



Social Risk Perceptions of Genetically Modified Foods of Engineers in Training: Application of a Comprehensive Risk Model

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Abstract

This survey was conducted in 2017 to investigate factors influencing social risk perception of biotechnologists and plant breeders in training toward GM food based on a conceptual model. A random sample of 210 biotechnologists and plant breeders in training was studied. Confirmatory factor analysis and the reliability tests (Cronbach's alpha) have been used to verify the uni-dimensionality of the measurement scale, SEM also was carried out to determine the most parsimonious models with the best fit for social risk perception of GM foods and path analysis was conducted to understand the exogenous variables introduced in the research model. The findings revealed that the engineers in training had moderate social risk perception regarding GM foods. Moreover, the results of structural equation modeling showed the capability of the model in predicting the social risk perceptions of engineers in training. The psychological attributes of risks, social benefit perception, attitude toward using technology, level of religiosity, and moral and ethical beliefs emerged as the most powerful predictors of the social risk perception. The social benefit perception and attitude toward using technology also mediated the effects of psychological attributes of risks, level of religiosity, and moral and ethical beliefs. The social benefit perception also had an indirect influence on the engineers in training's social risk perception of GM foods. Finally, we recommend the application of the model developed by this study for better understanding of social risk perception of stakeholders to have a more informed view of the development and promotion of GM foods.

Keywords GM foods · Social risk perception · Engineering ethic · Food safety · Food policy

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Introduction

The world population is expected to rise to 9.2 billion by the year 2050 (Azadi et al. 2015), with more than 3.9 billion people living below the poverty line around the world (Poncet 2008). In addition, according to United Nations reports, on average, about 1.3 billion people in the world (14%) lack adequate access to food, a number which will increase by 2050 (Fader et al. 2013). In order to meet the food needs of the growing population, food production and distribution must be improved greatly in the next decades, despite drought, limited access to arable lands and climate change (Jacobsen et al. 2013).

In this regard, different strategies are offered to address the challenge of food scarcity, among which application of GM foods technology is one, despite the widespread wave of debates among its opponents and proponents (Ghanian et al. 2015). Perhaps one reason for these controversies is different risk perceptions regarding new, unfamiliar, uncontrollable, unobservable, etc. risks associated with GM foods as Paul Slovic (2000) pointed out.

In general, risk perception refers to individual judgments and evaluations of hazards (that individuals might be exposed to) which can affect them, their properties, or the environments. Such perceptions lead to decisions to adopt or tolerate risks (Brown 2014). In the case of “GM foods,” perceptions may be shaped by different types of risks including social, economic, political, cultural, etc. (Hoyer and Macinnis 2009).

Some scholars claim that among different risk groups, social risks are the prominent barriers to the diffusion of GM foods since they postpone GM foods’ development (Ghasemi et al. 2013; Kim 2012). Exerting real or perceived impacts over different aspects of human life (e.g., welfare, environmental quality, health, economic opportunity, and working conditions), social risks arise from the features of companies’ products that have been questioned by stakeholders (Smith et al. 2012; Bueno 2008). Therefore, as noted by Angulo and Gil (2007), perceived social risks are the main factors in construction of consumer attitudes and purchasing intentions towards GM foods.

Although there have been a number of consumers, producers, and experts’ studies looking at knowledge, attitude and behavior towards 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; Bredahl 2001; Chen and Li 2007; Chen 2008; Kim 2012; Prati et al. 2012; Connor and Siegrist 2010), few studies have considered social risk perception of GM foods and the constructs influencing it. Furthermore, risk perception of biotechnology engineers and experts has been less investigated in comparison with other stakeholders.

In Iran, the increasing demand for improving agricultural productivity of strategic crops due to the population pressure and production challenges has led to the introduction of GM crops. GM crops in Iran are in their infancy in terms of research, development and deployment to be presented at the market level. Therefore, they are only cultivated for research purposes. Therefore, the future engineers as the influential gatekeepers are involved in invention, intermediation,

opinion leadership, or facilitation roles (Metoyer-Duran 1993) to positively or negatively influencing others' attitudes or behavior with regard to GM foods.

Biotechnologists and plant breeders in training are responsible for considering the social, environmental, and political ramifications of GM foods for people and reducing quantifiable levels of risk, working on GM foods risks, considering public and lay-people risk perceptions, undertaking comprehensive risk assessment of GM foods, etc. (Toms 2013). Furthermore, it is safe to assume that GM specialists in training aim to positively contribute to human well-being through their professional activities in an ethical or socially responsible manner (Zandvoort 2005). Hence, this study looks at engineers whose future functions and activities may negatively or positively affect others.

The aim of this study is to develop a comprehensive model that can explain and predict the contributing constructs of stakeholders' social risk perceptions with regard to GM foods. Accordingly, the study attempts to use the model to understand how biotechnologists and plant breeders in training perceive social risks of GMOs. In light of this purpose, the research framework and the constructs are first presented to enhance our understanding regarding the issue. Next, study methodology, results, and conclusions and implications for future works are presented.

Research Framework

The available models to explain risk perception of GM foods include psychological, cultural, social amplification, moral and reflexive modernization models. Each model considers and assesses a specific aspect of risk perceptions and offers particular insights regarding GM foods. But none of these models are comprehensive enough to assess the social risk perception towards GM foods. The psychological model only considers the attributes of emotional risks and does not claim to deal with social, cultural, and ethical risks. The cultural model considers risk perception at a theoretical level as the study of such models empirically is difficult given their time-consuming nature. Furthermore, the cultural model is suitable for studying risk perception in an international context. Three other social models of risk perception (the social amplification model, the moral model, the reflexive modernisation model) are also uni-dimensional and can't assess all aspects of risk perception alone. Therefore, in an attempt to fill these gaps, specific factors from each model have been combined while some new factors such as attitude to environment and benefit perception are added, resulting in the applied model proposed in this study, named the "Comprehensive Social Risk Perception Model" (CSRPM). Considering the theoretical and methodological problems of available models, we argue that CSRPM can be considered as a complementary model that can significantly improve the process and outcomes of social risk perception. The proposed model would also be an effective model to study the risk perception of GM products in the social, economic and cultural contexts. The CSRPM can be used for ex-ante as well as ex-post assessments. This model is shown in Fig. 1.

