Blockchain-based Traceability in the Food Supply Chain

Assessing Consumer Willingness to Pay for Transparency and Safety

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Abstract

This study investigates consumer willingness to pay (WTP) for enhanced traceability and safety in the food supply chain through blockchain technology. Utilizing an online survey with 73 participants from Iran, we examined WTP for two products: infant formula and salt, under three conditions: no certification, conventional certification, and blockchain-based certification. Our findings reveal a significantly higher WTP for blockchain-certified products, particularly for sensitive items like infant formula, highlighting the value consumers place on transparency and safety. The regression analysis showed no statistically significant impact of age, gender, income, and education on WTP. These results underscore the potential of blockchain technology to enhance consumer trust and support its broader adoption in the food industry. The study offers valuable insights for producers, retailers, and policymakers aiming to improve food safety and quality through advanced traceability systems.

Keywords:Consumer Research, Blockchain Technology, Willingness to Pay, Food Safety, Iran, Infant Formula, Food Sensitivity

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Abbreviations

WTP	Willingness To Pay
MLR	Multiple Linear Regression
CV	Contingent Valuation

1. Introduction

1.1 Background

A supply chain encompasses the entire network of entities directly or indirectly involved in producing, distributing, and delivering products from raw materials to final customers. It includes various processes such as sourcing, production, logistics, and customer service (Chopra & Meindl 2016). The International Trade Administration (2020) has noted that transactions within supply chains contribute to more than three-quarters of global trade. Agri-food supply chains, which are a vital part of the global economy, feeding billions of people and employing a significant portion of the workforce, face a variety of challenges that threaten food safety, integrity, and customer trust (Verny & Guan 2022). To reduce production expenses, major corporations frequently relocate their manufacturing operations to regions with lower labor costs (Shakhbulatov et al. 2020). This trend has led to the division of supply chain activities among an increasing array of partners. Consequently, supply chains have become more extensive, intricate, and reliant on a network of stakeholders spread across various locations, sometimes even crossing national borders (ibid). This complexity introduces significant management challenges, emphasizing the need for more efficient oversight and coordination across all stages of the supply chain (Shakhbulatov et al. 2020).

Food safety remains a major concern in the food industry, with incidents of contamination and disease outbreaks causing significant public health issues (Menon & Jain 2024). According to the World Health Organization (WHO 2022), foodborne diseases are a widespread and growing public health problem, affecting millions of people annually worldwide. These incidents not only lead to severe health consequences but also result in substantial economic losses due to medical costs, lost productivity, and diminished export potential (Menon & Jain 2024). Estimated that food contamination causes over 420,000 deaths worldwide annually (WHO 2022). The impact is particularly devastating among vulnerable populations, as mentioned by WHO (2022) “Children under 5 years of age carry 40% of the foodborne disease burden, with 125 000 deaths every year.” The economic ramifications are equally alarming, costing the global food industry US$30 to $40 billion a year, as highlighted in a report by PwC (2016).

Food fraud, which encompasses a range of illegal activities including adulteration, mislabeling, and the use of unauthorized additives, further exacerbates the issue (Spink & Moyer 2011). Food fraud represents a significant threat to the integrity of the global agri-food system, with numerous incidents highlighting the diverse and pervasive nature of this issue. The economic motivation behind food fraud is significant, driven by the opportunity to increase profits by substituting ingredients with cheaper alternatives or falsifying labels to exploit market demands for certain products. This threatens consumer trust and poses serious health risks.

One of the most severe cases of food adulteration occurred in China in 2008, involving the contamination of infant milk formula with melamine (Giannakas & Yiannaka 2023). This chemical was added to falsely elevate protein levels in the milk. The contamination resulted in 294,000 illnesses, the hospitalization of 50,000 infants, and six deaths (Zhang & Xue 2016). This incident highlighted the potential for catastrophic health consequences when food fraud occurs, emphasizing the critical need for stringent food safety and monitoring systems.

Moreover, in the United States, a major fraud case involved nonorganic grain being sold as organic, resulting in over $142 million in fraudulent sales due to weak certification processes (Parker 2021). The 2013 horsemeat scandal in Europe exposed horse DNA in processed beef products, driven by the demand for cheap food and complex supply chains (Manning 2016). Seafood mislabeling is prevalent, with an investigation revealing that 74% of seafood in sushi restaurants and 18% in grocery stores in the United States were mislabeled (Giannakas & Yiannaka 2023). In Australia, nearly 20% of honey was found to be adulterated with cane sugar or corn syrup, with similar issues in honey imported from Asia (ibid). The olive oil sector also faces widespread mislabeling, with lower-quality oils often falsely labeled as extra virgin, and many cases involving blending with other vegetable oils (Giannakas & Yiannaka 2023).

