

Green fields, safe meals: Applying the fuzzy delphi method to align experts agreement on sustainable agriculture practices in Malaysia

 Mohd Shahir Omar^{a,b}

 Muhammad Fakhrol Yusof^{a,c}

 Jack Kie Cheng^a

 Syed Radzi Rahamaddulla^a

 Shahryar Sorooshian^{d,e} 

^aFaculty of Industrial Management, Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuhr Persiaran Tun Khalil Yaakob, 26300 Gambang, Pahang Darul Makmur, Malaysia.

^bFederal Agricultural Marketing Authority (FAMA), Bangunan FAMA Point, Lot 17304, Jalan Persiaran 1, Bandar Baru Selayang, 68100 Batu Caves, Selangor Darul Ehsan, Malaysia.

^cNexus for Strategic Innovation in Sustainable and Digital Transformation (XSIST), Faculty of Industrial Management, Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuhr Persiaran Tun Khalil Yaakob, 26300 Gambang, Pahang Darul Makmur, Malaysia.

^dDepartment of Business Administration, University of Gothenburg, Gothenburg, Sweden.

^eFaculty of Engineering and Sustainable Development, University of Gävle, Gävle, Sweden.

 shahryar.sorooshian@gu.se (Corresponding author)

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ABSTRACT

Rising global food demand and environmental concerns have intensified the need for sustainable agricultural practices that ensure both food safety and long-term productivity. Food safety certification serves as a vital mechanism for promoting sustainable farming by enhancing product quality, market competitiveness, and compliance with international standards. This study examines the determinants influencing Malaysian farmers' adoption of food safety certification. A systematic literature review identified 35 potential elements, which were subsequently evaluated through expert consensus using the Fuzzy Delphi Method involving 30 agricultural professionals. The analysis validated 22 critical elements encompassing technological, organizational, environmental, and economic dimensions that significantly shape farmers' adoption decisions. The findings highlight that awareness, perceived market benefits, institutional support, and certification cost are among the most influential drivers and barriers. These results offer strategic insights for policymakers, certification authorities, and agribusiness practitioners in designing targeted interventions to strengthen farmers' participation in certification programs. The study contributes to a deeper understanding of adoption behavior in Malaysia's agricultural sector and provides a foundation for enhancing certification uptake in similar emerging economies, ultimately supporting regional food security and sustainable agri-food trade.

Contribution/Originality: This study contributes to the existing literature by being one of the very few studies investigating food safety certification adoption among Malaysian farmers. The paper's primary contribution is applying the Fuzzy Delphi Method to identify 22 critical adoption elements, offering the first logical framework to guide targeted policy and industry interventions.

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1. INTRODUCTION

The acceptance of food safety certification among food producers has become a critical issue shaped by consumer concerns and the globalization of food production. Numerous standards have been introduced to ensure food quality and safety, yet these create both opportunities and challenges, particularly for small-scale producers in developing countries such as Malaysia. Meeting the increasing number of food safety and quality regulations often requires substantial investment, making it difficult for farmers to access lucrative domestic and international markets (Trienekens & Zuurbier, 2008). Rising certification costs further strain producers' revenues, leading to slow adoption rates despite stronger market-driven and regulatory enforcement (Canales, Silva, & Anderson, 2022).

Globally, population growth continues to intensify pressure on food systems. The United Nations projects that the global population will reach 9.8 billion by 2050, requiring a significant increase in food production (Van Dijk, Morley, Rau, & Saghai, 2021). This growth underscores the urgency of adopting sustainable agricultural practices that can meet demand while protecting natural resources (Food and Agriculture Organization of the United Nations (FAO), 2020). However, under production pressure, many farmers turn to intensive practices, including excessive pesticide and fertilizer use, which can harm their health, degrade soil quality, and lead to market rejection of produce due to excessive residues, especially in export markets (Yadav, Dutta, & Kumar, 2021). Malaysia faces these challenges acutely. Farmers are under pressure to produce competitively for both domestic consumption and export markets, yet adoption of sustainable practices remains low (Serebrennikov, Thorne, Kallas, & McCarthy, 2020). Sustainable agriculture offers long-term benefits for soil health, farmer well-being, and land productivity (Tahat, Alananbeh, Othman, & Leskova, 2020). Food safety certification programs, including Good Agricultural Practice (GAP), were introduced to help farmers produce safe food, support sustainable farming systems, and improve market access (Iranloye & Okonkwo, 2023). Understanding the key factors influencing Malaysian farmers' adoption of these certifications is therefore essential to enhance compliance, protect public health, and strengthen food security (Manshor & Saad, 2023).

2. LITERATURE REVIEW

Figure 1 shows the research direction framework for this study. The research direction framework will help the researcher to give a comprehensive review of the most recent relevant research on the research subject. This facilitates researchers in understanding the current level of knowledge, identifying deficiencies, and building upon existing studies. The objective of this framework is to provide the reader with an overview of this study's direction. The focus of this study is food safety certification adoption among farmers in Malaysia.

