Social risk perception of genetically modified foods: towards a theoretical framework

Sedigheh Ghasemi and Mostafa Ahmadvand*

Department of Rural Development Management,
Yasouj University,
Yasouj, 75918-74831, Iran
Email: ghasemi.s.sh@gmail.com
Email: mahmadvand@yu.ac.ir
*Corresponding author

Ezatollah Karami

Department of Agricultural Extension and Education,
School of Agriculture,
Shiraz University,
Shiraz, 7144165186, Iran
Email: ekarami@shirazu.ac.ir

Hossein Azadi

Department of Economics and Rural Development,
Gembloux Agro-Bio Tech,
University of Liège,
5030 Gembloux, Belgium
Email: hossein.azadi@uliege.be

Abstract: The debates over uncertainty about the possible undesirable impacts on human and the environmental safety of GM foods have increased. Most of these debates are rooted in different risk perceptions of various societal stakeholders. Despite growing studies on GM foods' knowledge, attitude, or behaviour, few have documented the risk perception models to assess stakeholders' risk perceptions. Therefore, this study aimed to develop a model to explain the social risk perception of GM foods. To this end, current risk perception theories and models were critically reviewed, then an attempt was made to develop an integrated and more comprehensive model called the "Comprehensive Social Risk Perception Model" (CSRPM). Addressing the theoretical and methodological weakness of conventional models, CSRPM could be a complementary model to more effectively study the social risk perception of GM foods in developed and developing countries. Furthermore, CSRPM can also be used in ex-ante and ex-post risk assessments.

Keywords: GM foods; risk assessment models; social risk perception; agricultural development; agricultural extension; safe food; GM technology; consumer acceptance; food label information; consumer rights, perceived benefits.

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Biographical notes: Sedigheh Ghasemi is a PhD of Agricultural Development at Faculty of Agriculture, Yasouj University, Yasouj, Iran. Her interests and experience have been concentrated on social risk of GM crops and sustainable agricultural development, especially in agricultural development innovations.

Mostafa Ahmadvand is a Professor of Agricultural Extension and Development at Faculty of Agriculture, Yasouj University, Yasouj Iran. His interests and experience have been concentrated on social impact assessment, conflict resolution, and social risk, especially in agricultural development projects in Iran.

Ezatollah Karami is a Professor of Agricultural Development and Extension at School of Agriculture, Shiraz University, Iran. He has conducted research and published widely on issues of agricultural extension, drought, water and sustainable natural resources. He is a specialist in social research in agriculture and water scarcity. He has received an international award for his research on agriculture and environment.

Hossein Azadi is a Professor of the Department of Economics and Rural Development, University of Liège, Belgium. His research focuses mainly on "Land and Food" policies in which he tries to understand the impacts of land governance, land tenure and property rights on agrarian change and food security using political economy theory and mixed-method (quantitative and qualitative) approach.

1 Introduction

During the twentieth century, human beings faced many challenges, most notably the rapid growth of the world's population, increased demand for more and better food, decreased arable land, and bottlenecks of traditional and modern production. These challenges created the need for innovative agricultural technologies.

Historically, genetically modified (GM) foods are one of the latest human achievements, promising to solve some agricultural problems. GM foods are made by introducing genes of other species to their DNA (Bawa and Ani Lakumar, 2013). The term 'GM foods' has become controversial because its benefits for food producers and consumers are associated with potential risks and adverse impacts (Zhang et al., 2016). Some scholars claim that by producing GM foods, some benefits can be achieved, including agronomic benefits, economic benefits, a decrease in the chemical residues in food, improvement in food quality, etc. (Brookes and Barfoot, 2014; Kramkowska et al., 2013; Chandler and Dunwell, 2008). Despite these promised benefits, the debates over GM foods focus mainly on uncertainties about the possible undesirable effects of these foods on human health and environmental safety. Most people are concerned about the possibility of adverse effects on other organisms, the possibility of creating super weeds, creating gene mutation, allergenicity, environmental pollution, creating new pathogens,

socio-ethical risks, infertility in women, playing god, threatening animal rights, biodiversity and wildlife, the feasibility of gene flow between GM and non-GM foods and the fear of undesirable consequences (Azadi and Ho, 2010; Ghanian et al., 2015; O'Fallon et al., 2007). So, assessing and evaluating their risks before deciding to produce and release them is crucial.

Generally, in natural science, the risk is measured objectively, with its magnitude expected to be determined by the probability weighting of the adverse effects. In contrast, in social science, risk has been defined as subjective judgement (Vasvari, 2015). In other words, subjective judgements are usually regarded as risk perceptions within the social sciences, albeit leading to negative consequences (Renn, 2008). In general, risk perception implies how an individual judge and evaluate events (like hazards) that he might be exposed to and how he perceives his properties and the environments are affected. Such perceptions and or judgements lead to decisions about acceptance and tolerance of risks that finally shape behaviours (Thompson, 2011). In the case of GM foods, different types of risks (i.e., social, economic, political, cultural, etc.) might be considered (Hoyer and Macinnis, 2009). However, some scholars hold that social risks delay the diffusion of GM foods, postpone their adoption, and speed down their development (Ghasemi et al., 2013; Kim, 2012). 'Social risk' undermined human life and welfare (Bueno, 2008). In the case of GM foods, Slovic (2000) believes that they can be viewed as a typical example of the high perception of risks because their risks are newness, unfamiliar, uncontrollable, unobservable, etc.