As previously stated, outbreaks of diseases transmitted through food significantly impact public health. The most effective method to reduce this impact is by promptly and accurately detecting these outbreaks and identifying the tainted food product responsible (Jacobs et al. 2020). Beyond ensuring safety, food quality is crucial for providing consumers with products that are both safe and nutritious. Methods for verifying food quality are indispensable in preventing the circulation of substandard food items and preserving the integrity of the food supply. Traceability plays a vital role in pinpointing both positive and negative practices throughout the supply chain, critical for preventing food safety issues and guaranteeing the quality of food products. The Food and Agriculture Organization of the United Nations (FAO) highlighted in a 2009 report that traceability has become a fundamental element in numerous global food safety and quality assurance frameworks (FAO 2009).

Traditional systems for managing food safety and traceability are often fragmented, paper-based, and inefficient, leading to delays in identifying and addressing issues (Aung & Chang 2014). The lack of real-time data and transparency across the supply chain hampers swift responses to food safety

incidents and fraud, potentially endangering public health and eroding consumer trust (Tse et al. 2017).

1.2 Problem Statement

The frequency of food scandals has significantly eroded public trust in food quality and safety, leading to an increased demand for transparency within the food supply chain (Jin & Zhou 2014). Traditional certification methods have been instrumental in attempting to mitigate these concerns by providing a level of assurance to consumers regarding the quality and safety of food products. However, the utility of these certifications is limited, as they often provide information on only a single aspect of the product, failing to address the multifaceted concerns of today's consumers (ibid).

In the Netherlands, a scandal occurred when it was discovered that a product labeled as organic was actually not. This led Skal, the Dutch certifying organization for organic products, to withdraw its certification from a key supplier a large supermarket chain (Van Hilten et al. 2020). The consequences of this withdrawal were severe, resulting in the bankruptcy and liquidation of a local mushroom grower who depended on this certification for business viability (ibid). Such incidents illustrate how current certification systems cannot guarantee the promises they make about supervised food supply chains and underscore the critical need for more comprehensive traceability solutions that can rebuild consumer confidence by offering enhanced transparency and traceability in the food supply chain which will result in improved food quality and safety.

Despite the critical role of traceability in enhancing consumer confidence and safety, the adoption of advanced technologies like blockchain, which has the potential to revolutionize traceability in the food supply chain, is heavily dependent on consumer acceptance and their willingness to pay (WTP) a premium price for such enhanced traceability. According to Anderson et al. (1992), the concept of willingness to pay plays a pivotal role in shaping marketing strategies, influencing crucial marketing choices. Setting the initial price of a new product demands thoughtful consideration, as a misjudged launch price can undermine the investment made in its development and pose a risk to innovation success (Ingenbleek et al. 2013; Schmidt & Bijmolt 2020).

In this study, we choose Iran due to its status as a lower-middle-income country (Worldbank 2023), which typically faces significant challenges related to food safety. These challenges stem from issues such as inadequate regulatory frameworks, limited enforcement of food safety standards, and the prevalence of informal markets. Iran exemplifies these challenges, making it a relevant case study for examining solutions to food safety issues.

Moreover, in Iran, trust in the food supply chain can be inconsistent, similar to other middle-income countries. This inconsistency poses a substantial risk to consumer confidence and public health. Blockchain technology, with its potential to enhance transparency, presents a promising solution to these challenges. By

improving the traceability and accountability of food products, blockchain can build consumer trust in the safety and authenticity of the food supply. Thus, Iran provides a compelling context to explore the impact and implementation of blockchain in addressing food safety concerns. Furthermore, to the best of the author's knowledge, no study has been conducted on the willingness of Iranian consumers to pay for blockchain-based traceability up to this point.

Previous research has extensively discussed the value of certification and traceability in general terms but has paid limited attention to the comparative analysis of consumer WTP for conventional safety labels versus blockchain-based traceability systems. This gap is particularly evident in the context of how these technologies are perceived across different types of food products and the extent to which consumers value the added transparency and safety assurances they may offer.

The examination of how the sensitivity of a food product influences customer decisions in the context of blockchain-based traceability, presents an unexplored area of research. By selecting infant formula and salt as representative of sensitive and insensitive food categories, respectively, this research ventures into a critical analysis of consumer behavior dynamics in response to product sensitivity. Baby milk powder, considered a sensitive product, carries a heightened level of concern for parents and caregivers due to its direct impact on infant health and wellbeing. The sensitivity here is twofold: it encompasses both the physical health of the consumer (the infant) and the psychological peace of mind for the purchaser. The reason for choosing infant formula is that the target consumer group for this product is the most vulnerable group of people to foodborne diseases as mentioned before. In this light, the hypothesis is that the sensitivity associated with baby milk powder could lead to a higher willingness to pay for enhanced traceability and safety assurances provided by blockchain technology, reflecting an inherent demand for greater product transparency and quality assurance.

Conversely, salt, typically categorized as an insensitive product due to its widespread availability and perceived lower health impact, serves as a benchmark for comparing the effects of product sensitivity on consumer decision-making. The assumption is that consumers may exhibit a lower willingness to pay for blockchain traceabled insensitive products, given the lower perceived risk associated with their consumption. However, this comparison is essential to understand the breadth of consumer attitudes across different product types and the potential variability in the perceived value of blockchain traceability.

