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Consumer Evaluations of and Attitudes towards New Genome Editing Techniques: An Italian Case Study

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Abstract: The ever-increasing development of assisted evolution technologies (AETs) in agriculture has boosted crop improvement. The commercialization of improved biotech crops can be promoted by modern gene editing instead of conventional genetic modification, which is a cheaper and faster approach that can help address future agriculture challenges, such as food security, environmental sustainability, and climate change. However, the use of these technologies is still sensitive and debated in many countries. Each region promotes a different approach, depending on regulatory policies, and adopting these technologies requires knowledge of consumer views and stakeholder acceptance. For this purpose, we conducted a survey of 564 Italians regarding their knowledge of genetic techniques, informational tools, purchase preferences, environmental sustainability, and food safety issues. The research aims are twofold: (a) to assess the level of knowledge and (b) to determine how consumer background, including social and demographic characteristics, affects their level of knowledge. Our findings emphasize the importance of communication and dissemination activities, in which clarity and a broad appeal are key.

Keywords: assisted evolution technologies (AETs); consumer attitude; environmental risk and food safety; Italian consumer sample

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1. Introduction

In recent decades, interest in food security and environmental sustainability has steadily increased as the global population grows. Addressing these issues requires continuous improvement in food production methods, more sustainable systems, and higher product yields.

Advances in science and technology have significantly affected the food industry, improving food production, increasing crop resistance to diseases and drought, and increasing food nutritional content.

Consumers are increasingly interested in learning about their food sources and how different food production systems impact the environment and food safety. In particular, there is growing interest in understanding genetically modified food crops.

In Europe, as in many other places around the world, the related legislation represents the main obstacle to the use of these new technologies. Since 2001, assisted evolution technologies (AETs) have developed rapidly. In response, in 2019, the European Council asked the European Commission to assess the adequacy of existing legislation on the development and potential application of New Genomic Techniques. The resulting Commission study on NGTs (2021) found that the existing legislation was not fit for purpose and was ineffective in terms of risk assessment. The study argued that risk assessment should have requirements adapted to the characteristics and risk profile of a plant and stated that such assessment should be deemed unnecessary for plants produced through conventional plant breeding or classical mutagenesis. The study concluded that there are strong indications that the current EU GMO legislation is not fit to regulate NGT plants obtained by targeted

mutagenesis or cisgenesis, nor products (including food and feed) derived from them, and consequently, legislation should be adapted on the basis of scientific and technical progress [1–3].

This raises the problem of different applications of national laws between countries. Indeed, the various national legal frameworks show divergences in biotechnology regulation, which contributes to limiting biotechnological development [4]. Several GM food issues have also become controversial at different levels, from food security to environmental issues, including risks and benefits.

Assisted evolution technologies, including NBTs, are an alternative to traditional genetic selection tools and represent a potential response to the important challenge of sustainably increasing food production. Differently from GMOs, NBTs also allow the introduction of new characteristics without involving genes from other species, keeping the genetic heritage unaltered. Consequently, the resulting plant product is free from foreign genes and would not be distinguishable from the product generated by conventional breeding techniques [5].

Myths and facts guide consumer choices. One popular myth is that GM foods are not natural food products and, thus, are unsafe for consumption, as most of the relevant literature highlights. The fact is that GM foods are safe, and almost everything we eat is genetically modified; just think of "pachino" tomatoes, apples, or corn. The literature has also shown that consumers can have both positive and negative perceptions of GM products that are offset by personal values and ethics [6]. Scholars also stress that the perception and acceptance of GM foods could be influenced by the values held by specific groups, including overall concerns about global food and food security, climate change, and ethical beliefs. Moreover, empirical evidence suggests that more education in terms of quality information would allow consumers to make purchasing decisions that accurately reflect their beliefs [7].

The level of consumer acceptance of GM products is also guided by trust in institutions, scientific knowledge, and pricing. This means that the government's decision to ban or approve GM crop cultivation, as well as the communication strategies used, can influence consumer attitudes and choices [8,9]. Literature findings reveal that perceived benefits and risks play a significant role in determining consumer behavior toward GM food.

Finally, gender differences and income levels also seem to play a role in consumer perceptions. Bellows et al. [10] found that women were more strongly inclined to purchase non-GM foods, and income level impacts attitudes toward GMOs.

In light of the above, the present study aims to understand Italian consumers' feelings towards and perceptions of AET. By using a descriptive analysis, we study the correlation between the consumer's level of knowledge of AET and sample demographic characteristics. The correlation between consumer backgrounds and knowledge levels has been confirmed here. We used an original Italian sample administered via the Appinio agency platform. The relevance of this research is linked to the reluctance of Italian consumers to accept genetically modified foods. The results of this study reveal that consumer opinions are heavily linked to the information tools used, where information accessed via social media, press, and television is of poor quality, and scientific communications are aimed at a very small audience.

2. Literature Review

The development of new genomic techniques has been an incentive to launch a revision of the legal framework governing the use of agricultural biotechnologies. The use of advanced breeding techniques will likely be required by the Green Deal, which seeks to transform the EU into a modern, resource-efficient, and competitive economy.

These techniques could provide the key to addressing modern agricultural challenges (climate change, food supply, environmental sustainability). However, understanding consumer opinions is essential since they are the end users of products. Consumer knowledge of genetic techniques is low [11]. McGarry et al. [12] compared consumer knowledge levels

in the United States, Japan, and Italy, finding that US consumers were more likely to be familiar with GMOs, with a percentage of 40.9% compared to 33.3% in Japan and only 28% in Italy.

Lusk et al. [13] find heterogeneity in terms of knowledge and that some consumers recognize there are differences between GMOs and genome editing (GE). Consumers pay attention to risk analyses in terms of health and the environment rather than the process used to create new products. Consumer knowledge affects their attitudes toward GM food and other consumer goods. Knowledge of GM technology is also linked to consumers' perceptions of the benefits and risks of genetically modified food and is considered a significant factor in correcting distorted perceptions and intentions regarding GMOs [14].

Another branch of the literature points out that one of the main obstacles to consumer acceptance is attributable to the type of information tools used [7,15,16].

The concerns related to food safety remain, although there is some consensus on the contribution of biotechnology to sustainable food systems, particularly in creating opportunities for environmental protection and generating good performance in the agricultural and food sectors [17–21].

Some scholars agree that consumers perceive transgenic products with the same properties as conventional ones and, consequently, the same probability of being harmful to humans. These consumers also believe GM foods positively address global food insecurity [17,19,22]. Conversely, many consumers still believe that genetically modified plants are the result of an artificial crossing of naturally incompatible genes; hence, a source of high risk for human health. These consumers believe GM foods alter the characteristics of native foods, causing harmful health effects. Many uncertainties remain, and consumers show strong resistance to food safety dimensions, feeding the scientific debate on the use of biotechnology in the agri-food field [8,23–27].

De Marchi et al. [28] investigate the motivations for consumer acceptance of cisgenic products. By comparing four information treatments related to basic information, naturalness, health, and environment, the authors show that information on health-related benefits and, particularly, environmental benefits helps generate a positive communication landscape around cisgenic food. The results suggest the need to develop food policies and new communication strategies aimed at increasing consumer acceptance of edited food.

The introduction of GM food should be accompanied by adequate policies to guarantee consumer safety; this would allow a decrease in consumer-perceived risk concretely relating to health [29,30].

Controversies linked to sociocultural factors, lack of public education, deficits in science communication, and ethical issues remain.

It is necessary to develop scientific evidence-based decision-making models and assess the risks and benefits of agricultural biotechnology with the highest scientific rigor, considering agricultural biotechnology could reasonably be considered practicable when certain conditions are met: consumers have a good knowledge of the products; products are accepted globally and by the communities in which they are developed; there is potential to directly benefit farmers; and there is responsible design to limit and minimize risks [31].

