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Food Irradiation for Food Safety: Consumer Awareness, Attitudes, and Acceptance Toward Irradiated Food in Indonesia

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Abstract

Indonesia faces major food safety issues. Foodborne illness and food loss and waste (FLW) are affecting public health and the economy. This will likely continue unless these problems are addressed. Food irradiation is a non-thermal food processing technology that offers a promising means to address this issue by enhancing food safety and quality. However, the application of food irradiation could be limited. Consumer concerns could prevent the use of food irradiation in Indonesia due to limited knowledge and misconceptions regarding irradiation. This study examines Indonesian consumers' awareness, attitudes, and acceptance toward irradiated food. Moreover, explores differences in acceptance across socio-demographic groups. An online survey was conducted from May to July 2025. A total of 386 respondents participated. Descriptive statistics were utilized to analyze awareness, attitudes, and acceptance, while comparative tests assessed socio-demographic differences. Results reveal surprisingly high acceptance: 69.2% are willing to buy, and 69.0% are willing to consume irradiated foods, despite generally low awareness (45.3%). Consumers reported moderate perceived risk, substantial perceived benefits, and high trust. Acceptance did not differ significantly by gender but was notably lower among older, higher-educated, and higher-income groups. Indicate Consumers with higher education and income appear to be more critical and selective than those with lower education and income. Communication efforts should focus on raising awareness and providing information to help consumers understand the advantages of food irradiation. Overall, this study provides valuable empirical evidence for policymakers, the food industry, and academics to support the safe and broad application of food irradiation.

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Introduction

Food safety is a critical issue in the global food system, central to both public health and food security. One of the main problems is contamination by biological agents, particularly microorganisms (Elbehiry et al., 2023). These agents are ubiquitous in the environment and are a major cause of foodborne illness and product spoilage, which substantially contributes to food loss and waste (FLW) (Chatterjee & Abraham, 2018; Karanth et al., 2023; Odeyemi et al., 2020). The global burden is significant: according to the World Health Organization (2015), one in ten people worldwide falls ill each year due to contaminated food. Furthermore, about one-third of food produced for human consumption is lost before reaching consumers (Gustavsson et al., 2011).

This global challenge is particularly evident in Indonesia, where food safety issues persist. This is reflected in frequent outbreaks of food poisoning and the decline of Indonesia's food exports in international markets due to safety issues (Damayanti & Wahyati, 2019). According to The Economist Intelligence Unit (2016) Indonesia ranked second among 25 countries for the highest per-capita of FLW. Furthermore, the U.S. Food and Drug Administration recorded 1,451 rejections of Indonesian food products between 2011 and 2014 due to safety issues (Hariyadi, 2015). Ensuring food safety has critical implications not only for public health but also for economic resilience and sustainable development (Fung et al., 2018). These challenges highlight the urgent need for effective technologies for food production, processing, and preservation to improve food safety, support food security, and strengthen Indonesia's economy.

Food irradiation offers a promising solution to

these challenges and has several key advantages. It addresses both food quality and safety, and extends shelf life by inactivating parasites, reducing spoilage microorganisms, eliminating foodborne pathogens, delaying ripening of fruits, inhibiting sprouting in bulbs and tubers, and helping to control post-harvest losses from insect infestation (Ihsanullah & Rashid, 2017; Ravindran & Jaiswal, 2019; Singh & Singh, 2019). As a non-thermal, chemical-free process, irradiation preserves nutritional and sensory quality without the risks of heat or chemical treatments (Ashraf et al., 2019; Pi et al., 2021). Scientific research has consistently shown that food irradiation is a safe and effective method, and is endorsed by major international agencies, including WHO, FAO, IAEA, and the U.S. FDA (Clemmons et al., 2015; Farkas & Mohácsi-Farkas, 2011; Ravindran & Jaiswal, 2019). In Indonesia, food irradiation is regulated by the Indonesian Food and Drug Authority (BPOM) through Peraturan BPOM No. 3 Tahun 2018 tentang Pangan Iradiasi (BPOM Regulation No. 3/2018 on Irradiated Food).

Among food irradiation technologies, electron beam (e-beam) irradiation stands out for its rapid and efficient process. Unlike gamma irradiation, e-beam does not rely on radioactive isotopes and can be switched off when not in use, making it safer and easier to manage (Gautam & Venugopal, 2021). It delivers high doses and is effective while minimizing impacts on product quality (Ashraf et al., 2019). It offers precise dose control, maintains packaging integrity, and provides a fast and cost-effective process for ensuring food safety (Silindir & Özer, 2009).

