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ARTICLE

An Analysis of the Effectiveness of Food Quality and Safety Management Systems in Oman's Food Supply Chain

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ABSTRACT

The study examined the impact of information technology, food traceability, and safety regulations on supply chain performance. It also highlights the critical role of risk management. The study focused on the complex relationships among information technology, food traceability, supply chain risks, performance measures, and food safety regulations, exploring how these elements jointly shape the efficiency of the food supply chain. The study adopted a positivist research paradigm in the data collection, analysis, and discussion. Data analysis was undertaken by Smart PLS software to conduct structural equation modeling (SEM). Adopting information technology is critical for improving Oman's food supply chain. The research findings indicate that traceability and risk management, while significant factors, do not independently demonstrate a statistically significant enhancement of performance. Additionally, the study suggests that performance measures are detrimental to improving supply chain performance and traceability in the food industry. The study also reveals that while food traceability enhances the adoption of information technology, its effect on the overall supply chain performance is not statistically significant. Managing risks within Oman's food industry is closely related to adopting and using information technology, which is critical in establishing effective and robust risk management strategies. The study recommends that the Oman food industry should invest in advanced information technology and strengthen regulatory compliance to guaran-

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tee food safety—continuous improvement in food measures, comprehensive performance metrics, and proactive risk management strategies.

Keywords: Food Quality; Safety Management Systems; Regulatory Compliance; Traceability

1. Introduction and Background to the Study

Food safety is a significant concern as billions of people worldwide are prone to consuming unsafe food [1]. Safe food is critical for preserving human lives, promoting personal and public health, and boosting economic growth in regions that prioritise food safety [2]. To achieve food safety, there is a need for supply chain scientific research and equitable law enforcement [3]. As living standards continue to rise, the importance of food safety and the risk of potential contaminants remain serious health concerns [4]. Food quality and safety management systems are designed to ensure that food products are safe, nutritious, and high-quality from production to consumption. This study integrates and examines how traceability enhances the effectiveness of regulatory compliance and how technology mediates the performance of safety systems.

In the European Union (EU), food quality and safety management systems focus on creating a harmonised approach to implement the EU's requirements for Good Hygiene and Practice (GHP) and HACCP procedures [5]. This approach aims to establish a common understanding of food safety aligned with international standards, conduct audits and follow-up measures, and provide audit plan templates and checklists to support HACCP audits. In addition, Regulation (EC) No. 852/2004 of the European Parliament and Council makes it mandatory for food operators to implement procedures based on the HACCP principles. It covers holistic preventive and emergency arrangements, self-checks, adequate cleaning, disinfection, and personal hygiene to ensure safe and appropriate food within the European Union. Similar studies have critically looked at food safety across the globe focusing on quality assurance in the food industry, Good Manufacturing Practices (GMP), HACCP, and International Organization for Standardization (ISO) standards [2, 3].

Realising the effects of food safety risks, Gulf Corporation Council countries developed a unified food standard. These rules and regulations align with the Food and Agriculture Organisation (FAO)'s Codex Alimentarius, benchmarked for international practice [1]. The standards cover biotechnologies, novel foods, food-colouring agents, and other additives. The Gulf standards (G/S)9/1995 and 150/1993 safeguard shelf-life standards for food items. The Oman Ministerial Decree No. 74/2000 covers labelling of food and safety, labelling information on food and food products, and ensures that food products shall not contain alcohol, pork, lard, or their derivatives. The Sultanate of Oman has greatly emphasised benchmarking food safety to international standards such as ISO 22000: 2018, which specifies interactive communication, system management, prerequisite programs, and HACCP principles to guarantee food safety in supply chains [6]. In addition, Oman has established the Food Safety and Quality Centre [7] to ensure food safety across different sectors. It has been maintained that enacting regulations and implementing ISO 22000: 2018 enable food producers to identify expected food safety hazards in the supply chain. It is pertinent to note that, due to the challenge of food safety and quality issues, stakeholders need to enhance consumer awareness and generate a sense of responsibility for producers at all stages of production to ensure conformance with international standards.

Food safety is an urgent global concern, with millions affected annually, leading to preventable illnesses and deaths, underscoring the critical need for more robust safety management systems. To address these risks, the authorities in Oman must continue to embrace and enforce stricter responsibilities and rules for producers as early as possible in the food production processes. It is vital to strengthen food supply chains to meet international safety standards for protecting public health keeping consumer trust and safeguarding the reputation of the food industry in Oman. Regulatory enforcement, im-

proved transparency and ensuring that all stakeholders within the food supply chain adhere to stringent food safety requirements are of paramount importance. The concept that is guiding the study is presented in **Figure 1**.