Nonetheless, disagreement regarding GM foods persists on several levels, including whether it is safe, whether it should be labeled and if so, how, and whether agricultural biotechnology is needed to address world hunger now or in the future. The empirical evidence has demonstrated that innovations based on these new research techniques provide substantial economic benefits and environmental improvements in critical ecosystems with important overall contributions to sustainable development, specifically in terms of higher yields, lower pesticide use, increased farm incomes, reduced pollution, and increased resilience to weather [32].

Many consumers have no deep knowledge of GM foods and could overestimate their objective knowledge. Moreover, McGarry et al. [12] show that European consumers have a strong preference for organic foods, which could affect their attitudes toward GM products. The US and EU have two contrasting approaches to GMO legislation in terms of

approval. The US advocates for GMOs through approval and production, but in the EU, the precautionary principle toward GMO use is being applied. These legal norms are closely related to various social values, directly or indirectly [33]. The European Commission is taking action to rebuild the current EU GMO legislation in order to exclude NGTs from the current detection, labeling, and approval requirements with the aim of informing the public about the benefits of NGTs and breaking the resistance to GM crops.

Scholars have validated that social trust can play a prominent role, in particular, trust in regulatory agencies and procedures in use [31].

Increased knowledge through communication and education might affect public perceptions about agricultural biotechnology, in particular, building trusting relationships between experts, policymakers, regulators, and the public.

3. Materials and Methods

3.1. Survey Description

The purpose of this document is to examine, via a questionnaire, consumer's feelings about genetic modification techniques. In particular, we explore the relationship between level of objective and subjective knowledge and levels of income and education. The dataset used is original and derived from a sample analysis involving 564 men and women residing in Italy who answered 15 questions in Italian (see Appendix B). The survey was conducted by the Appinio research agency (Appinio DEU, Hamburg, Germany) using a CAWI methodology (computer-assisted web interviewing), which is a survey and data collection method that relies on web-based technology to administer questionnaires and collect responses from participants. Data was automatically collected on Appinio's own survey platform. Subjects came from two main sources: from Appinio's own panel, i.e., people who registered to the Appinio App and expressed their consent and availability to complete surveys, or from partner panels, which work as an extension of the Appinio panel.

In both cases, upon registration, panelists were invited to provide their basic sociodemographic information, mainly gender, age, location, educational level, employment status, civil status, and household income. Thanks to this information, Appinio can direct the survey invitations exclusively to respondents that match specific survey requirements (e.g., if the target group consists of people with a university degree, only people who previously declared having a degree would receive the notification). This methodology allows the Appinio data to be of high accuracy and quality—meeting exactly the quotas needed for each study.

After delivery of surveys, APPINIO collects the answers given by the end users and provides them in anonymous, aggregated form, together with anonymous demographic and statistical data on the client in the form of an evaluation for market research purposes.

Panelists provide us with this data voluntarily and to a self-determined extent. The data provided are aggregated and made available anonymously in a statistical evaluation that does not allow any conclusions to be drawn about individual users.

The information on the specific use of data that Appinio collects and provides is available in Appendix C.

The sample collected and used in this study is representative and stratified by sex and age. A high standard of responses was granted from Appinio quality controls, with a low margin of error and a high confidence level (e = 4.38% | 95% C.I.).

3.2. Survey Structure

The questionnaire was divided into four sections, as described in Figure 1. The first stage of the questionnaire includes a self-assessment of knowledge with questions related to subjective and objective knowledge; it explores what consumers think they know about genetically modified techniques (GMT) and what they really know. The next questions relate to the tools used to acquire information on GMTs. The third section comprises topics related to the environment, food safety, and willingness to purchase GM products.

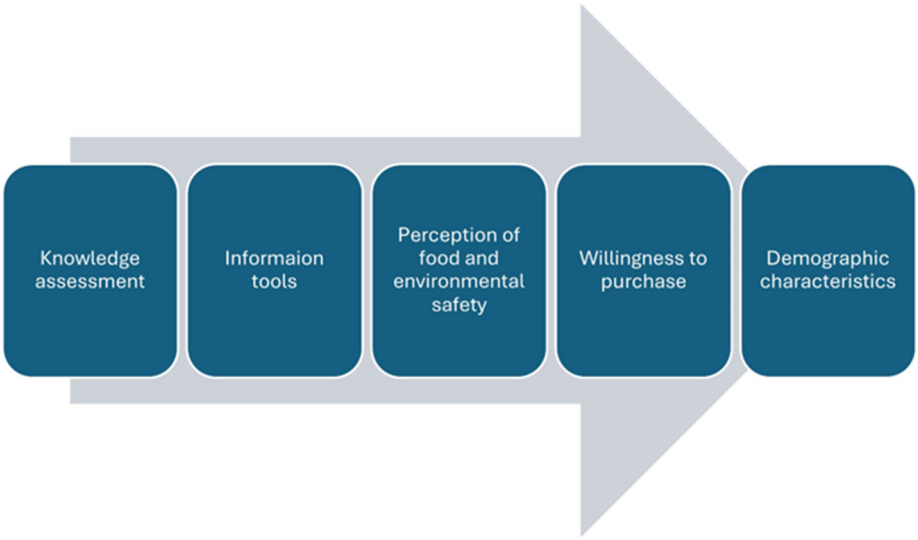

Figure 1. Survey structure.

Some of the responses were based on a 5-point Linkert scale; others were based on single or multiple-choice. Some of these responses were recorded based on their distribution.

In the first part of the survey, regarding knowledge, respondents answered four questions on GM food; three of these were related to subjective facts, while one was related to objective facts, with only one correct answer option (see Appendix B, questions F1 to F4 in the survey). Participants were asked what genetic improvement methods they know with multiple response options, mainly distinguishing between techniques that are used regardless of genetic modification and new techniques, like GMOs or NBTs (see Appendix B, question F1 in the survey). Moreover, the knowledge of the differences between NBTs and GMOs and the purpose of genetic modification has been investigated (see Appendix B, questions F2 and F3 in the survey). The last question of the first section regards the "objective" or real knowledge and investigates the consumer's knowledge of the most cultivated agricultural species, such as GMO seeds (see Appendix B, question F4 in the survey). A score ranging from 1 to 5 indicates the level of objective knowledge on the topic. Respondents who chose soy and cotton have a high level of objective knowledge. Based on the answer to question 1 (see Appendix B, question F1 in the survey), we generated a new variable to capture the subjective knowledge, which is the sum of the methods known by respondents. This variable captures the level of presumed knowledge. We also investigate what respondents think about the scope of genetic modification by evaluating both the single and multiple-choice responses (see Appendix B, question F3 in the survey).

Consumer knowledge is key in the consumer's perception and propensity to purchase GM products. Nevertheless, the literature highlights the existence of a gap between objective and subjective knowledge. The first one refers to what consumers really know about GM techniques, while the latter concerns what consumers think they know. Fernbach et al. [34] pinpoint that consumers who are opposed to GM products have a high subjective knowledge but low real knowledge. Therefore, it is important to understand this gap to address the propensity of the public to negatively regard NBTs and GMOs, which are often considered to be the same.

Section two includes a question related to the use of information tools (see Appendix B, question F5 in the survey). The variable related to information tools is scored from 1 to 5, and it is also coded as the sum of the total number of information tools used to acquire materials on GM food crops and products.

Section three includes questions related to the perception of food and environmental safety (see Appendix B, questions from F6 to F8 in the survey). Participants were asked to choose from the following options: (A) I believe GM foods are unsafe (to eat or for the

environment), (B) I believe they are a little safe, (C) I don't know, (D) I believe they are fairly safe, (E) I believe they are absolutely safe. Moreover, participants were asked whether they believe GM foods or crops could contribute to environmental sustainability. These variables are both re-coded between 1 and 3, where 1 corresponds to "No, they don't"; 2, "I don't know"; and 3, "Yes, they do".