In Indonesia, the application of food irradiation has the potential to strengthen food security and enhance food safety. At the same time, it can support economic growth by increasing product value and facilitating access to international markets that require strict food safety standards. However, the optimal implementation of food irradiation ultimately depends on consumer acceptance. Globally, despite rising acceptance rates for irradiated food over the past three decades, consumer hesitancy remains a significant barrier, particularly in developing countries, where acceptance rates are often lower compared to industrialized nations (Maataoui et al., 2025). Consumer concerns toward irradiation may lead to rejection, thereby limiting the effective adoption of this technology (Li et al., 2025; Maataoui et al., 2025).

Consumer hesitancy often stems from a lack of knowledge and high levels of uncertainty (Maherani et al., 2016; Rahman et al., 2018). Studies in various countries reveal a significant information gap. For instance, surveys have shown very low consumer awareness in Turkey (29%), Italy (15.8%), and even China (15.5%), one of the world's largest producers of irradiated products (Galati et al., 2019; Gunes & Deniz Tekin, 2006; Wang et al., 2023). This lack of knowledge fosters significant uncertainty; a Turkish survey found that a vast majority of consumers (80%) were uncertain about the safety of irradiated foods (Gunes & Deniz Tekin, 2006). Research suggests that this reluctance is not primarily driven by a firm belief that the technology is unsafe, but instead by a simple need for more information.

This knowledge gap is often filled with persistent misconceptions. The most common misconceptions are the erroneous association between the word "irradiation" and "radioactivity," which leads to unfounded fears about cancer and other negative health effects (Arvanitoyannis, 2010; Junqueira-Gonçalves et al., 2011; Lima Filho et al., 2017). Other widespread

Table 1. Variables and Measurement Indicators

Variables	Code	Indicators	Corrected Item–Total Correlation	Cronbach's Alpha
Awareness	AW1	Awareness of Food Irradiation	0.917	0.904
	AW2	Understanding of the Process	0.882	
	AW3	Understanding of the Purpose	0.912	
	AW4	Awareness of Regulations	0.813	
Perceived Risk	PR1	Perceived Health Risk	0.851	0.869
	PR2	Product Safety Concerns	0.840	
	PR3	Concerns about Nutritional Changes	0.819	
	PR4	Perceived Long-term Risk	0.877	
Perceived Benefit	PB1	Food Safety Benefit	0.765	0.749
	PB2	Extended Shelf-life	0.605	
	PB3	Product Quality	0.855	
	PB4	Environmental and Food Waste Benefit	0.789	
Trust	TR1	Trust in supervisory institutions	0.846	0.895
	TR2	Trust in the Regulations	0.872	
	TR3	Trust in Food Producers	0.880	
	TR4	Trust in the Technology Itself	0.893	
Consumer Acceptance	CA1	Willingness to buy	0.867	0.893
	CA2	Willingness to consume	0.878	
	CA3	Willingness to Recommend	0.828	
	CA4	Intent for Continued Purchase	0.779	
	CA5	Overall attitude	0.854	

Note: The validity of the measurement indicators was determined by the Corrected Item–Total Correlation (items were considered valid if r-count ≥ 0.0998 (at a significance level of $\alpha = 0.05$). Internal consistency reliability was assessed using Cronbach's Alpha (acceptable if ≥ 0.70).

misunderstandings include the belief that irradiation is a substitute for poor hygiene in food processing, that it significantly lowers nutritional value, and that it is an expensive process that primarily benefits the food industry rather than the consumer (Maataoui et al., 2025). Nevertheless, this information gap also presents an opportunity, as research consistently shows that consumer attitudes are highly influenced by information (Arvanitoyannis, 2010). This underscores that the main obstacle is not unchangeable fear, but rather an addressable lack of accurate and accessible information.

While studies on consumer acceptance of food irradiation have been conducted in several countries, research in Indonesia has predominantly consisted of technical reports (e.g., Wisnubroto et al., 2024) and literature reviews (e.g., Handayani & Permawati, 2017; Salam et al., 2025) rather than consumer-focused empirical studies. This represents a knowledge gap, as consumer acceptance will determine the success of implementing food irradiation in the national food system. To address this gap, the present study provides the first empirical analysis of Indonesian consumers' responses to irradiated foods. Specifically, this study quantitatively examines (1) consumer awareness and acceptance, (2) consumer attitudes regarding key psychological drivers (perceived risk, perceived benefit, and trust), and (3) acceptance levels across socio-demographic factors such as gender, age, education, and income. The findings are expected to establish a baseline understanding of consumer awareness, perceptions, and acceptance, thereby filling the local knowledge gap and providing insights to support effective communication strategies and evidence-based policymaking for broader adoption of this technology in Indonesia's food sector.

Materials and Methods

Study Design and Population

An online survey was used to collect data on Indonesian consumers. This method was chosen because it is efficient and able to reach a large and geographically diverse group of respondents (Ball, 2019). The target population consisted of Indonesian consumers aged 18 years and above. Because the population size was very large and undefined, a non-probability convenience sampling was used for its practicality (Etikan, 2016). A total of 386 consumers participated in the survey.