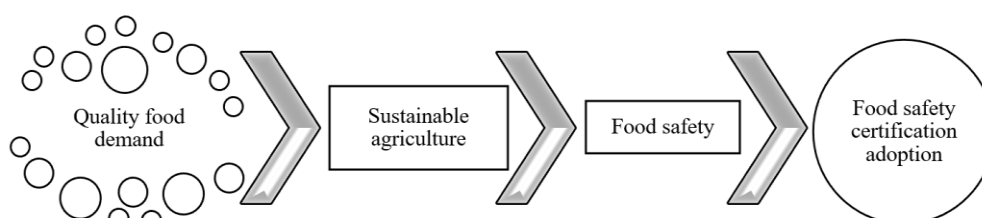


Figure 1. Research direction framework.

2.1. Quality Food Demand

The concepts of quality food demand and sustainable agriculture are closely intertwined, as both represent consumers' desire for food that is nutritious, safe, and produced using environmentally and socially responsible practices (Jararweh, Fatima, Jarrah, & AlZu'bi, 2023; Wijerathna-Yapa & Pathirana, 2022). Meeting this demand requires adherence to sustainable agricultural methods across the supply chain, from production to distribution (Cobelli, Chiarini, & Giaretta, 2021). Several studies have identified limited consumer awareness as a key barrier to high-quality agricultural production, particularly in developing economies. For instance, Akhtar et al. (2020) reported that consumers in Vietnam often choose lower-quality food due to income constraints, a trend also observed in Indonesia (Hussin, Manshor, Abdullah, Fazial, & Muhamad Don, 2024) and other Southeast Asian countries (Nguyen, Doan, Nguyen, & Nguyen, 2021). Low willingness to pay for certified products weakens incentives for farmers to adopt safer and more sustainable production methods (Huang, Wang, Yang, & Shiao, 2020). Higher production costs are another major challenge, as sustainable practices often involve additional labor, improved inputs, and compliance costs (Calabrese, Costa, Ghiron, Tiburzi, & Pedersen, 2021). Studies in China and India have shown that conventional farming can yield higher short-term profits because of unrestricted pesticide and fertilizer use (Guo, Bai, & Gong, 2019; Yaqoob et al., 2023). Regulatory requirements may also discourage smallholders from adopting improved methods if they perceive compliance as financially burdensome (Fernando, Ng, & Walters, 2015; Majone, 2019).

Overall, consumer awareness plays a pivotal role in driving demand for quality food and motivating farmers to adopt certification schemes (Adams, Agbenorhevi, Alemawor, Lutterodt, & Sampson, 2018; Purwanto, Haque, Sunarsi, & Asbari, 2021). Strengthening market incentives, combined with supportive policy interventions, is crucial to align farmers' behavior with sustainable production goals.

2.2. Sustainable Agriculture

The goal of sustainable agriculture is to produce food in a way that maintains natural resources, safeguards the environment, encourages biodiversity, and assures the system's long-term viability (Tilman, Cassman, Matson, Naylor, & Polasky, 2002). Achieving food production, ecosystem services, and increased yields while maintaining environmental integrity and public health is all part of sustainable agriculture (Rigby & Cáceres, 2001). Resource conservation, environmental non-degradation, technical appropriateness, economic viability, and social acceptance are all characteristics of sustainable agriculture (O'connell, 1992). The fields of biology, chemistry, physics, ecology, economics, and society are all integrated into sustainable agriculture to create innovative, environmentally friendly farming methods that are safe (Lichtfouse et al., 2009). A significant number of academics emphasize how important sustainable farming techniques are. Sustainable agriculture promotes practices that gradually raise or maintain agricultural yields to meet the nutrient needs of an expanding global population, as well as guaranteeing food security (Safta, 2022). Sustainable agriculture prioritizes the health of ecosystems, bolstering the resilience of natural systems and promoting vital ecological processes like pollination and nutrient cycling (Setsoafia, Ma, & Renwick, 2022). It improves regional food systems and diversifies revenue streams to maintain livelihoods and boost rural economies (De Bruin, Dengerink, & van Vliet, 2021). Appropriate labour standards, smallholder farmer empowerment, and the availability of resources for disadvantaged communities are all prioritized in sustainable agriculture (Abraham & Pingali, 2020). Triste, Debruyne, Vandenabeele, Marchand, and Lauwers (2018) added that sustainable agriculture fosters community involvement and cooperation, which helps farmers exchange knowledge and develop their skills.

Applying this method might involve initial investments and modifications to traditional farming practices. However, it has the potential to increase crop yields consistently and over a longer period, thereby improving the long-term economic sustainability of agricultural operations (Yang et al., 2022). Farming operations that implement sustainable farming methods are typically more flexible in response to shifts in market dynamics and commodity pricing. To encourage and support the implementation of sustainable agriculture practices, several governments and agricultural organizations offer various incentives and subsidies (Gorjian et al., 2021). These incentives collectively reduce the financial barriers to adopting sustainable farming methods. They encompass financial assistance, technical assistance, and access to various sustainable agriculture activities. Overall, it is clear that numerous previous researchers highlight the significance of sustainable agriculture in guaranteeing the prolonged usage of land and its beneficial, long-lasting effects on the environment and human welfare. However, there continue to be conflicts among farmers who serve as operators in the production of high-quality food. Participation in food safety certification programs will be promoted among farmers to achieve agricultural sustainability and ensure the production of safe food.

