Enhancing Agri-Food Traceability in Oman: Integrating RFID and Blockchain Technologies in Fulfillment of the Requirement for the Graduation Project

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ABSTRACT

This study explores how to integrate of RFID and Blockchain-based technologies into Oman's agri-food traceability framework with the objective to boost the safety of food, transparency, and trust among consumers. considering Oman's substantial reliance on food from abroad and obstacles that result from its dry the environment, it is essential to have an effective framework for monitoring and tracking the source and transportation of agri-food. This research project used a combination of methods, that included interviews and surveys with consumers, retailers, and government officials. The purpose was to examine the current position of traceability as well as gain insights about the potentials of emerging technologies. The results show major weaknesses in ability to track the source of both imported and locally grown food items. While there is a general belief over the possibility of RFID and Blockchain for improving traceability systems, yet still a noticeable gap in understanding and awareness amongst players. This variation underlines the importance for specialised educational initiatives. Ideas have been put here for both the development and deployment of inclusive systems for traceability that are simply offered to customers and embrace current technology. The study supports the introduction of standard food safety regulations, launching of pilot programmes that evaluate the application of technology, and the creation of partnerships between the public and private sectors that promote the implementation of technology. The research presented here enriches the current body of scholarship on the traceability of foods and offers useful suggestions for regulators and industry leaders in Oman, with the ultimate objective of encouraging a more secure and transparent agricultural and food industry.

Keywords: RFID, blockchain, food traceability, food safety, oman, agri-food system, consumer trust

INTRODUCTION

The need for strong agri-food traceability systems is becoming more apparent as global food markets develop and consumers increasingly demand openness. In Oman, the need for strict traceability of imported food is essential to guarantee food safety and enhance customer trust. Oman's agri-food business has unique obstacles due to its dry environment and the complicated logistics of food imports. Despite the advancements in traceability technology worldwide, there is a clear void in existing research that addresses these specific challenges. This study seeks to fill this need by examining the capacity of Radio Frequency Identification (RFID) and Blockchain technologies to improve the traceability and safety of food goods in the Sultanate. The study aims to enhance Oman's food safety regulations and promote a transparent and reliable food supply chain by using these technologies.

Recent research emphasizes the efficacy of RFID and Blockchain in enhancing supply chain transparency and operational efficiencies across diverse sectors (Cocco, 2021; Hasan, 2023). Nevertheless, the use of these technologies in Oman's agri-food industry has not been thoroughly investigated. This study aims to conduct a thorough evaluation of the existing condition of agri-food traceability in Oman. It will also investigate the practicality of implementing sophisticated technical solutions and examine the opinions of important stakeholders, such as consumers, distributors, and government officials. This study aims to provide in-depth analysis and understanding that can inform policy decisions, improve involvement of stakeholders, and

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contribute to the academic discussion on food traceability systems. In the end, the research will create opportunities for new and creative methods that can greatly enhance the reliability and effectiveness of Oman's food supply chain.

Problem Statement

The agri-food industry in the Sultanate of Oman has considerable difficulties with regard to preserving the level safety, quality, and traceability of its food products given its considerable reliance on imports and the difficult logistics associated with overseeing food supply in a desert location. Today's traceability approaches in Oman absence the necessary durability and precision needed to efficiently track and oversee the agri-food supply chain. This creates a major problem, given the crucial purpose that traceability systems serve in sustaining the integrity of food as well as improving customer confidence.

The deficiency of sophisticated tracking technology, such as RFID and Blockchain, leads to these issues through creating weaknesses in the governance of regulations regarding food safety and limiting timely reaction to incidents involving food safety.In addition, there is an apparent disconnect among the potential technological options that are readily accessible and how they are implemented within specific local conditions, which include various degrees of acceptance as well as comprehension among the individuals involved. Inadequate use of technology can result in ineffectiveness, increased wastefulness, and reduced trust among customers. Hence, it is vital to examine and evaluate the possibility of mixing RFID and Blockchain technology into existing traceability systems in Oman. This investigation seeks to address these significant knowledge deficits by determining existing traceability methods, exploring the possible advantages and disadvantages of adopting new technologies, and understanding different points of view of stakeholders. The ultimate goal is to foster an ideal setting for technological advancements and increased traceability in the agri-food industry.

Significance of the Study

This research is of the highest priority for many different reasons, as it addressed critical issues within Oman's agri-food business and contributes to wider debates on food security and traceability at both national and international levels. The value of this study may be summed into the following points:

1. The goal of this initiative is to considerably enhance the safety and quality of food items in Oman through the use of sophisticated monitoring technologies such as RFID and Blockchain. These innovations can help minimise the risks of foodborne illnesses, pollution, and damage, so preserving community health and possibly decreasing the economic consequences of issues related to food safety.

2. Facilitate visibility throughout the entire agri-food supply chain. Greater openness can lead to better accountability and compliance with safety rules, which is essential in the nation that depends extensively on imports of food. This kind of transparency not just boosts the effectiveness of recalls administration but also builds customer trust in the food supply chain.

3. The outcomes of this study might help government agencies expand their abilities to track and carry out regulations pertaining to food safety, therefore simplifying regulatory compliance as well as enforcement. RFID and Blockchain technologies provide an opportunity for streamlining compliance certification in Oman by providing tools for rapid monitoring and data analysis. This would allow the application of stringent safety regulations for both imported and domestically grown food.

4. Enabling customers via the introduction of tools for confirming the origin and safety of their food has the potential to shift the markets by increasing the need for high-quality and secure goods. Consumer empowerment will force firms to use sophisticated procedures as well as technology to meet their needs.

5. Provide recommendations based on evidence to inform political decisions about food safety and the adoption of technology in Oman. This gained knowledge could be used as a blueprint for other countries

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facing similar socio-economic and environmental issues, therefore extending its impact outside national borders.

6. Grows academic awareness and application knowledge through an examination of the usage of RFID and Blockchain in a creative context. This study extends to the current body of literature on traceability technology and gives an original perspective from a place that has gotten fewer resources in previous research. Mainly, it provides an in-depth examination of the challenges and benefits of integrating these innovations into traceability systems, giving as a blueprint for other countries and industries contemplating such advancements in technology.

7. Encouraging the fulfilment of Sustainable Development Goals (SDGs). Being able to effectively trace and control the source and safety of food items fits with several United Nations Sustainable Development Goals (SDGs), including Goal 3: Ensuring Good Health and Well-being, Goal 12: Promoting Responsible Food Use and Production, and Goal 2: Achieving Zero Hunger. This study assists Oman's efforts to achieve the objectives it sets through improving the security and long-term sustainability of food systems.

LITERATURE REVIEW/BACKGROUND OF THE STUDY

As we embark on this journey through the Literature Review chapter, we delve into the rich tapestry of existing research that has paved the way for our present investigation. This chapter serves as the intellectual foundation of our study, offering a comprehensive synthesis of relevant literature that not only informs our understanding but also positions our research within the broader academic discourse. Our objective is not merely to present a laundry list of studies but to critically engage with the literature, drawing connections, highlighting contradictions, and ultimately setting the stage for the original contribution our research aims to make. This Literature Review, therefore, becomes a bridge between the past and the present, a crucial juncture where the torch of knowledge is passed from previous scholars to the current generation of researchers. With a firm grasp of the existing scholarly conversation, we are poised to extend the discourse and, in doing so, contribute meaningfully to the advancement of knowledge in our field.

Prior Studies

Implementing robust food safety management systems is paramount for safeguarding the integrity of food and fostering consumer confidence by mitigating health risks associated with consumption. Agri-food traceability plays a pivotal role in ensuring food quality and safety, as underscored by numerous studies (Hobbs et al., 2020; Wadood et al., 2020; Tagarakis et al., 2021; Mirabelli, 2012; Demestichas, 2020; Rahman et al., 2021; Alfian et al., 2020). These studies emphasize the importance of traceability in incentivizing firms to uphold diligence standards and meeting consumer expectations for quality and safety. Notably, Hisjam et al. (2020) highlight the escalating significance of traceability in response to growing consumer demand for high-quality, health-conscious, and transparent food products, reflected in the increasing scholarly attention to traceability in agri-food, particularly concerning food safety.

