behind consumers’ concerns. Outcome uncertainty was generally regarded as a risk unto itself. This also explains the high importance which many consumers attach to long-term risk assessments and they perceive that unintended effects might only become apparent when a longer time window is applied to risk assessment than is currently the case.

Consumer misconceptions

Several types of misconceptions became apparent in the qualitative analysis of the consumer data. The first type of misconception was related to the categorisation of the particular novel food, as consumers believed the mutation-bred rice, which had been developed using a non-GM approach, to have substantially improved agronomic properties. Participants seemed to automatically assume that any novel food crop would have properties comparable to the "first generation" of GM foods. This explanation would suggest that consumers think about novel foods in terms of a prototype concept, unaware that the regulatory concept of novel foods does not have any meaning beyond the novelty of a product or process relative to what is currently available in the EU market.

The second type of misconception was related to an apparent ignorance of regulatory procedures. Most striking is that consumers appeared to assume that mutation-bred plant varieties would have to undergo ecological as well as food safety risk assessment. The current legislation governing novel foods is not monadic; rather, it consists of a whole network of interlinked regulations and directives. In consumers' evaluations of what they assumed to be current risk assessment practices, it became apparent that a number of them assumed that all novel foods were governed by the same body of legislation that applies to genetically modified foods. For example, consumers seemed to assume that environmental risk assessments, as stipulated by a separate directive on the deliberate release of GMOs into the environment, would also have to be conducted for the type of novel food investigated here. This is not the case; the regulation concerning novel foods and novel food ingredients does not provide for environmental risk assessment. On a more general level, regulatory bodies do not consider

mutation breeding as a novel process, which would make food safety assessment mandatory under the provisions of Regulation (EC) 258/97.

Both misconceptions may become relevant for future communication activities. The common problem is that consumers appear to regard GM foods as the prototype of all novel foods. Given the way the concept of novel foods has been discussed in popular media up until now, focusing exclusively on GM foods, this was only to be expected. The consequence is, however, that consumers are likely to over-generalise the negative as well as the positive specificities of GM foods to all foods which are framed in communications as being "novel foods" in terms of regulation. In the longer term separating GM foods from other novel foods could become beneficial for other types of novel foods not containing genetically modified elements.

A particular problem may occur when consumers become aware of the fact that novel foods other than GM foods do not have to undergo environmental risk assessment. If consumers regard the technologies involved in the development of such novel foods as potentially dangerous (which is likely for all processes involving irradiation), communications that run counter to consumers' expectations may shake their confidence in what they previously regarded a proper regulatory process.

Furthermore, most consumers appeared to assume that all stages in the risk assessment of novel foods were exclusively conducted by public authorities perceiving it as a trustworthy process. However, consumers' expectations are not quite correct concerning this point as, e.g., toxicity data are usually supplied by the applicant or collated from published sources. If communications to consumers made it clear that commercial actors

collected the data on which a risk assessment is based, the trustworthiness of the assessment might be tainted. In general, consumers are relatively sceptical as to the motives and honesty of commercial actors in the food chain.

Critical issues

The issues that consumers were most concerned about are somewhat problematic for risk communicators to handle. In many cases, the concerns consumers had about environmental consequences of, e.g., cultivation of plant species were related to complex, system-wide effects that cannot realistically be addressed in environmental risk assessments. In a similar way, consumers often reasoned about the rather complex influences which foods with altered health characteristics might have on whole patterns of consumption behaviour in the population. Again, this is an issue which is extremely difficult to address under current risk assessment guidelines.

Equally problematic are the issues consumers were not concerned about. Technical experts believe the rice variety investigated in this study to have potential benefits for public health due to the fact that inherent toxicants are overall reduced (reduced phytic acid content). Many of the consumers interviewed in this study simply ignored these health benefits or re-interpreted the product description, for example by assuming that the novel rice actually had a higher content of phytic acid, and that we had somehow made a mistake in its description. Several consumers even saw a general danger in the marketing of functional foods, fearing that such foods would give other consumers a pretext for maintaining otherwise unhealthy lifestyles.

As consumers usually did not have the necessary background knowledge to make sense of the biological effects of phytic acid, they tended to overestimate the potential nutritional efficacy of the rice, whilst technical experts believe "bio-fortified" staple foods not to be able to supply the same amount of minerals and vitamins as supplements or industrially fortified foods (Bouis, 2002).

Another interesting aspect is that the use of irradiation in the breeding of food crops has barely been mentioned in the media, whereas post-production use of irradiation (as a preservation method) has been an intensely covered topic. The findings in this study suggest that consumers use their existing knowledge about first generation of GM foods as well as post-production irradiation to create their own representation of an unfamiliar technology by combining different risk aspects from two known technologies.

Sometimes, it is argued in the literature (e.g., Zepeda, Douthitt & You, 2003) that consumer acceptance of agricultural biotechnology could be increased if companies focused on producing attributes with a clear benefit to consumers. The mutation-bred rice investigated in the present study had such beneficial characteristics, but participants seemed to selectively ignore positive information. When participants were confronted with positive information (e.g., that the rice could improve uptake of minerals), a number of participants counter-argued with statements like "the rice could lead to excessive uptake of minerals that are toxic" or "too many minerals will lead to a scarcity of other things". The selective disregard of information suggests that consumers may find information unconvincing that implies that they should regard their everyday diets as potentially dangerous.

Limitations

Due to the small sample sizes we used in the two studies presented here, the results are preliminary and should not be over-generalised. Some more specific limitations should be noted. The participants in our experts study were professionally concerned with risk assessment. We did not involve experts with professional responsibilities in legislation, risk management, or risk communication. Therefore, our expert participants' perfunctory discussion of legislative, managerial, and communicative aspects is only natural. Also, it should be noted that the potential hazards identified by our experts are by no means completely established yet. Their answers are working hypotheses, partly based on previous research, partly derived by analogy from related research, partly based on considerations of biological plausibility.

Furthermore, we investigated only one second-generation novel food and it is not possible to conclude from the results what experts or consumers would regard as risks or benefits in other types of novel foods. As previously mentioned, consumers had difficulty in considering this new type of rice to be more nutritious than conventional rice, which could simply be the result of consumers' current belief that conventional rice was healthy and that there was no obvious reason for enhancing its nutrient level. Perception of risk can vary according to the type of food the technology is applied to (Zepeda, Douthitt & You, 2003) consumer acceptance could be higher if the technology was used to improve those types of food that consumers perceived to be problematic for their health. Therefore the conclusions from this study point in certain directions for mutation-bred crops, but will always require detailed case-specific assessments before the results can be considered valid.

Finally, the consumer study reported here involved only Danish consumers. In several respects, our compatriots are "outliers" when compared to the average EU citizen. Danish consumers tend to trust public authorities, favour command-and-control regulation over voluntary codes of conduct, and are much less likely than consumers in other EU countries to think about or choose their foods on the basis of nutrient considerations (Gaskell, Allum & Stares, 2003; INRA Europe, 1998; Lappalainen, Kearney & Gibney, 1998). Hence, it is important to note that a replication of the consumer study in other EU member states might produce somewhat different results.

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ARTICLE 3

Submitted as:

Consumers and agrobiotechnologies:

The devil rides again

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Risk Analysis

Abstract

Existing evidence suggests that public scepticism towards emerging biotechnologies such as gene technology is rooted in unfamiliarity and uncertainty. Tacitly, it is often assumed that established technologies such as mutation breeding do suffer from such problems simply because they are not new, and that a history of safe use might even be taken as an indicator that the technology is accepted – but is it indeed? Based on representative survey data (N = 950), public attitudes towards mutation breeding were compared with attitudes towards gene technology. Structurally, attitudes towards mutation breeding shared most properties with attitudes towards gene technology, suggesting that consumers evaluate both biotechnologies by means of a joint evaluative schema. A noteworthy finding was that mutation breeding was evaluated most negatively by consumers, significantly more so than gene technology. Even though mutation breeding is not a novel technique and is not regulated as a novel food technology in most parts of the world, it appears that the technique would be strongly rejected by consumers if it ever became a public issue, even more so than gene technology.

Introduction

The application of new technologies in food and agriculture has become a contested issue in the last two decades. In Europe, the most prominent case was the heated debate about genetically modified (GM) foods that ensued between stakeholders in the mid-1990s and led to a five-year moratorium on the approval of new GM crops and foods (for a review, see Scholderer, 2005). The moratorium was lifted in 2004. Since then, the discussion has moved on to other emerging technologies such as cloning and

nanotechnology. A noteworthy aspect of these discussions is that they have become considerably more "proactive": more efforts are made at involving the relevant stakeholders, and these efforts are made at an earlier time (for example, see Rogers-Hayden & Pidgeon, 2007).

However, a blind spot in these discussions is that they tend to exclusive focus on technologies that are actually new. In part, this can be understood as a reflection of the relevant legislation. In the European Union, the approval of foods resulting from novel breeding and processing technologies is governed by the Novel Food Regulation (Regulation EC 258/97; currently under revision, see draft proposal COM 2007/872 and associated co-decision procedure 2008/0002 COD). The regulation defines as "novel" all foods, food ingredients, and breeding[4] and processing technologies with a potential impact on food safety that were not in use in the European Union before the date the regulation was published in the Official Journal of the European Communities (15 May 1997).

Although the pragmatic definition of novelty adopted in the Novel Food Regulation provides a reasonable degree of legal clarity, it may not fully take into account the concerns of the consumers it is meant to protect. Psychologically, it may make no difference for the acceptability of a technology to a consumer whether the technology is objectively novel in the sense that it has only recently been invented, or whether it is subjectively novel because the individual consumer has never been knowingly confronted with it before. Furthermore, it is highly questionable

[4] GM foods have been regulated separately since 2004 (under Regulation EC 1829/2003 on genetically modified food and feed).

whether European consumers will evaluate the acceptability of technologies with similar functions in a different manner simply because one technology has been applied in the European Union before 15 May 1997, whereas the other has only been applied after that date.

The aim of the research presented here is to assess whether, and to which degree, consumers differentiate in their attitudes between different classes of novel technologies in food and agriculture. The degree of differentiation will be assessed in terms of (a) the overall level of consumers' attitudes, i.e. how positively or negatively the different technologies are evaluated, and (b) the structure of consumers' attitudes, i.e. whether evaluations of different technologies are associated in a similar manner with other, more general attitude dimensions.

This study will examine these issues with respect to two agricultural biotechnologies that are excellent cases in point: gene technology (or DNA recombination) and mutation breeding (or mutagenesis). Both have the same function: to change the genome of crop plants in such a way that the resulting cultivars have improved agronomic, nutritional, or processing and storage properties. However, the technologies differ in three major respects:

- Gene technology involves a targeted change in the plant genome, usually affecting just a single gene, whereas mutation breeding induces random changes in the plant genome, often affecting numerous genes at the same time.

- Gene technology is a "novel", non-traditional breeding technology in terms of European law, whereas mutation breeding has routinely been

applied in the development of new crop cultivars for several decades and is not subjected to any specific regulation in the European Union.

- Gene technology has been the object of an intense public debate and can therefore be classified as relatively familiar to European consumers, whereas mutation breeding has never become a public issue and can therefore be classified as relatively unfamiliar to European consumers.

In the following sections, we will first review relevant previous research on consumer attitudes towards these two technologies. Then, predictions about their interrelationships will be derived from relevant attitude theory. The prediction will be tested based on a representative survey with Danish consumers. Finally, the implications of the results will be discussed.

Previous research on consumer attitudes towards gene technology

A considerable number of studies have been conducted in the last 15 years, assessing how consumers evaluate gene technology. Attitude surveys have found repeatedly and in numerous countries that consumer attitudes towards gene technology are strongly associated with more general socio-political attitudes, including attitudes towards technological progress, environment and nature, and trust in the institutions responsible for risk assessment and management (e.g., see Bredahl, 1999, 2001; Frewer, Lassen, Kettlitz, Scholderer, Beekman & Berdal, 2004; Grunert, Bredahl & Scholderer, 2003; Mosely, 1999; Siegrist, 2000).

In addition, qualitative studies have identified moral and ethical consumer considerations, for example that gene technology is often perceived as morally wrong, tampering with nature, or unnatural (Bredahl, 1999; Frewer, Howard & Aaron, 1998; Frewer, Howard & Shepherd, 1997;

Loureiro & Hine, 2004; Moon & Balasubramanian, 2004; O'Connor, 2004; O'Connor et al., 2006; Scholderer et al., 1999). Furthermore, aspects of uncertainty play a prominent role. Many consumers are concerned that the technology may have unpredictable effects (Frewer et al., 2004; Hagemann & Scholderer, in press; Scholderer et al., 1999; Sjöberg, 2004; Viella-Villa, Costa-Font & Mossialos, 2005). Equity considerations are another factor contributing to negative attitudes. Many consumers see the technology as only benefitting industry and being of little or no value to the public at large (Frewer, Risvik & Schifferstein, 2001; Sjöberg, 2004).

A common interpretation of these results is that consumers utilise their general socio-political attitudes as an evaluative schema (in the sense of Tesser, 1978), i.e. a template that enables them to form evaluative judgments of a technology they have no personal experience with.

Previous research on consumer attitudes towards mutation breeding

Mutation breeding has been used in the development of numerous plant varieties, including maize, barley, wheat and rice lines (for an overview, see Ahloowalia, Maluszynski & Nichterlein, 2004; Falk, Chassy, Harlander, Hoban, McGloughliln & Akhlagi, 2002). Altogether, 2540 mutant varieties have been officially released (FAO/IAEA Mutant Varieties Database, 2007). In the majority of these, ionizing radiation was used for inducing the mutagenesis events.

Previous research on consumer attitudes towards the use of radiation technologies in food and agriculture has concentrated on post-production applications (Wilcock, Pun, Khanona & Aung, 2004; Frenzen, DeBess, Hechemy, Kassenborg, Kennedy, McCombs, McNees & The Foodnet Working Group al., 2001; Sigurbjornsson & Loaharanu, 1989; Furuta,

Hayashi, Hosokawa, Kakefu & Nishihara, 1998; Bruhn, 1995) where the food is exposed to ionizing radiation with the intent to kill harmful bacteria, extending the shelf-life of the food and preventing food-borne diseases (Loaharanu, 2003). Consumer concerns about post-production uses of food irradiation tend to focus on safety, nutritional adequacy, potential harm to employees and the danger of living close to production facilities (Wilcock, Pun, Khanona & Aung, 2004; Bruhn 1995; Weaver & Marcotte, 1988). Research indicates that Europeans share the general concerns of US consumers but are much more reluctant to actually accept food irradiation (Wilcock, Pun, Khanona & Aung, 2004). Reflecting this, European regulators have kept a ban on post-production irradiation of foods, with no signs of the ban being lifted in the near future.

The large number mutation-bred crop varieties on the world market makes the lack of consumer studies on mutation breeding conspicuous. The only consumer study ever conducted on mutation breeding was a pilot investigation (Hagemann & Scholderer, 2007) related to the present research. In the qualitative results of this study, it became apparent that consumers tended to evaluate mutation-bred crop varieties in terms of the same attributes that can be found in qualitative studies of consumer perceptions of gene technology (e.g., see Bredahl, 1999; Hagemann & Scholderer, in press; Scholderer, Balderjahn, Bredahl & Grunert, 1999). Furthermore, consumers tended to assume that mutation-bred crop varieties would have similar traits as the first generation GM crops they were familiar with (increased yield, pest or pesticide resistance), and that mutation-bred crop varieties would be governed by the same body of legislation that applies to genetically modified foods (at present, however,

mutation-bred crop varieties are only subject to such regulation in Canada, but not in the EU, where the study had been conducted).

A balance theory perspective

Apparently, many consumers perceive mutation breeding to have the same characteristics as gene technology. This comes as no surprise: most of the public debate about food biotechnologies has been framed in the specific context of gene technology. Mutation breeding, on the other hand, has never been discussed to any significant degree outside the expert community. Hence, it can only be expected that a certain degree of generalisation from gene technology occurs when consumers attempt to evaluate the previously unfamiliar concept of mutation breeding. In theoretical terms, the issue can be understood as one of inter-attitudinal consistency.

In general, attitudes towards complex socio-technical issues are not isolated within an individual's mind, but are linked to other attitudes in thematically consistent structures, comparable to ideologies (Eagly & Chaiken, 1993; Judd & Krosnick, 1989; Tetlock, 1989). The earliest theoretical account of coherent inter-attitudinal structures is balance theory (Heider, 1946, 1958; also see the schema-theoretic reformulation by Tesser, 1978). The underlying assumption is that people strive for consistency in their cognitions. Heider calls this equilibrium "balance". Heider's theory provides a symbolic language for describing the structures that represent attitudes and their relation to other attitudes. The symbolic language contains three elements: the person *P*, the attitude object *X*, and the "other" *O*.