2.3. Food Safety Certification Program

After completing a food safety course or program, individuals or food producers are awarded a food safety certificate as evidence of their capacity to handle, prepare, and serve food safely and hygienically (Ab Talib, 2017; Phillip & Anita, 2010). Employers in the food industry or regulatory authorities typically require this certificate to ensure adherence to food safety regulations and laws (Fung, Wang, & Menon, 2018). In addition to assuring customers that the food supply chain is safeguarded, this reduces the danger of foodborne illnesses. Legal requirements for food safety certificates exist in most provinces and regions. They verify the possession of the fundamental knowledge and abilities necessary for safely handling food by an individual (Alzeer, Rieder, & Abou Hadeed, 2018; Liu, Ruiz-Menjivar, Zhang, Zhang, & Swisher, 2019; Mohamad, Shaari, & Ghazali, 2021). Studies have indicated that the food safety certificate elevates consumers' trust in the security of high-end products sold on Internet marketplaces (Mohd Nawi & Mohd Nasir, 2014). In the earlier studies, the primary objective of GLOBALGAP was to provide implementation recommendations for the promotion of good agricultural practices to all nations (Gichuki, Han, & Njagi, 2020; Pandit, Nain, Singh, Kumar, & Chahal, 2017). The policies of various nations will consider whether farmers should participate. Despite numerous studies demonstrating the opposite, farmers claim that the planned measures do not take into account their current situation (Monammad, Yu, Neal, Gibson, & Sujata, 2020; Villarino, Buenaseda Tejada, & Patterson, 2022). The primary sources of reference for these food safety certificates in agriculture are often produced by government agencies, industries, and international organizations through guidelines, rules, and laws (Ion, Popa, Sterie, & Tarhini, 2022). Mentioned by Tey et al. (2015), the FAO is a source for Good Agricultural Practice accreditation. The FAO and the World Health Organization (WHO) jointly launched the Codex Alimentarius Commission, whose guidelines may be followed for HACCP certification (World Health Organization, 2018). Standards established by government organic programs or independent certifying organizations recognized by the appropriate authorities may be followed for organic certification (Vogl, Kilcher, & Schmidt, 2005). These references act as standards for guaranteeing the integrity, safety, and quality of agricultural products through the food supply chain (Kunc, Mortenson, & Vidgen, 2018).

In Thanh Truc and Thuc (2022) research, fruit growers can increase their revenue and profitability while reducing production costs by implementing VietGAP. The most important advantages and motivators are access to new markets and legal compliance, while the biggest obstacle is the high cost of implementing food safety certification systems throughout the entire organization (Grace, 2015; Nowicki, 2016; Talib, Abdul Hamid, & Ai Chin, 2015). Eighty percent

of respondents felt that certification improved the production and distribution of safe food, and forty percent reported a decrease in food recalls because of certification (Food Safety Magazines (FSM), 2021).

Studies in the past have demonstrated the importance of certification in food production, particularly highlighted by numerous scholars. In addition to ensuring the quality of the food produced, it will also contribute to environmental conservation by implementing enforced regulations. Additionally, it will support the government's current efforts towards agricultural sustainability. Considering the conflicting agricultural environment in Malaysia, farmers are aware of the advantages of food certification and the government's efforts to produce high-quality and sustainable agriculture. However, the adoption rate of these practices remains poor.

2.4. Malaysia Agriculture Situation

The food security issue is also not new in Malaysia. To guarantee that Malaysians have a sufficient supply of food, a lot of work is being done by the Ministry of Agriculture and Food Security (MAFS). The Agricultural Agrotechnology Park, the Permanent Food Park (TKPM), and strategic partnerships between ministries, departments, agencies, and private parties are a few of the initiatives taken to guarantee that the food supply is stable, sustainable, and ready for the market (Ministry of Agriculture and Food Security (MAFS), 2023).