However, Oman's agri-food sector faces a myriad of challenges and opportunities. According to Mbaga (2015), ensuring food security remains a pressing concern for policymakers, particularly in arid regions like Oman. Desert conditions severely limit local food production, necessitating a heavy reliance on food imports, particularly grains and red meat. Despite its centrality to food security, food traceability remains conspicuously absent from Oman's research landscape, posing a significant knowledge gap.

RFID technology emerges as a promising tool with diverse applications across various sectors (Liya et al., 2022; Ahmad & Nababa, 2021). It facilitates robust item tracking and tracing, with applications ranging from logistics to healthcare. Alfian et al. (2020) propose an innovative RFID and IoT sensor-integrated system for tracking perishable food items, enhancing safety and quality. Similarly, Rahman et al. (2021) advocate for RFID-based traceability systems in fisheries supply chain management to ensure product quality and bolster consumer confidence. Nevertheless, despite its potential benefits, the societal implications of RFID technology warrant further exploration, particularly regarding privacy and surveillance concerns raised by Sellers (2021).

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Blockchain technology, introduced in 2008, offers a decentralized and transparent platform for secure digital transactions (Gaikwad, 2020). Singhal et al. (2018) underscore its transformative impact on various sectors, citing reduced transaction costs and enhanced transparency as key benefits. In the agri-food domain, Blockchain holds promise for improving traceability by offering enhanced security and transparency (Patelli, 2020; Feng, 2020; Aldrighetti, 2021). However, its successful application hinges on tailoring solutions to the unique needs of each supply chain (Patelli, 2020). While Demestichas et al. (2020) explore Blockchain's potential to enhance traceability, they highlight the need to address supply chain complexities and regulatory challenges. Additionally, the societal implications of Blockchain, such as accessibility and consumer empowerment, warrant closer scrutiny (Witte, 2016).

Overall, although there is a lot of research articles on agri-food traceability and the possible uses of technologies such as RFID and Blockchain, there is a distinct lack of study specifically focused on Oman. This gap extends beyond only focusing on agri-food traceability, embracing the wider context of the whole food supply chain inside the country. Hence, the primary objective of this study is to examine the current challenges in Oman's agricultural and food traceability sector. The study aims to investigate the potential of combining RFID and Blockchain technology to address these difficulties and improve both the effectiveness and precision of agri-food traceability in the supply chain of Oman.

This research aims to investigate the viewpoints of important stakeholders, such as distributors, customers, and government bodies, on the implementation of RFID and Blockchain technology for agri-food traceability in Oman. The study seeks to give significant insights that can enhance decision-making processes and drive the effective adoption of traceability technology in Oman's agri-food sector by clarifying these views. Furthermore, this study aims to establish the foundation for future research efforts focused on examining the societal consequences in the field of agri-food traceability.

Gaps in Prior Research

The current body of literature is mostly on the technical and economic advantages of technologies like RFID and Blockchain while neglecting important social aspects such as fairness, availability, and consumer empowerment. Hence, our research aims to elucidate these neglected facets, thereby enhancing our holistic comprehension of the ramifications of traceability technologies on society at large. The ultimate goal of this research is to facilitate socially responsible and inclusive progress in Oman's agri-food traceability practices.

Need for Additional Research

Despite the extensive body of literature explored in this literature review, it is evident that certain gaps and unanswered questions persist, beckoning for further investigation. The existing studies have laid a solid foundation, providing valuable insights into food traceability. However, a comprehensive understanding requires addressing nuanced aspects that remain unexplored. One notable gap revolves around Oman’s Agri-food traceability, where the existing literature provides a foundation but falls short in offering a thorough examination or a conclusive resolution. Therefore, the call for further research is not merely an acknowledgment of existing gaps but a proactive response to the evolving nature of knowledge in The Omani food supply chain faces significant challenges related to traceability, transparency, and security, risking food safety, quality, and trust due to the absence of an efficient tracking system from production to consumption, aiming to deepen and refine our comprehension of the intricate dynamics at play.

Study Design and Research Methods

The current study applies a mixed-methodologies strategy, bringing together both quantitative and qualitative methodologies to completely investigate the complexity of agri-food traceability in Oman. This thorough research explores different points of view of customers, retailers, and government officials, attempting to uncover the complicated processes of traceability systems and their degree of acceptability in the agri-food sector.

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Data Collection

Qualitative Data

Various agri-food retailers, including small local enterprises and huge supermarket giants, were interviewed employing semi-structured interviews. Observational visits have been carried out beside interviews in order to assess firsthand the traceability systems, communication between retailers and consumers over the origin of food, and how they complied with regulatory requirements.

Representatives in authoritative positions within the governing body, particular those in the Ministry of Agriculture, Fisheries, and Water Resources, took part in interviews to acquire knowledge about legislative structures, difficulties associated with enforcing them, and how the government views on technological advancements such as RFID and Blockchain that guarantee traceability in the food and agricultural sectors.

Quantitative Data

A comprehensive questionnaire researched the perspectives of 307 individuals from different socioeconomic groups regarding the traceability, quality, and safety of agri-food products. The information gathered enabled measurements of degree of trust, understanding of the public's awareness with traceability concepts, as well as assessment of possibilities in sophisticated traceability technologies.

Analysis of consumer surveys using quantitative approaches

The consumer responses has been assessed using a mix of inferential and descriptive statistical methods. In the beginning, we applied statistical methods that were descriptive, such as frequencies and percentages, to succinctly characterise the socioeconomic backgrounds of the individuals who took part in the survey. Furthermore, we studied the responses they provided to survey inquiries on the trust they have in the excellence and safety of agricultural food items, their knowing of traceability principles, and how familiar they were with RFID and Blockchain technology.

Additionally, inference-based statistics have been used to examine the connections between socioeconomic factors (such as age, gender, educational achievement, and income) as well as feelings towards traceability.

The research also included multidimensional methodologies, such as factor evaluation, in order to identify the basic variables that influence consumer choices when choosing agri-food goods. This method enables the analysis of how buyers within various demographic groups ranked characteristics such as cost, quality, brand integrity, and traceability.

Analysis of retailer interviews and observations using qualitative methods

The qualitative data gathered through informal conversations with merchants was recorded fully and afterwards examined using a thematic approach. The procedure involved containing the data to discover predictable trends relating to the current condition of traceability frameworks, the anticipated advantages as well as difficulties of implementing new technologies like RFID and Blockchain, and the feasibility of these technologies with current government rules and requirements. A quantitative study was carried out leveraging observational information gathered from agri-food shops to evaluate both the practical application of traceability programmes and the relationships between sellers and customers about concerns regarding the origin of food.

Additionally, the preference of retailers to adopt cutting-edge technologies has been categorised and analysed to evaluate the whole accessibility of the market regarding enhanced traceability solutions to them. The investigation assessed the stores' readiness to participate in experiments that employ RFID and Blockchain technologies. The findings showed a blend of eagerness and concerns amongst the shops.

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Analysis of interviews conducted with government officials using qualitative methods

The conversations that were performed with officials from the government have been subjected to content analysis with the goal to gather full details on the legal structures, the present efficiency of agri-food traceability systems, and how prepared the government is to support technological advancements in tracing food. The investigation showed gaps between policy objectives and their actual operation, as well as the advancements being made in the use of advanced traceability technologies.

This extensive data analysis approach ensures that the research findings are solid, covering the complex relationship between consumer requirements, retailer capabilities, and government regulations that influence the eventual development of agri-food traceability in Oman.

Research Questions

R1. What is the nature of the relationship among the existence of traceability data in Oman and consumer confidence in the safety and efficiency of agri-food products?

R2. What is the view of agri-food consumers in Oman with regard to the efficiency of RFID and Blockchain-based technologies to boost the identification and tracking of agri-food products?

R3. What is the attitude of agri-food retailers in Oman about the implementation of RFID and Blockchain technology in order to improve agri-food item traceability?

R4. What is the government's perspective of the present effectiveness of the agri-food traceability system in Oman, and what improvements do they consider necessary?

