Perceptions and attitudes of the Mexican urban population towards genetically modified organisms

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Abstract

Purpose – The purpose of this paper is to measure Mexicans' perceptions and attitudes about the production and consumption of genetically modified organisms (GMOs).

Design/methodology/approach – A questionnaire with 63 questions that encompassed 11 latent factors was used to obtain information. The questionnaire was administered to 14,720 people in Mexico's urban areas.

Findings – The results revealed important similarities and differences with studies in other countries, showing mainly that the respondents did not have sufficient information about GMOs, they have low level of knowledge about GMOs (31.28 percent), are highly distrustful of GMOs, perceive high risk regarding GMOs (59.13 percent), want transgenic products to be labeled (93.59 percent) and do not perceive GMOs' social values and positive health effects beyond increasing agricultural productivity. Also, it was observed that the higher the educational level of individuals, the lower the acceptance of GMOs.

Research limitations/implications – The authors conclude that it is necessary to generate and provide scientifically accurate information on GMOs, so that people are better informed and can give a critical opinion on the use of GMOs.

Practical implications – The major practical contribution of this research is that it provides empirical knowledge about the perceptions and attitudes toward the production and consumption of GMOs among the Mexican's urban society, which can be of great help for the Mexican government to rethink if it is an appropriate moment to completely open the doors to international companies to cultivate crops like maize and others that have been postponed due to pressure from the environmental groups, farmers and other sectors of the society.

Social implications – This is especially important in the context of maize as it is part of the cultural heritage of Mexico since ancient times. However, it is not clear what the overall perception is in the Mexican society on the use of GMOs for cultivation.

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Originality/value – Southern regions of Mexico are the center of origin of several cultivated plants such as maize and legumes. The introduction of GMOs, called transgenics, in agriculture and food continues to cause enormous controversy in the perceptions and attitudes mainly among environmental groups and farmers in Mexico.

Keywords Consumer attitudes, Consumer perceptions, Food safety, Consumer risk, Genetically modified foods

Paper type Research paper

1. Introduction

A genetically modified organism (GMO) or transgenic is defined as a living organism that is artificially created using genetic engineering (GE) through insertion of genes from other species (virus, bacteria, other plants and animals and even humans) into a plant, animal or microorganism. This engineering is done mainly to produce food and pharmaceutical products (Geoffrey *et al.*, 2014). These alterations to the genome allow scientists to bypass the natural selection process by transferring genetic material from one naturally incompatible species to another. However, this is not new; humanity has changed the genetics of plants and animals indirectly through cultivation and selective breeding over the last 10,000 years (Zohary *et al.*, 2012).

Biotechnology – defined as the use of biological processes to produce new types of products – has proved to be a useful tool for innovation in agriculture. The use of transgenic seeds and plants has spread in several countries due to their higher productivity, environmental sustainability and resistance to pests and drought (Hansson and Joelsson, 2013). Because of this cross-border transgenic traffic and growing globalization, agents involved in promoting biotechnology (politicians, scientists, business and social organizations) have expressed concern at the social debates surrounding biotechnology (Muñoz, 2004).

Public awareness of the importance of food safety has increased in recent decades, despite the broad scientific consensus that products derived from genetically modified (GM) crops do not pose any risk (American Association for the Advancement of Science, 2012; Blancke *et al.*, 2015). Discussions on the use of GMOs to generate products for human consumption have increased, and those opposed to their use argue that the risks have not been fully identified and question the objectivity of the authorities that regulate them.

For decades, governments of several countries have worked on developing guidelines to ensure safe use of GE products. For example, the Cartagena Protocol, ratified by about 160 nations, is an international agreement that seeks to ensure the handling, transport and safe use of GMOs resulting from the application of GE; it also contemplates their adverse effects on biodiversity and the potential risks to human health (Gupta, 2000). However, these principles are not being applied as expected. Therefore, it is necessary to know the perceptions and attitudes toward the production and consumption of GMOs, which can vary according to sociodemographic conditions (Corti, 2010).

In Mexico, biosafety-related issues were considered for the first time in 1987, but only to regulate health-related research activities and respond to requests by agrobiotechnology corporations for permission to experiment with GM crops (Jaffé and Zaldívar, 1992). According to the Food and Agriculture Organization (FAO), in Mexico, maize, wheat, cotton and soybean GM crop cultivation stands out (Organización de las Naciones Unidas (FAO), 2013). However, the introduction of GM crops (especially maize) has generated enormous controversy in the perceptions and attitudes mainly of

environmental groups and farmers. This is the reason why several sectors of society have come to the defense of the controversial seed. Rural and urban social movements argue the need for sustainable agriculture and the search for alternatives to create a more just-rural world. In addition, there are also different opinions about GMOs where the lack of knowledge about the advantages and/or disadvantages of genetic, economic, social, cultural, public health and ecological terms is observed. In view of the above, there is a clear need to conduct a comprehensive analysis of the situation to make the best decision on the feasibility of using these types of biotech crops (Reséndiz-Ramírez *et al.*, 2014).

To be able to measure the perceptions and attitudes of Mexico's urban population toward the production and consumption of GMOs, we chose to develop an original tool based on, but not the same as, tools developed and applied in other parts of the world. The reason for developing such a tool was because other tools were created for very specific populations, and we did not find a valid instrument that could be used for the Mexican urban population.

This paper contributes to the study of the perceptions and attitudes of the Mexican urban population toward the production and consumption of GMOs. Therefore, we present a descriptive analysis of the perceptions and attitudes in general and by educational level.

2. Materials and methods

2.1 Participants

To achieve validity at the regional level and similar levels of precision in each region, and based on a literature review and consulting experts, we proposed to estimate proportions close to 13 percent with a maximum relative error of about 17 percent, with a 90 percent confidence level; we used a value of 2.84 of design effect for each region. We assumed a response rate of 75 percent and established 1.29 as the average number of people per household. Regional sample size was determined using the following formula (Olaiz-Fernández *et al.*, 2006):

$$n = \frac{\left(Z_{\alpha/2}\right)^2 (1-p)(\mathrm{DEFF})}{r^2 (p)(\mathrm{RR})(h)}$$

where n is the sample size of households, p the proportion to estimate, $Z_{a/2}$ the quantile of a normal distribution associated with the $(1-\alpha) = 0.90$ confidence level, r the maximum relative error, DEFF the design effect (which is generally interpreted as the number of units collected by the survey that are equivalent, for estimation purposes, to a unit collected by a simple random sampling), RR the expected response rate and h the average number of people per household. Using this formula, we ended up with a sample size of 1,840 households per region. The sample size by region (1,840 households) was distributed in proportion to the geostatistical basic area units (AGEBs) that make up the region. The selection of primary sampling units is made up of the AGEBs listed in the 2010 Mexican census and the AGEBs of the 2010 census not listed in the 2010 census. Therefore, the selection of sample units was carried out in multiple stages, beginning with locations within each region, AGEBs within each location, blocks within each AGEB, households within each block and finally one individual within households. Table I presents the distribution of the 14,720 surveys taken nationally.

