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# Evolving Dynamics of Food Biotechnology: Consumer Knowledge of Genetically Modified Ingredients (GMI)

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**KEYWORDS**

*Genetically Modified Foods; Consumer Awareness; Perception; Food Technology Acceptance; GMO Labeling; Consumer Behavior; Emerging Markets..*

**ABSTRACT**

Genetically modified ingredients (GMIs) represent a critical innovation within the evolving global food landscape, offering potential solutions to challenges like food security, agricultural sustainability, and climate resilience. Yet, they remain contentious, especially in countries like India where GM foods have not yet been fully commercialized for human consumption. This study investigates the current state of consumer awareness and perception regarding GMIs through a structured descriptive survey conducted among Indian consumers, focusing predominantly on urban and semi-urban demographics. The research explores how three primary factors—consumer knowledge about GMIs, attitudes and perceptions towards genetically modified foods, and food-related habits such as label reading and preference for non-GMO options—contribute to overall awareness of GMIs.

Quantitative analysis, including reliability assessments, correlation matrices, and multiple regression modeling, revealed that all three constructs significantly influence consumer awareness. The regression model confirmed a strong predictive relationship. Among the predictors, perception emerged as the most influential factor, suggesting that consumers with strong positive or negative attitudes—whether trust in biotech or concern about health and ethics—are more attuned to GMO-related issues. Knowledge, encompassing factual understanding and information-seeking behavior, showed a moderate effect, while habits like ingredient checking and certification awareness also contributed meaningfully.

The study highlights a complex interplay between cognitive (knowledge), affective (attitudes), and behavioral (habits) dimensions in shaping consumer awareness. It affirms that awareness is not solely a function of information exposure but is also driven by underlying values, perceptions of risk and benefit, and individual shopping practices. These findings align with international literature emphasizing the centrality of trust, perceived naturalness, and scientific literacy in public acceptance of food biotechnology.

In terms of policy and practice, the results indicate that any future rollout of GM foods in India must be accompanied by proactive consumer engagement strategies. These include transparent labeling, inclusive public dialogues, educational outreach to clarify scientific facts and address safety concerns, and collaboration with trusted regulatory bodies and academic institutions. Ultimately, fostering a well-informed and critically engaged consumer base will be essential for the responsible integration of GM foods into the Indian market. The study provides timely insights that can inform stakeholder decisions and shape public communication strategies in the context of emerging food technologies.

## 1. INTRODUCTION

Genetically modified (GM) foods have emerged as both a potential solution to global food security challenges and a subject of public debate. GM ingredients (GMIs) are derived from organisms whose DNA has been altered using biotechnology to introduce desirable traits such as pest resistance, enhanced nutrition, or longer shelf life (Qaim, 2020; Siegrist, 2008). Proponents argue that GM technology can improve crop yields, reduce reliance on pesticides, and fortify foods with vitamins, thereby addressing hunger and malnutrition. For example, genetic modification has produced insect-resistant cotton and vitamin-A enriched rice, and even enabled the development of edible vaccines in crops (Domingo & Bordonaba, 2011). These innovations signal how biotechnology might transform the food supply to meet 21st-century needs. However, public perception of GM foods remains mixed and cautious. Consumers and advocacy groups often raise concerns about the long-term health effects of consuming GM products and the environmental impacts of cultivating them (Frewer et al., 2013; Curtis et al., 2004). Ethical questions about "tampering with nature" also fuel skepticism. Moreover, a lack of consensus in the scientific community and limited long-term toxicological studies contribute to uncertainty, leading consumers to question the safety of GM foods (Domingo & Bordonaba, 2011; Ryan et al., 2020). As a result, the introduction of GM foods has provoked widespread discussions on food safety, ethics, and labeling transparency.

