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Economic Implications of Biotech-Driven Functional Foods: The Role of Consumer Trust and Scientific Validation, Moderated by Health Awareness

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ABSTRACT: This study investigates the economic value of biotech-based functional foods by assessing the role of scientific validation and consumer trust, with consumer health awareness as a moderating factor. Grounded in Trust Theory (Mayer et al., 1995) and the Health Belief Model (Rosenstock, 1966; Becker & Maiman, 1975), the research frames economic value as an outcome of institutional credibility and consumer health behavior. A quantitative survey of 372 professionals in biotechnology, nutrition, the food industry, and regulatory fields was conducted using a five-point Likert scale. Results indicate that scientific validation (β = 0.635) and consumer trust (β = 0.508) significantly enhance the economic value of functional foods. Furthermore, health awareness (β = 0.472) strengthens the effect of trust, demonstrating its moderating role in shaping consumer adoption and willingness to pay. By integrating scientific credibility, trust, and health motivation, this study offers a comprehensive framework for understanding the drivers of market performance in functional foods. The findings provide actionable insights for policymakers, food companies, and health advocates seeking to promote preventive nutrition and secure consumer confidence.

KEYWORDS: Economic value; biotech-based functional foods; consumer trust; scientific validation; health awareness.

1. INTRODUCTION

The study topic examines the role of scientific validation and consumer trust, with health awareness serving as a moderating element, in order to solve the difficulties of creating economic value in the biotechnology-driven functional food industry. Because of growing consumer interest in nutrition and health, as well as scientific advancements that have made it possible to create new products with improved health advantages, the market for functional foods has increased dramatically worldwide in recent years (Bigliardi & Galati, 2013). However, consumers' level of faith in biotechnology-enhanced nutrition and the level of scientific validation supporting their credibility are intimately related to the economic ramifications of such goods (Chen, 2011). Market success is frequently determined by customer perceptions and acceptability, even while claims on safety and efficacy are supported by scientific validation (Annunziata & Vecchio, 2011). Purchase decisions are heavily impacted by consumer trust, which is impacted by a number of factors, including regulatory monitoring, openness, and past experiences with biotechnology in food systems (Siegrist, 2008).

In situations where health consciousness is growing, the relationship between consumer trust and scientific confirmation becomes very important. In addition to being more inclined to look for functional foods, health-conscious customers are also more skeptical of the veracity of product promises based on science (Dhungana, 2021). Therefore, by either boosting or lowering market confidence, health awareness can strengthen the link between consumer trust and the perceived economic worth of biotech-based functional foods. Even though biotechnology is becoming more and more important in food innovation, the literature that is currently available frequently looks at scientific or consumer perceptions separately rather than combining them into a comprehensive framework that also takes moderating factors like health awareness into account (Siro *et al.,* 2008). This disparity

indicates that in order to comprehend how economic value is generated and maintained in this developing industry, empirical research that concurrently captures these interconnected interactions is necessary.

Furthermore, it is impossible to properly comprehend the economic success of biotech functional foods without taking into account the institutional and cultural settings in which they are accepted. Concerns regarding food authenticity, transparency, and sustainability are influencing market behaviors more and more as consumer health awareness grows worldwide (Verbeke, 2005). For academics and business professionals looking to match biotechnology breakthroughs with consumer demands and legal obligations, a more thorough investigation of these relationships is crucial. In order to investigate the direct effects of consumer trust and scientific validation on the commercial value of biotech-based functional meals, this study creates an integrative model that modifies these interactions by taking health awareness into account.

The overarching research questions for this study are:

1. What is the impact of scientific validation on the economic value of biotech-based functional foods?
2. How does consumer trust in biotech-enhanced nutrition influence their economic value?
3. How does health awareness moderate the relationship between consumer trust and the economic value of biotech-based functional foods?

Guided by these questions, the study aims to provide both theoretical insights and practical implications for policymakers, food companies, and health advocates in advancing functional foods that are scientifically credible, economically viable, and socially trusted.

2. LITERATURE REVIEW

2.1. Economic Value of Biotech-Based Functional Foods

The ability of food innovations driven by biotechnology to deliver quantifiable advantages for producers and consumers by improving health outcomes, increasing consumer demand, and promoting market expansion is known as the economic value of biotech-based functional foods. As people look for foods that promote health and disease prevention, functional foods—defined as goods that offer health advantages beyond basic nutrition—have become more popular (Martirosyan & Singh, 2015). According to this concept, economic value is represented in both market performance and profitability as well as in the wider benefits to society that result from lower healthcare expenditures and higher standards of living (AT & Action, 1999). For instance, genetically modified grains enhanced with vitamins or probiotic yogurts fortified through biotechnology with strains that improve gut health are real-world examples of how innovation can be translated into measurable financial gains by satisfying consumer health demands and boosting brand competitiveness (Delgado-Pando *et al.,* 2021). Economic value in this industry is defined by the combination of consumer acceptability, scientific credibility, and the perceived fit between functional foods and personal health objectives. These factors all work together to increase customer willingness to pay higher prices and maintain market growth.