Malaysia is also aggressively pursuing sustainable agriculture to support the UN Sustainable Development Goals. However, Malaysian farmers place less emphasis on sustainable agriculture; instead, they believe that the main priorities should be meeting market demand and producing a certain quantity of food (Murad, Mustapha, & Siwar, 2008). This has been demonstrated by reports published in various local newspapers on the level of pesticide residue on Malaysian agricultural produce. It was reported that the pesticide residue rate for vegetable commodities in Cameron Highlands, a famous high-altitude tourism area in Malaysia, is still high, despite government declarations to the contrary that excessive pesticide use damages the environment, harms farmers and consumers, and stops vegetables from being exported to other nations (Bernama, 2019). 800 notifications regarding pesticide residues in agricultural exports from Singapore, Japan, Germany, and Taiwan are sent to Malaysia annually (Suhaini, 2020). These notices pertain to the existence of pesticide residues exceeding the permissible limit. The nation's reputation as a producer of the best agricultural products will be impacted by this media coverage, as well as farmers. The agriculture industry has been told to cease the production, distribution, sale, and use of carbofuran and chlorpyrifos pesticides by individuals and organizations (The Star, 2022). Consumer health will be impacted by the high concentration of pesticide residues (Carrasco Cabrera & Medina Pastor, 2022; Negatu, Dugassa, & Mekonnen, 2021). MAFS administers the food safety certification programme, which was initially implemented in Malaysia in 2002 for agricultural produce (Department of Agriculture Malaysia (DOA), 2022). By introducing this certification, producers are not only guaranteed to produce safe food, but it also helps sustainable agriculture and affects food security. However, based on the E-Ladang Kontrak system and the list of farmers who obtain either Malaysia Good Agriculture Practice (MyGAP) or the Malaysia Organic (MyOrganic) food safety certification, only 1 out of 32 farmers has this certification (Department of Agriculture Malaysia (DOA), 2022; FAMA, 2023), suggesting that this attempt appears to have been unsuccessful.

Table 1. Statistics of registered farmers in the E-Ladang Kontrak system and certified farmers in Malaysia (End of December 2023).

State	Registered farmers	Registered farmers adopt my GAP	Registered farmers adopt my organic
Perlis	14,168	99	-
Kedah	20,460	450	11
Pulau Pinang	13,222	209	3
Perak	10,428	521	8
Selangor	20,174	266	12
Negeri Sembilan	9,724	262	9
Melaka	5,676	67	1
Johor	11,352	664	22
Pahang	14,102	563	26
Terengganu	14,410	948	6
Kelantan	11,616	696	5
Sabah	20,240	244	15
Sarawak	3,872	142	3
Total	169,444	5,131	121

Source: Department of Agriculture Malaysia (DOA) (2022) and (Ministry of Agriculture and Food Security (MAFS), 2023).

The data shown in Table 1 makes it evident that there is a discrepancy in the proportion of certified vs registered farmers. Farmers in Malaysia are still not moving in that direction, despite earlier studies demonstrating several benefits, including increased market access (Barbancho-Maya & López-Toro, 2022), high selling value (Musa, 2019), higher quality production (Tri Ratnasari, Gunawan, Alif Rusmita, & Prasetyo, 2019), and good health and welfare for farm workers (Pandit et al., 2017). Comparable situations may be found with the MyOrganic certification, wherein a

mere 0.06% of farmers participate, even though organic agricultural products are highly sought after by Malaysians and people worldwide (Cavite, Mankeb, & Suwanmaneepong, 2022; Clements & Bihn, 2019; Cobelli et al., 2021).

The primary objective of this research is to identify the key factors influencing Malaysian farmers' adoption of food safety certification. Through analyzing these critical factors, this study aims to offer significant insights to relevant parties, empowering them to make well-informed decisions on where to focus their efforts and create plans that will encourage more Malaysian farmers to accept food safety certification. This level of understanding is essential for spearheading programs targeted at improving food safety procedures and encouraging the widespread implementation of certification programs in Malaysia's agricultural industry.

3. METHODOLOGY

This study employed a structured research design to investigate the adoption of food safety certification among farmers in Malaysia, ensuring methodological rigor and adherence to ethical standards. Ethical approval was obtained from the Ministry of Agriculture and Food Security (Reference No.: UMP.27.04/600-3/2/1). All participants were fully informed about the study objectives and procedures, and written informed consent was obtained before data collection, in accordance with institutional ethical guidelines.

3.1. Elements For Adapting Food Safety Certification Among Food Producers

To identify the factors that influence food safety certification adoption among food manufacturers, a literature search of past studies has been conducted. 348 articles were analyzed, and 35 elements were found as determinants or barriers to food safety certification adoption among food producers. This search used articles published in reputable journals from 2018 to 2023. The yearly criteria were set for six years to ensure the factors found in the past literature are relevant and up to date with the current issues faced by food manufacturers. Findings from the literature search will be used to analyze using the FDM to obtain expert agreement on factors influencing food safety certification adoption among farmers in Malaysia. The list of factors can be found in Table 4.

3.2. Fuzzy Delphi Method

The Fuzzy Delphi Method was introduced by Kaufmann and Gupta (1985). The fuzzy Delphi method (FDM) is an enhanced revision of the Delphi method (DM) that calculates the distance between the indicated levels of the expert panel via triangulation statistics (Chen, Wang, Wang, & Shen, 2018; Ishikawa et al., 1993). The benefits of utilizing the FDM are 1) time and cost savings on the questionnaire; 2) reduction in the overall number of surveys; 3) improved recovery rate through the use of questionnaires; 4) the ability for experts to provide comprehensive and consistent opinions; and 5) consideration of ambiguity that is necessary throughout the study (Chen, Wu, & Chen, 2022; Oteng, Zuo, & Sharifi, 2022; Padilla-Rivera, do Carmo, Arcese, & Merveille, 2021). Figure 2 illustrates the steps taken in this study to get an expert agreement on elements of adapting food Safety certification among farmers in Malaysia.