Data Collection Procedure

The data were collected using an online questionnaire in Google Forms and distributed via social media platforms. The survey took place between May and July 2025. The questionnaire consisted of closed-ended items measuring five main variables: Awareness (AW), Perceived Risk (PR), Perceived Benefit (PB), Trust (TR), and Consumer Acceptance (CA). Each variable was measured using several indicator items adapted from previous studies, such as Arvanitoyannis (2010), Bruhn (2008), Siegrist (2008), and Siegrist & Hartmann (2020). All responses were rated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The questionnaire also collected socio-demographic information, including domicile (province), age, gender, education, and income.

Instrument Validation

Before the data analysis, the questionnaire was tested for its validity and reliability. Validity was assessed using Pearson's correlation coefficients, whereas internal consistency reliability was evaluated using Cronbach's alpha. Items were considered valid if they showed a significant positive correlation with the total construct score. The instrument was deemed reliable when Cronbach's alpha was ≥ 0.70. The result is presented in Table 1.

Data Analysis

Descriptive statistics (means, standard deviations, and frequencies) were used to summarize respondent characteristics and the main variables. Comparative analyses were performed to examine differences in consumer acceptance across socio-demographic groups. Independent-samples *t*-tests were used for two-group comparisons (e.g., gender), and one-way analysis of variance (ANOVA) for variables with more than two groups (e.g., age, education, income). Tukey's HSD post hoc tests were applied when ANOVA results were significant. All statistical analyses were conducted using SPSS version 25.

Results and Discussion

Socio-demographic Characteristics

The socio-demographic profile of the 386 respondents is detailed in Table 2. The majority of respondents were female (61.1%), while males accounted for 38.90%. About 65.0% are young adults aged 18–34. In terms of education, the group was quite educated, as 67.4% of respondents had reached a higher education level (Diploma/Bachelor's Degree or Postgraduate). The sample spanned a wide range of income levels. Respondents were distributed across 24 provinces as shown in Figure 1, with Java being the majority of the sample.

Figure 1. Geographical Distribution of Respondents by Province. The figure shows the geographical distribution and concentration of the 386 respondents across 24 provinces in Indonesia.

Consumer Awareness

The study identified a relatively low level of awareness among Indonesian consumers toward food irradiation. Over half of the respondents (54.7%) indicated they were unfamiliar with or uncertain about food irradiation (AW1). This is not surprising, considering that food irradiation has not yet been widely adopted in

Table 2. Characteristics of Respondents

Socio-demographic	Characteristics	Frequency (Person)	Percentage (%)
Gender	Male	150	38.90
	Female	236	61.10
Age (years)	18–24	134	34.70
	25–34	117	30.30
	35–44	51	13.20
	45–64	81	21.00
	≥ 65	3	0.80
Education	Junior High School or below	3	0.80
	High School or equivalent	123	31.90
	Diploma / Bachelor's Degree	238	61.70
	Postgraduate	22	5.70
Income (monthly)	< Rp 1,000,000	67	17.40
	Rp 1,000,000 - 2,999,999	88	22.80
	Rp 3,000,000 - 5,999,999	111	28.80
	Rp 6,000,000 - 9,999,999	65	16.80
	≥ Rp 10,000,000	55	14.20

Note: Total respondents (n) = 386. This table shows the socio-demographic profile of the consumers participating in the study.

Indonesia and irradiated food products are rarely visible in retail markets. Similar trends have occurred in other countries. For instance, Wang et al. (2023) reported that 84.5% of Chinese consumers were either unfamiliar with or possessed limited knowledge about irradiated food. In Chile, 76.5% of consumers did not know about food irradiation (Junqueira-Gonçalves et al., 2011). While in Brazil, 57% of consumers had never heard of food irradiation (Lima Filho et al., 2017).

Looking at other indicators, the results indicate that awareness is inconsistent. Although 45.3% of respondents reported some familiarity with food irradiation (AW1), the results do not indicate deeper knowledge. In fact, only 34.2% of respondents claim to know how irradiation works (AW2). The gap between familiarity and actual comprehension is clearly demonstrated by the descriptive statistics in Table 3, which show that AW2 had the lowest mean score of responses.

A seemingly contradictory pattern also became evident in the data collected. A majority (54.7%) of participants were unfamiliar with food irradiation as a concept, whereas an unexpectedly large number were aware of its purposes (47.4% agreement on AW3) and regulations (50.8% agreement on AW4). This may indicate that these responses did not represent true knowledge, but instead seem to be based on assumptive knowledge, and therefore factual knowledge. respondent likely assumed the purpose of irradiation based upon their preconceived notions of food technologies and believed they would improve food quality, and also assumed that all food products are monitored by government authorities, instead of possessing real knowledge of the specific regulations themselves.