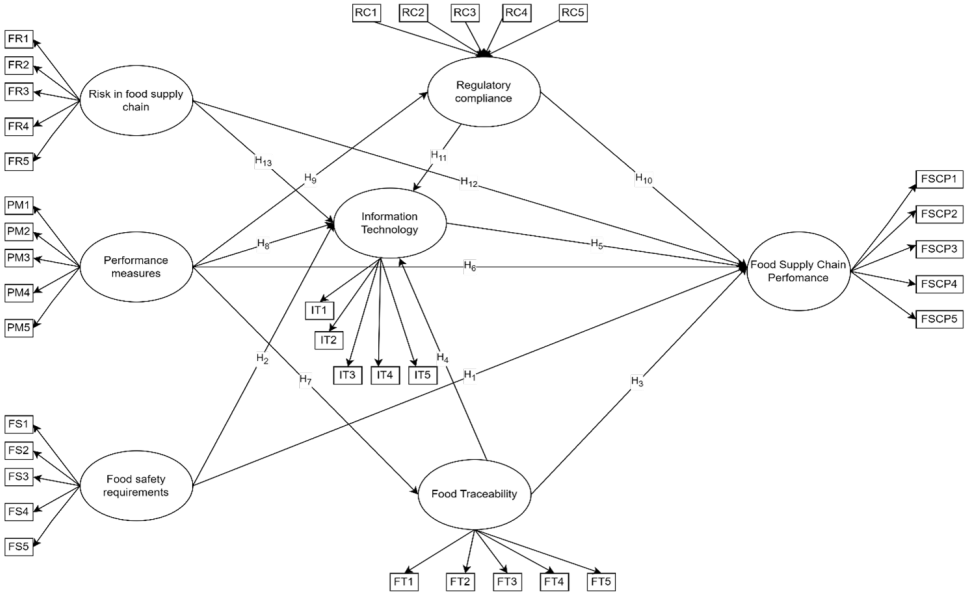

Figure 1. Conceptual model.

Note: Conceptual model on the factors that improve food supply chain performance.

2. Measurement Scales and Their Sources

Table 1 presents the scales and their sources, which the study used to develop the model constructs and measurements and their sources.

3. Research Objectives

Following objectives were set for the study:

1. To assess the impact of food safety requirements on food supply chain performance and the adoption and utilization of information technology.
2. To evaluate the effects of food traceability on food supply chain performance of the Omani food industry and its relationship with information technology.
3. To examine the role of information technology in enhancing Omani food industry supply chain performance.
4. To determine the influence of performance measures on food supply chain performance, food traceability, and regulatory compliance in the Omani food industry.
5. To evaluate the impact of regulatory compliance on food supply chain performance and its influence on the use of information technology in the Omani food industry.
6. To examine the impact of risks within the food supply chain on its performance and the utilization of information technology for risk management in the Omani food industry.

Table 1. Measurement scales and their sources.

Item Code	Description	Sources of Questions
	Risk in Food Supply Chains	
FR1	Natural events like tsunamis	[8, 9]
FR2	Financial crisis such as exchange risks	
FR3	Labour disputes	
FR4	Inadequate and improper storage	
FR5	Wrong temperature levels	

Table 1. *Cont.*

Item Code	Description	Sources of Questions
	Food Safety Requirements	
FS1	Security of the food source	[8, 10, 11]
FS2	Independent and public health judgement	
FS3	Concrete action in the enforcement regulations	
FS4	Process control	
FS5	Training and education	
	Food Traceability	
FT1	Traceability technology adoption	[12–14]
FT2	Traceability accuracy systems	
FT3	Recall management efficiency	
FT4	Quality control	
FT5	Blockchain	
	Information Technology	
IT1	Inventory management systems	[8, 15, 16]
IT2	Supply chain visibility	
IT3	Demand forecasting and planning tools	
IT4	Transportation technology	
IT5	Logistics technology	
	Performance Measures	
PM1	Risk analysis and risk investment	[17–19]
PM2	Risk investment	
PM3	Flow of information between supply chain partners	
PM4	Customer satisfaction	
PM5	Revenue indicators	
	Regulatory Compliance	
RC1	Audit findings	[20, 21]
RC2	Regulatory compliance score	
RC3	Adherence to Food Safety Standards	
RC4	Legal compliance costs	
RC5	Compliance measures	

4. Hypothesis Development

Following hypotheses were formulated in the study:

H_1. *Food safety requirements significantly impact food supply chain performance in the Omani food industry.*

H_2. *Food safety requirements influence the implementation or utilization of information technology in the Omani food industry.*

H_3. *Food traceability significantly affects food supply chain performance in the Omani food industry.*

H_4. *Food traceability significantly impacts the use of information technology in the Omani food industry.*

H_5. *Information technology significantly improves food supply chain performance in the Omani food industry.*

H_6. *Performance measures significantly impact food supply chain performance in the Omani food industry.*

H_7. *Performance measures significantly influence food traceability in the Omani food industry.*

H_8. *Performance measures significantly impact the use of information technology in the Omani food industry.*

H_9. *Performance measures significantly affect regulatory compliance in the Omani food industry.*

H_{10}. *Regulatory compliance significantly impacts food supply chain performance in the Omani food industry.*

H_{11}. *Regulatory compliance significantly influences the use of information technology in the Omani food industry.*

H_{12}. *Risks in the food supply chain significantly impact its performance in the Omani food industry.*

H_{13}. *Risks in the food supply chain significantly affect the use of information technology in the Omani food industry.*

H_{14}. *Food safety requirements, performance measures, regulatory compliance, and risks in the food supply chain indirectly affect food supply chain performance through the combined mediation of information technology and food traceability.*

5. Literature Review

5.1. Risks in Food Supply Chain and Food Supply Chain Performance

Food supply chain management is a systematic connection of different actors, people, activities, technologies, information, and resources in the production and distribution of food. It combines different specializations and logistical steps and includes phrases such as 'farm to fork' or 'paddock to plate' processes [8]. According to Gurtu and Johny [22], risk management in supply chains incorporates strategic development and implementation of plans to manage supply chain networks, continuous risk assessment, reducing supply chain vulnerability, and ensuring supply chain resilience. The hype of international trade, regional integration, and technology adoption has increased the costs for food supply chains and distribution centres [23]. These risks negatively impact a country's food supply chain performance. The food supply chain operation has complex risks due to many actors [24].