R5. What is the government's degree of willingness for implementing RFID and Blockchain technology with the goal to better the traceability of agri-food products, and what initiatives are being planned or put into effect to promote this adoption?

Hypotheses

- The null hypothesis ($H0_1$) there is no connection whatsoever between trust among consumers in the quality and efficiency of agri-food products and the accessibility of traceability data in Oman.
- The alternative hypothesis (Ha_1) states that there is an immediate connection within consumer trust in the quality and efficiency of agri-food products and the accessibility of traceability data in Oman.

- Null Hypothesis ($H0_2$): Agri-food customers in Oman do not observe RFID and Blockchain technology as successful means for increasing agri-food item traceability.

- The alternative hypothesis (Ha_2) agri-food customers in Oman consider RFID and Blockchain technology to be successful means for enhancing agri-food traceability.

-Null Hypothesis ($H0_3$): Agri-food retailers in Oman are not oriented towards using RFID and Blockchain technology to better agri-foodfood traceability.

- The alternative hypothesis (Ha_3) agri-food retailers in Oman have a desire for using RFID and Blockchain technology in order to improve agri-food product traceability.

- Null Hypothesis ($H0_4$): Government the government officials in Oman consider the established agri-food traceability framework as effective and do not see considerable enhancements as needed.

- Alternative Hypothesis (Ha_4): Government officials in Oman believe the existing agri-food traceability system to be insufficient and acknowledge the requirement for considerable improvements.

- Null Hypothesis ($H0_5$): The Omani government does not have the willingness to employ RFID and

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Blockchain technologies for boosting agri-food product traceability, and has not undertaken any initiatives or efforts to encourage the implementation of such technologies.

- Alternative Hypothesis (Ha_5): The Omani government is committed to employ RFID and Blockchain technology with the goal to boost the traceability of agri-food products. They already have established plans or undertaken initiatives to promote the implementation of these technologies.

Ethical Frameworks

Prior to getting started, this study acquired authorization from a committee of ethics. Before taking part, everyone who took part got presented with an in-depth discussion of the implications of their involvement, including what they are entitled to. Following that, their permission was obtained. To ensure the confidentiality of the those involved, every piece of data gathered was completely cleaned of any personally identifiable information.

RESULTS AND DISCUSSION

Agri-food Customer Survey: their Perceptions in Agri-food Traceability

Moderate Confidence in Agri-food Safety

Given the findings shown in Figure 1, 53% of the participants stated a moderate level of confidence in the safety and quality of agriculture-food goods, which is defined as "Somewhat confident." However, when adding up the amount of those who state "Not very confident" (31.3%) compared to those who report being "Not confident at all" (6.4%), a comparable proportion of the population shows scepticism about agri-food standards, corresponding with the proportion of people who seem reasonably secure. Barely a little minority (9.3%) exhibited complete confidence ("Very confident"), suggesting room for enhancement within the industry. After studying demographic data, it was discovered that confidence levels remained fairly stable all over various ages and genders. Yet, an obvious pattern developed, demonstrating people with more advanced educational backgrounds expressed greater concerns, which could indicate a higher level of attention towards agricultural-food practices.

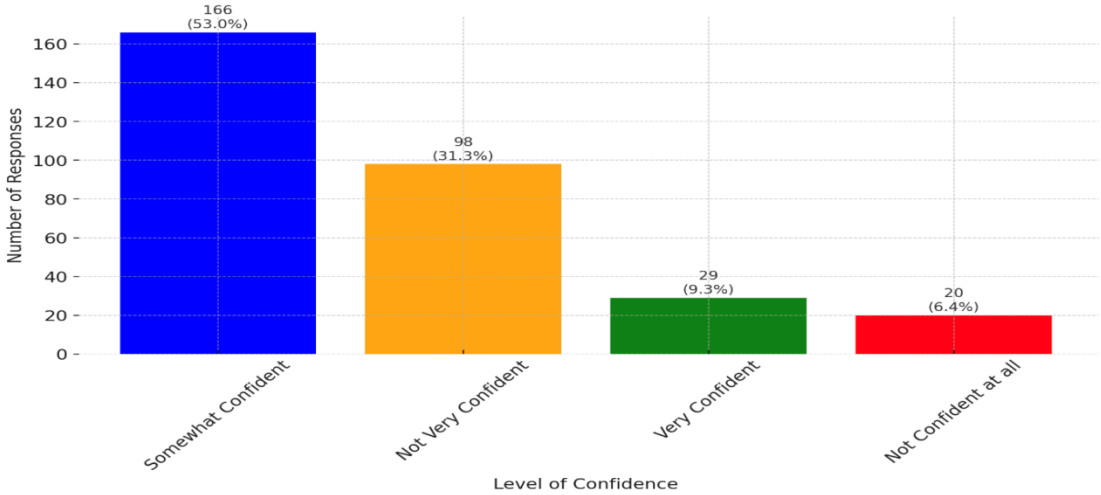

Figure 1 Confidence in Quality and Safty of AgripFood Products

Limited Public Understanding of Food Traceability Principles

The results of the survey demonstrated an important absence of general awareness on the fundamentals of traceability concept, as quite a few of the participants chose their answer as "Neutral" (25.2%) or confessed to being "Not very familiar" (19.2%). Merely a fraction of the respondents (13.1%) indicated being "Very familiar," stressing a notable deficit in broad knowledge and illustrating the need for educational activities.

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There were no noteworthy differences regarding knowledge across all age groups and genders. Still those with advanced levels of schooling had a little clearer knowing of traceability concepts.

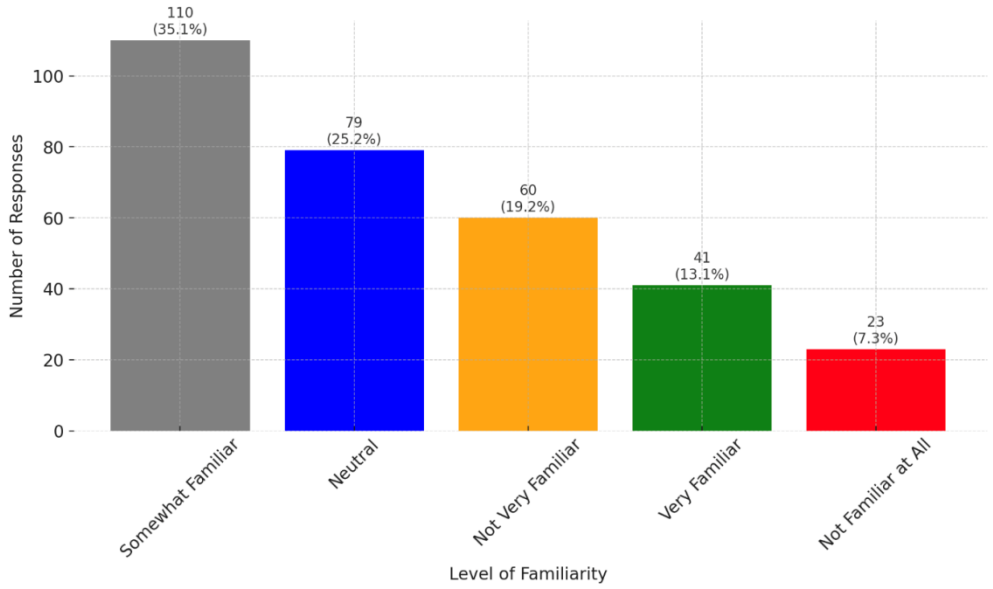

Figure 2 Familiarity with Food Traceability

Low Public Awareness of RFID Technology in Agri-food Traceability

The people who responded revealed an apparent lack in their comprehension of RFID technology, with 31.6% of them indicating "Not knowledgeable at all" as their most common response. Merely a small minority (8%) classified themselves as "Highly knowledgeable." It demonstrates that the vast majority of people are not aware of RFID technology, and this provides a window for concentrated teaching activities. It was a constant lack of awareness regarding RFID across a lot demographic groups, including persons with different ages, genders, and educational levels.