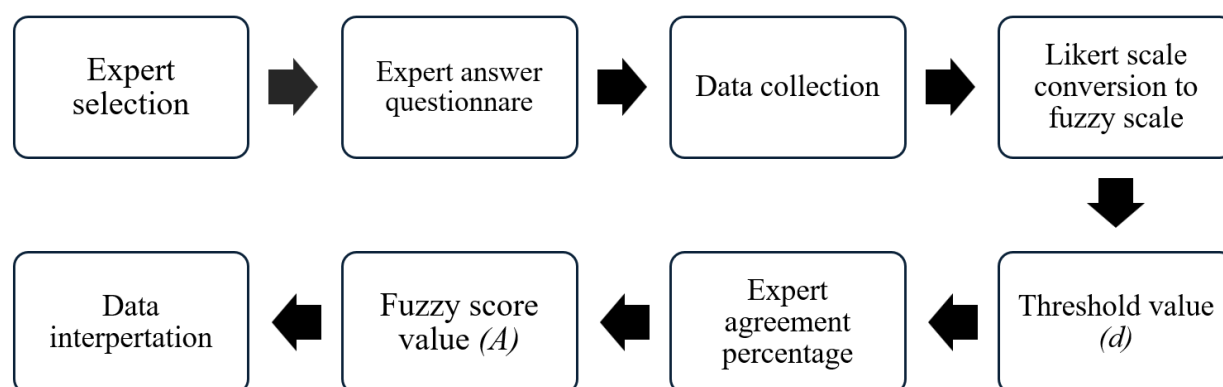


Figure 2. Fuzzy Delphi method process.

Source: Jamelaa Bibi and Siti Ilyana (2018) and Mohd Ridhuan (2016).

3.2.1. Expert Selection

The experts who responded to this questionnaire were selected using a convenience sampling method. A total of 30 experts were chosen for this study, which is considered an adequate sample size to achieve a reliable expert consensus. According to Jamil, Hussin, Noh, Sapar, and Alias (2013), Delphi-based techniques typically require between 10 and 30 experts to ensure a balance between diversity of opinions and manageability of responses. Similarly, Ciptono, Setiyono, Nurhidayati, and Vikaliana (2019) emphasize that a panel size within this range is sufficient to produce credible and representative agreement on the subject matter. Thirty experts with a background in agriculture who remain active in agricultural-related activities were selected. Additionally, the chosen experts possess over five years of experience in agriculture. Berliner (2004) and Mohd Ridhuan (2016). An individual with five years or more of experience in their field is considered an expert. Data collection on human subjects was done according to Universiti Malaysia Pahang Al-Sultan Abdullah (2022), and all respondents gave written consent for the activity.

3.2.2. Expert Answer Questionnaire

The questionnaire integrated all results from previous literature review about the elements that influence producers' decision to obtain food safety certification. The experts were presented with response options on a Likert scale ranging from one to seven, representing their level of agreement. By comparison, the seven-scale exhibits a comparatively reduced fuzziness value of 3.3%, while the five-scale demonstrates a fuzziness value of 20% (Chang, Hsu, & Chang, 2011). This study employs a scale value of 7 to reduce fuzziness. Table 2 details the utilized scale number.

Table 2. Likert scale table.

Scale	Level of agreement
1	Strongly disagree
2	Disagree
3	Somewhat disagree
4	Neither disagree nor agree
5	Somewhat agree
6	Agree
7	Strongly agree

Source: Jamelaa Bibi and Siti Ilyana (2018).

3.2.3. Data Collection

Each of these questionnaires is distributed via Google Forms, and each expert responds to one independently. The researcher's presence during the questioning session ensures that the experts understand the questions and that they have no contact with one another, thereby preventing any potential bias in this study.

3.2.4. Likert Scale Conversion To Fuzzy Scale

After the data collection process, the Likert scale number will be converted to a fuzzy scale number to assess the level of agreement among experts. Table 3, show the Likert scale conversion to fuzzy scale number. Assume that the fuzzy r_{ij} number is the variable for each criterion for expert K for $i = 1, \dots, m, j = 1, \dots, n, k = 1 \dots k$ and $r_{ij} = 1 / K$ ($r1ij \pm r2ij \pm rKij$).

Table 3. Likert scale conversion to fuzzy scale number.

Likert scale number	Fuzzy scale number
1	0.0,0.0,0.1
2	0.0,0.1,0.3
3	0.1,0.3,0.5
4	0.3,0.5,0.7
5	0.5,0.7,0.9
6	0.7,0.9,1.0
7	0.9,1.0,1.0

Source: Jamelaa Bibi and Siti Ilyana (2018) and Mohd Ridhuan (2016).