Although scholars have studied the possible risks of GM foods in both developed and developing countries (Ghasemi et al., 2013; Ghanian et al., 2015; Aerni, 2005; Amin et al., 2014; Angulo and Gil, 2007; Chen and Li, 2007; Connor and Siegrist, 2010), almost little attempt has been reported regarding GM foods' risk perception models. Therefore, there is no comprehensive model for assessing the risk perception of GM foods. Therefore, the main question is which model could be suitable for these assessments. Furthermore, what are the drivers of social risk perception in GM foods?

2 Social risk perception: a brief history

Risk can be classified as objective and subjective. Traditional risk assessment assumes that risk is objective that can be measured, quantified, objectively, and accurately (Wickson, 2007). Also, the most famous objective definition of risk is: Risk = Hazard × Exposure, 'hazard' is described as a position that could cause harm (injury or damage). Exposure means the degree to which an entity (human, plant, microbe) comes into contact with or is influenced by the hazard (Boholm and Corvellec, 2011). Subjective risk is the public's judgements about negative and unexpected consequences of events, conditions, or activities, known as risk perceptions (Renn, 2008). Generally, risk perception implies how people make sense of and respond to potentially unsafe events and then form a decision about their seriousness, possible likelihood, and risk-averse or risk-taking behaviour. In other words, when attributes of technical risks are analysed through culturally different viewpoints, then perceptions are formed accordingly.

Some scholars have claimed that behaviour is more directly identified by subjective evaluations of risk than by objective risk. This hypothesis applies to new technologies

(such as nuclear energy or GM foods) on which there is little knowledge and experience. In fact, if the main target is to explain an individual's decisions over risky alternatives, then risk perceptions are premier (to technical-assessed risks), as people make choices upon their personal preferences (Kusev et al., 2017). Since the perception of risk is subjective, uncertainty is inherent to this definition. What is hazardous in the eye of the beholder may not be the same to another. For example, GM products were introduced to the world with the promise of increasing food security and environmental protection. Fears of unknown and long-term possible impacts on humans and the environment took the public stand against any new technology that poses any risk, while the scientific community seems to be amazed by the public response to GM products. This is due to different rationality toward perceived risk (Hall, 2010). Furthermore, Chauncey Starr (1969) has claimed that society has attained stability and balance in risk judgement, so each level of actual risk arising in society is acceptable provided that it is voluntary (e.g., driving a car) but not mandatory (e.g., GM products). However, Slovic (2000) challenged this claim and found that if people enjoy consuming a product, they judge its benefit high and its risks low and will tend to accept its risks. So risk acceptance highly depends on intuition, experiential thinking, and emotions.

In studies about consumers' behaviour, risk perception has been considered as a part of other factors, impacts of other factors on risk perception, or influence of risk perception on other factors or indicators. For example, Cheung and Lee (2000) and Corritore et al. (2005), found that risk perception is part of the trust construct. Kanungo and Jain (2004) added risk perception to the technology acceptance model (TAM). Ha (2002) studied the influence of knowledge on risk perception when deciding to buy new products.

Generally, two main schools (paradigms), individualism and conceptualism, have informed theory structures in risk perception (Slovic and Weber, 2002). The individual is the starting point of analysis in the individualism mode, while the conceptualist style begins with the context (e.g., cultural structure, social milieu, group membership). Since 1944, various scholars have studied the subject of risk perception in various fields of science. Each of these scientists has been the founder of a special theory or model to assess people's risk perception. In Table 1, the social theories of risk perception have been shown based on the individualist mode.

Table 1 Social theories of risk perception: individualist mode

	Scholar	*Year*	*Theory title*	*Main finding*
			Early theories of risk	
1	Von-Neuman and Morgenstern	1944	Mixed-motive game theory	• Risk perception is constructed rationally • Probabilities, costs, benefits.
2	Kahneman and Taversky	1979	Expected utility theory	Laboratory constraints, mathematical models, ignoring social and cultural context.

Table 1 Social theories of risk perception: individualist mode (continued)

	Scholar	*Year*	*Theory title*	*Main finding*
	Individual differences approach: focused upon cognitive style			
1	Starr	1969	Technological risk model	• Technical estimates, subjective dimensions, information, voluntary and involuntary risks
2	Kahneman and Taversky	1979		• •Risk perception biased by heuristics (rules of thumbs or operating principles)
3	Fischhoff et al	1978	Psychometric model	• Introducing factors influencing risk perception: voluntary, immediacy of effect, known, catastrophic, dread, novelty
4	Slovic et al	1982	Risk perception of lay people and experts	Comparing lay people and experts' risk perception
5	Krimsky and Wrubel	1996	Difference between lay people and experts	• Identifying the criteria lay people apply to assess technological risks
6	Sjoberg	1996	BRPM: basic risk perception model	• Adding the factors of attitude, risk sensitivity, and particular fear, and sometimes trust and ethical values.
7	Sjoberg and Drottz-Sjoberg	2001 2002	Moral values	• Adding morality (moral value)
8	Gregory and Satterfield	2002	Stigma	• Stigma (lack of fairness and risk to future generations) is significant predictors of risk perception
9	Janmaimool and Watanabe (2014)	2014		• Dynamic process of risk perception

Also, in Table 2, social theories of risk perception have been mentioned based on the conceptualist mode.