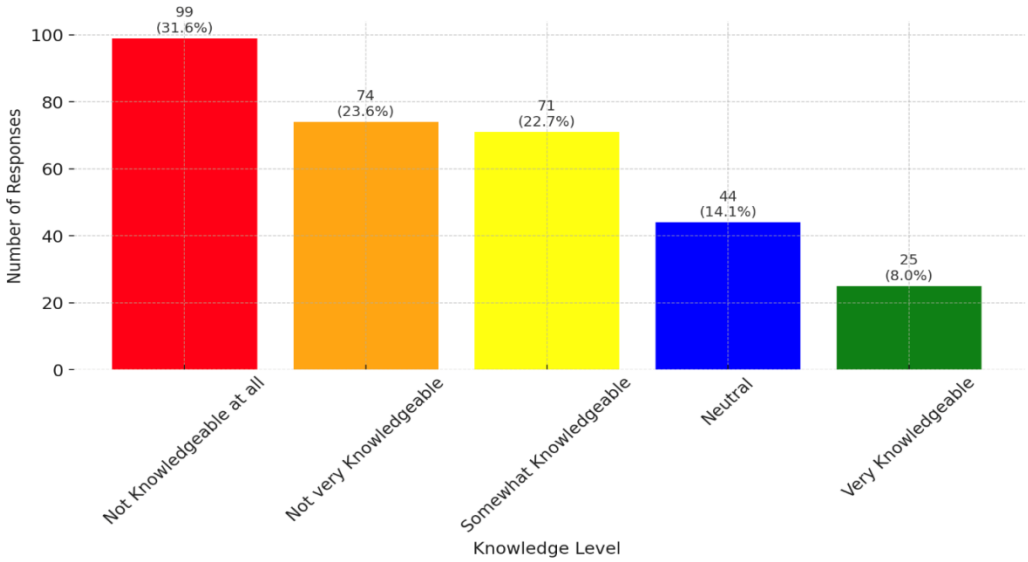

Figure 3 Knowldege of RFID Technology Among Participants

Limited Awareness of Blockchain Technology Among Consumers

The survey's findings showed that a large number of those responding had little understanding of Blockchain, particularly matches what has been found with RFID technology in general. This means the majority of the public has yet to gained complete awareness about the wide adoption and impact caused by the technology known as Blockchain. Participants who have obtained an undergraduate degree or further had an a bit greater

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level of understanding. Even so, there is still an apparent absence of knowledge that needs consideration across different levels of education.

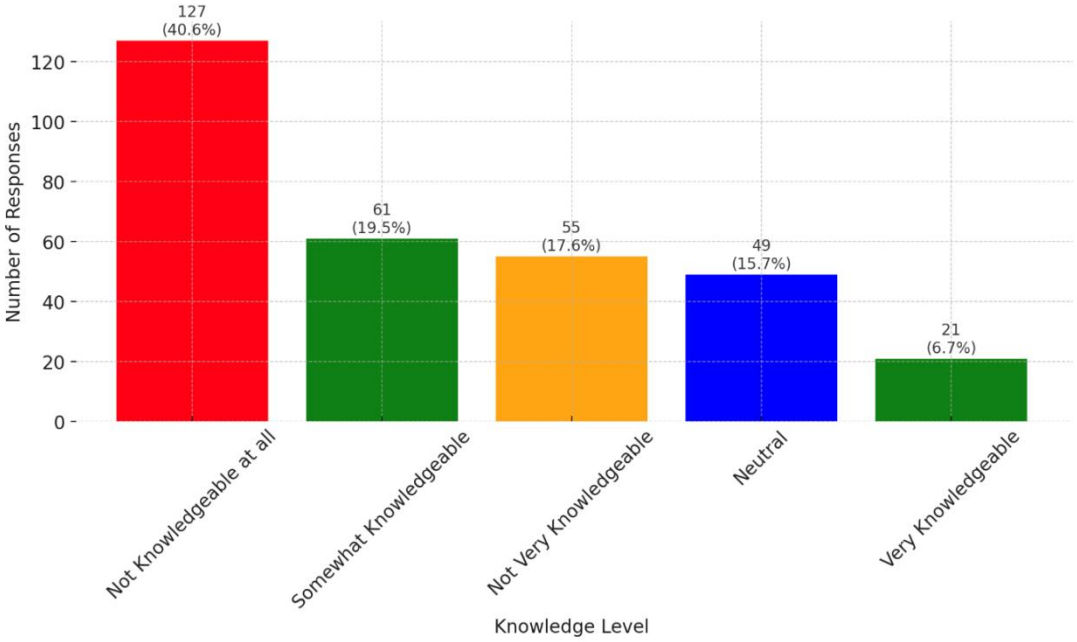

Figure 4 Knowldege of Blochchain Technology Among Participants

Consumer Priorities in Agri-food Selection: Quality, Price, and Beyond

The investigation of customer preferences in the agri-food industry shows an exclusive business where quality gets priority (30.5%) as the main consideration affecting purchasing choices, emphasising the theoretical benefit of tracking mechanisms which ensure the authenticity of products. Though price continues to be a significant consideration (26.8%), it is clear that customers can put a greater importance on proved quality and safety, which is frequently expressed by the country of origin (22%). This indicates how traceability could serve as a vital tool for verifying the reliability of statements about where an item originates from. The consumer's belief in the brand's claims and the importance of packaging as a way of providing data on traceability are reflected in the reputation of brands (14.6%) and packaging (6.1%). These results suggest a traceability system ought to be applied not just for tracking, but additionally as an effective way for communicating quality, safety, and authenticity. This will assist with fulfil the demands and needs of consumers in Oman's agri-food sector.

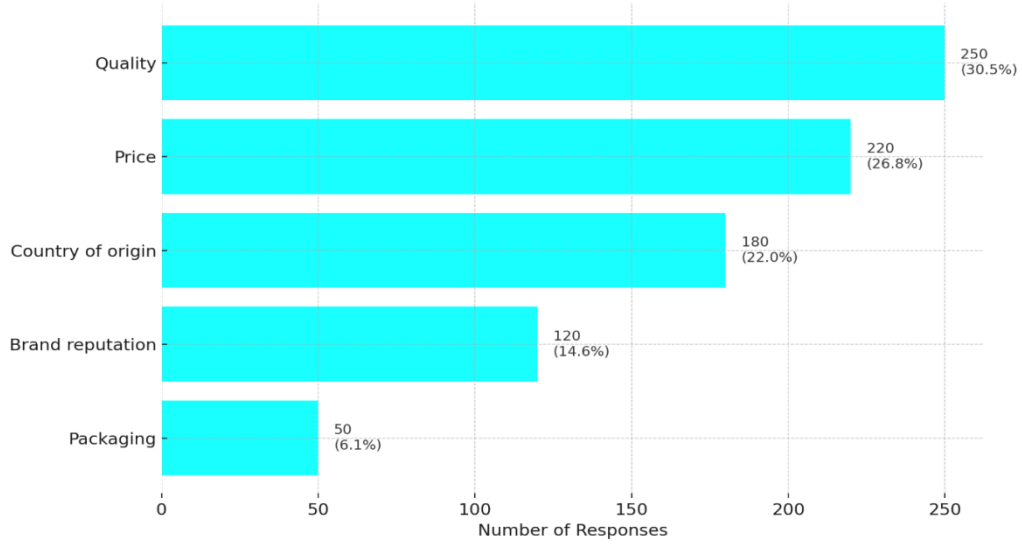

Figure 5 Key Factors Influencing Decision When Choosing Agri-food Products

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Consumer Valuation of Traceability in Agri-food Products

Among the sample of individuals researched, traceability was considered to be extremely important, with 39.9% ranking it as 'Somewhat Important' and 30.4% as 'Very Important' in regards to decisions about their purchases. roughly 17.3% of those who responded claimed neutrality, suggesting perhaps uncertainty or a shortage of enough data to form an accurate opinion. Importantly, a small minority of people viewed traceability as 'Not Very Important' (10.2%) or 'Not Important at All' (2.2%). This trend implies a widespread acceptance of the role of traceability between various demographic categories, yet the extent of acceptance has differed. The predominant agreement concerning the value of traceability shows its perceived significance for maintaining the safety and quality of food, which reflections a growing demand from consumers for transparency in the agricultural and food supply networks.