Public attitudes toward GM foods can significantly influence the success of this technology's adoption. In regions like Europe, consumer opposition has historically been strong, pressuring policymakers to impose strict regulations or outright bans on GM crops (Gaskell et al., 2010; Costa-Font et al., 2008). In contrast, some developing countries exhibit more acceptance of GM foods when the perceived benefits—such as improved nutrition or food security—outweigh the risks (Curtis et al., 2004; De Steur et al., 2010). The variability in consumer acceptance across countries underscores the importance of understanding the determinants of public opinion on GMIs. Prior research indicates that factors such as knowledge and awareness of biotechnology, trust in institutions (government, scientific bodies, industry), perceived naturalness of the food supply, and cultural values all shape how consumers perceive GM foods (Chen & Li, 2007; Siegrist, 2008). For instance, consumers who are more informed about food science and who trust regulatory agencies tend to evaluate GM foods more on scientific evidence rather than fear or hearsay (Huffman et al., 2007; Brossard & Nisbet, 2007). Conversely, individuals with low knowledge often rely on heuristics or external cues, which can lead to heightened concern or outright rejection of GM products (Scott et al., 2016; McFadden & Lusk, 2015). Emotional factors also play a role; studies have shown that some consumers have a moral or visceral opposition to genetic modification, associating it with feelings of disgust that are resistant to change via factual debate (Scott et al., 2016; Ryan et al., 2020).

India presents a particularly interesting context for studying consumer attitudes towards GM foods. To date, India has not approved any GM food crop for direct human consumption, and GM foods are not legally sold in the market (Sendhil et al., 2022; Defence Food Research Laboratory, 2013). Only GM cotton is cultivated commercially, while food crops like Bt brinjal (eggplant) have been held back due to regulatory and public resistance. Despite this, the discourse around GM foods in India has been growing, fueled by global developments and the country's own food security concerns. The Food Safety and Standards Authority of India (FSSAI) has been deliberating guidelines for GM food labeling and approvals, indicating that the policy landscape may evolve in the near future. In anticipation of potential policy changes, it is crucial to gauge current consumer awareness and perception of GMIs in the Indian market context. Indian consumers' exposure to GM foods is limited to media reports and imported products (like soybean oil) that may contain GM ingredients. This limited exposure could mean low familiarity and many misconceptions among the public. At the same time, rising education levels, urbanization, and greater media connectivity (social media and internet) especially among youth might be creating pockets of informed consumers. Understanding where Indian consumers stand on GM foods—whether curious, cautious, or indifferent—will help stakeholders (policymakers, food companies, and public health advocates) prepare appropriate strategies for public communication and engagement.

The present study aims to fill this knowledge gap by systematically examining consumers' awareness of and attitudes toward genetically modified ingredients in food. Specifically, we investigate how three key factors—knowledge about GMIs, perception of GM foods (i.e., attitudes and beliefs), and consumer habits related to food purchasing—influence overall awareness of GMIs. These factors were chosen based on insights from prior literature and theoretical frameworks of consumer behavior. Knowledge represents the cognitive familiarity with GM technology (understanding what GMOs are, their purported benefits/risks, and the ability to identify GM products). Perception captures the affective and evaluative stance towards GM foods—whether consumers see them as safe, beneficial, unnatural, risky, etc. Habits reflect the conative or behavioral aspect, such as checking labels for GM information or preferring non-GM foods. We hypothesize that higher knowledge, positive perceptions, and mindful food habits each contribute to greater consumer awareness of GMIs. In addition, demographic variables like age, education, and urban/rural residence are considered as they might moderate awareness (for instance, younger or more educated consumers could exhibit higher awareness). By testing these relationships, our study seeks to provide a nuanced understanding of what drives GMI awareness in a market on the cusp of policy change. Ultimately, the insights will be useful for designing effective consumer education programs and marketing strategies for GM foods, ensuring that if and when these products enter the marketplace, they are met with an informed public rather than one driven by fear or misinformation.

