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Research review

Consumer acceptance of technology-based food innovations: Lessons for the future of nutrigenomics

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Abstract

Determinants of consumer adoption of innovations have been studied from different angles and from the perspectives of various disciplines. In the food area, the literature is dominated by a focus on consumer concern. This paper reviews previous research into acceptance of technology-based innovation from both inside and outside the food domain, extracts key learnings from this literature and integrates them into a new conceptual framework for consumer acceptance of technology-based food innovations. The framework distinguishes 'distal' and 'proximal' determinants of acceptance. Distal factors (characteristics of the innovation, the consumer and the social system) influence consumers' intention to accept an innovation through proximal factors (perceived cost/benefit considerations, perceptions of risk and uncertainty, social norm and perceived behavioural control). The framework's application as a tool to anticipate consumer reaction to future innovations is illustrated for an actual technology-based innovation in food science, nutrigenomics (the interaction between nutrition and human genetics).

Keywords: Food; Innovation; Technology; Adoption; Consumer acceptance; Nutrigenomics

Contents

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Introduction

Scientific and technological innovations have contributed greatly to various domains of man's quality of life, delivering both benefits to the individual consumer (e.g., personal computers) and society at large (e.g., food preservation). Many of these technology-based innovations (e.g., information technology) have been incorporated into daily life with high levels of consumer acceptance whereas others have met with substantial resistance (e.g., nuclear energy). Both within and external to the food domain, this has stimulated research to understand consumer acceptance of technology-based innovations. Such research is most prominent in the areas of information technology (Legris, Ingham, & Collerette, 2003), high-technology products (Ziamou & Ratneshwar, 2002) and service delivery (Meuter, Bitner, Ostrom, & Brown, 2005). Within the food area a similar picture emerges, with some recent technology-based innovations having been adopted easily and others essentially rejected by consumers (Cardello, 2003). Prominent examples of the latter are genetically modified foods (GMFs) in Europe (Gaskell et al., 2000) and food irradiation (Henson, 1995).

Consumer acceptance of technologies and technology-based innovations in food bears many similarities with that in other fields. However, they differ in at least one important respect, namely that novel foods are actually ingested by the consumer (Rozin, 1999). This may explain why consumer concerns and risk perceptions have received considerable attention in the literature on consumer acceptance of food innovations (Cardello, 2003; Miles & Frewer, 2001). There is, however, a need to understand consumer acceptance of food innovations in a broader context. For the specific area of food, learnings may be extracted from other areas where consumer acceptance has been studied extensively, such as information technology.

The aim of the present paper is to enrich the literature on consumer acceptance of technology-based food innovations with relevant insights from innovation research in other fields. We will selectively integrate the relevant insights that have not received due attention in the food area, into a more comprehensive conceptual framework for consumer acceptance of technology-based food innovations. Such broader insight is important not only for better understanding of consumer uptake of existing technologies. It can also provide a useful framework for the anticipation of future consumer acceptance of emerging food technologies, and provide a basis from which to identify potential barriers to consumer acceptance. We illustrate this application in the context of nutrigenomics.

Food technologies and innovations

Carayannis, Gonzalez, and Wetter (2003) distinguish between technology and innovation. Technology is the whole complex of knowledge, skills and equipment, often science-based, necessary to produce a product or service. These new products or services—applications available for the user—are considered to be *innovations.* For example, gene technology is the technology from which GMFs emerge as the innovation, and similarly for food irradiation and irradiated foods. Although it is useful to make a distinction between the two concepts, they cannot be seen separately from each other. Lam and Parasuraman (2005) operationalise technology acceptance as the initial acquisition of a technology-based product or subscription to a technology-based service. This implies that much of the insight in technology acceptance is derived from consumer acceptance of its applications (innovations), although some studies focus on consumer acceptance of technologies *per se*. We appreciate that technologies and innovations emerging from them are not always strictly separable, neither in definition, in daily use of the terminology nor in research applications (see, for example, Bredahl, 2001). The scope of this paper is consumer acceptance of technology-based innovations in particular. For reasons of conciseness, from this point onwards we will use the term "innovation" to indicate this specific type of innovations.

In the area of food and nutrition, various technological applications, which have resulted in novel foods, have emerged in the past decades. Many of these were related to prolonging the shelf life of foods and enhancing their safety, e.g., pasteurisation, and novel food packaging. A food preservation technology that has failed to reach widespread adoption is food irradiation. Despite the fact that the scientific community recognised food irradiation as a safe and effective process, significant consumer resistance has inhibited the application of the technology (Henson, 1995). In the 1990s, the genetic modification of foods also met with great consumer scepticism (Bredahl, 2001; Sparks, Shepherd, & Frewer, 1994). In recent years, many of the new food technologies and food innovations have been targeted at the promotion of good health. Fortification and restoration of foods were used as methods to add nutrients to food products that did not contain them originally or had lost them in the manufacturing process. Functional foods constitute a range of novel foods designed to deliver benefits beyond nutritional value to the person consuming them (Frewer, Scholderer, & Lambert, 2003b), and the so-called nutraceuticals provide medical or health benefits by maintaining and modifying bodily functions (Hardy, 2000).

These previous developments have all entered the marketplace at time of writing. Some are widely used and others are less successful from a consumer acceptance perspective.

Nutrigenomics is an emerging technology in the health maintenance and promotion area. Its area of innovation is represented by personalised food products and services. Nutrigenomics is a sub-area within the field of genomics, which is a relatively new term indicating research into the functioning of the genome. Nutrigenomics has been defined as 'understanding how nutrition influences metabolism and maintenance of the internal equilibrium in the body, how this regulation is disturbed in the early phase of a diet-related disease, and to what extent the individual genotype contributes to such diseases' (Müller & Kersten, 2003). In other words, the technology of nutrigenomics focuses on developing an improved understanding of the relationship between human nutrition and human genetics in order to maintain and promote health and prevent the occurrence of disease. The innovative feature of nutrigenomics in nutritional sciences is that it is based on knowledge of the individual's genetic constitution. This information is used to explain the effect of specific nutrients on human physiology and even idiosyncratic responses to food intake.[1] Besides advancing the fundamental understanding of diet–disease relationships, nutrigenomics may have another important spin-off. It could provide opportunities for the development of food products or dietary advice tailored to the nutritional needs of specific groups of consumers, or even individuals. Some authors have optimistically argued that these so called "personalised foods" will shift the food market from a technology push into a consumer pull system, where innovation development is determined by the demand side of the market. In that situation, the consumer's preference for optimal health is a major driver for food choice, and as a consequence for how foods are produced (German, Yeretzian, & Watzke, 2004).

Despite its promise, nutrigenomics may also raise consumer concerns regarding the impact of human genetics on the integrity of nature, privacy and control over sensitive information. In a Canadian research project, genomics research related to food evoked strong associations with genetic modification of crops and foods, e.g., Golden Rice (Burgess, 2003). Such associations are inevitable and deserve substantial attention and a careful management of expectations, concerns and promises of the potential deliverables of nutrigenomics.