Low awareness may affect both perceived risk and trust toward food irradiation and, consequently, lead to misconceptions. For example, the erroneous association of “food irradiation” with “radioactivity” can result from a lack of factual awareness and will inherently reduce consumer acceptance. Thus, developing effective communication strategies will be essential to preventing misconceptions and subsequently increasing consumer acceptance and promoting the long-term sustainability of food irradiation.

Perceived Risk

Consumers expressed a moderate, rather than overwhelming level of concern regarding food irradiation. They are primarily concerned about hypothetical risks. The most significant concern involved perceived health risks, which had the highest mean score (PR1), with 56.5% of respondents reporting concern about potential negative health effects (PR1). Additionally, 52.4% reported concern that irradiating food could lead to nutritional changes (PR3). This emphasis on hypothetical health risks is consistent with global findings showing that the term “food irradiation” often evokes negative associations with radiation or nuclear hazards, which can heighten perceived risk through the affect heuristic (Siegrist & Hartmann, 2020). These concerns, rooted in limited knowledge and cognitively shaped by such negative affective associations, are further reflected in the 49.5% of respondents who reported worry about long-term effects (PR4).

In contrast, concern declined regarding the immediate safety of the product (PR2). Less than a third (31.3%) of respondents thought the product would be unsafe, while over a third (36.3%) indicated that they were unsure. The high degree of uncertainty is an important finding, as it suggests that the issue is more a function of a lack of information rather than a strongly held belief in danger. Some other countries have demonstrated similar findings, like Italy and China (Galati et al., 2019; Li et al., 2025).

Taken together, these findings illustrate that risk perception and awareness are closely connected. When consumers are unaware or have limited knowledge, they tend to feel less certain and thus perceive a greater risk. Therefore, there is an opportunity to improve Indonesian consumers' perceptions of risk by developing targeted

Table 3. Descriptive Statistics and Response Distribution

Variables	Code	Indicator	Response Distribution			Mean	SD
			(1-2)	(3)	(4-5)		
Awareness	AW1	Awareness of Food Irradiation	34.2%	20.5%	45.3%	3.06	1.294
	AW2	Understanding of the Process	42.2%	23.6%	34.2%	2.76	1.252
	AW3	Understanding of the Purpose	33.9%	18.7%	47.4%	3.11	1.351
	AW4	Awareness of Regulations	28.2%	21%	50.8%	3.30	1.310
Perceived Risk	PR1	Perceived Health Risk	23%	20.5%	56.5%	3.49	1.160
	PR2	Product Safety Concerns	32.4%	36.3%	31.3%	2.98	1.106
	PR3	Concerns about Nutritional Changes	23.8%	23.8%	52.4%	3.38	1.161
	PR4	Perceived Long-term Risk	25.4%	25.1%	49.5%	3.35	1.193
Perceived Benefit	PB1	Food Safety Benefit	19.7%	35.5%	44.8%	3.30	1.002
	PB2	Extended Shelf-life	3.9%	17.1%	79%	4.17	0.866
	PB3	Product Quality	13.4%	30.8%	55.7%	3.53	0.934
	PB4	Environmental and Food Waste Benefit	9.6%	28.5%	61.9%	3.73	0.950
Trust	TR1	Trust in Supervisory Institutions	10.3%	19.7%	70%	3.87	1.006
	TR2	Trust in the Regulations	11.4%	26.7%	61.9%	3.66	0.954
	TR3	Trust in Food Producers	9.1%	30.3%	60.7%	3.68	0.938
	TR4	Trust in the Technology Itself	8.3%	24.9%	66.8%	3.80	0.924
Consumer Awareness	CA1	Willingness to Buy	6.5%	24.4%	69.2%	3.84	0.845
	CA2	Willingness to Consume	6.4%	24.6%	69%	3.79	0.829
	CA3	Willingness to Recommend	12.9%	38.3%	48.7%	3.46	0.903
	CA4	Intent for Continued Purchase	9.6%	21%	69.4%	3.85	0.980
	CA5	Overall Attitude	8%	35.8%	56.2%	3.60	0.848

Note: (1-2) = Strongly Disagree/Disagree; (3) = Neutral/Uncertain, (4-5) = Agree/Strongly Agree. SD = standard deviation.

communications. Primarily through awareness raising and strengthening institutional trust through transparent, science-based information.

Perceived Benefit

Although respondents reported a moderate level of concern about the risks associated with food irradiation, they also had favorable views of the benefits associated with food irradiation. The most recognized benefit was the perceived extended shelf-life of irradiated foods (PB2), which had the highest mean score (4.17) and was acknowledged by 79% of respondents. This suggests that consumers tend to value clear, tangible benefits they believe would directly affect them. This contrasts with global findings that such practical benefits are often overlooked (Maataoui et al., 2025).

Additionally, respondents believed in many additional benefits of Food Irradiation beyond its ability to extend shelf life. They believed Food Irradiation has the potential to support consumers' desire for reduced food waste (PB4; 61.9%) and better-quality products (PB3; 55.7%), both of which are aligned with consumer values related to sustainability and quality, demonstrating that respondents see Food Irradiation as a means to preserve product quality in an environmentally efficient manner.