1.3 Objectives and Aims

This study aims to address the critical gap in existing literature by investigating consumers' willingness to pay a premium for products that offer increased traceability through the implementation of blockchain technology in the food supply chain. Specifically, it seeks to compare consumer WTP for products with traditional safety labels against those with blockchain-based traceability systems.

This comparison is important for understanding the potential market acceptance of blockchain technology in the food industry and for assessing whether the increased transparency and safety assurances it provides translate into a higher WTP among consumers. Through this analysis, the study will contribute to a deeper understanding of consumer preferences in the context of food safety and traceability, offering valuable insights for producers, retailers, and policymakers regarding the adoption and implementation of blockchain technology in the food supply chain.

Moreover, this exploration aims to uncover whether and how the sensitivity of a food product shapes consumer preferences and decision-making regarding blockchain-enhanced traceability. It seeks to determine if the intrinsic characteristics of a product, significantly influence consumer willingness to invest in the added value of blockchain traceability.

Research questions:

1. Are consumers willing to pay more for enhanced traceability in products using blockchain technology compared to products conventionally labelled for safety?
2. Does the sensitivity of a product influence consumer willingness to pay?
3. What are the factors influencing consumer willingness to pay?

2. Literature Review

2.1 Conventional Food Certificate Challenges

Hatanaka and Busch (2008) explored the transformations in the agri-food system influenced by neoliberal trade policies and the expansion of global trade. These changes have facilitated the transition of regulatory responsibilities for food safety and quality standards from public entities to private organizations, including third-party certifiers. Alongside governmental regulations, these third-party entities ensure compliance with specific production standards and management requirements (UNDP 2021). Consequently, government involvement in regulation is becoming less direct, leading to retailers and NGOs playing a larger role in formulating food quality and safety standards. Retailers are establishing private standards to enhance competitiveness, distinguish themselves from competitors, and mitigate risks. In this situation, third-party certification has taken a crucial role in regulating the global food and agriculture sector (Hatanaka & Busch 2008; Zhang 2023).

Traditional food traceability methods, such as tracking the product's path using paper-based records, fail to meet consumer demands and foster trust. These methods suffer from several drawbacks, including opaque processes, data inaccuracies, challenges in tracking the product's route, and the potential for document loss or damage (Aung & Chang 2014). For example, paper records are prone to being lost or destroyed, and they cannot guarantee the accuracy of the information (ibid.). Since maintaining records is a crucial element for tracing food products (Olsen & Borit 2013), and given that data is at the heart of traceability, it's vital to explore the obstacles encountered in traditional food traceability systems. These challenges encompass the extent and reliability of the data, its security, and how it is managed. Additionally, the information provided through labels and certifications are often inaccessible to consumers (Verbeke 2005).

One significant issue with traditional food traceability methods is ensuring the accuracy of the data recorded. Even though maintaining records is fundamental to tracing food products, it does not ensure that these records are authentic. Both intentional misconduct, such as fraud, and accidental errors in documentation can result in misleading assertions about the products, thereby diminishing the

confidence of consumers and relevant stakeholders (Olsen & Borit 2013). Moreover, the protection of data within conventional traceability systems raises concerns. For instance, RFID technology, often employed in these systems, is prone to security breaches and manipulation, as the RFID tags are susceptible to unauthorized reading and memory access, thus jeopardizing the data's integrity (Kelepouris et al. 2007).Additionally, conventional methods typically depend on a centralized authority for the management of information exchange, which can contain inaccuracies and false claims during the data collection process (Xu et al. 2020). Despite arguments by Verdouw et al. (2013) that information concerning production, processing, and transport must be centralized for effective compilation, many parties in the food supply chain are hesitant to disclose their information to a central node.

Blockchain-based food traceability technology promises enhanced transparency, trust, and improvements in food safety (Varavallo et al. 2022; Casino et al. 2021; Behnke & Janssen 2020). Nonetheless, the high costs associated with its implementation may lead to higher prices for the end consumer (Shew et al. 2022). It is therefore essential to examine consumer attitudes toward this technology to assess its viability. This section focuses on determining how much consumers are willing to spend on blockchain traceabled food products. 'Willingness to pay' represents the maximum price a customer is willing to pay for a product or service, indicating the perceived value of that product, which can differ due to factors like income, personal preferences, and alternative options (Dwivedi et al. 2018). Additionally, 'price premium' is the additional amount a consumer is willing to pay over the cost of similar products, which reflects the added value perceived in the product or service due to specific products attributes (Dwivedi et al. 2018).

2.2 Blockchain Technology

Blockchain technology, initially rooted in the innovative invention of cryptocurrencies and financial services (Menon & Jain 2024), has undergone a remarkable evolution, extending its transformative capabilities well beyond monetary transactions. Its function across different sectors exemplifies its versatility from securing digital currencies to revolutionizing sectors like healthcare (Dwivedi et al. 2019), where it ensures data security and patient privacy; energy, through facilitating decentralized energy trading (Andoni et al. 2019); e-governance (Sullvian & Burger 2019), by improving governmental operations efficiency and digital identity and ; and sustainability and circular economy (Upadhyay et al. 2021), with applications in carbon emissions tracking and waste management. Furthermore, recent explorations into the agri-food supply chain underscore blockchain's potential to enhance food traceability, safety, and sustainability, showcasing its role in addressing pressing global challenges (Kamble et al. 2020).