The inherent newness of the emerging science and the likely ambivalence in consumer attitudes towards nutrigenomics make it a particularly appropriate case to illustrate the framework we develop as a conceptual tool for anticipating future consumer acceptance. The framework will be based on a review of studies addressing consumer acceptance of technology and innovations in the food area including GMFs (e.g., Frewer, 2003; Saba & Vassallo, 2002; Siegrist, 2000), and functional foods (e.g., Childs & Poryzees, 1998; Frewer et al., 2003b; Schmidt, 2000) and extend beyond these to include relevant findings from other domains (such as information technology).

In summary, the aim of this paper is twofold. First, we develop a comprehensive conceptual framework for consumer acceptance of food innovations, based on an integration of food-related literature enriched with relevant findings from other domains. Second, the newly developed conceptual framework is illustrated as a structuring tool to identify the potential critical success and failure factors for the emerging science of nutrigenomics and personalised nutrition.

Conceptual framework development

Consumer acceptance of innovations has been studied from various disciplines and theoretical perspectives. A rough distinction can be made between research at the (macro-) level of society, for example, by sociologists and economists, and at the (micro-) level of individual consumer behaviours, for example, by psychologists and researchers of perceived risk.

Perceived cost/ benefit considerations

From a traditional *economic* point of view, the acceptance of technological developments in society has been approached as an economic *cost/benefit analysis*, where a trade-off is made between societal benefits and economic costs associated with a certain technology or activity (Starr, 1969). For example, in the economic cost approach of Starr, risk was measured as the probability of fatalities per hour of exposure of the individual to the hazard under consideration, and the benefits were represented in terms of the monetary value of the average annual benefit *per* person involved. Obtaining maximum social benefit at minimum social cost would be the ultimate goal of this trade-off. Although an elaborate discussion of this economic research area is beyond the scope of this review, the main contribution lies in its focus on the trade-off between costs and benefits inherent in the innovation as a determinant of consumer acceptance of innovations.

The trade-off between individual costs and benefits of an innovation is also a critical element in Rogers' diffusion of innovation theory (Rogers, 2003) and attitudinal models of innovation acceptance, where this trade-off may contribute to the relevant attitudes that consumers hold to the innovation, and which may determine acceptance or rejection (Frewer, 2003). Often, such personal considerations of cost benefit trade-offs are the more important determinant of actual behaviour (Klandermans, 1992).

[1] Note that nutrigenomics does not involve the genetic manipulation of food products. This is the field of gene technology that should be distinguished from nutrigenomics.

Diffusion of innovations

The study of diffusion of innovations has a long history in *sociology* and can be largely traced back to an early study on the diffusion of hybrid seed corn among Iowa farmers (Ryan & Gross, 1943). This study revealed that the rate of adoption of the agricultural innovation followed an S-shaped curve when plotted against time. Innovations primarily differ in the slope of the curve: the rate at which larger groups of consumers begin to accept the innovation. Rogers (1995, 2003) has made a major contribution in popularising these original findings and extending on them to develop a more comprehensive theory on diffusion of innovations, which has been a fruitful source for a wide spectrum of applications (see Tornatzky and Klein (1982) for a meta-analysis).

Rogers' theory defines *diffusion* as the process by which an innovation disseminates over time among the members of a social system (Rogers, 2003, p. 5). His theory builds on four cornerstones, namely the identification of adopter categories, communication, the individual innovation-decision process and the identification of important characteristics of an innovation. Individuals can meaningfully be classified in terms of the relative speed at which they adopt innovations. Following a standard normal distribution curve, the *adopter categories* are defined as (1) innovators, (2) early adopters, (3) early majority, (4) late majority, and (5) laggards (Rogers, 2003, p. 22). *Communication* is a crucial process through which individuals become aware and knowledgeable about different innovations. The *innovation-decision process* is the mental process through which an individual passes from (1) initial knowledge of an innovation to (2) forming an attitude toward the innovation, to (3) a decision to adopt or reject it, to (4) implementation of the new idea, and to (5) confirmation of this decision. In this process the individual obtains information in order to gradually decrease uncertainty about the expected consequences of the innovation. Individuals vary in the time it takes them to go through the different stages. For the purpose of anticipating consumer reactions to innovations, a particularly relevant finding from Rogers' research is the identification of five *characteristics of innovations* that help explain the differences in adoption rates. These are:

(1) *Relative advantage*: i.e. delivering a certain advantage over preceding technologies or methods, be it in terms of economics, convenience, social prestige or satisfaction.
(2) *Compatibility*: or fitting in with existing values, past experiences and needs of potential adopters.
(3) *Complexity*: an innovations' ease of use will lead to rapid adoption.
(4) *Trialability*: potential adopters want the availability of experimenting with an innovation on a limited basis before adopting.
(5) *Observability*: the results of an innovation should be easily observed and communicated to others.

To summarise, Rogers' theory states that the likelihood of a particular individual adopting a specific innovation is a function of characteristics of the innovation itself, characteristics of the potential adoptee, and the information, which accompanies the innovation (both in terms of *content* and the *amount* of information provided). Rogers' model is defined at a fairly general level, which makes it widely applicable, but does not allow it to provide very detailed information in specific cases of innovations. To our knowledge it has not been extensively applied in the area of acceptance of food technologies and innovations.

Attitudinal models

In *psychology*, the attitudinal models of Fishbein and Ajzen have been widely applied to explain adoption of innovations. As an extension of the Theory of Reasoned Action (TRA), the Theory of Planned Behaviour specifies Perceived Behavioural Control (whether the person thinks he or she can actually perform the behaviour) as a determinant of behaviour and behavioural intention, together with social norm (i.e. whether significant others are likely to endorse the use of the innovation or activity) and attitude (i.e. the extent to which an individual is positive about engaging in the behaviour under consideration) (Ajzen, 1991). Attitude models have found wide application in explaining consumer adoption and diffusion of information systems (particularly in the work place). Building on Rogers and as an extension of the TRA, Davis (1989) developed the popular Technology Acceptance Model (TAM). This model replaces many of TRA's attitude measures with two technology acceptance measures: *ease of use*, and *usefulness*, which represent Rogers' dimensions of complexity and relative advantage respectively and have been confirmed in many studies (see Lee, Kozar, & Larsen, 2003).

Attempts have been made to combine and integrate different theories of consumer acceptance of innovations to enhance predictive ability (Lee et al., 2003). For example, from an integration of TAM and seven competing models, Venkatesh, Morris, Davis, and Davis (2003) proposed the Unified Theory of Acceptance and Use of Technology (UTAUT) with superior predictive ability. UTAUT includes four key determinants (performance expectancy, effort expectancy, social influence and facilitating conditions) and up to four moderators of key relationships (gender, age, experience and voluntariness of use). This work shows that integration of existing models can lead to a better understanding of consumer behaviour in the context of adoption of innovations.