However, perceived food safety benefits (PB1) were less strongly recognized. Only 44.8% of respondents believed that irradiation increases food safety, while 35.5% remained uncertain. This finding is noteworthy because generally, the purpose of food irradiation is to enhance safety by eliminating foodborne pathogens. This could imply that while consumers recognize or perceive the immediate personal advantages, like longer shelf life, they have more difficulty perceiving benefits that are technical and less visible. scientific outcomes, like pathogen reduction, are less likely to be understood without clearer and deeper knowledge.

Consumers are generally more willing to accept something new when they feel that its benefits outweigh the potential risks. In this context, increasing awareness is important, as limited knowledge may prevent consumers from fully recognizing the benefits of food irradiation. Offering clearer and more accessible information could help consumers better understand these benefits, which may ultimately support higher acceptance.

Consumer Trust

Consumer trust in food irradiation was generally high across all indicators. A number of 70% respondents expressed trust in the supervisory institutions that handle and supervise food irradiation (TR1), representing the highest level of conviction among all trust indicators (Mean = 3.87). Then followed by trust in the technology itself, with 66.8% of respondents expressing trust (TR4) and 61.9% expressing trust in regulations (TR2). While trust in food producers (TR3) was the lowest of the four at 60.7%. These suggest that consumers perceive both regulatory bodies and technological systems as

Table 4. Comparison of Consumer Acceptance across Socio-demographic Groups

Socio-demographic	Characteristics	N	Mean	Statistic	p-value
Gender	Male	150	3.69	t = -0.336	0.737
	Female	236	3.72		
Age	18–24	134	3.79[a]	F = 9.094	< 0.001
	25–34	117	3.84[a]		
	35–44	51	3.86[a]		
	45–64	81	3.30[b]		
Education	High School	123	3.89[a]	F = 6.501	< 0.001
	Diploma / Bachelor's Degree	238	3.65[b]		
	Postgraduate	22	3.26[b]		
Income	< Rp 1,000,000	67	3.83[a]	F = 7.497	< 0.001
	Rp 1,000,000 - 2,999,999	88	3.71[a]		
	Rp 3,000,000 - 5,999,999	111	3.85[a]		
	Rp 6,000,000 - 9,999,999	65	3.73[a]		
	≥ Rp 10,000,000	55	3.24[b]		

Note: Means within the same variable that do not share a common superscript letter (a, b) are significantly different ($p < 0.05$) based on Tukey's HSD post-hoc test. Categories with very small sample sizes (e.g., Age ≥65, Education Junior High School or below) were excluded from this table for statistical reliability.

reasonably reliable.

These findings are a good sign, because Trust plays a central role in how consumers assess both risk and benefit. this may help explain why, despite low awareness, respondents still perceived several benefits and reported only moderate levels of risk. Also, consumers may rely on that trust to form positive judgments, even when their knowledge is limited. Therefore, maintaining and reinforcing consumer trust through transparent communication and credible oversight is essential to supporting acceptance, particularly in contexts where awareness remains limited.

Consumer Acceptance

Indonesian consumers showed a favorable and high level of acceptance for irradiated food. The majority of respondents expressed a willingness to buy irradiated food products (CA1; 69.2%) and to consume them (CA2; 69.0%). As 69.4% of the respondents indicated they will continue to purchase irradiated products if they are satisfied with their previous experiences (CA4). This provides evidence of a stable and favorable orientation toward future use. Indonesian consumers exhibited higher levels of acceptance than those in Brazil and China, which are considered to be part of an emerging economy and have been shown to exhibit lower levels of acceptance (Lima Filho et al., 2017; Wang et al., 2023).

Attitudes toward irradiated food in general (CA5) were somewhat positive. respondents had a positive view for about 56.2%, and a neutral view for 35.8%. However, the recommendation of irradiated foods to others (CA3) showed significantly lower acceptance. only 48.7% of respondents indicated they would recommend the product, and 38.3% remain unsure. The difference between respondents' personal acceptance of irradiated foods and their willingness to recommend them to others appears to reflect perceived social risk. Consumers seem comfortable with the decision-making process involved in purchasing products for themselves. Still, they may be less willing to recommend new products when their recommendations may influence or be judged by others.

The high levels of acceptance observed in this study, even with low awareness and moderate perceived risk, may reflect the combined influence of strong trust and relatively positive perceived benefits. High consumer trust in supervisory institutions, regulations, and the technology itself likely plays a moderating role. Dampening the effect of uncertainty and mitigating perceived risks. Additionally, the perceived benefits, which are tangible to consumers, likely increased acceptance of irradiated foods, regardless of respondents' levels of knowledge about irradiation. The combination of these factors appears to counteract the respondents lack of knowledge and enable them to formulate positive behavioral intentions.