Table 2 Social theories of risk perception: conceptualist mode

	Sociological theory of risk: cultural theory of risk			
	Scholar	*Year*	*Theory title*	*Main finding*
1	Douglas	1960	Social groups	• Social groups, cultural context
2	Douglas	1966	Cultural theory	• Social context (social structures, group membership, cultural milieu) as the main factor
3	Douglas and Wildavsky	1982	Grid/group, Cultural bias	• Adding way of life that is combination of cultural bias and social relations, cultural biases types

Table 2 Social theories of risk perception: conceptualist mode (continued)

	Sociological theory of risk: cultural theory of risk			
	Scholar	*Year*	*Theory title*	*Main finding*
4	Dake	1991	people's cultural bias	• Testing cultural theory, Cultural world views
5	Beck	2000	Risk society approach	• Governmental risk, strategies and rationalities, emotional and aesthetic perceptions, iniquitousness, powerlessness, dependency
6	Hobson-West, Beck	2003, 2005	Uncertainty instead of risk	• managing unpreventable uncertainties
7	Lupton and Zinn	2006, 2007	Socio-cultural approach	• Power relations, habituations, emotions, cultural contexts
8	Aven and Renn Lopez-Navarro	2010 2013		• Social forces, interests and values of each group
	Social amplification approach			
1	Kasperson et al	1988	Social amplification framework	• Psychometric and cultural theory, media, organisational responses, social impacts, public concern, risk events, minor physical results,
2	Renn et al.	1992	Social amplification framework	• It is a social theory, People and organisations can act like amplifier stations
3	Burns et al	1993	Social amplification theory	• It is sociological rather than psychological and describes risk perception higher than the other 2 approaches
4	Gregory and Satterfield	2002	Stigma	• Impact of social amplification or attenuation on stigma
5	Kasperson et al.	2003	Social amplification, risk behaviour	• Social groups and individuals can heighten or attenuate risk perception and shape risk behaviour
	Reflexive modernisation theory			
1	Beck	1986	Risk distributions	• From wealth to risk distributions, Welfare is accessible and protected, Modern times have brought many unknown risks, Social class, risk
2	Bonss	1995	Reflexive modernisation theory	• Uncertainty instead of risk, Social and cultural rationalities, Political conflicts, risk, security
3	Giddens	1999		• External risk, manufactured risk.
4	Lupton	1999	Modern risk	• Modern risks

3 GM foods risk perception models: a critical review

Regarding people's subjective assessment of the attributes and intensity of risk, the term "risk perception " is most commonly applied to environmental or health hazards, such as GM foods. Several theories have described why different people make different judgements on the severity of risks. Five famous theories of risk perception include psychometric, cultural, social amplification, reflexive modernisation, and moral theories that have been used to explain GM food risk perceptions.

3.1 Psychometric theory

Psychometric means the measurement or assessment of individual differences in abilities, attitudes, behaviour, intelligence, and other attributes through psychological tests (Busko, 2010). The early model of risk perception has been introduced by Psychometric theory (Slovic, 2016). This theory assumes that risks are quantifiable and can be assessed by psychological scales. This theory implies that peoples' risk perception has been shaped by the physical properties of risks and psychological and cognitive factors (Fischhoff, 2015). According to this theory, each person should determine the 'personality of hazards' by rating them on various attributes and characteristics (e.g., dread, voluntariness, controllability, catastrophic potential) (Slovic, 2016). This theory has introduced a list of risk attributes in two categories: unknown risk (vs. known) and dread risk (vs. not dreaded). High unknown risk means the hazard is unobservable, unknown, new, and delayed (e.g., GM products). 'High dread risk' denotes high levels of lack of control perception, high images of dread, and significant catastrophic potential and fatal consequences (e.g., nuclear energy) (Bodemer and Gaissmaier, 2015). In fact, the unknown risk is different from the uncertainty. Because uncertain situations imply both consequences and probabilities, or at least the probabilities are unknown, the unknown risk is a psychological structure primarily related to the novelty of risk and could be objectively quantified (Meder et al., 2013). Furthermore, the risk perception of experts and laypeople has been compared in psychometric theory. It denotes that experts' risk judgements are correlated with quantitative estimates, but laypeople's risk perceptions are richer and more sensitive, taking into account other factors such as controllability, voluntariness, familiarities, etc. Therefore, the risk perceptions of the same risks are different for experts and laypeople. As reported by different studies, dread and unknown risks have been used for predicting public risk perception in this theory. Results revealed that dread risk was better than the unknown risk in assessing risk perception (Al-Rawad and Al-Khattab, 2015).

According to the psychometric model, GM products probably have unknown risks that are identified by newness, unobservable, delayed effect, unknown to science, and those exposed. The higher the unknown risk, the higher the risk perception of GM products (Schmidt, 2004). For example, GM products might create new risks by designing faster and stronger growth such that it might destroy native varieties or create cross-pollination. GM products may also have some dread risks known to categorise into uncontrollable, global catastrophic, not equitable, and high risk to future generations (Ng and Rayner, 2010). This issue explains the cause of laypeople's susceptibility to GM products and their willingness to amplify its risks. The fact that GM products do not pose a health risk would allow biologists to demonstrate their safety. While skeptics claim that

no evidence of GM products' risk is possible, it does not mean these products are safe because they may have delayed effects (Hall, 2010).