Perception of risk and uncertainty

Perceptions of risk and uncertainty have been shown to play an important role in the acceptance of food innovations (Cardello, 2003; Frewer, Miles, & Marsh, 2002). The widespread research attention for understanding consumer concerns about new technologies (e.g., Cardello, 2003) is not surprising given the intimate relationship consumers have with foods which are actually ingested into the human system (Rozin, 1999). In addition, food technologies typically possess many of the risk characteristics that engender greatest concern among consumers (Cardello, 2003). Among these are whether new technologies are perceived to be largely involuntary, unobservable, out of control by the consumer and may have unknown, delayed and potentially fatal health effects (in the eyes of some consumers) (Slovic, 1987). Indeed, food technologies are often associated with so-called credence qualities (Darby & Karni, 1973), the costs and benefits of which cannot be unambiguously verified by the individual consumer from personal experience, such as safety, sustainability, health, and naturalness. These credence qualities are particularly prone to generate perceived risk and uncertainty, particularly when information is inconsistent and trust in authorities is low. Trust in risk regulators and managers plays an important role in public risk perceptions and has been found to be hard to acquire and easy to lose (Frewer & Salter, 2002; Slovic, 1999). Psychometric studies into consumer associations with a broad range of hazards (e.g., Fischhoff, Slovic, Lichtenstein, Read, & Combs, 1978; Sparks & Shepherd, 1994) reveal that consumer concerns with new technologies centre around the dimensions of *dreadedness* and *the extent to which a hazard is judged to be unknown,* the former being the most important. The higher a particular hazard rates on these two dimensions, the higher its perceived risk, the more people want to see its current risk reduced, and the more they want to see strict regulation to reduce the risk (Slovic, 1987). A study by Miles and Frewer (2001) confirms that consumer concerns regarding food hazards are important determinants of acceptance, and some concerns (for example, health concern) were common to all hazards included in the study.

Consumers perceive a hazard as riskier when they also perceive that the consequences of the hazard are highly unknown to scientific experts (e.g., Slovic, 1987). Scientific uncertainty about the potential advantages and disadvantages of a technological innovation, and the way these are being communicated to the public, can have a major impact on its consumer acceptance (see, for example, Frewer, Howard, & Shepherd, 1998), particularly under circumstances whereby the public perceive that the uncertainty is being "hidden" by regulatory institutions (van Kleef et al., 2006).

Uncertainty exists when details of situations are ambiguous, complex, unpredictable, or probabilistic; when information is unavailable or inconsistent; and when people feel insecure about their own knowledge or the state of knowledge in general. It can trigger uncertainty management strategies on the part of the consumer, such as seeking or avoiding information to manipulate uncertainty in the desired direction (Brashers, 2001). The degree of uncertainty basically determines whether a negative aspect of a technological innovation is categorised as a cost or a risk.

Altogether, much work has been undertaken to model consumer adoption and societal diffusion of innovations in general and technology-based food innovations in particular. Together they incorporate many aspects of the consumer adoption process from awareness of the innovation to actual adoption. However, a comprehensive and systematic overview, which includes all potentially influential determinants is lacking. To fill this gap, we developed a conceptual framework for consumer acceptance of food innovations (Fig. 1) that reflects state of the art thinking in food research augmented with relevant findings from outside the food domain.

In our framework, consumers' actual adoption of innovation in the food area is ultimately determined by their intention to use it. The framework distinguishes between proximal and distal determinants of consumer adoptions. At the proximal level, adoption (intention) is determined by (1) perceived costs and benefits, (2)

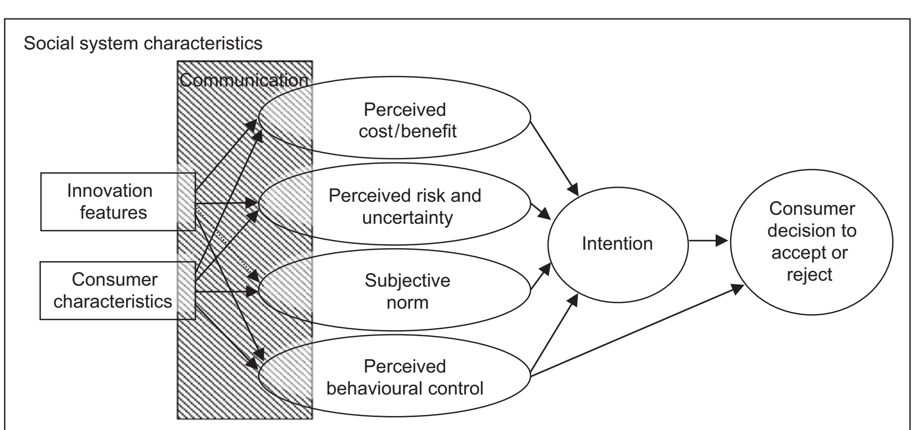

Fig. 1. Conceptual framework for research on acceptance of technology-based food innovation.

perceived risk and uncertainty, (3) subjective norm, and (4) perceived behavioural control. However, these perceptions are affected by a set of more distal determinants, namely (a) features of the innovation, (b) consumer characteristics, and (c) characteristics of the social system of which the consumer is part. Whereas innovation and consumer characteristics hold a direct relationship with perceptions of the proximal determinants, characteristics of the social system affect the framework more generically (see Fig. 1).[2] Communication is represented in our framework as an important means linking innovation features to consumer perceptions. We appreciate that this communication may need to be adjusted depending on the characteristics of the consumer (segment) at which the innovation is targeted.

Our conceptual framework integrates various elements from the theories we have already discussed regarding consumer acceptance of food technologies and innovations. The framework utilises the attitude model as its basic structure, but extends it to include perceptions of risk and uncertainty. The attitude construct is more implicitly defined in terms of perceived costs and benefits, which includes the rational cost benefit considerations suggested in the economic literature. Rogers' innovation characteristics enter the framework at various places.[3] Relative advantage, compatibility, and complexity primarily relate to perceived cost-benefit, whereas trialability relates more strongly to perceived behavioural control. Observability relates more to social visibility, and hence the subjective norm dimension of the framework. Several studies (e.g., Grunert, Bech-Larsen, Lähteenmäki, Ueland, & Åström, 2004; Grunert, Bredahl, & Scholderer, 2003; e.g., Prislin, Wood, & Pool, 1998) have revealed that consumer attitudes and intentions toward specific objects can also be shaped by more general attitudes. These general attitudes held by consumers, together with their value structure and lifestyle factors, are contained in the framework as more enduring consumer characteristics, which may shape their intentions through the proximal determinants in our model.

In summary, the main lines of thinking on consumer acceptance of food technology and the innovations emerging from it are integrated into this conceptual framework, which distinguishes between proximal and distal determinants of acceptance and recognises the important role of communication in linking distal to proximal determinants. In the following sections, we will review previous research on consumer acceptance of food technologies and food innovations against our framework and augment this with relevant findings from outside the food domain. Analysis of these studies is a complex task, because previous studies vary greatly in the abstraction level of the determinants that are being addressed. Also, across these studies we found almost as many measures of acceptance as there are researchers. Table 1 provides an overview of the studies (ordered alphabetically by first author) that are being reviewed in terms of basic characteristics of the study and how they fit into the proposed framework (Fig. 1). The studies included in the review are selected on the criterion that they have relevant terms in keywords, title or abstract (e.g., consumer, acceptance, rejection, perception, risk, innovation, technology, food), and are published in leading journals (e.g., Journal of Marketing Research, Journal of Applied Social Psychology, Journal of Consumer Policy, Appetite, Food Quality and Preference, Trends in Food Science and Technology, Risk Analysis). Below we will discuss these studies in more detail in relation to our conceptual framework.

[2]Note that empirically, social system characteristics play a unique role as, compared to characteristics of the innovation and the consumer, they cannot easily be manipulated as an independent variable in empirical research.