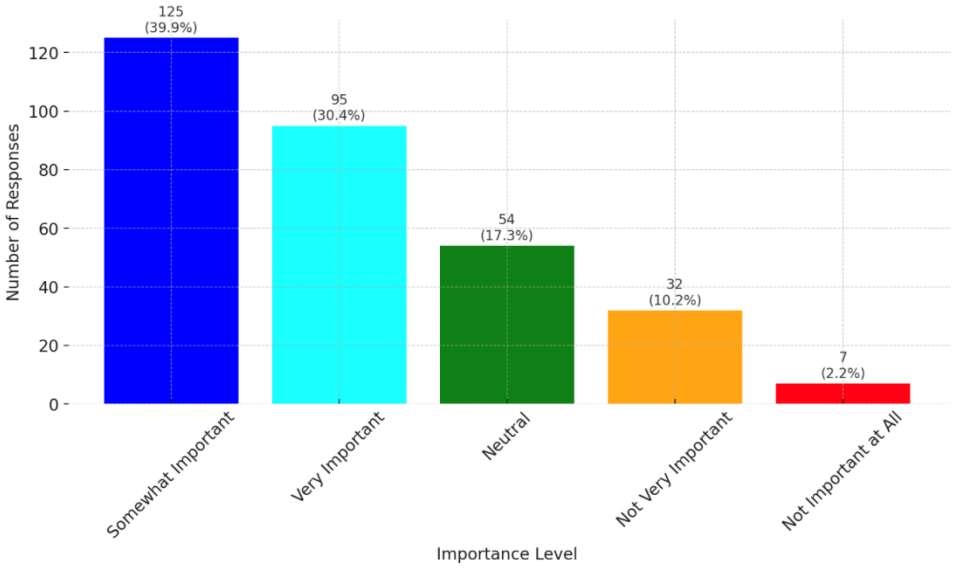

Figure 6 Importance of Knowing the Origin and Journey of Agri-food Products

Consumer Optimism for Blockchain and RFID Adoption in Agri-food

43.1% of those surveyed agreed and 22.7% completely agreed on the combination of Blockchain and RFID technology in the agri-food marketplace, confirming an increasing level of optimism. Yet, a substantial percentage of the respondents chose the "Neutral" choice (32.3%), implying an issue that is uncertain or absence of sufficient knowledge to strongly choose a point of view. The amount of disagreement regarding the incorporation of these innovations stayed extraordinarily very little.

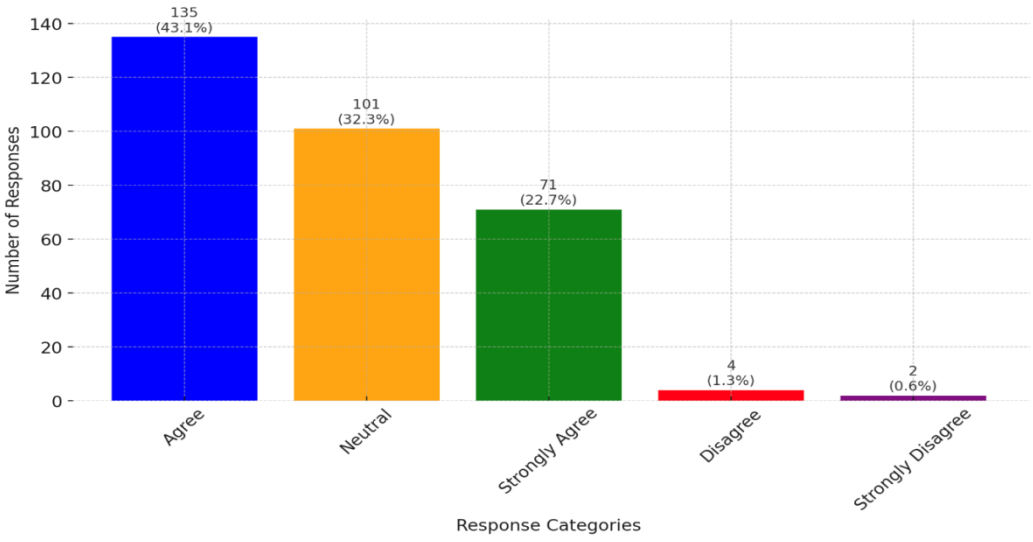

Figure 7 The potential of integrating RFID and Blockchain technologies in agri-food traceability

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High Consumer Willingness to Choose Traceable Agri-food Products

With regard to question concerning the likelihood of picking agricultural products that were developed by traceability using the application of RFID and Blockchain technology, the responses revealed an optimistic outlook. Most respondents expressed an extent of possibility for selecting these products, with 58.5% indicating the answer was "Somewhat likely" and 37.7% saying they were "Very likely". Barely just a small percentage (3.8%) stated a lack of interest regarding purchasing such items, suggesting huge potential in the marketplace for agri-food products that include monitoring features.

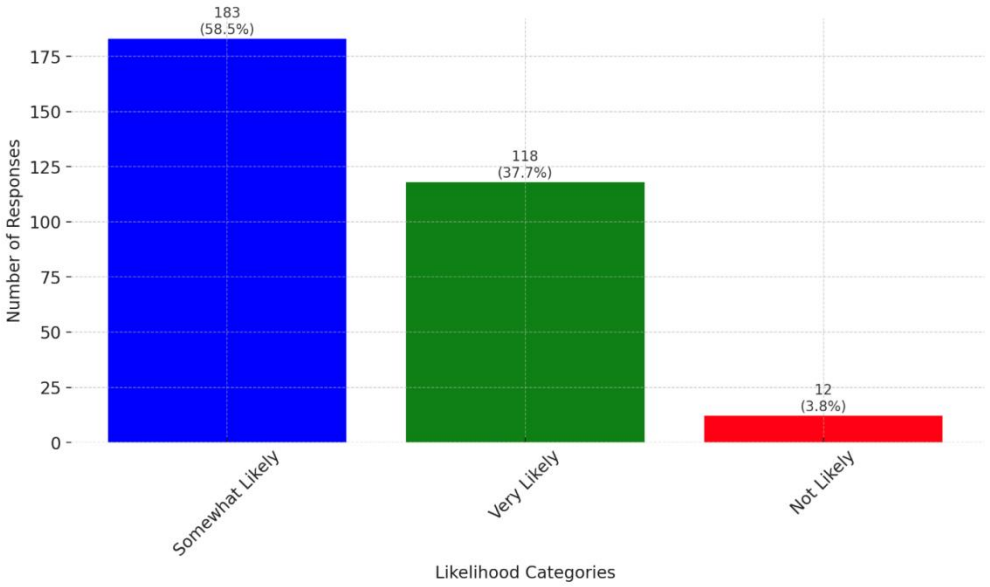

Figure 8 Likelihood of Adopting New Technologies in Agri-food Traceability

In short, the initial research carried out amongst Omani consumers of the agricultural and food industry shows significant results regarding traceability considerations and a desire to support novel technologies including RFID and Blockchain. The findings highlight a situation where confidence among customers has been undermined because of worries and an absence of transparency, despite an apparent willingness to accept advances in technology in agricultural food.

The outcomes point to an average amount of trust with regard to the quality and safety of agricultural goods, with 40% of the respondents reporting concerns. This moderate guarantee illustrates an essential need in the sector to improv traceability techniques that are seen as reliable and honest by buyers. What makes this issue even more serious is the reported lack in knowledge. 60% of the people questioned either demonstrate indifference or acknowledge that they have a poor grasp of food traceability concepts. This substantial gap creates an important obstacle in making sound choices, which could affect trust regarding the food supply chain. Moreover, there is a widespread insufficient comprehension of RFID and Blockchain across individuals throughout all age groups, suggesting a major deficiency in education. This absence of comprehension restricts customers in looking for cutting-edge monitoring methods.