However, a psychometric model considers risk as a simple and objective phenomenon without social, cultural, or moral aspects (norms or values that might have been threatened by risky behaviours). In fact, the psychological model is one-dimensional in that it assumes a passive perceiver role for individuals in a social context independent of particular membership status (Sjoberg, 2004; Hall, 2010). This implies that cultural, moral, religious, and social factors are at least as important as those psychometric factors ignored in this model. The assumption that risks as objective entities are independent of the complex subjective entities (i.e., social, cultural, and institutional contexts in which people perceive them) has diminished the applicability of psychometric models (Chong, 2005).

3.2 Cultural theory

While the psychometric model indicates individuals' risk perception, cultural theory notes that risk perception is not independent of social and cultural context. According to cultural theory, risk perception is primarily shaped by values and cultural worldviews. So, risk perception implies the interests and values of each group and different meanings of risk within each group (Aven and Renn, 2010; Lopez-Navarro et al., 2013). Douglas (1966) claimed that certain products or foods in different cultures are tabooed not because of the objective hazard of their consumption but to protect and reinforce the moral, political, religious, or social order that binds the members of that culture together. Based on this theory, two main dimensions specify the risk perceptions: grid and group (Du, 2012), combining in a matrix that results in four 'worldviews' or 'culture biases' include: hierarchical, egalitarian, individualistic, and fatalistic views (Ueland et al., 2012). Grids are defined as assessing the constraining classifications that act on the members of each social grouping and group as the degree of social relationships and the degree to which people depend on social networks (Rayner, 1992). In the high grid and high group hierarchical systems, all individuals depend on others despite limited transfer between levels of authority. In terms of risk, perception is primarily about control and management. So, providing appropriate regulations is the best response to risk. For the egalitarian, cooperative relations and equality are the main goals. They respond to risk based on precautionary principles and seek to reduce harm by preventing risky behaviour rather than controlling and managing. With a low group and low grid, individuals see risks as opportunities for progress. Market mechanisms are preferred to bureaucratic regulation. Potential impacts can be mitigated by insurance. Lastly, in the fatalist viewpoint, risks are explained as predictable, and avoiding harm is simply a matter of luck (Bodemer and Gaissmaier, 2015). Cultural models of risk perception differ significantly from psychometric models in several ways. First, it challenges the psychometric conception of the ontological status of risk. This means that risk has its roots in nature but stems from social processes. Second, it goes beyond the perception of underlying causes of risks and looks at the social norms or values being threatened. Thus, organisational structure cannot be replaced by physical attributes. Third, while the psychometric approach emphasises individual meaning, cultural analysis is focused on sharing meaning among individuals, institutions, and communities (Sjoberg, 2004).

Cultural factors have been recognised as affecting the risk associated with GM foods (Herrick, 2005). For example, considering a geographical perspective to evaluate GM foods' risk perception, Herrick (2005) has found that the risk perceptions concerning GM foods differ culturally and are formalised by policymakers. In fact, there are differences in attitudes and perceptions of GM foods among people in different countries (Hall, 2010). In another study, political beliefs were found to have significantly influenced risk perceptions of GM foods, making left-wingers think they had fewer benefits but more risks than right-wing views (Hall, 2010). Also, it has been concluded that purchasing GM food is negatively related to a country's wealth (Siegrist, 2003), as GNP per capita and perceived risk of GM food were positively correlated in Europe (Siegrist, 2001). Accordingly, foods associated with cultural values determine the risk perception of GM food.

In sum, this theory shows how GM risks are interpreted, but it does not describe GM risk perception over time and its dynamics. This gap can be filled by the social amplification theory of risk perception.

3.3 Integrative theory: social amplification of risk

The most complicated risk assessment issues are that some insignificant risks can provoke strong public concerns and influence society and the economy. Such concerns are usually the consequence of 'social amplification'; in other words, the risk perception and response are defined by psychological, social, institutional, and cultural processes. The risk of social amplification is likely to be increased when it is associated with doubt and uncertainty (e.g., GM products). Two major stages are involved in risk amplification: (1) the transfer of knowledge and information about risk and (2) the social response system. Individuals and social entities (amplification stations) transfer and process signals about risk. A scientist or an expert may be a risk assessor; a social entity may be the news media, cultural groups, or interpersonal networks. The amplified risk perception causes secondary ripple impacts (Kasperson, 2012). There are seven phases to the social risk amplification framework, including risk events, sources, and channels of amplification, social stations and individual stations of amplification, group and individual responses, and other ripple outcomes and impacts (Le Khak, 2008). For example, one person has eaten a GM apple (risk event). He or she felt terrible after consuming it and thought of poison (amplification sources). He or she explained this event to family and friends (amplification channels). They spread this news through email and Facebook to all their friends. One of them is a journalist with a negative viewpoint on GM products. So, he or she may publish this story with exaggeration (social amplification stations). Alternatively, the editor invites experts to explain this event in detail (individual amplification stations). The issue was published broadly, leading to public fear and concern (group and individual responses). This would spread through other journals, and people would influence this dramatic media coverage and generalise this impact to all GM products (ripple effects). This issue would decrease consumers' trust in GM foods' safety. They would stop consuming GM products, and as a result, farmers' cultivation of GM seeds would decrease. Thus, hazards may be perceived through not only technical but also social, psychological, cultural, and institutional processes that may increase or attenuate responses to the risk (Kasperson, 2012). Evidence supports the idea that receiving information increases the risk of uncertain,