In each household, we selected an adult aged between 18 and 65 years. Similarly, in each selected block of households, one household at each cardinal point was selected. The survey was conducted from May 22 to July 22, 2015, using the instrument given in Table II. The information collected shows that the percentages of women and men surveyed were almost equal, 50.96 and 49.03 percent, respectively. We observed a greater participation of people between 30 and 44 years of age (35.37 percent), followed by individuals younger than 30 years (25.61 percent), people 55 years or older (20.98 percent) and finally people between 45 and 54 years (18.03 percent). Most respondents had only secondary education (30.88 percent), followed by high school (28.04 percent), primary education (or less) (25.52 percent) and undergraduate or higher education (15.55 percent).

2.2 Measuring instrument

The data collection instrument was based on studies conducted in different countries, and it attempted to characterize those factors that measure perceptions and attitudes toward the production and consumption of GMOs. We identified 11 such factors: knowledge, trust, perceived benefits, perceived risks, attitude toward technology, attitude toward gene technology, religion, labeling, societal values, attitude toward buying and attitude toward promotion. After a pilot study and corrections done to the first versions of the instrument, we finally got the questionnaire shown in Table II, which consists of 11 factors and 63 binary items (1 = yes, 0 = No) that measure the perceptions and attitudes of the Mexican urban population toward the production and consumption of GMOs.

Also, for each of the 11 factors, we created a new variable that describes the observed average per factor, which was determined based on the items in each factor. The variables are KNpro, TRpro, PBpro, PRpro, ATTpro, AGTpro, RELpro, LApro, SVpro, ABpro and PROpro and correspond to the following factors: knowledge, trust, perceived benefits, perceived risk, attitude toward technology, attitude toward gene technology, religion, labeling, societal values, attitude toward buying and attitude toward promotion. Also, five socio-demographic factors were asked: educational level (categories: 1 = elementary school or less, 2 = middle school, 3 = high school and 4 = college or higher), age groups in years (categories: < 30, 30-44, 45-54 and $\geqslant 55$), labor sector (categories: agriculture, cattle raising, fishing, manufacturing, trade, service, forest, mining, construction, home, transport and others), mass media from where they learnt about GMOs (categories: radio, newspapers, magazines, social networks, friends, specialized literature, internet, academic meetings and others) and gender (male and female). However for reasons of space, only we present the results for

Id	Region	Provinces	Locations	AGEBs	Blocks	People
1	Mexico City	1	13	98	500	1,840
2	South Central	4	19	98	547	1,840
3	North Central	3	14	103	511	1,840
4	Northeastern	3	17	100	504	1,840
5	Western	5	16	95	511	1,840
6	South	5	18	96	504	1,840
7	Center	5	19	94	505	1,840
8	Northwest	4	14	100	502	1,840
	National	30	130	784	4,084	14,720

Table I. Distribution of the sample by region in Mexico

Latent factor	Item	Item
Knowledge (KN)	KN1	Do you know what genetically modified organisms or transgenics are?
	KN2	Do you know the difference between "genetically modified organisms" and "conventionally modified organisms"?
	KN3	Do you know what are the transgenic food products for human consumption?
	KN4	Do you know which transgenic food products we eat in our country?
	KN5	Do you know a transgenic product for human consumption that is imported into Mexico?
	KN6	Have you ever eaten a transgenic food product?
	KN7	Do you know that some crops may become resistant to certain pests by genetic modification?
	KN8	Do you know if there are laws or regulations that regulate the production and consumption of genetically modified products in Mexico?
	KN9	Do you know that some drugs for humans, such as insulin and some clotting factors, are produced with "genetically modified organisms"?
Trust (TR)	TR1	Do you have confidence in the work of scientists who are genetically modifying plants and animals, in order to generate products for human consumption?
	TR2	Do you have confidence in scientists in Mexico and around that world who work in universities and are genetically modifying plants and animals for human consumption?
	TR3	Do you have confidence in companies that are genetically modifying plants and animals for human consumption?
	TR4	Do you have confidence in pharmaceutical companies that are using transgenic plants and animals to produce medicines?
	TR5	Do you have confidence in farmers who are using genetically modified seeds to increase the generation of food products?
	TR6	Do you have confidence in companies who make products with genetically modified ingredients for human consumption?
Perceived benefits (PB)	PB1	Do you think that genetically modified crops will bring benefits to the environment of our country?
	PB2	Do you think that the production of transgenic products will bring benefits to you and your family?
	PB3	Do you think that crops with genetically modified seeds will increase crop production in Mexico?
	PB4	Do you think it is beneficial that companies make medicines for human consumption based on genetically modified animals and plants in Mexico?
	PB5	Do you think that genetically modified products will help to improve the nutrition of Mexicans?
	PB6	Do you think that consumption of genetically modified products will improve the Mexican economy?
	PB7	Do you think that genetically modified products are improving the nutritional quality of food in Mexico?
Perceived Risks (RP)	PR1	Do you think the consumption of genetically modified products is a risk to the health of Mexicans?
	PR2	Do you think that the cultivation of genetically modified crops will cause severe environmental damage in Mexico?