Interestingly, the analysis anticipates favourable prospects for the use of RFID and Blockchain technology in the context of agricultural food. A significant percentage (67%) appreciate the likely advantages of these kinds of technologies for boosting the tracking of food and safety. Unexpectedly, almost everyone who responded express an intense desire to choose agricultural products that can be easily tracked back to their original source. This can be demonstrated by the large proportion of 98% who have a tendency or very probable to do so. This indicates a nearly general support for traceable agricultural goods, yet nearly one-third of those surveyed stay neutral. This points to the need for additional details on the practical implications and cost advantages associated with carrying out these types of innovations.

The distinction between belief and fear expresses The findings from the questionnaire underscore the critical need for educational programmes that are specifically designed to improve customer understanding regarding

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traceability principles and technologies. Such educational efforts perform an essential part in closing the understanding gap, leading to the growth of a consumer base that is educated, confident, and supportive of technological advancements. Also, the conflicting emotions encountered by many voices indicate a possibility for stakeholders in the industry to start transparent and productive conversations about the functioning, benefits, and economic viability of RFID and Blockchain technologies.

In general, this questionnaire gives an opening for Oman's agri-food industry to show the leadership of innovation. It also underlines the value of educating people and providing open communication. By stressing these essential variables, stakeholders may take advantage of customer demands for prioritising food safety and quality. This would offer a suitable feeling for adopting RFID and Blockchain technology improvements. These initiatives are essential for progressing the industry towards more transparency, increasing security measures, and establishing confidence in the supply chain of food and agricultural goods.

Agri-food Retailers Interviews and Observations

Overall Awareness and Understanding of Traceability Technologies

The vast majority of small to medium-sized agri-food retailers showed a fundamental knowledge of traceability systems, a concept they claimed could help improve the safety of products and build confidence among consumers. At the start, retailers had a limited grasp of particular innovations including RFID and Blockchain. Even so, while getting a clarifying, individuals displayed awareness of the possible gains associated to these technologies. The results of the research indicated an important desire for acceptance the application of technology, as 17 out of 22 people interviewed indicated they were prepared to take advantage of such tools for better efficiency and openness in the supply chain.

Observational findings on product information

Investigations carried out at different retailers uncovered an enormous absence of clear information about products, most notably with respect to vegetable crops. The vast majority of the products were merely labelled with a the price, without providing proper information relating to their country of origin, manufacturing materials, storage methods, or harvesting dates. Extensive lack in data could be observed across smaller and medium-sized stores as well as bigger ones, while those that were larger frequently offered somewhat more information about the goods.

Regulatory Inspections

The interviews stated that governmental inspection primarily concentrated on the overall cleanliness and arrangement of shops, instead of testing of the safety of food or laboratory checks on food items. It suggests a potential gap in the regulation and oversight concerning the traceability and security of food and agricultural commodities.

Perceptions of Retailers Regarding Technology and Traceability

The businesses owners have stated major collaboration as well as an overwhelming a desire for learning insight into traceability technological advances. Given their initial absence of awareness about RFID and Blockchain, they rapidly showed an elementary grasp after the concepts were described. This points to an initial understanding that might be improved further by encouraging the effective application of technology.

Pilot programmes and technological benefits are of great interest.

A large percentage of those who participated showed an intense interest in participating in experiments for the combined use of RFID and Blockchain technology. About fifty percent of those who took part exhibited an obvious desire, and the other half expressed an interest that was contingent upon getting more details. When asked regarding the chances of offering agricultural goods that could be tracked, the most retailers replied positively. They stated their willingness to back such attempts, given that they are actually advantageous for customers, demonstrating an organisation philosophy that values customer satisfaction.

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Factors that influence the selection of a product

The most significant variable which affected the choice of goods among all sellers was quality, which was additionally underlined by the significance of pricing and packaging. Growing requests for data on traceability shows an increasing consumer thirst for food quality and transparency concerning where it comes from, which might influence upcoming market developments.

In generally, Agri-food merchants in Oman hold an optimistic outlook on the deployment of RFID and Blockchain technology in order for better the traceability of goods. The vast majority of the investigated stores exhibited an intense curiosity in these new technologies after they were made aware of their benefits, despite the fact they in the beginning lacked familiarisation with the fundamentals. This reflects an extensive willingness for using cutting-edge technology and an acceptance of the possible advantages it can bring for goods tracing. Retailers indicated an important desire to accept methods that can quickly improve their customers' experience, including providing more detailed item information and guaranteeing the security of products. Their willingness to participate in piloting initiatives further underlines their desire for investigating these technological advancements.

Retailers see innovations in technology, specifically traceability technologies such as RFID and Blockchain, as essential aspects for fostering trust about the security and efficacy of agriculture and food products. Information gathered from both interviews as well as observations demonstrate that the implementation of advanced tracing systems, that offer comprehensive data on the source, handling, as well as safety of items, is associated with a greater degree of customer confidence. Retailers have become conscious that advancements regarding technology not just increase their operational effectiveness, but they also match customer demands for openness and dependability in the agricultural and food industries.

Government Official Interviews: Assessing Policies, Procedures, and Public Trust Challenges in Implementing Comprehensive Agri-food Tracking

The authorities at the government have made clear that despite they are making progress on establishing a tracking system for agriculture-related goods that can track them up until they approach the point of sale, these technologies presently cannot enable consumers to see the tracking information. The lack of consistency in the framework reveals an apparent insufficiency in accessibility, which might negatively affect customer trust and fulfilment. The shortage of customer engagement in the traceability procedure highlights a requirement for regulatory adjustment to guarantee that traceability information is easily readily accessible and understood to end consumers. This could enhance accountability and accessibility in the supply chain for food.

Public Perception of Government Responsibility in Food Safety

Public surveys have shown that there is an accepted view amongst the general population believe the government has a responsibility for assuring the traceability and safety of agricultural and food items. Yet, this point of view has to be compared with an obvious lack of complete confidence with government regulations that ensure the quality of food. The gap between what the government does and the general trust illustrates the immediate requirement for better communication and involvement by the public means that restore and expand confidence in governmental food safety protocols.

Impact of Service Availability on Consumer Interest in Food Traceability

The results of this study point out that the governoment officials think that customers' perceived lack of curiosity in the historical background of what they eat but we think this is due to the scarcity of this information, instead of an actual lack of curiosity. The evidence reveals consumers have a tendency to be engaged with information regarding traceability if it is offered to them. This underlines the need of not just providing these platforms easily accessible, but additionally assuring they are easy to navigate and use.

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Inconsistencies in Regulatory Enforcement Between Imported and Local Produce

The currently in place regulatory system has a stringent policy towards exported agricultural goods, guaranteeing that they adhere to safety and compliance inspections. On the other hand, local agri-food products, primarily those coming from little and not registered landowners, are covered by fewer regulations and monitoring, which could result in possible dangers to the safety of food. The current difference demands the establishment of an uniform legislative strategy that implements identically strict standards across all products derived from agriculture, independent of their source, in order to provide comparable food safety.

Need for Enhanced Research on Agri-food Safety and Traceability

Regulators underlined an obvious lack in studies and research regarding illnesses or obstacles linked to agri-food goods inside the country as a whole. The shortage of specific studies conducted by appropriate health and food safety agencies could hinder the ability to develop effective policies and manage emergencies related to food safety. This stresses the requirement for strategic research and continual evaluation of food safety and health criteria.

Governmental Readiness and Prioritization for Traceability Technologies even though acknowledging their benefits. The importance for carrying out fundamental changes, specifically in the regulation for domestic agricultural goods, has been emphasised as an essential requirement for the effective implementation of new technology. It has been suggested that an evolutionary approach, beginning with goods from abroad that have an established position in the marketplace, may be essential for the purpose to gradually introduce new systems into the local industries

Government and Specialist Engagement in Traceability Development

The pleasant reaction from authorities about matters of traceability and their desire to assist with assessing the results of research indicate a growing curiosity and awareness of the worth of traceability systems. This association is crucial to advancing progress in the development of traceability technologies and methods.

