



Research article

Awareness of GMOs in terms of the Iran biosafety act: A case study of Tehran city

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ABSTRACT

Given emerging food supply challenges for the world population, Genetic Modified Organisms (GMOs) are referred to as a solution to the upcoming food security crisis. Besides technological advancement, other significant components such as public Awareness play an important role in national and international scientific regulations. Towards this, this study evaluated Tehranian consumers' Awareness (a sample including 946 respondents) about GMOs' risks and benefits, trust in governmental regulation, and the ways to obtain information about GMOs. Specific questionnaires were designed and distributed among participants in four districts in Tehran, and the collected data were used to conduct descriptive and inferential statistics by applying the ANOVA test.

The Findings showed that 39 % with a p-value <0.01 of the public is unaware of GMOs in Tehran despite 20 years of commercialization, consumption, and controversial debate about GMOs in media and social networks. Therefore, the goals of public Awareness of science concerning biotechnology have not been met yet. Based on these findings, it can be concluded that public Awareness is not a crucial component in biotechnology advancement, and the other factors, including policymakers' desire, may have more weight.

1. Introduction

The expanding population coupled with increasing climate change demands the need for a future with higher agricultural productivity, availability of healthier food, and environmental sustainability Besides the social and political aspects of these crises, the ever-increasing food demand and famine have called for greater flexibility in food production systems, innovation in crop resilience, and improving nutritional quality. Since technological advances in food production are regarded as inevitable changes in 'today's food industry, developing GMOs is one of the answers to those problems.

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Many novel foods or food ingredients consumed worldwide have been produced through GMOs since the mid-1990s [1]. GMOs are an intrinsically complex issue that has created intense public debates, from scientific journals, mass media, and social networks, to family gatherings [2]. Moreover, strong legislation, strict commercial procedures, and various preventive laws have been passed and implemented to regulate different facets of GMOs at the national and international levels. All these rules and practices are known as biosafety acts [3].

Although many objections to the cultivation and the release of GMOs have been expressed based on environmental or health considerations, according to reliable sources such as the Food and Drug Administration (FDA) in the USA, GMOs have not yet caused disease or allergies, and G.M. foods have been considered safe to consume [4,5]. In addition, according to previous studies, they have not had detectable impacts on the environment or biodiversity [6]. Over-regulations created high costs, reduced investment, suspended innovations, and consequently limited such 'products' commercialization [7].

Despite the urgent need to finance biotechnological advancements and regulate its policies to meet the complex challenges that threaten the sustainable food supply, GMOs are influenced by factors seemed beyond empirical scientific comprehension, including [5, 8]. The intricate interplay of ecological, social, and economic variables makes predicting their long-term impacts challenging, necessitating a comprehensive and interdisciplinary approach to their assessment. Public Awareness of Science (PAS) has been defined in this case study as informing, educating, and raising Awareness of science-related topics [9,10]. The essential goal of PAS is to promote science in society and create an informed public of the implications and limitations of science in human affairs [11]. Accordingly, it is crucial to survey the public awareness level and the relationship between consumers' Awareness and their perception of GMOs derived foods, which may affect their attitudes regarding food choices.

The relationship between consumers' Awareness and their attitudes has been studied in social psychology, moral-religious, marketing, and public policy fields. Previous studies indicated that some significant factors influence consumers' Awareness, such as the risks and benefits perception [12,13], consumers' trust in government regulations [14–18], and mass media [1,19–22].

Additionally, different research has been conducted in various regions, such as China, the USA, and European countries, to investigate public Awareness about GMOs food; however, fewer studies have explored public Awareness in developing countries such as Iran.

The results of previous public awareness surveys in different regions of Iran have shown that trust in government agencies and biotechnology institutes and the perception of risks and benefits have been the most vital variables affecting people's attitudes toward G.M. products [23,24]. These surveys have indicated that many respondents do not know about GMOs, and the primary source of information is social networks, television, and Internet websites, respectively. However, these resources do not efficiently broadcast accurate and enough information about GMOs [24]. Nevertheless, previous research has not addressed the relationship between the three factors of knowing about the risks and the benefits, trust in the government regulations, and the source of gaining information about GMOs, and they were explored separately in each research.

This survey, abreast of previous studies, sought to comprehend consumer awareness about a. awareness of GMOs risks and benefits, b. awareness of food safety regulations, and c. the ways of gaining information about GMOs. Also, this research intended to examine the three factors at the same time and measure their relationship as much as possible.

2. The current situation in Iran

The Islamic Republic of Iran signed the Cartagena Protocol on Biosafety on April 23, 2001, and ratified it on November 20, 2003. Along the same lines as the provisions of the Cartagena Protocol, after six years of controversial negotiations and bargaining among various government agencies, and stakeholders, the Biosafety Act was enacted by Parliament in 2009 [25]. Unlike promoting scientific and legal infrastructures in Iran, such as investing in research centers (Agricultural Biotechnology), setting up reference laboratories, and training human resources, Iran did not take full advantage of its progress in plant biotechnology.