Two theoretical stances offer crucial insight to comprehend this complex idea: the Health Belief Model (HBM) and Trust Theory. According to Mayer, Davis, and Schoorman's (1995) Trust Theory, views of competence, kindness, and integrity serve as the foundation for trust. When goods are supported by thorough scientific validation, clear labeling, and reliable endorsements from health authorities, consumer trust in biotech-based functional foods is increased and perceived hazards related to biotechnology are decreased (Frewer *et al.,* 2011). By increasing purchase intention and brand loyalty, trust helps customers adopt new items more easily and directly adds to economic value. The successful commercialization of plant-sterol-based cholesterol-lowering margarines, for example, demonstrates how consumer confidence and scientific validation may result in widespread acceptance and significant economic effect (Jones & Jew, 2007). This viewpoint is supported by the Health Belief Model (Rosenstock, 1966; Becker & Maiman, 1975), which uses perceived susceptibility, perceived severity, perceived advantages, and perceived obstacles to explain consumer actions. High health awareness consumers are more inclined to incorporate functional foods into their diets when they understand how beneficial they are in preventing chronic diseases, which increases market demand (Liu *et al.,* 2023). The growing global market for omega-3-enriched goods, for instance, is a reflection of consumer perceptions that these foods lower cardiovascular risks and, thus, warrant higher prices (Verbeke, 2005). When combined, Trust Theory and the HBM shed light on the psychological, cognitive, and relational elements that support the economic worth of biotech-based functional foods, emphasizing that consumer trust and health-conscious decision-making are just as important to their commercial success as technological innovation.

2.2. Critical Analysis of Theoretical Frameworks

This research uses the Health Belief Model (HBM) (Rosenstock, 1966; Becker & Maiman, 1975) and Trust Theory (Mayer et al., 1995) to critically analyze how consumer perceptions influence the economic value of biotech-based functional foods, with an

emphasis on the moderating effect of health awareness. As per Gefen (2000), the Trust Theory highlights that consumer trust stems from perceptions of competence, benevolence, and integrity. It suggests that consumers are more likely to accept biotech foods on the market when they are backed by transparent communication and credible scientific validation. According to Chaudhuri and Holbrook (2001), trust promotes loyalty and desire to pay, which in turn leads to the development of economic value. It also lessens ambiguity regarding biotechnology. In addition, the HBM offers a health psychology viewpoint by suggesting that perceived vulnerability to health hazards, the seriousness of possible ailments, and the advantages of dietary treatments all influence consumers' acceptance of functional foods (Janz & Becker, 1984). Consumers are more likely to include biotech-enhanced foods in their diets as preventative measures in environments where health consciousness is growing, which increases their economic value. By combining both viewpoints, the framework shows that the economic success of functional meals results from the interaction of customer confidence driven by trust and behavioral goals inspired by health, rather than only from technological improvement.

2.2.1. Trust Theory

According to Mayer et al. (1995), trust theory offers a fundamental framework for comprehending how consumer trust influences economic value in uncertain markets, such as those for functional foods derived from biotechnology. According to Mayer et al. (1995), trust is fundamentally defined as the readiness of one party to be susceptible to the acts of another, predicated on the expectation that the other would carry out a certain activity that is significant to the trustor, regardless of the capacity to supervise or control them. According to this framework, consumers' reliance on scientific validation, ethical marketing, and transparent labeling to evaluate the safety and efficacy of products is a manifestation of the three main dimensions—ability, benevolence, and integrity—that influence perceptions of trustworthiness in the context of functional foods (Doney & Cannon, 1997). For example, when biotech-enhanced functional foods, like plant-sterol-enriched cholesterol-lowering spreads, are approved by doctors and validated by thorough clinical trials, they show "ability" and "integrity," which increases consumer confidence and adoption readiness (Jones & Jew, 2007).

The relationship and behavioral mechanisms via which trust results in economic consequences are further highlighted by the application of trust theory to this field. Trust increases long-term customer loyalty, improves purchasing intentions, and lowers perceived risks related to biotechnological innovations—all of which increase economic value (Chaudhuri & Holbrook, 2001). Furthermore, as premium price structures are frequently associated with functional foods, customer trust becomes the key to maintaining willingness to pay and setting brands apart in competitive marketplaces (Elena & Jose, 2001). This theoretical approach shows how commercial value in biotech-driven nutrition arises not only from technology improvement but also from the social creation of credibility and confidence in food systems by presenting consumer decision-making as a trust-based assessment process. Thus, trust theory offers a critical lens through which to view how views of competence, kindness, and integrity work together to convert scientific validation into consumer acceptability, which in turn supports the commercial success and financial sustainability of functional foods based on biotechnology.

2.2.2. Health Belief Model (HBM)

A strong framework for comprehending how individual perceptions of health risks and benefits influence consumer behaviors, particularly concerning the adoption of biotech-based functional foods, is provided by the Health Belief Model (HBM), which was first presented by Rosenstock in 1966 and expanded upon by Becker and Maiman in 1975. Fundamentally, the HBM asserts that perceived vulnerability to disease, perceived seriousness of possible health consequences, perceived advantages of preventive activities, and considered obstacles that might hinder adoption all have an impact on health-related behaviors (Janz & Becker, 1984). According to this model, consumers are more likely to buy and incorporate biotechnology-driven products into their diets when they are aware of their susceptibility to long-term illnesses like cardiovascular disease and when they think these products offer real protective advantages. For instance, consumers strongly believe that probiotic dairy products and omega-3-enriched meals might lower health risks and enhance long-term well-being, which has led to their widespread adoption (Siro *et al.,* 2008).