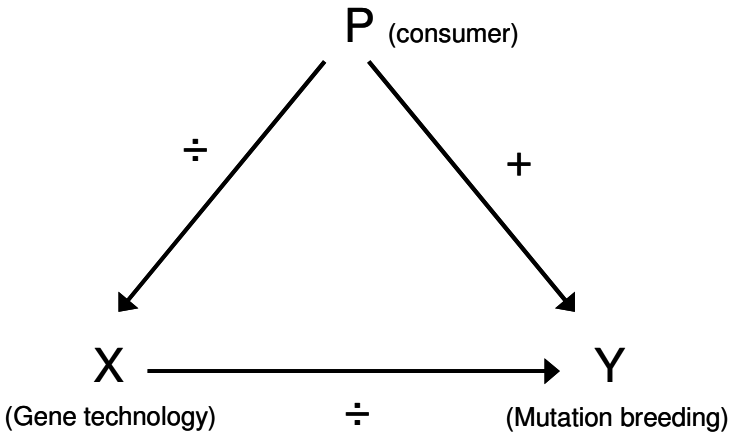

Figure 1. Balance theory example (adapted from Heider, 1946).

Classically, *O* stands for a significant other person or a reference group. Interpreted in a wider sense, however, the "other" may also stand for another attitude object *Y*. In the context of the present research, *P* will stand for a consumer, *X* for a particular food biotechnology the consumer is attempting to evaluate, and *Y* for another food biotechnology (Figure 1). When the entities *P*, *O*, and *X* are set into a relation to each other during the course of an evaluative judgment, "unit relations" are constituted. If a valence becomes associated with a unit relation, a "sentiment relation" is constituted. According to balance theory, a sentiment relation between a person and an object is an attitude.

According to Heider (1946), a balanced state exists either when all sentiment relations in the system are positive, or when the sum product of all sentiment relations has a positive sign. If, for example, a consumer evaluates gene technology negatively, and if mutation breeding is perceived to be related to gene technology, the consumer is predicted to evaluate mutation breeding negatively, too. If, on the other hand, the

consumer sees mutation breeding as a separate entity (without any connection to gene technology) she or he might evaluate the technology in a completely independent manner (i.e., negatively, neutrally, or positively).

Hypotheses

The logic of balance theory predictions for three-entity systems can be extended to attitude systems containing more attitude objects (Cartwright & Harary, 1956). In addition to the two food biotechnologies (gene technology, mutation breeding), the system may contain more abstract attitude objects (e.g., technical progress, environment and nature, and the institutions constituting the socio-technical system from which technological innovations emerge). If these are symmetrically set into relation to the two food biotechnologies, and the food biotechnologies are set into relation to each other, a joint attitude system can be said to exist. If both attitudes are embedded into this joint system in a coherent manner, a balanced state is predicted:

- *Hypothesis 1:* the product of the signs of the sentiment relations corresponding to the unit relations is expected to be positive, or equivalently, the signs of the correlations between attitude towards gene technology and a set of other relevant attitudes are expected to be equal to the signs of the correlations between attitude towards mutation breeding and the set of other attitudes.

If the prediction holds, both attitudes can be understood as emerging from the same evaluative schema (Tesser, 1978), i.e. the evaluative judgments of the two attitude objects derive from the same set of more general attitudes. The existence of common causes implies a correlation between the resulting evaluative judgments:

- *Hypothesis 2:* a high positive correlation between attitude towards gene technology and attitude towards mutation breeding is expected.

Finally, the causal structure of the joint attitude system will be explored. In most previous investigations, researchers made strong theoretically motivated assumptions regarding the mediation relationships in the system (e.g., Bredahl, 2001; Saher, Lindeman & Koivisto, 2006; Siegrist, 2000) but failed to provide statistical tests of these assumptions or compare their causal models to alternative model structures. In several instances, the respective assumptions were later falsified when designs with a higher internal validity were used in experimental tests of the assumptions or when more stringent statistical tests were applied in re-analyses of the original data (e.g., Eiser, Miles & Frewer, 2002; Frewer, Scholderer & Bredahl, 2003; Poortinga & Pidgeon, 2004, 2005, 2006; Scholderer, 2004). In order to avoid errors caused by incorrect theoretical assumptions, a data-driven approach will be adopted in the explorations.

Method

Participants and procedure. The survey was conducted in August and September 2005. Participants were sampled at random from GfK Denmark's national opinion research panel. The survey was conducted by mail. Of the altogether 1500 panel members who had received the questionnaire, 943 responded (62.9%). Considering the length of the questionnaire (266 items), the response rate can be regarded as satisfactory.

Table 1. *Demographic characteristics of participants*

		Count (N)	Percent Sample	Percent Population
Age	18-25 years	108	11.4	8.6
	26-35 years	164	17.4	13.5
	36-45 years	183	19.4	15.0
	46-55 years	161	17.1	13.4
	55-65 years	145	15.4	13.1
	66-75 years	115	12.2	8.0
	Above 75 years	67	7.1	7.0
Gender	Female	498	52.8	50.5
	Male	445	47.2	49.5
Cohabitation	Single	633	67.1	60.0
	Living with partner	299	31.7	40.0
Number of persons in household	1	213	22.6	17.5
	2	383	40.6	29.4
	3	150	15.9	11.9
	4	145	15.4	11.9
	5+	50	5.3	2.6
Presence of children (under 18) in household	Aged 0-3	89	9.5	4.8
	Aged 4-9	126	13.5	7.6
	Aged 10-17	180	19.3	9.6
Gross annual household income	Below DKK 200,000	168	17.8	36.4
	DKK 200,000-299,999	159	16.9	21.7
	DKK 300,000-399,999	144	15.3	13.3
	DKK 400,000-599,999	252	26.7	4.7
	DKK 600,000-799,999	140	14.8	3.2
	DKK 800,000 and above	65	6.9	1.4
Education	7 to 9 years of schooling	158	18.7	37.5
	10 to 12 years schooling	218	25.8	12.4
	Occupational training	316	37.5	40.8
	Higher education	152	18.0	9.3

The mean age of the respondents was 47.4 years (*SD* = 17.4), 52.8% were female. Levels of education ranged from primary school to university level.

The majority had occupational training, but no higher education. The sample was representative for the adult Danish population (aged 18 and above) with the exception of gross annual household income and education level. In regard to the gross annual household income the sample had an overrepresentation of people in the lower income classes (below 300,000 DKK) compared to the population and an underrepresentation of people in higher income classes (400,000 DKK and above). The deviation in regard to education level is found in regard to the higher education as the sample is underrepresented compared to the population. All participants received an incentive (EUR 10) as an appreciation of their time. Demographic characteristics are shown in Table 1.

Measures

Overall attitudes towards gene technology in plant breeding and mutation breeding were measured by three semantic differential items respectively. Participants were asked to globally evaluate each technology on seven-point semantic differential scales ranging from 1 to 7, with end points labelled "extremely bad – extremely good", "extremely stupid – extremely wise", and "I am all against – I am all for". Means and standard deviations are shown in Table 2.

The first group of background variables consisted of three general socio-political attitude dimensions. Attitude towards technological progress was measured by five items adapted from Hamstra (1991). Attitude towards industrial food production was measured by five items developed by Beckmann, Brokmos & Lind (2001). All items were answered on seven-point scales ranging from 1 ("completely disagree") to 7 ("completely agree").

Table 2. *Means and standard deviations of items measuring attitudes towards the two technologies* **(AGM, AMB).**

No.	Item	M (SD)
AGM1	Using gene technology in plant breeding is (extremely bad/extremely good)	3.38 (1.80)
AGM2	Using gene technology in plant breeding is (extremely stupid/extremely wise)	3.36 (1.87)
AGM3	I am (all against/all for) using gene technology in plant breeding	3.20 (1.94)
AMB1	Using irradiation in plant breeding is (extremely bad/extremely good)	2.79 (1.79)
AMB2	Using irradiation in plant breeding is (extremely stupid/extremely wise)	2.80 (1.84)
AMB3	I am (all against/all for) using irradiation in plant breeding	2.63 (1.84)

The second group of background variables consisted of three trait dimensions, related to consumers' habits and thought styles. Habitual avoidance of unfamiliar foods was measured by five items from Pliner and Hobden's (1992) food neophobia scale. Need for cognition and faith in intuition were measured by ten items from Epstein, Pacini, Denes-Raj and Heier's (1996) short form of the rational-experiential thinking inventory. All items were answered on seven-point scales ranging from 1 ("completely disagree") to 7 ("completely agree").

The third group of background variables was consumers' trust in various actors and institutions involved in the assessment and management of risk, and the research, development, production, and distribution of foods. Ten items were formulated based on Siegrist's (2000) operationalisation of social trust. Following the vignette "How much faith do you have in the following groups and institutions in terms of whether they deal responsibly with novel types of foods", participants were asked to indicate their trust in

each institution on a seven-point scale, ranging from 1 (“no trust at all”) to 7 (“very high trust”).

Table 3. *Means and standard deviations of items measuring attitude towards technological progress (ATEC), attitude towards industrial food production (AIFP), food neophobia (FN), need for cognition (NFC), faith in intuition (FII) and social trust (ST).*

No.	Item	M (SD)
ATEC1	A country's degree of civilisation e can be measured from the degree of its technological development.	4.37 (1.70)
ATEC2	New technological inventions and applications make up the driving force of the progress of society	5.23 (1.35)
ATEC3	In Denmark and in the rest of Europe we are probably better off than ever, thanks to the tremendous progress in technology	4.99 (1.49)
ATEC4	Throughout the ages, technological know-how has been the most important weapon in the struggle for life	4.83 (1.58)
ATEC5	Because of the development in technology we will be able to face up to the problems of tomorrow’s society	4.19 (1.69)
AIFP1	Most food manufacturers are more interested in earning money than in the nutritional quality of their products	5.36 (1.48)
AIFP2	Modern food production removes vitamins and minerals from food products	4.53 (1.66)
AIFP3	The food industry is very concerned about the nutritional value of their products	3.69 (1.49)
AIFP4	Most foods are so processed that they have lost their nutritional value	4.46 (1.60)
AIFP5	The majority of food products can be eaten without risk	4.41 (1.74)
FN1	I am constantly sampling new and different foods	3.64 (1.69)
FN2	I don’t trust new foods	3.60 (1.73)
FN3	If I don’t know what is in a food product, I won’t try it	5.08 (1.92)
FN4	I am afraid to eat things I have never had before	2.77 (1.77)
FN5	I will eat almost anything	4.75 (2.00)
NFC1	I don’t like to have to do a lot of thinking.	2.27 (1.72)
NFC2	I try to avoid situations that require thinking in depth about something.	2.28 (1.70)
NFC3	I prefer to do something that challenges my thinking abilities rather than something that requires little thought.	4.95 (1.89)
NFC4	I prefer complex to simple problems.	4.14 (1.66)
NFC5	Thinking hard and for a long time about something gives me little satisfaction.	3.47 (1.88)

Table 3. *Means and standard deviations of items measuring attitude towards technological progress (ATEC), attitude towards industrial food production (AIFP), food neophobia (FN), need for cognition (NFC), faith in intuition (FII) and social trust (ST).*

No.	Item	M (SD)
FII1	I trust my initial feelings about people.	4.99 (1.67)
FII2	I believe in trusting my hunches.	5.57 (1.30)
FII3	My initial impressions of people are almost always right.	5.15 (1.47)
FII4	When it comes to trusting people, I can usually rely on my "gut feelings".	5.39 (1.34)
FII5	I can usually feel when a person is right or wrong even if I can't explain how I know.	5.34 (1.45)
ST01	University scientists	5.30 (1.31)
ST02	National food administration	5.23 (1.35)
ST03	EFSA	4.45 (1.51)
ST04	Plant breeders	4.30 (1.38)
ST05	Farmers	4.23 (1.55)
ST06	Food producers	3.66 (1.44)
ST07	Retailers	3.72 (1.38)
ST08	Restaurants	3.91 (1.37)
ST09	Takeaways	2.70 (1.28)
ST10	Canteens	3.77 (1.41)

Although Siegrist (2000) originally conceptualised social trust as a highly generalised, one-dimensional construct, exploratory factor analysis indicated that three dimensions would be necessary to model the covariation between the ten trust items. Hence, a three-dimensional simple-structure measurement model was specified for the trust items (latent factors: trust in public institutions, trust in agribusiness actors, trust in retail and food service actors) and fitted to the data. The model showed an acceptable fit (Satorra-Bentler χ^2 = 223.91, df = 32, RMSEA = 0.08, standardised RMR = 0.06). The three factors were substantially intercorrelated (φ[trust in public institutions, trust in agribusiness actors] =

0.39, $p < 0.001$; φ[trust in public institutions, trust in retail and food service actors] = 0.37, $p < 0.001$; φ[trust in agribusiness actors, trust in retail and food service actors] = 0.58, $p < 0.001$), suggesting the existence of a second-order factor. Unfortunately, a second-order factor model is statistically indistinguishable from a model that only contains first-order factors when the number of first-order factors is three (Rindskopf & Rose, 1988), hence the existence of a second-order factor cannot explicitly be tested here. Means and standard deviations are reported in Table 3.

The final group of background variables consisted of two dimensions of "objective" knowledge. Knowledge about biotechnology was measured by 20 items adapted from Gaskell, Allum and Stares (2003) and Søndergaard, Grunert and Scholderer (2005). Participants were asked to evaluate the correctness of factual statements on binary "true" versus "false" scales. Knowledge about nutrition was measured by 21 items adapted from the USDA Healthy Eating Index (Variyam, Blaylock, Smallwood & Bastiotis, 1998). The first five items asked participants to evaluate the correctness of factual statements on binary "true" versus "false" scales. The remaining 16 items had a forced-choice format. Participants were asked to indicate out of two different foods which had a higher content of a particular nutrient. The percentage of correct responses to each item is shown in Table 4 (missing responses counted as incorrect responses).

Reliability

The reliability of the different scales was assessed by means of three measures. The first two measures, Jöreskog's rho (Werts, Linn & Jöreskog, 1974) and the coefficient of maximal reliability (Conger, 1980) measure reliability in terms of internal consistency.

Table 4. Percentage correct responses to items measuring knowledge about biotechnology (KB) and knowledge about nutrition (KN).

No.	Item	Percent correct (%)
KB01	Gene technology is used in all foods	91.2
KB02	Irradiation is used in all foods	92.5
KB03	All foods are enriched with healthy ingredients	87.3
KB04	All bacteria found in foods are harmful	84.1
KB05	We eat DNA every day	53.4
KB06	Some proteins found in food can be toxic	46.3
KB07	"Natural" is not necessary the same as healthy	92.2
KB08	All processed foods are produced with the help of genetically modified organisms	90.0
KB09	Food has to be sterile before eating in order to be healthy	88.4
KB10	There are no laws or rules for the use of gene technology in food production	81.3
KB11	There are bacteria which live from waste water	92.6
KB12	Ordinary tomatoes do not contain genes, while genetically modified tomatoes do	70.6
KB13	The cloning of living things produces genetically identical offspring	78.0
KB14	By eating a genetically modified fruit, a person's gene could also become modified	78.8
KB15	Viruses can get infected by bacteria	52.6
KB16	Yeast for brewing beer consists of living organisms	92.6
KB17	Genetically modified animals are always bigger than ordinary ones	84.5
KB18	More than half of human genes are identical to those of chimpanzees	79.1
KB19	It is impossible to transfer animal genes into plants	40.2
KB20	It is possible to find out in the first few months of pregnancy whether a child will have Down's Syndrome	91.9
KN01	Cholesterol is found in vegetable products	47.6
KN02	Cholesterol is found in animal products	87.3
KN03	Cholesterol is found in all foods containing fat or oil	28.8
KN04	Saturated fat tends to be liquid rather than solid	72.3
KN05	Unsaturated fat tends to be liquid rather than solid	55.8
KN06	Which food contains more fibre: fruit or meat	70.5
KN07	Which food contains more fibre: cornflakes or oatmeal	89.1
KN08	Which food contains more fibre: orange juice or an apple	79.2
KN09	Which food contains more fibre: whole meal bread or white bread	94.1

Table 4. Percentage correct responses to items measuring knowledge about biotechnology (KB) and knowledge about nutrition (KN).