'Iranian researchers' successes in the field of G.M. plants, include transferring the Bt gene to an Iranian Rice variety (Taram Moulae') [26], producing G.M. cotton [27] and potato [28], and transferring the pests-resistant gene to sugar beet and alfalfa [29]. These accomplishments highlight the country's advancements in biotechnology and its potential contributions to agriculture. Although Iran became one of the producers of GM rice in 2004 before enacting Biosafety Law, its production was stopped in 2006 due to biosafety concerns and political conflicts after the change in administration. In consequence, no type of G.M. crops has been licensed officially to be cultivated in Iran.

Currently, Iran is an importer of GM products, which are mostly used for feeding livestock and by food and beverage processing companies [30]. Also, soybean derivatives, including vegetable oils, soybean flour, lecithin, and soybean protein, have a massive share in the Iran market, of which only about 10 % are non-GM in many countries. Moreover, G.M. grains exist in 20 % of the market cereals. Most research estimated that more than 90 % of vegetable oil on Iranian supermarkets' shelves includes at least a fragment of a GMO [25]. Considering everything, Iran is highly dependent on the imports of G.M. products (soybean, cotton, corn, canola, and vegetable oil).

¹ Such achievement in Iran received a considerable attention from the world as this rice called "Taram Moulae" is the first GM version of rice released into the world and the first GM product produced in Muslim countries and Middle East, which has reached the farms.

3. Materials and methods

3.1. Data collection method

The research tool was a researcher-made questionnaire consisting of 16 questions. The initial design of the questionnaire was adapted from the standard survey model established by the Cartagena Protocol on Biosafety Secretariat² to assess the level of public Awareness. The questionnaire was modified to some extent according to the research objectives.

Four sets of questions were designed to achieve the research goals: the first set considered the demographics of respondents, including education, gender, and age were questioned. The second set of questions was about Awareness of G.M. Products' definition, the type of G.M. products in the market, and their advantages and disadvantages. The third set evaluated the Awareness of biosafety regulations, labeling criteria, and attention to the GMO label when purchasing. The fourth set assessed how to acquire general knowledge about GMOs, and whether is important or not.

The validity of the questionnaire was evaluated by peer review; for this mean the questionnaire was sent to ten reviewers, and the received comments were considered in two rounds.

Questionnaires were distributed during July 2021 in public places including chain stores, parks, and amusement parks, in four districts of Tehran (districts 1, 5, 18, and 22) which have been chosen based on differences in citizen economic level. Participants were in four age ranges (<20, 20–40, 41–65, 65< years old); and were from different employment and education levels. Moreover, the respondents who were directly related to the research topic due to their job natures, and being familiar with the products that contain GMOs like poultry sellers, were removed to avoid bias in the obtained data. Also, it was anticipated that some respondents may give careless or wrong information, so to evaluate the accuracy of answers, the questions were arranged to identify falsification. In such a way, the accuracy of the answer to each question could be measured based on the next question.

Since the subject is unfamiliar to the general public, and the questions included many scientific terminologies, to reduce the possibility of errors, the survey was conducted by a biologist expert. The expert read and simplified the questionnaire to the respondent and marked their answers.

3.2. Data analysis method

In this study, two types of questions were designed; Some were Dichotomous scales, and others were based on the Likert scale [31] with a range of 1–6 options (1: I do not know - 6: very much).

The collected data were classified in Excel software, and the categorized data were analyzed by using SPSS, version 16.0 (SPSS Inc., Chicago, Ill., USA).

In the first step, descriptive statistics, including frequency analysis were conducted. The results of the frequency analysis of some questions were compared to each other for better understanding.

Based on the descriptive statistic results, various assumptions were considered. Therefore, in the second step, inferential statistical tests were applied to examine the level of significance of assumptions, which were tested by Chi-square and 'Fisher's protected Least Significant Difference (LSD) test at $P < 0.05$ [32].

4. Results

4.1. Demographic statistic

To obtain the goals of this survey, including measuring Tehranian consumers' Awareness of GMOs, their risks and benefits, and sources of obtaining information about them, a series of 14 yes/no questions and 12 questions on the Likert Scale were elaborated. The respondents, randomly selected from all age groups with different education levels and genders, were asked to answer the questions. The obtained demographic data are presented in Fig. 1. The total number of people who were asked to participate was 1267 of which 946 of agreed to participate.

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4.2. Awareness of GMOs and the types of G.M. Products in the market

Despite the abundance of products containing GMO ingredients in Tehran, it has been found that Tehranian 'consumers' Awareness of GMOs is low. Table 1 shows that 39 % of consumers said they hardly ever heard the term of GMO, and almost half of them (48.2 %) did not notice labeling.