[3]Note that in Rogers' model no strict distinction is made between objective characteristics of the innovation (features in our model) and consumer perception thereof (proximal variables in our model). Studies that focus on technology features, rather than consumer interpretations, will be classified in the technology feature part of our framework.

Previous empirical research into proximal determinants

The core of our framework is constituted by the four proximal constructs that influence consumers' attitude towards an innovation. We will use the structure of our conceptual framework for discussing these factors in the following section.

Perceived cost/benefit considerations

Benefit perceptions were reported as a determinant of consumer acceptance of innovations in the majority of reviewed literature. Of the 27 studies that identified perceived benefit as an influential factor, nine studies report an effect on actual behaviour, 10 on behavioural intention and another eight on attitude or related evaluative constructs. Actual adoption behaviour appears more often as the acceptance measure in high-technology research contexts such as information technology (Davis, 1989), where it is seemingly easier to explore adoption in real usage contexts than in food-related areas.

In cost-benefit-related determinants a distinction can be made between the benefits for the individual consumers, such as health benefits (Deliza, Rosenthal, & Silva, 2003; Magnusson & Koivisto-Hursti, 2002; Urala & Lähteenmäki, 2004), and benefits to society more broadly such as environmental benefits (Magnusson & Koivisto-Hursti, 2002; Titchener & Sapp, 2002). In addition, in some studies benefits are measured as a summary construct, e.g., by asking respondents: "Do you think this innovation is beneficial?" (Tanaka, 2004), while in most other studies benefits are measured at a more specific level such as in terms of sensory benefits (Lähteenmäki et al., 2002), or personal relevance (Frewer, Howard, Hedderley, & Shepherd, 1999). As to the type of costs and benefits studied in literature, several clusters can be identified; those related to elements of innovation usage, to sensory aspects, to health, to the environment, and

Table 1
Overview of the reviewed studies

Reference	Field of study	Distal determinants			Communication[a]	Proximal determinants				Acceptance measure
		IF	CC	SSC		PC/B[b]	PRU[c]	SN	PBC	
Bogue, Coleman, and Sorenson (2005)	Health-enhancing foods		×			B				Dietary behaviour
Bouyer, Bagdassarian, Chaabanne, and Mullet (2001)	Broad range of hazards		×				G,J			*Risk perception*
Cardello (2003)	Food processing technologies		×		2					(Expected) product liking
Cestre and Darmon (1998)	Diffusion of wide range of new product	×	×							Consumer preference
Childs and Poryzees (1998)	Functional foods	×				B				Purchase interest
Choo et al. (2004)	New processed food products in India		×					×		Intention to buy; Actual purchase behaviour; Attitude
Costa et al. (2000)	GMF (vegetable oils)		×							Purchase intention
Cox et al. (2004)	Functional foods, GM and dietary supplements								×	Intentions to consume functional foods
Dabholkar and Bagozzi (2002)	Technology-based self-service					C			×	Intention
Dahlberg et al. (2003)	Mobile payment					C	K			Adoption
Davis (1989)	Information technology					C				Usage
Deliza et al. (1999)	GMF (vegetable oils)	×								Purchase intention
Deliza et al. (2003)	Non-conventional food-processing technology (high pressure)	×			2	B	H			Intention to purchase
Eiser et al. (2002)	Food technologies (GM, irradiation, additives, pesticides)						G,K			Acceptance
Fam et al. (2004)	Controversial products			×						Offensiveness
Finucane et al. (2000)	Health and safety risks		×				G			*Risk perception*
Florkowski et al. (1998)	New food production technologies		×				G			Support of technology
Fox et al. (2002)	Food irradiation				2					Willingness-to-pay
Frewer et al. (1997)	Food-processing technologies (cheese)	×				A,E,F				Purchase likelihood
Frewer et al. (1998)	GMF		×		4					Attitude
Frewer et al. (1999)	GMF				1,2					Attitude
Frewer et al. (2002)	GMF				4	A	G,K			*Risk/benefit perception*
Frewer et al. (2003a)	Food risks (from expert point of view)				4					Public distrust in science
Greer and Murtaza (2003)	Web personalisation					C			×	Acceptance
Griffin and Dunwoody (2000)	Lead in drinking water				2					Preventive behaviour adoption
Grunert et al. 2003)	GMF		×							Attitude
Grunert et al. (2004)	GMF		×							Attitude → Purchase intention
Honkanen and Verplanken (2004)	GMF		×							Attitude; Intention to buy
Karahanna and Straub (1999)	E-mail			×		C		×		System use
Kwon and Chidambaram (2000)	Cellular telephones		×			C		×		Use
Lähteenmäki et al. (2002)	GMF (cheese)		×			D				Attitude → Intention to buy
Laros and Steenkamp (2004)	GMF				3		J			Attitude
Loureiro and Bugbee (2005)	GMF (tomato)	×	×			A				Willingness to pay
Magnusson and Koivisto-Hursti (2002)	GMF		×			B,E				Willingness to purchase
Moreau et al. (2001)	Cameras and cars	×	×			A				Adoption
Palmer (2003)	Health and technological risks		×				G			*Risk perception*
Rimal et al. (2004)	Irradiation (beef)	×	×		2					Purchase intentions; Actual purchase

Table 1 (*continued*)

Reference	Field of study	Distal determinants			Communication[a]	Proximal determinants				Acceptance measure
		IF	CC	SSC		PC/B[b]	PRU[c]	SN	PBC	
Saba and Vassallo (2002)	GMF (tomato)		×			A		×	×	Intention to eat
Savadori et al. (2004)	Biotechnology in food and medicine	×	×			A	G			*Risk perception*
Scholderer and Frewer (2003)	GMF				2	A				Attitude
Siegrist (1998)	Gene technology		×							Attitude
Siegrist (2000)	Gene technology		×			A	G,K			Consumer acceptance
Siegrist et al. (2000)	Several risks			×		A	G			*Risk/benefit perception*
Stolt et al. (2002)	Neonatal screening		×				I			Attitude
Tanaka (2004a)	Gene-recombinant technology		×			A	G			Attitude
Tanaka (2004b)	Nuclear power	×				A	G			Attitude
Tenbült et al. (2005)	GMF					D				Acceptance
Titchener and Sapp (2002)	Biotech foods					F	H,K			Intent and willing to eat
Townsend and Campbell (2004)	GMF (apple)		×				G,J			Willingness to purchase
Tuorila et al. (2001)	Unfamiliar foods		×							Willingness to try
Urala and Lähteenmäki (2004)	Functional foods		×		3	C				Willingness to use
Verdurme and Viaene (2001)	GMF		×			A	G,K			Attitude
Ziamou and Ratneshwar (2002)	High technology products				2		G			Adoption intention
Ziamou (2002)	Computer/ telecommunication						G			Adoption intention

[a]Sub-classification of communication: 1 = source, 2 = information, 3 = consumer interest/confidence, 4 = public discussion.
[b]Sub-classification of perceived cost/benefit: A = C/B not specified, B = health-related C/B, C = usage-related C/B, D = sensory C/B, E = environmental C/B, F = production C/B.
[c]Sub-classification of perceived risk and uncertainty: G = various types of risk, H = safety, I = concerns, J = feelings, K = trust.

to production. The sub-classification of the construct is represented in Table 1.