According to the proposed model, the main factors affecting social risk perception of GM foods include:

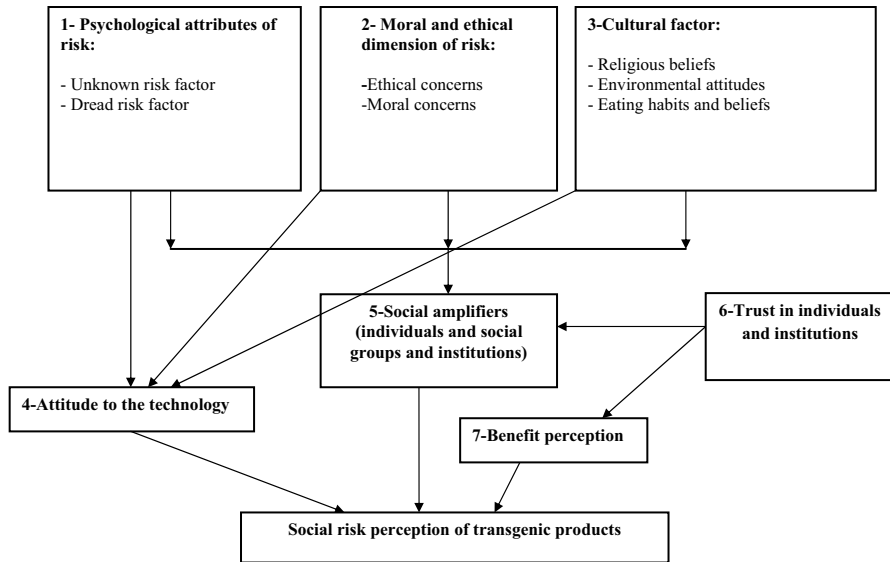


Fig. 1 Comprehensive social risk perception model of transgenic products

Psychological Attributes of Risk

The psychological model indicates some psychological attributes of risk that may play an important role in shaping people's social risk perception toward GM foods (Siegrist et al. 2006), including 'uncontrollable', 'delay effect', 'unpredictable', 'unfamiliar to science', 'being invisible', and 'being new to those exposed' (Siegrist et al. 2006). According to this model, people build risk perceptions based on cognitive (knowledge), and affective (emotional), and aspects (Wickson 2007).

Generally, two main categories of psychometric risk attributes can be identified: unknown risk (known vs. unknown) and dread risk (not dreaded vs. dreaded). The unknown risk factor reflects the extent to which GM food is unknown, unobservable, unfamiliar, and has delayed consequences. The dread risk factor reflects the extent to which GM food is seen as dreaded, uncontrollable, fatal, not equitable, high risk to future generations, not easily reduced, involuntary, and potentially catastrophic (Hall 2010).

These variables have been evaluated in other studies. For example, Balzekiene et al. (2014) revealed the anxiety caused by whether people feel they lack personal control of risks/unknown risks of GM foods. Results from another study revealed that feelings of "unknown consequences of GM food, risks posed to future generations, and unfairly distributed risks" can increase consumer risk perception toward GM foods (Poortinga and Pidgeon 2003). Siegrist et al. (2006) showed that lay people perceived that GM products have high "unknown risk" and "dread risk" so they have high risk perception about them.

According to our proposed model, psychological attributes of GM food risks indirectly influence social risk perception through affecting consumers' attitude toward

technology. It means that respondent perception of GM foods' psychological risks may affect their beliefs of new technologies and their usefulness as a whole and then influence their risk perception of GM foods.

Moral and Ethical Dimension of Risk

Moral models have suggested that moral and ethical dimensions of risk like 'tampering with nature' or 'unnatural risk' seem to be better predictors of risk perception than psychometric or cultural factors (Amin et al. 2014; Sjoberg 2000). It means that if people feel that GM foods have some moral and ethical attributes, they may perceive more risk about these foods. Shiva (2000) also showed that moral and ethical factors affected risk perception and therefore refusal of GM foods.

Moral aspects of GM crops are: the principle of 'public well-being', which enjoins institutions to protect and promote the best interests of the public, the 'people's rights' principle, which upholds their rights to have free choice as consumers, and finally, the principle of 'justice', which confirms the equitable division of the benefits and risk of GM foods (Goyal and Gurtoo 2011).

The Nuffield Council on Bioethics (2003) has added an additional key principle named the 'ethical status' of the natural world. According to this principle, 'tinkering' with nature is essentially wrong due to human manipulation to genetic attributes which could contradict certain religious beliefs (Yang 2013). Opponents were concerned about environmental ethics of GM crops such as cross-pollination from GM crops to related wild plants, and creating 'super weed' (Hall 2010).

The main effect of moral concerns on public acceptance of GM crops has been highlighted by several studies. For example, Azadi et al. (2011) concluded that GM foods are expensive and will not be available to poor farming communities and may even distort the economies of developing countries. Other scholars have considered the impossibility of conscious and free choice of food by consumers as the social risk of GM products (Chen and Li 2007; Wheeler 2009). Magnusson and Hursti (2002) concluded that vegetarians should be able to choose or avoid GM foods to which animal genes have been transferred. Maghari and Ardekani (2011, p. 114) also considered socio-ethical risks and concerns of GM products including "consumer rights to have mandatory labeling, independent testing for safety and environmental impacts, and liability for any damage" associated with these products. They argued that the majority of GM products confer benefits to multinational companies and the farming industry with dispersed costs to consumers, which is not ethical.