In particular, many participants believed that G.M. products are cultivated domestically and imported from other countries. Also, some respondents thought GMOs are available for both human consumption and animal feed. It is interesting to note that some of their information was inaccurate since G.M. crops have not been cultivated in Iran since enacting the Biosafety Act.

In addition, 47.1 % and 42.5 % of respondents declared they were aware of the import and cultivation of GMOs for animal feed,

² available at: https://bch.cbd.int/onlineconferences/portal_art23/pa_survey.shtml.

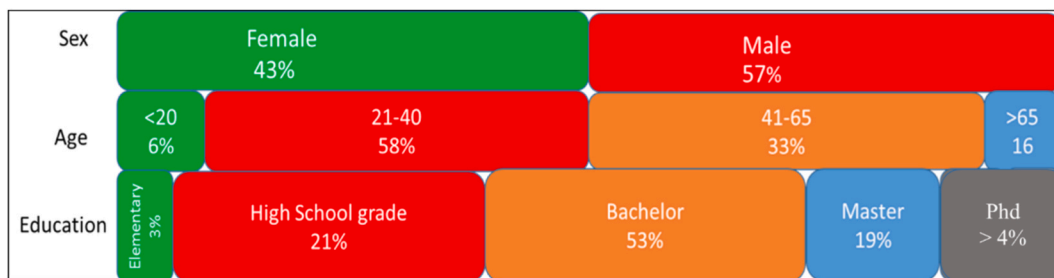


Fig. 1. Demographic data.

Table 1

The Descriptive statistics of respondents on Awareness of GMOs and the types of their consumption.

| Statement | Yes | | No | | 'Don't Know | |
|--|-----|------|-----|------|-------------|------|
| | n | % | n | % | n | % |
| 1 Respondents' awareness level of GMOs | 575 | 60.7 | 371 | 39.2 | - | - |
| 2 Notice of the GMOs labeling | 369 | 39.0 | 456 | 48.2 | - | - |
| 3 Importing GMOs for animal feed | 445 | 47.1 | 98 | 10.3 | 403 | 42.6 |
| 4 Cultivating GMOs for animal feed | 402 | 42.4 | 118 | 12.4 | 426 | 45.3 |
| 5 Importing GMOs for human consumption | 425 | 44.9 | 105 | 11.9 | 416 | 43.9 |
| 6 Cultivating GMOs for human consumption | 420 | 44.3 | 160 | 16.9 | 366 | 38.6 |
| 7 Providing GMOs processed products (oils, cakes, biscuits, tuna, etc.) to the consumer market | 521 | 55.1 | 87 | 0.09 | 338 | 35.7 |

while 52.9% and 57.5% stated they were unaware of the import and cultivation of GMOs for animal feed, respectively. The results also delineated that while 16.9% of participants had low exposure to information about the cultivation of GMOs for human consumption, 43.9% did not know about importing. Moreover, 44.3% of respondents said they were aware of the cultivation of GMOs for human consumption, and 55.7% were unaware of importing. Over half of the participants (55.1%) had adequate knowledge about processed products containing GMOs (oils, cakes, biscuits, tuna, etc.). On the flip side, 35.7% of them said they were unaware of this matter (Table 1).

Based on the data comparison, indicated in Table 1, among 575 respondents that claimed they were aware of GMOs, only 46.7% were informed about the available types of G.M. products, specifically. This contrast shows that the respondents answered imprecisely.

To test the assumption of "Tehranian consumer's awareness of GMO production is low", we used a Chi-square independence test, in which a p-value less than 0.05 indicated statistical significance. The result showed that the null hypothesis was meaningful and served as an indicator of the low level of participants' awareness of GM products. ($\chi^2 = 44.085$; $df = 1$; $p = 0.003$). Also, the null hypothesis regarding "Tehrani's consumers do not notice GMO labeling" was accepted ($\chi^2 = 461.441$; $df = 1$; $p = 0.002$) which means Tehranian do not notice the GMO labeling.

Furthermore, LSD test results reveal that the assumption "Tehrani's consumer's awareness of the types of GMO products is low" was accepted. The data were tested at $p < 0.05$ level for the five groups (Table 1, items 3, 4, 5, 6, and 7), and the result ($F(3.945) = 3.627$, $p = 0.013$) showed that the null hypothesis was significant.