The introduction of blockchain technology has significantly impacted supply chain management, particularly through the implementation of smart contracts. Smart contracts are automated protocols that facilitate, verify, or enforce the

negotiation or performance of a contract, activated when predetermined conditions are met (Casino et al. 2019). This innovation enables a more efficient execution of agreements between parties, enhancing the flow of information among supply chain members (ibid).

Smart contracts utilize blockchain's distributed ledger technology to ensure that payment terms are automatically processed once contractual conditions are fulfilled (Ferris 2019). This approach improves transparency within the supply chain, allowing for an auditable history of products, enhanced traceability, and improved monitoring of shipments and storage conditions (ibid). For consumers, this technology provides increased visibility of the product journey from farm to fork, while regulators gain access to reliable data for compliance monitoring (Ferris 2019).

The inherent attributes of blockchain technology present a robust solution to several traceability issues in the food supply chain. The decentralized nature of blockchain allows for the coordination of individual activities across the supply chain without the need for centralized storage, thereby reducing the vulnerability of a centralized data repository and ensuring continuity in case of localized failures (Galvez et al. 2018). Furthermore, blockchain's probabilistic approach to validation ensures that all entries into the ledger are transparent and verifiable without the need for a central authority, which is particularly useful in verifying the authenticity of food origin and handling. This process is supported by the network of computers solving complex mathematical problems, ensuring that only valid, non-fraudulent transactions are recorded (ibid). The permanence of recorded transactions on the blockchain provides an immutable history, essential for tracing the journey of food products from farm to table. This capability assures consumers of the provenance and safety of their food, allowing for precise identification and rapid response in the event of a food safety incident. Furthermore, the inability to delete data assures that the full history of a product's journey is always available (Bonneau et al 2015), providing a level of security and reliability that traditional databases cannot offer.

2.3 Consumer Willingness to Pay for Blockchain-Based and Other Methods of Traceability

Food traceability is critical for several reasons, including the ability to quickly respond to food safety incidents, verify the authenticity of food products, and substantiate sustainability claims (Aung & Chang 2014; Ringsberg 2014). With technological advancements, manufacturers can now provide detailed information about food products through QR codes, barcodes, and blockchain technology, enhancing transparency and enabling consumers to make informed purchasing decisions (Li & Messer 2019).

Recent literature explains the growing consumer interest in the traceability of food products, underscoring a willingness to pay towards traceability methods such as blockchain technology. Shew et al. (2022) centered their study in the USA on

meat products, discovered a relatively low awareness among consumers about blockchain and its benefits in improving traceability. They also noted that consumers placed a premium on USDA certification, valuing it at approximately $2.00 more than blockchain based certification. Lin et al. (2022) observed a contrasting preference in China, with consumers showing a stronger trust and willingness to pay an additional $0.63 per pound for blockchain-traceable meat over conventional methods of traceability. Additionally, the literature indicates that personal factors such as income level and family structure, alongside knowledge and confidence in eco-labels, significantly affect consumer willingness to pay (Czine et al. 2020; Tran et al. 2022; Liu et al. 2022). However, demographic attributes such as age, gender, and education level appear to have negligible influence on it (ibid.) In the context of the UK, Dionysis et al. (2022), through a questionnaire study design found that 75.6% of consumers were prepared to pay at least 5% more for blockchain-traceable coffee compared to basic organic coffee variants. Also consumers link blockchain to the authenticity of origin rather than improved health or taste.

To take a different approach, Tran et al. (2022) focused on the Vietnamese vegetable market and revealed through a discrete choice experiment that consumer trust is a key determinant in food certification evaluation suggesting that trustworthiness in labelling significantly affects consumer willingness to pay. Addressing other food categories, Liu et al. (2022) studied the Chinese egg market and found that factors such as knowledge, income level, having children, and trust in eco-labels inconsiderably influenced willingness to pay. In contrast, Czine et al. (2020) highlighted the influence of label of origin on Hungarian consumers' preferences for meat, indicating a willingness to pay for this information with a significant influence of age, gender and income level on it. Furthermore, Duckworth et al. (2022) emphasized the high value placed on sustainability and locality in food sourcing within the UK rice market, pointing out that consumers have the highest willingness to pay for these attributes.

To identify broader trends in this field of research a meta-analysis conducted by Tran et al. (2024) synthesizes findings from 72 peer-reviewed articles since 2002 and reveals that consumers' WTP for food traceability has shown a steady upward trend, reaching a price premium of around 32%. Notably, consumers in developing countries exhibit a higher WTP for traceable food compared to those in developed countries. Additionally, traceability for meat products commands a higher premium than for other food categories.