Global disruptions including the COVID-19 container crisis, the Gulf War, and the 11 September crisis, have exposed the vulnerabilities of supply chains during uncertainties [9]. To reduce the food supply chain risk, companies need to implement supply chain integration and solutions that fully integrate supply chains (SCs). This is because Supply Chain Integration (SCI) improves data interchange processes with customers and suppliers. It is important to note that SCI has an incremental benefit to hedging against the opportunistic behaviour of SC members, geopolitical risks, sovereign risks, and exchange rate risks prevalent in food distribution.

Companies need to limit investments in the number of facilities but should carry out a cost-benefit analysis between the investment and the cost associated with the disruption [25]. These risks affect a country's performance capabilities and food security. Therefore, investment in risk-mitigation tools and contingent planning is paramount to food supply chain management and performance. Players in the food supply chain must understand that the longer a supply chain, the greater the risk of failure [26].

5.2. Food Safety Requirements and Food Supply Chain Performance

Implementing food safety and quality requirements is not merely a compliance issue, it also has significant implications for public health and safety. Conformance to food safety requirements positively impacts consumer confidence and global competitiveness [27]. The ever-growing consumer demands, changes in consumer behaviour, and expansion of international trade have created an unprecedented need for food supply chains to have rigorous checks to identify sources of diseases and infections. Governments are key to ensuring that food security follows the expected standards. In that view, the EU has been instrumental in ensuring food production actors comply with safety standards. In Croatia and European legislation, the first security step is food safety at source, followed by sanitary correctness (food safety) [10]. The EU calls for establishing effective communication across the supply chain to avoid information bottlenecks among actors. The EU emphasises that legislation enforcement and control are the key elements in food safety in the supply chain. Countries need a regulatory framework that ensures quality and sets mandatory standards through inspection.

The most commonly used quality monitoring systems are the Global Food Safety Initiative, International Food Standards, International Organization for Standardization, and Safe Quality Food [24]. Some of the global scandals, such as the China melamine milk contamination in 2008 and 2009, USA and Canada peanut butter contamination with Salmonella, German bean sprouts contaminated with *E. coli*, Ireland pork contamination with dioxin in 2008, and the existence of a high series of product recalls have eroded public confidence [2, 8].

Based on the literature discussion, it is important to note that food standards cannot be narrowed down to a specific country, but they must be transparent, consis-

tent, and communicated with global supply chain partners to mitigate possible risks. Resultantly, compliance with food safety standards mitigates possible legal issues and positively influences a country's brand image, market growth, profitability, and operational efficiency. Food retailers are crucial in promoting food safety in supply chains as they exist as conduits between producers and consumers.

5.3. Performance Measures and Food Supply Chain Performance

Supply chain performance measures enable supply chain actors to oversee relevant performance indicators of products and facilitate setting business objectives with periodic reviews [28]. There is a growing concern that companies in the food industry face some challenges in establishing performance measurement systems due to the non-alignment of network goals [8]. Notably, collaboration in the network is a crucial strategy in ensuring efficient performance measures.

Sustainability initiatives and deteriorating manufacturing ethics have resulted in consumers seeking clarity in food integrity, safety, and diversity [29]. Furthermore, pesticides and other dangerous chemicals have resulted in authorities demanding accountability of supply chain performance measurements [17]. Consumer opinions have been quite explicit regarding a broad range of quality standards, shelf life of products, and reliability. Timely and accurate information are crucial elements of supply chain management, and its success relies on adopting the right metrics that accurately measure and motivate desired supply chain processes.

A notable aspect that complicates performance measurement in the food supply chain is the variation of information prioritisation with each actor. The coexistence and cooperation of supply chain actors have a win-win result in the performance measurements of supply chain actors. An uninterrupted flow of information, a transparent communication structure, and recognition of each actor lead to supply chain success [21, 22]. Various scholars have pointed out that food supply chains lack adequate performance measures for benchmarking and strategic decision-making. Additionally, due to the lack of these performance measures and standardised performance measurement indicators, actors are constantly putting their resources into fulfilling their goals.

5.4. The Impact of Information Technology on Food Supply Chain Performance

The incorporation of information technology (IT) has a significant impact on both external and internal operational characteristics of a supply chain [11]. Integration of information technology improves firms' ability and performance. Given the high risk in the food industry supply chain, companies have been adopting technology at an unprecedented rate to remain competitive.

Research has also concluded that food supply chain viability relies on correctly gathering and using information and technology tools to improve supply chain performance [15]. Ideally, information technology should be able to process, interpret, store, and filter information across the different actors of the supply chain. This would enable the dissemination of accurate, high-quality information to help mitigate risks and reduce uncertainties.