(*continued*)

Table II.
Factors and items to measure perceptions and attitudes of the Mexican urban population on the production and consumption of GMOs

Latent factor	Item	Item
	PR3	Do you think genetically modified products will greatly affect your family's quality of life ?
	PR4	Do you think the consumption of genetically modified products could have negative effects on your descendants?
	PR5	Do you think that the production and consumption of GM products threaten human nature?
	PR6	Do you think that GM products can cause diseases in your family?
Attitude Toward Technology (ATT)	ATT1	Do you think that science and technology are important for social development?
	ATT2	Do you think that science and technology are fundamental to the development of Mexican society?
	ATT3	Do you think that science and technology are essential for generating healthy products for Mexicans?
	ATT4	Do you think that new technological developments will affect the ecological equilibrium in Mexico?
	ATT5	Do you think that science and technology can contribute to improving the Mexican economy?
Attitude toward Gene Technology (AGT)	AGT1	Do you think that the production of transgenic products is contributing to increasing the amount of food in Mexico?
	AGT2	Do you think the production of transgenic products for consumption by Mexicans is morally acceptable?
	AGT3	Do you agree that transgenic products should be produced and consumed in Mexico?
	AGT4	Do you think that transgenic products have higher nutritional content than organic products?
	AGT5	Do you think the consumption of transgenic products will increase life expectancy in Mexico?
	AGT6	Do you agree with promoting transgenic products for family consumption?
Religion (REL)	REL1	Is your religion in favor of developing transgenic products for human consumption?
	REL2	Does your religion forbid the consumption of transgenic products?
	REL3	Does your religion consider, for moral reasons, that you should not eat genetically modified products?
	REL4	Does your religion consider the processing of transgenic products morally incorrect?
	REL5	Does your religion believe it is right for scientists to genetically modify plants and animals for human consumption?
Labeling (LA)	LA1	Do you have the habit of reading the labels of the products your family consumes before buying them?
	LA2	Do you think that labels on transgenic products must indicate they contain genetically modified ingredients?
	LA3	Do you think that advertisements of genetically modified products should inform the consumer of the content of the product in question?
	LA4	Do you think that the Mexican government should create laws to regulate the labeling of transgenic products?
Societal Values (SV)	SV1	Do you agree to consume transgenic products with your family?
	SV2	Do you agree that gene technology should be used in the production of transgenic products for human consumption?

Table II. (*continued*)

Latent factor	Item	Item
	SV3	Do you think that transgenic products can help in the fight against hunger in Mexico?
	SV4	Do you think that gene technology can solve the lack of food in Mexico?
Attitude toward Buying (AB)	AB1	Would you buy transgenic products if they contain less fat than conventional products?
	AB2	Would you buy transgenic products if they were cheaper than organic products?
	AB3	Would you buy transgenic products if they were grown under similar environmental conditions as organic products?
	AB4	Would you buy transgenic products if their price is equal to the price of organic products?
	AB5	Would you buy a kilogram of tortillas made with transgenic maize if the price is equal to a kilogram made with conventional maize?
	AB6	Would you buy a kilogram of transgenic beans if the conventional kilogram of beans cost the same?
Promotion (PRO)	PRO1	Do you agree that the Mexican government should allow the production and consumption of transgenic products?
	PRO2	Do you agree that the Mexican government should economically support businesses to produce transgenic products?
	PRO3	Do you agree that the Mexican government should provide funding to public research institutes for the development of transgenic products?
	PRO4	Do you agree that the Mexican government should provide funding to conduct scientific research aimed at creating transgenic drugs?
	PRO5	Do you agree that the government should allow production and importation of biotech crop products for consumption by Mexicans?

Table II.

the educational level in this paper. The logistic regression and Beta regression were used to study the association between the indicators of each factor and the educational level. The logistic regression was implemented for each binary item of each factor, and each item was considered a dependent variable (where 1 = yes and 0 = no), and the ordinal variable educational level was considered the independent variable. In the Beta regression, we used as dependent variable the average of each factor, explained above, and as independent variable the educational level. We used the logistic regression for binary dependent responses and the Beta regression for continues dependent variables that take values between zero and one as suggested by Stroup (2012). These analyses help us to understand in a detailed way the existing differences between educational level on the perceptions and attitudes toward the production and consumption of GMOs. Both regression analyses were done in the Glimmix procedure of the Statistical Analysis System software, version 9.4 (SAS Institute, 2014).

3. Results

The results of the perceptions and attitudes for each of the 11 latent factors are presented below, and also the associations with educational level.

3.1 Latent factors

Knowledge. The percentage of respondents who know about the existence of laws governing the production and consumption of transgenic products is low

(KN8, 18.81 percent). In general, percentage regarding knowledge of these items does not exceed 50 percent (Figure 1, left panel), indicating that respondents do not know which transgenic products are on the market (KN1, KN2, KN3, KN4 and KN6 with 37.63, 22.55, 34.73, 33.44 and 38.9 percent, respectively), whether transgenics are imported (KN5, 24.14 percent) or their medicinal uses (KN9, 25.09 percent). These values suggest that part of the surveyed population has a relatively low level of knowledge on the subject of GMOs (KNpro, 31.28 percent). This is consistent with findings reported by Luntulwandile (2014) in studies conducted in Europe and South Africa, respectively, that found a significant lack of knowledge about biotech issues among those surveyed.

Trust. The right panel of Figure 1 shows that just over half of the respondents have some confidence in universities in Mexico and around the world on their work on genetic modification of plants and animals for human consumption (TR1, 50.09 percent, and TR2, 54.08 percent). Based on the foregoing, trust in farmers (TR5, 49.8 percent), the pharmaceutical industry (TR4, 47.41 percent), companies in general (TR3, 38.02 percent) and companies specializing in using transgenic ingredients (TR6, 35.99 percent) is at the lowest level percent. Therefore, based on the average latent factor (TRpro, 45.91 percent) and all items of this factor, we inferred that just over half of the surveyed population has no confidence in the institutions and companies who develop products based on GMOs. This is consistent with results reported by Barrena-Figueroa and Sánchez (2004), European Commission (2006) and Lang (2013) that identified scientists, health professionals and universities as sources of information with more credibility, followed by the media and finally politicians and industries.