Outside the food domain, costs and benefits are often expressed in terms of Rogers' (2003) innovation characteristics usefulness (relative advantage) (Dahlberg, Mallat, & Öörni, 2003; Davis, 1989; Karahanna & Straub, 1999; Kwon & Chidambaram, 2000), compatibility (Greer & Murtaza, 2003), ease of use (complexity) (Dabholkar & Bagozzi, 2002; Dahlberg et al., 2003; Davis, 1989; Greer & Murtaza, 2003; Karahanna & Straub, 1999; Kwon & Chidambaram, 2000), and trialability (Greer & Murtaza, 2003), with ease of use and usefulness consistently reported as the strongest determinants of acceptance (Tornatzky & Klein, 1982).

Sensory attributes, especially appearance and taste, have always been important in the evaluations of food products (Grunert et al., 2003) and that is no different for technological innovations in food (Cardello, 2003). Several studies include sensory costs and benefits in their analysis of consumer acceptance of food innovations (Deliza et al., 2003; Rimal, McWatters, Hashim, & Fletcher, 2004). Lähteenmäki et al. (2002) showed that perceptions of the sensory qualities of GM cheeses would improve consumers' intentions to buy GM cheese. Consumer expectations of product quality in terms of sensory aspects and process characteristics are essential for new product success (Grunert, 2005). Expectations also play an important role in cost/benefit considerations regarding credence qualities delivery by the innovation such as the belief that food innovations would have disease-preventing ability, which was found to positively influence purchase interest (Childs & Poryzees, 1998).

Perceived reward from using functional foods, and perceived necessity for functional foods, were benefits found to predict willingness to use them by Urala and Lähteenmäki (2004). Over time, these beliefs may be stored in pre-existing overall evaluations that may affect future evaluations of specific innovations, as in the case of GM foods (e.g., Scholderer & Frewer, 2003).

In sum, there is considerable support from both food and non-food studies that perceived costs and benefits are a major determinant of consumer acceptance of food technology and innovations arising from it. Individual benefits, which have been more frequently studied in previous research, include usage- and health-related benefits. Among the costs and benefits at the societal level are included production benefits (e.g., increased food production), and necessity for society (e.g., by facilitating a healthy lifestyle). It is important to note that the perceptions of the consumer are not necessarily identical to the technical benefits and costs of an innovation as defined by its features.

Perceived risk and uncertainty

Risk and uncertainty appear in many published studies, which is not surprising (Cardello, 2003) as the actual qualities of innovations, and food innovations in particular, are often difficult or even impossible to estimate by consumers as they are either invisible, uncertain or only materialise in the long term. Therefore, consumer perceptions of risk and uncertainty associated with innovations play an important role for acceptance, especially in the context of life sciences. Interestingly, interactions between cost/benefit perceptions and risk perception can and do occur. For example, potential harm, potential benefit and risk perception were found to be interrelated in the context of several applications of biotechnology (Savadori et al., 2004).

Eleven out of 19 of the risk-related studies we reviewed measured risk as a summary construct and hence at a fairly general level. For example, Finucane, Slovic, Mertz, Flynn, and Satterfield (2000), used a four-category scale to measure the level of perceived risk of various activities and technologies. Others (e.g., Verdurme & Viaene, 2001) further differentiate between specified types of risk such as health and environmental risk perceptions. Studies outside the food domain frequently include perception of performance uncertainty (i.e. whether the innovation works as intended) as a determinant which was found to negatively affect consumers' intention to adopt high-technology products (Ziamou & Ratneshwar, 2002) and telecommunications (Ziamou, 2002).

Other studies focus on perceived safety for current human health or for the environment (Deliza et al., 2003; Titchener & Sapp, 2002), or to safety consequences for the future (Townsend & Campbell, 2004). Various consumer concerns, for example, those related to storage of sensitive information, or to the right to be informed about research results (Stolt, Liss, Svensson, & Ludvigsson, 2002) also influence consumer acceptance.

Feelings as a result of innovations have also been subject of study. Anxiety, for example, was shown to positively affect perceived risk across a broad range of hazards (Bouyer et al., 2001). Laros and Steenkamp (2004) investigated the role of fear in the context of GMF. Consumers in their study felt more fear for GMF than for other types of food, more specifically functional foods, organic foods and regular foods. Feelings of dread about GM technology in food production reduced the willingness to purchase GM apples (Townsend & Campbell, 2004).

Another group of studies categorised under risk and uncertainty deals with the concept of trust. Trust in public health officials and scientists (Titchener & Sapp, 2002), in regulatory institutions (Frewer et al., 2002) and in food producers (Verdurme & Viaene, 2001) is beneficial for consumer acceptance of innovations, mostly studied within the field of biotech-foods. It has also been found that the acceptance of several other food technologies (GMF, irradiation, additives and pesticides) increased with higher levels of consumer trust (Eiser, Miles, & Frewer, 2002). Outside the food domain, it was found that an individual's disposition to trust (i.e. whether a person is inclined to have trust in general) indirectly increased adoption of mobile payment (Dahlberg et al., 2003). A general disposition to trust is likely to influence many processes related to acceptance of innovations, also within the food domain.

In sum, several previous studies support the role of risk and uncertainty as a determinant of consumer acceptance of food innovations. The construct contains multiple aspects, namely safety issues, consumer concerns, emotions, and trust. Trust plays an important role in consumer acceptance as it reduces the perceptions of uncertainty and may reduce perceived risk.

Perceived behavioural control and subjective norm

Perceived behavioural control and subjective norm also affect consumer acceptance or rejection of innovations (e.g., Cook, Kerr, & Moore, 2002). Self-efficacy is a central concept in relation to perceived behavioural control, supported by research in the field of functional foods (Cox, Koster, & Russell, 2004) and technology-based self-service (Dabholkar & Bagozzi, 2002). An interesting study in the field of GMF found that perceived behavioural control had a negative influence on the intention to eat a GM tomato, and the attitude of relevant others had a positive relation with this intention (Saba & Vassallo, 2002). A study in India showed that the subjective norm was particularly important to people's attitude towards new processed foods in this culture (Choo, Chung, & Pysarchik, 2004).

Perceived behavioural control and social norm have not received much attention in the literature on consumer acceptance of food technology and innovations. Outside the food domain, in the area of web personalisation, perceived trialability was found to have a positive effect on acceptance (Greer & Murtaza, 2003). Social pressure—the extent to which a person believes he should use the innovation for obtaining a higher social status—was found to mediate the relationship between age and the use of cellular telephones (Kwon & Chidambaram, 2000), with older consumers experiencing more social pressure to use cell-phones. It can be expected that pressure from the social environment will exert its influence in other cases as well. Outside of the food domain, adoption of an innovation in peer groups had a positive relationship with perceived usefulness. The higher the social presence of e-mail, the more users would find it appropriate for a wide range of communication tasks. Furthermore, the degree of social influence exerted by supervisors (i.e. the use of the innovation by the boss) appeared to predict perceptions of usefulness of an e-mail system, and thereby system use (Karahanna & Straub, 1999). We believe that the degree of social influence is also relevant in the food context, as eating is, by its very nature, a social activity.