4.3. Awareness of GMOs risks and benefits

In the second part of the questionnaire, the consumer's knowledge about the possible risks and benefits related to GMOs was measured. Table 2 shows that most of the respondents were not aware of the possible ecological risks (26% 'Don't know, 11.1% very little, and 11.1% little) while some of them had heard or read about it (26.8% somewhat, 14.4% much, and 9.6% very much). Particularly, 7.5% of consumers had enough information about ecological benefits whereas 27.9% had less knowledge on this matter

Table 2

The Descriptive statistics of respondents on the level of Awareness of GMOs risks and benefits.

| Statement | Very much | | Much | | Somewhat | | Little | | Very little | | 'Don't Know | |
|---|-----------|-------|------|-------|----------|-------|--------|-------|-------------|-------|-------------|-------|
| | n | % | n | % | n | % | n | % | n | % | n | % |
| 1 Possible ecological risks of GMOs | 91 | 9.61 | 137 | 14.48 | 254 | 26.84 | 105 | 11.09 | 105 | 11.09 | 251 | 26.53 |
| 2 Ecological benefits of GMOs | 71 | 7.5 | 114 | 12.05 | 224 | 23.67 | 130 | 13.74 | 143 | 15.11 | 264 | 27.9 |
| 3 Possible risks of GMOs for human health | 119 | 12.57 | 161 | 17.01 | 247 | 26.1 | 108 | 11.41 | 102 | 10.78 | 209 | 22.09 |
| 4 Benefits of GMOs for human health | 74 | 7.82 | 134 | 14.16 | 220 | 23.25 | 123 | 13.00 | 134 | 14.16 | 261 | 24.58 |
| 5 food security and agricultural benefits of GMOs | 92 | 9.72 | 151 | 15.96 | 205 | 21.67 | 125 | 13.21 | 128 | 13.53 | 245 | 25.89 |
| 6 The Coexistence of GMOs with other production systems | 46 | 4.86 | 89 | 9.4 | 198 | 20.93 | 115 | 12.15 | 121 | 12.79 | 377 | 39.85 |

(Table 2).

Regarding human health, it turns out that nearly more than half of the participants ‘hadn’t information about GMOs’ possible risks (22.1 % ‘don’t know, 10.7 minimal, and 11.4 % little). Only 12.5 % had enough knowledge about those risks. Of note, whereas some consumers were aware of the human health benefits (7.8 % very much, 14.1 much, and 23.2 somewhat), 24.5 % had no familiarity with the health benefits, and 14.1 % had little knowledge about them (Table 2).

Participants had a low-level awareness of food security and the agricultural benefits of GMOs. In general, although over 25.8 % of respondents did not know about the issue, 13.5 % had less knowledge, and 9.7 % were well-informed (Table 2).

Using the calculations of inferential statistics, the hypothesis of “Tehranian consumers are more aware of the GMOs’ risks rather than their benefits” was assessed. LSD test results about Tehranian consumers’ Awareness of environmental GMO risks at $p < 0.05$ level for the two groups (Table .2, rows 1 and 2) were calculated. According to the result ($F(3,945) = 28.524, p = 0.015$) the null hypothesis was accepted. The same test about Tehranian consumers’ Awareness of the health risks of G.M. products was calculated. the level of significance at $p < 0.05$ for the two groups (Table 2, rows 3 and 4) was tested and the same result ($F(3,945) = 28.524, p = 0.004$) was indicated.

In addition, to test the assumption that “Tehranian consumers are not aware of GMOs’ benefits for food security and agriculture,” the Chi-square independence test was used. A p-value less than 0.05 indicated statistical significance. The result shows that the null hypothesis was accepted ($\chi^2 = 36.321; df = 1; p = 0.002$).

4.4. Awareness of the food safety regulation

It also investigated how much participants were aware of biosafety regulations. Fig. 2b shows that more than half of the respondents (69%) replied that they did not know about the Biosafety Act whereas 31 % knew about it. Also, Fig. 2a indicates that 45 % of participants said they paid attention to the G.M. labels when purchasing and 55 % did not notice.

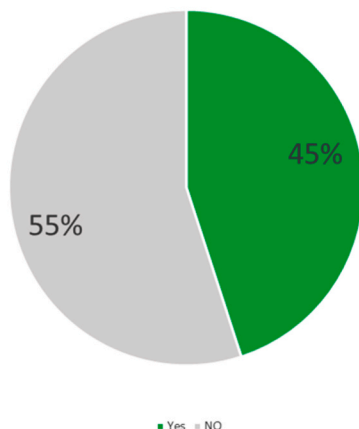
Substantiated by data presented in Table 3, although Tehranian consumers were not informed about the GMOs’ safety assessment (36.6 % ‘don’t know, 13.7 % very little, and 12.3 % little), 7.1 % said they were aware. Results also show that 51.5 % of the participants did not know that the biosafety law allowed the consumption, production, release, export, and import of GMOs (Object 2 of the Biosafety Law), and only 5 % were aware of the matter.