## 2. LITERATURE REVIEW

Consumer perception of genetically modified (GM) foods has been widely studied, revealing that knowledge, perceived risks and benefits, trust in information sources, and regulatory environments all play vital roles in shaping attitudes. Public understanding of GM food technologies remains generally low across populations, which contributes to skepticism and resistance. For instance, Cui and Shoemaker (2018) found in a large-scale Chinese study that only 12% of respondents claimed to understand GM technology, while nearly half held unfavorable views. Brossard and Nisbet (2007) explained that in the absence of sufficient scientific literacy, people resort to cognitive heuristics, forming opinions based on existing values and their trust in science rather than facts. In New York, respondents showed limited factual knowledge about GMOs, and their opinions were more aligned with whether or not they trusted scientific authorities. Although several studies report that greater education and awareness are correlated with higher acceptance of GM foods (Chen & Li, 2007), the effect is not always straightforward. For example, Onyango (2003) observed that even among consumers with high factual knowledge about GMOs, those with strong risk-aversion tendencies were still reluctant to support GM foods. These findings suggest that while knowledge may support informed decision-making, it alone does not guarantee acceptance. Instead, how knowledge interacts with individual values, such as preference for natural foods or ethical concerns, determines the outcome.

An important dimension in consumer decision-making around GM foods is the balance between perceived risks and perceived benefits. Consumers tend to weigh these competing factors based on subjective judgment and emotional triggers. Moon and Balasubramanian (2003) found that perceived risk had a significantly greater influence on consumers' willingness to pay to avoid GM foods than the benefits had on their willingness to accept them. This dynamic of risk aversion was particularly evident in the UK, where consumers were willing to pay premiums for non-GM alternatives. A meta-review by Costa-Font et al. (2008) affirmed that public resistance is more strongly driven by distrust and concerns over safety than by a lack of understanding of benefits. Nevertheless, studies have shown that when tangible, consumer-facing advantages are offered—such as enhanced flavor or nutritional improvements—attitudes can shift slightly. Loureiro and Bugbee (2005) demonstrated that some consumers were willing to pay more for second-generation GM foods with direct consumer benefits, though this willingness remained cautious. Additionally, attitudinal segmentation, such as that explored by Verdurme and Viaene (2003), reveals that the public is not monolithic in their views. Their research in Belgium categorized consumers into Enthusiasts, Green Opponents, Balancers, and Half-hearted participants. Most consumers occupied the middle ground, indicating potential to influence attitudes through tailored communication strategies that either reinforce perceived benefits or address specific concerns.

Trust in institutions and the credibility of information sources also play a pivotal role in shaping consumer attitudes toward GM foods. When information is disseminated by trusted entities—such as independent scientists or regulatory bodies—consumers are more likely to be receptive. Rousu et al. (2007), in an experimental auction study, found that consumers responded more positively to third-party information compared to material from industry or activist groups. This suggests that neutral, science-based sources provide more effective public reassurance. On the other hand, low institutional trust often exacerbates fears, with consumers believing that government or corporations may prioritize profit over safety. Compounding this is the influence of misinformation. Ryan et al. (2020) analyzed thousands of online articles and found that conspiracy-themed or emotionally charged misinformation about GMOs tended to go viral more often than fact-based communication. This trend of "monetizing disinformation" has led to increased consumer demand for non-GMO labels and contributed to a distorted public narrative, despite the scientific consensus on GMO safety. Further complicating acceptance are psychological traits like food neophobia and beliefs in food naturalness. Siegrist and Hartmann (2020) argued that people who value food naturalness or hold strong moral objections to "tampering with nature" are unlikely to accept GM foods, regardless of safety evidence. These individuals often require communication strategies that resonate emotionally, such as emphasizing continuity with traditional agricultural methods or using natural analogies to explain genetic modification.

The regulatory and policy context plays an equally influential role, particularly in countries like India where GM food products are not yet available for human consumption. In such cases, public opinion is often formed in the absence of direct experience and relies heavily on policy cues and media narratives. Sendhil et al. (2022), in a bibliometric analysis, noted that regulatory decisions—such as approval or bans—directly influence public sentiment. Where governments clearly communicate benefits and follow transparent approval processes, consumer trust and acceptance tend to increase. Labeling policies, a prominent aspect of regulation, also affect perception. Costanigro and Lusk (2014) showed that labels reading "contains GMOs" did not cause alarm per se, but their framing—whether presented as mandatory or voluntary—altered consumer reactions. Mandatory labels were sometimes interpreted as warnings, while voluntary labels were seen as quality signals. Thus, the design and communication of GMO-related labels can either build trust or unintentionally stigmatize GM foods. Overall, the literature consistently indicates that public attitudes are shaped by a constellation of factors that include knowledge, perceived risk and benefit, trust in sources, and policy context. These factors are not isolated but interact dynamically. For instance, a well-informed consumer may still reject GM foods if they distrust institutions or prioritize naturalness. Conversely, a skeptical consumer might accept GM products if trusted authorities highlight strong consumer benefits and implement clear, transparent regulations.