The HBM also emphasizes how health motivation and cues to action drive economic value, as people who are more conscious of their health actively look for items that have been scientifically shown to meet their preventive health objectives (Champion & Skinner, 2008). In this way, biotech-based functional foods become popular when presented as legitimate treatments that provide easy-to-follow dietary recommendations and address perceived health risks. Customers frequently find that the advantages greatly lower their health risks, outweighing perceived obstacles such as taste preferences or cost concerns (Liu *et al.,* 2023). The HBM offers a crucial theoretical framework for comprehending the financial ramifications of biotech-driven functional meals by elucidating how cognitive assessments of risk, benefit, and motivation influence purchase decisions. It indicates that the

psychological processes through which consumers understand and react to health-related information are just as important to the commercial worth of such breakthroughs as technology improvement and scientific validation.

2.3. The Impact of Scientific Validation on the Economic Value of Biotech-Based Functional Foods

Scientific validation is the process of proving the safety and health advantages of biotech-based functional meals via thorough investigation, clinical testing, and open regulatory approval. Validation is not just a technical process in the functional food industry; it is also a vital factor in boosting customer trust and economic value since buyers are more likely to buy goods whose efficacy and safety have been verified (Kaur *et al.*, 2017). Biotech functional foods' ability to provide unique market offers and solve consumer health problems is what gives them the potential to create economic value. For example, after being supported by clinical data showing their effectiveness in lowering low-density lipoprotein cholesterol, cholesterol-lowering margarines supplemented with plant sterols saw broad adoption and a notable increase in sales (Clarke *et al.,* 1997). Similarly, by coordinating innovation with public health requirements, the creation of biofortified staple crops like golden rice demonstrates how scientific validation offers legitimacy and commercial opportunity (Stein & Qaim, 2007). Therefore, the combination of verified health outcomes, customer desire to pay for preventive nutrition, and industry ability to commercialize innovations supported by reliable data results in economic value.

Two philosophical stances—pragmatism and positivism—offer a clearer understanding of how scientific validation affects economic value. According to Comte (1974), positivism places a strong emphasis on using empirical observation and experimentation to verify knowledge objectively. According to this viewpoint, the legitimacy of scientific data that dispels doubt and supports product claims serves as the foundation for the commercial worth of biotech functional foods. Measureable evidence that influences consumer acceptability and regulatory clearance is provided by validated results, such as clinical trials showing the effect of probiotics on digestive health or omega-3-enriched diets on cardiovascular risk (Shimizu, 2003). The positivist perspective emphasizes how scientific verification underpins biotechnology trust by converting theoretical nutritional promises into measurable financial benefits. It emphasizes how markets for functional foods develop dramatically when claims are supported by data, as seen by the probiotics market's explosive expansion, which was valued at USD 61.1 billion in 2021 and was mostly driven by scientific confirmation of the advantages for gut health (Stanton *et al.,* 2001).

Conversely, pragmatics assesses knowledge and invention based on their applicability in the actual world and its practical implications (Dewey, 1938). According to this paradigm, scientific validation entails establishing both efficacy and relevance to consumer lifestyles and public health agendas. According to pragmatism, the economic worth of biotech functional meals is contingent upon the degree to which verified information is converted into easily marketed goods that customers believe would enhance their well-being (Adefegha, 2018). For instance, the practical way in which gluten-free biotech-enhanced products meet consumer demands for dietary solutions that are in line with medical conditions like celiac disease or gluten sensitivity is just as important to their commercial success as laboratory confirmation of their nutritional advantages (Singh & Whelan, 2011). Therefore, pragmatism moves the emphasis from abstract validation to practical value creation, where the degree to which scientific credibility is ingrained in routine consumer patterns determines economic relevance.

A more comprehensive understanding of how scientific validation affects the commercial value of biotech-based functional meals is possible through the merging of positivism and pragmatism. While pragmatism emphasizes that validation must ultimately serve practical purposes by linking innovation with consumer health priorities and lifestyle demands, positivism guarantees that claims are scientifically validated, lowering consumer uncertainty and facilitating regulatory support. This integration emphasizes that when scientific data is reliable and practical, economic value is maximized. For example, omega-3-enriched dairy products achieve both scientific legitimacy and market relevance by combining consumer-friendly forms that are simple to include in everyday diets with empirical proof of cardiovascular benefits (Givens & Gibbs, 2008). This dual perspective is further demonstrated by the economic value of biofortified crops in emerging markets, such as vitamin A-enriched cassava or iron-rich beans. Their practical adoption addresses nutritional deficiencies in low-income populations, resulting in both social and economic benefits, while their scientific validation ensures health efficacy (Zulfiqar *et al.,* 2024).

By combining these viewpoints, it is clear that scientific validation plays a crucial role in converting biotechnology advancements into long-term financial gains rather than just being a scholarly activity. Consumer trust is anchored, premium pricing is supported, regulatory approval is fostered, and alignment with health goals is ensured. By doing this, it bridges the gap between technical promise and actual consumer adoption, directly contributing to the economic value of biotech functional foods. Therefore, our study suggests that functional meals based on scientifically verified biotechnology produce more economic value by lowering informational asymmetries and providing useful health advantages that meet customer expectations.