To add, Table 3 indicates that 56.8 % did not know about the governmental organization’s responsibilities regarding biosafety licensing (Objects 4 and 5 of the Biosafety Act), while 3.3 % and 5.1 % heard or read at some level. A few participants (3.8 %) had enough information about implementing mandatory GMO labeling (Object 7 of the law Biosafety). Meanwhile, 5.6 %, 11.8 %, and 9.9 % were not informed or knew little about labeling regulation, respectively. Stimulatingly, 15.1 % of the responses to the question “Do risk assessment tests have been done before GMOs entered the market?” were “no.” Furthermore, 56.8 % of the respondents had not adequate information about conducting research and field experiments on transgenic crops, and 43.2 % stated they had enough information about this topic.

According to the Chi-square independence test, it has been found that the hypothesis of “Tehranian consumers are not aware of the biosafety regulation and its details.” was accepted. The details include four items (1, 2, 3, and 4) in Table 3. A p-value less than 0.05 indicated statistical significance about all these items.

- H_{01} : Tehranian consumers are not aware of GMO safety Assessment. ($\chi^2 = 38.376; df = 1; p = 0.001$); the null hypothesis was accepted.

Noticing GMOs labels at purchasing time



Familiarity with biosafety regulation

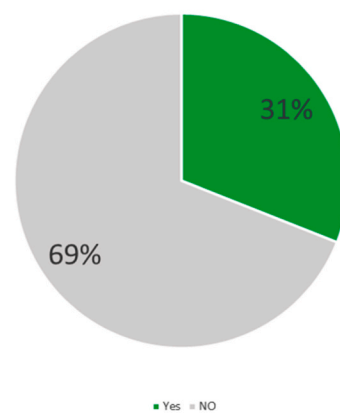


Fig. 2. a Noticing G.M. labeling at the time of purchasing Fig. 2b. Familiarity with biosafety regulation.

Table 3
The Descriptive statistics of respondents on Awareness of food safety regulation.

| Statement | Very much | | Much | | Somewhat | | Little | | very little | | 'Don't Know | | P-Value |
|---|-----------|-------|------|-------|---------------|-------|--------|-------|-------------|-------|-------------|-------|-----------|
| | n | % | n | % | n | % | n | % | n | % | n | % | |
| 1 GMOs Safety Assessment | 67 | 7.08 | 92 | 9.72 | 193 | 20.4 | 117 | 12.36 | 130 | 13.74 | 347 | 36.68 | p < 0.001 |
| 2 Legal authorization for consumption, production, release, export, and import of GMOs based on the law | 48 | 5.07 | 46 | 4.86 | 132 | 13.95 | 100 | 10.57 | 133 | 14.05 | 487 | 51.47 | p < 0.061 |
| 3 The governmental organizations' responsibilities regarding biosafety license | 32 | 3.38 | 48 | 5.07 | 111 | 11.73 | 96 | 10.14 | 120 | 12.68 | 538 | 56.87 | p < 0.005 |
| 4 Implementation of mandatory GMO labeling | 36 | 3.8 | 68 | 7.18 | 105 | 11.09 | 94 | 9.93 | 112 | 11.83 | 53 | 5.6 | p < 0.004 |
| Statement | Yes n | % | No n | % | 'Don't Know n | % | | | | | | | |
| 5 Implement risks assessment tests before GMOs enter the market | 265 | 28.01 | 143 | 15.11 | 538 | 56.8 | | | | | | | |
| 6 Conduct research and field experiments on transgenic crops | 409 | 43.23 | 107 | 11.31 | 430 | 45.54 | | | | | | | |

The data comparison shows that the respondents do not have enough information and might answer inaccurately because Iran has one of the strictest regulations on risk assessment and labeling. Interestingly, 55 % of respondents claimed they did not notice the G.M. labels when they purchase food (Fig. 2b), just 16.5 % are thoroughly aware of the mandatory labeling.

- H0₂: Tehranian consumers are aware of legal authorization to consume, production, release, export, and import of GMOs based on the law.
($\chi^2 = 24.267$; df = 1; p = 0.061); the null hypothesis was accepted.
- H0₃: Tehranian consumers know the organizations' responsibilities regarding biosafety licensing.
($\chi^2 = 40.373$; df = 1; p = 0.005); the null hypothesis was accepted.
- H0₄: Tehranian consumers are aware of the implementation Mandatory GMO labeling.
($\chi^2 = 51.551$; df = 1; p = 0.004); the null hypothesis was accepted.

Also, by comparing the result of Fig. 2a and Table 2 a couple of interesting points can be made. Among 651 participants who were unaware of the Biosafety Act, 32.4 % and 41.8 % claimed that they utterly understood GMOs' environmental and health risks, respectively. On the flip side, 38.4 %, 45.8 %, and 21.8 % of them believed they understood GMOs benefits for the environment, health, and food security. It should be pointed out that participants who said "yes" in answer to the question of being aware of GMOs, only 29.40 % knew about the labeling and monitoring process.