Perceived benefits. Most respondents believe that transgenics crops will increase Mexico's agricultural production (PB3, 64.57 percent), but also that their use affects the environment (PB1, 38.86 percent), the Mexican economy (PB6, 45.19 percent) and human health (PB4, 46.62 percent). In general, respondents do not consider that the use of GMOs may benefit Mexican families (PB2, 37.5 percent), for example, by improving the nutritional value of food (PB5, 37.93 percent; PB7, 35.64 percent). They show a slightly negative attitude toward the perceived benefits of GMOs (PBpro, 43.76 percent), which coincides with the findings reported by European Commission (2010), where a large part of the European community showed great mistrust regarding the safety of

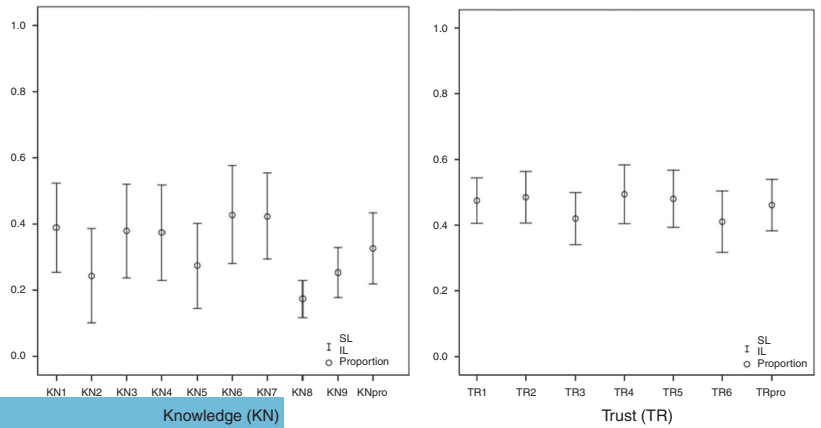

Figure 1.
Sample proportions (confidence interval 95 percent) of the items of knowledge and trust

GMOs because they do not perceive the benefits. Similarly, a study by the European Commission (2010) found that respondents consider agriculture a key factor for the future and agree that farmers should take advantage of biotechnology to be more competitive and combat the effects of climate change.

Perceived risks. Overall, respondents perceived a high risk in GMOs (PRpro, 59.13 percent). Proof of this is that the majority of respondents believe that eating transgenic food is a risk for health (PR1, 62.09 percent; PR6, 65.35 percent), the quality of family life (PR3, 57.11 percent) and human offspring (PR4, 60.61 percent). This distrust of GMOs is also observed in the European population as reported by the European Commission (2010). Also, just over half of the respondents felt that transgenic products will adversely affect the environment (PR2, 54.33) and human nature (PR5, 55.41). Their concern about environmental effects was consistent with that reported by Yue (2014), who claim that consumers care about the environmental consequences resulting from the use of agricultural biotechnology.

Attitude toward technology and Gene technology. The left panel of Figure 2 shows that a high percentage of respondents consider science and technology as important factors for human development (ATT1, 90.36 percent), and specifically for Mexican society (ATT2, 86.73 percent) and its economy (ATT5, 74.35 percent). Likewise, most respondents agree that science and technology are important for producing and processing healthier products (ATT3, 78.95 percent); however, they showed a significant concern about the environmental effects of transgenics (ATT4, 66.66 percent). These results coincide with those reported by Aerni (2006), where most Mexican respondents believe GE is a useful tool to address the problems of agriculture and nutrition but are concerned about the possible environmental risks of transgenic crops, for example, transgenic pollination of local landraces.

More than half of the respondents (Figure 2, right panel) believe that GMOs are essential for increasing Mexico's agricultural production (AGT1, 61.57 percent). However, they did not consider GMOs morally acceptable for consumption (AGT2, 42.96 percent) and rejected their production and consumption in Mexico (AGT3, 44.91 percent). Moreover, most respondents do not believe that GM products provide more nutrients than organic products (AGT4, 28.61 percent) nor that their consumption can increase the life expectancy of Mexicans (AGT5, 30.46 percent); therefore, they disagree with promoting the consumption of GMOs in their families (AGT6, 36.28 percent).

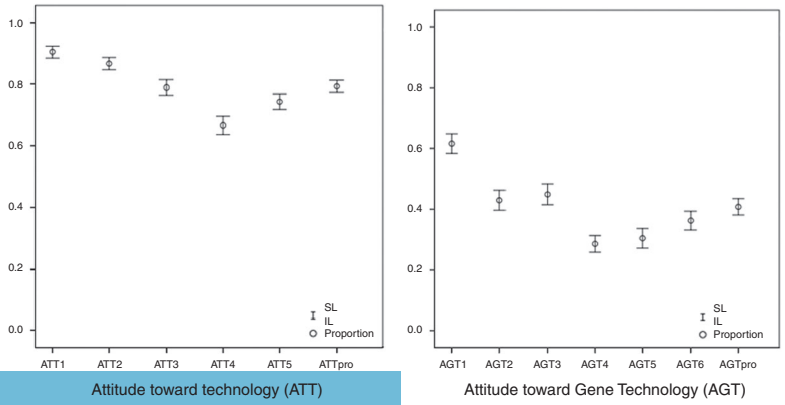

Figure 2.
Sample proportions (confidence interval 95 percent) of the indicators of attitude toward technology and attitude toward gene technology

These results are in contrast to those reported by He and Bernard (2011) who showed that most consumers did not regard all kinds of biotechnology equally. There seems to be less rejection of medical applications of GE than applications related to food and agriculture, as well as greater acceptance of genetic modification of plants than animals; finally, GE applications that provide tangible consumer benefits are more widely accepted (Lusk and Rozan, 2011).

Religion. The religion professed by respondents is not in favor of genetic modification of plants and animals for human consumption (REL1, 20.7 percent, REL5, 18.27 percent); however, it does not forbid its production and consumption, because this activity is not considered morally wrong (REL2, 9.35 percent; REL3, 12.71 percent, and REL4, 15.15 percent). These results contrast with results of surveys conducted in Muslim countries, where respondents are concerned about the halal status of food; therefore, they avoid transgenic foods with genes from animals, insects or humans. Similarly, Hindus, Buddhists and Jews do not eat grains that may contain genes of pigs (Ali, 2014; Bonne and Verbeke, 2008; Crist, 1996).

Labeling and attitude toward buying. The results of the survey sample (left panel, Figure 3) show that more than half of respondents read the labels of products they consume (LA1, 63.25 percent), which is consistent with the fact that respondents believe that transgenic products must carry warning labels about their transgenic content (LA2, 93.59 percent, and LA3, 93.69 percent). Also, participants believe that the Mexican government must legislate the labeling of GMOs (LA4, 93.23 percent). These results are consistent with reports from studies conducted in Mexico by Aerni (2006) and in Turkey by Tas *et al.* (2015), which found that consumers are in favor of mandatory labeling of transgenic products.