No.	Item	Percent correct (%)
KN10	Which food contains more fibre: Kidney beans or lettuce	67.4
KN11	Which food contains more fibre: popcorn or pretzels	56.4
KN12	Which food contains more cholesterol: liver or steak	31.0
KN13	Which food contains more cholesterol: butter or margarine	74.5
KN14	Which food contains more cholesterol: skimmed milk or full-fat milk	88.3
KN15	Which food contains more cholesterol: egg white or yolk	78.7
KN16	Which food contains more fat: pork chops or rib (roast)	80.8
KN17	Which food contains more fat: sausages or ham	88.5
KN18	Which food contains more fat: peanuts or popcorn	76.7
KN19	Which food contains more fat: yoghurt or cream	76.8
KN20	Which food contains more fat: ice cream or sorbet	89.2
KN21	Which food contains more fat: roast chicken leg or fried chicken leg	88.9

Instead, they merely assume a congeneric test model (Lord & Novick, 1968) allowing the ratio of true-score variance in the variance of the observed responses to differ across the items of a scale. Jöreskog's rho can be understood as a measure of the reliability of an unweighted sum score of items with unequal factor loadings. The coefficient of maximal reliability is a measure of the reliability of an optimally weighted sum score of items with unequal factor loadings (e.g., a factor score). Re-test reliability was assessed by repeating the survey with 50 randomly chosen respondents after a period of two weeks and correlating the sum scores for each scale to the sum scores from the original survey. Results are shown in Table 5.

The internal consistency reliability estimates were satisfactory for most scales except for attitude towards industrial food production, food

neophobia and need for cognition. However, it must be taken into account that the items of these scales are formulated in such a way as to measure different behavioural responses that can be regarded as functions of the respective underlying construct. In this sense, the constructs measured using these scales are broader than the constructs measured using scales whose items were formulated in parallel, letting only the attitude object or the response scale labels differ.

The re-test reliability estimates were satisfactory for most scales as well, indicating that the attitudes measured in the present survey were not just momentary constructions but reasonably stable. The re-test reliabilities of the scales measuring attitudes towards gene technology and mutation breeding turned out to be even higher than expected. However, there were some exceptions: the scales measuring attitude to technological progress, need for cognition, and faith in intuition yielded rather low estimates.

Table 5. Estimates of scale reliabilities

Scale	Jöreskog's Rho	Maximum reliability	Re-test reliability
Attitude towards gene technology	.95	.95	.59
Attitude towards mutation breeding	.94	.94	.68
Attitude towards technological progress	.90	.82	.41
Attitude towards industrial food production	.62	.65	.62
Trust in public institutions	.71	.75	.71
Trust in agribusiness actors	.85	.92	.68
Trust in retail and foodservice actors	.85	.87	.64
Food neophobia	.61	.65	.70
Need for cognition	.63	.90	.52
Faith in intuition	.87	.87	.33

Particularly surprising was the low stability of need for cognition and faith in intuition, the two scales taken from Epstein, Pacini, Denes-Raj and Heier's (1996) short form of the rational-experiential thinking inventory. The present results shed serious doubt on the conceptualisation of the two scales as measures of general, trait-like thought styles assumed to be typical of an individual. Rather than stable differences between individuals, the two scales seem to measure differences in processing styles triggered by the characteristics of the situation in which the questionnaire is answered.

Questionnaire translation

A majority of the scales used in the questionnaire originated from English and were therefore translated into Danish. To validate the first translation the translated versions were subsequently back translated into English by a group of people unrelated to the NOFORISK project. The questionnaire was afterwards pre-tested by 20 Danish consumers and adjusted for minor inconsistencies.

Question order

In order to avoid systematic biases due to carry-over effects result, six different versions of the questionnaire were used with varying question order.

Results

Evaluative judgments of gene technology and mutation breeding

Unbiased estimates of the correlation between attitude towards gene technology and attitude towards mutation breeding were obtained by means

of confirmatory factor analysis. Since the response category labels of the semantic differential items were the same for both attitude objects, significant method covariation had to be assumed. In order to compensate for this, the measurement errors of the three pairs of identically formulated items were allowed to correlate.

The resulting measurement model showed an excellent fit to the data (Satorra-Bentler χ^2 = 1.12, *df* = 5, RMSEA = .000, standardized RMR = .004). The estimate of the latent variable correlation between attitude towards gene technology and attitude towards mutation breeding was φ = .72, indicating that the relationship between the two attitude objects was very close but that the two attitudes still possessed discriminant validity. This result is a direct confirmation of Hypothesis 2. Standardised estimates are shown in path diagram notation in Figure 2.

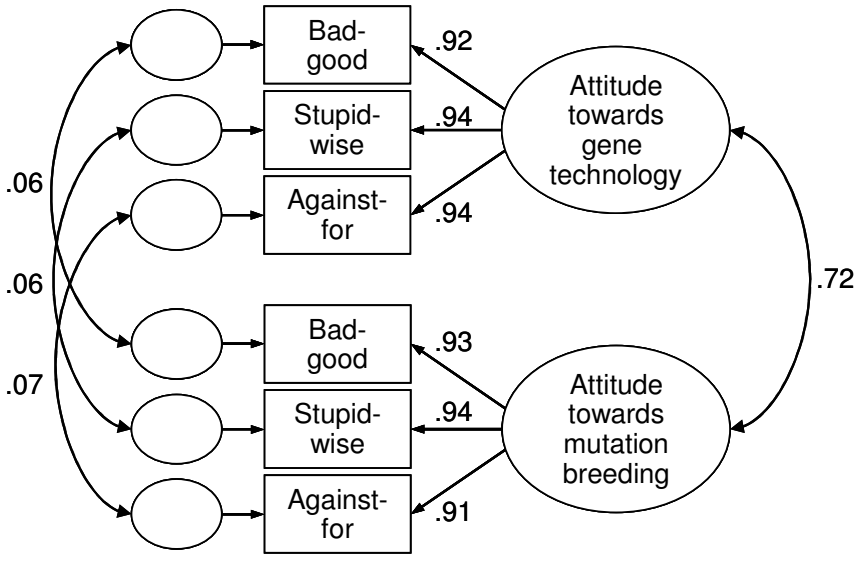

Figure 2. Confirmatory factor analysis results: Attitudes towards gene technology and mutation breeding (standardised estimates)

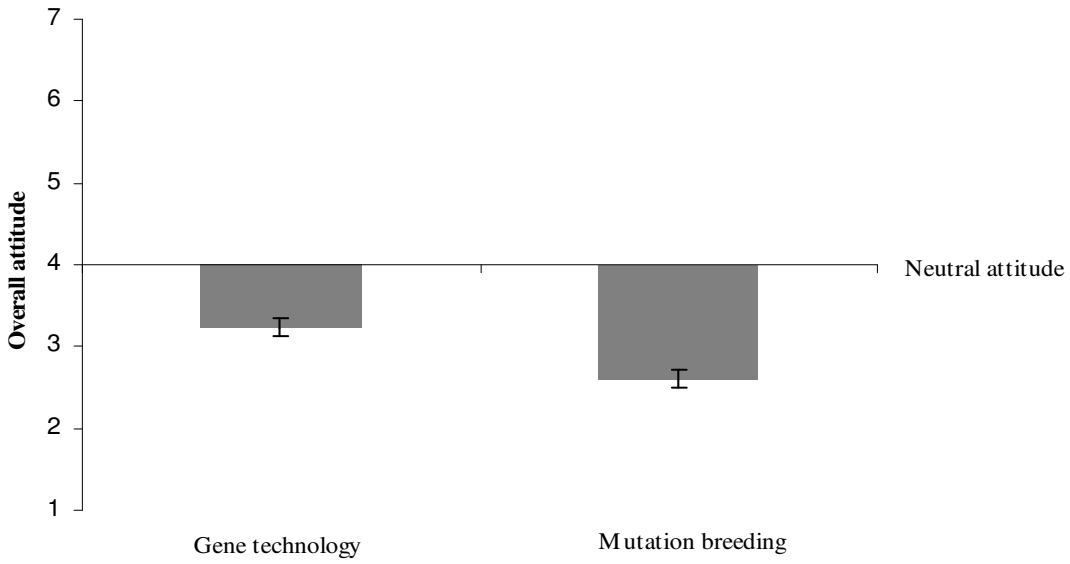

Figure 3. Overall attitudes towards food biotechnologies (arithmetic means; min = 1, max = 7; error bars indicate 95% confidence intervals).

Within-subjects analysis of variance was conducted in order to assess differences in the means of consumer evaluations of these technologies, yielding a highly significant result (F[3,940] = 543.85, $p < 0.001$, partial η^2 = 0.63). In absolute terms, the average evaluation of gene technology was weakly negative (M=3.2, SD = 1.69), and the evaluation of mutation breeding moderately negative (M=2.6, SD = 1.51). The means are shown in Figure 3.

Relationships with other attitudes

The hypothesis that attitude towards gene technology and attitude towards mutation breeding would exhibit the same pattern of correlations with other attitude, trust and knowledge dimensions was tested by a series of

confirmatory factor analysis models. All models were estimated by means of robust maximum likelihood (Satorra & Bentler, 1994) in LISREL 8.72.

In Model 0, latent variable correlations between attitude towards gene technology and the eleven validation criteria were estimated (Satorra-Bentler χ^2 = 2125.04, *df* = 1111, RMSEA = .044, standardized RMR = .059). The estimates obtained from this model provided a "benchmark" for all subsequent models. Then, three models were estimated in which attitude towards mutation was included instead of gene technology.

In Model 1, all parameters were left unconstrained (Satorra-Bentler χ^2 = 2179.82, *df* = 1111, RMSEA = .045, standardized RMR = .063).

In Model 2, interval restrictions were imposed on the latent variable correlations between attitude towards mutation breeding and all validation criteria in such a way that they imposed the same sign on the respective correlations as had been found in the estimates for Model 0 (where gene technology had been the attitude object). The fit of the model did not change, indicating that all relationships were in the same direction as in Model 0 (Satorra-Bentler χ^2 = 2179.82, *df* = 1111, RMSEA = .045, standardized RMR = .063). This result is a direct confirmation of Hypothesis 1.

In Model 3, equality constraints were imposed on the latent variable correlations between attitude towards mutation breeding and all validation criteria, imposing the same numerical value on the correlation as had been found in Model 0 (Satorra-Bentler χ^2 = 2209.98, *df* = 1122, RMSEA = .045, standardized RMR = .066). Relative to Model 2, the overall fit decreased significantly (Satorra-Bentler $\Delta\chi^2 = 28.11$, $\Delta df = 11$, $p < .01$).

Table 6. Similarity between attitude towards gene technology and attitude towards mutation breeding in the pattern of correlations with different validation criteria

Validation criterion	Latent variable correlation (φ) with		Test ($\Delta[\varphi_1,\varphi_2] = 0$)
	Attitude towards gene technology (φ_1)	Attitude towards mutation breeding (φ_2)	
Attitude towards technological progress	.22***	.11*	n.s.
Attitude towards industrial food production	.36***	.35***	n.s.
Magical beliefs about food and health	-.23***	-.20***	n.s.
Food neophobia	-.29***	-.27***	n.s.
Need for cognition	.02 n.s.	.03 n.s.	n.s.
Faith in intuition	-.08 n.s.	-.22***	**
Trust in public institutions	.24***	.19***	n.s.
Trust in agribusiness actors	.07 n.s.	.23***	n.s.
Trust in retail and foodservice actors	.11*	.05 n.s.	n.s.
Knowledge about biotechnology	.10 n.s.	.02 n.s.	n.s.
Knowledge about nutrition	.11*	.04 n.s.	n.s.

Note. *** $p < .001$, ** $p < .01$, * $p < .05$; n.s. = not significant

However, further analyses indicated that the overall decrease in model fit was caused by a single significant difference in the strength of the two univariate relationships with "faith in intuition" (Satorra-Bentler $\Delta\chi^2 = 7.08$, $\Delta df = 1$, $p < .01$). All other pairwise differences between correlations were insignificant. Hence, with the exception of one variable, an even stronger version of Hypothesis 1 holds. The results are summarized in Table 6.

Structural relations between socio-political attitudes and attitudes towards food biotechnologies

In a final step of the analysis, a structural equation model was estimated and tested. The aim of this analysis was to assess the "causal layering" of the attitude system. In an initial step, the total sample was subdivided into a learning sample (odd case numbers, N = 470) and a test sample (even case numbers, N = 470).

In the learning sample, the best-fitting model was identified by means of a causal search algorithm. The algorithm employed for this was the MIMBUILD algorithm in TETRAD IV (Spirtes, Glymour & Scheines, 2000). Applied to a multivariate data set, the algorithm identifies a class of equivalent structural equation models that may have generated the covariance structure observed in the data. It can be understood as performing an exhaustive, multivariate equivalent to the task that "ordinary" statistical tests for mediation perform for three-variable sets.

The resulting causal graph was then estimated as a structural equation model, using the robust maximum likelihood estimator in LISREL 8.72. The model showed satisfactory fit to the data (ML χ^2 = 1441.36, Satorra-Bentler χ^2 = 1267.76, *df* = 484, RMSEA = 0.059, standardised RMR = 0.082, R^2 = .22 for attitude towards gene technology and .53 for attitude towards mutation breeding).

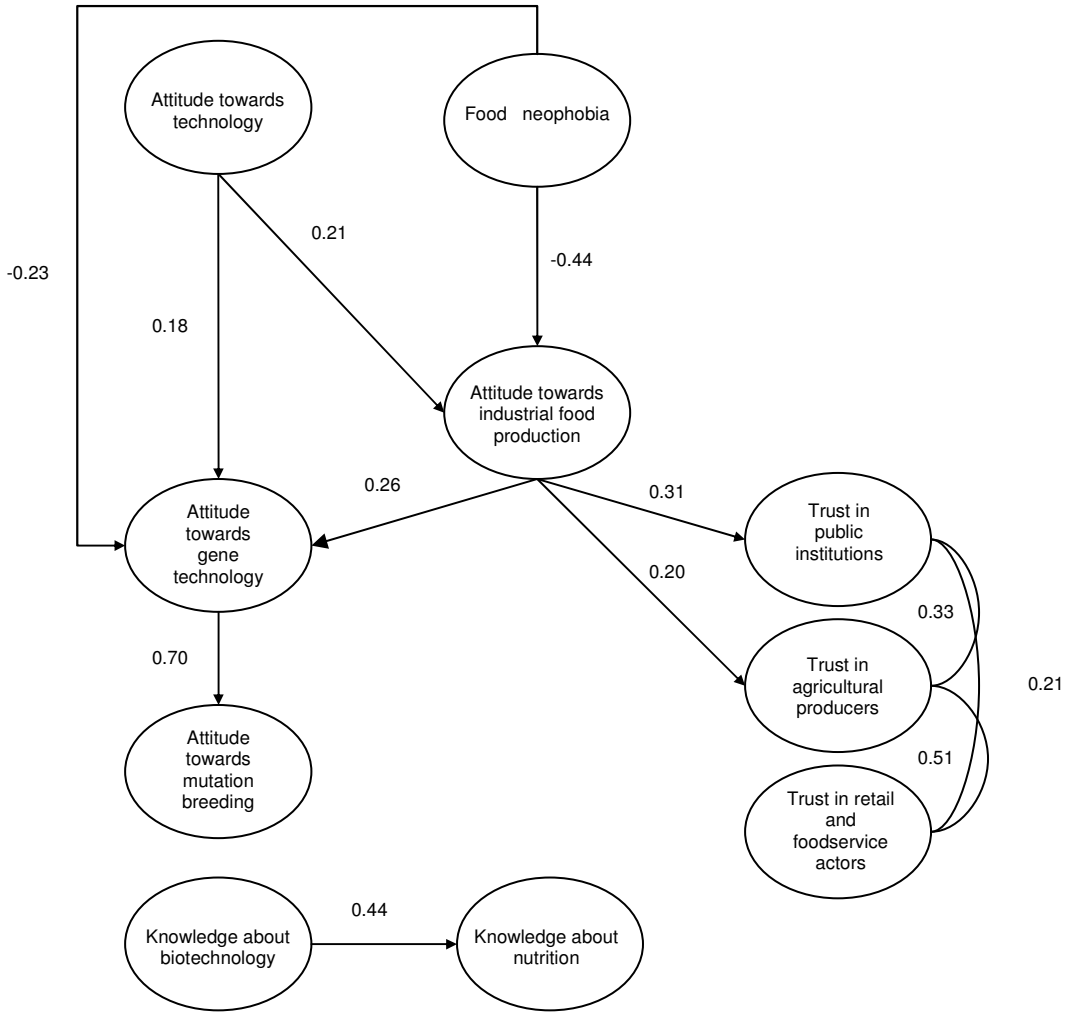

Figure 4. Structural equation model of the wider attitude system in which attitude towards gene technology and mutation breeding are jointly embedded.

In a final step, the parameter estimates obtained in the learning sample were imposed on the test sample, providing a cross-validation of the model that had been identified by the causal search algorithm. Again, the model showed a satisfactory fit to the data (ML χ^2 =1553.1, Satorra-Bentler χ^2 = 1234.2, *df* = 554, RMSEA = 0.051, standardised RMR = 0.070), indicating that it can be regarded as reasonably stable. Standardised estimates of the parameters of the structural model are shown in Figure 4.