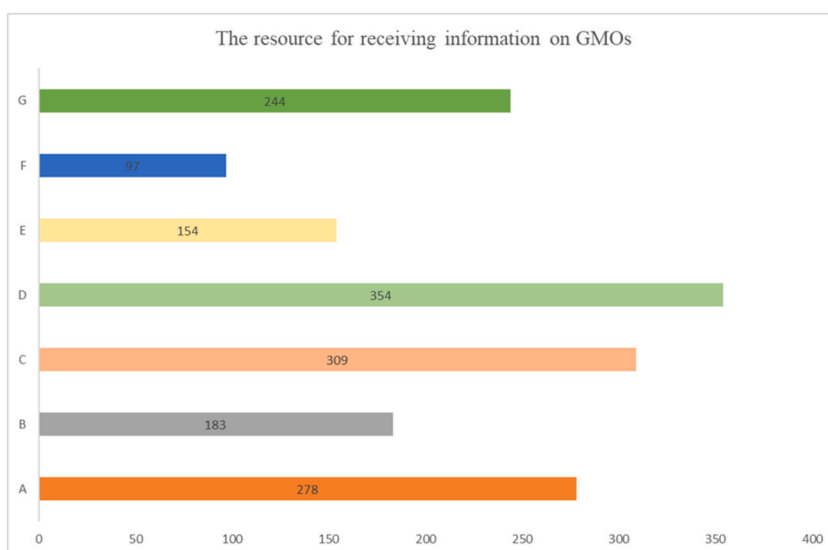


Fig. 3. The resource for receiving information on GMOs. A: Friends, family, and co-workers, B: Books/seminars/conferences and workshops, universities and significant associations, C: Informal social network pages, D: T.V., E: Newspapers, news agencies, F: national-official reference and laws. G: Search engines.

4.5. Receiving information about GMOs

One of the essential goals of this study was to identify the sources of Awareness about GMOs.

Based on Fig. 3, less than half of respondents (37.4 %) acquired at least some news from television, 32.6 % from social network pages, and 29.3 % from people they know (relatives and friends). While 19.3 % and 16.2 % received information from scientific articles, newspapers, and magazines, respectively.

As shown in Fig. 4, most repliers preferred to obtain information on the benefits and possible risks of GMOs, firstly from T.V. (48.7 %) and secondly from national-official references and laws (28.1 %). Also, Fig. 4 shows that only 20.1 % of respondents are interested in obtaining information from newspapers and news agencies.

Fig. 5a and b depict that a majority of consumers expressed a concern for being informed about the significance of transgenic issues (70 % versus 30 %). Conversely, a mere fraction of survey participants feel adequately informed, with only 14 % noting enough available information on GMOs compared to 86 % expressing the opposite.

Additionally, the Chi-square independence test was used to test the assumption of “Tehranian consumers do not care about receiving information about GMOs”. A p-value less than 0.05 indicated statistical significance. The calculation shows that the null hypothesis was accepted ($\chi^2 = 10.484$; $df = 1$; $p = 0.014$). Also, the null hypothesis regarding “Tehranian consumers receiving information about GMOs from radio and T.V. more than any other resources” was accepted ($\chi^2 = 96.062$; $df = 1$; $p = 0.023$).

A comparison of the results of this section with the data presented in Table 2 provides interesting points. Based on Table 2. Of the 248 people who claimed they were informed enough about the environmental and health risk of GMOs, more than half of them (67.2 %) received their information from sources other than T.V. Also, based on Fig. 2a among 651 respondents who were not informed about the Biosafety Act, 43.1 % received their information from T.V, indicating that television didn't perform well.

5. Discussion

It has been thought for a long time that 'people's decisions about consuming GMO products in their daily diet are hugely influenced by the extent of their awareness. It also is believed that the unaware public is the origin of an endless battle between pro-GM and anti-GM, which affected policies and can postpone technological advancement for several decades [33]. Nonetheless, based on the interpretation of this study, it can be discussed that public Awareness is not an influential component for GMOs acceptance, and other factors such as governance approach, policymaker interests, and enforcement of laws may have more weight. More specifically, researchers believed that the lack of scientific governance and national benefits-based approaches are the reasons for such significant inconsistency between Iran's capacities and achievements in plant biotechnology [25].