In sum, perceived behavioural control and subjective norm have received only limited attention in studies on consumer acceptance of food technology and innovations. Research on food acceptance in general and innovation acceptance research in non-food domains, confirms that this may be an important proximal determinant but this has yet to be verified through extensive empirical research on consumer acceptance of food innovations.

Previous empirical research into distal determinants

Distal determinants of consumer adoption of innovations are easy to measure, but tend to have a low explanatory power as their effects are mediated through more abstract consumer perceptions. Our framework distinguishes between features of the innovation to be adopted (e.g., price), of the subjects potentially adopting it (e.g., age), and of the social system in which the innovation is introduced (e.g., collectivistic, as opposed to individualistic, culture).

Innovation features

Ten papers found innovation features to have an influence on measures of acceptance, mostly behavioural intention. At the lowest level of abstraction are determinants like price (Cestre & Darmon, 1998; Deliza, Rosenthal, Hedderley, MacFie, & Frewer, 1999; Deliza et al., 2003), complexity (Cestre & Darmon, 1998), convenience-related features, taste properties (Deliza et al., 2003), and physical appearance (Rimal et al., 2004), all identified in the area of food. In the context of foods that help prevent disease, Childs and Poryzees (1998) found that both delivery method (natural foods), and naming of the product (user-friendly name), had a positive influence on consumer belief in the disease-preventing properties of foods, and thereby on purchase interest. Likewise, the food-processing technology with which cheese is produced was also found to influence purchase likelihood. Genetic modification was deemed the least acceptable method of production compared to traditional methods, which were most acceptable to the majority of respondents (Frewer, Howard, Hedderley, & Shepherd, 1997). Loureiro and Bugbee (2005) similarly found that type of modification affected consumers' willingness to pay for GM tomatoes. For example, when modification resulted in enhanced flavour, enhanced nutritional value or in pesticide reduction, consumers were willing to pay more for the modified product, which confirms our distinction between proximal and distal determinants.

Innovation features, the objectively measurable characteristics of the innovation, are not always easily separable from consumer perceptions in terms of their definition and their application in empirical studies. Previous research confirms the framework's contention that their effect on consumer acceptance is mediated through more proximal perceptions, mainly of cost/benefit and risk and uncertainty.

Consumer characteristics

Socio-demographic variables, whilst easy to measure, represent consumer characteristics with generally low explanatory power. More specifically, socio-economic status, income, nationality, age, gender, race, and familiarity have been found to have significant effects on one or more measures of innovation acceptance (Bogue et al., 2005; Bouyer et al., 2001; Cardello, 2003; Choo et al., 2004; Costa, Deliza, Rosenthal, Hedderley, & Frewer, 2000; Finucane et al., 2000; Florkowski, Elnagheeb, & Huang, 1998; Loureiro & Bugbee, 2005; Magnusson & Koivisto-Hursti, 2002; Palmer, 2003; Rimal et al., 2004; Siegrist, 1998, 2000). The phenomenon that white males perceive the risks of health and technology hazards as low compared to white females and people of colour is referred to as the 'white male effect' (Slovic, 1999). This effect is thought to be explained by socio-political factors including worldviews (e.g., individualistic, egalitarian) (Bouyer et al., 2001; Palmer, 2003).

Knowledge and expertise were consistently found to be determinants of risk perceptions, attitude towards gene technology and GMF and of dietary behaviour, but the direction of the association varied. Expertise increased consumers' risk perception of a broad range of hazards (Bouyer et al., 2001), whereas knowledge about gene technology and GMF had a positive effect on attitude (Siegrist, 1998; Verdurme & Viaene, 2001). Knowledge about food safety appears to reinforce consumer intention to purchase irradiated beef (Rimal et al., 2004). Science knowledge had a negative relationship with risk perception about biotechnology (Savadori et al., 2004). Research outside the food domain confirms the complex relationship between knowledge, expertise and adoption. Existing relevant knowledge was shown to increase consumer preferences for continuous (i.e. incremental) innovations. For discontinuous (i.e. disruptive, radical) innovations, however, this was only true when this consumer expertise was accompanied by supplementary knowledge, enabling the knowledgeable consumer to understand and appreciate the discontinuous innovation (Moreau, Lehmann, & Markman, 2001).

In terms of more enduring psychological determinants, world views such as universalism and hedonism had an impact (negative and positive, respectively) on attitude and intention to buy GMF (Honkanen & Verplanken, 2004). An interesting and very relevant set of traits are innovativeness-related characteristics. Reverting to Rogers' work, his classification of consumers into segments of adopters was also based on consumers' innovativeness. Food specific personality traits such as food neophobia and the opposite willingness to try new foods was studied and found to exert an effect (negative and positive, respectively) on new food behaviour in various papers (Tuorila, Lähteenmäki, Pohjalainen, & Lotti, 2001; Urala & Lähteenmäki, 2004; Verdurme & Viaene, 2001).

General attitudes, partly based on previous experiences, may also affect consumer acceptance of food innovations in a top-down manner. These general, relatively stable attitudes can be categorised into several main topics: science and technology (Cardello, 2003; Grunert et al., 2003; Stolt et al., 2002; Verdurme & Viaene, 2001), environment and nature (Grunert et al., 2003; Siegrist, 1998; Verdurme & Viaene, 2001), health and nutrition (Bogue et al., 2005; Frewer et al., 1998; Grunert et al., 2003; Lähteenmäki et al., 2002; Saba & Vassallo, 2002; Verdurme & Viaene, 2001), sense of ethics (Tanaka, 2004), and altruism (Stolt et al., 2002).

Previous research, which has focused on consumer characteristics, has centred around four groups: socio-demographics, knowledge, personality and general attitudes or values. This empirical evidence provides good support for the inclusion of this concept in our conceptual framework.

Social system characteristics

Characteristics of the social system, which can potentially determine acceptance of innovations, have not received widespread attention in the research literature. However, it is important to realise that developments in the market place are always dependent on their social context. The acceptance of a food innovation is not only related to the innovation itself but also to the nature of the economic, political and social environment in which food choice takes place (Henson, 1995). For acceptance of new technology it is important that technology fits with and is embedded in the daily public discourse (te Molder & Gutteling, 2003). A qualitative study into the discourse of GMF revealed that an important barrier is that scientists tend to engage with the public from their own frame of reference thereby causing an inability to connect with the other members of society (Cook, Pieri, & Robbins, 2004).

Social trust—the willingness to rely on those responsible for decision-making related to technology management—is shown to be a key predictor of perceived benefits and risks of several technologies. Social trust is in turn determined by shared values (i.e. people holding similar salient values), another element of the social system (Siegrist, Cvetkovich, & Roth, 2000).

Religion is important for almost every culture and still plays a role in influencing consumer behaviour. Fam, Waller, and Erdogan (2004) investigated a range of controversial products and found that religion is indeed an indicator for the offensiveness of these products. For example, Muslims found the advertising of gender/sex-related products, societal related products, and health and care products most offensive compared to Christians, Buddhists and non-religious believers. This might have implications for marketing innovations as well; imagine a technology appealing to feelings of "hampering with nature" or "playing God", as is the case with GM.

In sum, social system characteristics as a macro determinant have received only limited attention in previous research, but several studies confirm their importance as a determinant of consumer acceptance of food innovations.