The discussions that were performed with those in government resulted in helpful information about the current status and obstacles connected to agri-food traceability in Oman. These discussions underlined the critical need of improving both the regulatory structures and technological infrastructure with the goal to enhance the security and traceability of food systems. The primary issues to take into account are the understanding of an important gap in consumer accessibility to traceability information, an inconsistent implementation of legislation for imported and locally grown food, and an overall deficiency in studies and expertise concerning food safety and traceability.

The outcomes show the essential function of government agencies in promoting an effective traceability system that not only conforms with international regulations but also answers to the particular demands and needs of domestic consumers. The shortage of trust among consumers, together with the obvious disinterest resulting from the scarcity of traceability services, demands a strategic reconsideration regarding how traceability information can be communicated while remaining accessible.

Statistical Analysis of Hypotheses

This part reveals the outcomes of the hypothesis's evaluation, employing T-tests and Chi-squared tests in order to evaluate correlations and variances throughout our data set.

First Hypothesis

This hypothesis studied the connection among consumer confidence in the quality and efficiency of agricultural products and the accessibility of tracing information within Oman.

Statistical Test: T-test Method

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We executed a T-test to determine the overall rates of consumer confidence among groups that had traceability information and groups that did not have traceability information. This method enables the examination to determine if the incorporation of traceability information has an important influence on trust among customers levels.

The T-test revealed a significantly different outcome ($p < 0.05$), highlighting that buyers who know traceability information enjoy a higher degree of confidence in the safety as well as effectiveness of agri-food products. The result points out the important role of openness in the supply chain, emphasising the availability of traceability data could enhance confidence among consumers which may affect consumer purchasing decisions therefore supporting the alternative hypothesis..

Second Hypothesis

This hypothesis tested whether or not agri-food buyers in Oman think RFID and Blockchain technological advances to be advantageous ways for boosting the transparency of agricultural products.

Statistical Test: Chi-squared test

We implemented a Chi-squared test in assessing the relationship amongst customer opinions and the actual effectiveness of RFID and Blockchain technologies. This examination is helpful when examining categorised data and grasping the different viewpoints of different groups concerning the efficiency of these kinds of technologies.

The Chi-squared test indicated a significantly different finding ($p < 0.05$), revealing a strong relationship connecting customer opinions and the actual effectiveness of RFID and Blockchain technologies to enhance transparency, supporting the alternative hypothesis. Customers that acquire familiarity with these innovations see them as having benefits for increasing the traceability and overall safety of agri-food items.

Third hypothesis

This hypothesis studied the opinions of agri-food retailers in Oman for the implementation of RFID and Blockchain technology to boost traceability of agri-food items.

Statistical Test: T-test Method

We carried out a T-test to analyse the overall perspectives of agri-food retailers with respect to the use of RFID and Blockchain technological advances. From the examination of average viewpoints, we can discover if retailers likely to be encouraging or suspicious regarding such advancements in technology.

The T-test revealed a statistically significant favourable view ($p < 0.05$) across agri-food retailers regarding the application of these technologies, offering backing for the alternative hypothesis. Businesses recognise the probable positive effects of RFID and Blockchain-based systems in making it possible traceability, streamlining managing stock, and strengthening trust among consumers.

Furth hypothesis

The current hypothesis investigated the perspectives of elected officials with regard to the actual effectiveness of the agri-food traceability framework in Oman including the desire for serious modifications.

Statistical Test: Chi-squared test

We utilised a Chi-squared test to figure out the association amongst the perspectives of elected officials and the perceived requirement for developments in the system for traceability. This examination aims to find out whether or not there is an overall consensus between government officials on the adequateness of the system currently in place.

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The chi-squared analysis revealed findings that were statistically significant ($p < 0.05$), implying that administrators see the current system as unsatisfactory and acknowledge the necessity for notable changes. This conclusion highlights the requirement for changes in regulations and the application of cutting-edge technology for a better traceability mechanism therefore we support the alternative hypothesis.

Fivth hypothesis

This study hypothesis the Omani government's potential for implementing RFID and Blockchain innovation with the objective to boost the transparency of agricultural and agri-food-related products.

Statistical Test: T-test Method

We undertook a T-test to look over the extent of disaster preparedness among governmental officials in respect to the deployment of RFID and Blockchain technologies. This evaluation is intended to determine how far in which government agencies are appropriately ready and willing to use these kinds of technologies.

The T-test showed a considerable disaster preparedness level ($p < 0.05$) amongst authorities to accept RFID and Blockchain-based technologies, therefore verifying the alternative hypothesis. The findings demonstrate that there is regulatory encouragement and an intentional strategy for integrating these technologies with the objective to better the transparency of agricultural products and food goods.

The statistical analyses lend proof in favour of the alternative hypotheses across all given hypotheses. The outcomes of the T-tests and Chi-squared tests showed statistically significant variations and connections, confirming that participants have constructive beliefs and opinions relating to the utilisation of RFID and Blockchain technology in general. Moreover, the outcomes underline the noticed shortcomings and the requirement for changes in the present traceability framework, verifying the feasibility and suitability of introducing advanced traceability technologies in the Sultanate of Oman agri-food market.

RECOMMENDATIONS

1- **Development and Implementation of Comprehensive Traceability Systems**: In order to improve food safety and guarantee superior standards in Oman, it would be beneficial for the government to put first establishing and supporting of modern traceability systems that integrate RFID and Blockchain technologies. Such systems have to be established with the potential to simply track food goods from their original source to the final customer, assuring not just a record of trace but additionally enabling transparency in order to ensure consumers have easy access to information regarding the source as well as safety of their food. By applying these sophisticated systems, Oman's agri-food industry will be upgraded to comply with global safety requirements while boosting the trust of consumers.

2- **Stakeholder Education and Training Enhancement**:

The proper use of RFID and Blockchain technologies depends on the awareness and participation of all parties affected. Hence, it is essential to carry out focused educational programmes and seminars involving consumers, retailers, and government officials. These efforts ought to concentrate on explaining the strategic benefits and real-world applications of these technologies, thereby establishing an optimal environment for their successful deployment. Knowledgeable individuals who feel that they have an interest in a traceability structure that is capable of reacting rapidly to changes are crucial for its continued effectiveness.

3- **Standardization of Regulations for Imported and Local Products**:

The establishment of requirements for imported and local products is crucial because it helps to guarantee reliability in food safety procedures, therefore protecting the health of the public. It is suggested to engage in a joint effort with regulatory agencies in order to make certain that all food and agricultural goods in Oman conform with standard safety regulations. This could enhance confidence among consumers while bringing Oman's practices in line with worldwide requirements for food safety.

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4- **Pilot Projects for Technology Integration Testing**:

Intended to evaluate integration of technology, trials have been suggested to be carried out in certain areas or with specific agricultural categories of goods prior a countrywide deployment. The pilot projects are going to be utilised to detect problems with operation and highlight the real-world benefits of RFID and Blockchain technology. This will make way to facilitate the optimisation of systems in order to attain the highest level of productivity.

5- **Cultivation of Public-Private Partnerships**:

Establishing meaningful collaborations involving the government and the companies community is critical. These partnerships have the ability for combining government regulation and entrepreneurial innovation, establishing an environment suitable to fast advancement in technology. Furthermore, they may assist in divide the financial expenditures and monetary consequences associated with establishing such systems.

6- **Ongoing Research and Development**:

Continuous development and research is required for keeping up with the latest technological developments and shifts in the agri-food traceability industry. Oman's committment to innovations will make certain that its traceability systems continued to be at the leading edge of technological advances, meeting the ever-evolving demands of the marketplace and approaching modifications to legislation.

Adopting these suggestions would not just strengthen Oman's traceability approaches but additionally provide significant improvements to the globally conversation on food safety. This will boost the confidence of consumers and assure conformance to international safety and quality standards.

Limitations of the Study

1. **Technological Complexity**: This research analyses complicated technologies such as RFID and Blockchain, which require complicated technological details that might have been poorly grasped by everyone who took part. This could end up in questionnaire and interview responds that are impacted by a narrow awareness, consequently affecting the obvious level of familiarity and excitement for emerging technologies.

2. **Stage of Technology Adoption**: Because RFID and Blockchain remain developing technologies in Oman's agri-food sector, the research's conclusions concerning deployment obstacles as well as advantages depend mainly on theoretically and anticipated results instead of significant practical implementation. At the beginning of execution, there could be limitations in precisely predicting operational problems and long-term consequences.