According to our proposed model, moral and ethical attributes of GM food risks have indirect influence on social risk perception through affecting consumers' attitude toward technology. It means that respondent perception of GM foods' moral and ethical risks may affect their beliefs of new technologies and their usefulness as a whole and then influence their risk perception of GM foods.

Cultural Factors

Cultural models are based on the fact that perception of risk goes beyond the individual, and it is a social and cultural construct reflecting values, beliefs, morals, history, and symbols (Jackson et al. 2006) such that Herrick (2005) has concluded that risk perceptions toward GM crops are culturally different. In this model some cultural factors such as environmental attitudes (Hall 2010), religious beliefs (Fritz et al. 2004), etc. have been found to have a significant effect on risk perception.

Since it has been argued that cultural theory predicts the essential beliefs and attitudes of cultures, innovations, environment and risks, it seems to be appropriate for appraising social risk perceptions of GM crops (Ng and Rayner 2010). Although individual attributes are important factors in explaining differences in risk perception, cultural theorists believe that there are also important cultural factors that are appropriate for exploring social risk perceptions. Therefore, cultural context may lead to different risk perceptions of GM foods (Hall 2010). Based on these statements, this variable has been added to the model.

According to the proposed model some cultural factors such as cultural beliefs about foods, environmental attitudes, and religious beliefs can affect social risk perception of GM foods. Other studies have also considered these factors. For example Siegrist (2001) revealed that cultural beliefs about foods may be important determinants for assessing GM foods' risk perception. In her study of GM food, Vicsek (2013) found that cultural values associated with food may be important in determining social risk perception of GM foods in any given country. Hall (2010) claimed that environmental issues and environmental attitudes influenced social risk perceptions of GM foods. Dunlap et al. (2000) had developed "The New Ecological Paradigm" (NEP) scale to explore environmental values that can influence GM foods risk perception (Hall and Moran 2006). The NEP scale includes five main aspects of environmental attitude: "balance of nature", "limits to growth" and "human dominance over nature", "the idea that humans, unlike other species, are exempt from the constraints of nature", and "the threat of an eco-crisis". These dimensions constituted people's overall environmental worldview (Ng and Rayner 2010).

Attitudes Toward Technology

Reflexive modernisation models have focused on modern and manufactured risk that is a novel risk of which we have little previous knowledge and experience, such as GM foods (Jabareen 2015). According to reflexive modernisation theory, science and technology not only lead to better living conditions (the 'positives'), but also expose people to hazards by e.g. environmental pollution, radiation, and climate change (the 'negatives'), which often go beyond national boundaries (Beck et al. 2003). This theory indicates that people tend to view science and technology with doubt and uncertainty. Most individuals think that scientific innovations would change every aspect of their life, without exception. They also feel that some new technologies, like GM foods, break down their beliefs of right and wrong.

Subsequently, they support this idea that science has made their lives healthier, more convenient and more comfortable. However, those who felt greater risks about GM foods probably have negative attitudes toward science and technology (Hall 2010). Schwartzman et al. (2011) in their study concluded that attitude towards technology and benefit perceptions are the main factors that predict risk perception of GM foods.

Grunert et al. (2003) in his study found that risk perception and negative beliefs of consumers toward GM foods arose in general attitudes to technology. In addition, Siegrist (2003) found that general attitudes towards technology influenced attitudes and perceptions about GM foods. Gaskell et al. (2003) in their study also reported that high social risk perception of Europeans regarding GM foods had been influenced by the fragility of nature and the impact of technology on nature (general attitude to the technology).

Therefore, the variable, attitudes toward technology was added to the proposed model of this study. This variable is expected to have a direct effect on social risk perception of GM foods. It means that positive attitudes toward the usefulness of new technologies such as GM foods can decrease social risk perception.

Social Amplifiers

Social amplification models indicate that some individuals and social entities (amplification stations) transfer and process signals about risk. They also have the ability to amplify or attenuate any risk in society. The individual might be a scientist or expert or, for example, a risk assessor; a social entity might be the news media, a cultural group, or an interpersonal network. The amplified risk perception leads to secondary impacts or ripples (Kasperson 2012). Social amplification is probably increased when the risks are serious and are associated with doubt and uncertainty. In essence, risk amplification occurs at two major stages: (1) the transfer of knowledge and information about the risk and (2) the response systems of society. Also, the social amplification framework of risk consists of seven phases which include risk events, sources of amplification, channels of amplification, social stations of amplification, individual stations of amplification, group and individual responses, ripple outcomes, and impacts (Wirz et al. 2018).

In the case of GM crops, the key actors of debate include: markets, hierarchical and egalitarian societies, entrepreneurs, bureaucrats and NGOs that have their own strengths and weaknesses as social resources (Hall 2010; Nordgard et al. 2015; Salleh 2008). Some scholars have claimed that the media have an effect on rejection of GM crops in some nations because they introduced these crops with considerable and unknown risks. For example, Vilella-Vila and Costa-Font (2008) found that public perception of GM crops' risks increased through news reports.

In this regard, a variable "social amplifiers" was included to the model proposed by this study. The variable covers the amplifying role of newspapers, TV, scientific books and journals, physicians, department of environment, scientific members in biosafety committee, NGOs, Ministry of Health and Medical Education, and Food Standard Institute.

Trust

Most stakeholders (such as consumers, producers, etc.) especially in developing countries have lack of extensive knowledge and information about new technologies such as GM foods (Siegrist et al. 2006). One way people make decisions in this situation is to rely on experts and institutions to manage risks and technologies. It means that when people cannot directly evaluate risks and benefits of GM foods they get information from professionals or other resources.

Some scholars claimed that trust is the influencing factor in the GM foods risk perception. For example Siegrist (2003) found that trust in organizations that are busy on GM research are the most important factor that influences both risk and benefit perceptions.