The right panel of Figure 3 shows that more than half of the respondents have a positive attitude toward the consumption of GMOs that contain less fat (AB1, 61.61 percent), are cheaper (AB2, 59.06 percent) and organically grown (AB3, 56.88 percent). However, they would choose to buy organic foods, such as corn and beans, if the price was the same as that of transgenics (AB4, 34 percent; AB5, 30.24 percent; AB6, 30.07 percent). Such results are not entirely consistent with those obtained by Sebastian-Ponce *et al.* (2014), who argue that although consumers express their preference for organic products and claim to be willing to pay a little more for them, finally they are inclined to buy the less costly product. Similarly, Yang *et al.* (2015)

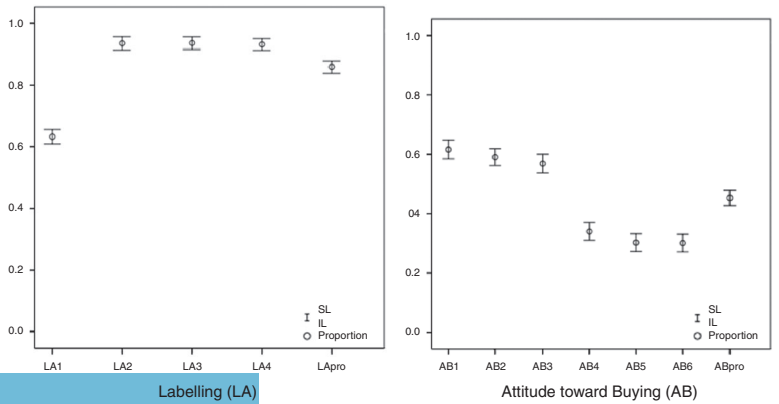

Figure 3.
Sample proportions (confidence interval 95 percent) of labeling and attitude toward buying

found that Taiwanese spend a little more to avoid buying transgenic foods. The results of this survey show that participants opt for less expensive products. Furthermore, O'Brien *et al.* (2012) note that respondents are not entirely satisfied with the consumption of transgenic products whose fat content has been modified (35 percent), which contrasts with our results, where respondents would opt for transgenic foods with less fat.

Societal values and promotion. More than half of respondents believe that the use of transgenic products can help to combat food shortages in Mexico (SV4, 53.76 percent) and thereby help fight hunger (SV3, 60.63 percent). On the other hand, less than half of the respondents agree with the use of GE to produce food for human consumption (SV2, 45.1 percent). Likewise, a low percentage would be willing to consume GM food with their families (SV1, 44.87 percent). Overall, just over half of respondents perceived no societal value in the use of GMOs (SVpro, 51.12 percent). This perception may be justified by the low awareness about GMOs shown by the respondents and because as Critchley (2008) and Siegrist (2000) point out that people rely on societal trust in the absence of biotechnological knowledge, particularly toward people who are carrying out scientific research; these factors become crucial for understanding attitudes toward GMOs (Marques *et al.*, 2014).

Just over half of the respondents agree that the government should provide support to public institutes for research on new biotech drugs and allow their production and use (PRO1, 50.35 percent; PRO3, 56.92, and PRO4, 58.03 percent). However, slightly less than half of the respondents agree that the government should support companies to conduct research on GMOs and produce or import transgenic products for consumption in Mexico (PRO2, 49.59 percent, and PRO5, 40.79 percent). This behavior can be explained by a statement made by James (1997) who claims that companies using GE have a utilitarian view of nature and are indifferent to the consequences for humans. On the other hand, the sympathy shown toward medical applications of GMOs is consistent with studies conducted by Rimal *et al.* (2004) and Lusk and Rozan (2006), which show that respondents favor the use of GE in medicine over its use in food. Finally, in our study, just over half of the respondents agree that the Mexican government should promote GMOs (PROpro, 51.14 percent).

3.2 Association of indicator latent factors with educational level

This section shows sample proportions obtained by educational level on each of the studied factors and the significance of educational level by the implementation of the regression analysis.

Knowledge and trust. College or higher education denotes the group with a higher level of knowledge (Figure 4, left panel). We noted that the higher the educational level, the greater the knowledge regarding GMOs (elementary school or less, 20.47 percent; middle school, 26.30 percent; high school, 35.09 percent, and college or higher, 52.14 percent). This is supported by the regression analysis given in Table III where we can see that educational level is statistically significant for all items of this factor and also we can see in this Table that the lower the educational level, the lower the knowledge regarding GMOs. Given that KN7 obtained the highest percentages in most groups (elementary school or less, 34.82 percent; middle school, 39.08 percent, and high school, 50.94 percent), we can say that most respondents at all educational levels know that some crops may become resistant to certain pests through genetic modification.

In the case of trust (Figure 4, right panel), the highest percentages are for the TR2 indicator at all levels of study, indicating that universities are the most reliable in terms of working with GMOs (middle school, 54.67 percent; high school, 55.14 percent, and college or higher, 54.87 percent). At the other extreme are companies using transgenic ingredients (TR6), because they have the lowest levels of trust (elementary school or less, 36.63 percent; middle school, 37.30 percent; high school, 35.94 percent, and college or higher, 32.96 percent). In general, at all educational levels, there is little confidence in GMOs (elementary school or less, 46.48 percent; middle school, 47.44 percent; high school, 45.64 percent, and college or higher, 42.43 percent). In this factor, the educational level was not statistically significant (Table III) only for item TR1 and the average of these items (TRpro), and in general, the higher the educational level, the lower the trust in GMOs.

Perceived benefits and risks. For the perceived benefits (Figure 5, left panel), PB3 has the highest percentage at all educational levels, indicating that more than half of respondents believe that crops with transgenic seeds will increase crop production in Mexico (elementary school or less, 59.84 percent; middle school, 65.01 percent; high school, 65.62 percent, and college or higher, 69.68 percent). On the other hand, the item with the lowest percentage was PB7 (elementary school or less, 37.88 percent; middle school, 36.86 percent; high school, 34.64 percent, and college or higher, 31.42 percent), indicating that respondents do not consider that transgenic products will improve the nutritional quality of food. On average, it is observed that the people with middle school level education perceived the larger benefits (elementary school or less, 43.70 percent; middle school, 45.08 percent; high school, 43.47 percent; college or higher, 41.83 percent). However, in this factor, the educational level was not significant for items PB4 and PB6 and for the average factor (PBpro) (Table III), and in items PB2, PB5 and PB7, the lower the educational level, the higher the perceived benefits, while in PB3, the higher the educational level, the higher the perceived benefits.