risky technologies such as GM foods. In addition, to more information received, the greater uncertainty about the risks of these technologies is expressed (Ghasemi et al., 2013; Ghasemi et al., 2020). For example, Frewer et al. (2002) found that risk perception of GM products will increase through a high level of knowledge and reporting about them. This demonstrates that the media has an indirect influence on perceptions of risk such that Hall (2010), in his study, found that farmers had believed that the media would not directly influence their own decisions or perceptions of risk but emphasised that they were aware of the negative and indirect impacts of the media on public opinion and their adoption decisions. In the case of GM foods, the main actors in the debate are hierarchical and egalitarian societies, markets, entrepreneurs, bureaucrats, and NGOs, which have their strengths and weaknesses as social resources. Some scholars have argued that the media have been responsible for rejecting GM foods in some countries because they have introduced these foods with significant and unknown risks. For example, Vilella-Vila and Costa-Font (2008) stated that public perception of GM foods' risks increased due to news reports. On the other hand, consumers often need social trust to tolerate the lack of knowledge about GM foods (Siegrist et al., 2006). Indeed, the current controversial and conflicting information about the risks and benefits of GM foods has led stakeholders to rely on amplification stations such as the media, scientists, etc.

3.4 Reflexive modernisation theory

The reflexive modernisation or reflexive modernity concept was introduced by three sociologists, Anthony Giddens, Ulrich Beck, and Scott Lash. Reflexive modernisation is about restrictions and conflicts of modern order. This theory believes that nature is not under human control and cannot be adapted to human needs and purposes. In fact, nature is part of human society (Dutta and De Souza, 2008). Also, Beck (2009) found that science and technology did not create a better and easier life but resulted in more challenges and hazards with impacts often beyond the national boundaries. These risks are usually not directly visible and thus objective by laypeople. However, they only can be assessed by experts. Therefore, public and government officials trust these experts for knowledge and information about modern risks. At the same time, there are disagreements among experts and authorities on risks associated with new technologies such as GM products (Le Khak, 2008). In this regard, Beck (2009) posed the idea of a risky society in which the consequences of technology usage are dread, novel, unfamiliar to science, and uneasy. In this situation, humans can only manage risks politically and economically. In the case of GM products, this theory states that individual contaminants can never identify the concentration of pollutants in all people. It means that what may look negligible for one product may be significant when collected in the consumer bodies that are happening in the advanced level of marketing (Beck, 2005).

Therefore, it is impossible to judge the health risks of GM products based on individual case reports. GM products may not be subjected to any heating but may affect the whole population's health and the increasing need for medications to control the symptoms. This theory has claimed that unknown and unintended risks become more important than they have been in psychometric theory. According to this theory, ethical status and legitimation (recognition) of new technologies' risks are also the main factors influencing public risk perception of that technology. In the case of GM products, in some countries, GM products may be rejected by producers and consumers because of

ethical status and legitimating (recognition) of these products that, lead to different interpretations and debates.

According to this theory, there is an inverse link between social class and risks. The poor will buy and consume GM products, while the rich will be skeptical of them and intend to buy non-GM products. In this regard, the issue of 'organised irresponsibility' states that some people and organisations are responsible for creating risks, but none are accountable. For example, who will be held responsible if GM foods would create 'super weeds' resistant to herbicides?

Giddens (1999) also distinguished two types of risks, including external risk (that happens unexpectedly but is predictable and insurable) and manufactured risk (that is new with little previous experience). According to this statement, GM products' risks are categorised as manufactured risks because humans do not know much about them and cannot calculate them based on probability tables. If this is the case, then GM product risks (as manufactured risks) entail irresponsibility as the links among responsibility, decision-making, and risk change (Le Khak, 2008). While reflexive modernisation is a valuable theory to identify and interpret modern macro-level risks, some scholars criticise it for making broad and loose speculations.

3.5 Moral theory

More recently, some scholars, such as Sjoberg (2000) and Chong (2010), argued that since people interpret risk based on their belief systems, moral and ethical dimensions of risk appear to be better predictors of risk perception than characteristics suggested by psychometric or cultural models. The contributions of moral concerns to public acceptance of GM foods have been highlighted in several studies (Amin et al., 2014; Chong, 2005). Moral aspects associated with GM foods are the principle of "common good", which requires institutions to protect and promote the best interests of the public; the principle of "people's rights", which affirms the rights of consumers to choose freely; and finally, the principle of "justice", which affirms the equitable distribution of benefits, policies and practices (Goyal and Gurtoo, 2011). The Nuffield Council on Bioethics (2003) added another key principle, the 'ethical status' of the natural world. According to this principle, 'interference' with nature is essentially wrong. This is because of the view that tampering with genetic traits might contradict religious beliefs (Yang, 2013). Opponents were concerned about ethical factors related to the environment, such as the cross-pollination of GM food crops to related wild plants and the creation of 'weedy' plants (Hall, 2010). However, the review of the moral model revealed the following shortcomings: moral and ethical criteria are considered alike in all countries and for all individuals. In US, for example, the most important moral factors are utilitarian values (e.g., respect for consumer health), whereas, in European and Asian cultures, moral concerns such as species integrity, landscape design, and traditional way of life take precedence over utilitarian values (Eyck and Gaskell, 2003). This implies that no universal set of moral and ethical issues is applicable worldwide.