Finally, the survey explores consumers' attitudes toward purchasing GM products (see Appendix B, questions from F9 to F10 in the survey). Specifically, it investigates the willingness to purchase GM foods. Also, this score, initially ranging between 1 and 5, has been re-coded in a new variable with 1 for "I don't buy", 2 for "I don't know", and 3 for "I do buy". Additionally, we investigate the willingness to buy depending on the product's origin.

Table 1 shows the demographic characteristics (The survey, reported in Appendix B due to space constraints, includes only questions related to income, educational degree, and geographical area. Gender and age were used for the sample stratification.) of the sample regarding age, gender, income, education level, and region. The respondents, men and women between 18 and 65 years old, were prescreened by gender, education, household, region, and income to ensure the representativeness of the statistical population. The distribution of the sample by geographical area is illustrated in Figure 2, with a greater component in northeastern Italy, equal to 14.5% of the women and 14.7% of the men.

Table 1. Demographic characteristics (*N* = 564).

Gender	***N***	**(%)**
Male	275	48.7
Female	288	51.1
No response	1	0.2
Total	***564***	***100***
Income		
0–15,000 Euros	160	28.3
15,000–30,000 Euros	249	44.3
30,000–50,000 Euros	99	17.6
>50,000 Euros	55	9.8
Total	***564***	***100***
University Degree		
Doctorate Degree	27	4.8
Master	98	17.4
First Degree	77	13.7
High school diploma	304	53.9
Middle school diploma	55	9.8
No qualification	3	0.4
Total	***564***	***100***
Number of family members		
1	85	15.1
2	158	28.0
3	175	31.0
4	115	20.4
5	27	4.8
+6	3	0.5
No response	1	0.2
Total	***564***	***100***

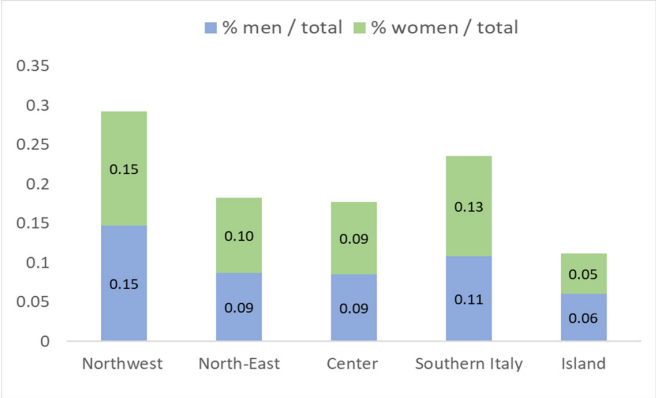

Figure 2. Sample distribution by geographical area.

As shown in Table 1, respondents comprise 275 men (48.8%) and 288 (51.1%) women. More than half of the sample reported having a high school diploma, 13.7% a bachelor's degree, and 17.8% a master's degree. Forty-four percent of respondents earn between 15,000 and 30,000 euros per year (249 participants out of 564, or 44.3%), while the remainder are divided between those who earn more than 30,000 euros and those who earn less than 15,000 euros.

4. Results

4.1. A Preliminary Analysis of the Survey Results

Among all techniques, most people (68%) stated that the most improved methods they know are the GM methods, followed by in vitro culture techniques (47%). Specifically, the vitro culture technique is more known by women than men (W: 51% vs. M: 42%). Only 7.1% are informed about new breeding techniques; we can say that Italian consumers have heard little about NBTs, and the percentage of respondents is really informative in that sense. The responses to this question highlight the knowledge gap in the Italian population. This is strictly related to the other two questions on the differences between GMOs and NBTs and on the purpose of genetic modification. Concerning the differences between GMOs and NBTs, 42% stated they know that there are differences between all the new breeding techniques, but only 15% really know what these differences are. In contrast, 2.8% claimed to know that differences between these two kinds of techniques exist (Figure 3a). Regarding the scope of genetic improvement, resistance to pests, diseases, and herbicides was recognized as the main purpose of genetic modification (48%), especially by respondents belonging to the age group 55–65. Adaptation to climate change was the second most selected option (Figure 3b).

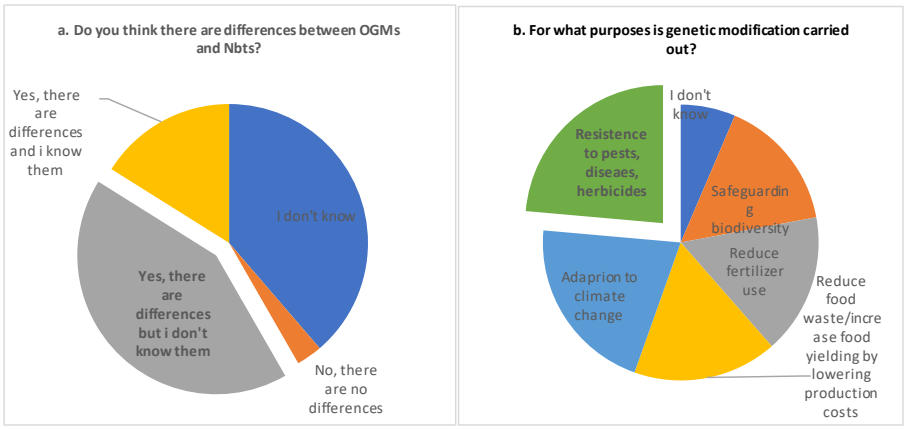

Figure 3. (**a**,**b**) Knowledge level of genetic improvement.

4.1.1. Consumers' Subjective and Real Knowledge

As the literature points out, consumers' knowledge affects their attitudes toward GM food. Consumers' knowledge of GM techniques is also related to their perceptions of the aims, risks, and benefits of GMOs. However, the level of knowledge is strictly related to educational level. Below, we analyze the subjective and real knowledge of the level of income and education.

Concerning the real knowledge, a question related to the most commonly cultivated GM seed was posed. Thirty-five percent of respondents thought this was maize, 21% wheat, while only 19% of respondents correctly selected soya, and 5% selected cotton. These results emphasize a distortion in consumers' real knowledge. This suggests that the level of consumer knowledge is relatively low. Because of this, confidence in GM products is undermined, and consumers may delay or avoid making decisions because they feel anxiety or uncertainty about their purchase consequences [14].

The second section of the survey deepens the relationship between genetic editing and environmental and food sustainability. Participants answered questions on two issues: whether they feel the GM products are safe to eat and whether they consider AET safe for the environment (Figure 4). Regarding GM food safety, 34% of respondents responded in the affirmative. Among them, men were more likely to be confident with them (average—M: 3.3% vs. W: 3%), and most of these respondents hold a doctoral degree.

Figure 4. Food and environmental safety.

A degree of skepticism among Italian people towards genetically modified organisms has been confirmed [12]. However, when they are interviewed about the possible purposes/benefits of AET for the environment, their opinions improve. Thirty-eight percent of the sample believe that AETs are fairly or very safe for the environment, while more than half of the sample (55%) felt that AETs could contribute to environmental sustainability (Figure 4). Younger generations are more likely to identify the preservation of biodiversity as a goal. Twenty-seven percent were undecided on the subject. Men recognized the contribution of AET to sustainability more than women (M: 61% vs. W: 49%). Figure 4 shows that people have similar feelings in terms of food and environmental issues.

Scholars suggest people generally support cisgenic application to reduce pesticide residues but maintain more negative perspectives on GM foods [35].

4.1.2. Consumer Information Tools

Notably, when asked about the tools used to obtain information on GM products, 35.8% of respondents indicated social media, 33.7% scientific publications, 46.6% press and television, and 16.1% friends and acquaintances, while 12.3% do not use any kind of information tool and 1.4% selected "other". This result highlights how our sample relies on Press/Television and social media (with a percentage of 84%). This finding reflects the fact that confidence in scientific publications plays a lesser role in comparison to the other tools used by our sample. Unsurprisingly, this outcome is confirmed by other empirical

work, such as [36], which suggests that the Press and Television can often create confusion that affects levels of the acceptance of GMOs. On the other hand, social media plays an intermediate role, more popular among young people [19,20].