The college or higher level (PRpro, 63.16 percent) stands out as the perceived higher risk group (Figure 5, right panel and Table III). They are followed by the high school level (59.23 percent), elementary school or less (58.06 percent) and finally, middle school (57.95 percent) level. In general terms, all groups of education perceived moderate risk toward GMOs, and the higher the level of education, the higher the risk perceived. In this factor, the educational level was significant for all items except for items PR2 and PR3 (Table III), and the higher the educational level the higher the perceived risk (Table III).

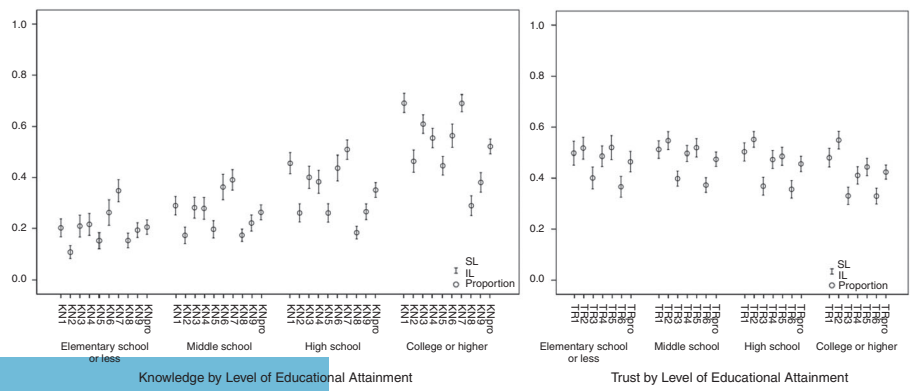

Figure 4.
Sample proportions (confidence interval 95 percent) of knowledge and trust by level of education

	β coefficients 1	2	3	p-values 1	2	3		β coefficients 1	2	3	p-values 1	2	3
KN1	−2.056	−1.658	−0.900	*< 0.0001*	*< 0.0001*	*< 0.0001*	AGT1	−0.251	−0.200	−0.095	*< 0.0001*	*0.001*	0.105
KN2	−1.904	−1.445	−0.863	*< 0.0001*	*< 0.0001*	*< 0.0001*	AGT2	0.156	0.076	−0.008	*0.012*	0.177	0.884
KN3	−1.655	−1.369	−0.812	*< 0.0001*	*< 0.0001*	*< 0.0001*	AGT3	0.155	0.067	0.038	*0.013*	0.234	0.496
KN4	−1.408	−1.152	−0.679	*< 0.0001*	*< 0.0001*	*< 0.0001*	AGT4	0.240	0.180	0.052	*0.001*	*0.004*	0.408
KN5	−1.283	−1.084	−0.700	*< 0.0001*	*< 0.0001*	*< 0.0001*	AGT5	0.171	0.147	0.011	*0.011*	*0.016*	0.862
KN6	−1.170	−0.867	−0.520	*< 0.0001*	*< 0.0001*	*< 0.0001*	AGT6	0.234	0.108	0.016	*0.000*	*0.063*	0.782
KN7	−1.357	−1.076	−0.634	*< 0.0001*	*< 0.0001*	*< 0.0001*	AGTpro	0.055	0.038	−0.009	0.147	0.274	0.788
KN8	−0.692	−0.637	−0.542	*< 0.0001*	*< 0.0001*	*< 0.0001*	REL1	0.500	0.381	0.141	*< 0.0001*	*< 0.0001*	0.052
KN9	−0.846	−0.704	−0.460	*< 0.0001*	*< 0.0001*	*< 0.0001*	REL2	0.282	0.204	0.188	*0.007*	*0.034*	*0.049*
KNpro	−1.374	−1.110	−0.679	*< 0.0001*	*< 0.0001*	*< 0.0001*	REL3	0.260	0.157	0.212	*0.005*	*0.066*	*0.012*
TR1	−0.019	0.002	0.007	0.748	0.972	0.903	REL4	0.351	0.196	0.226	*< 0.0001*	*0.015*	*0.005*
TR2	−0.141	−0.089	−0.056	*0.020*	0.106	0.309	REL5	0.383	0.288	0.070	*< 0.0001*	*< 0.0001*	0.355
TR3	0.188	0.132	0.065	*0.003*	*0.020*	0.256	RELpro	0.157	0.112	0.064	*< 0.0001*	*< 0.0001*	*0.030*
TR4	0.226	0.217	0.153	*0.000*	*< 0.0001*	*0.006*	LA1	−0.662	−0.521	−0.345	*< 0.0001*	*< 0.0001*	*< 0.0001*
TR5	0.232	0.170	0.079	*< 0.0001*	*0.002*	0.155	LA2	−1.102	−0.661	−0.439	*< 0.0001*	*< 0.0001*	*0.002*
TR6	0.130	0.096	0.042	*0.039*	0.091	0.467	LA3	−0.984	−0.525	−0.309	*< 0.0001*	*< 0.0001*	*0.026*
TRpro	0.053	0.048	0.036	0.178	0.179	0.310	LA4	−1.112	−0.709	−0.388	*< 0.0001*	*< 0.0001*	*0.004*
PB1	0.159	0.169	0.044	*0.011*	*0.003*	0.435	LApro	−0.293	−0.202	−0.115	*< 0.0001*	*< 0.0001*	*< 0.0001*
PB2	0.289	0.181	0.063	*< 0.0001*	*0.002*	0.277	SV1	0.137	0.070	0.009	*0.027*	0.208	0.871
PB3	−0.459	−0.267	−0.161	*< 0.0001*	*< 0.0001*	*0.009*	SV2	0.057	0.025	0.041	0.354	0.651	0.456
PB4	−0.008	0.026	0.025	0.900	0.633	0.646	SV3	−0.096	−0.028	0.049	0.132	0.635	0.402
PB5	0.285	0.221	0.125	*< 0.0001*	*< 0.0001*	*0.031*	SV4	−0.101	−0.088	−0.022	0.102	0.119	0.696
PB6	0.029	0.061	0.104	0.645	0.279	0.063	SVpro	0.001	−0.007	0.011	0.975	0.840	0.748
PB7	0.253	0.173	0.075	*< 0.0001*	*0.003*	0.200	AB1	0.335	0.364	0.201	*< 0.0001*	*< 0.0001*	*< 0.0001*
PBpro	−0.029	0.012	−0.003	0.454	0.733	0.937	AB2	0.458	0.441	0.253	*< 0.0001*	*< 0.0001*	*< 0.0001*
PR1	−0.198	−0.110	−0.085	*0.002*	0.058	0.143	AB3	0.151	0.192	0.123	*0.016*	*0.001*	*0.030*
PR2	−0.106	−0.082	−0.056	0.092	0.146	0.319	AB4	0.107	0.095	0.033	0.100	0.103	0.573
PR3	−0.111	−0.084	−0.034	0.079	0.139	0.555	AB5	0.116	0.095	−0.014	0.085	0.118	0.819
PR4	−0.205	−0.149	−0.101	*0.001*	*0.010*	0.080	AB6	0.136	0.100	0.008	*0.044*	0.098	0.896
PR5	−0.173	−0.145	−0.050	*0.006*	*0.011*	0.372	ABpro	0.148	0.153	0.072	*< 0.0001*	*< 0.0001*	*0.040*