Chen and Li (2007) also found that trust in public authorities and regulators have a positive impact on the perceived benefit and a negative influence on the perceived risk of the products. Guehlstorf (2008) claimed that positive or negative perceptions to risky issues such as GM foods are related to the level of trust in governing structures. The degree of people's trust in risk managers determines the level of risk perception, and as a result, the acceptability of special activities or technologies.

Consequently, the factor of trust has been added to the proposed model. This model assumes that respondent's trust can indirectly affect social risk perception through direct influence on social amplifiers and benefit perception. It means that people's trust in social amplifiers leads to their attitudes being shaped based on information that the social amplifiers introduce and ultimately, it affects their risk perception. Also trust in information resources can increase perceptions of benefits and these perceptions may decrease risk perception of respondents.

Benefits Perception

Bredahl (2001) claimed that consumers' attitudes toward GM foods are shaped by their risk and benefit perception of these foods. This idea has been supported by other studies (Ghasemi et al. 2013; Ghanian et al. 2015; Chen and Li 2007). Fischhoff et al. (2000) claimed that more risk could be tolerated if activities offered more benefit. One reason for this is that people make decisions based on affect and cognition (Hall 2010). Applying this relationship to GM technology reflects that producing positive utility for GM foods causes a perception of low risk. Accordingly it has been claimed by many authors that acceptance of GM technology is low when perception of benefits is low and perception of risks is high (Spetsidis and Schamel 2002; Ghanian et al. 2015). Similarly, Grunert et al. (2003) found that risk perception of GM foods would not be easy to change by knowledge and information alone, but the experience of the benefits of these foods is the main contribution to modifying it. Furthermore, Bredahl (2001) concluded that risk was a barrier to benefit perception of GM foods.

In this regard, for considering the effect of GM foods' benefit perception on their social risk perception this variable has been added to the model. As can be seen in

Fig. 1, benefit perception has a direct effect on social risk perception. It means perceiving more benefits from GM foods can decrease social risk perception.

Research Method

This survey was conducted in 2017 to investigate factors influencing social risk perception of biotechnologists and plant breeders in training toward GM food based on the CSRP model. The population of this study consisted of graduate students of agricultural biotechnology and plant breeding disciplines in agricultural colleges ($N=429$) in Iran. The biotechnologists and plant breeders in training were selected as the study population, because they are the main sources of society's trust for future adoption or rejection of GM foods and their attitudes have a major impact on shaping attitude of the public.

A sample of 210 biotechnologists and plant breeders in training was randomly selected. Barlett et al. (2001) guidelines were used to determine the sample size. A stratified random sampling method, selecting universities as strata was used.

Variables and Measurements

Data for this study were collected using a structured questionnaire. The constructs were first developed via conducting a preliminary literature review. The face validity of the study instruments were established by an expert panel of the faculty. A pilot test was designed to determine the scales' reliability. Each scale includes several perceptions using ordinal ranking measures (from 1 to 5), according to which summation, the scale score is computed. The reliability of the scales was tested using Cronbach's alpha coefficients (see Table 1). The response rate (Baruch and Holtom 2008) was complete ($RR=100\%$) since all the interviews were personally conducted by the first author, a process which took 3 months.

Results and Discussion

Profile of Respondents

In order to give the profile of respondents, a brief description of their characteristics is presented. The results showed that 59% of respondents live in big cities and metropolises and 41% of them live in small towns and villages. Most of them (63.5%) were female and all of them had high levels of education.

The biotechnologist and plant breeders in training perceived (Table 2) fairly low level of psychological risks (newness, unfamiliar, uncontrollable, etc.) about GM foods ($\bar{x}=2.89$) and feel that these foods are not in conflict with their religious beliefs and are ethically fairly acceptable ($\bar{x}=2.11$). Furthermore, respondents were very committed to ethical principles ($\bar{x}=4.02$). In other words, they observed people and animals' rights, socio-ethical principles, and attempted to help the poor

Table 1 Study variables

Variable	Definition	Measurement	Cronbach's alpha coefficient
Social risk perception	Concern and uncertainty in the consumer's mind that the particular purchased and consumed food probably will cause health risk, environmental risk, or socio-ethical risk	It was measured including 3 indicators: health risk perception with 11-item scale (gene mutation, allergenicity, etc.), environmental risk perception with 8-item scale (threaten natural genetic balance, transform safe species to unsafe, etc.), and socio-ethical risk perception with 9-item scale (interfering in God's creation, increasing the gap between rich and poor, etc.); ordinal variable ranging from 1 (Strongly disagree) to 5 (Strongly agree)	0.74
Eating habits and beliefs	The way a person or a group eats, considered in terms of what types of food are eaten, in what quantities, and when according to his or her cultural and religious beliefs	It was measured with 7-items including natural and free of preservatives, dietary, less chemical inputs, home-grown, etc.; ordinal variable ranging from 1 (Strongly disagree) to 5 (Strongly agree)	0.80
Moral beliefs about GM foods	Personal views about morality of GM foods	It was measured with 8 items including contrary to my religious beliefs, GM animal food is morally unacceptable, etc.; ordinal variable ranging from 1 (Strongly disagree) to 5 (Strongly agree); ordinal variable ranging from 1 (Strongly disagree) to 5 (Strongly agree)	0.94
Commitment to ethics	A duty, a moral obligation, or personal boundary and the morals a person goes by	It was measured with 11 items include being good and acceptable in social settings, have rules and ethics and following them, tell the truth, etc.; ordinal variable ranging from 1 (Strongly disagree) to 5 (Strongly agree)	0.81
Level of religiosity	Adopting a certain religious creed and numerous aspects of religious activity, dedication, and belief (religious doctrine)	It was measured with 10 items including implementation of religious customs, allocated time to perform religious duties, etc.; ordinal variable ranging from 1 (Strongly disagree) to 5 (Strongly agree)	0.74

Table 1 (continued)