Discussion and conclusion

The findings of the present study suggest that consumer attitudes towards mutation breeding share most of their structural properties with attitudes towards gene technology. The latent variable correlations between attitudes towards the two food biotechnologies (gene technology and mutation breeding) on the one hand, and the eleven attitude, trust and knowledge dimensions serving as validation criteria on the other hand, did not significantly differ between the two food biotechnologies with respect to ten out of the eleven validation criteria.

Furthermore, consumers' attitudes towards the two food biotechnologies were highly intercorrelated (latent variable correlation = .72). The results suggest that attitudes towards gene technology and mutation breeding are indeed embedded into a joint system of other attitudes. The correlation patterns found in the present analysis were so similar that it might even be suspected that attitude towards gene technology and attitude towards mutation breeding do not possess separate construct validity.

However, additional structural equation analyses suggested that a particular type of causal layering in the system may be responsible for the extreme similarity of the two attitudes. The upper layers of the system appear to operate as a coherent evaluative schema. Food neophobia (the habitual avoidance of unfamiliar foods; Pelchat & Pliner, 1995) appears to be the central variable in this schema; a finding that corroborates the results of previous research on the structure of consumer attitudes towards gene technology (Bredahl, 2001; also see the reviews by Frewer et al., 2004; Grunert et al., 2003).

Food neophobia can be interpreted as provide initial negative affect as input to the system. The negative affect appears to be transferred from broad and abstract attitude objects (technology in general) via contextual specifications into the relevant socio-technical domain (industrial food production) to the category of novel food technologies, of which gene technology seems to be the prototype. Mutation breeding is likely to be perceived by consumers as having a high feature overlap with gene technology (see Hagemann & Scholderer, in press). Evaluative affect may be directly transferred to it from gene technology, the prototype object, with relatively little consideration of the more specific features of mutation breeding.

To the extent that the structural equation modelling results can be considered valid, a striking consequence of the affect transfer process is that the effect of the more general attitude dimensions on attitude towards mutation breeding is completely mediated by attitude towards gene technology. No direct effects of attitude towards technological progress and attitude towards industrial food production on attitude towards mutation breeding could be established. In essence, the mediation pattern suggests that consumers *derive* their attitudes towards mutation breeding from their attitudes towards gene technology.

The methodology by which the structure of the system was identified can be criticised, of course. Like all purely data-driven methodologies, it may capitalise on chance variations in the data (e.g., see MacCallum, Roznowski & Necowitz, 1992). In the present study, precautions were taken in order to reduce the likelihood that such capitalisation on chance would invalidate the modelling process. Before the analysis, the data had been divided into non-overlapping learning and test samples. The

parameter estimates obtained in the learning sample were then imposed on the test sample, providing an independent cross-validation. Still, some of the findings deserve critical discussion. The "effect" of knowledge about biotechnology on knowledge about nutrition is probably spurious, likely to be caused by an omitted variable that is the common cause of both knowledge dimensions.

A most surprising and – from a practical point of view – rather worrying finding was that mutation breeding was evaluated even *more negatively* by consumers than gene technology. As initially suspected, public scepticism may not only be related to technologies that are "novel" in the sense of being recent inventions or innovations. The fact that a technology is not new does not mean that the public regards it as familiar and unproblematic; the technology may simply not have become a public issue *yet*.

Furthermore, the results of the present study shed interesting lights on the role of knowledge and trust in consumer evaluations of biotechnologies. The two knowledge dimensions assessed in the present study (knowledge about biotechnology and knowledge about nutrition) were uncorrelated to the rest of the attitude system. These findings add further evidence to the mounting criticism of the "educational deficit model" underlying much of modern science communication (see Frewer et al., 2003; Scholderer & Frewer, 2003, for similar arguments), specifically undermining the assumption that increased knowledge will lead to more enthusiasm for science-based innovations such as food biotechnologies and the products resulting from them, such as functional foods.

Finally, the structural equation modelling results suggested that social trust may not be a mediator in the technology evaluation process (as often

assumed and rarely tested in previous research) but merely a by-product, jointly dependent with attitudes towards the two biotechnologies investigated here. To the extent that the results of the present study can be generalised (note that roughly similar results were obtained by Eiser, Miles & Frewer, 2002; Poortinga & Pidgeon, 2004, 2005, 2006), this finding is extremely problematic. Since the late 1990s, public authorities (in particular those at EU level) have followed a strategy that predominantly aimed at increasing public confidence in the assessment and management of risks related to food biotechnologies. A tacit assumption in this strategy was that technology acceptance would be able to "piggyback" on increased trust, equivalent to the assumption that trust would exert a causal influence on technology acceptance. The findings of the present study suggest that this assumption may be misguided. Public policies that selectively increase trust without affecting the *actual* antecedents of technology acceptance may not be likely to yield the intended results.

The results obtained in the present study may even be interpreted as suggesting that the causal direction of the relationship is from attitude to trust, and not the other way round (as a "piggyback" model would assume). Such an interpretation would be consistent with the predictions made by social judgment theory (1961). Consumers may anchor their judgments of the trustworthiness of institutions in terms of the perceived attitudinal distance of the institution from themselves, i.e. they may only be prepared to trust an institution to the degree that they perceive the institution to have a political position towards agricultural biotechnology that is not too far from their own attitude. Evidence for such a causal relation has indeed been found in experimental studies (Frewer at al., 2003; Hagemann & Scholderer, submitted) and cross-sectional studies employing detailed

mediation analyses (Poortinga & Pidgeon, 2004, 2005). However, more research is needed before a definite judgment of the causal direction can be made.

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ARTICLE 4

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Consumer attitudes towards agricultural biotechnology: Effects of repeated exposure to information

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Risk Analysis

Abstract

Altogether 815 consumers participated in an attitude change experiment. The information stimuli varied in terms of content, source, and valence. Participants were exposed three times to evaluative consistent information about a genetically modified crop. A systematic attitude change effect was observed in response to the first exposure to positive information (effect size d = .50). The effect remained stable over subsequent exposure periods. No systematic attitude change was observed in response to negative information. The effect was not moderated by the content of the information materials or the source to which they had been attributed. Mediation analyses indicated that the attitude change effect operated through an "ends-justify means" process in which evaluations of the desirability of the outcome legitimised the use of gene technology as a means to achieve it. Two different operationalisations of trust were tested as alternative mediators. Corroborating the results of previous research, trust did not mediate attitude change. Instead, trust was subject to strong assimilation effects, depending on the perceived distance between the position advocated by a source and participants' own prior attitudes.

Introduction

The heated GM foods debate of the 1990s triggered a massive amount of research on consumer attitudes towards biotechnology – first in Europe, then in New Zealand and Australia, and finally in the United States and in developing countries (for reviews, see Costa-Font, Gill & Trail, 2008; Finucane & Holup, 2005; Frewer, Lassen, Kettlitz, Scholderer, Beekman, & Berdal, 2004; Scholderer, 2005). With few exceptions, researchers utilised cross-sectional survey designs in their studies. Up until now, no

more than ten studies have been published in the scientific literature that specifically investigated the effects of communication about gene technology on consumer attitudes by means of controlled attitude change experiments.

Previous research

Frewer, Howard and Shepherd (1998) presented consumers with a list of ten very simple messages that all stressed the benefits of GM foods. Apart from a depolarisation effect that may have simply been a consequence of regression towards the mean (the split into initially positive and negative consumers had been performed based on an unreliable measure of initial attitude), no systematic attitude change was observed. Furthermore, the authors found that perceptions of source credibility were strongly dependent on participants' initial attitudes towards GM foods.

In a follow-up study, Frewer, Howard, Hedderley, and Shepherd (1999) confronted consumers with sets of similar simple messages that all stressed the benefits of GM foods, but varied in persuasiveness. The persuasiveness of the messages did not have a significant overall impact on attitudes towards realistic types of GM foods, but tended to decrease the negativity of attitudes towards unrealistic, "shocking" types of GM applications (e.g., transfer of human DNA into animals for agricultural purposes).

Scholderer and Frewer (2003) confronted consumers with realistic communication materials of three different types: argumentatively balanced, general information about gene technology in food production, information about the benefits of particular example products, and conventional product advertising. Compared to a control group where

participants had not been exposed to any information, none of the information groups showed any changes in attitudes in response to the communication. No polarisation or depolarisation effects were observed either.

In a related study, Frewer, Scholderer and Bredahl (2003) used the same information materials, attributed to different sources, and investigated whether perceived source credibility mediated the relationship between information exposure and attitude change. The authors found no attitude change effects and no mediating effects of source credibility. Rather, perceived source credibility was subject to a strong assimilation effect, corroborating the findings of Frewer, Howard and Shepherd (1998): the degree to which a participant trusted an information source was a function of the degree to which the information attributed to that source confirmed the participant's prior attitude.

Peters (2000) confronted his participants with four different newspaper articles and four different television features, all dealing with relatively complex issues relating to gene technology. Analysis of think-aloud protocols gathered in this study showed that consumers generated substantially more negative cognitive responses than positive ones, and that the evaluative tendency in the cognitive responses was correlated to the consumers' initial attitudes. Although positive cognitive responses as such had higher effects on attitude change, the altogether higher number of negative responses neutralised this effect, resulting in an overall absence of attitude change.

Miles, Ueland and Frewer (2005) investigated whether information about improved traceability of genetically modified food ingredients through the

food chain would have a positive effect on consumer attitudes towards GM foods. Participants in the traceability-information condition received a page of information about traceability of GM material and new detection methods. Participants in the no-information condition did not receive this information. However, no attitude change effect could be observed.

Søndergaard, Grunert and Scholderer (2007) examined whether media reports featuring the process and outcomes of public participation exercises would have an impact on consumer attitudes towards industrial gene technology applications. However, the effect of such information did not differ from the effect of media reports featuring traditional forms of technology assessments – with or without stakeholder involvement – neither did it depend on the institution that was conducting the participation exercise. Furthermore, all media reporting on technology assessments yielded negative attitude change effects relative to a control group that had not been exposed to any information.

Taken together, the results of these studies suggest that single exposure to information by means of simple mass-communication techniques may not have enough persuasive power to change consumer attitudes towards gene technology. Furthermore, it appears that communication about new forms of risk assessment and management (such as public participation exercises, traceability systems) suffers from the same lack of persuasiveness as more traditional risk-benefit communication.

A number of recent studies used more complex information scenarios. Wilson, Evans, Leppard and Syrette (2004) report the results of a laboratory study in which participants were given the opportunity to access up to twelve news stories about GM crops from a stylised media portal.

Although no systematic attitude change occurred, attitudes were more polarized after the information-gathering task than they had been before.

Dean and Shepherd (2007) exposed their participants to pairs of relatively complex messages about GM foods. The messages in each pair were attributed to two different sources that were either in consensus or in conflict regarding their assessment of risk or benefit associated with GM foods. Attitude change in terms of a decrease in perceived risk was observed in response to consensus pairs of messages but not in response to conflicting pairs of messages. Attitude change in terms of an increase in perceived benefit was observed in response to both conflict and consensus pairs of messages. Although the authors did not conduct formal mediation analysis, the similarity of the findings they obtained for source credibility as the dependent variable suggest that trust may have been involved in the attitude change process, either as a mediator or subject to an assimilation effect (as observed by Frewer et al., 1998, and Frewer et al., 2003).

Qin and Brown (2007) obtained a small but significant attitude change effect in response to information material that was partially comparable to the conflict condition in the Dean and Shepherd (2007) study. The information described a specific application in depth (AquaBounty's genetically modified AquAdvantage™ salmon) and then outlined the positions of several major stakeholder groups towards the application and towards genetic engineering in general. The attitude measure taken in this study only referred to the specific application, however; hence it is uncertain whether the information materials also affected participants' evaluation of the technology in general.

Hypotheses

The results of the ten attitude change experiments reviewed above suggest that consumer attitudes towards gene technology are rather resistant to persuasion: eight of these studies observed no systematic attitude change at all. However, all studies had a design aspect in common that seriously limits their ecological validity: participants were exposed to information only once. Outside the laboratory, on the other hand, attitudes are in constant flux, evolving over time and in interaction with multiple stimuli in a person's environment. Particularly striking is that the only studies that ever obtained some form of systematic attitude change in response to communication (Dean & Shepherd, 2007; Qin & Brown, 2007) used a single-exposure design too, but exposed participants to materials that contained multiple messages.

Traditional as well as modern theories of attitude change (Petty & Cacioppo, 1986; Gawronski & Bodenhausen, 2006) would predict that exposure to multiple messages will increase the number of evaluative associations to the attitude object. Peripheral (in traditional terminology) or implicit (in modern terminology) attitude change will then occur as a function of the number, valence and accessibility of the newly associated evaluations. Central or explicit attitude change will occur when an individual consciously reasons about the arguments in the messages and decides that they have a bearing on the way she or he should feel about the object. The propositional evaluation may also influence future attitudinal responding, either when it becomes a part of the associative structure, or when a similar propositional reasoning process is triggered by the next confrontation with the attitude object.

Hence, if an individual is exposed to multiple messages of the same valence over time, implicit attitude change can be expected to occur in a gradual and cumulative manner as new evaluative associations with the attitude object are stored in memory. Explicit attitude change can be expected to follow a similar cumulative pattern, both (a) because propositional reasoning about an attitude object always activates the associative representation of the attitude and is therefore confounded by it, and (b) because the total time available for elaboration and propositional reasoning will necessarily increase with time. In the experiment reported below, we will test this prediction by exposing our participants to several messages over time. Each individual will receive three evaluatively consistent messages that cover different issues related to a particular GM crop example.

Furthermore, we will examine several potential mediators of attitude change that are mainly relevant for attitude change via propositional reasoning. Previous investigations have focused on trust, operationalised in the tradition of the source credibility approach (see Berlo, Lemert & Mertz, 1969; Hovland & Weiss, 1951). For several reasons – either because no systematic attitude change occurred in the respective studies (e.g., Frewer et al., 1998, 2003) or because no mediation tests were carried out (e.g., Dean & Shepherd, 2007), the role of source credibility as a potential mediator of attitude change in the context of communication about gene technology is not fully understood yet. Until now, the only robust result is that consumer perceptions of source credibility are subject to strong assimilation effects. As predicted by social judgment theory (Sherif & Hovland, 1961), consumers appear to judge the credibility of an

information source based on the perceived distance between the source's position towards the issue and their own prior attitude.

We expect to replicate this finding. Still, the source credibility instrument used in these studies (19 items originally developed by Frewer, Howard, Hedderley & Shepherd, 1996[5]) does not so much measure the credibility of a source per se but the credibility of information issued by or experimentally attributed to that source. Hence, we expect that the Frewer et al. (1996) instrument may yield valuable data about the nature of the propositional reasoning processes in which participants engage in response to information exposure, even if it may not necessarily mediate attitude change.

An alternative conceptualisation of trust has become popular in recent years but has not yet been investigated in the context of attitude change studies. Based on ideas of Luhmann (1988), Siegrist, Earle and Gutscher (2003) developed a dual model of trust. The first dimension, confidence, reflects an individual's belief that the actions of a person or an organisation will lead to the expected result, based on knowledge about their past performance. The second dimension, social trust, reflects an individual's willingness to rely on a person or an institution without knowledge about their past performance. Social trust is assumed to be motivated by a heuristic judgment of value similarity. The dependence of trust on

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[5] Research using this instrument is sometimes misleadingly characterised as a "dimensional" approach to trust. The items of the instrument have awkward measurement characteristics and cannot be represented by a simple-structure model (this only works for small subsets of the 19 original items).

perceived value similarity resembles the prediction by social judgment theory that the perceived credibility of an information source will depend on the perceived attitudinal distance between the source and the self (Sherif & Hovland, 1961). We expect that the explicit inclusion of this dependence by the dual trust approach may provide a better model of trust-mediated attitude change than the source credibility approach, in which the dependence remains implicit.

Finally, we will investigate whether attitude change is mediated by consumer evaluations of an example application that is featured in the information materials. An effect of such information on attitude towards the example application itself has been found in previous research (Qin & Brown, 2007). However, it is as yet unclear to which degree an information-induced change in attitudes towards a specific application will be generalised to the technology as such. Up until now, such effects have only been demonstrated in studies where direct experience with real products was used as a treatment (e.g., Grunert, Bech-Larsen, Lähteenmäki, Ueland & Åström, 2004; Lähteenmäki, Grunert, Ueland, Åström, Arvola & Bech-Larsen, 2004; Grunert, Bredahl & Scholderer, 2003). The present study will investigate whether such effects can also be observed in response to information treatments.

Method

Participants and procedure

The experiment was conducted in January and February 2007. Participants were recruited by means of random-digit dialling. A total of N = 815 Danish consumers participated.