The method of communicating traceability information significantly impacts consumer WTP. Embedded codes, such as QR codes, tend to lower WTP, likely due to the additional effort required by consumers to access the information. In contrast, explicit communication about traceability-enabling technologies, such as blockchain, positively influences WTP (Tran et al. 2024). This suggests that consumers value transparency and the reliability provided by advanced traceability technologies.

Combining traceability with other credence attributes, such as organic certification or animal welfare, enhances consumer WTP. This indicates that

consumers perceive greater value when traceability information is associated with additional quality assurances (Hobbs et al. 2005). Conversely, combining traceability with intrinsic attributes, like appearance or flavor, tends to reduce WTP. This is because intrinsic attributes can be evaluated through direct experience, diminishing the perceived necessity of traceability information (Castillo & Carpio 2019).

Methodological factors also play a crucial role in determining reported WTP. Studies involving university populations, offline data collection, purposive sampling, and hypothetical methods generally report higher WTP. However, incorporating techniques such as "cheap talk" to mitigate hypothetical bias results in more accurate and lower WTP estimates (Tran et al. 2024).

3. Methodology

3.1 Research Philosophy

The development of knowledge is shaped by the research philosophy, which encompasses the researcher's assumptions and beliefs (Saunders et al. 2019). These foundational assumptions stem from ontological and epistemological perspectives that guide the study's methodology (Guba & Lincoln 1994). Ontology, in this regard, concerns the fundamental nature of reality (Slevitch 2011). Objectivism holds that reality exists independently of human thought (Crotty 1998), indicating that objective truths and association links await discovery within the context of the agri-food supply chain. Given that this study utilizes quantitative data gathered online from consumers in Iran, it adopts an objectivist ontological stance (Bell et al. 2022). In this framework, objectivism views the interactions between social phenomena and actors as separate, allowing researchers to observe without participating (ibid.).

Epistemology, intertwined with ontology, addresses the nature of truth and what constitutes valid knowledge, building logically on the ontological basis (Slevitch 2011). Thus, a chosen ontological viewpoint inherently influences the epistemological approach (Bell et al. 2022). Positivism, as the relevant epistemological position, advocates for the use of empirical observation and measurable data to identify these objective truths and create generalizable knowledge. In this positivist framework, social phenomena are subject to direct observation and measurement through survey methods, as implemented in this thesis. Consistent with this philosophical orientation, the research employs a deductive reasoning approach, generating hypotheses from existing theories and prior research, which are then tested and validated through data collection and analysis.

3.2 Survey Design

Contingent Valuation (CV), as described by Mitchell and Carson (1989), is a widely used technique to collect data on stated preferences. Grunert et al. (2009)

highlight its usability to determine WTP in situations where market prices are unavailable.

CV provides a direct measurement of WTP and is especially useful for assessing the value of non-market goods. It is particularly recommended for evaluating entirely new products that lack existing market prices (Cuccia 2020). This method allows respondents to express their economic valuation for such goods. According to Mitchell and Carson (1989), CV involves using survey questions to elicit people's preferences for public goods by asking how much they would be willing to pay for specified improvements in products or services.

Due to its effectiveness in eliciting WTP where market data is unavailable or tangible products cannot be tested, CV has expanded from a methodology for valuing natural resources to a marketing tool. This technique has been used to estimate WTP for market goods, such as food products, by researchers like Boccaleti and Nardella (2000), Grunert et al. (2009), and Gil et al. (2000). Moreover, the CV method offers greater flexibility and is more cost-effective than other methods that aim to replicate real purchasing scenarios, such as experimental market studies (Boccaleti & Nardella 2000).

Consequently, CV method, a stated preference technique, was employed to estimate consumer's willingness to pay for blockchain-traceable goods in this study. This approach is particularly useful in assessing how respondents might behave in hypothetical market scenarios. Given that blockchain-traceable goods are not currently available on the Iranian market, non-hypothetical methods of assessing consumer behavior and transactions in this context are inapplicable. Therefore, the CV method serves as an ideal approach for this research. It allows for the exploration of potential consumer transactions and preferences in a hypothetical context where these advanced traceability features are assumed to be available.

The survey was conducted from April 10 to April 17, 2024, utilizing an online questionnaire hosted on the Qualtrics platform. This section outlines the methodology employed in the design and execution of the survey.

3.2.1 Participants and Data Collection

The data was collected through a close-ended questionnaire. The study targeted individual consumers in Iran as the unit of analysis, using a convenience sampling method. The survey was initially developed in English and subsequently translated into Persian to facilitate understanding among local participants. A total of 188 participants were recruited. All of them were above 18 years of age. Informed consent was obtained at the beginning of the survey, where participants were also informed about the study's purpose, the confidentiality of their responses, voluntary participation, and their right to withdraw at any time (please refer to Appendix A). It was also emphasized that all data collected would be treated anonymously and used for academic research purposes only.

3.2.2 Introduction and Educational Component

Following consent, an educational block introduced participants to the concept of blockchain technology within the food supply chain. This brief information block aimed to provide a basic understanding of how blockchain could enhance food safety and authenticity, setting the stage for the questions that followed. Information was phrased neutrally to avoid presenting the technology too positively.