3. **Regulatory Dynamics**: The outcomes of the research rely on the present legal environment in Oman, that might shift as time passes. The recommended traceability approaches might be subject to modifications to rules or requirements for compliance, that may affect their suitability and effectiveness. It could happen that the research fails to entirely examine these possible developments.

4. **Economic Constraints**: The financial consequences of introducing RFID and Blockchain technology have been taken into consideration, although no thorough cost-benefit investigations were carried out. Additional research is needed to assess the financial viability of these innovations to small to medium businesses in Oman's agri-food sector.

5. **Stakeholder Engagement**: As the study covered numerous stakeholders, the degree of participation possibly differed, leading to possible inadequate representation of conclusions from smaller agricultural enterprises or individuals who had little understanding of technology. This could be having an influence on one's understanding of all the obstacles and advantages associated with the execution of traceability technology.

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6. **Technological Bias**: The primary focus on RFID and Blockchain might obscure or overlook the investigation of additional traceability methods or innovations that might prove equally beneficial. This focus can limit the search to additional or alternative approaches that may seem more feasible or affordable.

7. **Cultural and Behavioural Factors**: The research anticipates a certain degree of acceptability and modification of attitude from stakeholders, this might not take place as predicted. The resistance of particular societies to accept new technology and adjust procedures for operation could pose an important barrier to the introduction and efficacy of RFID and Blockchain in the system for traceability.

8. **Data Privacy and Security Concerns**: The paper recognises the beneficial effects of better traceability via technological advances, however it fails to thoroughly address the complexities and worries of stakeholders about the security and confidentiality of data. These worries are essential in the procedure of embracing technology, yet they need a deeper look from both a legislative and technological standpoint.

9. **Longitudinal Impact**: The investigation is carried out in a qualitative manners, providing a brief glance into current circumstances and perspectives. It lacks its ability to monitor and document modifications that take place over time, which is vital to grasping the enduring impacts and longevity of technology installations in traceability solutions.

CONCLUSION

This research project intended at examining the feasible incorporation of RFID and Blockchain technology in Oman's agri-food traceability framework. The driving force behind this investigation was the urgent need for better food safety, transparency, and trust among consumers. The results demonstrate an essential issue in Oman's agri-food industry, in which advances in technology might considerably shift the existing traceability approaches that are filled with gaps and constraints, particularly with regard to tracking and guaranteeing of the quality and safety of locally produced and imported food items.

The examination found an important weakness in today's traceability processes, specifically the shortage of complete systems that combine modern technologies like RFID and Blockchain. Applying such technologies is both possible and vital for establishing an effective traceability system which will strengthen Oman's food safety targets and encourage the country's economic development. The reported excitement and confidence among various participants, such as customers, retailers, and government officials, imply a readiness and possible tolerance to accepting these kinds of technologies. Yet, such positive outlook is balanced by an important absence of awareness and acquaintance with the technology, underlining the immediate need for educational endeavours.

The importance of these results is outstanding. In the first place, the analysis emphasised the requirement for governments to take steps to formulate and carry out food safety regulations effectively for all products, no matter of their origin source. This initiative would successfully tackle the current gaps in food safety regulations across imported and domestically produced foods, thus ensuring a safer and more trustworthy food supply chain. Moreover, the adoption of RFID and Blockchain technologies ought to be studied via trials that can offer a variety of advantage and facilitate the improvement of systems before broader adoption.

In addition, the investigation stresses the need for ongoing involvement and training among stakeholders in order in order to encourage smooth implementation of new technology. Collaborations between the public and private sectors have an opportunity to promote innovation through providing the necessary capital and collaborative joining of resources to overcome financial and technical obstacles to the adoption of technology. Also, such alliances might help with creating regulations which foster an ideal atmosphere for advances in technology while also ensuring the protection of consumer rights and safety.

Thus, the efficient implementation of RFID and Blockchain technologies into Oman's agri-food traceability system depends on the shared dedication of every party concerned to embrace new technologies capable of solving actual hurdles. Oman is able to enhance its food safety standards, improve consumer trust, and become a standard for other countries in the area through this step. These ideas attempt to offer guidance for the long-

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term strategy and initiatives needed to attain these aims, providing a road map for a more secure, more transparent, and efficient food supply chain in Oman.

Student Statement of Authorship

We understand that we are responsible for any academic work we submitted to the University of Nizwa. we declare that this project is my original work and any references and sources we have used were properly acknowledged. We claim the sole ownership of this academic work which was not done by any other person.

If the University of Nizwa discovers that the foregoing declaration is incorrect and/or that cheating or plagiarism has occurred, the University reserves the right to impose academic sanctions against me.

Course Code: **MNGT433**

Course Title: **Graduation Project**

Title of Assignment/Project: **Enhancing Agri-Food Traceability in Oman: Integrating RFID and Blockchain Technologies**

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Similarity Check Report

List of Terminologies

Terminologies	**Meaning**
RFID - Radio Frequency Identification	A technology that uses electromagnetic fields to automatically identify and track tags attached to objects.
IoT - Internet of Things	A network of interconnected devices that communicate and exchange data without human intervention.
SCM - Supply Chain Management	The management of the flow of goods and services, involving the movement and storage of raw materials, work-in-process inventory, and finished goods from point of origin to point of consumption.
SDG - Sustainable Development Goals	A collection of 17 global goals designed to be a "blueprint to achieve a better and more sustainable future for all" set by the

	United Nations General Assembly in 2015.
FSMS - Food Safety Management System	A network of interrelated elements that combine to ensure that food does not cause adverse human health effects.

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APPENDICES

Survey on Agri-food Traceability in Oman (Survey Questions)

Age *
- 18-24
- 25-34
- 35-44
- 45-54
- 55 or older

Gender *
- Male
- Female

Monthly Household Income *
- Less than OMR 500
- OMR 500 - OMR 1,000
- OMR 1,001 - OMR 1,500
- OMR 1,501 - OMR 2,000
- More than OMR 2,000

Education Level *
- Less than high school
- High school graduate
- Some college or vocational training
- Bachelor's degree
- Postgraduate degree

How often do you purchase agri-food products? *
- Daily
- Weekly
- Monthly
- Rarely

How confident are you in the quality and safety of the agri-food products you consume? *
- Very confident
- Somewhat confident
- Not very confident
- Not confident at all

How familiar are you with the concept of food traceability? *
- Very familiar
- Somewhat familiar
- Neutral
- Not very familiar
- Not familiar at all

How much do you know about RFID (Radio-Frequency Identification) technology? *
- Very knowledgeable
- Somewhat knowledgeable
- Neutral
- Not very knowledgeable
- Not knowledgeable at all

How much do you know about Blockchain technology? *
- Very knowledgeable
- Somewhat knowledgeable
- Neutral
- Not very knowledgeable
- Not knowledgeable at all

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How much do you trust the traceability systems used in the agri-food industry to ensure product quality and safety? *

- ◯ Fully trust
- ◯ Somewhat trust
- ◯ Neutral
- ◯ Do not trust much
- ◯ Do not trust at all

What factors influence your decision when choosing agri-food products? *

- ☐ Price
- ☐ Quality
- ☐ Brand reputation
- ☐ Organic/natural ingredients
- ☐ Packaging
- ☐ Country of origin
- ☐ Other

Have you ever provided feedback or complaints regarding agri-food products you purchased? *

- ◯ Yes, frequently
- ◯ Yes, occasionally
- ◯ No, never

How important is it for you to know the origin and journey of the agri-food products you purchase? *

- ◯ Very important
- ◯ Somewhat important
- ◯ Neutral
- ◯ Not very important
- ◯ Not important at all

Do you believe that integrating RFID and Blockchain technologies can enhance agri-food traceability and safety in Oman? *

- ◯ Strongly agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly disagree

How likely are you to choose agri-food products that are labeled as traceable using RFID and Blockchain technologies? *

- ◯ Very likely
- ◯ Somewhat likely
- ◯ Not likely