Table 1. Demographic characteristics of participants (total $N = 815$).

		Frequency		
		Count (n)	Percent Sample	Percent Population
Age	18-25 years	68	8.4	5.4
	26-35 years	159	19.5	12.9
	36-45 years	212	25.9	14.9
	46-55 years	203	24.9	13.5
	56-65 years	129	15.8	13.4
	Above 65 years	44	5.4	15.3
Gender	Female	498	52.8	50.5
	Male	445	47.2	49.5
Cohabitation	Single	214	26.3	60.4
	Living with partner	601	73.7	39.6
Number of persons in household	1	146	17.9	38.6
	2	295	36.2	33.0
	3	134	16.4	11.5
	4	167	20.5	11.5
	5+	73	8.9	4.0
Presence of children in household	Between 0 and 3 years	93	20.6	21.4
	Between 4 and 9 years	143	31.8	33.0
	Between 10 and 17 years	214	47.6	45.5
Gross annual household Income (DKK)	Below 200,000	96	11.8	33.5
	200,000-299,999	107	13.2	20.0
	300,000-399,999	126	15.5	15.5
	400,000-799,999	405	50.0	10.3
	800,000 and above	251	31.0	2.0
Education	Up to 9 years of education	77	8.5	22.3
	10-12 years of education	295	32.7	28.9
	13-16 years of education	65	41.8	13.1
	Higher education	154	17.1	4.3

Demographic characteristics are shown in Table 1. The representativeness of the sample was rather balanced as a majority of the demographics was representative for the adult Danish population (aged 18 and above) with the exception of gross annual household income and education level. In regard to the gross annual household income the sample had an overrepresentation of people in the lower income classes (below 300,000 DKK) compared to the population and an underrepresentation of people in higher income

classes (400,000 DKK and above). The deviation in regard to education level is found in regard to the higher education as the sample is underrepresented compared to the population.

Upon agreement to participate, participants received an e-mail with a link directing them to the web survey platform in which the experiment had been implemented. The experiment consisted of three phases. All participants started with demographic questions and an initial (T_1) assessment of their attitudes towards GM crops. Then, participants were assigned at random to one of the experimental conditions. Participants in information-exposure conditions were asked to read the first information text. Across information-exposure groups, the texts varied in terms of content, valence, and source (see below). No time limitation was given. Information exposure was followed by a second (T_2) assessment of participants' attitudes towards GM crops. In addition, participants were asked to respond to a set of items measuring their trust in the information source to which the first text had been attributed, and their attitudes towards the example crop that had been featured in the information materials. Participants in the control conditions received no information and were not asked to respond to attitude or trust items after their initial attitudes had been assessed.

For the second phase, the participants in each experimental condition were divided into three groups. The first group continued directly with Phase 2, the second group after a one-week interval, and the third group after a two-week interval (participants in these groups received a new link by e-mail). Phase 2 began a third (T_3) assessment of participants' attitudes towards GM crops. Participants in the information-exposure conditions continued with a set of true-false questions measuring how much of the information from

Phase 1 they still remembered, followed by exposure to the second information text, a fourth assessment of their attitudes towards GM crops (T_4), a set of items measuring their trust in the information source to which the second text had been attributed, and their attitude towards the example crop that had been featured in the information materials. Participants in the control conditions did not answer the recall questions, received no information text, and were not asked to respond to attitude or trust items after their attitudes had been assessed.

The third phase followed the same procedure as the second phase. Each participant had the same interval between the second and third phase as the interval between the first and second phase. Phase 3 began a fifth (T_5) assessment of attitudes towards GM crops. In the information-exposure groups, this was followed by recall questions referring to the information from Phase 2, exposure to the third information text, a sixth assessment of their attitudes towards GM crops (T_6), and a set of items measuring their trust in the information source to which the third text had been attributed and their attitude towards the example crop. Participants in the control conditions did not answer the recall questions, received no information text, and were not asked to respond to further attitude or trust items after their attitudes had been assessed. Finally, all participants were presented with a disclaimer, clarifying that the information materials been constructed for scientific purposes and had not in fact been issued by the organisations to which they had been attributed.

Information materials

The information materials had been experimentally varied in terms of three factors: content, source, and valence. Valence was chosen based on the often replicated finding in economic psychology (e.g., Kahneman & Tversky, 1979) and social psychology (e.g., Peeters & Czapinski, 1990; Skowronski & Carlston, 1989) that information about negative outcomes of alternatives, attributes of events, or characteristics of persons tends to exert a stronger influence on judgments than information about positive attributes, it might be expected that the valence of the messages may have a moderating effect on the degree of attitude change. As previously explained is source included in the study in order to replicate previous findings. Industry and government was chosen as they often lack public trust and credibility (Frewer, Howard, Hedderly & Shepherd, 1999) whereas citizen panels where chosen as this kind of participatory processes are assumed to have a positive effects (Verbeke et al, 2007; Frewer et al, 2004). Finally was content experimentally varied as previous research has found that attitude change is mediated by consumer evaluations of an example application that is featured in the information materials (see section about hypothesis).

All materials began with a short characterisation example application (a genetically modified potato with altered starch composition) and its potential usefulness in preventive nutrition (reduction of metabolic syndrome risk). Then, the content of the information materials focused either on the specific properties if the example application, the technology that was used to express the trait, or the regulatory issues related to its approval (risk assessment, authorisation, co-existence management, labelling). The materials were attributed to three different sources: a

fictitious agribusiness company, the European Food Safety Authority, or a citizens' jury run by the Danish Board of Technology. The valence of the overall message communicated in the information materials was either negative or positive. The stimuli were based on actually existing information materials targeted at the general public, edited by the experimenters to fit the experimental design and the typical wording and style of the sources to which the materials were attributed. From an initial master set of evaluatively neutral materials, versions with positive and negative valence were developed by systematically inserting positive or negative policy positions and assessment outcomes. All texts had a length between 500 and 800 words.

Measures

Attitudes towards GM crops were measured by three semantic-differential items originally developed by Bredahl (2001) and had been used in several of the studies reviewed above (e.g., Frewer et al., 2003; Scholderer & Frewer, 2003; Søndergaard et al., 2007). The scale had high reliability (Jöreskog's rho = .97). Trust was operationalised in two different ways. Trust in the tradition of the source credibility approach was measured by 19 items adapted from Frewer et al. (1996). These items had been used in several of the studies reviewed above (e.g., Frewer et al, 2003; Dean & Shepherd, 2007). Trust in terms of the dual trust model was operationalised by eight items adapted from Siegrist et al. (2003), measuring value similarity (three items, Jöreskog's rho = .73), social trust (two items, Jöreskog's rho = .79), and confidence (three items, Jöreskog's rho = .82), respectively. Furthermore, attitudes towards the example crop, which had been featured in the information materials used in the present study, were measured. This was done on two separate dimensions: attitude towards the

trait expressed in the crop (three items, Jöreskog's rho = .96) and attitude towards the technical means by which expression had been achieved (three items, Jöreskog's rho = .98). The block with the dependent variables was placed in the beginning of the questionnaire (block 1) followed by items related to attitude toward crops trait and the technique (block 2) and finally questions regarding trust in source credibility (block 3). Within these blocks the order of the questions were randomised.

Table 2. Measures

Scales/items	Standardised factor loading
Attitude towards genetically modified crops	
Applying gene technology in crop breeding is… *(1: extremely bad … 7: extremely good)*	.97
Applying gene technology in crop breeding is… *(1: extremely stupid … 7: extremely wise)*	.95
I am (1: completely against … 7: completely for) gene technology in crop breeding	.95
Value similarity	
The (source) values profit more highly than I do (1: completely disagree ... 7: completely agree)[1]	.68
The *(source)* sees the risks associated with genetically modified foods completely different than I do *(1: completely disagree ... 7: completely agree)*[1]	.63
Public health is not very important for (source) (1: completely disagree ... 7: completely agree)[1]	.75
Social trust	
The *(source)* communicates openly and honestly about possible health effects of genetically modified foods *(1: completely disagree ... 7: completely agree)*	.78
Should it turn out that genetically modified foods are a threat to human health, the *(source)* would openly and honestly inform the public *(1: completely disagree ... 7: completely agree)*	.82
Confidence	
The *(source)* has the knowledge to ensure that consumption of genetically modified foods does not threaten human health *(1: completely disagree ... 7: completely agree)*	.88
The *(source)* possesses the competence necessary to assess any health risks associated with genetically modified foods *(1: completely disagree ... 7: completely agree)*	.86
In the future, we don't need to fear health risks from genetically modified foods *(1: completely disagree ... 7: completely agree)*	.59
*Attitude towards trait of example cro*p	
Developing potatoes with a healthier starch composition is… *(1: extremely bad … 7: extremely good)*	.96

Scales/items	Standardised factor loading
Developing potatoes with a healthier starch composition is … *(1: extremely stupid … 7: extremely wise)*	.88
I am *(1: completely against … 7: completely for)* developing potatoes with a healthier starch composition	.97
Attitude towards technique by which trait was achieved	
Using gene technology to develop potatoes with a healthier starch composition is… *(1: extremely bad … 7: extremely good)*	.98
Using gene technology to develop potatoes with a healthier starch composition is… *(1: extremely stupid … 7: extremely wise)*	.97
I am *(1: completely against … 7: completely for)* using gene technology to develop potatoes with a healthier starch composition	.98
Source credibility	
Information about food-related hazards from *(source)* is trustworthy *(1: completely disagree ... 7: completely agree)*	n.a.[2]
Information about food-related hazards from *(source)* is accurate *(1: completely disagree ... 7: completely agree)*	n.a.[2]
Information about food-related hazards from *(source)* is factual *(1: completely disagree ... 7: completely agree)*	n.a.[2]
The *(source)* is likely to withhold information about food-related issues from the public *(1: completely disagree ... 7: completely agree)*[1]	n.a.[2]
Information about food-related hazards from *(source)* is distorted *(1: completely disagree ... 7: completely agree)*[1]	n.a.[2]
Information about food-related hazards from *(source)* is truthful *(1: completely disagree ... 7: completely agree)*	n.a.[2]
Information about food-related hazards from *(source)* is biased *(1: completely disagree ... 7: completely agree)*[1]	n.a.[2]
The *(source)* has the freedom to provide information to the public about food-related hazards *(1: completely disagree ... 7: completely agree)*	n.a.[2]
The *(source)* has a vested interest in promoting a particular view about food-related hazards *(1: completely disagree ... 7: completely agree)*[1]	n.a.[2]
Information about food-related hazards from the *(source)* has been proven wrong in the past *(1: completely disagree ... 7: completely agree)*[1]	n.a.[2]
The *(source)* is knowledgeable about food related hazards *(1: completely disagree ... 7: completely agree)*	n.a.[2]

Scales/items	Standardised factor loading
The *(source)* feels a responsibility to provide good food-related information to the public *(1: completely disagree ... 7: completely agree)*	n.a.[2]
The *(source)* is expert in the area of food-related hazards *(1: completely disagree ... 7: completely agree)*	n.a.[2]
The *(source)* provides sensationalised information about food-related hazards *(1: completely disagree ... 7: completely agree)*[1]	n.a.[2]
The *(source)* has a good track record of providing information about food-related hazards *(1: completely disagree ... 7: completely agree)*	n.a.[2]
The *(source)* provides accurate information about food-related hazards only to protect themselves and their own interests *(1: completely disagree ... 7: completely agree)*[1]	n.a.[2]
The *(source)* is accountable to other (for example, regulatory bodies) if mistakes are made in the food-related information provided *(1: completely disagree ... 7: completely agree)*	n.a.[2]
The *(source)* is concerned about public welfare *(1: completely disagree ... 7: completely agree)*	n.a.[2]
I am personally in favour of using the *(source)* to obtain information about food-related hazards *(1: completely disagree ... 7: completely agree)*	n.a.[2]

[1] Negatively formulated items were recoded before the analysis.

[2] Source credibility will be analysed on an item-by-item basis.

Semantic differential items had been constructed in analogy with the items measuring overall attitude towards GM crops. All items are listed in Table 2.

Results

Systematic attitude change

Systematic attitude change effects were assessed by means of a linear mixed-model ANOVA. The model included fixed effects of time (T_1, T_2,

T_3, T_4, T_5, T_6), information source (agribusiness company, food safety authority, citizens' jury), information content (product, technology, regulation), valence (positive, negative), and exposure interval (0, 1, 2 weeks). A heterogeneous first-order autoregressive error structure was specified for the repeated measurements of the dependent variable, attitude towards genetically modified crops. The model was estimated by means of restricted maximum likelihood. The fit was satisfactory (Maddala's generalised $R^2 = .35$).

The analysis yielded main effects of time ($F[5, 2255] = 9.58$, $p < .001$) and valence ($F[1, 605] = 17.60$, $p < .001$) were qualified by a highly significant ordinal interaction of time and valence ($F[5, 2255] = 26.83$, $p < .001$). Analysis of simple effects indicated that the interaction effect was due to a strong positive attitude shift that occurred in the positive-valence condition between T_1 and T_2 (effect size d = .50) and remained relatively stable over subsequent observation periods. Notably, the effect was not moderated by the content of the information material participants had been exposed to, or the source to which the material had been attributed (none of the main effects of these factors or interactions with these factors were significant). No systematic attitude change was observed in the negative-valence condition. The effects are plotted in Figure 1.

Furthermore, the length of the interval between exposures had a small but significant main effect ($F[2, 598] = 4.87$, $p < .01$) that was qualified by a three-way interaction between exposure interval, time and valence ($F[8, 2250] = 2.67$, $p < .01$), indicating that attitudes in general, and the attitude shift observed in positive-valence condition in particular, remained more stable over shorter than over longer intervals between measurements.

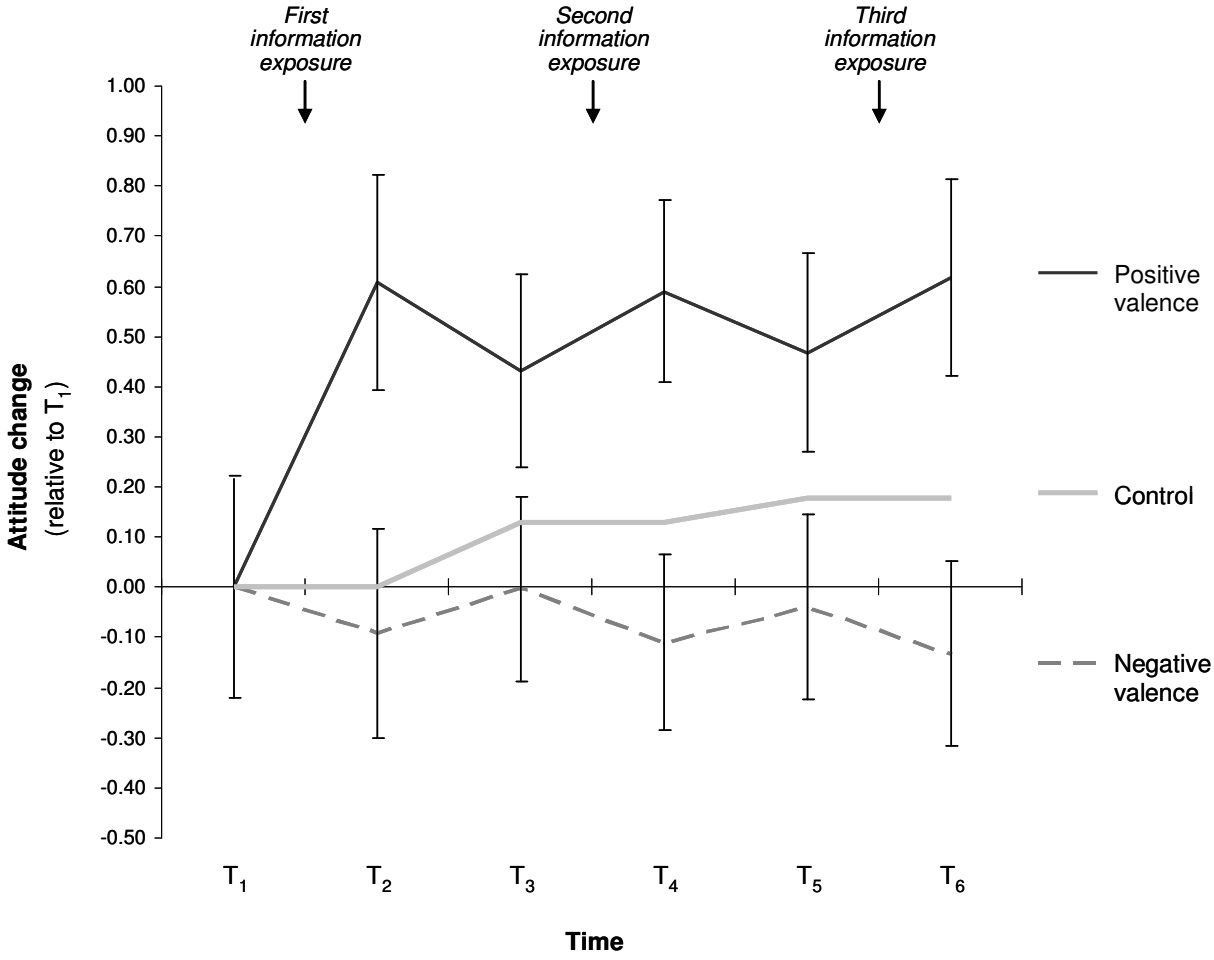

Figure 1. Systematic attitude change effects as a function of information valence (expected marginal means; error bars indicate 95% confidence intervals).