This study builds upon these insights by empirically analyzing the influence of knowledge, attitudes, and purchasing behavior on awareness of GM ingredients in food. In doing so, it contributes to the ongoing conversation about consumer readiness and policy preparedness in emerging markets where GM food adoption may soon become a reality.

## 3. METHODOLOGY

### Research Design

This study adopted a descriptive survey approach to investigate the relationships between consumer knowledge, perception, habits, and their overall awareness of genetically modified ingredients (GMIs) in food. The design enabled statistical analysis of prevailing consumer behaviors and attitudes in a context where GM foods are not yet commercially available but remain a subject of increasing interest.

The analysis focused on how awareness of GMIs—defined as familiarity with and attention to genetically modified ingredients, including recognition of terms, understanding, and engagement with related information—is shaped by three key factors. These included: factual and self-perceived knowledge of GMOs; attitudes regarding the safety, usefulness, and ethical aspects of GM foods; and food purchasing behaviours such as label-checking or preferences for certified non-GMO products. Demographic characteristics (such as age, gender, education, income, and location) were also considered for their potential role in influencing consumer awareness, although they were not treated as primary predictors.

Three relationships were examined: whether greater knowledge correlates with higher awareness; whether individuals with stronger opinions (positive or negative) about GMOs tend to be more attentive to GM-related content; and whether those who exhibit conscious habits—such as avoiding or selecting GMO products—show greater awareness of such ingredients. These relationships were tested statistically at a 95% confidence level ($\alpha = 0.05$).

### Conceptual Framework

The conceptual framework outlines the hypothesized influence of consumer knowledge, perception, and purchasing habits on GMI awareness. Demographic variables were collected to assess variation across groups, though not modelled as direct causal factors.

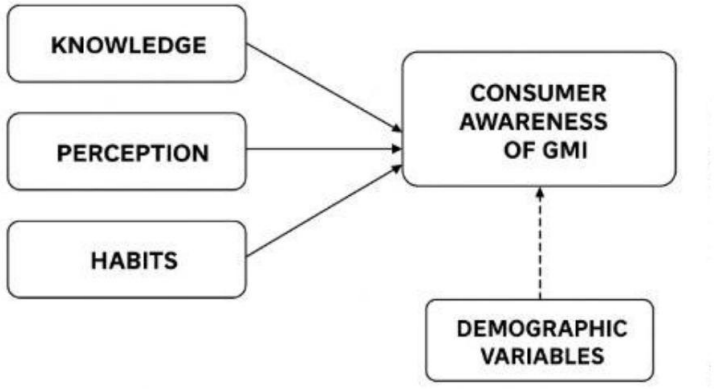


**Figure 1 – Conceptual Framework**

### Sample and Data Collection

The study was conducted among Indian consumers responsible for food-related decisions in urban and semi-urban settings, where packaged food consumption and exposure to food technology are more common. A total of 254 individuals participated, selected through non-probability convenience sampling. Questionnaires were distributed both online (via email and social media) and offline (in shopping malls and supermarkets in a major Indian city). Though convenience sampling limits the generalizability of findings, diversity was ensured through targeted inclusion across gender, age, education, and income categories. Participants were informed about the study's general topic—consumer food choices—without direct reference to GMOs to minimize bias.

The respondent pool consisted of 53.5% females and 46.5% males. Age distribution skewed young, with 57% aged between 18 and 30. Participants predominantly lived in urban or semi-urban areas. Most had at least an undergraduate degree, and a substantial portion held postgraduate qualifications. In terms of income, the sample represented middle- to upper-income brackets common in urban Indian settings. This demographic context should be considered when interpreting results, as the sample may show higher GMI awareness than the national average due to educational and media exposure advantages.