(continued)

Table III. β coefficients and p-values of the regression analysis using educational level as the independent variable

Table III.

	β coefficients			p-values				β coefficients			p-values		
	1	2	3	1	2	3		1	2	3	1	2	3
PR6	−0.173	−0.132	−0.030	*0.008*	*0.025*	0.609	PRO1	0.040	0.029	0.032	0.519	0.601	0.570
PRpro	−0.099	−0.077	−0.038	*0.011*	*0.028*	0.274	PRO2	0.103	0.025	0.068	0.096	0.651	0.222
ATT1	−1.164	−0.721	−0.358	*< 0.0001*	*< 0.0001*	*0.003*	PRO3	−0.051	−0.048	−0.019	0.417	0.394	0.731
ATT2	−0.934	−0.493	−0.250	*< 0.0001*	*< 0.0001*	*0.009*	PRO4	−0.036	−0.055	0.009	0.564	0.326	0.872
ATT3	−0.591	−0.449	−0.239	*< 0.0001*	*< 0.0001*	*0.001*	PRO5	0.094	0.091	0.074	0.138	0.111	0.195
ATT4	−0.232	−0.163	−0.034	*0.000*	*0.006*	0.571	PROpro	0.014	0.006	0.022	0.714	0.867	0.533
ATT5	−0.703	−0.525	−0.303	*< 0.0001*	*< 0.0001*	*< 0.0001*							
ATTpro	−0.279	−0.183	−0.084	*< 0.0001*	*< 0.0001*	*0.007*							

Notes: Logistic regression was performed for the binary indicators of Table II, and for the average of each factor, a Beta regression was performed. The educational level is an ordinal variable and the reference category was 4 = college or higher. In italics are given the significant *p*-values (< 0.05)

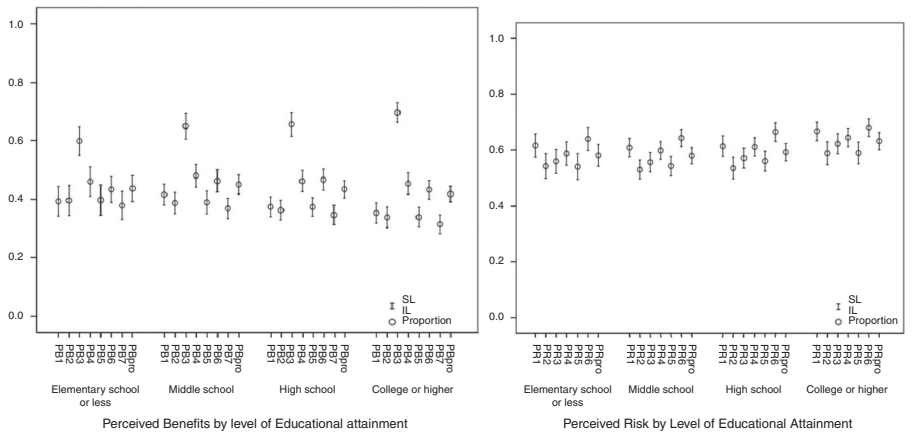

Figure 5.
Sample proportions (confidence interval 95 percent) of the perceived benefits and risks by level of education

Religion and attitude toward technology and gene technology. Due to the low averages in RELpro items (elementary school or less, 16.23 percent; middle school, 15.49 percent; high school, 15.20 percent, and college or higher, 13.57 percent) at all levels of education, it is considered that religion is not strongly affected by level of education, even that educational level was significant for all items of this factor (Table III), and the lower the educational level, the higher the percentages for items in this factor (Table III). The attitude toward the use of technology is very positive and increases with a higher level of education (elementary school or less, 75.42 percent; middle school, 78.47 percent; high school, 80.97 percent, and college or higher, 84.76 percent) (Table III). Coinciding with this are the ATT1 (up 86 percent) and ATT2 (over 82 percent) items, indicating that science and technology are important for Mexico's social development, although based on the high ATT4 percentages (up to 60 percent), respondents also believe that new technological developments will affect the ecological balance in Mexico. Also, for this factor, educational level was significant for all items (Table III), and the higher the educational level, the better the attitude toward technology (Table III). Also, for the attitude toward gene technology, respondents at all educational levels have similar percentages in all indicators, and based on the averages, (AGTpro: elementary school or less, 41.02 percent; middle school, 41.89 percent; high school, 40.07 percent, and college, 39.65 percent), a negative attitude is evident. In this factor, the educational level was significant for all items except for the average (AGTpro), and the lower the educational level, the higher the acceptance to gene technology.

Labeling and societal values. Most respondents at all levels of education read the labels of the products they consume (LA1 greater than 50 percent); this habit increases as the educational level increases (elementary school or less, 58.02 percent; middle school, 60.24 percent; high school, 64.81 percent; college, college or higher, 75.13 percent). According to the high percentages of the LApro indicators, most respondents at all levels of education are in favor of labeling transgenic products; this is greater with higher levels of study (elementary school, 83.52 percent; middle school, 84.82 percent; high school, 86.29 percent, and college or higher, 91.20 percent). All the above is supported by Table III, where we can see that the educational level was significant for all items of the factor labeling, and the higher the educational level, the higher the observed percentage for implementing labeling in GMOs. With respect to

societal values by level of education, we see that higher relative societal utility toward GMOs is observed in middle (52.30 percent) and high school (51.86 percent) groups compared to the perceived levels in college or higher (50.23 percent) and elementary school or less (49.46 percent); however, the educational level was significant only for the item SV1.