4 Social risk perception practical model: A proposed model for assessing GM foods' social risk perception

Each theory of risk perception offers exclusive insights into GM products' risk perception. The psychological model has introduced a number of the psychometric attributes of risk, while the cultural theory claims that risk perception is not an individual phenomenon but a socio-cultural structure that implies values, beliefs, morals, history, and symbols of certain societies (Jackson et al., 2006). Risk amplification indicates that some individuals and social entities can amplify or mitigate any risk in society. This theory can explain GM food risks over time. The moral model has supplemented other theories, such as psychometric or cultural factors, with some moral and ethical factors, such as 'interference with nature or 'unnatural risks' (Amin et al., 2014). Finally, the reflexive modernisation model has highlighted the novel modern and manufactured risk for which we have little prior knowledge and experience, such as GM food (Jabareen, 2015). However, as stated in previous sections, none of these models is comprehensive enough to assess the risk perception of GM products. Therefore, if all previous models fail, what is a more successful risk perception model? To answer this question, we first review previous studies on the risk perception of GM products and examine the most important factors considered in each study (shown in Table 3).

Table 3 Main factors affecting risk perception of GM products in previous studies

Main factors that affect GM food risk perception	*References*
Involuntarily, uncontrollable, scientifically unproven or incompletely proven, newness, potential unforeseen risks, uncertainty and doubt religious and ethical problems, unknown, long-term effect, risk to future generation, unfairly distributed risk, newness, delayed effect, dread risk, number of people exposed to GM products	Hall (2010), Siegrists et al. (2006) and Grabner et al. (2001)
Type of application such as food vs. medicine; and organisms modified such as plants vs. animals	Siegrist (1999) and Frewer et al. (1997)
Geographical factor	Siegrist (2003) and Madsen et al. (2003)
Media report	Vilella-Vila and Costa-font (2008) and Aerni (2005)
World views, environmental attitudes, age, gender, income, personal experience, national	Siegrist (2000, 2001)
Trust, moderate role of trust	Hall (2010), James and Markes (2008), Walles et al. (2005), Siegrist (2003) and Sjoberg (2004)
Knowledge	Scholderer and Frewer (2003)
Moral factors	Pardo et al. (2002) and Siegrist (2003)
Interfering with natural processes	Sjoberg (2000)
Social amplification of risk	Kasperson et al. (1995) and Pidgeon et al. (2003)
Cultural values, personal experience, socio-cultural context	Gaskell et al. (2004), Finucane and Holup (2005)

Table 3 Main factors affecting risk perception of GM products in previous studies (continued)

Main factors that affect GM food risk perception	*References*
Belief system	Shepherd et al. (2000)
Socio-cultural beliefs, values, customs and histories that help people decide in the face of uncertainty	Finucane and Holup (2005)
Political, cultural and social context in developing countries, inappropriate risk regulation, cultural diversity, poor capacity for field testing under closely monitored conditions	Paarlberg (2000)
Cultural bias	Flynn et al. (1994)
Socio-demographics, education, Married or single, having children under 15	Gaskell et al. (2003)
Political beliefs(left-wing or right-wing people), Wealth of country (GNP per capita), Regulatory positions	Siegrist (2001, 2003) and Herrick (2005
Attitude to the nature, attitudes about manipulation of nature, fragility of nature, environmental attitudes, attitude to GM products, Conservative attitude to new technologies	Gaskell et al. (2003), Siegrist (2003) and Aerni (2005)
Benefit perception	Mucci and Hough (2004)

Afterward, essential factors in each of the five risk perception models that were more relevant to GM food, along with some new factors such as attitude toward the environment and benefit perception (Table 4), were selected to build the model.

Table 4 Main factors in GM products' risk perception in previous models and the new proposed model

Factor \ *Model*	*Psychological*	*Cultural*	*Social amplification*	*Reflexive modernisation*	*Moral*	*New model*
Involuntary	×			×		×
Catastrophic	×					×
Unknown	×			×		×
Uncontrollable	×					×
Unpredictable long-term risks	×					×
Newness	×					×
Trust	×	×	×			×
Political beliefs		×				×
Wealth level of country(GNP per capita)		×				×
World views of people		×				×
Cultural values of crops		×				×
Socio demographic characteristic		×				×

Table 4 Main factors in GM products' risk perception in previous models and the new proposed model (continued)

Factor \ Model	Psychological	Cultural	Social amplification	Reflexive modernisation	Moral	New model
Media(information resource)		×	×			×
Ethical status		×		×	×	×
Social class		×		×		×
Manufactured risk				×		×
Moral values					×	×
Religious beliefs					×	×
Environmental values and attitude to the nature						×
Attitude to the technology						×
Cultural and Political context in the country						×
Benefit perception						×
Knowledge						×

As can be inferred from Table 4, the factors are placed in rows, and the related models are placed in columns. In addition, the last column is dedicated to the proposed model in this study. Therefore, any factor that is expressed in each model is marked with the symbol × in front of it.

According to these two tables, the so-called "comprehensive social risk perception model" (CSRPM) as an applied model is proposed in this study. Considering the theoretical and methodological limitations of conventional models, we argue that CSRPM, as a complementary model, could be a powerful method to analyse the process and outcomes of social risk perception. In addition, the proposed model would be effective for studying the risk perception of GM products in social, economic, and cultural contexts. The CSRPM can be used for both ex-ante and ex-post assessments. This model is shown in Figure 1.