Empirical research on the capacity of organisations to gather data using different information technology tools reflects that information technology facilitates companies' ability to be agile and make proactive decisions [30]. In addition, data collection by companies facilitates every stage of the supply chain to access the latest trends and benchmark operations with international standards. This data is essential as it allows individuals to measure performance and facilitates collaboration and coordination of supply chain actors. The availability of data among the supply chain members is vital in ensuring that there are uninterrupted linkages that minimise operational costs. Information technology is pivotal in improving and maintaining food standards and allows food companies to integrate with suppliers and customers. The integration is noted by who further asserts that adopting information technology removes information bottlenecks and increases response to supply chain emergencies [16].

5.5. Food Traceability Impact and Food Supply Chain Performance

Food traceability refers to the ability to trace the movement of food through specified stages of production, processing, and distribution [11]. To ensure effective food traceability, organisations should focus on three components, namely input traceability process and output traceability, as products move along the supply chain. These components are foundational for reducing contamination as food items move from one supply chain participant to another [31].

A study on the halal food industry reported issues regarding traceability. Concerns have been raised regarding exact halal requirements as slaughtering methods differ, which complicates the implementation of a comprehensive traceability system. Interestingly, a study has raised concerns regarding the mislabelling of chicken as 'halal' by Kentucky Fried Chicken, also known as KFC [32].

Establishing a traceability system is not easy, especially in the food industry. Traces of pork DNA reported in some food products have led Muslim consumers to call for strict traceability of the supply chain [13]. The establishment of an integrated traceability system allows for tracking food products in real-time. According to one study, a supply chain control tower should be implemented to increase visibility, allowing for continuous monitoring and reporting of all actors' activities Despite the ongoing debate among academics and industry experts about implementing monitoring systems, most scholars concur that the majority of consumers place limited emphasis on food traceability [14].

It is important to note that, the traceability system improves the quality of food by allowing the detection of product failures. In the livestock industry, identification and meat traceability systems have been adopted to reduce mislabelling and provide accurate information to consumers. It is also worth noting that these systems are crucial for responding to changes in consumer expectations, improving company loyalty, reducing risks, ensuring safe consumption, and lowering medical costs.

5.6. Regulatory Compliance Impact and Food Supply Chain Performance

Over the past decade, governments across the globe have struggled to develop comprehensive food safety regulations to ensure compliance and guarantee consumer health. As the food supply chains have become interconnected and complex, visualising and managing safety risks has become challenging. Safety concerns and lack of proper regulations are key issues raised by producers, manufacturers, and retailers in the food industry. The World Trade Organization (WTO) oversees food safety concerns in global trade [20]. Between 2010 and 2020, the food industry encountered significant challenges due to a lack of robust regulations and proactive policies at governmental levels. Therefore, there is a need to foster effective innovations in the production process and reduce time and distance between production and consumption to minimise health risks [33] .

Food-borne diseases represent a major global health challenge. According to the WHO, unsafe food causes 600 million illnesses per year, with 420 million deaths (30% occur among children below five years of age) [21]. Despite the successful implementation of HACCP in Argentina's fish processing plant and yogurt plant in Brazil, its universal application is still questionable and not applicable in some sectors.

The most recommended and WTO-approved global food management systems include HACCP, GMP, GHP, and Sanitation Standard Operating Procedures (SSOP). HACCP is considered the most appropriate system in different industries, and it has gained much traction across the globe. As a result, governments have tried to set regulations, procedures, and guidelines that enhance the successful implementation of the HACCP principles. The HACCP food management system consists of activities to ensure food safety where health hazards are likely to occur. The food industry recommends HACCP for use in food production because it allows for checks and balances in all stages of food production (from raw materials to final production).

6. Research Methodology

This study applied a pragmatic research paradigm that involved the use of both quantitative and qualitative research approaches in the collection and presentation of results [34]. Instrument development went through a pilot study, where industry and research experts were consulted to remove ambiguous statements and verify the flow of questions. A structured questionnaire with a Likert scale ranging from 1 (disagree) to 5 (strongly agree) was used to collect responses. The presentation of the research results, analysis, and discussion provides an overview of understanding food quality and safety management systems in the Sultanate of Oman. The study sample size was determined using Krecjcie and Morgan's (1970) sample determination table. Meanwhile, the qualitative approach established the sampling techniques and methods. Data were collected mainly in Muscat and Sohar, Oman's major food supply chain centres. The study used structural equation modelling using SMART PLS 4 in the data analysis process.

The following section presents the demographic characteristics.

7. Demographic Characteristics

The gender distribution indicated that 55% were females, while the remaining were males. These results are not surprising but relevant since they show the dominance of females in food logistics and the supply chain in Oman. The higher proportion of female respondents in the food supply chains in Oman reflects gender dynamics, supporting the significance of gender equality in SGD goal number 5. The age characteristics of participants indicated that they were drawn from varying career stages within the industry. Most of the participants were aged 36–45 years (40%), followed by 26–35 years (30%), 46–55 years (20%), and 55 years and above (10%). This distribution reflects a diverse mix of age groups capable of providing different insights into food safety supply chains in Oman. Varied age groups bring along diverse knowledge and experiences; for example, the young are technology-savvy while the older generation has experience and historical insights of the food industry. The geographical location of the participants indicated that 60% were mainly from Muscat (Oman's food industry hub), 25% from Sohar (the second logistics hub), and 15% from other areas. The high concentration of respondents from Muscat, followed by Sohar, suggests that food distribution companies are operating from these cities mainly because they are the centres of development. These results can help policymakers to devolve and decentralise economic development in the country so that it can spread across the whole country. Food safety management is usually adopted and implemented by top management. The study participants (70%) held top-level management positions, while 30% held middle-level positions. Top- and mid-level managers play a critical role in enforcing food safety strategies, as they are formulated and enforced at the highest organisational level. The study is inclusive as it included participants from the manufacturing industry (45%), retail (25%), 3PL (20%), and other sectors (10%). This gives a reflection of the complexity of the food industry and food supply chains. The study participants included a balanced representation of food safety decision makers, including 40% quality control specialists and 60% supply chain managers drawn from 50% medium- and 50% large-scale food industries. Participants were identified through social media networks, industry connections, and other logistics and supply chain platforms. The study used a sample of 268 participants based on the Krecjcie and Morgan sample size calculation, which is adequate for a population of 57,000 in the Oman logistics industry. The following section reflects on the path analysis.