### Measures

Data were collected using a structured questionnaire comprising both categorical and Likert-scale items. The instrument included five sections: demographic details, awareness of GMIs, knowledge, perception, and consumption-related habits.

Awareness was measured through binary and Likert items, such as a yes/no question about having heard of GMIs, and agreement ratings on statements like "I understand what genetically modified ingredients are." A question on frequency of information exposure (weekly, monthly, rarely, or never) helped gauge engagement levels.

Knowledge was assessed using items that explored both self-assessed knowledge and proactive learning behaviors, such as "I can identify foods with GMI" or "I seek out information about GMI when shopping." These responses were aggregated into a knowledge score.

Perception was evaluated through agreement with statements such as "I believe GM foods are safe," "GMI improves food sustainability," and "I am concerned about health risks from GMI." Negatively phrased items were reverse-coded so that a higher overall score reflected more favorable or open-minded attitudes. Scale reliability was verified through internal consistency testing.

Consumer habits were measured using statements on shopping behaviors, including "I check food labels for GMI" and "I prefer non-GMI foods even if they cost more." Reverse-coded items like "I do not consider GMI when shopping" were included to balance the scale. These responses formed a composite measure of GMI-related behavior in purchasing decisions.

**Data Analysis**

Following data collection, responses were coded and analyzed using standard statistical procedures. Descriptive statistics and percentage analyses were first applied to summarize respondent demographics and assess baseline awareness, such as responses to the question, "Have you heard of GMI?"

Next, the internal consistency of multi-item scales—knowledge, perception, habits, and awareness—was evaluated using Cronbach's alpha. Reliability coefficients above 0.70 were considered acceptable, confirming that the items within each construct measured a common underlying dimension.

To examine the proposed relationships, multiple linear regression was conducted with awareness of GMIs as the dependent variable and knowledge, perception, and habits as independent variables. This analysis tested the combined and individual predictive effects of the three factors, with coefficients indicating the strength and statistical significance of each. The model's validity was confirmed by checking assumptions such as linearity, normal distribution of residuals, and absence of multicollinearity.

Model fit was assessed using the coefficient of determination ($R^2$), showing the proportion of variance in awareness explained by the predictors. The F-statistic from the ANOVA table confirmed the overall model significance, while t-tests were used to assess the contribution of individual predictors (using p-values $< 0.05$ for significance and $< 0.001$ for high significance).

## 4. RESULTS

**Sample Characteristics and Basic Awareness**

Among the 254 respondents, 69% reported having heard of genetically modified ingredients (GMIs), indicating moderate baseline awareness. However, this awareness reflects recognition rather than deep understanding. Only 18% engaged with GMI-related information on a weekly basis, while 46% encountered such information rarely, and 36% did so monthly. This suggests that although the concept of GMIs is familiar to many, it is not actively discussed or regularly encountered by most.

Demographic trends revealed higher awareness scores among younger participants (18–30), aligning with greater exposure to food technology and scientific discussions. Similarly, those with graduate or postgraduate education reported greater familiarity with GMIs compared to less educated respondents. No notable gender differences were observed in baseline awareness.

**Scale Reliability**

All multi-item scales demonstrated acceptable internal consistency, confirming the reliability of the constructs. The Knowledge scale (5 items) had a Cronbach's alpha of 0.846, indicating strong coherence in items related to information-seeking and factual understanding. The Perception scale (5 items) showed an alpha of 0.795, reflecting reliable measurement of attitudes toward GM food safety, benefits, and quality. The Habits scale (6 items) achieved a reliability score of 0.707, acceptable but slightly lower due to behavioral diversity across items. The Awareness scale (approximately 5–6 items) had an alpha of 0.815, confirming it as a cohesive measure of consumer attentiveness to GMIs.

Composite indices for Knowledge, Perception, Habits, and Awareness were computed by averaging their respective items and used in further regression analysis.