3.2.3 Survey Structure and Scenario-Based Questions

The core of the questionnaire comprised two main blocks of scenario-based questions, focusing on purchasing decisions for infant formula and salt under different conditions of traceability and certification. Each product scenario was presented in three variations to assess the impact of traceability features on willingness to pay:

1. **Infant Formula scenarios** involved choices between no safety label, conventional certification, and blockchain-based traceability, with price options ranging from zero to three times the average market price. The products were otherwise the same, apart from their traceability label.
2. **Salt scenarios** mirrored the structure of the infant formula scenarios, differing only in the product context but maintaining similar variations in information availability and certification.

Participants responded to these scenarios in a randomized order to minimize order effects, and at the end of each block, they were asked to rate the realism of the scenarios to determine the applicability to their daily experiences. To design the scenarios inclusive for a larger sample size (as infant formula is typically bought only for young children), we asked respondents to assume they were asked by a close friend to buy the products. The price range for both products was from zero to three times more than the average market price in Iran.

3.2.4 Demographic Component

Subsequent sections of the questionnaire collected socio-demographic information, including age, gender, education level, household income, and familiarity with blockchain technology.

3.3 Method of Analysis

3.3.1 Wilcoxon Signed Rank Test

The Wilcoxon Signed Rank Test is a non-parametric statistical test used to compare two matched samples, related samples, or repeated measurements on a single sample to assess the difference between their population distributions (Corder & Foreman 2014; Wright & London 2009). This test is appropriate for use when the normality assumption for a standard parametric test cannot be verified (Corder & Foreman 2014). For this study, the Wilcoxon signed-rank test was employed to compare consumer WTP for salt and infant formula under three different certification scenarios.

The choice of the Wilcoxon signed-rank test for this study is motivated by several factors. Firstly, the WTP data collected in the survey is not expected to follow a normal distribution, which makes a non-parametric test more appropriate. The Wilcoxon signed-rank test does not require the assumption of normality (Corder & Foreman 2014). Secondly, the survey responses for WTP are interval data, as they measure the amount participants are willing to pay under different certification conditions. The Wilcoxon signed-rank test appropriately handles such data by ranking the differences (ibid). This test uses information about the magnitude of the differences (Corder & Foreman 2014).

3.3.2 Regression

Multiple Linear Regression (MLR) is a statistical technique used to examine the relationship between one dependent variable and two or more independent variables (Elliott & Woodward 2007; Fink 2003; Evans 2013). It extends the simple linear regression model by allowing for multiple predictors, providing a comprehensive analysis of the factors influencing the dependent variable (Elliott & Woodward 2007).

In the context of this study, MLR was employed to analyze the factors affecting consumer WTP. More specifically, a regression analysis was conducted to examine the influence of demographic factors (age, gender, household income, education level), on WTP. The data was reshaped from a wide to a long format to account for correlations within individuals more effectively.

The model included dummy variables for the different certification types and controlled for demographic characteristics to isolate the effect of differences in the certification types on WTP. The dependent variable was WTP, and the independent variables included certification type, age, gender, household income, education level.

3.4 Validity

3.4.1 Small Sample Size and Associated Risks

The validity of this study's findings may be influenced by the relatively small sample size of 73 respondents. Small sample sizes pose risks of increased Type I and Type II error. A Type I error, or false positive, occurs when the null hypothesis is incorrectly rejected, suggesting that there is an effect when there is none (Saunders et al. 2019). For example, in the context of this study, this could mean incorrectly concluding that blockchain certification has a significant effect on WTP when it does not. Conversely, a Type II error, or false negative, occurs when the null hypothesis is not rejected when it should be, leading to a failure to detect an actual effect. Following our previous example this could result in missing the true impact of blockchain certification on WTP. Small sample sizes reduce the statistical power of the study, making it harder to detect true effects and increasing the risk of both types of errors (Bell et al. 2022).

3.4.2 Bias in Sample Selection

Bias in sample selection is another validity concern (Bell et al. 2022). The study employed a convenience sampling method targeting consumers in Iran who were willing to participate in an online survey. This method may introduce selection bias, as it may not represent the broader population of Iranian consumers. Those who chose to participate might have specific characteristics or interests, such as a higher interest in blockchain technology or food safety, which could skew the results. This self-selection bias can affect the generalizability of the findings, limiting the extent to which the results can be applied to the general consumer population in Iran or other contexts (Bell et al. 2022).

3.4.3 Hypothetical Bias in Contingent Valuation

Hypothetical bias is a significant issue in CV and other preference methods, where respondents are asked to state their willingness to pay in hypothetical scenarios. This bias arises because there are no real financial consequences for their stated preferences, leading to discrepancies between hypothetical WTP and real WTP. A comprehensive study by Schmidt and Bijmolt (2020) delves into this phenomenon through a meta-analysis of 77 studies, revealing important insights into the nature and extent of hypothetical bias in consumer goods valuation.