Building upon the foundational theoretical framework, we construct the reasoning that underpins the development of the first hypothesis as follows:

H1: Scientific validation has a positive impact on the economic value of biotech-based functional foods.

2.4. The Impact of Consumer Trust in Biotech-Enhanced Nutrition on the Economic Value of Biotech-Based Functional Foods

Consumer trust in biotech-enhanced nutrition is one of the most important variables influencing the economic value of foods generated through biotechnology. It refers to the faith customers have in the safety, effectiveness, and moral purity of these foods. Trust boosts willingness to pay for high-end items marketed as health-enhancing solutions, lowers perceived dangers, and lessens skepticism about scientific innovation (Cao *et al*., 2017). Consumer confidence in biotechnology greatly increases market adoption, according to empirical research, as people are more inclined to buy and eat functional foods often when they think that producers behave ethically and openly (Siegrist & Hartmann, 2020). For instance, customer confidence in the brands' integrity and established reputations, which translate scientific promises into real market demand, is just as important to the success of probiotic dairy products in Europe and Asia as clinical validation (Granato *et al.,* 2010). By maintaining loyalty, defending premium pricing, and promoting differentiation in cutthroat food markets, consumer trust functions as a psychological and financial asset that transforms intangible impressions into quantifiable market worth.

Integrating interpretivism and critical realism can help us better understand how customer trust affects economic value. Interpretivism places a strong emphasis on the lived experiences and subjective interpretations that people create while interacting with social phenomena (Schwandt, 1994). According to this viewpoint, consumers' interpretations of stories about food safety, sustainability, and individual well-being influence their level of faith in biotech-enhanced nutrition. Promoting naturalness, transparency, and ethical sources raises perceived value by creating symbolic meanings that are in line with consumer ideals (Lenway *et al.,* 2022). For example, the interpretive framing of plant-based biotech proteins, like those used in meat substitutes, as solutions to climate change and animal welfare issues strongly influences consumer willingness to embrace these products, thereby enhancing economic value and fostering trust (Bryant & Barnett, 2018). Interpretivism emphasizes that the economic value of functional foods is co-created by shared cultural meanings and consumer narratives of identity, responsibility, and health rather than being solely based on scientific assertions.

By acknowledging that consumer impressions are subjective but also based on underlying structures and causal mechanisms that impact behavior, critical realism enhances this (Bhaskar, 1978). Critical realism highlights how business practices, institutional credibility, and regulatory frameworks influence the circumstances in which consumer trust grows and converts into financial results in the context of biotech-based functional foods. Consumers are given confidence in the legitimacy of products by structural procedures including government clearance, third-party certifications, and scientific agreement (Kjaernes *et al.,* 2007). The European Food Safety Authority's support of health claims serves as an example, since it has been demonstrated to greatly boost consumer trust and desire to buy functional foods with proven benefits (van Trijp & van der Lans, 2007). Critical realism emphasizes that economic value arises from institutional arrangements and systemic conditions that sustain trust, in addition to consumer perceptions, by concentrating on these deeper causal processes.

A thorough grasp of how consumer trust affects the financial worth of biotech-based functional meals is made possible by the combination of interpretivism and critical realism. Critical realism stresses the structural facilitators that convert trust into steady market performance, whereas interpretivism shows how human narratives of health, safety, and ethics and symbolic meanings co-create trust at the consumer level. Collectively, they demonstrate how consumer trust is both a structurally conditioned reality and a socially produced illusion. The market expansion of genetically modified rice varieties in Asia, for instance, shows how trust is established by combining institutional assurances through transparent regulatory approvals and public health endorsements (critical realist perspective) with cultural narratives about preventing malnutrition (interpretivist perspective) (Qaim, 2020). Similar to this, the expansion of the market for organic biotech-enriched supplements demonstrates that when consumer perceptions of wellness and authenticity collide with regulatory certifications and scientific support, both the structural and interpretive aspects of trust are strengthened, maximizing economic value (Hughner *et al.,* 2007).

It is clear from combining these two theoretical stances that consumer trust serves as a vital link between the development of biotechnology and its financial effects. When institutional dependability, cultural significance, and scientific credibility come together to maintain long-term market value, trust enables functional foods to make their way from the lab into homes. Therefore, based on both interpretative consumer narratives and structural processes that institutionalize credibility, our study suggests that consumer belief in biotech-enhanced nutrition has a positive and considerable influence on the economic value of biotech-based functional foods.Using the theoretical framework as a starting point, we create the following line of reasoning to support the formation of the second hypothesis:

H2: Consumer trust in biotech-enhanced nutrition has a positive impact on the economic value of biotech-based functional foods.

2.5. Moderating Role of Health Awareness of Consumers

According to Michaelidou and Hassan (2008), health awareness is the degree to which people are informed, concerned, and proactive in maintaining and enhancing their own well-being through lifestyle, nutrition, and preventative health practices. Health consciousness is a key moderator in the field of biotech-based functional foods because it influences how consumer trust is converted into financial value. Consumer readiness to accept new goods is based on their trust in biotechnology-driven nutrition, but this trust is increased or decreased based on the level of health consciousness that influences their purchase decisions (Chen, 2011). High levels of health consciousness increase the economic benefits of reliable functional meals because customers actively seek out food innovations that support preventive healthcare objectives in addition to valuing scientific legitimacy. Health-conscious people, for instance, are more prepared to pay higher costs for biotech-enhanced foods that are fortified with antioxidants or omega-3 fatty acids because they view these qualities as crucial investments in their long-term health (Ares & Gámbaro, 2007). On the other hand, even well-known biotech goods might not produce a substantial amount of economic value in customer categories with lesser health awareness, since there would be less incentive to emphasize a preventative diet.