8. Construct Variables Explanation and Magnitude

8.1. Factor Loadings, Construct Reliability and Validity

This study used Cronbach's alpha, Rho_A, composite reliability, and average variance extracted (AVE) in **Table 2** to determine construct reliability and validity. According to the general rule of thumb [35], values that are >0.7 show high reliability, while Rho_A values closer to Cronbach's alpha show internal consistency. The values obtained from any study (**Table 2**) range show

stronger internal consistency, marked by higher values (composite reliability > 0.7), further confirming that the reliability of the constructs is high (AVE > 0.5 is considered valid) and the factor loadings > 0.7 are considered acceptable, indicating that at least half of the variance in the indicator can be explained by the construct.

Table 2. Factor loadings, construct reliability and validity.

	Factor Loading	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
Food safety requirements		0.891	0.899	0.920	0.696
FR1	0.797				
FR2	0.793				
FR3	0.884				
FR4	0.886				
FR5	0.806				
Food supply chain performance		0.933	0.934	0.949	0.789
FS1	0.907				
FS2	0.901				
FS3	0.817				
FS4	0.907				
FS5	0.904				
Food traceability		0.836	0.844	0.883	0.603
FT1	0.758				
FT2	0.836				
FT3	0.819				
FT4	0.747				
FT5	0.717				
Information technology		0.936	0.936	0.951	0.796
IT1	0.913				
IT2	0.898				
IT3	0.828				
IT4	0.914				
IT5	0.905				
Performance measures		0.956	0.958	0.966	0.850
PM1	0.930				
PM2	0.936				
PM3	0.872				
PM4	0.930				
PM5	0.940				
Regulatory compliance		0.884	0.885	0.916	0.685
RC1	0.756				
RC2	0.858				
RC3	0.858				
RC4	0.816				
RC5	0.845				
Risks in the food supply chain		0.885	0.888	0.916	0.686
	0.752				
	0.861				
	0.861				
	0.816				
	0.847				

8.2. Discriminant Validity

The Heterotrait Monotrait (HTMT) (**Table 3**) ratio is widely used to measure distinct constructs in structural equation modeling (SEM) [35]. HTMT values below 0.9 indicate discriminant validity. The results in **Table 3** satisfy the requirements of discriminant validity, as they are higher than all their correlation values. The results confirm the recommendation that the HTMT ratio can be used in measuring the discriminant validity to increase the robustness of our data before proceeding with the factor loading.

Table 3. Heterotrait-monotrait ratio (HTMT).

	Food Safety Requirements	Food Supply Chain Performance	Food Traceability	Information Technology	Performance Measures	Regulatory Compliance
Food supply chain performance	0.823					
Food traceability	0.150	0.285				
Information technology	0.431	0.639	0.374			
Performance measures	0.547	0.696	0.162	0.276		
Regulatory compliance	0.387	0.408	0.434	0.663	0.210	
Risks in food supply chain	0.689	0.685	0.301	0.379	0.473	0.659

The next section presents direct relationships and hypothesis testing.

8.3. Direct Relationships and Hypothesis Testing

T-statistics was utilised to assess the difference between the means of two different groups. The higher the T-statistic value, the greater the evidence against the null hypothesis. This section presents the study's direct relationship and hypothesis testing (**Table 4**).

- **H_1.** *Food safety requirements significantly impact food supply chain performance in the Omani food industry.*

The results indicate a low standard deviation of (0.046), implying that the data points are closer to the mean. These results indicate that food safety requirements consistently and reliably influence food safety performance. In addition, food safety requirements and supply chain performance have a T-statistic value of 7.978, which is high enough to reject the null hypothesis. These results suggest that enhancing food safety requirements positively affects the performance of food supply chains in the Omani food industry. The results are supported by Masengu et al.[11], who emphasised the critical influence that food safety has on the entire effectiveness of the supply chain in the Omani food industry.

- **H_2.** *Food safety requirements influence the implementation or utilization of information technology in the Omani food industry.*

The results indicate a higher standard deviation (0.080) and considerable T-statistics (3.568). The results imply more variability in the influence of food safety requirements on information technology. Interesting to note is the fact that the T-statistics results are considerably above the threshold of a 95% confidence level, which relates to statistical significance with the positive relationship. These results show that the government of Oman needs to strengthen its food safety by adopting information technology and related aspects. These results are consistent with the finding that food standards cannot be narrowed down to a specific country. Still, they must be transparent and consistent and communicate with global supply chain partners to mitigate possible risks Adopting technology facilitates the country's compliance with food safety standards, mitigates possible legal issues, and positively influences a country's brand image, market growth, profitability, and operational efficiency[36]. Companies involved in the food industry need to use the available information technology infrastructure to promote and communicate food safety in supply chains, as they exist as conduits between producers and consumers[30].