Consumer Acceptance Based on Socio-demographic Characteristics

Consumer acceptance of irradiated food was found to be consistent based on gender. However, it was found to differ significantly across age, education, and income, as detailed in Table 4. No statistically significant difference was found in consumer acceptance between male and female respondents. It implies that gender is not a determinant of acceptance for food irradiation in Indonesia. There are also similar results reported in a study conducted in Poland, which found no significant differences between men and women in their attitudes toward food irradiation (Buczkowska et al., 2023).

In contrast, significant differences were found across age groups. Post-hoc analysis revealed that acceptance was significantly higher among consumers under 45 compared to the older group (45–64). This result is consistent with Galati et al. (2019), who reported that younger consumers are generally more open to novel food technologies, including irradiation, while older consumers are less inclined to accept them. Similarly, Buczkowska et al. (2023) found that positive attitudes

toward food irradiation were more common among younger respondents.

Interestingly, this study found an inverse relationship between acceptance and both education and income. Acceptance was highest among those with a high school education and lower-to-middle incomes, and was significantly lower in the postgraduate and highest-income groups. One possible explanation is that consumers with higher education and economic status may adopt a more critical and selective stance, giving greater consideration to potential risks before accepting novel technologies.

On the other hand, consumers with lower education tend to lack understanding of potential risks. They often have limited knowledge of how food choices affect health, and even the origin of the food itself (Araque-Padilla & Montero-Simo, 2025). Consumers with lower incomes generally tend to prioritize price and its benefit for them. they are not as selective as higher education and higher income consumers, who prefer healthy and quality food. Even though food irradiation actually has been proven safe and can enhance safety and quality. So, as long as irradiated food can fulfill their needs, they may likely accept it.

This may explain why higher education and income are less accepting of irradiated foods and vice versa. However, this does not mean that higher-education and higher-income consumers strongly reject irradiated foods. It is more likely that they just need more detailed information, so they can be sure before fully accepting irradiated foods. So this requires different communication approaches. Scientific explanations and safety information for higher-educated, higher-income consumers are suitable for addressing their concerns. Meanwhile, for lower-educated or lower-income consumers, emphasizing practical benefits such as freshness and longer shelf life should be more effective. This finding contrasts with evidence from other contexts, such as Brazil, where higher education and income were associated with greater acceptance of irradiated foods (Lima Filho et al., 2017). highlighting the influence of socio-cultural factors in shaping consumer attitudes in Indonesia.

Strategic Implications and Future Directions

Based on the findings of this study, several implications are suggested to increase awareness and acceptance of irradiated foods in Indonesia. First, public communication efforts need to focus on providing simple explanations about what food irradiation is, what it does, and why it is safe. Government agencies and food safety regulators should also improve public education by providing clear and consistent information and incorporating irradiation into national food safety campaigns. Since respondents showed difficulty understanding technical benefits, especially food safety benefits (pathogen reduction), information should be delivered using clear visuals, short explanations, and examples rather than scientific jargon. Second, trust emerged as an important factor supporting acceptance. Therefore, communication from regulatory bodies, food safety authorities, and credible institutions should be made more visible, transparent, and consistent. Third, producers and retailers could highlight the practical advantages that consumers already appreciate, such as longer shelf life and reduced food waste. This can be shown through product labeling, point-of-sale information, and public education campaigns. Emphasizing these benefits may help sustain and further increase acceptance, even among consumers with initially low awareness.

For future research, experimental studies are recommended to examine how consumers respond when comparing irradiated and non-irradiated foods. Consumers can show which one they would prefer, particularly in terms of taste, sensory acceptance, or just overall preference. Such studies would provide direct behavioral evidence beyond stated attitudes. Additionally, research on willingness-to-pay (WTP) can be conducted to assess whether consumers are willing to buy irradiated foods at a premium price. In case the producers price it slightly higher due to processing costs. However, the benefit was that they got a longer shelf life and better safety and quality. Understanding how price interacts with perceived benefit, trust, and perceived risk would provide deeper insights into consumers' purchasing behavior.

Conclusion

Indonesian consumers exhibit high acceptance of irradiated food despite generally low awareness. Consumers expressed moderate perceived risk, alongside high perceived benefits and trust. Acceptance varies across socio-demographic groups and was lower among older, higher-educated, and higher-income consumers, while no significant differences were found based on gender. These findings highlight a favorable foundation for the implementation of food irradiation as a food safety and quality enhancement technology in Indonesia. Targeted communication and education strategies are recommended to increase awareness and support broader implementation, contributing to safer and higher-quality food production systems in Indonesia.