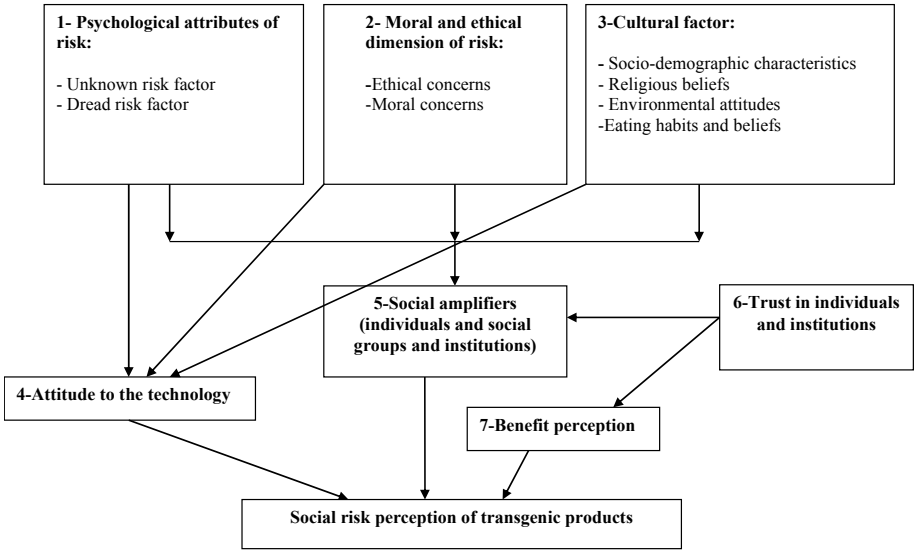
According to the proposed model, the most important factors influencing the risk perception associated with GM foods include the following:

4.1 Psychological attributes of risk

The psychological theory assumes that risk perceptions constructed by people are based on cognitive, affective, and behavioural aspects (Wickson, 2007). According to psychometric research, some psychological attributes of risk can influence the risk perceptions of people toward GM food (Siegrist et al., 2006). This model shows that the main categories of psychometric risk attributes include: unknown risk (vs. known) and dread risk (vs. not dreaded). The application of the psychometric theory is likely prevalent in situations where people feel little self-restraint to the risk they expose to and

where the relevant institutions indicate an uncertain and unknown risk. In these cases, uncontrollable risks are related to a high-risk perception.

Figure 1 Comprehensive social risk perception model of transgenic products



Other studies have evaluated these variables. For example, Balzekiene et al. (2014) found that the feeling that GM foods have uncontrollable and unknown risks is associated with consumers' risk perception. Another similar study showed that some psychometric attributes of GM food, such as unknown consequences, posed risks to succeeding generations and had unfairly distributed the risks to influence and reinforce consumers' risk perception towards these foods (Poortinga and Pidgeon, 2003).

Based on the proposed model, psychological attributes of risks associated with GM food indirectly affect risk perception by affecting their technology attitude. That is, the perception of people and their feeling about psychometric attributes of risks associated with GM food may first influence their beliefs about new technologies and their overall usefulness and then their risk perceptions of GM food.

4.2 Moral and ethical dimension of risk

According to moral theory, moral and ethical factors of risks have the main role in predicting risk perception. That is, feeling that GM foods might have some moral and ethical implications, people may perceive more risks related to those foods. Vandana Shiva (2000) also argued that moral and ethical considerations increased respondents' perception of the risk of GM food and led to the dismissal of these products.

Generally, the moral considerations associated with GM food include: 'public well-being' (protection and support of public's interests), 'people's rights' (consumer's free choice), 'justice', (equitable distribution of the benefits, policies, and practices) (Goyal and Gurtoo, 2011), and finally 'ethical status' ('tinkering' with nature is fundamentally wrong, so genetic manipulation could raise religious objections (Yang, 2013).

In this regard, Azadi et al. (2011) found that GM food is expensive and will not be available to the poor it, and this issue may deepen the gap between the poor and the rich in society. Other scholars showed that consumers who cannot choose GM foods consciously and voluntarily had high levels of social risk perception about these foods (Chen and Li, 2007; Wheeler, 2009).

According to the proposed model, the moral and ethical attributes of risks associated with GM food indirectly affect risk perception via attitudes toward the technology. Respondents' perceptions of GM food's moral and ethical risks may influence their beliefs about new technologies and their overall benefits and then influence their risk perceptions of GM food.

4.3 Cultural factors

Comparing pertinent in explaining differences in perceptions of risk, cultural theorists posit that individual characteristics are important while factoring in perceptions of risk and that other cultural factors can help determine the risk profile. In fact, despite apparent differences between cultures and countries, there is a difference in risk when weighing socio-demographic characteristics and cultural context. Hence, risk perceptions cannot be evaluated or understood outside of social life. Consequently, this study is likely relevant, considering the varying adoption and acceptance of GM technology across countries and cultural groups in societies. As a result, cultural factors such as socio-demographics (gender, education, income, etc.), cultural beliefs about foods, environmental attitudes, and religious beliefs have been added to the model. Other studies have also considered these factors. For example, according to Michael Siegrist (2001), cultural beliefs about foods may play a major role in assessing GM foods' risk perception.

Furthermore, some studies have found that demographic features (such as gender, level of education, people with children under 15, age, etc.) influence the social risk perception of GM foods (Hall, 2010; Ng and Rayner, 2010; Renn, 2008). According to LillaVicsek (2013), cultural values associated with food may be crucial in determining the social risk perception of GM foods in any given country. In Hall (2010), environmental impacts and attitudes are thought to be liable for GM foods' social risk perceptions. Dunlap et al. (2000) released the 'The New Ecological Paradigm' (NEP) scale to study the environmental values that can influence the risk perception of GM foods (Hall and Moran, 2006).