Variable	Definition	Measurement	Cronbach's alpha coefficient
Attitude toward the use of technology	Individual's positive or negative feelings about using technology in life	It was measured with 8 items which include make life easier by using new technologies, created environmental problems, poverty can be eradicated in the world, etc.; ordinal variable ranging from 1 (Strongly disagree) to 5 (Strongly agree)	0.51
Attitude toward environment	Individual's views about the environment	It was measured with 14 items (humans were not meant to rule over the rest of nature, the earth is like a spaceship with very limited room and resources, When humans interfere with nature it often produces disastrous consequences, etc.	0.54
Social amplifiers	Individuals, social groups and institutions that can amplify or diminish risks of GM foods	It was measured using 19 items including Internet, mass media, scientific books and journals, etc.; ordinal variable ranging from 1 (not at all) to 5 (very high)	0.86
Trust in individuals and agencies	People's willingness to rely on experts and institutions in the management of risks and technologies	It was measured with 8 items including researchers, government, Standard Institute, etc.; ordinal variable ranging from 1 (Strongly disagree) to 5 (Strongly agree)	0.60
Social benefit perception	Personal views about GM foods social benefits	It was measured with 17 items including 3 indicators, economic benefits perception with 6-item scales (higher yields, longer storage shelf-time, etc.), environmental benefits perception with 5 items (higher environmental protection, reduce pesticide use, etc.), and health benefits perception with 6-item scales (higher nutrients' quality, Reduce Malnutrition, etc.); ordinal variable ranging from 1 (Strongly disagree) to 5 (Strongly agree)	0.95

Table 1 (continued)

Variable	Definition	Measurement	Cronbach's alpha coefficient
Psychological attributes of risks	Psychological factors such as catastrophic, dread, unobservable, uncontrollable, etc.	It was measured with 10 items and each item represented one of the psychological risks of GM foods; ordinal variable ranging from 1 (Strongly disagree) to 5 (Strongly agree)	0.95

Table 2 Descriptive statistics of respondents' perception variables

Study variables	Mean ^a	SD
1. Psychological attributes of risks	2.89	1.05
2. Moral beliefs about GM foods	2.11	0.89
3. Commitment to ethics	4.02	0.46
4. Level of religiosity	3.52	0.70
5. Attitude toward environment	3.31	0.33
6. Attitude toward the use of technology	3.52	0.53
7. Eating habits and beliefs	3.42	0.69
8. Social amplifiers	3.24	0.62
9. Trust in individuals and agencies	3.14	0.62
10. Social benefit perception	3.92	0.73

^aPossible mean range: 1–5

and be trustworthy. Results showed that respondents were fairly religious persons ($\bar{x}=3.65$), such that religious legitimacy about foods is important to them, they allocate time to perform religious duties and believed that religious persons are more reliable. Reviewing findings in Table 2 indicates that respondents had moderate mean on variables like eating-habit trends ($\bar{x}=3.42$) and attitude toward environment ($\bar{x}=3.42$). These findings show that respondents prefer to use natural, organic and homemade foods instead of industrial foods, and believe that environmental protection is very important and therefore ought not to be modified to suit human needs. They also believed in efficient use of limited natural resources. These respondents have appropriate trust in researchers, physicians, and Food Standard Institute.

In the case of GM foods' benefit perception, results showed that respondents have fairly high perception ($\bar{x}=3.92$). In fact, they believed that GM foods can generate more health (owing to higher nutrients' quality, increased food security, etc.), environmental (higher environmental protection, reduce pesticide use, etc.), and economical (higher yields, lower production costs, etc.) benefits. Respondents also had positive attitudes about the use of technology ($\bar{x}=3.52$). In other words, they believed that life would be more comfortable and the environment more protected by using new technologies. In general, they think that benefits of technologies are more than their risks.

Social Risk Perception of Respondents

The respondents' social risk perception of GM foods was investigated by computing environmental, health and socio-ethical risk perception indexes. Results have been shown in Table 3. Considering the possible range (1–5), engineers in training have moderate health risk perception about GM foods ($\bar{x}=2.60$). In other words, respondents believed that consuming GM foods may have unknown impact on health in the long run; the allergic reactions in some people, the human resistance to antibiotics and some rare and unknown disease in humans. Furthermore, in the case of environmental risk perception index ($\bar{x}=2.70$), respondents have some concerns about negative impacts of GM foods for the natural environment such as threat to natural

Table 3 Social risk perception and its aspects

Variables	Mean ^a	SD	Rank
1. Environmental risk perception of GM foods	2.70	0.69	1
2. Health risk perception of GM foods	2.60	0.74	2
3. Socio-ethical risk perception of GM foods	2.41	0.69	3
Total Social risk perception of GM foods	2.57	0.65	

Boldface entry indicates the computed value for social risk perception of GM foods, on a scale from 1 to 5

^aPossible mean range: 1–5

genetic balance to compete with other non-GM foods to get healthy food; the loss of beneficial insects; and the creation of new bacteria and viruses. Also, respondents had some socio-ethical risk perceptions about GM foods ($\bar{x}=2.41$). Respondents have stated that the main socio-ethical concerns of GM foods to Iranians are about creating disorders in human and animals; animal suffering due to altering GM technology choices for producing high quality products; increasing the gap between the rich and the poor in the country; increasing risks facing future generations (such as water, soil, natural resources property, etc.).

Total social risk perception of GM foods has been achieved by computing the above three indexes. As can be seen in Table 3, respondents have perceived moderate level of GM foods' social risk perception ($\bar{x}=2.57$). The engineers in training will have more concerns about social risks of these crops and believe that these crops probably will have negative effects on human health and environment and are in conflict with socio-ethical beliefs of people. This finding is supported by Traill et al. (2005), Chern et al. (2002) and Hossain et al. (2003) studies, that indicated the main social risks of GM products including human and environmental health risks.