The potential of health awareness to convert consumer trust into enduring loyalty and repeat business—both of which are essential for market development and profitability—demonstrates its moderating influence. According to research, consumers who are concerned about their health are more likely to read labels carefully, look for transparency, and assess functional benefits more thoroughly. As a result, their confidence in biotech foods is more likely to translate into real economic behaviors like brand loyalty and word-of-mouth promotion (Pappalardo & Lusk, 2016). One real-world example is the rising demand in Sub-Saharan Africa for biofortified crops, such as vitamin A-enriched sweet potatoes, where consumer health awareness campaigns greatly boosted adoption and trust, improving market performance and nutritional outcomes (De Brauw *et al.,* 2018). In these situations, trust in biotechnology is mediated via the prism of health consciousness, which determines whether or not trust materializes as consumer behavior. Trust in biotechnology does not generate economic value on its own.

The relationship between health consciousness and consumer trust emphasizes that economic value is a relational construct influenced by cognitive and motivational factors rather than a direct result. While health awareness serves as a trigger that influences the degree and consistency of market reaction, trust offers the crucial guarantee of safety and legitimacy. This moderating impact becomes more substantial in circumstances of growing global health consciousness, indicating that biotech-based functional foods will have higher commercial potential when high health awareness reinforces consumer trust. Accordingly, the study suggests that where health motives are deeply ingrained in consumer decision-making, health awareness amplifies the economic advantages by positively moderating the link between customer trust and the economic worth of biotech-based functional meals.

Based on the guiding theoretical framework and perspectives, the reasoning for hypothesis three is articulated below:

H3: Health awareness of consumers moderates the impact of consumer trust in biotech-enhanced nutrition on economic value of biotech-based functional foods.

Grounded in robust theoretical foundations, this study enhances its academic significance through the presentation of the following conceptual framework.

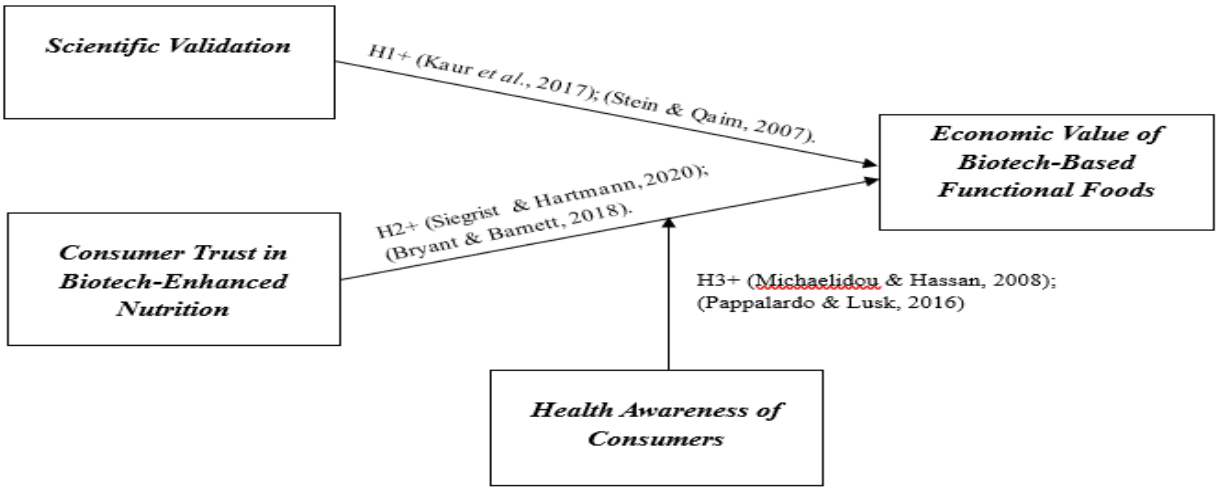

Figure 1: The Paper Conceptual Framework

3. METHODS

3.1. Research approach and strategy

To identify and validate patterns, this study employed a quantitative research strategy, which enables the methodical collection and evaluation of numerical data (Creswell & Creswell, 2017). The data was objectively analyzed using statistical approaches to produce quantifiable results (Babbie, 2010). This approach was chosen in order to support the goals of the study and investigate the relationships between important factors. Furthermore, a framework for deductive reasoning was used, which is ideal for quantitative research since it facilitates hypothesis testing, prediction insights, and evidence-based conclusions drawn from statistical data.