The asymmetric attitude shift observed in the present study ran counter to our expectations, and it did so in two important ways: it occurred exclusively after the first information exposure, contradicting our expectation of cumulative effects, and it only occurred in response to information with positive valence, contradicting our expectation that the effects would be symmetric with respect to the valence of the information participants had been exposed to. In the following analyses we will attempt

to shed light on the mediation processes through which the asymmetric attitude shift between T_1 and T_2 may have operated.

Effects on credibility

The first set of potential mediators for which measurements had been collected in the present study was the perceived credibility of information as attributed to a particular source (Frewer et al., 1996, 1998, 2003). Previous investigations of the effects of information exposure on consumer attitudes towards gene technology found that such perceptions were strongly biased by consumers' prior attitudes. The finding can be interpreted as an assimilation effect: consumers were more prepared to lend credibility to an information source when the source took a position towards gene technology that was not too distant from their own prior attitudes. In order to replicate this finding, the T_2 measurements (taken immediately after the first information exposure) of the 19 items of Frewer et al.'s (1996) source credibility instrument were subjected to a MANOVA with information source, valence, a term for the interaction between source and valence, and linear and quadratic terms for prior attitude as independent variables.

The source to which the information had been attributed had a significant effect (Wilks' $\Lambda = .52$, $F[38, 1234] = 12.78$, $p < .001$; effect size partial $\eta^2 = .28$). Across the 19 source credibility dimensions, participants tended to perceive information as most credible when it was attributed to the European Food Safety Authority, less credible when it was attributed to a citizen's jury run by the Danish Board of Technology and again less credible when it was attributed to an agribusiness company. Although smaller than the main effect of source, the linear (Wilks' $\Lambda = .94$, $F[19,$

617] = 1.96, $p < .01$; partial $\eta^2 = .06$) and quadratic (Wilks' $\Lambda = .95$, F[19, 617] = 1.96, $p < .05$; partial $\eta^2 = .05$) terms for prior attitude were significant as well, indicating that the expected assimilation effects did in fact occur. The assimilation effects are plotted in Figure 2 (adjusted for the source and valence of the information to which participants had been exposed).

Only one of the 19 source credibility dimensions was systematically affected by the valence of the information participants had been exposed to, rendering the overall multivariate effect insignificant and ruling out the other 18 dimensions of source credibility as mediators of the valence-dependent attitude shift. The dimension for which a significant univariate effect of valence was found was the perception that the information to which participants had been exposed was sensationalising (F[1, 635] = 5.66, $p < .05$; partial $\eta^2 = .01$): information with negative valence was perceived to be more sensationalising than information with positive valence.

It could be speculated that such a perception might have decreased participants' motivation to process the information in the negative-valence condition. Indirect evidence for this was found in the aided recall measures that had been taken at T_3. Participants who had been exposed to positive information during the previous phase of the experiment remembered more of the content they had been exposed to (mean number of correctly answered recall questions: 57.1%) than participants who had been exposed to negative information (mean number of correctly answered recall questions: 48.9%; F[1, 470] = 11.14, $p < .001$; partial $\eta^2 = .02$).

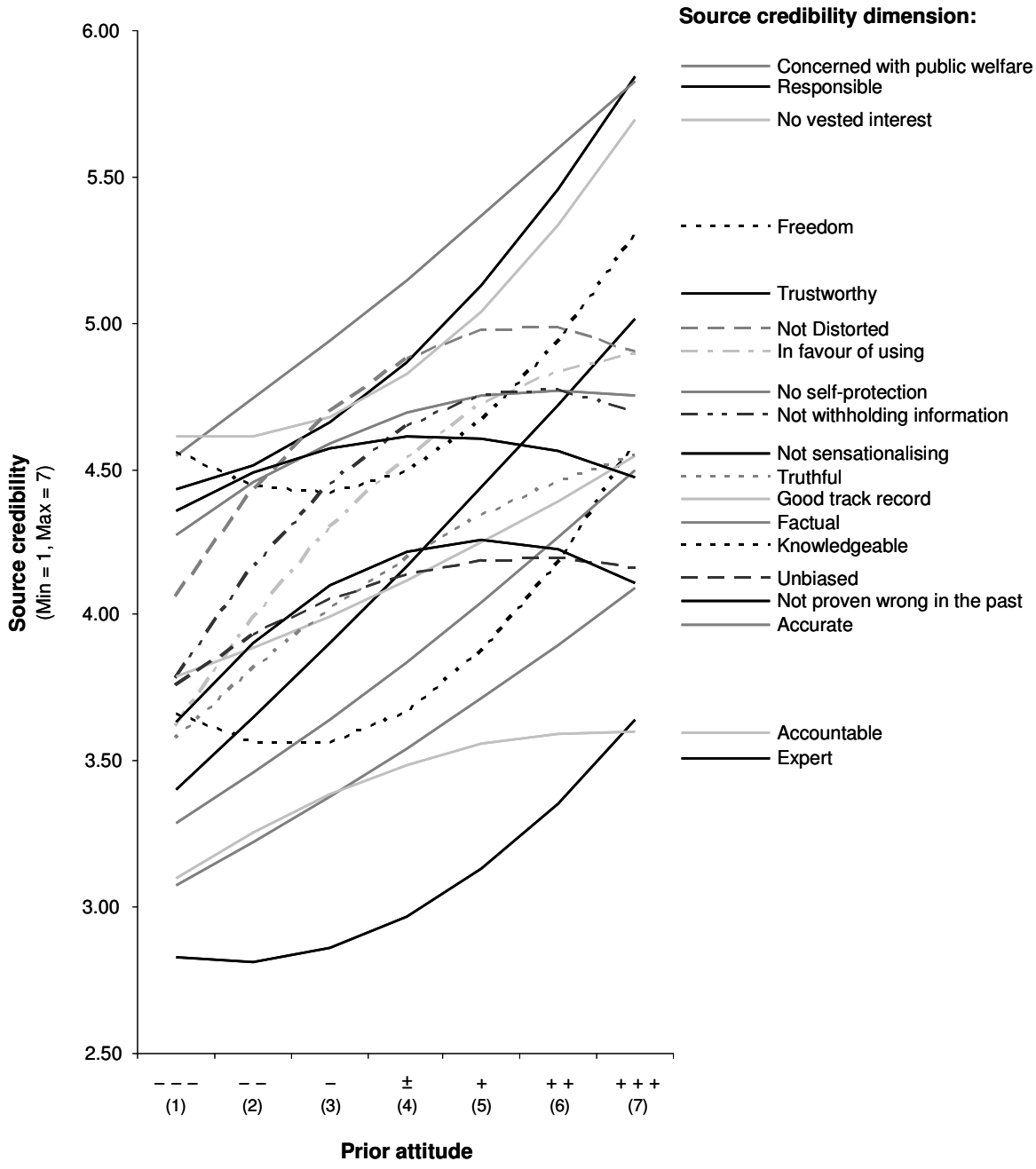

Figure 2. Assimilation of source credibility to prior attitude (expected marginal means of perceived source credibility dimensions at T_2 as a function of attitude at T_1, controlling for information source and valence).

However, a series of formal hypothesis tests (following the procedures outlined by Preacher, Rucker & Hayes, 2007) indicated that no simple or

moderated mediation process[6] involving valence-dependent perceptions of sensationalising information was responsible for the asymmetric attitude change findings discussed above.

Effects on value similarity, social trust and confidence

The second set of potential mediators for which measurements had been collected in the present study consisted of the three central constructs of the dual trust model (Siegrist et al., 2003): value similarity, social trust and confidence. Due to the unsatisfactory reliability of the measures, the mediation hypothesis was tested via structural equation modelling (using robust maximum likelihood estimation in LISREL 8.72). A saturated structural model was specified, containing free parameters for the effects of all exogenous variables on all endogenous variables, all mediators on the dependent variable (attitude towards GM crops at T_2), and directed effects of value similarity on social trust and confidence. The fit was satisfactory (Satorra-Bentler $\chi^2 = 339.82$, $df = 94$, RMSEA = .06). The model explained 33% of the variation in value similarity, 59% of the variation in social trust, 16% of the variation in confidence, and 67% of the variation in attitudes

[6] Moderated mediation occurs when the strength of an indirect effect depends on the level of some variable, or in other words, when mediation relations are contingent on the level of a moderator (Preacher, Rucker & Hayes, 2007).

towards GM crops at T_2. Standardised parameter estimates are displayed in Figure 3.

As already observed for source credibility, the constructs of the dual trust model were subject to strong assimilation effects towards participants' prior attitudes. Furthermore, they were significantly affected by the valence of the information participants had been exposed to and the source to which the information was attributed. However, neither value similarity nor social trust or confidence had significant effects on attitude towards GM crops at T_2 when attitude at T_1 was controlled for.

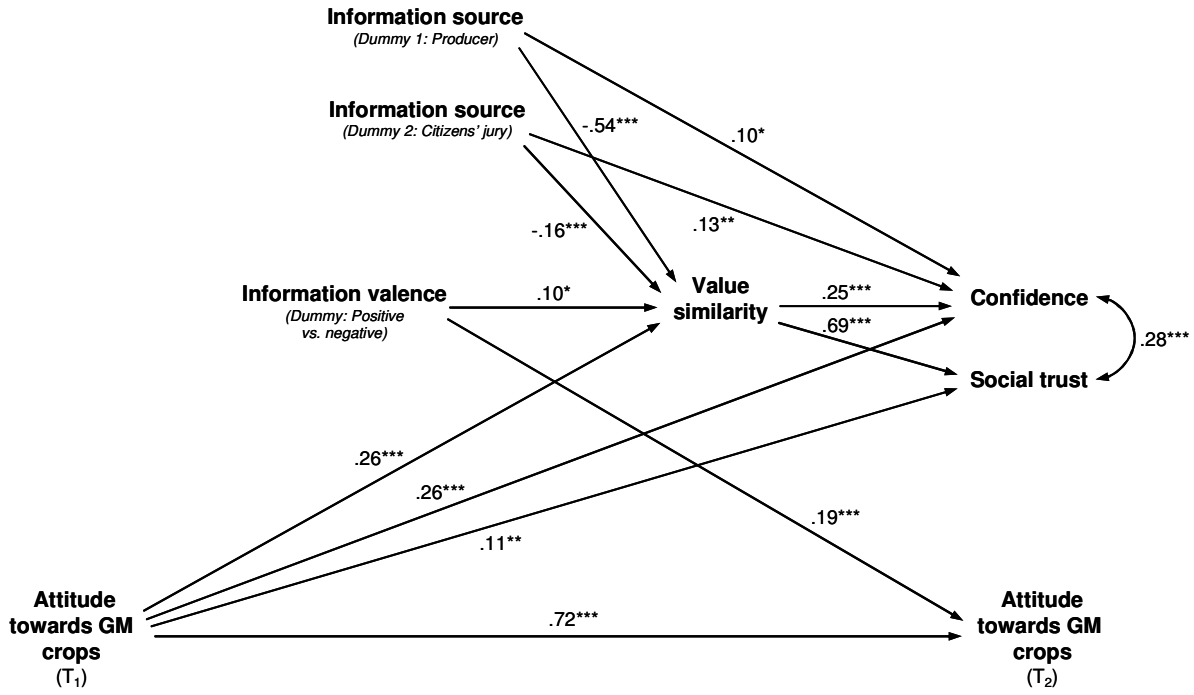

Figure 3. Structural model of the attitude change process: no mediation by value similarity, social trust, or confidence (standardised path coefficients; *** $p < .001$, ** $p < .01$, * $p < .05$; insignificant paths omitted).

Formal hypothesis tests on the unconditional and conditional indirect effects of valence on attitude at T_2 confirmed that no simple or moderated mediation process involving valence-dependent perceptions of value similarity, social trust or confidence was responsible for the asymmetric attitude shift observed between T_1 and T_2.

Mediation by attitudes towards the example application

As a third set of potential mediators, a collection was made of measurements of participants' attitudes towards the trait expressed in the example crop (healthier starch composition in a potato, reducing metabolic syndrome risk), and the technical means by which expression had been achieved (genetic modification of the potato plant). Again, the mediation hypothesis was tested via structural equation modelling. A saturated structural model was specified, containing free parameters for the effects of all exogenous variables on all endogenous variables, all mediators on the dependent variable, and directed effects of attitude towards the crop trait on attitude towards the technique by which the trait was achieved.

The model was estimated by means of robust maximum likelihood. The overall fit was satisfactory (Satorra-Bentler $\chi^2 = 141.22$, $df = 56$, RMSEA = .07). The model explained 23% of the variation in participants' attitudes towards the trait of the example crop, 69% of the variation in attitudes towards the technical means by which trait expression had been achieved, and 80% of the variation in attitudes towards GM crops at T_2. Standardised parameter estimates are displayed in Figure 4.

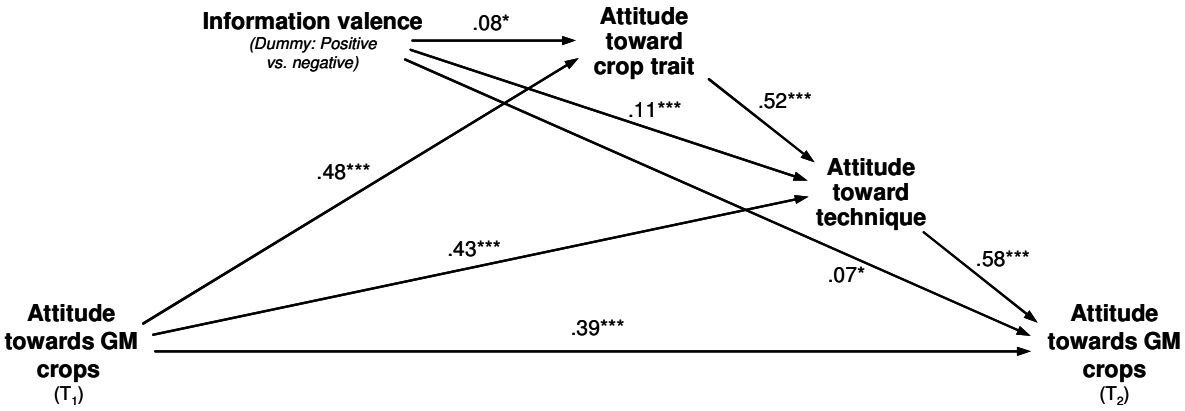

Figure 4. Structural model of the attitude change process: mediation by attitude toward the trait expressed in the crop and attitude towards the technical means by which it had been achieved (standardised path coefficients; *** $p < .001$, ** $p < .01$, * $p < .05$; insignificant paths omitted).

A formal hypothesis test on the indirect effect of information valence on attitude towards GM crops at T_1 confirmed that the mediation effect via attitudes towards the trait expressed in the example crop and attitudes towards the technical means by which expression had been achieved was significant (indirect effect = .30, SE = .09, t = 3.27, p[one-tailed] < .001, standardised indirect effect = .09).

Discussion and conclusion

Communication about genetically modified foods – including crops, processing aids, and the various public policy issues related to them – has been the topic of an extraordinary amount of musings and deliberations over the past two decades[7]. Considering the importance of the topic,

[7] At the time of writing, a Google search using the query *consumer AND information AND food AND ("genetically modified" OR "genetically engineered")* yielded over 1.5 million results.

surprisingly little research has been conducted on the effectiveness of different forms of communication. The ten studies in which this was done (see above) had meagre results. With two recent exceptions (Dean & Shepherd, 2007; Qin & Brown, 2007), no systematic attitude change was observed in any of these studies. The experimental designs used in these studies shared a feature that might have been responsible for the absence of effects: unlike in real life, where attitudes towards political issues are in constant flux and evolve over time, participants in the respective attitude change experiments were exposed to single information treatments.

Our initial expectation was therefore that repeated exposure to information would have the persuasive power that the single-exposure treatments in previous studies had been lacking. However, the hypothesised gradual and cumulative attitude change did not occur. Instead, we observed a strong positive attitude shift (at a size of d = .50 standard deviations) after the first exposure, equivalent to attitude change following single exposure to information. In the context of GM foods, this particular result makes the present study the first one that has ever achieved systematic attitude change by means of a single exposure to a single message.