Determinant of Social Risk Perception

Independent Latent Variables: Confirmatory Factor Analysis Results

The uni-dimensionality of each construct was assessed through confirmatory factor analysis (CFA) and the reliability tests (Cronbach's alpha). This was crucial to ensure that each set of indicators has only one underlying trait or construct in common (Gursoy and Rutherford 2004). Cronbach's alpha scores shown in Table 4 indicate that each construct exhibited strong internal reliability. The items or indicators with high cross-loadings on other factors are deleted as the threshold for factor loadings was set at 0.30 (Hair et al. 2006; Aiken 1997). Table 4 shows the results of CFA and the factor loadings larger than 0.5 for the measurement scale of social risk perception on GM foods using maximum likelihood estimation. The Cronbach's alpha coefficients for the majority of the constructs were considered good (above 0.50; Table 4). The factor loadings and composite reliability were assessed to test convergent validity (Hair et al. 2010). The standardized loadings of all factors were greater than 0.5 indicating good convergent validity (Table 4).

Table 4 Confirmatory factor analysis

Construct/indicator	Item	Standardised factor loading	Cronbach's alpha	Mean	SD
1. Psychological attributes of risks	PAR1	0.85	0.95	2.85	1.07
	PAR2	0.71			
	PAR3	0.84			
	PAR4	0.94			
	PAR5	0.92			
	PAR6	0.87			
	PAR7	0.87			
	PAR8	0.86			
	PAR9	0.71			
2. Ethical and moral commitments	EMC1	0.79	0.76	2.11	0.89
	EMC2	0.86			
	EMC3	0.74			
	EMC4	0.87			
	EMC5	0.87			
	EMC6	0.88			
	EMC7	0.74			
	EMC8	0.82			
3. Level of religiosity	LR1	0.73	0.74	3.63	0.77
	LR2	0.81			
	LR3	0.55			
	LR4	0.55			
	LR5	0.79			
	LR6	0.86			
	LR7	0.72			
	LR8	0.58			
4. Attitudes toward environment	ATE1	0.64	0.54	3.75	0.79
	ATE2	0.57			
	ATE3	0.51			
	ATE4	0.50			
5. Attitudes toward technology	ATT1	0.58	0.51	2.79	0.77
	ATT2	0.77			
	ATT3	0.53			
	ATT4	0.50			
6. Social amplifiers	SA1	0.74	0.86	3.18	0.72
	SA2	0.78			
	SA3	0.72			
	SA4	0.64			
	SA5	0.58			
	SA6	0.56			

Table 4 (continued)

Construct/indicator	Item	Standardised factor loading	Cronbach's alpha	Mean	SD
7. Trust	T1	0.79	0.60	3.23	0.84
	T2	0.76			
	T3	0.84			
	T4	0.56			
	T5	0.50			
8. Social benefit perception	SBP1	0.72	0.95	3.97	0.75
	SBP2	0.75			
	SBP3	0.77			
	SBP4	0.77			
	SBP5	0.86			
	SBP6	0.81			
	SBP7	0.80			
	SBP8	0.80			
	SBP9	0.70			
	SBP10	0.77			
9. Social risk perception	SRP1	0.75	0.74	2.84	0.63
	SRP2	0.73			
	SRP3	0.82			
	SRP4	0.78			
	SRP5	0.72			
	SRP6	0.68			
	SRP7	0.67			
	SRP8	0.62			
	SRP9	0.63			
	SRP10	0.66			
	SRP11	0.65			
	SRP12	0.60			
	SRP13	0.59			

Testing of the Proposed Model: Structural Equation Results

After verifying the uni-dimensionality of the measurement scale, SEM was carried out using AMOS 20 structural equation program with a maximum likelihood function. A series of four nested models were tested to determine the most parsimonious models with the best fit for social risk perception of GM foods. Additionally, to increase the model fit, according to Hair et al. (2010), three items with large standardized residual covariances were dropped in the third model. In the fourth model, an additional path suggested by the modification index was included (Byrne 2010). Only 19 hypothesized paths (cut-off $p < 0.05$) based on the likelihood ratio statistic were retained in the final model (Fig. 2). According to Hair et al. (2010) and

$n=210$, $cmin=2.040$, $df=2$, $p=.361$, $RMSEA=.010$, $CFI=1.000$, $NFI=.997$

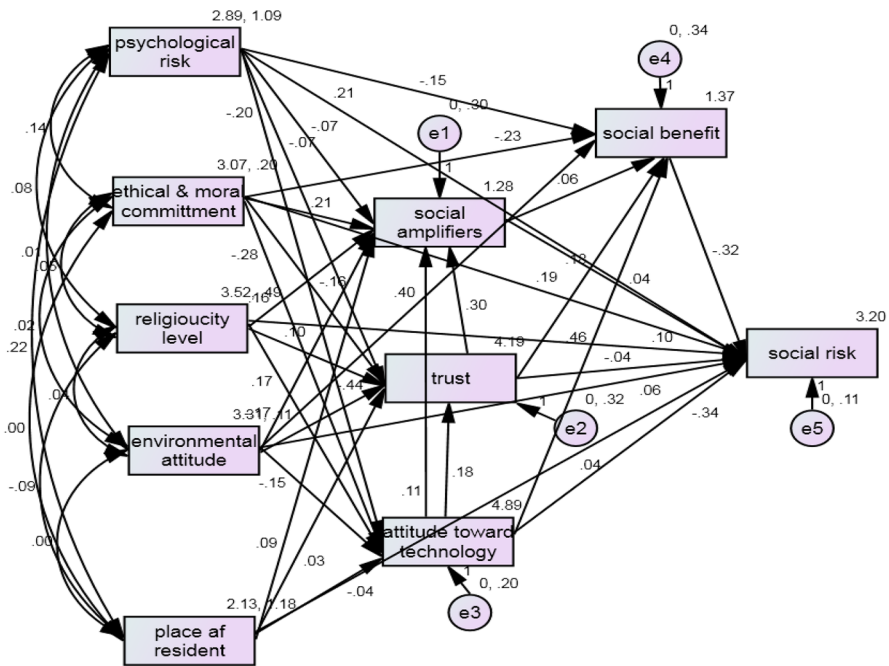


Fig. 2 Factors influencing GM food's social risk perception

Zainudin Awang (2012), a well-fitting model should evidence a comparative fit index (CFI), Tucker–Lewis index (TLI) and normed fit index (NFI) values greater than 0.90, and a root-mean-square error of approximation (RMSEA) value of < 0.05 as an indicator of a good model fit. Inspection of the RMSEA, CFI, NFI and TLI revealed that the final model was found to have a good fit with $\chi^2/df=1.020$, CFI of 1.00, NFI of 0.99, TLI of 0.99 and RMSEA of 0.01 with a 90% confidence level.