3.2. Participants

This study employed a purposive stratified sampling technique to ensure both empirical robustness and contextual relevance within the biotechnology-driven functional foods sector. Eligible participants were individuals with at least two years of practical experience in food innovation, biotechnology application in nutrition, health communication, or consumer policy relating to functional foods. Four main categories of expertise were stratified to ensure diversity and representational depth:

1. Food scientists and biotechnology researchers engaged in the development, testing, and validation of biotech-enhanced functional foods, responsible for providing empirical evidence of safety and efficacy;
2. Nutritionists, dietitians, and healthcare professionals who integrate biotech-based functional foods into dietary recommendations and assess their preventive health value for consumers;
3. Industry practitioners and product developers working in food companies, particularly those involved in branding, marketing, and commercializing functional food innovations to translate scientific validation into consumer acceptance;
4. Policy advisors, regulatory officials, and consumer rights advocates engaged in drafting, monitoring, and communicating food safety standards, certification frameworks, and labeling regulations that sustain consumer trust.

To be included in the survey, participants were required to have direct involvement with at least one of the following: designing or validating biotech-enhanced functional foods, implementing consumer trust–building strategies through branding and labeling, or conducting health awareness initiatives related to nutrition and food safety. Stratification factors included professional role, organizational affiliation, technical specialization, and degree of exposure to functional food adoption programs.

The survey was disseminated through professional networks, including biotechnology research institutes, nutritionist associations, and food industry trade bodies, as well as consumer health forums and academic mailing lists. Additional outreach was conducted via international nutrition and food technology conferences, health awareness campaigns, and LinkedIn professional communities related to food biotechnology and health promotion.

Responses were measured on a five-point Likert scale, ranging from “strongly disagree” to “strongly agree,” capturing perceptions of scientific validation, consumer trust, economic value, and health awareness. Out of 724 distributed questionnaires, 385 valid responses were retained after screening for completeness, consistency, and relevance. The stratified sample enabled a comprehensive quantitative analysis of how scientific validation and consumer trust—moderated by health awareness—jointly shape the economic value of biotech-based functional foods. By capturing perspectives across scientific, health, industry, and regulatory domains, the study ensured that its findings reflect both consumer-facing and structural drivers of functional food adoption and market performance.

4. RESULTS

4.1. Reliability analysis

Table 1: Reliability analysis of “Economic Value”. Source: (The authors, 2025)

Reliability Statistics

Cronbach's Alpha	N of Items
.726	4

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
EV1	7.705	8.612	.713	.720

EV2	7.023	7.440	.672	.688
EV3	7.659	7.419	.648	.689
EV4	8.580	7.617	.673	.711

Where questions 1 through 4, evaluating the notion of Economic Value (EV), are represented by survey items EV1 through EV4. All of these dependent sub-variables yielded adjusted item–total correlation values of at least 0.3, as shown in Table 1. The total Cronbach's alpha coefficient was 0.726, which was higher than the generally recognized cutoff of 0.7 and better than any other values that may have been obtained by eliminating specific items. Furthermore, even when taken into account separately, every sub-item showed Cronbach's alpha values greater than the corresponding adjusted item–total correlations. All four things were therefore considered trustworthy and kept for additional examination. For the other variables, the Cronbach's alpha findings similarly showed a comparable degree of internal consistency.

4.2. Exploratory factor analysis (EFA)

Table 2: Rotated Component Matrix. Source: (The authors, 2025)

Rotated Component Matrix[a]			
Component with loading factors			
1	2	3	4
EV1 .655	SV1 .771	CT1 .618	HA1 .682
EV2 .699	SV2 .540	CT2 .740	HA2 .638
EV3 .620	SV3 .680	CT3 .703	HA3 .629
EV4 .676	SV4 .600	CT4 .793	HA4 .689
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.			
a. Rotation converged in 7 iterations.			

Through questions 1 through 4 of each construct, survey items SV1 to SV4, CT1 to CT4, and HA1 to HA4 were created to evaluate two independent variables and the moderator, respectively. The 16 sub-items were successfully categorized into four different factors using the rotating component matrix, as shown in Table 2. These factors exactly corresponded to the moderator variable (HA), the two independent variables (SV and CT), and the dependent variable (EV). The relevance of each item to the targeted constructs was confirmed by factor loadings over the 0.5 criterion. As a result, no items were eliminated from the component analysis, suggesting that all variables had excellent construct validity.

4.3. Multiple linear regression model

Table 3: Coefficients[a]. Source: (The authors, 2025)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	6.680	.912		4.007	.000
	SV	.656	.906	.635	3.844	.003
	CT	.519	.722	.508	3.485	.005

a. Dependent Variable: EV

Where **EV**: mean of EV1 to EV4; **SV**: mean of SV1 to SV4; **CT**: mean of CT1 to CT4

The t-test findings showed significant (Sig.) values of.003 and.005, both of which were below the conventional alpha threshold of 0.05, as shown in Table 3. This suggests that the dependent variable, economic value, is statistically significantly impacted by the independent variables, consumer trust and scientific validation. Additionally, the findings support the idea that health awareness moderates this association. As a result, the results offer empirical backing for every hypothesis that has been put out.