3.2.5. Threshold Value (d)

The triangular fuzzy number is utilized in data analysis to determine the threshold value (d). Therefore, the initial stipulation is that the threshold value (d) should be less than or equal to 0.2 (Cheng & Lin, 2002). The vertex method was implemented to compute the distance between the average r_{ij} . The threshold value (d) of the two (2) fuzzy numbers $m = (m_1, m_2, m_3)$ and $n = (n_1, n_2, n_3)$ is calculated using the formula:

$$d(\tilde{m}, \tilde{n}) = \sqrt{\frac{1}{3} [(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2]}$$

3.2.6. Expert Agreement Percentage

Once the threshold (d) value has been attained, the value of the expert agreement will be revealed. Mentioned by Chu and Hwang (2008), Mohd Ridhuan (2016), and Murry Jr and Hammons (1995), the obtained percentage of expert consensus must exceed 75%.

3.2.7. Fuzzy Score Value (A)

To determine the ranking of the elements, experts will calculate a fuzzy score value (A). The formula used to derive the fuzzy score (A) is as follows:

$$A = (1/3) * (m_1 + m_2 + m_3)$$

4. RESULT AND DISCUSSION

The 22 accepted elements are arranged based on their ranking. Based on the findings, experts have concluded that the following components affect Malaysian farmers' adoption of food safety certification. Table 4 presents the results of a ranking study about the parameters associated with farmers' adoption of food safety certification. The ultimate acceptance/rejection decision, fuzzy score values (A), expert agreement percentages, fuzzy assessment process circumstances, and threshold values (d) are applied to each factor. Ascending order is applied to the items based on

their fuzzy ratings. Based on the analyses and rankings provided, the first factor that experts unanimously agreed upon is the premium price offer from the market, which has a threshold value score of 0.08 and an expert consensus rating of 97%. This factor serves as a key determinant for farmers in Malaysia to adopt food safety certification. The economic benefit of receiving premium prices provides a strong incentive for farmers to comply with certification requirements, as it directly impacts their income and profitability. Previous research highlights that sustainable agricultural products can attain premium prices depending on the quality (Li & Kallas, 2021; Ma, Liu, Meng, Florkowski, & Mu, 2022).

With a threshold value score of 0.19 and an expert consensus rating of 93%, farmers' awareness regarding food safety is the second factor that experts agree upon. Awareness plays a crucial role in adoption since farmers who understand the benefits of food safety certification are more likely to participate in certification programs. Awareness campaigns and extension services can help bridge knowledge gaps, enabling more farmers to engage in safe agricultural practices (Omar et al., 2014). Third in the list, with an expert consensus rating of 100% and a threshold value score of 0.15, is a good demand for agricultural produce with a food safety logo. Demand for sustainability has been increasing (Aripin, Mezhuyev, Nawair, Yusuf, & Haron, 2023). Higher consumer demand for certified products creates a pull factor, motivating farmers to comply with certification standards to access better markets and improve their competitive advantage. Studies have shown that consumers are increasingly prioritizing food safety, which influences production decisions (Bal, Yayar, & Arslan, 2024). Farmers' future direction factor comes in fourth with an expert consensus rating of 90% and a threshold value of 0.19. This suggests that farmers who have long-term goals and strategies for their businesses are more likely to invest in food safety certification. Future thinking and vision-setting by the farmers, even with assistance, are essential for ensuring sustainable agricultural practices (Chitakira, Torquebiau, & Ferguson, 2012; Kuan, Wang, & Wang, 2021). Farming experience ranks fifth with a threshold value score of 0.20 and an expert consensus rating of 90%. Experienced farmers are more likely to adopt food safety certification as they have a better understanding of agricultural risks and benefits. Moreover, experienced farmers tend to have established supply chain networks, making certification a logical step for business expansion (Kuan et al., 2021).

The consumer recognizing MyGAP and MyOrganic logos received a threshold value score of 0.19 in the sixth ranking, with a 93% expert consensus percentage. When consumers recognize and trust certification logos, it reinforces the value of certification and motivates farmers to adopt it. Brand awareness and consumer trust play a crucial role in determining market success for food safety-certified products (Bal et al., 2024; Wongprawmas & Canavari, 2017).

With an expert consensus percentage of 90%, consumer awareness regarding food safety reached a threshold value of 0.20 at the seventh position. Consumer education on food safety standards encourages demand for certified products, which in turn influences farmers to comply with regulations. Public campaigns and educational initiatives can enhance consumer trust in certified products (Li & Kallas, 2021). The technology affordability factor ranked eighth, with a threshold value of 0.17 and an expert consensus percentage of 97%. Affordable technology solutions reduce barriers to adoption, making it easier for farmers to meet certification requirements. Research indicates that financial assistance programs can enhance access to technology for smallholder farmers (Zainon, Yusuf, & Ramle, 2024).

With an expert consensus percentage of 100% and a threshold value score of 0.12, the government's involvement and support aspect came in ninth place. Government policies, subsidies, and training programs are critical enablers for food safety certification (Hoffmann & Jones, 2021). Supportive regulatory frameworks can enhance adoption rates among farmers (Guo et al., 2019). With a threshold value score of 0.19 and an expert consensus percentage of 93%, farm size was determined to be the tenth factor. Larger farms often have more resources and capacity to comply with certification requirements, whereas smaller farms may struggle due to financial and administrative burdens. Policies tailored to support small-scale farmers could improve overall adoption rates (Guo et al., 2019; Kuan et al., 2021).