Previous empirical research into communication

Communication is important in determining how innovative science-based products and services are received by the consumer, as it links the concrete, distal determinants and the proximal, psychological constructs in our framework. Communication extends beyond the sheer exchange of facts. Persuasive communication is related to matters of judgment, rather than to certainty. This is particularly important for communication surrounding controversial issues, such as technological innovations (Frewer et al., 1999; Simons, 2001).

Various aspects of communication play a role. In the context of GMF, the importance of characteristics of the source that brings the message was shown; a trusted source had an indirect positive influence on attitude (Frewer et al., 1999). In the context of the health hazard of lead in drinking water, it was demonstrated that interpersonal communication (by health professionals) was more effective when attempting to get people to adopt preventive behaviours compared to mass media and impersonal pamphlets distributed among the residents potentially at risk (Griffin & Dunwoody, 2000).

The type and amount of information is repeatedly found to play a significant role in acceptance of innovations. Deliza et al. (2003) showed that information on the label of foods produced with non-conventional food-processing technology promoted a more positive attitude towards the product through perceptions of benefits. Safety and handling information on the package of irradiated beef reinforced purchase intentions and even actual purchase (Rimal et al., 2004). In another study, willingness to pay for irradiated food increased when information was positive, but lowered when information was negative or if the information was both positive and negative (Fox, Hayes, & Shogren, 2002). The amount of information influenced the intention to adopt high-technology products through consumer perceptions of performance uncertainty, as shown by Ziamou and Ratneshwar (2002). They found that more information about the new product reduced consumers' uncertainty about its performance when the product had a familiar functionality (i.e. what a product does for the consumer), but increased performance uncertainty when the product had a new functionality. Visual exposure to products and statements about safety and benefits of the use of several food-processing technologies raised consumers' expected product liking in research by Cardello (2003). A large-scale cross-national experimental study showed that various types of information provision did not result in attitude change towards GMF. In fact, information material even activated the, often negative, pre-experimental attitudes, decreasing the probability of consumers' choosing the GM products (Scholderer & Frewer, 2003).

Media discussion of risks of GMFs had a differential impact on public perceptions of benefit and risk in a study by Frewer et al. (2002). When media attention was focused on GM foods in the media, risk perceptions increased temporarily, while benefit perceptions diminished more permanently. Another communication issue, related to concern and trust, is communicating risk uncertainty. Admission of risk uncertainty was found to improve consumer attitudes towards GMF by Frewer et al. (1998). It is notable that experts appear to believe that that information provision of risk uncertainty would increase public *distrust* in science (Frewer et al., 2003a).

An aspect of communication closer to the receiver is confidence in information, which was crucial for consumers' willingness to use functional foods (Urala & Lähteenmäki, 2004). Another example is interest in information related to food production, which increased when people were more fearful of GMF (Laros & Steenkamp, 2004).

Communication affects how distal characteristics are perceived by consumers, and it is these perceptions which will eventually determine consumer intention to adopt an innovation. The communication source appears to be important, as is the type and amount of information, the interest and confidence consumers themselves have in this information, and the way innovations are discussed in public. Communication and information are particularly important in situations where people have to rely on judgement rather than certainty, which is certainly the case for innovations.

This section has described and categorised a body of empirical support for our theoretical framework. For all the constructs we defined, a certain amount of evidence is available in which the constructs are related to a measure of innovation acceptance. The group of perceived benefits has received the largest research attention so far, compared to the other constructs, whereas perceived behavioural control and subjective norm have been studied less intensively in the food area. Also, interactions between determinants have been studied to a limited extent and require future attention.

Discussion

We substantiated our framework by mapping existing studies onto it, to provide it the scientific body it requires. This analysis confirms that the framework is comprehensive in capturing all of these studies. Our mapping of existing studies (see Table 1) shows that none have captured all the determinants of consumer technology acceptance comprehensively. Most studies focus on a subset of determinants, with a dominant focus on consumer characteristics, perceived cost-benefit considerations, perceived risk and uncertainty, and the effect of specific features of the innovation, which is in line with arguments put forward by Cardello (2003). The effect of communication on consumer acceptance has also attracted considerable research attention. However, research into social system characteristics, subjective norm and perceived behavioural control has received much less research attention. In terms of future research, the latter three determinants would require more attention. In terms of proposed relationships in the framework, we found empirical examples for almost all of them. The only two relations that have not previously been addressed are the influence of innovation characteristics on the subjective norm and of social system characteristics on perceived behavioural control. Intuitively, this may make sense, but it may also provide opportunities for future research to investigate these relations. A further striking result from our review is that most studies focused on specific benefits delivered by the innovation and relatively few on the specific cost-benefit trade-off that occurs between the perceived advantages and disadvantages of using the new technological innovations.

We are aware of the fact that a literature review is never completed, as scientific research continues to progress. However, up to date no studies exist that test the full complexity of the framework. The framework we propose is well based in the existing scientific literature, but is still a "mind model". What is needed to further substantiate and possible refine the framework is a comprehensive empirical test of it to also assess the relative importance of the determinants in shaping consumer acceptance of new food technologies and food innovations.

Our conceptual framework is largely built on retrospective studies of consumer acceptance of innovations. But as a "mental model" it is also suitable for use as a structuring and decision tool in anticipation of consumer acceptance of current or future innovations. Such foresight into likely consumer response is particularly important for major innovations that have potentially large societal benefits but at the same time may also generate consumer concern. From genetic modification of crops and foods we have learned that the public has become increasingly wary of innovations if these incorporate possible risks, especially if previous and thorough debate about implications did not take place (Sjöberg, 2004). Considering these sensitivities in advance and acting on it, may prevent misinterpretation and ultimately rejection of the technology and its innovations.

The case of nutrigenomics

In this section we will use the newly developed framework to reflect on the possible determinants of consumer acceptance of nutrigenomics. As argued before, nutrigenomics is a particularly appropriate case as it potentially involves highly relevant consumer benefits (health maintenance and improvement) but may also generate considerable consumer concern due to its genetics associations.

In terms of *cost-benefit perceptions*, the benefits of nutrigenomics are potentially high; a gain in personal health could be achieved with just nutrition as the tool (van Trijp & Ronteltap, in press). Health benefits relate to the maintenance of health (adding health to years), improving performance (e.g., in sports) and ultimately longevity (adding years to life). At a societal level, nutrigenomics may contribute to healthier food consumption and reduction in health-care costs. This brings in the issue of which group in society will benefit the most of nutrigenomics. Drawing the parallel with genetic modification, industry was the only obvious group with benefits from genetic modification of crop seeds. There were no better, healthier or cheaper products available for consumers, whereas they felt they were confronted with the possible risks accompanying GM. Another benefit nutrigenomics can deliver is attributable to the simplification of dietary choice (van Trijp & Ronteltap, in press). Nutritional information based on genomics is specifically aimed at a particular individual or information receiver, which makes it highly relevant, and a useful tool in making food choices. A *cost* factor of personalised nutrition is the price premium that will have to be paid for this personalisation (van Trijp & Ronteltap, in press). Nutrigenomics tests currently on the market in the US cost between $400 and $500 for broad-based analysis and fairly general advice (Oliver, 2005).