4.2. Consumer Behavior

In the survey, we included a question related to product origin. Four in ten Italians would buy a product from GM crops. Consumers are more confident in products coming from Western Europe (62%) and North America (50%) than those from African (24%) and Asian (26%) countries (Figure 5).

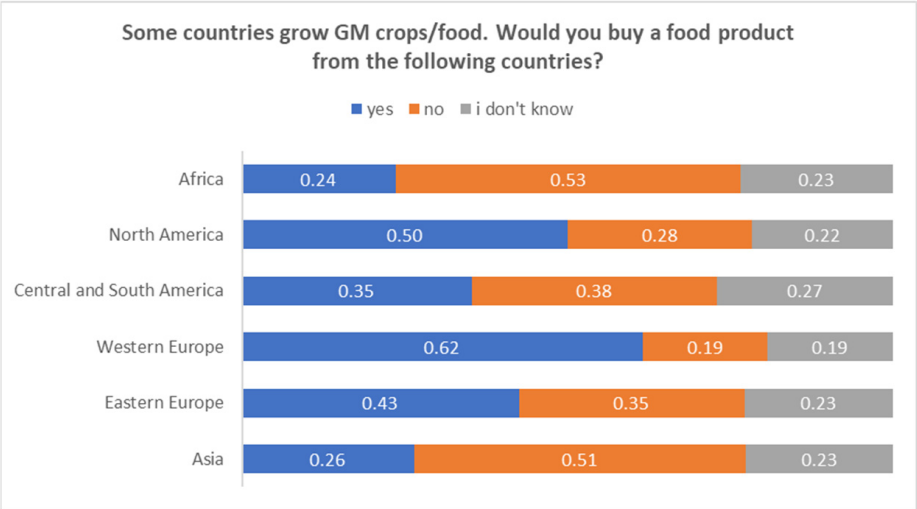

Figure 5. Geographical purchasing preferences.

4.3. Descriptive Analysis

Two statistical techniques were selected to analyze qualitative and quantitative variables extracted from the survey: (i) contingency tables have been used to explore the relationships between categorical variables (e.g., real knowledge, gender); (ii) a correlation matrix has been adopted to examine correlations between quantitative variables collected in the questionnaire (e.g., food security, environmental safety). The data were analyzed using R software (version 2023.06.1+524), and visualizations (e.g., tables, bar charts) have also been provided accordingly [37].

4.3.1. Consumer Analysis of Real and Subjective Knowledge

Figure 6 illustrates the conditional distribution of real knowledge for each subjective knowledge category. It sheds light on how people's self-assessments align with their understanding of the most grown GM crops. It is evident that a significant percentage of respondents (39.6%) confidently identify corn as the most cultivated GM crop, followed by wheat (27.5%), soy (20.9%), and cotton (8.8%) (see Table A1—Appendix A). Although many respondents consider themselves knowledgeable about GM crops and believe that corn is the most cultivated, in fact, the correct response is cotton and soybean.

Figure 7 offers insights into the conditional distribution of subjective knowledge across different levels of education, revealing how individuals' self-assessed knowledge varies based on their level of education. Among individuals with a high school diploma, which is the most prominent group, representing 54% of the overall sample, a significant proportion (52.7%) acknowledged a lack of knowledge by responding with "I don't know". In contrast, 7.3% confidently asserted "No" to having knowledge about GMOs. Approximately 31% expressed uncertainty with "Yes, I don't know", while 9.1% selected "Yes, I know". This pattern indicates that a notable portion of those with a high school diploma tend to admit uncertainty in their knowledge of GMOs.

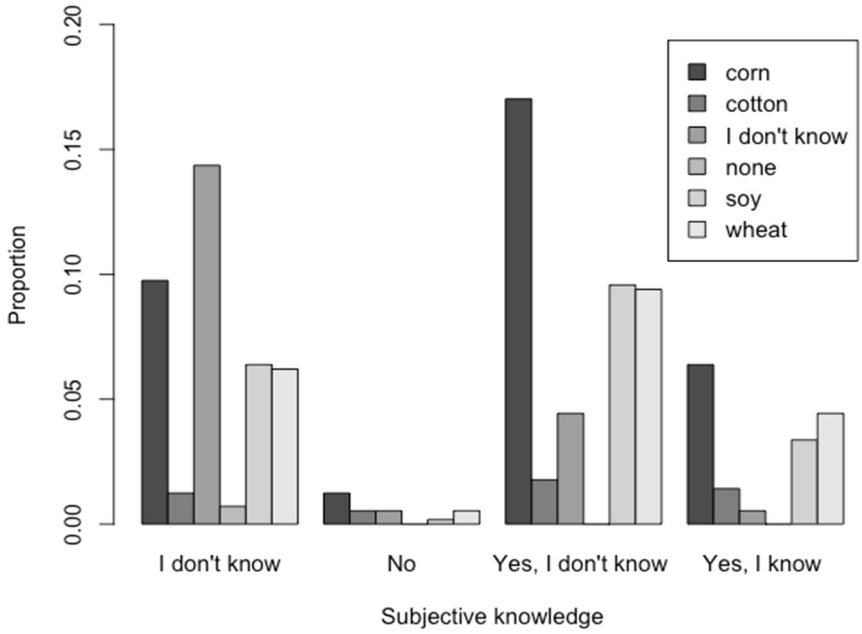

Figure 6. Conditional distribution of real knowledge by subjective knowledge category (proportion).

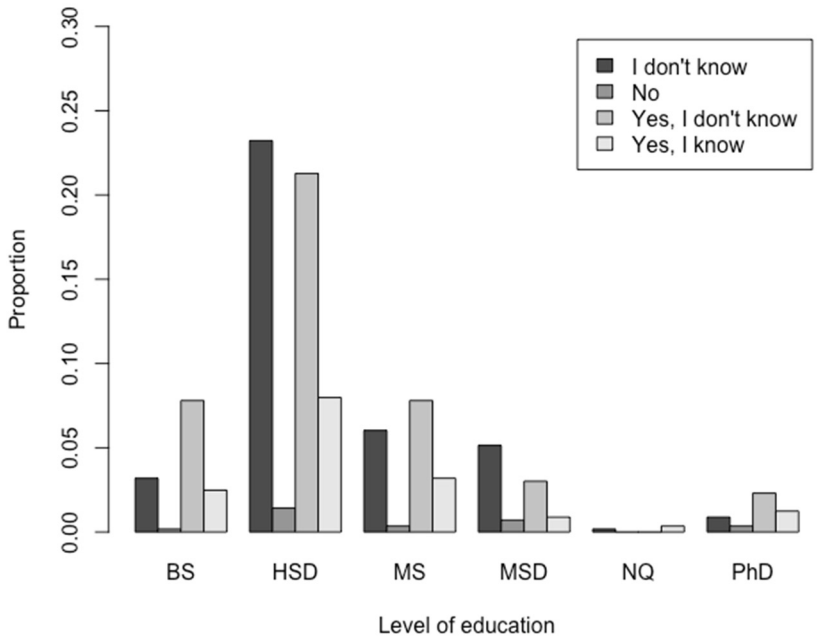

Figure 7. Conditional distribution of subjective knowledge by level of education (proportion). Note: bachelor's degree (BS), high school diploma (HSD), master's degree (MS), middle school diploma (MSD), no qualification (NQ), and doctoral degree (PhD).

Figure 8 examines the distribution of real knowledge across different educational backgrounds. As we can see from Figure 8, the following percentages indicate the respondents who have identified corn as the most cultivated crop: 39% (bachelor's degree), 30.6% (high school diploma), 44.9% (master's degree), 32.7% (middle school diploma), and 66.7% (no qualification). Individuals with doctoral degrees exhibited a lower percentage, with 25.9%, when identifying corn as the most cultivated crop. Conversely, they reported soy with 33.3% as the most cultivated GM crop, indicating a relatively greater real knowledge compared to other educational categories (see Table A2—Appendix A).