Correlation of Proposed Latent Variables Within a Confirmatory Factor Analysis

The preconditions for the implementation of path analysis was explored through, Pearson correlation analysis (Table 5).

These coefficients show that the relationship between social risk perception and psychological risks, moral beliefs, and place of residence are positive and significant, while trust, attitude toward technology and social benefit perception has significant negative relation with social risk perception.

This suggests that respondents with high perceived psychological risks about GM foods (e.g. GM foods have unknown, uncontrollable, involuntary, and long term effects) also have high level of perceived social risk. However, respondents who think GM crops production is in conflict with their religious beliefs, and is interfering in God's creation, or is generally not morally acceptable, perceived higher social

Table 5 Correlation coefficient of proposed latent variables

Variables	1	2	3	4	5	6	7	8	9	10
1. Psychological risk	1									
2. Moral beliefs	0.29**	1								
3. Level of religiosity	0.11	0.17*	1							
4. Attitude toward environment	0.20	0.15*	0.15*	1						
5. Place of residence	0.20	-0.005	-0.11	-0.009	1					
6. Social amplifiers	-0.12	0.03	0.19**	-0.12	0.08	1				
7. Trust	-0.22**	-0.21**	0.06	-0.25**	-0.02	0.35**	1			
8. Attitude toward technology	-0.44**	-0.31**	0.13	-0.09	-0.17*	0.19**	0.28**	1		
9. Social benefits perception	-0.43**	-0.31**	0.10	0.08	-0.06	0.16*	0.28**	0.50**	1	
10. Social risks perception	0.68**	0.46**	0.09	0.07	0.18**	-0.10	-0.30**	-0.65**	-0.68**	1

* $p < 0.05$; ** $p < 0.01$

risks in GM foods. Furthermore, people who live in big towns perceived higher social risks in GM crops than others. This finding is supported by Hall (2010), Frewer et al. (2013), Ng and Rayner (2010) and Renn (2008).

The maximum correlation coefficient refers to the relationship between social risk perception and two variables of psychological risks and social benefit perception and is equal to 0.68 and -0.68 , respectively. The minimum amount of correlation coefficient is related to the relationship between attitude toward environment and two variables of moral beliefs and level of religiosity, and is equal to 0.15. It should be noted that the maximum value of variables refers to social benefit perception and the lowest belongs to social risk perception.

Analysis of the Structural Model: Path Analysis

In order to understand how the exogenous variables (psychological attributes of risks, moral and ethical beliefs, level of religiosity, attitude toward environment, place of residence, social amplifiers, trust, attitude toward technology, and social benefits perception) introduced in the research model (Fig. 1) can (directly/indirectly) influence the endogenous variable (social risks perception), path analysis was conducted using AMOS software. The results of path analysis are shown in Table 6. Figure 2 also presents the results of the path analysis with non-significant paths as dotted lines, and the standardized path coefficients between constructs. Social risk perception on GM foods in this study was jointly predicted by psychological attributes of risks ($\beta = -0.34$, $p < 0.001$), social benefit perception ($\beta = -0.36$, $p < 0.001$), attitude toward the use of technology ($\beta = -0.28$, $p < 0.001$), level of religiosity ($\beta = 0.11$, $p < 0.001$), and moral and ethical beliefs

Table 6 Path analysis coefficients of the exogenous and endogenous variables (estimated by AMOS)

Variables	Direct effects	Indirect effects	Total direct effect	SE	R ²	Correlation coefficient
1. Psychological attributes of risks	0.34**	0.24	0.58	0.02	0.65	0.68**
2. Moral and ethical beliefs	0.13**	0.16	0.29	0.05	0.73	0.46**
3. Level of religiosity	0.11**	0.10	0.01	0.04	0.74	0.09
4. Attitude toward environment	0.02	-0.01	0.02	0.07	–	0.07
5. Place of residence	0.06	0.03	0.09	0.02	–	0.18**
6. Social amplifiers	0.04	-0.10	0.02	0.04	–	-0.10
7. Trust	0.04	0.05	0.09	0.05	–	-0.30 **
8. Attitude toward technology	-0.28 **	-0.13	-0.41	0.06	0.70	-0.65 **
9. Social benefits perception	-0.36 **	0.000	-0.36	0.04	0.46	-0.68 **

* $p < 0.05$; ** $p < 0.01$

about GM foods ($\beta=0.13$, $p<0.001$). These variables explained 74% of the variance in social risk perception ($R^2=0.74$).

The direct effects (D.E.) of the variable in Table 6 explain that “social benefit perception” is the most effective factor which has a significant negative effect on the social risk perception of the respondents toward GM foods (D.E. = -0.36 ; $p<0.01$). In other words, when social benefit perception scores increase, social risk perception scores decrease. This finding can be supported by Chen and Li (2007) who found that more risk perception of GM foods arise from less perception of benefits. Furthermore, Grunert et al. (2003) concluded that the negative attitude toward GM foods that was shaped by risk perception would be changed by the experience of products that offer benefits to the consumers (benefit perception). Findings of a similar study by Hall (2010) have shown that respondents with high risk perception about GM foods had low benefit perception about them.