References

Araque-Padilla, R. A., & Montero-Simo, M. J. (2025). The importance of socio-demographic factors on food literacy in disadvantaged communities. *Frontiers in Sustainable Food Systems*, *9*. https://doi.org/10.3389/fsufs.2025.1441694

Arvanitoyannis, I. S. (2010). Consumer Behavior toward Irradiated Food. In *Irradiation of Food Commodities: Techniques, Applications, Detection, Legislation, Safety and Consumer Opinion* (pp. 673–698). Elsevier. https://doi.org/10.1016/B978-0-12-374718-1.10017-3

Ashraf, S., Scholor, R., Sood, M., Professor, A., Bandral, J. D., Professor, A., Trilokia, M., Kashmir, J. &, Manzoor, I. M., & Manzoor, M. (2019). Food irradiation: A review. ~ *131 ~ International Journal of Chemical Studies*, *7*(2), 131–136.

Ball, H. L. (2019). Conducting Online Surveys. *Journal of Human Lactation*, *35*(3), 413–417. https://doi.org/10.1177/0890334419848734

Bruhn, C. M. (2008). Editorial: Consumer acceptance of food innovations. In *Innovation: Management, Policy and Practice* (Vol. 10, Issue 1, pp. 91–95).

eContent Management Pty Ltd. https://doi.org/10.5172/impp.453.10.1.91

Buczkowska, M., Dudczak, A., Szajnoga, D., Górski, M., Malinowska-Borowska, J., Kulik, A., & Szczyrba, A. (2023). *The attitude of Polish consumers toward food irradiation as one of the methods of food preservation*. https://doi.org/https://doi.org/10.3389/fpubh.2022.1047127

Chatterjee, A., & Abraham, J. (2018). Microbial Contamination, Prevention, and Early Detection in Food Industry. In *Microbial Contamination and Food Degradation* (pp. 21–47). Elsevier. https://doi.org/10.1016/b978-0-12-811515-2.00002-0

Clemmons, H. E., Clemmons, E. J., & Brown, E. J. (2015). Electron beam processing technology for food processing. In *Electron Beam Pasteurization and Complementary Food Processing Technologies* (pp. 11–25). Elsevier Inc. https://doi.org/10.1533/9781782421085.1.11

Damayanti, F. N., & Wahyati, E. (2019). Food safety in the protection of the right to health. *IOP Conference Series: Earth and Environmental Science*, *292*(1). https://doi.org/10.1088/1755-1315/292/1/012047

Elbehiry, A., Abalkhail, A., Marzouk, E., Elmanssury, A. E., Almuzaini, A. M., Alfheeaid, H., Alshahrani, M. T., Huraysh, N., Ibrahem, M., Alzaben, F., Alanazi, F., Alzaben, M., Anagreyyah, S. A., Bayameen, A. M., Draz, A., & Abu-Okail, A. (2023). An Overview of the Public Health Challenges in Diagnosing and Controlling Human Foodborne Pathogens. In *Vaccines* (Vol. 11, Issue 4). MDPI. https://doi.org/10.3390/vaccines11040725

Etikan, I. (2016). Comparison of Convenience Sampling and Purposive Sampling. *American Journal of Theoretical and Applied Statistics*, *5*(1), 1. https://doi.org/10.11648/j.ajtas.20160501.11

Farkas, J., & Mohácsi-Farkas, C. (2011). History and future of food irradiation. In *Trends in Food Science and Technology* (Vol. 22, Issues 2–3, pp. 121–126). https://doi.org/10.1016/j.tifs.2010.04.002

Fung, F., Wang, H. S., & Menon, S. (2018). Food safety in the 21st century. In *Biomedical Journal* (Vol. 41, Issue 2, pp. 88–95). Elsevier B.V. https://doi.org/10.1016/j.bj.2018.03.003

Galati, A., Moavero, P., & Crescimanno, M. (2019). Consumer awareness and acceptance of irradiated foods: the case of Italian consumers. *British Food Journal*, *121*(6), 1398–1412. https://doi.org/10.1108/BFJ-05-2018-0336

Gautam, R. K., & Venugopal, V. (2021). Electron beam irradiation to control biohazards in seafood. In *Food Control* (Vol. 130). Elsevier Ltd. https://doi.org/10.1016/j.foodcont.2021.108320

Gunes, G., & Deniz Tekin, M. (2006). Consumer awareness and acceptance of irradiated foods: Results of a survey conducted on Turkish consumers. *LWT*, *39*(4), 444–448. https://doi.org/10.1016/j.lwt.2005.03.001

Gustavsson, J., Cederberg, C., Sonesson, U., Otterdijk, R. Van, & Meybeck, A. (2011). *Global Food Losses and Food Waste*. FAO.

Hariyadi, P. (2015). *Keamanan Pangan: Tantangan Ganda bagi Indonesia* (Vol. 91).