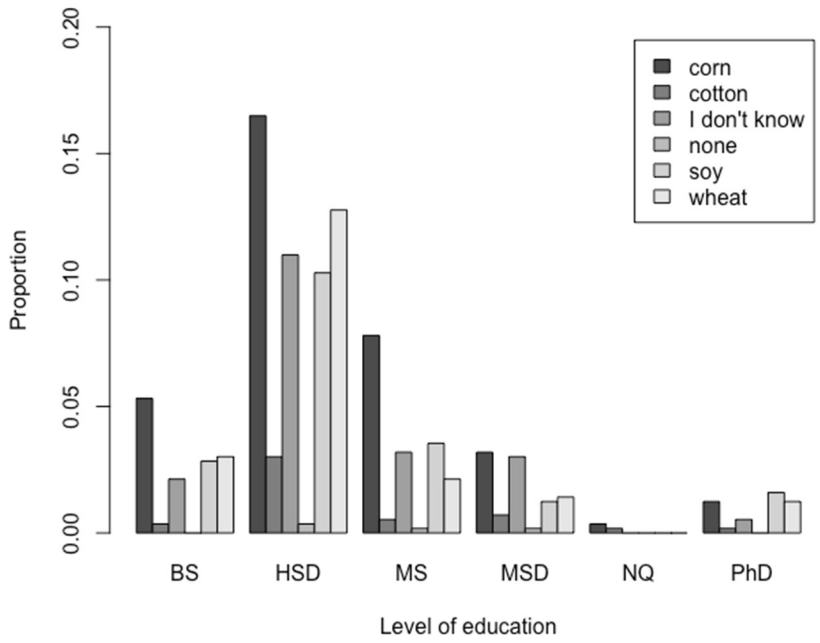

Figure 8. Conditional distribution of real knowledge by level of education (proportion). Note: bachelor's degree (BS), high school diploma (HSD), master's degree (MS), middle school diploma (MSD), no qualification (NQ), and doctoral degree (PhD).

Figure 9 shows the distribution of real knowledge across individuals based on gender. Male respondents displayed a higher response rate regarding corn at 38.9%, while female respondents had a lower percentage at 30.1%. Conversely, women exhibited a higher response rate regarding soy, with 21.1%, compared to men, who had a slightly lower percentage at 17.8%. Additionally, women tended to express more uncertainty, with 21.8% responding "I don't know", while men had a slightly lower percentage at 17.8% (see Table A3—Appendix A).

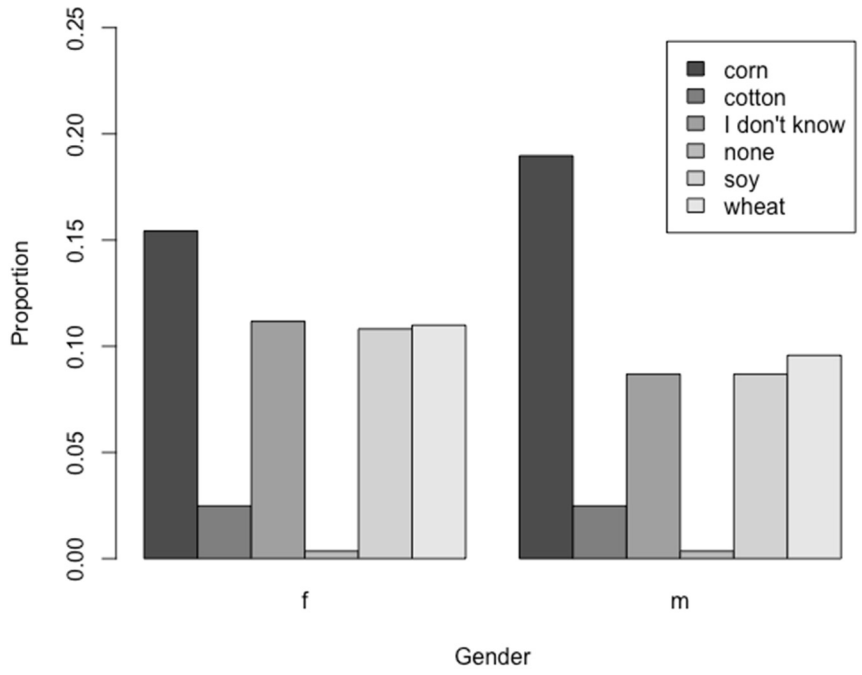

Figure 9. Conditional distribution of real knowledge by gender (proportion).

4.3.2. Consumers' Subjective Knowledge and Environmental Sustainability According to Income Levels

Figure 10 displays the conditional distribution of subjective knowledge among individuals with varying income levels. People with incomes between EUR 15,000–30,000 and between EUR 30,000–50,000 exhibited similar knowledge patterns. However, 50% of those with incomes below EUR 15,000 expressed uncertainty, responding with "I don't know", indicating a remarkable level of doubt regarding their knowledge of GMOs. Conversely, individuals with incomes exceeding EUR 50,000 displayed the highest percentage of having no knowledge of this topic, with 11% (see Table A4—Appendix A).

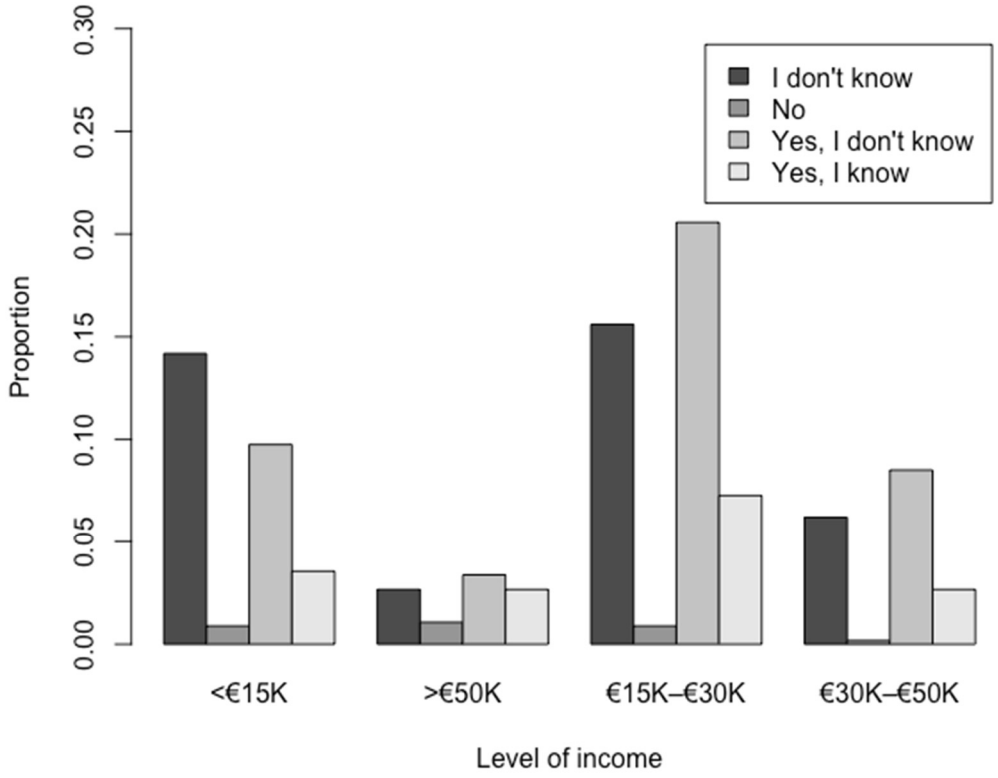

Figure 10. Conditional distribution of subjective knowledge by level of income (proportion).