The psychological attributes of risks have a significant positive direct effect on the social risk perception of GM foods (D.E. = 0.34 ; $p<0.01$). It means if a particular GM food has more psychological attributes of risks such as unknown, involuntary, uncontrollable, unpredictable, newness, catastrophic, etc., then its social risk perception will rise. Indirectly, this factor affects the social risk perception by influencing social benefit perception of GM foods and attitude toward the use of technology. In other words, engineers in training who perceived less benefit from GM foods or have negative attitude about use of new technologies in life, probably would have more psychological risks about GM foods and as a result would have perceived more risk perception of these foods.

This finding is supported by Balzekiene et al. (2014) who stated that the psychological attributes such as uncontrollable and unknown risks influenced GM foods’ risk perception. Results from another study by Poortinga and Pidgeon (2003) revealed that unknown consequences, long-term risks to future generations, and unfairly distributed risks can affect social risk perception and enhance it. Furthermore, Siegrist et al. (2005) showed that in the case of GM foods, dread, unknown, and catastrophic psychological risks exert a more direct effect on social risk perception of GM foods. Results from other studies such as Fern Wickson (2007), Janus Hansen et al. (2003) and Miles and Frewer (2003) have supported these results.

Attitude toward the use of technology has a significant negative direct effect on the social risk perception of GM foods (D.E. = -0.28 ; $p<0.01$). In other words, engineers in training who think that the application of new technologies has created environmental risks on human life, and generally have negative attitudes toward new technologies, perceived more social risks of GM foods. This finding is supported by Siegrist (2003), Gaskell et al. (2003), Hall (2010) and Schwartzman et al. (2011). Siegrist (2003) and Gaskell et al. (2003) found that beliefs and attitudes towards technology significantly influence the risk perceptions of GM foods. Schwartzman et al. (2011) in their study concluded that attitude towards technology is the main factor predicting the risk perception of GM foods.

Results indicate that moral and ethical beliefs about GM foods have a significant positive direct effect on the social risk perception of GM foods (D.E. = 0.13 ; $p<0.01$). In other words, respondents with stronger moral and ethical beliefs have

more negative general attitudes toward the use of technologies in life and consequently have high risk perception about GM foods (as new technology).

This finding is supported by other scholars. Connor and Siegrist (2010) in their study have concluded that moral and ethical beliefs have significant influence on people's risk perception toward GM foods. Frewer et al. (2013) found that moral and ethical factors affected people's social risk perception of GM foods. Similar findings from the study of Poortinga and Pidgeon (2003) supported that moral concerns about GM foods have direct effect on risk perception.

Level of religiosity has a significant positive direct effect on the social risk perception of GM foods ($D.E.=0.11$; $p<0.01$). In other words, religious respondents will perceive more social risks associated with GM foods and indirectly, it affects social risk perception by influencing attitude toward the use of technology and social amplifiers. In other words, people with a high level of religiosity, have a more negative attitude toward the use of new technologies (such as GM foods) and have more trust in social amplifiers, so they will perceive more social risk perceptions about GM foods. This finding is supported by Chen and Li (2007), Latifah et al. (2006) and Fritz et al. (2004). They also found that religious beliefs or customs have significant effect on risk perception of GM foods.

Conclusion and Recommendations

Based on current literature this study developed a comprehensive model to explain and predict the social risk perceptions of GM food production. The model is called comprehensive due to the fact that it is multi-dimensional and in addition to dimensions considered in previous models, it covers aspects such as attitude toward environment, attitude toward technology, level of religiosity, and social benefit perception. Hence, the proposed model makes an important contribution to the emerging literature on risk perception, especially with regard to GM food development. The results suggest that the comprehensive model has good explanatory power and is robust in predicting risk perception of GM foods. The model can be used for ex-ante and ex-post risk perception assessment in both developed and developing countries.

The findings of this study also shed light on some important issues related to engineers in training's social risk perception about GM foods that have not been addressed in previous studies. The results revealed that biotechnologist and plant breeders in training had moderate social risk perception about GM foods. Since this group has adequate knowledge about GM foods, this level of social risk perception is significant or valued. This group is future engineers and experts of GM foods that can significantly affect other peoples' risk perception and attitudes toward GM foods.

The findings suggest that the perceived benefit, psychological risks, attitudes toward technology and moral-religious beliefs are the main drivers of future biotechnologists and plant breeders social risk perception of GM foods, where perceived social benefits have the greatest negative effect, and the psychological attributes of risks have the greatest positive effect. This study provides an initial scheme to develop further understanding of this causal relationship.

Results also revealed that level of religiosity has significant effect on social risk perception. The religious engineers in training have perceived more social risks of GM foods than others. Hence, it is suggested to clarify the religious legitimacy of GM foods by religious scholars. Furthermore, it is recommended to improve knowledge of the Iranian religious scholars about real advantages and disadvantages of GM foods through journals, TV and radio programs, workshops, seminars, catalogues, conferences.

This study reveals that the social benefit perception and psychological attributes of risks are the most influential factors, implying that increasing the benefit perception and decreasing psychological attributes of GM crop risks will decrease social risk perception of these foods. So, it is suggested that by publishing valid scientific articles, providing radio and television programs, workshops, etc., the public's knowledge and awareness of real benefits of GM foods would be increased and the ambiguity and newness of GM product's risks and therefore their social risk perceptions would be decreased. Also, it can be suggested that the engineers try to identify and research on some GM foods that have more social benefits and fewer risks for introduction in Iran.

Finally, for better understanding of social risk perception of other crucial stakeholders of GM foods in Iran such as consumers, producers, and agricultural managers, the use of proposed model is recommended. The model developed by this study and the methodology adopted can be used to assess the social risk of GM foods in other countries and to have a more informed adoption or rejection of these foods.

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