Anatomy of the attitude change effect

Mediation analyses showed that the attitude shift observed in the present study operated largely through participants' evaluations of the example product that had been featured in the information materials they had been exposed to. The results suggest a three-step process. In the first step, confrontation with positive materials led to a more positive evaluation of the trait that had been expressed in the crop plant (healthier starch composition, reducing the risk of metabolic syndrome and thereby the risk

of diabetes, obesity, and cardiovascular disease). This, in turn, led to a more positive evaluation of the technical means by which this particular outcome had been achieved (genetic modification of potato plants), which in the third step led to more positive attitudes towards genetically modified crops in general. Apparently, the attitude change process observed in the present study followed an "ends-justify-means" rationale that in the last step of the process became associated with GM crops in general.

Contrary to our expectation, we observed systematic attitude change only in response to positive but not to negative information. At first glance, this may seem to contradict a robust result of risk communication research. When confronted with ambivalent messages about risk, people tend to evaluate negative arguments as more trustworthy than positive ones (e.g., Peters, 2000; Siegrist & Cvetkovich, 2001; Slovic, 1993). However, more recent research has shown that the alleged negativity bias in risk communication is actually a confirmatory bias (Poortinga & Pidgeon, 2004; White, Pahl, Buehner & Haye, 2003). People simply assign higher weights to pro-attitudinal than to counter-attitudinal arguments, and in risk communication, where prior attitudes towards a hazard tend to be negative, this general psychological tendency (see Festinger, 1957; Zillman & Bryant, 1985) manifests itself in a preference for negative arguments. Moreover, the information materials used in the present study were not ambivalent but had been manipulated in such a way as to present relatively unambiguous positive or negative information, respectively.

A more realistic interpretation of the effect asymmetry observed here may be that the logic of "ends justify means" cannot easily be transferred to negative outcomes. From a utilitarian point of view, desirable ends may legitimate a wide range of means, even if the means are initially regarded

as undesirable. The reverse, however, does not hold: undesirable ends justify nothing, an axiom that applies in all ethical frameworks. Hence, a symmetric effect in response to structurally identical information with opposite valences should not have been expected in the first place.

Trust: manifestation of attitude, not cause

Two other potential sets of mediators were tested in the present study. The items of source credibility instrument originally developed by Frewer et al. (1996) – a set of variables included in several previous studies (Dean & Shepherd, 2007; Frewer et al., 1998, 2003) – did not mediate attitude change, corroborating the results of previous research. The central constructs of the dual trust and confidence model (Siegrist et al., 2003) – an alternative conceptualisation of trust – had no mediating effects either. In both operationalisations, trust was subject to strong assimilation effects towards participants' prior attitudes. Consistent with the classical predictions of social judgment theory (Sherif & Hovland, 1961), trust in an information source appeared to be a function of the perceived attitudinal distance between the perceived position of the source and participants' own prior attitudes towards the issue.

In theoretical terms, these results cast further doubt on the operational independence of trust from attitude. In agreement with other evidence from the risk perception and communication literature (Eiser, Miles & Frewer, 2002; Frewer et al., 2003; Poortinga & Pidgeon, 2004, 2005, 2006), the results of the present study support an "associationist" view where trust in the actors and institutions involved in the development and regulation of a technology is just a particular expression of a more general attitude towards the technology. In practical terms, our results suggest that consumer trust

does not lead to the acceptance of products, policies or technologies but will follow it if the products, policies or technologies are sound and their benefits to the consumer are well articulated.

Differences to previous findings

Considering the results of previous research, it is not immediately understandable why consumer attitudes towards GM crops were changed so easily in the present study. We believe that two factors may have been responsible for this. The first one is related to the nature of the crop trait that was featured in our communication materials. All materials (including those with a focus on the technology or the regulatory issues) included at least a short characterisation of the crop trait and its potential usefulness in preventive nutrition. We chose a second-generation GM crop example with a consumer health benefit (reduction of metabolic syndrome risk) that was relevant to the majority of the population, not just a narrow target group, and explained the nature of the risk and the intended mode of action in enough detail to be understood by consumers. Unlike hedonic benefits such as taste and texture, health benefits can easily be communicated by means of verbal materials. And unlike environmental benefits, health benefits are of immediate personal relevance to most consumers, especially when they tap into multiple aspects of consumers' protection motivation (nutritionists regard metabolic syndrome as a likely mediator of several chronic diseases, including cardiovascular disease, diabetes, and obesity).

The second possible factor is a historical one. With the exception of the two previous studies in which some form of attitude change was observed (Dean & Shepherd, 2007; Qin & Brown, 2007), all other attitude change studies were conducted at times where the GM foods debate in the

respective countries was intense and polarised. In Europe, media attention waned during the years of the moratorium and has not significantly picked up again. In Denmark, where the present study was conducted, a NEXIS® search of all news media yielded no more than 54 articles on GM issues for the year 2006 (i.e., the twelve months prior to the period in which the present study was conducted) compared to 161 articles for the year 1999 when the GM foods debate peaked. The absence of the debate from the mass media is reflected in public opinion about biotechnology. Comparisons of Eurobarometer results over time (e.g., Gaskell, Stares, Allansdottir, et al., 2006) indicate that the attitudes of Europeans have become neutral again. Low issue salience and neutral average attitudes tend to be associated with low attitude strength – a situation in which attitude change is much more likely to occur (see Eagly & Chaiken, 1995) than in a heated and polarised opinion climate such as in the late 1990s.

An alternative but related interpretation, backed up by the finding that participants in the present study perceived information materials with negative valence as more sensationalising, is that people may regard the purported risks of GM crops as something that has been blown out of proportion for long enough. A similar interpretation can be applied to the finding that our participants did not in any way respond to deliberative democracy elements: information attributed to a citizens' jury run by the Danish Board of Technology did not lead to more attitude change than information attributed to other sources, and it was not regarded as particularly trustworthy either. Again, it is important to understand historical context here: public engagement elements (such as the famed consensus conferences) were popular in Denmark under the labour government of the 1990s but were disbanded by the liberal-conservative

government that came into office in 2001. Since then, bottom-up elements of deliberative democracy have acquired an image of the old-fashioned, symbolising a burgeoning and inefficient public sector that was virtually paralysed by the multitude of participatory elements by which it sought to legitimise its further expansion.

Limitations

As has become clear from the previous paragraphs, not all findings of the present study may be generalisable to the socio-political context in other countries. Furthermore, it should be stressed that the treatments used in the present study had forced-exposure character. The overwhelming majority of consumers have no interest in agricultural biotechnology. For example, a recent assessment in which objective, behavioural measures of consumer interest were collected from a representative Danish sample (Scholderer & Czienskowski, 2008) suggests that no more than 5% of the Danish population would voluntarily read any information materials about novel foods, crops or the consumer products derived from them.

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CONCLUSIONS AND IMPLICATIONS

The application of modern biotechnology in food and agriculture has been a contested issue over the last 15 years. In the European Union, the debate reached its peak in the late 1990s with a period of intense stakeholder dispute that was widely covered in the media, culminating in a five-year moratorium on the approval of new genetically modified foods and crops. After a complete overhaul of the relevant legislation, the moratorium was lifted in 2004. Since then, the debate has become considerably calmer, mainly led between stakeholders and only rarely reaching the attention of the popular media (for reviews, see Brossard, Shanahan & Nesbitt, 2007; Scholderer, 2005).

In regular intervals, however, the conflict between the different camps is resurfacing. In May 2008, for example, the European Commission issued a somewhat provocative statement (COM 2008 450/5) calling for a more liberal stance on GM crops, motivated by the food security crisis that was dominating agricultural policy discussions at the time. A number of EU member states (chiefly France and Austria) have, for various domestic policy reasons, issued national bans on certain GM crops (notably, the genetically modified maize line MON210), explicitly violating EU legislation and leading to open conflict with the Commission and the Council. Finally, the ongoing revision of the Novel Food Regulation (Regulation EC 258/97; see Commission proposal COM 2007 872 and associated co-decision procedure 2008/0002 COD) has prompted heated disputes between MEPs over the fundamental objectives and the scope of

the regulation. The discussions surrounding the revision of Regulation (EC) 258/97 have made the smouldering lines of conflict particularly apparent:

- Genetically modified foods have historically been treated as a special case in Europe. An elaborate network of hard and soft legislation has been constructed, governing their testing, approval, and post-market monitoring. In contrast to that, other "problem technologies" in food and agriculture have largely been disregarded; no comparable body of horizontal legislation exists for any of them.

- Historically, policy makers have reduced the question of acceptability to one of measurable risk. The existing novel food legislation, for example, exclusively addresses food safety issues, and it does so in the traditional terms of toxicity, allergenicity, and mutagenicity. Ethical and environmental concerns have no legal bearing in the existing novel food legislation. Hence, novel foods derived from biotechnologies other than genetic modification are exempt from the extended regulation governing GM foods.

The aim of the research presented in this thesis was to assess the comparative acceptability of *different* biotechnologies in food and agriculture from the perspective of the consumer. The research was conducted with two cases in point: gene technology (or DNA recombination) and mutation breeding (or mutagenesis). Both have the same function, that is, to change the genome of crop plants in such a way that the resulting cultivars have improved agronomic, nutritional, or processing and storage properties. However, there are marked differences between the two technologies. In the European Union, applications of gene technology in food and agriculture are subject to detailed horizontal

regulation (see above). Applications of mutation breeding, on the other hand, do not have to undergo any further approval processes than the ones applying to all crop cultivars. Furthermore, gene technology has been the subject of an intense public debate and had at times a high profile in the popular media. Mutation breeding, on the other hand, was never discussed to any significant degree outside the expert community.

The theoretical basis for the research conducted here was classical attitude theory (Ajzen, 1988; Cartwright & Harary, 1956; Eagly & Chaiken, 1995; Fishbein & Ajzen, 1975; Heider, 1946, 1958; Petty & Cacioppo, 1986; Sherif & Hovland, 1961; Sherif, Sherif & Nebergall, 1965), together with its modern reformulations in the terms of social cognition (Gawronski & Bodenhausen, 2006; Mussweiler, Rüter & Epstude, 2004; Tesser, 1978). Three overall research questions were addressed:

- What is the content of the belief systems related to consumer attitudes towards different food biotechnologies and their applications?

- Are attitudes towards different food biotechnologies embedded into a joint system of other attitudes that causes commonalities between them, or do their relationships to other attitudes differ?

- Will repeated exposure to information lead to changes in consumer attitudes towards food biotechnologies?

In the first two studies (Papers 1 and 2), the belief basis of consumer attitudes towards the two different food biotechnologies was investigated. The methodology adopted here was qualitative, aiming to identify the content of the belief systems. In the third study (Paper 3), the inter-attitudinal structures related to these attitudes were examined (in particular,

their relations to other attitude dimensions and their relation to each other), assessing the degree of commonality in these structures. In the fourth study (Paper 4), the changeability of such attitudes was analysed. In the following, the central conclusions from the research will be presented, and their implications will be discussed.

The content of consumers' beliefs systems

The two biotechnologies studied in this thesis were initially assumed to be very different: gene technology, although still a relatively novel technology, had been at the centre of an intense public debate and was therefore considered to be relatively familiar to consumers. Mutation breeding on the other hand had been in use for many years but had never attracted a significant degree of public attention. Hence, it could be considered as relatively unfamiliar to consumers.

A large overlap

A comparison of the results of Studies 1 and 2 indicates that, despite the differences in familiarity, a majority of the issues and attributes in terms of which consumers understood the two biotechnologies were identical. These issues included the general impact of novel crop varieties on the environment, concerns about current risk assessment and management practices, impact of novel foods with functional properties on population-wide consumption patterns, distrust in the motives of producers, and broader concerns about potential evolutionary consequences that are as yet uncertain in terms of their very nature. It appears that there is a large overlap between the belief-systems related to the two biotechnologies – so large in fact as to border on indistinctness.

Incorrect overgeneralisations

The most striking evidence for this was found in certain over-generalisations. The information consumers received about the example applications of the two biotechnologies investigated here did not contain anything about the agronomic properties of the respective crop cultivars derived from them. Nonetheless, many consumers implicitly assumed that both of them had substantially improved agronomic properties. This we found peculiar; one explanation would be that consumers (quite plausibly) assume agribusiness companies to concentrate their R&D efforts on the development of crop plants with improved agronomic properties. Another explanation would be that consumers automatically assumed any novel crop or food derived from a non-traditional breeding technology to have properties comparable to the "first generation" of GM crops, which have dominated the public debate about biotechnology during the last two decades.

A second type of overgeneralization was related to an apparent unfamiliarity with regulatory procedures. The current legislation is not monadic; rather, it consists of a whole network of interlinked regulations and directives that do not equally apply to all biotechnologies currently applied in food and agriculture (see above). In consumers' evaluations of what they assumed to be current risk assessment practices, it became apparent that a number of them assumed that crop cultivars derived from mutation breeding were governed by the same body of legislation that applies to genetically modified crops. For example, consumers seemed to assume that environmental risk assessments (as stipulated by Directive 2001/18/EC on the deliberate release of GMOs into the environment) would also have to be conducted for crop cultivars derived from other

biotechnologies, notably the mutation-bred rice line that was used as an example in Study 2. This is not the case; Regulation (EC) 258/97 concerning novel foods and novel food ingredients, for example, does not provide for environmental risk assessment, and crop cultivars developed by means of mutation breeding are not even defined as a novel food. The provision for environmental risk assessment is part of specific legislation which only applies to genetically modified organisms. Hence, novel foods or crops that do not at any stage involve the deliberate release of GMOs into the environment cannot be subjected to environmental risk assessments, at least not with immediate regulatory relevance.

A prototype representation

Theoretically, the overgeneralisations observed in Studies 1 and 2 suggest that consumers' attitudes towards different food biotechnologies may operate according to the principles assumed by representation theories of attitude (see, for example, Lord & Leppe, 1999; Pratkanis, 1989; Sia, Lord, Blessum, Ratcliff, & Lepper, 1997; Smith & Sarate, 1992). In these theories, an attitude towards a category object (in this case, biotechnologies in food and agriculture) is assumed to be cognitively represented in terms of the accessible exemplars of that category. If a single exemplar completely dominates the representation of the category, it can be understood as the prototype of the category.

The observed overgeneralization of properties of the "first generation" of GM crops to properties of mutation-bred cultivars suggests that gene technology may indeed be such a prototype object, dominating consumers' cognitive representation of the category of biotechnologies in food and agriculture. When confronted with an unfamiliar exemplar of that category,

consumers may infer its properties simply by replacing missing information about its features with stored information about the features of the prototype object.

Implications for risk communicators

Both types of overgeneralization observed in Studies 1 and 2 may become relevant for future communication activities by regulators and manufacturers. The common problem is that consumers appear to regard genetically modified crops as the *prototype* of all novel foods. Given the way the concept of novel foods has been discussed in popular media, focusing exclusively on GM foods, this could only be expected. The consequence is, however, that the negative as well as the positive specificities of GM foods are likely to be over-generalised by consumers to all crops and foods which are framed in communications as being "novel foods" in terms of the existing Novel Food Regulation (EC) 258/97 or as stemming from "non-traditional breeding techniques" in terms of the recently proposed revisions to the Novel Food Regulation (see Commission proposal COM 2007 872 and associated co-decision procedure 2008/0002 COD).

A particular problem may occur when it becomes apparent to consumers that novel foods other than GM foods do not have to undergo environmental risk assessment. If consumers regard the biotechnologies involved in the development of such foods as potentially dangerous (which is likely, for example, for all processes such as mutation breeding that involve the use of ionising irradiation), communications that run counter to consumers' expectations may shake their confidence in what they previously regarded a trustworthy regulatory process.

Embeddedness into systems of general socio-political attitudes

Psychologically, attitude formation via a feature generalisation process such as the one suggested above would imply that a novel exemplar, together with the features of the prototype object, also inherits the evaluative associations to the prototype object and the evaluative associations to its features that, together, constitute the attitude towards the prototype object. In this respect, representation theories of attitude (e.g., (e.g., Lord & Leppe, 1999; Pratkanis, 1989; Sia et al., 1997; Smith & Sarate, 1992) are closely related to the consistency theories of attitude in terms of which the research presented here had initially been framed, in particular the original (Heider, 1946, 1958) and extended versions (Cartwright & Harary, 1956; Tesser, 1978) of balance theory.