Figure 11 illustrates variations in perceptions of the environmental sustainability of GMOs across diverse income levels. Individuals with incomes ranging from EUR 30,000 to 50,000 exhibited significant support for environmental sustainability, with 62.6% responding affirmatively with a "Yes". Furthermore, among those with incomes exceeding EUR 50,000, a substantial majority of 60% distinctly embraced a positive perspective on GMO's environmental sustainability. Within the income bracket of EUR 15,000 to 30,000, a significant 55.6% of individuals endorsed environmental sustainability, highlighting substantial support for GMO-related environmental sustainability in this income category. Lastly, individuals with incomes below EUR 15,000 also demonstrate substantial support, with approximately 46.9% expressing a favorable view of environmental sustainability (see Table A5—Appendix A).

4.3.3. Consumers' Real Knowledge According to Geographical Area

Figure 12 sheds light on how residents in the central, northeastern, northwestern, and southern areas understand the main GM crop cultivations. Individuals in all surveyed regions provided a high response rate related to corn, with percentages ranging from 30.1% to 40%. When looking at soy, the northeastern region stood out with 28.2%. In contrast, the central and northwestern regions exhibited rates of 20% and 23%, respectively, while the southern region presented a notably lower response rate on soy with 11.7%. Across all

geographical regions, responses regarding cotton were relatively modest, ranging from 3% to 5.8% (see Table A6—Appendix A).

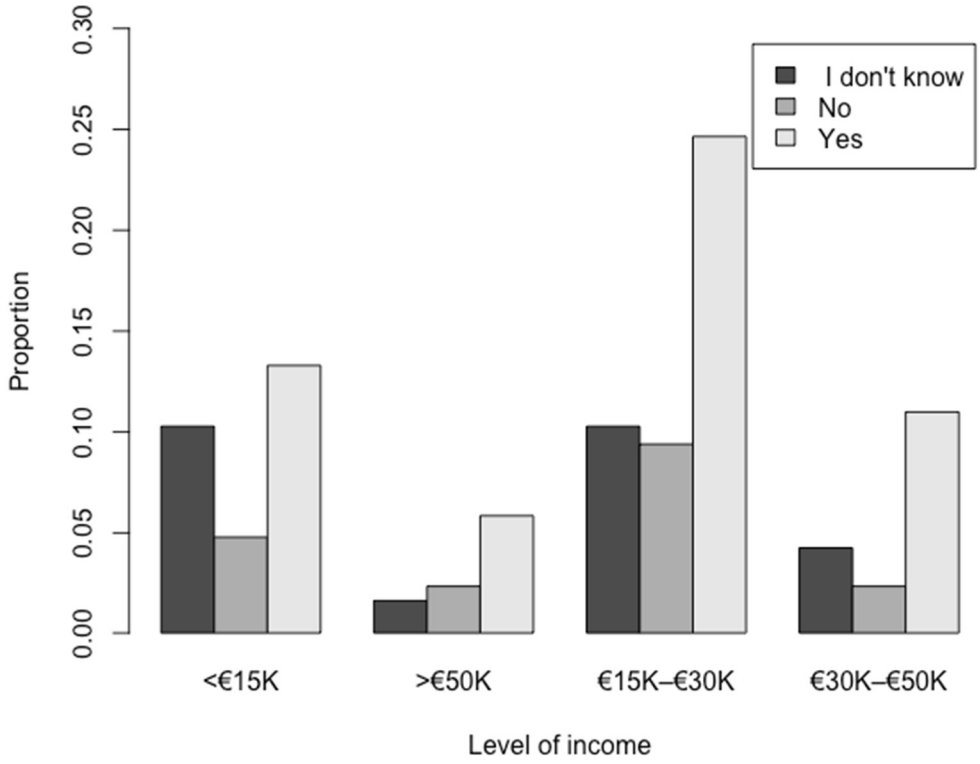

Figure 11. Conditional distribution of environmental sustainability by level of income (proportion).

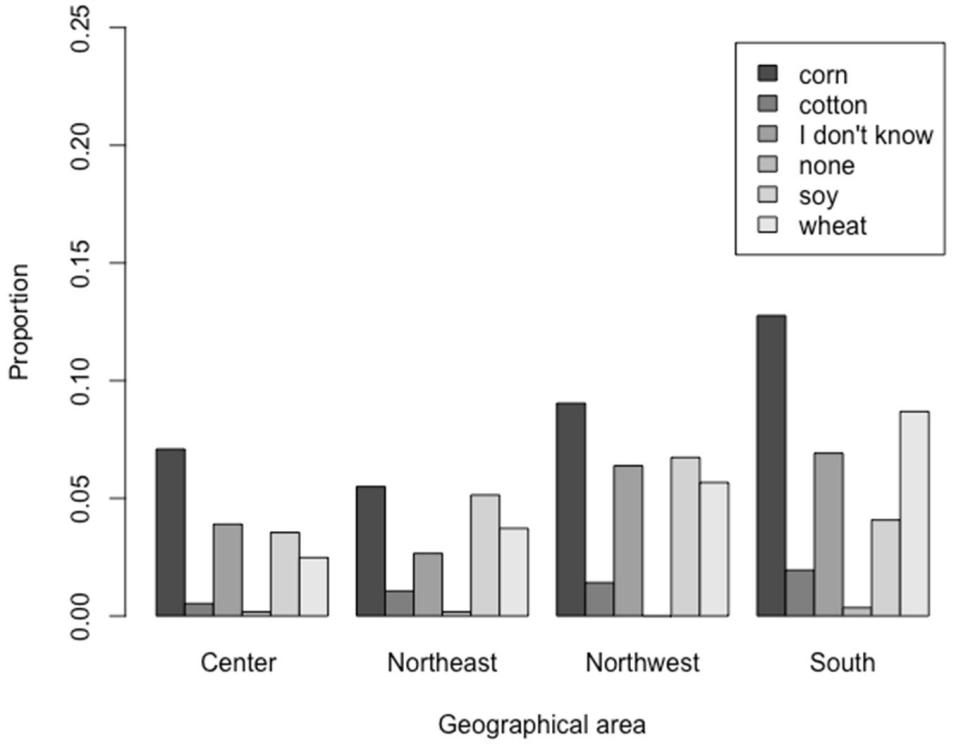

Figure 12. Conditional distribution of real knowledge distribution by geographical area (proportion).

4.3.4. Correlation Analysis: Food Security, Environmental Safety, and Consumer Purchase Propensity for GMOs

Figure 13 displays the level of correlation based on the Pearson correlation coefficient across key responses provided on the Likert scale: food security, environmental safety, and consumer purchase propensity for GMOs. The correlation analysis indicates a strong relationship between the analyzed variables. Firstly, a significant positive correlation of 0.8 was observed between food security and environmental safety responses. This suggests that as levels of food security perception increase, the perception of GMO environmental safety increases as well. Secondly, there was a positive correlation of 0.7 between food security and consumer purchase propensity. It indicates higher levels of food security responses associated with a greater purchasing intention. Thirdly, a robust positive correlation of 0.8 exists between environmental safety and consumers' attitudes toward purchasing GM products. This correlation implies that individuals who consider GM crops or foods environmentally safe may also be more inclined to purchase GM products.