**Table 1. Reliability of Measurement Scales (Cronbach's α)**

| Construct | Number of Items | Cronbach's α |
|---|---|---|
| Knowledge about GMI | 5 | 0.846 |
| Perception of GM foods | 5 | 0.795 |
| Habits (GMI-related) | 6 | 0.707 |
| Awareness of GMI | ~6 | 0.815 |

**Regression Analysis: Factors Influencing Awareness**

To test the hypothesized relationships (H1, H2, H3), a multiple linear regression was conducted with awareness of GMIs as the dependent variable and knowledge, perception, and habits as independent variables. The overall model was statistically significant, $F(3, 250) = 81.5$, $p < 0.001$, with approximately 49% of the variability in awareness explained by the predictors ($R^2 = 0.495$, adjusted $R^2 = 0.489$).

Each predictor showed a positive and significant effect on awareness:

- Knowledge ($B = 0.258$, $\beta = 0.261$, $t = 5.65$, $p < 0.001$): Greater knowledge significantly predicted higher awareness, supporting H1. Respondents who were more informed or actively sought information about GMIs were also more attentive to related food labels and issues.
- Perception ($B = 0.289$, $\beta = 0.295$, $t = 6.13$, $p < 0.001$): Perception was the strongest predictor, supporting H2. Consumers with clear attitudes—positive or negative—toward GM foods tended to engage more with GMI-related content, highlighting the role of attitudinal involvement.
- Habits ($B = 0.223$, $\beta = 0.237$, $t = 4.97$, $p < 0.001$): Food purchasing behaviors also significantly predicted awareness, supporting H3. Individuals who routinely checked labels or preferred non-GMO options showed greater attentiveness to GMIs.

No multicollinearity issues were found; all predictors contributed uniquely to the model. Supplementary bivariate ANOVA tests confirmed significant individual associations between each predictor and awareness, reinforcing the regression results. Specifically:

- Knowledge vs. Awareness: $F(1, 252) \approx 29.7$
- Perception vs. Awareness: $F(1, 252) \approx 27.2$
- Habits vs. Awareness: $F(1, 252) \approx 13.5$

(All $p < 0.001$)

These findings support all three hypotheses. Knowledge, perception, and habits each exert a significant, positive influence on consumer awareness of GMIs, with perception emerging as the most impactful predictor.

**Table 2. Multiple Regression Results Predicting GMI Awareness**

| Predictor | B (Unstd.) | SE(B) | Beta (Std.) | t-value | p-value |
|---|---|---|---|---|---|
| (Constant) | 0.978 | 0.213 | – | 4.59 | < 0.001 |
| Knowledge | 0.258 | 0.046 | 0.261 | 5.65 | < 0.001 ** |
| Perception | 0.289 | 0.047 | 0.295 | 6.13 | < 0.001 ** |
| Habits | 0.223 | 0.045 | 0.237 | 4.97 | < 0.001 ** |

**Model Summary**: $R = 0.704$, $R^2 = 0.495$, Adjusted $R^2 = 0.489$

**$F(3, 250) = 81.5$, $p < 0.001$**

**Note**: All predictors are significant at the 0.001 level (**$p < 0.001$**), denoted by **.

The regression results provide clear support for all three hypothesized relationships. Knowledge ($\beta = 0.26$, $p < 0.05$), perception ($\beta = 0.30$, $p < 0.05$), and habits ($\beta = 0.24$, $p < 0.05$) each had a positive and statistically significant influence on GMI awareness, leading to the rejection of all three null hypotheses. These findings suggest that greater knowledge, stronger attitudinal engagement, and more deliberate food-related behaviors contribute meaningfully to consumers' awareness of genetically modified ingredients.

Beyond the core hypotheses, descriptive insights from the data add further nuance. Respondents reported moderate levels of self-assessed knowledge, suggesting a gap in public understanding. Over 60% expressed concern about potential health risks from GM foods, even while acknowledging some benefits—indicating mixed attitudes. A slight majority (~55%) preferred non-GMI products even at a higher cost, while approximately 40% were neutral or disagreed, implying a sizable segment of consumers prioritizes other factors such as price or taste over GM content. These patterns mirror international findings; for example, a French study showed that 42% of consumers were willing to purchase GM food if it were cheaper. The diversity within the sample—between cautious, label-checking individuals and more indifferent or pragmatic shoppers—underscores the importance of perception as a driver of awareness. Consumers who care about GMOs, whether positively or negatively, are more likely to seek out information and remain informed.