Identical patterns of inter-attitudinal relations

These predictions were tested in Study 3, based on standardised survey data. Again, consumers' attitudes towards the two biotechnologies investigated here (gene technology and mutation breeding) turned out to be remarkably similar. Their correlation patterns with altogether eleven validation criteria were virtually identical: only a single significant difference could be found with respect to one out of the eleven general attitude and knowledge dimensions that had, based on previous research, been selected as the criteria representing the wider attitude system into which attitudes towards biotechnologies in food and agriculture are embedded (for reviews of previous research, see Bredahl, Grunert & Frewer, 1999; Costa-Font, Gil & Traill, 2008; Frewer, Lassen, Kettlitz, Scholderer, Beekman, & Berdal, 2004). Furthermore, the correlation between consumers' attitudes towards gene technology and mutation

breeding was so high (r = .72) as to suggest that consumers' attitudes towards these two biotechnologies have more in common than distinguishes them.

From a construct validity perspective, the research presented in Article 3 can be understood as a test of the question whether the two attitude constructs investigated in this thesis – attitude towards gene technology and attitude towards mutation breeding – occupy different positions in the relevant nomological network (Cronbach & Meehl, 1955). Based on the results obtained here, and backed up by the qualitative results obtained in Studies 1 and 2, the answer has to be a "not really", at least for the time being: at present, the position of the two constructs in the nomological network of other attitude and knowledge dimensions appears to be more or less identical.

Schematic reasoning processes

Analyses of the structural properties of the wider attitude system suggested that evaluations of novel food technologies are generated by a coherent evaluative schema (cf. Tesser, 1978). Food neophobia – the habitual avoidance of unfamiliar foods – appears to be the central variable in this schema, providing initial negative affect that is then transferred by means of propositional reasoning processes from broad and abstract attitude objects (such as technological progress in general) via contextual specifications into a particular socio-technical domain (industrial food production), to the prototype object dominating the category of biotechnologies in food and agriculture (gene technology). Social trust appears to be a by-product of this system, contextualising the negative

affect not into the world of objects but into the world of actors and institutions (regulators, manufacturers, food service operators).

Taken together, the system can be understood as an evaluative schema that enables an individual to generate heuristic judgments of unfamiliar technologies. Similar conclusions about the schematic properties of consumers' wider attitude systems were drawn in recent research by, for example, Scholderer and Finucane (2006) and Scholderer, Søndergaard and Grunert (submitted).

Most importantly, it appears that in the final processing step of the system, evaluative affect seemed to be transferred directly from the prototype object (gene technology) to the novel exemplar object (mutation breeding). It should be stressed that this interpretation was fully supported by the results of the structural equation analysis: the effects of all general attitude dimensions on attitude towards mutation breeding were completely mediated by attitude towards gene technology. These results add further evidence to the "prototype" interpretation outlined above. In a certain sense, it can therefore be said that consumers *derive* their evaluative judgment of a previously unfamiliar biotechnology such as mutation breeding from the similarity of that technology to the category prototype of all biotechnologies in food and agriculture, gene technology.

Attitude change

A pragmatic consequence of the derivative nature of consumers' attitudes towards mutation breeding was that, in Study 4, attitude change processes were only investigated with respect to the prototype object, gene technology, and not the object of the derivative attitude, mutation breeding.

However, previous studies that attempted to change consumer attitudes towards gene technology had only yielded meagre results. Based on the predictions of classical (Petty & Cacioppo, 1987) and modern (Gawronski & Bodenhausen, 2006) theories of attitude change, we had therefore originally expected that repeated exposure to communication materials would be necessary in order to achieve enough persuasive power to influence consumers' attitudes towards gene technology.

Ends justify means: the persuasive power of convincing applications

Much to our surprise, we did not observe the gradual and cumulative attitude change process in response to repeated exposures that we had expected. Instead, we obtained a positive attitude shift after the first exposure to positive information. The effect was strong (at a size of half a standard deviation) and remained stable over subsequent exposure periods. No systematic attitude change was observed in response to negative information. The effect was not moderated by the content of the information materials or the source to which they had been attributed. Mediation analyses showed that the attitude change effect operated largely through consumers' evaluations of the example product that had been featured in all information materials. The results suggested a three-step process:

- Step 1: Confrontation with positive materials led to a more positive evaluation of the trait that had been expressed in the crop plant (healthier starch composition, reducing the risk of metabolic syndrome and thereby the risk of diabetes, obesity, and cardiovascular disease).

- Step 2: A more positive evaluation of the trait led, in turn, to a more positive evaluation of the technical means by which this particular outcome had been achieved (genetic modification of potato plants).

- Step 3: Finally, a more positive evaluation of the technical means by which the particular outcome had been achieved in the example application led to more positive attitudes towards genetically modified crops in general.

Apparently, the attitude change process observed in the Study 4 followed an "ends-justify-means" rationale in which evaluations of the desirability of the outcome legitimised the use of gene technology as a means to achieve it. In the last step of the process, the legitimisation appeared to be generalised towards the application of gene technology in food and agriculture in general.

Taken together, the results suggest that convincing applications may be the cornerstone to change in the attitudes of consumers towards biotechnology in food and agriculture: applications with substantial consumer benefits do indeed have the power to persuade. However, these benefits have to be substantial enough to outweigh the "GM stigma", they must be communicable through the chosen medium, and they must be of immediate personal relevance to the consumers whose attitudes are at stake.

Consumer trust: consequence, not cause of attitudes

A secondary aim of Study 4 had been to investigate the role of trust as a potential alternative mediator of attitude change. Social judgment theory (Sherif & Hovland, 1965; Sherif, Sherif & Nebergall, 1965; Mussweiler, Rüter & Epstude, 2004) predicts that persuasive arguments and other

attitudinally relevant message properties – such as the trustworthiness of the source – will be evaluated relative to judgmental anchors. Typically, these anchors are set by consumers' prior attitudes, resulting in assimilation or contrast effects, depending on the perceived attitudinal distance between the source of the communication and the consumer himself or herself. Previous studies that investigated the changeability of consumer attitudes towards gene technology have indeed found such effects (e.g., Frewer, Howard & Shepherd, 1998; Frewer, Scholderer & Bredahl, 2003). In these studies, the degree to which a consumer trusted a source of information appeared to be a function of the degree to which the position attributed to that source confirmed the consumer's own prior attitude.

The results of Study 4 confirmed these effects. In addition to the classical conceptualisation of trust as perceived source credibility (Hovland & Weiss, 1951), a more recent conceptualisation was included in the mediation analyses, the dual trust and confidence model (Siegrist, Earle & Gutscher, 2003). However, in both cases, the respective dimensions of trust turned out to be by-products of consumers' attitudes towards gene technology, rather than causes or mediators of attitude change. As predicted by social judgment theory, trust in an information source was simply a function of the perceived attitudinal distance between the source and the consumer him- or herself.

In agreement with other evidence from the risk perception and communication literature, the results support an "associationist" view of trust where trust in the actors and institutions involved in the development and regulation of a technology is just a particular expression of a more general attitude towards the technology (see, for example, Eiser, Miles & Frewer, 2002; Frewer, Scholderer & Bredahl, 2003; Poortinga & Pidgeon,

2006). In practical terms, the results suggest that consumer trust does not lead to the acceptance of products, policies or technologies but will follow it if the products, policies or technologies are sound and their benefits to the consumer are well articulated.

Suggestions for future research

In the research presented here, interrelationships between consumer attitudes towards different biotechnologies were investigated in terms of just two technologies (gene technology and mutation breeding). Obviously, the first question that needs to be addressed in future research is whether, and to which extent, the findings can be generalised to other existing and emerging biotechnologies in food and agriculture (e.g., the cloning of animals, cisgenic modification of plant genomes, etc.). Taking the question a step further, one could also ask to which degree the results can be generalised to other technological fields such as the emerging field of nanotechnologies. At present, even the very concept of nanotechnology appears to be completely unfamiliar to a large majority of consumers, both in the United States and in Europe (see, for example, Baindridge, 2002; Cobb, 2005; Cobb & Macoubrie, 2003; Priest, 2006; Scheufele & Lewenstein, 2005). Should a dominant prototype technology emerge in the same way as gene technology did in the area of agrobiotechnologies, similar overgeneralization processes might occur as were observed in the research presented here.

The second question on which future research should concentrate is related to the strong attitude change effects observed in Study 4: precisely *what* makes an application of biotechnology in food and agriculture convincing enough to consumers to influence their general attitudes towards the

technology? The application featured in the communication materials used in Study 4 had been fictitious. At present, no genetically modified crop variety exists that could even remotely claim such substantial and broadly relevant health benefits as the ones that had been made up for the fictitious example used in the study.

At present, the application coming closest to such an ideal is "Golden Rice" (Potrykus, 2001). However, the health benefits of this particular application mainly apply to populations with serious malnutrition problems, i.e. where vitamin A deficiency-caused blindness is still a substantial risk. In the developed world, similar "killer applications" of gene technology are still lacking. The reality is usually much more prosaic, and the degree of uncertainty is considerable, in particular when the applications are at an early stage of development.

Limitations

The product examples used in the first two studies – a genetically modified potato with altered glycoalkaloid content and a mutation-bred rice line with lowered level of phytic acid – are not available on the market and have not yet been submitted for official approval according to the relevant EU legislation. At the time of writing, both products had been assessed in terms of their safety and nutritional properties (Poulsen, Kroghsbo, Schrøder et al., 2007; Poulsen, Schrøder, Wilcks et al., 2007; Knudsen & Poulsen, 2007; Langkilde, Schrøder, Stewart et al., 2008).

However, the results of these assessments were not fully conclusive. Therefore, questions about the "real" risks and benefits associated with these products cannot definitely be answered, or at least not yet. Of course,

such uncertainties are the rule rather than the exception when descriptions of *real* products are used as stimulus materials in research with consumers (such as in Studies 1 and 2), as opposed to fictional products (such as in Study 4). This is particularly the case with innovations that are at an early stage of development and have not yet passed regulatory approval.

During the benchmarking studies with experts that were conducted as part of the first two articles included in this thesis, some experts indicated that there may be beneficial or adverse effects that are unknown at present in terms of their very nature, but that this information may emerge at some point in the future when more data have accumulated. Including these considerations of uncertainty in the articles caused considerable debate among the journal reviewers: during the review process, the author was asked several times to elaborate on this and provide examples of these "unknowns" (note that, if there were such examples, they would not be unknowns) and also to provide probabilities of occurrence (despite the fact that it is not logically possible to provide a probability of an event that is unidentified in terms of its very nature).

It is interesting to note that even the critical social scientists that served as reviewers for the journals to which the articles had been submitted were evidently unwilling to grant technical experts the liberty to admit that essential uncertainties will always exist in risk assessment of real products. More important to them, it appeared, was the unambiguous suitability of the examples as stimulus materials for the studies. In contrast to that, no objections were raised by the reviewers about the artificially constructed product example in Study 4, even though it is patently unrealistic to assume that it will ever be possible to establish a causal link between the consumption of a single food (such as the fictitious potato used in the

communication materials in the study) and the reduction in the risk of such a complex disorder as metabolic syndrome and, following that, a reduction in the risk of diabetes, obesity, and cardiovascular disease.

Ethical issues

The research reported in this thesis had been conducted as part of two large research projects in which real applications were developed and/or assessed. In the context of such projects, it is often an implicit objective that the consumer studies conducted as part of the projects should identify strategies to reduce consumer scepticism towards the developed applications. To a certain degree, this was also the case in the projects under which the research presented here was conducted. However, in order not to bias the research a priori towards an artificially limited set of results, a thoroughly balanced perspective was employed in all using studies. Consumer perceptions of risk received the same attention as consumer perceptions of benefit (Studies 1 and 2). Negative attitudes received the same attention as positive attitudes (Studies 3 and 4). Negatively framed communication materials were used side by side with positively framed communication materials (Study 4). After completion of the studies, all participants were thoroughly debriefed according to generally accepted standards for ethics in social science research.

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Summary - English

This thesis explores consumers' attitude toward different applications of food biotechnology. Specifically, the thesis investigates the attitude structure and changeability in relation to two different applications of food biotechnologies being; gene technology and mutation breeding. Four articles were constructed in order to answer three research questions.

Research question 1

The first research question investigated the *content of the belief systems* related to consumer attitudes towards the two food biotechnologies and their respective applications. The content of the belief system was reported separately in two different articles using same methodology. The studies revealed that there is a large overlap between the belief-systems related to the two biotechnologies as the attributes that consumers related to the two biotechnologies were the same.

Research question 2

The second research question asked whether consumer attitudes towards different food biotechnologies are *embedded into a joint system of other attitudes* that causes commonalities between them, or whether their relationships to other attitudes differ. Again, consumers' attitudes towards the two food biotechnologies investigated in this thesis turned out to be remarkably similar. The correlation between consumers' attitudes towards the two food biotechnologies was so high (.72) as to suggest that the two attitudes have more in common than distinguishes them. An additional structural equation modelling analysis suggested that the relationship

between general attitude dimensions and attitude towards mutation breeding might be mediated by attitude towards gene technology. The result adds further evidence to the "prototype" interpretation, suggesting that consumers derive their evaluative judgment of a previously unfamiliar biotechnology such as mutation breeding from the similarity of that technology to the category prototype of all biotechnologies, gene technology.

Research question 3

The third research question asked whether *attitudes towards food biotechnologies can be changed by means of repeated exposure* to information. Contrary to the predictions, the hypothesised gradual and cumulative attitude change did not occur. Instead, a strong positive attitude shift was observed in consumers after their first exposure to positive information. Mediation analyses indicated that the attitude change effect operated through an "ends-justify means" process in which evaluations of the desirability of the outcome legitimised the use of gene technology as a means to achieve it. Taken together, applications with substantial consumer benefits have the power to persuade. However, these benefits have to be substantial enough to outweigh the "GM stigma", they must be communicable through the chosen medium, and they must be of immediate personal relevance to the consumers whose attitudes are at stake.

Summary - Danish

Denne afhandling undersøger forbrugeres holdning til to forskellige fødevarer bioteknologier, værende genteknologi og mutation breeding. Specielt, undersøges hvilke holdninger forbrugeren har til de to fødevare bioteknologier, hvordan holdningerne er struktureret samt om man kan ændre disse holdninger via information. Fire artikler er blevet udarbejdet for at besvare tre undersøgelsesspørgsmål.

Undersøgelsesspørgsmål 1

Det første undersøgelsesspørgsmål belyste "*indholdet af de overbevisninger*" som er relaterede til forbrugerens holdninger til de to fødevare bioteknologier. Undersøgelsen mundede ud i to artikler som anvendte samme fremgangsmåde og påviste, at forbrugerne relaterede mange af de samme attributter til hver af de to fødevare bioteknologier. Dette bevirker, at der er en stor overlap mellem de overbevisninger (system af overbevisninger) som forbrugeren har til henholdsvis genteknologi og mutation breeding.

Undersøgelsesspørgsmål 2

Det andet undersøgelsesspørgsmål belyste om forbrugerens holdninger til de to fødevare bioteknologier var *"en del af et fælles system af andre holdninger"*. Såfremt at bioteknologierne var en del af samme system ville forbrugerens holdning til bioteknologierne og relaterede holdninger være ens. Er de to fødevare bioteknologier ikke en del af et fælles system ville der være forskel på holdninger til fødevare bioteknologier og deres relaterede holdninger. Det viste sig igen, at holdningerne til de to fødevare bioteknologier er bemærkelsesværdige ens. Korrelationen mellem

holdninger til de to fødevare bioteknologier er så høj, at man må formode at forbrugeren ser dem som ens og ikke som to meget forskellige bioteknologier. En strukturel lignings models analyse viste at forholdet mellem generelle holdnings-dimensioner og holdningen til mutation breeding med stor sandsynlighed er mediated af holdninger til genteknologi. Dette resultat støtter "prototype" fortolkningen som foreslår, at forbrugerne vurderer en ukendt fødevare bioteknologi ud fra ligheden mellem denne bioteknologi og hvad man anser for at være prototypen for alle fødevare bioteknologier, nemlig genteknologi.

Undersøgelsesspørgsmål 3

Det tredje undersøgelsesspørgsmål belyste om *holdninger til fødevare bioteknologier kan ændres via multiple eksponeringer* med information. Modsat vores forudsigelser, viste undersøgelsen at flere eksponeringer ikke gav en gradvis og kumulativ ændring i holdning. I stedet blev der observeret en stærk positiv holdningsændring allerede efter første eksponering med positive informationer. En mediation analyse viste at holdningsændringen opererer igennem en "*enden helliger midlet*" proces idet en evaluering af det ønskede resultat legitimerer brugen af genteknologi som middel til at opnå dette resultat. Alt i alt, kan de fødevare bioteknologier som giver substantielle fordele for den enkelte forbruger ændre holdning. Disse fordele skal dog være så substantielle at de kan veje tungere end det "GM-stigma" som eksisterer, skal kunne kommunikeres igennem det valgte medie og skal have direkte personlig relevans for forbrugeren.