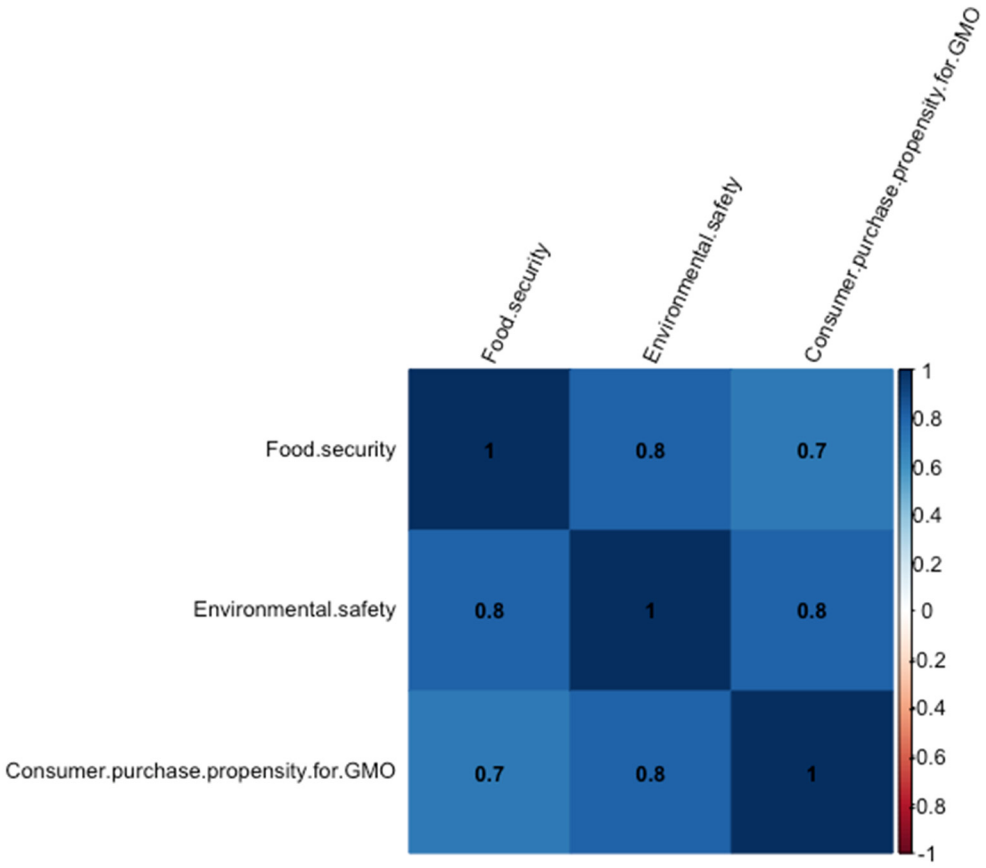

Figure 13. Heatmap: food security, environmental safety, and consumer purchase propensity for GMOs. Note: The color intensity represents the value of the data point, with lighter colors indicating lower values and darker colors indicating higher values.

5. Discussion and Conclusions

This study offers fresh insights into the knowledge of AET, the information tools employed, and the behavioral intentions of a sample of Italian consumers.

The analysis reveals that only a low percentage of consumers know NBTs; conversely, most respondents know in vitro culture techniques and GMOs. Only 16% of the sample stated that there are differences between GMO products and products obtained through the use of new breeding techniques, and they know what these are.

Additionally, consumers feel more confident if products originated in the most developed countries (Western Europe and the US). These results align with the research

conducted by Hwang and Nam [14] in South Korea, which focuses on the influence of consumer knowledge on perceptions and purchase intentions toward GM food. The authors show that higher levels of education, income, and food involvement affect knowledge level by producing an overestimated effect.

The education level guides the subjective and real knowledge. Consumers with a high school diploma recognize a lack of precise knowledge of these techniques. Surprisingly, what is generally expected does not match the level of education. These results could be explained by the different information tools used to improve consumers' knowledge. Indeed, individuals often prefer non-scientific information tools, such as the Internet and media, which may contain not only expert sources but also consumers' feelings and unsupported claims. Consequently, consumers most exposed to negative feelings or information are more likely to overestimate their knowledge level. This has also been found by other researchers in different countries [38,39].

The literature has highlighted that a better understanding of GM foods is associated with a positive consumer attitude and purchase intention. However, this connection could be beneficial if the information is tailored and based on scientific approaches. Furthermore, subjective knowledge is linked to an income level where the low- and high-income categories seem to guide consumer knowledge. The role of the scientific community is a key point: researchers, together with other relevant stakeholders (e.g., government agencies, regulatory authorities, and biotechnology companies), should cooperate in developing communication strategies and dissemination activities to inform consumers about GM foods and crops and how the new genetic techniques differ from the traditional ones. The right communication could play a role in informing people and changing attitudes for a future consensus and acceptance of GM food products.

This study shows that both real and subjective consumer knowledge is relatively low, and there is a need to reduce the potential and imbalance gap between these two knowledge levels. Of course, this result could be reached through consumer education as part of educational curricula at school in the case of young people and with the right transparent and understandable communication for the other consumer category.

We are aware of the limitations of the current study, which is mainly based on descriptive analysis. This is a preliminary work that suggests the need for further investigation using econometric analysis. Our future research will entail: (a) enlarging the sample size and including other countries (EU and non-EU); (b) customizing the survey by adding questions on who should legislate AET, labeling, risk perception, and the willingness to pay for GM food; and (c) reinforcing the scope of some questions already present in the survey. Finally, we go further to deeply understand and test the real knowledge level and the intention to purchase.

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Data Availability Statement: The data supporting the findings of this study are available from the corresponding author on request.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Conditional distribution of real knowledge for each subjective knowledge category (percentage).

		Subjective Knowledge				
		I Don't Know	No	Yes, I Don't Know	Yes, I Know	Total
Real knowledge	corn	25.2	41.2	40.3	39.6	34.4
	cotton	3.2	17.7	4.2	8.8	5
	I don't know	37.2	17.7	10.5	3.3	19.9
	none	1.8	0	0	0	0.7
	soy	16.5	5.9	22.7	20.9	19.5
	wheat	16.1	17.7	22.7	27.5	20.6
	Total	100	100	100	100	100

Note: Pearson chi-squared test (8) = 28.5365 Pr = 0.000. We used the χ^2 test of association to verify whether or not subjective and real knowledge are independent or associated. The *p*-value suggests the variables are not independent; therefore, a strong relationship between these two categorical variables (subjective knowledge and real knowledge) exists.

Table A2. Conditional distribution of real knowledge for each level of education (percentage).

		Level of Education						
		Bachelor's Degree	High School Diploma	Master's Degree	Middle School Diploma	No Qualification	Doctoral Degree	Total
Real knowledge	corn	39	30.6	44.9	32.7	66.7	25.9	34.4
	cotton	2.6	5.6	3.1	7.3	33.3	3.7	5
	I don't know	15.6	20.4	18.4	30.9	0	11.1	19.9
	none	0	0.7	1	1.8	0	0	0.7
	soy	20.8	19.1	20.4	12.7	0	33.3	19.5
	wheat	22.1	23.7	12.2	14.5	0	25.9	20.6
	Total	100	100	100	100	100	100	100

Note: Pearson chi-squared test (20) = 31.9910 Pr = 0.043. The χ^2 test of association suggests that the two categorical variables (level of education and real knowledge) are not independent.

Table A3. Conditional distribution of real knowledge by gender (percentage).

		Gender		
		Female	Male	Total
Real knowledge	corn	30.1	38.9	34.4
	cotton	4.8	5.1	5
	I don't know	21.8	17.8	19.9
	none	0.7	0.7	0.7
	soy	21.1	17.8	19.5
	wheat	21.5	19.6	20.6
	Total	100	100	100

Note: Pearson chi-squared test (4) = 5.2681 Pr = 0.261. The χ^2 test value shows that real knowledge and gender are independent.

Table A4. Conditional distribution of subjective knowledge for each level of income (percentage).

		Level of Income (EUR)				
		<15K	>50K	15K–30K	30K–50K	Total
Subjective knowledge	I don't know	50	27.3	35.2	35.4	38.7
	No	3.1	10.9	2	1	3
	Yes, I don't know	34.7	34.6	46.4	48.5	42.2
	Yes, I know	12.5	27.3	16.4	15.2	16.1
	Total	100	100	100	100	100

Note: Pearson chi-squared test (9) = 32.4408 Pr = 0.000. The χ^2 value claims a strong association between income level and subjective knowledge.