- **H_3.** *Food traceability significantly affects food supply chain performance in the Omani food industry.*

Food traceability and supply chain performance results show low standard deviation (0.032) and T-statistic (1.434). These results provide evidence that food traceability on food supply chain performance is consistent, although falling below the conventional threshold of significance, suggesting that the relationship between food traceability and food supply chain performance is not statistically significant. These are not surprising to the study because similar studies have confirmed that establishing the traceability system is difficult, especially in the food industry. Traces of pork deoxyribonucleic acid (DNA) reported in some food products have led Muslim consumers to call for strict traceability of the supply chain[37]. The establishment of an integrated traceability system can track food products

in real-time. According to one study, supply chain control should be implemented to increase visibility, allowing for continuous monitoring and reporting of all actors' activities.

- **H_4.** *Food traceability significantly impacts the use of information technology in the Omani food industry.*

The results indicate moderate consistency, with a standard deviation of 0.051 and a T-statistic of 2.561, which reflects a statistically significant relationship between the variables. These results are essential in that they confirm that the ability of retailers to implement food traceability initiatives influences the use of information and technology within the food supply. Therefore, food traceability significantly influences the use of information technology within the food supply chain. These results suggest that the company's improvement in traceability is likely facilitated by its commitment and advancement in information and technology adoption [38]. The results align with most studies that confirm that most consumers do not emphasise food traceability, and traceability systems improve food quality by detecting product failures. In the livestock industry, identification and meat traceability systems have been adopted to reduce mislabelling and provide accurate information to consumers.

- **H_5.** *Information technology significantly improves food supply chain performance in the Omani food industry.*

The relationship between information technology and supply chain performance is high, with a T-statistic value of 6.193 and a standard deviation of 0.065, suggesting strong evidence against the null hypothesis and moderate consistency in the results. Supply chain performance relies on the information gathered by [15] to maintain and improve the standards of last-mile delivery and remove bottlenecks, enabling quick responses to emergencies. This confirms that information technology has a highly significant and positive impact on food supply chain performance, emphasizing the critical role of IT in enhancing supply chain efficiency and effectiveness in the Omani food industry [39].

- **H_6.** *Performance measures significantly impact food supply chain performance in the Omani food industry.*

Empirical studies have shown a growing concern that companies in the food industry face some challenges in establishing performance measurement systems [40] due to the non-alignment of network goals. Notably, collaboration in the network is a crucial strategy in ensuring efficient performance measures. The results obtained in this study indicated that performance measures play an essential role in food supply chain performance; hence, the Oman food industry's adoption of proper metrics and evaluations significantly enhances supply chain outcomes.

- **H_7.** *Performance measures significantly influence food traceability in the Omani food industry.*

A T-statistic value of 2.291 for the relationship between food traceability and performance measures suggests significant evidence against the null hypothesis. Thomas et al. [41] state that food traceability has raised concerns about the halal food industry. This agrees with [27] Che and Feng [17], who contend that food traceability reduces misinformation and provides customers with information, even though scholars have yet to decide on food traceability. These results are crucial, especially in the Omani food industry, since they suggest that supply chain performance measures directly impact food traceability. These results raise the point that Oman's food industry needs to come up with robust metrics to ensure traceability within the supply chain.

- **H_8.** *Performance measures significantly impact the use of information technology in the Omani food industry.*

The results indicate a moderate variability with a standard deviation (0.061) and T-statistics of (1.527), which signifies that the relationship is not statistically significant. The results confirm that data availability is insufficient to guarantee performance measures. There is a growing dilemma in the food industry in establishing performance measurement systems [40] due to the non-alignment of network goals. A notable aspect that complicates performance measurement in the food supply chain is the variation of information prioritisation with

each actor. The coexistence and cooperation of supply chain actors have a win-win result in the performance measurements of supply chain actors. An uninterrupted flow of information and data, clear communication structure, and recognition of each actor lead to supply chain success [15].

- **H_9.** *Performance measures significantly affect regulatory compliance in the Omani food industry.*

The results indicate moderate consistency in the data with a standard deviation (0.068) and T-statistics (2.816) that show a significant relationship between performance measurement and regulatory compliance. The results confirm the importance of creating regulatory measurements in Oman's food industry to enhance performance measurements. The results align with the recommendations to apply HACCP principles through the use of perequisite procedures of GMP, GHP and SSOP which are considered good housekeeping and preventive measures in the food industry [42]. These regulatory principles are vital since they focus on managerial commitment, staff specialisation, motivation, resources, and communication of the program to implement set regulations and procedures.