A prominent aspect of nutrigenomics is related to *risk and uncertainty*. Divulging personal information to third parties, a necessary condition for constituting personalised advice (Karat, Brodie, Karat, Vergo, & Alpert, 2003), may introduce concerns about privacy. Genetic information is stable over time, potentially interesting for various parties and it is still uncertain what exactly will be its future use. Consumers may be uncertain where information about their DNA will be stored and whether it may be used against them (Chadwick, 2004). As a result, risks of loss of privacy, loss of employment or insurance will be likely consumer concerns (Oliver, 2005). They may also experience personalisation as an undesirable interference with personal preferences, and as an attempt by marketers to persuade them (Simonson, 2005). Besides consumer perceptions, considerable scientific uncertainty is involved in the development of nutrigenomics as it is a young science. The predictive validity of genotype information for phenotypic conditions is crucial, as is the extent to which the effect of genes can be attenuated by nutrition. Both seem to be limited at this point in time, especially for complex diseases such as diabetes and obesity (Kutz, 2006; van Trijp & Ronteltap, in press).

Perceived behavioural control in the context of nutrigenomics can be expressed in terms of the way people can, and will, respond once their genetic profile has been assessed. Imagine that the test results show that an individual has a certain genetic disorder. Will he change his lifestyle in order to prevent this disorder? Or will he become deterministic and change nothing at all, as his genes have already condemned him to the disease?

Perceived self-efficacy, or consumers' confidence in their own ability to act upon the test results (Ajzen, 1991), will be a determinant of their behaviour. Much is related to the issue of empowerment of the individual consumer in terms of access to information and improved decision making (Bouwman et al., 2005). Clarity about which actions an individual can take after the genetic test is necessary to answer these questions.

As to *subjective norm*, the family doctor can play an important role in the societal introduction of nutrigenomics. Traditionally, family doctors are among the most important and trustworthy sources of nutritional information (van Dillen, Hiddink, Koelen, de Graaf, & van Woerkum, 2004), so they—or other authoritative medical sources—can be an important gatekeeper in the process of advising consumers about nutrigenomics tests and personalised nutrition. Furthermore, the opinions and behaviours of peers, for example friends or colleagues, are also likely to have a strong impact on consumer adoption of nutrigenomics. In sum, there is a strong need to develop the social networks that support the uptake of this new technology.

When considering the distal determinants of consumer acceptance of nutrigenomics and personalised nutrition, many likely relations with the proximal determinants appear. One highly important *innovation characteristic* is the extent to which following personalised dietary guidelines is effective. This has a direct effect on the perceptions of benefits delivered and behavioural control. Note that there are two types of nutrigenomics applications: diagnostic genomics tests and nutritional products stemming from them (Oliver, 2005), both with different consequences for consumer acceptance. Another aspect is the terminology used for the technology and the innovation. Burgess' (2003) research has shown that 'genomics' is susceptible for associations with genetic modification, and a recent American survey revealed that the term 'personalised nutrition' was markedly preferred by consumers over 'nutrigenomics' or 'nutritional genomics' in both appeal and relevance (Oliver, 2005). Furthermore, it is important to realise that nutrigenomics in itself is a complex science. It requires considerable knowledge about health, nutrition, nutrients, genes and physiology in general to understand how personalised nutrigenomics-based advice might work.

Consumer characteristics too are likely to influence proximal determinants of nutrigenomics acceptance. The genotype is the crucial consumer feature for personalised dietary advice, but as it is sensitive and stable information, it can trigger perceptions of risk and uncertainty. The people who are likely to be the innovators for using applications of nutrigenomics are those experienced with (diet-related) diseases, personally or in their close environment. They are motivated to take preventive actions and prone to be interested in nutrigenomics deliverables in an early stage of its development. Other potentially relevant consumer characteristics in the context of food innovation acceptance are habits. People do not always decide after in-depth, deliberate reasoning, especially in potentially risky food consumption situations (Fischer, Jong, Jonge, Frewer, & Nauta, 2005).

The difference in public reception of GMF between the US and most European countries demonstrates clearly what influence the *social system* can have on societal responses (Gaskell, Bauer, Durant, & Allum, 1999). Culturally embedded socio-ethical, moral and religious obligations can cause a reluctance to "interfere with nature". Another characteristic of the social system is the increasing financial burden of diet-related diseases such as diabetes, obesity, and certain types of cancer (Oliver, 2005), which strengthens the need for solutions. The earlier discussed role of health care practitioners as providers of nutrition information depends on their level of education and motivation. In general, physicians have been undereducated and under-interested in how diet can affect health (Oliver, 2005). More broadly, the health care establishment is slow to adopt new practices, and will not recommend their use until scientific evidence accumulates (Oliver, 2005). Legislation is another relevant factor at societal level. Under current regulatory frameworks, the rules of the European General Food Law Regulation are applicable to all foodstuffs. Furthermore, legislation on dietetic foods, food supplements or novel foods, and two proposals on nutrition and health claims and the addition of substances to foods, may be applicable to nutrigenomics products, depending on their nature and their use (Coppens, Fernandes da Silva, & Pettman, 2006). Currently, claims related to reducing risk of disease (or maybe even curing disease)—the type of claims most likely to be useful for nutrigenomics-based products—are prohibited (van Trijp & Ronteltap, in press). Due to the amount of regulations and procedures to be followed, getting nutrigenomics products ready for the market will be an expensive and time-consuming process (Coppens et al., 2006). This may have large implications for the type of companies able and willing to invest in nutrigenomics products.

Communication surrounding nutrigenomics will play a crucial role in its development. Nutrigenomics is a complex science, and thus needs to be simplified by understandable messages that communicate the tangible benefits delivered (Oliver, 2005). If information is too complex for consumers, they tend to be more sensitive to superficial information than to in-depth and detailed scientific information (Petty & Cacioppo, 1986). This is exemplified by the influential statement on the part of Prince Charles in the discussion on biotechnology, when he referred to GMFs as "Frankenstein Foods".[4] Despite the need for simple and clear messages, communication does not equal education, i.e. a one-way process from expert to layman. The so-called deficit model, still a popular paradigm among experts, states that it is a lack of knowledge among

[4]http://news.bbc.co.uk/onthisday/hi/dates/stories/february/5/newsid_4647000/4647390.stm (Accessed October 9, 2006).

consumers that leads to scepticism with regard to technological innovation and science in general (Wynne, 1991). Our review shows that consumer knowledge is indeed a determinant of innovation acceptance, but that it is certainly not exclusive. A lack of communication, for example on scientific uncertainties, can in itself be a source of consumer scepticism (Frewer, 2003). Communication as an iterative two-way process is needed to pro-actively involve the public in the development of nutrigenomics.

Conclusion

Due to a lack of published empirical studies on consumer evaluation of nutrigenomics, this case could not be discussed exhaustively. However, the utility of the proposed framework demonstrates that it can be useful in the identification and structure of the many triggers and barriers that an emerging science such as nutrigenomics will face before it will acquire wide societal acceptance. The framework helps in identifying critical success and failure factors for the further development of nutrigenomics and the possible innovations emerging from it. To fully do justice to our framework, and the complexity of this new science area, future research should involve a wide diversity of stakeholders, such as scientists, business people, policy-makers, health-care professionals and consumer interest groups, to jointly assess the many factors involved in consumer acceptance and to design the appropriate strategies and actions to manage consumer expectations.

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