The meta-analysis by Schmidt and Bijmolt (2020) finds that, hypothetical bias results in 21% increase in reported WTP when measuring hypothetical WTP compared to real WTP. This means that when respondents state their WTP in a hypothetical context, they tend to overstate it by this margin compared to what they would actually pay in real-life situations.

Measurement method is one of the factors influencing hypothetical bias. Contrary to conventional wisdom, the study finds that indirect methods (e.g.,

choice-based conjoint analysis) often result in a higher hypothetical bias compared to direct methods (Schmidt & Bijmolt 2020). Indirect methods, which simulate real shopping experiences, were thought to be more accurate, but the findings suggest otherwise (Schmidt & Bijmolt 2020). Direct methods, despite their simplicity, tend to evoke lower hypothetical bias. Thus, this study will use direct method (close-ended questions) to decrease the hypothetical bias.

4. Results and analysis

The online questionnaire resulted in 73 responses out of 188, after screening out 115 undesired responses. The responses that were missing an answer for any of the six shopping scenarios were omitted.

4.1 Descriptive Statistics

4.1.1 Categorical Variables

In the questionnaire, participants provided information on four categorical variables: their highest educational degree, gender, household income, and awareness of blockchain applications in food safety.

Table 1 presents a summary of the descriptive statistics for these variables. The survey data revealed the distribution of the highest educational degree attained by the participants. Out of 72 respondents, a majority, representing 50%, hold a Bachelor's degree. This is followed by 31.94% of participants with a Master's degree. Those with higher degrees constitute 9.72%, while the least represented group is that of respondents with a High School Diploma at 8.33%. The cumulative percentages indicate a progressively inclusive higher education level among the participants. One participant decided to not indicate her education level.

Regarding gender distribution of participants, 72.60% of the 73 respondents identified as female, whereas 27.40% identified as male. This data shows that female respondents formed the majority of participants in the survey. Other subcategories were not chosen by any of the participants.

Household income was divided into four categories among the 73 participants. Five respondents decided not to disclose their monthly household income. Respondents with an income below 20 million Toman constituted the largest group, representing 38.24%. The second largest group, at 35.29%, consisted of those earning between 20 and 40 million Toman. The two smaller groups included respondents with incomes between 40 and 60 million Toman (13.24%) and those above 60 million Toman (13.24%). The majority of respondents reported income in the lower ranges—below 20 million Toman and between 20-40 million Toman. This left relatively fewer participants in the higher income categories (40-60 million Toman and above 60 million Toman). Consequently, the income distribution is not

symmetric and shows a higher concentration of respondents in the lower income ranges, indicating a left-skewed distribution.

The data on awareness of blockchain application in food safety showed that the majority (72.60%) of the 73 respondents indicated that they have never heard about the application of blockchain technology in the food supply chain for ensuring safety and authenticity of the food products, while 27.40% reported being aware of it. This result suggests that a majority of respondents are unfamiliar with blockchain applications in this context.

Table 1 Descriptive Statistics for Highest Degree, Gender, Household Income, and Awareness of Blockchain Applications in Food Safety

Category	Subcategory	Absolute Frequency	Percentage (%)
Highest Degree	High School Diploma	6	8.33
	Bachelor's Degree	36	50.0
	Master's Degree	23	31.94
	Higher Degrees	7	9.72
Gender	Female	53	72.6
	Male	20	27.4
	Other	0	0
Household Income	Lower than 20M Toman	26	38.24
	20-40M Toman	24	35.29
	40-60M Toman	9	13.24
	More than 60M Toman	9	13.24
Awareness of Blockchain in Food Safety	No	53	72.6
	Yes	20	27.4

4.1.2 WTP Variables

In the questionnaire, participants provided information on six shopping scenarios. These scenarios were designed to gauge customers' willingness to pay for salt and infant formula in three conditions: when the product lacks a safety certificate, when it has conventional certificates, and when it uses blockchain-based certification. Table 2 presents the descriptive statistics for these six scenarios for all 73 participants. All monetary values are expressed in Iranian Toman.

Table 2 Descriptive Statistics for Variables Measuring Customer Willingness to Pay for Salt and Infant Formula in Three Conditions: No Certificate, Normal Certificate, and Blockchain Certificate. (The Values are Expressed in Iranian Toman)

Scenario	Mean	Median	Standard Deviation	Min	Max
Salt WTP (No Certificate)	15,452.05	12,000	15,585.82	0	60,000
Salt WTP (Normal Certificate)	32,383.56	30,000	18,807.97	6,000	60,000
Salt WTP (Blockchain Certificate)	36,246.58	36,000	18,532.09	6,000	60,000
Infant Formula WTP (No Certificate)	733,561.6	450,000	1,111,182	0	4,500,000
Infant Formula WTP (Normal Certificate)	1,417,808	1,350,000	1,083,409	450,000	4,500,000
Infant Formula WTP (Blockchain Certificate)	1,775,342	1,350,000	1,218,353	450,000	4,500,000

For salt, the mean WTP without any certificate is 15,452.05 Toman and median of 12,000 Toman, with a substantial variation as indicated by a standard deviation of 15,585.82 Toman, and values ranging from 0 to 60,000 Toman. The presence of a normal certificate increases the mean WTP to 32,383.56 Toman and the median to 30,000 Toman, although variability remains high (standard deviation of 18,807.97 Toman), and the range extends from 6,000 to 60,000 Toman. The introduction of a blockchain certificate further elevates the mean WTP to 36,246.58 Toman and the median to 36,000 Toman, with slightly reduced variability (standard deviation of 18,532.09 Toman) compared to the normal certificate scenario, maintaining the same range.