- **H_{10}.** *Regulatory compliance significantly impacts food supply chain performance in the Omani food industry.*

Due to the rapid increase in globalisation, safety concerns and lack of proper regulations are critical issues for producers, manufacturers, and retailers in the food industry. The results confirm the above statement with the T-statistics (3.370) that suggest a statistically significant relation between regulatory compliance and food supply chain performance. Given a lack of regulatory aspects, the World Trade Organization (WTO) oversees food safety concerns in global trade [2]. In the last decade (2010–2020), the food industry has gone through significant challenges due to a lack of robust regulations and proactive policies at the governmental levels

- **H_{11}.** *Regulatory compliance significantly influences the use of information technology in the Omani food industry.*

The results indicate a very high T-statistics (9.438) and a standard deviation (0.061), reflecting a moderate consistency in the data. These results underscore the point that regulatory compliance by supply chain stakeholders is a strong driver of information technology adoption and implementation in the food industry in Oman. In support of these results, adopting information technology is critical to improving and maintaining supply chain performance measures and food standards. The integration is noted by [9] who further asserts that the adoption of information technology removes information bottlenecks, increases response to supply chain emergencies, helps to identify problems and allows the efficiency and effectiveness of the supply chain.

- **H_{12}.** *Risks in the food supply chain significantly impact its performance in the Omani food industry.*

The results indicate a high T-statistic (4.417) for the difference between the mean values of food supply chain risks and supply chain performance. The standard deviation (0.055) reflects moderate variability. The results reflect that risks in the food supply chain in Oman have an essential impact on supply chain performance. The results are significant in understanding that supply chain players in Oman's food industry need effective risk management strategies to enhance supply chain efficiency The food supply chain operation has complex risks due to many actors [22]. Risk sources include varying qualities, stock restrictions, regulations, and traceability at each level. Global disruptions such as the COVID-19 container crisis [9], Gulf War, and 11 September crisis exposed the vulnerabilities of supply chains during uncertainties. To reduce the food supply chain risk, companies need to implement supply chain integration.

- **H_{13}.** *Risks in the food supply chain significantly affect the use of information technology in the Omani food industry.*

Risks in the supply chain and adoption of information technology show standard deviation (0.087) and T-statistic (2.754). This implies that the relationship is statistically significant, suggesting that risks in the food supply chain significantly influence the adoption and use of information technology. Evidence shows that the food industry has been marred with uncertainties that have

impacted countries' food security worldwide. The incorporation of information technology reduces risks and has a significant impact on both external and internal operational characteristics of a supply chain [28].

Table 4. Direct relationships and hypothesis testing.

	Standard Deviation (STDEV)	T-Statistics (|O/STDEV|)
Food safety requirements-> Food supply chain performance	0.046	7.978
Food safety requirements-> Information technology	0.080	3.568
Food traceability -> Food supply chain performance	0.032	1.434
Food traceability -> Information technology	0.051	2.561
Information technology -> Food supply chain performance	0.065	6.193
Performance measures-> Food supply chain performance	0.053	5.544
Performance measures-> Food traceability	0.064	2.291
Performance measures-> Information technology	0.061	1.527
Performance measures -> Regulatory compliance	0.068	2.816
Regulatory compliance -> Food supply chain performance	0.064	3.370
Regulatory compliance -> Information technology	0.061	9.438
Risks in food supply chain -> Food supply chain performance	0.055	4.417
Risks in food supply chain -> Information technology	0.087	2.754

8.4. Indirect Relationship and Hypothesis Testing

- **H_{14}.** *Food safety requirements, performance measures, regulatory compliance, and risks in the food supply chain indirectly affect food supply chain performance through the combined mediation of information technology and food traceability.*

This section presents the mediation relationship and hypothesis testing (**Table 5**). In PLS-SEM, a third variable can be introduced between two variables to identify the mediation effect [35]. This implies that the mediator dictates the nature of the relationship between the exogenous and endogenous constructs. Based on **Table 5**, the mediation effect was done using information technology; however, the study went so far as to establish the interconnectedness relationship of these variables to supply chain performance so that we increase the robustness of the results and understanding of the complexities in the supply chain as supported by [43]. In this study, the indirect effects of food safety requirements, performance measures, risks in the food supply chain, regulatory compliance, and food traceability were mediated through information technology. The T-tests were used to analyse the mediation of food safety requirements → information technology → food supply chain performance indicates a T-value = 2.713. The results imply that integrating information technology into food supply chain performance will result in food safety and efficiency in food supply chain performance. This result resonates with researchers who indicate that the accurate collection of data and the adoption of information technology, such as blockchains for traceability and artificial intelligence (AI) in quality, have a positive impact on a country's food supply chain performance [15].

To assess the mediation effect of food risk in food supply chains → information technology →food supply chain performance, the results showed a significant and positive T-test value = 2.351. The results helped understand information technology adoption in the management of food supply chains. They established that, due to the complexities of supply chain risks, incorporating information technology is crucial in building resilience and agile food supply chains. This reinforces the arguments made by scholars such as Gurtu and Johny [22], who emphasise technology's role in mitigating supply chain risks. Furthermore, the mediation of performance measure → food traceability → food supply chain performance showed a T-test value = 1.025. These results show that the mediation effect may be weak but exhibits interest since it shows that food traceability has a low impact on food supply chain performance. This could add to the debate that consumers are less likely to focus on food traceability.

The mediating effect of performance measures → regulatory compliance → food supply chain performance

reflects a significant and positive T-value = 2.537. This validates that regulatory compliance is vital in food supply chain performance. This also confirms similar studies showing that food industries fail to meet food safety and quality standards due to noncompliance with international standards[33]. This requires different industry actors to actively measure and manage the compliance issues of supply chain actors to avoid unforeseen disruptions and risks.