5.1. The insufficient consumers' awareness of GMO products, possible risks, and benefits

Statistical analysis of this study shows exciting results concerning the 'consumers' Awareness of GMOs. Despite passing 20 years

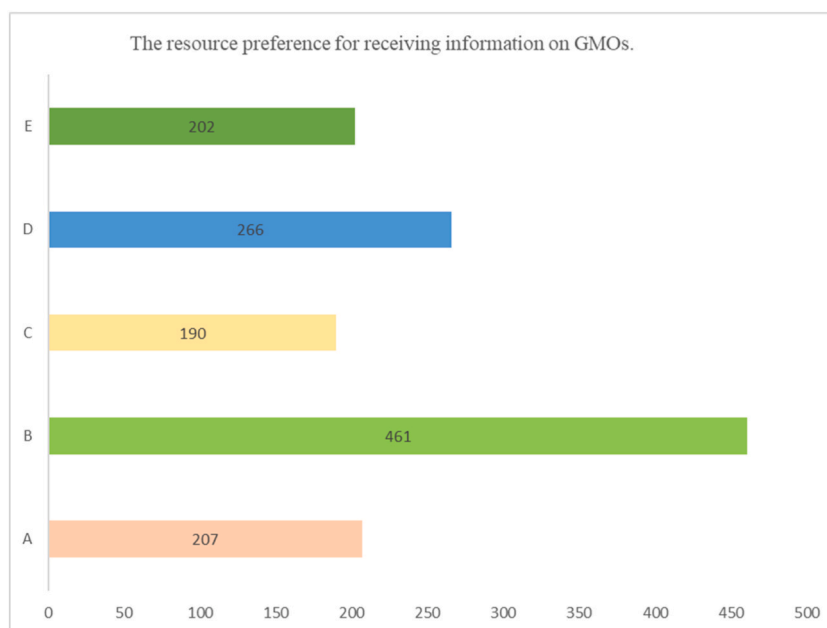
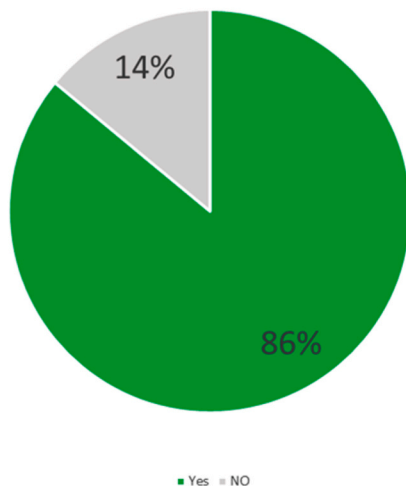


Fig. 4. The resource preference for receiving information on GMOs. A: Informal social network pages, B: T.V., C: Newspapers, news agencies, D national-official references and laws, E: Search engines.

Enough information is published about GMOs



The importance of Transgenic issues

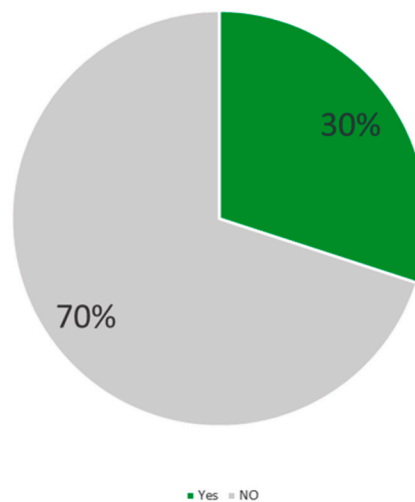


Fig. 5. a. Enough information is published about GMOs Fig. 5b. The importance of Transgenic issues.

since the first transgenic products were introduced in Iran and tense debates at the policy-making and media levels have proceeded, Tehranian are not familiar with the GMO term. According to others conducted research over the last 40 years, some other researchers also reported limited consumer knowledge of GMOs [34–36]. In addition, several previous studies have shown that the majority of consumers just have heard the name of G.M. foods, but they are confused due to the lack of specific information [14,37,38].

This study results indicated that Tehranian consumers had inaccurate knowledge about the type of GMO products: some were not informed, and others exaggerated the cultivation of transgenic crops in Iran. Based on the official announcement, no kind of G.M. crops have been cultivated in Iran. All the available GMOs in the Iran market are imported from other countries only for animal feeding or processing in the food industry, mostly for producing cooking oil. Most processed food, such as cakes, biscuits, canned tuna, popcorn, etc., which contain oil, is somehow related to GMOs. *Ministry of Health and Medical Education* (MOHME) declared that only four transgenic GM G.M. products, including oilseeds of canola, soybean, cotton, and corn, can be imported to Iran. G.M. soy was introduced to the Iran market more than 15 years ago, and since most processed foods derived from soy in the world are also GMO, most Iranians have consumed such products. Therefore, despite the abundance of products with G.M. ingredients in the shelf store, it has been found that the consumer is not aware of or does not care about this matter. Other researchers found the same result in the United States [19].

According to this study's findings, in line with low consumer awareness of the GMO term, half of the respondents are unfamiliar with the possible risks and benefits. It should be mentioned that the small portion who claimed they are well-informed, know more about the dangers than the benefits. Also, as others have noted, health risks get more attention than the ecological and agricultural aspects [18].