For the 11 factors, with a threshold value score of 0.17 and an expert consensus percentage of 97%, experts have identified the high cost of renewal as a significant factor influencing the adoption of food safety certification among farmers in Malaysia. The financial burden associated with renewing certification can deter farmers from maintaining compliance. Streamlined renewal processes and financial incentives may help mitigate this challenge (Hoffmann & Jones, 2021). Moving on to the 12th rank, policies and regulations enforced by the government scored a threshold value of 0.16, with an expert consensus percentage of 100%. Clear and well-implemented policies provide a structured framework for food safety certification, ensuring compliance and industry-wide standards (Guo et al., 2019).

At the 13 ranks, the factor of increased market access and channels scored a threshold value of 0.13, with an expert consensus percentage of 97%. Market access plays a pivotal role in motivating farmers to obtain certification. Certified products often reach premium markets, leading to better economic returns for farmers (Li & Kallas, 2021; Ma et al., 2022).

Technology innovation introduced was also recognized by experts as a driving factor in the adoption of food safety certification, with a threshold value of 0.14 and an expert consensus percentage of 97% at the 14 ranks. Emerging technologies such as blockchain, IoT, and digital monitoring systems can simplify compliance and improve transparency in food safety certification (Aripin et al., 2023; Maarof, Nawair, & Fakhrul, 2022).

Finally, the financial constraints factor ranked 15, with a threshold value score of 0.16 and an expert consensus percentage of 93%. Limited financial resources pose significant challenges for farmers, highlighting the need for targeted subsidies and financial aid programs (Hoffmann & Jones, 2021).

Table 4. Result of analysis using the fuzzy Delphi method.

Factor number	Factor	Conditions triangular fuzzy number conditions		Conditions of fuzzy evaluation process				Expert agreement	Factor accepted	Ranking
		Threshold value, (d)	Percentage of expert agreement (%)	m1	m2	m3	Fuzzy score (A)			
20	Premium price offers from the market	0.08	97	0.79	0.94	1.00	0.91	Accept	0.91	1
8	Farmer awareness regarding food safety	0.19	93	0.69	0.85	0.95	0.83	Accept	0.83	2
25	Good demand for agricultural produce with a food safety logo.	0.15	100	0.67	0.85	0.96	0.83	Accept	0.83	3
11	Farmers future direction	0.19	90	0.68	0.85	0.95	0.82	Accept	0.82	4
16	Farming experience	0.20	90	0.67	0.83	0.94	0.81	Accept	0.81	5
24	Consumers recognizing MYGAP and MYORGANIC logos	0.19	93	0.65	0.82	0.94	0.81	Accept	0.81	6
18	Consumer awareness regarding food safety	0.20	90	0.65	0.82	0.94	0.80	Accept	0.80	7
4	Technology affordability	0.17	97	0.65	0.82	0.94	0.80	Accept	0.80	8
34	Government involvement and support	0.12	100	0.63	0.82	0.96	0.80	Accept	0.80	9
14	Farm size	0.19	93	0.65	0.82	0.94	0.80	Accept	0.80	10
29	The high cost of renewal	0.17	97	0.64	0.82	0.94	0.80	Accept	0.80	11
30	Policies and regulations enforced by the government	0.16	100	0.63	0.80	0.94	0.79	Accept	0.79	12
23	More market access or channel	0.13	97	0.61	0.81	0.95	0.79	Accept	0.79	13
1	Technology innovation introduced	0.14	97	0.60	0.80	0.94	0.78	Accept	0.78	14
12	Financial constraints	0.16	93	0.60	0.79	0.94	0.78	Accept	0.78	15
33	A lot of documentation preparation	0.17	90	0.59	0.78	0.92	0.77	Accept	0.77	16
2	Technology transfer occurs in the market.	0.14	93	0.58	0.78	0.93	0.76	Accept	0.76	17
22	Cooperative or association membership	0.14	97	0.59	0.77	0.93	0.76	Accept	0.76	18
27	Incentives offered by the government	0.18	93	0.59	0.77	0.92	0.76	Accept	0.76	19
6	The contract offers	0.13	97	0.57	0.77	0.93	0.76	Accept	0.76	20
35	Training	0.13	93	0.56	0.76	0.92	0.75	Accept	0.75	21
10	Time constraints	0.15	77	0.57	0.75	0.91	0.74	Accept	0.74	22
3	Technology acceptability	0.24	53	0.59	0.77	0.90	0.75	Reject	#N/A	#N/A
5	The output volume	0.28	53	0.39	0.59	0.77	0.58	Reject	#N/A	#N/A
7	The extension of the contract	0.26	67	0.24	0.42	0.62	0.43	Reject	#N/A	#N/A
9	Having logistics or good supply chain management	0.33	53	0.38	0.56	0.73	0.55	Reject	#N/A	#N/A
13	The status of the farm (Tenure period)	0.24	43	0.57	0.75	0.88	0.73	Reject	#N/A	#N/A
15	The age of farmers	0.25	63	0.42	0.62	0.80	0.61	Reject	#N/A	#N/A
17	Farmer education background	0.23	47	0.56	0.74	0.88	0.72	Reject	#N/A	#N/A
19	Competitive pressure	0.23	53	0.59	0.77	0.90	0.75	Reject	#N/A	#N/A
21	Higher return on investment	0.23	73	0.41	0.61	0.79	0.61	Reject	#N/A	#N/A
26	Limited demand from the market surrounding the farm.	0.28	43	0.58	0.75	0.87	0.74	Reject	#N/A	#N/A
28	The high cost of applying	0.23	73	0.42	0.61	0.80	0.61	Reject	#N/A	#N/A
31	Legal liability makes farmers not interested	0.23	47	0.56	0.74	0.88	0.72	Reject	#N/A	#N/A
32	Farm location close to industry area	0.19	67	0.56	0.74	0.89	0.73	Reject	#N/A	#N/A