4.4. Moderator analysis

Table 4: Results analysis of “health awareness”. Source: (The authors, 2025)

Model : 1

Y : EV

X : SV
W : HA
Sample Size: 385
****

OUTCOME VARIABLE:
EV

Model Summary

R	R-sq	MSE	F	dl1	dl2	p
.696	.484	.724	5.606	3.000	381.000	.000

Model

	coeff	se	t	p	LLCI	ULCI
constant	7.009	.860	61.361	.000	7.898	7.783
SV	.621	.743	4.966	.000	.717	.701
HA	.632	.591	4.300	.000	.705	.698
Int_1	.472	.582	4.576	.000	.736	.721

Where **HA**: mean of HA1 to HA4

The interaction term (Int_1) has a p-value of 0.000, which is much less than the typical significance level of 0.05, as shown in Table 4. This indicates that Consumer Trust (CT) and Health Awareness (HA) have a statistically significant interaction effect on Economic Value (EV). The beneficial impact of customer trust on the economic value of biotech-based functional meals is amplified by higher levels of health awareness, according to the interaction coefficient of 0.472. Consequently, there is empirical evidence for hypothesis H3.

5. DISCUSSION

5.1. Result Summary

The scientific validation of biotech functional foods has a positive and significant impact on the economic value of biotech-based functional foods, with a coefficient of 0.635. Consumer trust in biotech-enhanced nutrition also demonstrates a strong influence on economic value, with a coefficient of 0.508. In addition, consumer health awareness plays a moderating role in shaping the relationship between consumer trust and economic value, with a coefficient of 0.472, indicating that higher levels of health awareness strengthen the positive impact of consumer trust on the perceived and realized economic value of biotech-based functional foods.

5.2. Theoretical Implications

The conclusion that scientific validation significantly increases the economic worth of biotech-based functional meals (β = 0.635) provides strong support for the interpretivist thesis that consumer perceptions co-construct economic value. This finding is in line with Shimizu (2003), who highlighted that scientific evidence boosts consumer confidence in product reliability, and Clarke et al. (1997), who showed that clinical studies give credibility to functional food health claims, thereby legitimizing market acceptance. Our findings are consistent with Kaur et al. (2017), who demonstrated that empirical validation raises readiness to embrace functional foods, and Stein and Qaim (2007), who contended that regulatory approval based on scientific assessment boosts the economic potential of biotech breakthroughs. Collectively, these results strengthen the theoretical argument that positivist evidence converts intangible nutritional claims into quantifiable monetary worth, emphasizing that scientific legitimacy is a cultural process that influences consumer meaning-making and willingness to pay in addition to being a technical requirement.

Interpretivist thinking is further supported by the examination of customer trust, which shows a strong effect on economic value (β = 0.508). This is consistent with the findings of Chaudhuri and Holbrook (2001), who found a clear correlation between brand trust and loyalty and willingness to pay, as well as Siegrist and Hartmann (2020), who claimed that ethical and transparent methods increase customer confidence in biotech-based functional foods. The results are also consistent with van Trijp and van der Lans (2007), who discovered that institutional certifications and approvals increase trust in functional food products, and Mayer et al. (1995), who defined trust as a readiness to accept vulnerability based on perceptions of competence and integrity. The findings here indicate that trust becomes economically significant when integrated into larger structures of validation and health-oriented decision-making, whereas previous research focused on trust as a stand-alone driver of acceptance. This highlights the fact that consumer confidence is a relational and structural determinant of market success.

By demonstrating that customers who are more health-conscious increase the conversion of trust into economic value, the moderating function of health awareness (β = 0.472) supports the Health Belief Model's explanatory power. This is in line with Chen (2011), who pointed out that preventative health concerns greatly enhance the desire to purchase such items, and Michaelidou and Hassan (2008), who contended that more health awareness predicts better adoption of functional foods. The findings also corroborate those of Pappalardo and Lusk (2016), who discovered that health awareness strengthens the role of trust in promoting loyalty and repeat consumption, and Ares and Gámbaro (2007), who noted that consumers with strong health orientations are more willing to pay premium prices for nutrition-enhancing products. The combination of these results emphasizes how trust and health motives combine to create economic value, and it shows that structural factors related to health consciousness serve as modifiers that amplify the psychological and relational impacts of trust.

When combined, these theoretical ramifications show that technology innovation alone does not create economic value in the biotech functional food industry; rather, a combination of consumer health orientations, relational processes based on trust, and scientifically proven evidence does. Claims are empirically supported by scientific validation, consumer trust converts credibility into acceptance and readiness to pay, and health awareness amplifies these benefits by coordinating economic behavior with preventive health motivations. The study advances theory by connecting these dimensions and demonstrating that functional food markets are supported by both interpretive meaning and positivist evidence. Critical realist structures like institutional certification and health consciousness shape the circumstances in which validation and trust result in long-term economic value.

5.3. Practical Implications

The findings of the study suggest a number of useful ramifications that might direct business and legislative initiatives in the functional food space. First, as goods backed by clinical data and regulatory clearance have a higher chance of being accepted and maintained in competitive marketplaces, scientific validation becomes a fundamental component of market legitimacy (Clarke *et al.,* 1997; Shimizu, 2003). Validation increases the ability of biotechnology discoveries to provide long-term financial value while also lowering customer uncertainty by bolstering trust (Stein & Qaim, 2007; Kaur *et al.,* 2017). Second, customer trust is a key factor that influences economic results. Perceptions of safety and integrity improve when businesses prioritize ethics and transparency, which encourages customer loyalty and a willingness to pay more for high-end goods (Mayer *et al.,* 1995). Reputable brands and institutional certificates further increase trust, converting scientific guarantees into long-term commercial acceptance (Chaudhuri & Holbrook, 2001; Siegrist & Hartmann, 2020). Finally, by enhancing the conversion of trust into concrete economic activity, health awareness acts as a moderator. Increased market value results from more health-conscious consumers' propensity to embrace preventive diets, carefully consider the advantages of products, and make repeat purchases (Michaelidou & Hassan, 2008; Chen, 2011). This suggests that in order to achieve both commercial viability and societal value, biotechnology innovation must be in line with scientific credibility, trust-building strategies, and health-oriented involvement (Ares & Gámbaro, 2007; Pappalardo & Lusk, 2016).