Ihsanullah, I., & Rashid, A. (2017). Current activities in food irradiation as a sanitary and phytosanitary treatment in the Asia and the Pacific Region and a comparison with advanced countries. *Food Control*, *72*, 345–359. https://doi.org/10.1016/j.foodcont.2016.03.011

Junqueira-Gonçalves, M. P., Galotto, M. J., Valenzuela, X., Dinten, C. M., Aguirre, P., & Miltz, J. (2011). Perception and view of consumers on food irradiation and the Radura symbol. *Radiation Physics and Chemistry*, *80*(1), 119–122. https://doi.org/10.1016/j.radphyschem.2010.08.001

Karanth, S., Feng, S., Patra, D., & Pradhan, A. K. (2023). Linking microbial contamination to food spoilage and food waste: the role of smart packaging, spoilage risk assessments, and date labeling. In *Frontiers in Microbiology* (Vol. 14). Frontiers Media SA. https://doi.org/10.3389/fmicb.2023.1198124

Li, G., Zeng, Z., & Wang, K. (2025). Influencing Factors of Chinese Consumers' Acceptance of Irradiated Food. *Food Science and Nutrition*, *13*(6). https://doi.org/10.1002/fsn3.70353

Lima Filho, T., Della Lucia, S. M., & Lima, R. M. (2017). Thoughts, attitudes and profile of Brazilian consumers regarding food irradiation. *International Journal of Consumer Studies*, *41*(5), 518–525. https://doi.org/10.1111/ijcs.12360

Maataoui, J., Abduljaber, M., & Khaddor, M. (2025). Global perceptions and acceptance of irradiated food: a comparative systematic review. *Italian Journal of Food Safety*, *14*(2). https://doi.org/10.4081/ijfs.2025.12885

Maherani, B., Hossain, F., Criado, P., Ben-Fadhel, Y., Salmieri, S., & Lacroix, M. (2016). World market development and consumer acceptance of irradiation technology. *Foods*, *5*(4), 1–21. https://doi.org/10.3390/foods5040079

Odeyemi, O. A., Alegbeleye, O. O., Strateva, M., & Stratev, D. (2020). Understanding spoilage microbial community and spoilage mechanisms in foods of animal origin. *Comprehensive Reviews in Food Science and Food Safety*, *19*(2), 311–331. https://doi.org/10.1111/1541-4337.12526

Pi, X., Yang, Y., Sun, Y., Wang, X., Wan, Y., Fu, G., Li, X., & Cheng, J. (2021). Food irradiation: a promising technology to produce hypoallergenic food with high quality. In *Critical Reviews in Food Science and Nutrition* (Vol. 62, Issue 24, pp. 6698–6713). Taylor and Francis Ltd. https://doi.org/10.1080/10408398.2021.1904822

Rahman, M. H., Islam, M. S., Begum, S., Ali, M. L., Sutradhar, B. C., neil, V. O., Hossain, M. A., & Nandwa, C. (2018). Scientific Opinion on the Standards and Regulations of Irradiated Food. *Journal of Nutrition & Food Sciences*, *08*(04). https://doi.org/10.4172/2155-9600.1000718

Ravindran, R., & Jaiswal, A. K. (2019). Wholesomeness and safety aspects of irradiated foods. In *Food Chemistry* (Vol. 285, pp. 363–368). Elsevier Ltd.

https://doi.org/10.1016/j.foodchem.2019.02.002

Siegrist, M. (2008). Factors influencing public acceptance of innovative food technologies and products. *Trends in Food Science and Technology*, *19*(11), 603–608. https://doi.org/10.1016/j.tifs.2008.01.017

Siegrist, M., & Hartmann, C. (2020). Consumer acceptance of novel food technologies. In *Nature Food* (Vol. 1, Issue 6, pp. 343–350). Springer Nature. https://doi.org/10.1038/s43016-020-0094-x

Silindir, M., & Özer, A. Y. (2009). Sterilization Methods and the Comparison of E-Beam Sterilization with Gamma Radiation Sterilization. In *J. Pharm. Sci* (Vol. 34).

Singh, R., & Singh, A. (2019). Food irradiation: An established food processing technology for food safety and security. *Defence Life Science Journal*, *4*(4), 206–213. https://doi.org/10.14429/dlsj.4.14397

The Economist Intelligence Unit. (2016). *Fixing Food – Towards a More Sustainable Food System*. https://impact.economist.com/perspectives/health/fixing-food-2016-towards-more-sustainable-food-system

Wang, K., Pang, X., Zeng, Z., Xiong, H., Du, J., Li, G., & Baidoo, I. K. (2023). Research on irradiated food status and consumer acceptance: A Chinese perspective. In *Food Science and Nutrition* (Vol. 11, Issue 9, pp. 4964–4974). John Wiley and Sons Inc. https://doi.org/10.1002/fsn3.3511

World Health Organization. (2015). *WHO estimates of the global burden of foodborne diseases : foodborne disease burden epiemiology reference group 2007-2015*. World Health Organization. https://iris.who.int/handle/10665/199350