## 5. DISCUSSION

This study provides empirical evidence on the determinants of consumer awareness of genetically modified ingredients (GMIs) in a market where GM foods are not yet mainstream. Knowledge, perception, and habits all significantly influenced awareness, offering valuable insights for policymakers, educators, and industry stakeholders.

Knowledge emerged as a strong predictor of awareness, supporting earlier research (Huffman et al., 2007) that emphasizes the role of information in shaping informed attitudes. However, consistent with findings by Onyango (2003) and McFadden & Lusk (2015), knowledge alone does not guarantee acceptance. Many informed participants still expressed concern, highlighting the need for credible, trust-based communication in public education campaigns.

Perception proved to be the strongest predictor. Whether positive or negative, strong attitudes toward GMOs drive information-seeking and attentiveness. This aligns with theories of motivated reasoning and selective exposure (Scott et al., 2016). Engaged consumers—supporters or skeptics—tend to follow developments closely, while indifferent individuals remain disengaged. Public communication efforts should address both benefits and concerns to engage this passive segment.

Habits also contributed independently to awareness. Shoppers who check labels or prefer non-GMO products demonstrated higher attentiveness to GMIs, suggesting that behavioral routines reinforce awareness. This supports global findings that health-conscious consumers are more informed about food content. Introducing clear labeling could not only support informed choice but also elevate general public awareness over time.

International comparisons reveal both alignment and distinction. Similar to studies in Europe (Verdurme & Viaene, 2003), many Indian respondents preferred to avoid GMOs, even at a premium. Yet, others expressed neutrality or openness if products offered benefits or cost savings (Noussair et al., 2004). This reflects heterogeneity in consumer priorities and reinforces the need for diverse product offerings and transparent communication.

Trust was another underlying theme. Respondents showed limited confidence in the food industry, consistent with global trends where corporate interests are often viewed with skepticism. Regulatory bodies and independent scientists must take the lead in outreach to ensure credibility. As seen in Iran (Akbari et al., 2023), corporate social responsibility can also positively influence public perception.

Demographic observations showed that younger and more educated consumers had higher awareness, consistent with broader research (Sendhil et al., 2022). Gender differences were minimal in overall awareness but present in perception—female respondents tended to express greater health concerns. These nuances suggest the value of targeted messaging for different consumer segments.

Importantly, while this study did not measure media influence directly, limited information exposure reported by respondents suggests that digital platforms—particularly social media—play a role. Given the risk of misinformation (Ryan et al., 2020), guiding consumers to reliable sources through influencers, curriculum integration, and partnerships with credible institutions becomes essential.

Ultimately, awareness alone does not guarantee acceptance. But awareness combined with transparent information, public engagement, and choice can foster informed deliberation instead of resistance. Countries that have successfully introduced GM foods have often done so alongside trust-building efforts, safety regulations, and benefit-driven messaging.

## 6. CONCLUSION

This study explored how knowledge, perception, and habits influence consumer awareness of genetically modified ingredients, using data from urban Indian consumers. All three factors had a significant positive impact, underscoring that awareness is shaped not only by information, but also by attitudes and behavior.

For regulators, food companies, and communicators, the implications are clear. Educational outreach must be accompanied by efforts to build trust and provide meaningful consumer choice. Clear labeling, transparency in marketing, and third-party certifications can empower both informed and cautious consumers. Offering both GM and non-GM product lines respects consumer autonomy while supporting innovation.

India is approaching a pivotal moment in its GM food policy. The moderate yet engaged awareness observed in this study presents an opportunity: stakeholders can still shape public perception before GM foods enter the market. Proactive communication, transparent approval processes, and responsiveness to consumer concerns will be essential in ensuring acceptance.

As global food demands rise, GMOs may offer important solutions—but their success depends as much on public confidence as on scientific progress. This study highlights the need to understand and involve consumers as partners in this transition. Future research should extend to rural populations, assess longitudinal shifts in perception, and evaluate the effectiveness of specific communication strategies. For now, one conclusion is clear: informed, trusting consumers are the foundation of successful biotech food adoption

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