Attitude toward buying and promotion. There is a clear distinction between two groups within attitude toward buying GMOs in all levels of education (Figure 6, left panel). The first group consisting of the indicators AB1, AB2 and AB3, and they have the highest percentage (over 50 percent), while the second group consists of AB4, AB5 and AB6 and they have the lowest percentage (below 35 percent). It is clear that regardless of their education level, the respondents would buy transgenic products if they contain less fat, are cheaper than conventional food products, and are grown in similar environments as organic products. On the other hand, respondents do not see transgenic products as an option if their prices are equal to those of conventional products. In general, average percentages do not exceed 50 percent (ABpro: elementary school or less, 45.85 percent; middle school, 47.50 percent; high school, 44.77 percent, and college or higher, 41.11 percent), indicating a negative attitude toward purchasing GM products prevails at all levels of education. In this factor, the educational level was not significant only for items AB4 and AB5 (Table III), and for the significant items like AB1, AB2 and AB3, the lower the educational level, the higher the acceptance toward buying products with GMOs.

In the case of promotion (Figure 6, right panel), the percentages of the items behave similarly among the different levels of education (PROpro: elementary school or less, 50.94 percent; middle school, 51.96 percent; high school, 51.40 percent, and college or higher, 49.38 percent), which is congruent with Table III, where we can see that educational level was not significant in any of the items of this factor. The items with the highest and lowest percentages are PRO4 (elementary school or less, 57.17 percent; middle school, 58.16 percent; high school, 58.78 percent, and college or higher, 57.80 percent) and PRO5 (elementary school or less, 41.58 percent; middle school, 42.79 percent; high school, 39.94 percent, and college or higher, 37.03 percent), respectively. This suggests that more than half of respondents at all levels of education

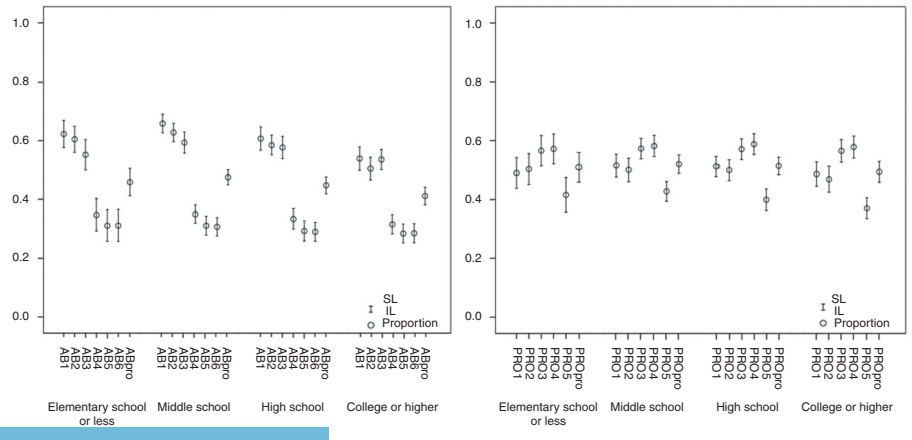

Figure 6.
Sample proportions (confidence interval 95 percent) of the attitude toward buying and promotion by level of education.

agree that the Mexican government should provide funding to create drugs based on GMOs but do not believe the government should open the door for production and importation of transgenic products.

4. Conclusions

In general, the respondents showed a low level of knowledge regarding GMOs. This may explain the distrust, low benefits and high risks of GMOs they perceive. Despite this, it is important to highlight their positive attitude toward technological development, although not particularly toward gene technology. There is considerable sympathy for GMO application in agricultural development in Mexico and in the production of biotech drugs, although there is little consensus on allowing the production and importation of GMOs to Mexico. Most respondents read the labels of the products they consume and believe that GM products must be labeled indicating transgenic content. They also support the idea that the Mexican government should legislate mandatory labeling of GMOs.

With regard to the trust attributed to those working with GM products, universities and scientists at the national or international level inspired the greatest confidence, compared with pharmaceutical companies working on transgenic products. As for the attitude toward buying, the individuals surveyed showed a preference for buying GM products if they were cheaper, had less fat and had been grown under similar conditions as conventional organic products. With regard to promotion, respondents showed a slightly positive attitude toward the Mexican government providing funding for research involving GMOs, in order to generate new drugs. However, respondents did not agree that the government should fund private companies to produce or import transgenics.

Results revealed that the higher the educational level, the greater the knowledge about GM products, the lower the trust, greater the perceived risks, the greater the acceptance of technology, and the greater the acceptance to implement labeling. While, in general, the lower the educational level the better the attitude toward buying, perceived benefits and acceptance of gene technology. Therefore, there are elements to state that the Mexican society still does not accept all transgenic products. There are those who flee in fear, but often their fears are a result of lack of information. Therefore, further studies and national information campaigns are required to improve the knowledge about GMOs to modify the perceptions and attitudes of the Mexican public on the production and consumption of GMOs. Also, it is important to have greater participation in technological decisions in the country, in order to balance the interests of large corporations with strict public control by providing scientifically accurate information on GMOs to Mexican society.

The major practical contribution of this research is that it provides empirical knowledge about the perceptions and attitudes toward the production and consumption of GMOs in the Mexican urban society, which can be of great help for the Mexican government to rethink if it is an appropriate moment to completely open the doors to international companies to cultivate crops like maize and others that have been postponed due to pressure from the environmental groups, farmers and other sectors of the society. Also, our findings can be used to improve the acceptance of GMOs in Mexico by developing specific strategies to those factors and educational levels where the level of acceptance of GMOs is low and to start the implementation of research programs, regulations or legislation to

promote GMOs in those factors where the acceptance is not low. In academia, our findings can be used to propose and implement programs of high quality for the education in biotechnology and GE to increase the knowledge of our people about gene technology and have a clear picture about the real benefits and risk of this technology to the Mexican society.

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