5.4. Limitations

Despite its merits, this study has drawbacks. First, because consumer trust, health awareness, and economic value were examined all at once, the cross-sectional design limits the capacity to prove causation. Second, response bias may be introduced by using self-reported survey data, especially when it comes to attitudes toward preventive health practices and views of scientific validity. Third, although expert knowledge is guaranteed by the intentional stratified sample of professionals, generalizability to larger consumer groups—who ultimately determine market demand—is constrained. Last but not least, the paradigm ignores contextual elements that might affect the uptake of functional foods in different geographical areas, such as cultural preferences or regulatory variances.

5.5. Future Research Directions

This study could be expanded upon in future research by examining the ways in which institutional and cultural circumstances influence the link between economic value, consumer trust, and scientific validation in various geographical areas. To document how changing health trends and legal frameworks affect consumers' adoption of biotech-based functional foods over time, longitudinal designs are required. In order to effectively forecast consumer choices in preventive nutrition, future models should also incorporate behavioral economics and sustainability considerations. Furthermore, examining the function of multi-actor partnerships—like those involving food corporations, authorities, and health groups—may provide light on how shared governance promotes market performance and customer confidence.

5.6. Conclusion

This study offers a thorough examination of the ways in which consumer confidence and scientific validation affect the financial worth of biotech-based functional foods, with health consciousness acting as a moderator. Using viewpoints on consumer

behavior and market legitimacy, it illustrates how technical innovation by itself cannot ensure customer acceptance without the bolstering of credibility and trust. The empirical results support all of the hypotheses put out and advance our theoretical knowledge of the adoption of functional foods. In the conclusion, the findings highlight that in order to have a long-lasting economic effect, sustained growth in this sector requires the merger of scientific credibility, trust-building techniques, and health-conscious involvement.

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APPENDIX: Survey

Table 6. Survey Questionnaire

Background information

Which of the following best represents your age?	Under 18	18-24	25-34	25-44	45-54	55 and above
Professional role most closely related to biotechnology-driven functional foods?	Food scientist or biotechnology researcher	Nutritionist, dietitian, or healthcare professional	Industry practitioner or product developer in food companies	Policy advisor, regulatory official, or consumer advocate	Other	
Years of professional experience in food, health, or biotechnology-related fields?	Less than 2 years	2–5 years	6–10 years	More than 10 years		
Level of involvement in functional food activities? (e.g., research, product development, health communication, regulation)	Very low	Low	Moderate	High	Very high	

No.	Variables	Coded Sub-variables	Content
1.	Economic Value of Biotech-Based Functional Foods	EV1	Functional foods enhance value-added opportunities within the food industry. (Kaur et al., 2017)
		EV2	Biotechnology-based nutrition contributes to lowering healthcare expenditures through preventive benefits. (Stein & Qaim, 2007)
		EV3	The commercial success of functional foods relies on the balance between product cost and perceived health benefit. (Siegrist & Hartmann, 2020)

		EV4	The broader economic value of biotech innovations is reflected in the willingness to pay for functional foods. (Bryant & Barnett, 2018)
2.	Scientific Validation	SV1	Health benefits of biotech-based functional foods become credible when supported by clinical studies. (Clarke et al., 1997)
		SV2	Regulatory approval provides legitimacy and enhances the economic potential of functional foods. (Stein & Qaim, 2007)
		SV3	Scientific evidence strengthens the reliability of health claims in functional food products. (Shimizu, 2003)
		SV4	Empirical validation increases the likelihood of market acceptance of biotech-enhanced foods. (Kaur et al., 2017)
3.	Consumer Trust in Biotech-Enhanced Nutrition	CT1	Transparency and ethical practices increase confidence in biotech-based functional foods. (Siegrist & Hartmann, 2020)
		CT2	Trust in functional food brands enhances willingness to pay for these products. (Chaudhuri & Holbrook, 2001)
		CT3	Perceived safety and integrity of biotech-based nutrition strongly determine purchasing decisions. (Mayer et al., 1995)
		CT4	Institutional certifications and regulatory approvals strengthen trust in functional foods. (van Trijp & van der Lans, 2007)
4.	Health Awareness of Consumers	HA1	Higher levels of health awareness are associated with greater adoption of biotech-based functional foods. (Michaelidou & Hassan, 2008)
		HA2	Preventive health considerations increase willingness to purchase functional foods. (Chen, 2011)
		HA3	Consumers with strong health orientation are more prepared to pay premium prices for functional foods. (Ares & Gámbaro, 2007)
		HA4	Health awareness enhances the role of trust in fostering loyalty toward functional food products. (Pappalardo & Lusk, 2016)

Survey link: https://docs.google.com/forms/d/e/1FAIpQLScvgsxMlj8lpB3TS8DaElUeI_2y3a9Efl4bFK2slD26fxl_vQ/viewform?usp=header