5. DISCUSSION

The findings of this study reveal that economic incentives play the most significant role in encouraging Malaysian farmers to adopt food safety certification, with the premium price factor ranked highest by experts (97% consensus). This is consistent with Meemken et al. (2021), who found that premium price opportunities strongly motivate farmers to participate in sustainability programs. The result underscores the importance of market-driven incentives in shaping farmers' decisions, suggesting that policymakers and buyers should strengthen price premium mechanisms to make certification more attractive.

Farmers' awareness of food safety emerged as the second most influential factor, aligning with Akhtar et al. (2020), who reported that knowledge and understanding of certification benefits are critical in driving adoption. This finding emphasizes the need for continuous extension programs, training sessions, and knowledge-sharing platforms to close awareness gaps. Similarly, the third-ranked factor, demand for agricultural produce with a food safety logo, confirms the observations of Lian and Rajadurai (2020) and Quoquab, Mohamed Sadom, and Mohammad (2020) that consumer demand exerts a pull effect, creating strong market signals that encourage compliance. Therefore, government and industry campaigns to promote consumer trust in certification logos, such as MyGAP and MyOrganic, could indirectly enhance adoption rates.

Structural and capacity-related factors such as farm size, farming experience, and farmers' future orientation were also identified as important determinants. These findings are consistent with Kuan et al. (2021) who found that larger, experienced farmers with strategic business goals are more likely to adopt innovation and comply with certification requirements. These results imply that tailored policy support, especially for smallholders such as subsidies, shared services, and simplified documentation, may help close the adoption gap.

Government involvement and policy enforcement were highlighted as key enablers, echoing the findings of Jie, Khan, Alharthi, Zafar, and Saeed (2023) and Zakaria, Mohd, Mohamed, Ahmad, and Binti Hasan (2017) who emphasized that supportive regulatory frameworks and financial incentives significantly enhance adoption. The present study also highlights barriers such as high renewal costs and financial constraints, which have been reported in prior research as major obstacles to sustained compliance. Policymakers could address these issues through cost-sharing programs, renewal fee waivers, or grants targeted at resource-constrained farmers.

Finally, technological factors both affordability and innovation, were recognized as essential drivers. This is consistent with Giampietri and Trestini (2020) and Malik, Chadhar, Vatanasakdakul, and Chetty (2021), who reported that affordable digital solutions and innovations such as blockchain and IoT can reduce compliance burdens and improve transparency. Public-private partnerships that improve technology access and reduce costs could further accelerate certification uptake.

Collectively, these findings extend existing literature by not only confirming known drivers such as economic incentives and consumer demand but also by prioritizing them using a systematic expert consensus approach. The results carry strong implications for policymakers, suggesting that a holistic strategy, combining market incentives, awareness-building, policy support, and technology access, will be most effective in increasing the adoption of food safety certification among Malaysian farmers.

6. CONCLUSION

In summary, this study identified five key factors that strongly influence Malaysian farmers' adoption of food safety certification: premium price offers from the market, farmers' awareness, consumer demand for produce with food safety logos, farmers' future orientation, and farming experience. These factors collectively demonstrate that both market-driven incentives and regulatory support play a decisive role in motivating farmers to pursue certification. The findings suggest that stakeholders should adopt a holistic approach that combines economic incentives, awareness campaigns, and supportive policies to enhance the adoption of MyGAP and MyOrganic certifications nationwide.

Despite its contributions, this study has some limitations. The findings are based primarily on expert opinion through the Fuzzy Delphi Method rather than direct farmer surveys, which may limit the generalizability of the results to the broader farming population. Future research could address this limitation by triangulating expert consensus with large-scale farmer surveys or case studies, enabling a more comprehensive understanding of the barriers and motivators at the ground level. Additionally, future work could develop simulation models to examine interactions between the identified factors and predict the potential impact of policy interventions on certification adoption.

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