5.2. Doubt in biosafety regulation

Based on the results of this study, most Tehranian had less knowledge of the Biosafety Act and related regulations. Furthermore, people who claimed they were informed about the Biosafety Act were unfamiliar with the details such as mandatory labeling, and its risk assessment. Even though Biosafety Act has permitted the cultivation, production, consumption, export, and import of G.M. products, Iran enforced one of the most restrictive regulations regarding issuing licenses for cultivation.

According to this Act, an agency called "Biosafety Council" is established, responsible for monitoring, policymaking, and regulating the various GMOs' aspects. The council includes three governmental bodies, the *Ministry of Agriculture-Jihad* (IRI-MAJ), MOHME, and the *Department of Environment* (DOE). On the other hand, a government-security body called the Passive Defense Organization of Iran, which is not directly mentioned in the Biosafety Act, considers its institutional duty to be involved in implementing the Biosafety Act and regulating modern biotechnology materials. This organization's action has been one of the reasons for the long pause in issuing licenses for planting GMO crops in Iran.

On top of the Biosafety Act, licenses issued by *Iran's Food & Drug Administration* (FDA) to import G.M. Foods are based on strict criteria as follows; in the first place, the imported G.M. product should also be consumed in the country where these products are produced. In the second place, G.M. products should have an international license from the FDA of the United States or the European Food Safety Authority (EFSA) with a transparent genetic engineering process [30,39]. Consequently, Tehrani's consumer underestimates the amount of monitoring and assessment of GMOs, in contrast to what is happening.

5.3. T.V. still is the first resource for acquiring GMOs information

Despite the expansion of online resources, most Tehranin still receives information about G.M. products through television. Other studies make a similar point about the profound influence of T.V. on consumers' minds [40,41]. In this research, fewer respondents got their information from scientific sources such as scientific magazines, articles, and scientific documentaries, which aligns with previous research. They claimed that scientific literacy is limited in shaping public and Awareness of scientific issues and has a small share in influencing science-related decision-making [42]. Most respondents in this survey who declared they were well informed about the possible risk of GMOs mostly obtained their information from social networks. Under such circumstances, it is crystal clear that information in that kind of resource stresses the adverse aspects of GMOs rather than the benefits. Accordingly, choosing an efficient way of gaining knowledge is crucial to increase accurate scientific information [43].

The results of this research show that even though the participants do not receive enough appropriate information from the media, they still care about being aware of G.M. products, which can be attributed to the media's poor performance and scientists' informing the public. Limited Awareness of people has roots in two potential sources: either scientists do not express scientific content in a common language, or the media and science reporters do not convey the message well enough to be understandable.

6. Conclusion

This study identified and characterized Tehranian consumers in terms of their Awareness of G.M. foods. Although there have been numerous infrastructures and achievements in the field of agricultural biotechnology, and the Biosafety Act obligated Iran's government to facilitate the different aspects of GMO consumption, public Awareness at least in Tehran remains at a low level over the last 30 years. Therefore, a low level of awareness about GMOs' advantages and disadvantages, monitoring process, import and export guidelines, and the absence of informed media are persuasive signs that Iran's government was not successful in PAS, at least in Tehran city. Such significant inconsistency between Iran's capacities and achievements in plant biotechnology emanates from the lack of scientific governance and national benefits-based approaches.

It is time to ask, despite the urgent need for GMOs for future crisis such as climate change and ever-growing food demand, whether this biotechnology should still be limited to raising public Awareness. After more than 40 years of trying to familiarize the public with G.M. food, public Awareness and interest in this topic are negligible. One of the most important limitations of this study was a case study in Tehran. To continue the extensive research and study on people's views regarding transgenic products, the same poll should be conducted in different cities in Iran. Another limitation of this research was that a similar study in this field had not been published in Iran, and it was not possible to compare the data of this study with other studies in Iran. The major findings of this study can be summarized as: ', and all of these items were the strengths and key points of our research:

1. Tehranian are not aware of the advantages and disadvantages of GMO foods.
2. Policymakers have a significant role in educating people about GMO and conventional food production.
3. Labeling GMO foods could be useful, but if it does not convey a clear message, it might not significantly assist consumer choices, especially in the case of a lack of education. However, consumers are either confused about the different agricultural methods of food production, or do not care about how foods are produced as long as they are more affordable.

Authors contributions

Fatemeh Seraji: Data curation. Fatemeh Loni: Conceptualization. Azadeh shooshtari: Project administration. Mohammad Reza Ghaffari: Visualization, Conceptualization. zahra Hajatpour: Validation

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Consent for publication

Not applicable.

Declaration of competing interest

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest in the subject matter or materials discussed in this manuscript.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.heliyon.2024.e25487>.

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