Relatedly, the mediation relationship of regulatory compliance → information technology → food supply chain performance shows that technology can be a catalyst in proving regulatory compliance and improving food supply chain performance by a T-test value = 4.732. These results are phenomenal since they show that the ever-increasing regulatory complexities and the need to monitor compliance in real-time reporting cannot be understated. The most exciting aspect of this study came from the interconnected relationship among food safety requirements, performance measures, risk in the food supply chain, regulatory compliance, food traceability, and information technology. The results reflect a significant T-test value = 2.596, confirming similar studies that concluded that integrating these factors among the supply chain actors builds resilience, agility, and robustness of food supply chains, such as the work of[9]. This integrated approach highlights the multi-layered nature of supply chain management, where technology, compliance, and safety measures are deeply interconnected.

Table 5. Indirect relationship and hypothesis testing.

	Standard Deviation (STDEV)	T-Statistics (|O/STDEV|)
Food safety requirements-> Information technology -> Food supply chain performance	0.042	2.713
Performance measures-> Food traceability -> Food supply chain performance	0.007	1.025
Performance measures-> Regulatory compliance -> Food supply chain performance	0.017	2.537
Regulatory compliance -> Information technology -> Food supply chain performance	0.050	4.732
Risks in food supply chain -> Information technology -> Food supply chain performance	0.041	2.351
Performance measures-> Regulatory compliance -> Information technology -> Food supply chain performance	0.017	2.596

9. Conclusions

This research offers key insights into the food logistics and supply chain in Oman, based on data collected from a diverse range of participants. Path analysis reveals that food safety requirements, traceability, and information technology have a positive impact on supply chain performance, while regulatory compliance and risk management emerge as critical factors.

Moreover, the study shows that food safety requirements enhance supply chain performance and influence the adoption of information technology, which in turn boosts supply chain performance. Interestingly, performance measures impact both regulatory compliance and traceability. The model exhibits high explanatory power, highlighting the relevance of these variables in shaping robust supply chain outcomes. Lastly, the findings indicate that integrating food safety measures, regulatory adherence, and advanced technologies is essential for improving the efficiency and resilience of food supply chains in Oman.

10. Limitations

- The results are based on a data set that is specific to the Omani food industry; hence, they may not be generalised to other countries and industries.
- This study is cross-sectional rather than longitudinal; therefore, it may fail to capture future trends.
- Although the study used a complex model with multiple variables, it may have limitations in capturing other variables affecting the food supply chain such as political, economic, and consumer behaviour.
- These findings suggest that policymakers should prioritise the integration of technology into regulatory frameworks, thereby promoting industry-wide compliance and facilitating the development of more secure food supply chains.

11. Novelty of the Research

- The study is unique since it comprehensively analyzes interconnected variables within the Omani supply chain, including food safety requirements, traceability, information technology, performance measures, regulatory compliance, and risks.
- It goes beyond a narrow and isolated analysis by providing a holistic understanding of their collective impact on supply chain performance.
- The robust statistical analysis that outlines the different relationships of variables provides insights into the best ways to leverage technological advancements and regulatory compliance to enhance supply chain efficiency and safety.

12. Recommendations

Based on the findings of the research, the following recommendations are presented for anyone involved with managing and supervising Oman's food supply chain:

- Continuous improvement of food safety standards is crucial. This entails following current laws, predicting future safety issues, and revising procedures appropriately. Refining food safety standards on a continuous basis ensures that the industry is keeping track of global threats and associated food safety risks. Furthermore, it is vital to engage stakeholders on a regular basis to incorporate feedback from industry, researchers, and policymakers. HACCP software, predictive analytics, IoT, and sensors are among tools the that can be used in the food safety chain.
- Cutting-edge information technologies should be leveraged to ensure regulatory compliance of supply chain activities. They involve data analytics, blockchain, AI, and other tools to provide better traceability and control to food supply chains. Revolutionization of food supply chains to meet regulatory standards and food safety requirements can be achieved by integrating information technology such as the Internet of Things, artificial intelligence (AI), data analytics and blockchain in these supply chains. The use of technology can help predict and identify potential hazards and deploy resources to reduce the impact, improve decision-making and mitigate risks.
- Applying a comprehensive strategy to identify and manage risks in the food supply chain is essential. Technology can aid in detecting and handling possible disruptions. A holistic approach to risk management in the food supply chain is critical in preventing and mitigating disruptions. Potential risks that are common in the food supply chain from the farm to the table must be identified and technology that deals with these risks must be incorporated. Risk mitigation technologies help improve the food supply chains, reduce financial losses and maintain consumer trust. These technologies include IoT sensors and risk management software.

Author Contributions

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Institutional Review Board Statement

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Informed Consent Statement

The authors and respondents participated voluntarily and willingly. All questionnaires included consent to participate in the introductory section. The authors agree with the journal's terms and conditions.

Data Availability Statement

The necessary data for the research findings may be obtained by submitting a written request to the grant funder, which in this case is the Ministry of Higher Education, Research, and Innovation in the Sultanate of Oman and the Middle East College principal researcher. The data supporting this study's findings are available from the corresponding author (Reason Masengu) upon reasonable request.

Conflicts of Interest

The authors declares no conflict of interest.

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