4.4 Attitudes toward technology

According to reflexive modernisation theory, science and technology are seen as having an uncertain and doubtful view. GM foods are also believed to break down their beliefs of right and wrong, too. On the other hand, some experts claim that science has made their lives safer, more suitable, and more comfortable. In this regard, Hall (2010) has claimed that science and technology opponents were probably more inclined to consume GM foods. Schwartzman et al. (2011) argued that attitudes toward technology and benefit perceptions are key factors in predicting the risk perception of GM foods. In addition, Siegrist (2003) stated that general attitudes toward technology affected GM food' risk perception.

As a result, the variable of attitudes toward technology was added to the proposed model, which directly affects the social risk perception of GM foods. If a respondent has a positive or negative attitude about the usefulness of new technologies such as GM foods, the risk perception may increase or decrease.

4.5 Social amplifiers

According to the social amplification model, individuals and social entities (as social amplifiers) can amplify or attenuate the influence of psychological, cultural, moral, and other factors on public risk perception (Kasperson, 2012).

The critical actors of debate concerning GM foods are markets, hierarchical and egalitarian societies, entrepreneurs, bureaucrats, and NGOs. Each has its strengths and weaknesses as social and economic resources (Hall, 2010; Nordgard et al., 2015; Salleh, 2008). Scientists have argued that the media were responsible for GM food rejection in some countries because they introduced these foods with significant unknown risks. For example, Vilella-Vila and Costa-Font (2008) noted that news reports increased public perception of the risks of GM foods. Therefore, the so-called social amplifiers variable was added to the proposed model, which includes newspapers, TV, scientific books and journal papers, physicians, the Department of Environment, Scientific members of the Committee on Biosafety, NGOs, the Ministry of Health and Medical Education, and the Institute of Food Standard. As the model shows, independent variables such as psychological attributes of GM food' risk, moral and ethical aspects of GM foods, cultural factors (environmental attitude, cultural beliefs about food, etc.), and benefit perception can be amplified or attenuated by these social amplifiers and then can increase or decrease risk perception of respondents.

4.6 Trust

In most countries, especially developing countries, people (such as consumers, producers, etc.) do not have access to enough scientific knowledge about GM products. So to fill this gap, they rely on other resources to increase their knowledge and information (Siegrist et al., 2006). This means that people who cannot directly assess the risks and benefits of GM foods obtain information from professionals or other sources. In this situation, the trust factor plays a crucial role in shaping the perceptions of people. Likewise, Siegrist (2003) reported that trust in organisations involved in GM research influences risk and benefit perception.

Guehlstorf (2008) asserts that perceptions of risky issues such as GM foods are related to the degree of trust in government structures. The degree of trust people have in risk managers determines the degree of risk perception and, thus, the acceptance of specific activities or technologies.

Following this literature, the trust factor was added to the proposed mode. According to the model, trust can indirectly influence risk perception by directly binding to social amplifiers and benefit perception. That is, people's trust in social amplifies, leads them to shape their attitudes based on the information they contribute, and ultimately influences their risk perceptions. Reliance on information resources can also increase or decrease perceptions of benefits, and these perceptions can influence respondents' risk perception.

4.7 Benefits perception

Most sound studies have shown that perceptions and attitudes toward GM foods are shaped by perceptions of the risk and benefits of these foods (Ghasemi et al., 2013; Ghanian et al., 2015; Chen and Li, 2007). Fischhoff et al. (2000) also claimed that more risk might be accepted if activities provide more benefit. One reason is that people's decisions are based on their effect and cognition (Hall, 2010).So, it can be concluded that introducing GM foods with more benefits for consumers may reduce their perception of risk. Generally, many authors have claimed that acceptance of GM technology is low when perceptions of benefits are low and perceptions of risks are high (Spetsidis and Schamel, 2002; Ghasemi et al., 2015). According to Grunert et al. (2003), risk perception of GM foods might not be easily changed by knowledge and information alone, but experiencing the benefits of these foods would largely contribute to modifying them.

As a result, the model was added to incorporate this variable to understand how GM foods affect their benefit perception. As shown in Figure 1, benefit perception is a direct effect on risk perception. It means that if respondents have perceived more benefits from GM foods, their risk perception will decrease.

5 Conclusion

Risk perception studies are in quest of a novel, more complete, and more robust model that can be applied to both modelling and risk perception assessment, especially in developing countries. This paper reviewed five risk perception models, including psychometric, cultural, moral, social amplification, and reflexive modernisation. Scholars have investigated the shortcomings of each model in assessing the risk perception of GM products and indicated the need for integration. This paper integrated the five risk perception models to create an inclusive model called the "comprehensive social risk perception model" (CSRPM). This model is comprehensive because, in addition to factors stated in previous models, other variables (e.g., attitude toward the environment, attitude toward technology, level of religiosity, and social benefit perception) were also incorporated into it. Hence, CSRPM contributes to the emerging risk perception literature by better understanding GM foods' risk perception.

The CSRPM can be applied to social risk perception assessment and planning. The proposed model has the potential to be used for both ex-ante and ex-post assessments of the risk perception of GM products in different social, economic, and cultural contexts. Application of CSRPM to transgenic foods' risk perception contributes towards more sustainable development.

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