Table A5. Conditional distribution of environmental sustainability for each level of income (percentage).

		Level of Income (EUR)				
		<15K	>50K	15K–30K	30K–50K	Total
Environmental sustainability	I don't know	36.3	16.4	23.2	24.2	26.4
	No	16.9	23.6	21.2	13.1	18.8
	Yes	46.9	60	55.6	62.6	54.8
	Total	100	100	100	100	100

Note: Pearson chi-squared test (6) = 15.8169 Pr = 0.015. Even in the case of environmental sustainability and income level, a relationship is confirmed by the χ^2 test.

Table A6. Conditional distribution of real knowledge by geographical area (percentage).

		Geographical Area				
		Center	Northeast	Northwest	South	Total
Real knowledge	corn	40	30.1	30.9	36.7	34.4
	cotton	3	5.8	4.9	5.6	5
	I don't know	22	14.6	21.8	19.9	19.9
	none	1	1	0	1	0.7
	soy	20	28.2	23	11.7	19.5
	wheat	14	20.4	19.4	25	20.6
	Total	100	100	100	100	100

Note: Pearson chi-squared test (12) = 20.3211 Pr = 0.061. The χ^2 test reveals once again an association between real knowledge and geographical areas.

Appendix B

Hamburg, 05.01.2023

Knowledge Genetic Improvement

Question No.	Survey	Question Type
F1	What genetic improvement methods do you know? Please select all the methods you have heard about. A: Crossing and selection B: Induced genetic mutation C: Assisted selection with molecular markers D: In vitro culture techniques E: New breeding techniques (Nbts) F: GMO G: None of these (not randomized)	Multiple Choice (Answers randomized)

Question No.	Survey	Question Type
F2	Do you think there are differences between GMO products and products obtained through the use of New breeding techniques (Nbts)? A: Yes, there are differences and I know them B: Yes, there are differences but I don't know them C: No, there are no differences Q: I don't know	Single Choice
F3	For what purposes is genetic modification carried out? Select, from the following options, what you think are the purposes of genetic modification. A: Resistance to pests, diseases, herbicides B: Adaptation to climate change C: Reduce food waste/increase food yield by lowering production costs Q: Reduce fertilizer use E: Safeguarding biodiversity F: I don't know (not randomized)	Multiple Choice (Answers randomized)
F4	Based on your knowledge, which of these agricultural species is the most cultivated as GMO seed? A: Soyabean B: Corn C: Wheat D: Cotton E: I don't know (not randomized) F: None of the above (not randomized)	Single Choice (Answers randomized)
F5	What information tools do you use to obtain information on GM products? A: Friends and acquaintances B: Press and television C: Social Media D: Scientific and information publications E: None of these (not randomized) Other tools: (Freetext)	Multiple Choice (Answers randomized)
F6	Do you think GM food products are safe to eat? A: Not at all safe B: Not very safe C: I don't know Q: Quite safe E: Absolutely safe	Likert
F7	In your opinion, could AET contribute to environmental sustainability? A: Yes B: No C: I don't know	Single Choice
F8	How environmentally safe do you think AETs are? A: Not at all safe B: Unsafe C: I don't know Q: Quite safe E: Absolutely safe	Likert
F9	How likely would you be to buy a product from GM crops? A: No chance B: Low probability C: I don't know Q: Some probability E: High probability	Likert
F10	Some countries grow GM crops/food. Would you buy a food product from the following countries? Answer: A: yes B: No C: I don't know Items: A: Africa B: North America C: Central and South America D: Western Europe E: Eastern Europe F: Asia	Matrix (Items randomized)

Question No.	Survey	Question Type
F11	What region do you live in? A: Valle d'Aosta B: Piedmont C: Liguria D: Lombardy E: Trentino Alto-Adige F: Veneto G: Friuli-Venezia Giulia H: Emilia Romagna I: Tuscany J: Umbria K: Marche L: Abruzzo M: Lazio N: Molise O: Campania P: Basilicata Q: Puglia R: Calabria S: Sardinia T: Sicily	Single Choice
F12	Please indicate the highest degree you have earned (degree you have actually completed—not the degree you are currently studying for). A: No qualification (primary school) B: Secondary school C: High school diploma D: Bachelor's degree E: Master's degree F: Doctorate	Single Choice
F13	What is your gross annual income? A: Less than 15,000 euros B: Between 15,000 and 30,000 euros C: Between 30,000 and 50,000 euros Q: More than 50,000 euros	Single Choice

Appendix C

Appendix C.1. Data Protection at Appinio

Data protection and the associated protection of privacy are of central importance to Appinio as a market research company. We are committed to our clients and panelists to ensure at all times that all data is protected in accordance with the legal requirements of the GDPR.

For Appinio, data protection and transparency about how data are handled are principles we follow throughout our product development, also known as Privacy by Design. As a market research company, we have a special position and responsibility with respect to data privacy, as we are always in the middle between clients and survey participants.

Below, we list resources that are available to you as an Appinio customer to inform you about our privacy practices. At the same time, this information will help you to also act in a privacy-compliant manner and to ensure that your own privacy, as well as that of the survey participants, is protected at all times.

Appendix C.2. Data Minimisation and Data Retention

Part of our data protection concept is data economy. According to our data retention policy, we only store the data we really need and only for as long as necessary. Data that users delete on Appinio will be removed within a maximum of 30 days. The only exceptions to this are very specific data, such as invoices and log files, which we need to keep in order to comply with our own legal obligations. For more information, please see our privacy policy.

To be able to guarantee these standards, we train our employees in the responsible handling of data in accordance with legal requirements and our internal guidelines. In addition, we have appointed a Data Protection Officer to oversee DSGVO-compliant data use at Appinio.

Our goal is not only to comply with legal requirements and our internal policies. We want to ensure that when you use Appinio, whether through our platform, in interactions with our employees, or as an Appinio panelist, you always feel good about your privacy as well. Therefore, we are committed to protecting your data and privacy.

Appendix C.3. Data Security

Encryption: All sensitive data (this includes all customer data, panelist data, and survey/response data) are secured via Sha265 encryption. All servers are also SSL secured, which means all data transfer is encrypted.

Server location: All servers are located in Germany (Frankfurt). Appinio uses the infrastructure of AWS (Amazon Web Services) to guarantee the highest security standards and, at the same time, the highest accessibility of the systems. All survey data are stored here and made available exclusively to you, our customer, via our platform.

Appendix C.4. Data Usage and Documents

The following is information on the specific use of data that Appinio collects and provides. These data processing operations are also listed in our privacy policy and terms and conditions. All documents can be accessed in their original form at:

Customer T&Cs (for use of the survey platform) https://research.appinio.com/#/en/tos (accessed on 4 July 2023) Customer Privacy Policy (for website, platform, webapp) https://www.appinio.com/en/privacy (accessed on 4 July 2023).

App Panelist T&Cs (accessible via app/play store and Appinio app) https://link.appinio.com/#/en/tos (accessed on 4 July 2023).

App Panelist Privacy Policy (accessible via app/play store and Appinio app) https://link.appinio.com/#/en/privacy (accessed on 4 July 2023).

The app privacy policy lists what happens to our panelists' data. The Website, Platform, and Web App Privacy Policy lists how we handle data from our customers and web app participants.

This information is intended to help understand and be transparent about the exact data processing procedures. Our privacy statements contain all the data processing provisions our customers need to be DSGVO compliant. In addition, our technical and organizational measures explain what security measures are in place internally to ensure data protection.

After delivery of surveys, APPINIO collects the answers given by the end users and provides them in anonymous, aggregated form, together with anonymous demographic and statistical data, to the client in the form of an evaluation for market research purposes.

Panelists provide us with this data voluntarily and to a self-determined extent. The data provided are aggregated and made available anonymously in a statistical evaluation that does not allow any conclusions to be drawn about individual users.

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