For infant formula, customer WTP without any certificate averages at 733,561.6 Toman and the median is 450,000 Toman, with a standard deviation of 1,111,182 Toman, showing significant variability, with values spanning from 0 to 4,500,000 Toman. With a normal certificate, the mean and median WTP dramatically

increases to 1,417,808 Toman, and 1,350,000 Toman respectively; however, the variability is high (standard deviation of 1,083,409 Toman), with all values tightly packed at the upper range limit of 4,500,000 Toman. Incorporating a blockchain certificate sees the highest mean WTP at 1,773,342 Toman, again with extremely high variability (standard deviation of 1,218,353 Toman), and a maximum value consistently at 4,500,000 Toman. In this scenario, the median remains unchanged at 1,350,000 Toman compared to the scenario with a normal certificate.

These statistics indicate a clear trend of increased WTP associated with the presence and type of certificate, suggesting that certification, particularly blockchain certification, has an influence on consumer valuation of these products.

4.1.3 Other Variables

Apart from the previously mentioned variables, participants were also asked about their age and their overall familiarity with blockchain technology. Table 3 provides a summary of the descriptive statistics for these two variables.

Table 3 Descriptive Statistics for Age and Familiarity of Participants with Blockchain Technology

Variable	Observations	Mean	Median	Standard Deviation	Min	Max
Age	72	33.05556	30.5	9.497055	21	62
Blockchain Familiarity	62	3.483871	4	2.890016	0	10

The variable "Age" is reported for 72 participants (1 respondent decided to skip the question), revealing an average age of 33.06 years while median is 30.5. The spread of ages among participants is fairly broad, as evidenced by a standard deviation of 9.47 years, with ages ranging from 21 to 62 years. This indicates a slightly diverse sample in terms of age.

The "Blockchain Familiarity" scores are reported for 62 participants, suggesting that some respondents did not provide data for this variable. The average familiarity score is 3.48 on a scale from 0 (no familiarity) to 10 (extremely familiar), with a standard deviation of 2.89. This moderate average score, coupled with the range of scores from 0 to 10, suggests a varied level of understanding and exposure to blockchain technology among the participants.

4.2 Evaluating Statistical Significance Between Certification Types and Consumer WTP

To determine significant differences in consumer WTP across certification conditions (No Certificate, Normal Certificate, and Blockchain Certificate), we employ the Wilcoxon signed-rank test. This non-parametric statistical method is ideal for comparing paired samples. It allows us to detect subtle differences in consumer preferences among the certification scenarios for each product type. By conducting this analysis at a conventional 0.05 significance level, we aim to ensure that the impact of certification on WTP is statistically significant. In the next two sections, we present our findings for both salt and infant formula.

4.2.1 Comparing Distributions of WTP for Salt

Table 4 displays the results of Wilcoxon signed-rank tests comparing the distribution of consumer WTP for salt across different certification scenarios. The compared scenarios include "No Certificate vs. Normal Certificate," "No Certificate vs. Blockchain Certificate," and "Normal Certificate vs. Blockchain Certificate.

Results Analysis:

1. **No Certificate vs. Normal Certificate:** The Z-value is -6.548, and the corresponding p-value is 0.0000. This result ($p < 0.05$) indicates that the data are not consistent with the WTP coming from the same distribution.
2. **No Certificate vs. Blockchain Certificate:** The Z-value is -7.043, with a p-value of 0.0000. Similar to the previous comparison, the p-value shows a difference ($p < 0.05$) between salt with no certification and the one with a blockchain certificate. This suggests that data are not consistent with the null hypothesis.
3. **Normal Certificate vs. Blockchain Certificate:** This result also points to a difference ($p < 0.05$) in customer WTP between salt with a normal certificate and that with a blockchain certificate. The null hypothesis is that the variables come from the same distribution. The observed data do not fit well with what would be expected if the null hypothesis was true. Thus, the null hypothesis is rejected.

Overall Conclusion: These findings highlight the impact of certification type on customer willingness to pay for salt, with the blockchain certificate being the most preferred option, followed by the normal certificate.

Table 4 Wilcoxon Signed-Rank Test Results Comparing Customer WTP for Salt Across Different Certification Scenarios

Compared Scenarios for Customer WTP for Salt	Z	p
No Certificate / Normal Certificate	-6.548	0.0000
No Certificate / Blockchain Certificate	-7.043	0.0000
Normal Certificate / Blockchain Certificate	-3.184	0.0015

4.2.2 Comparing Distributions of WTP for Infant Formula

Table 5 presents the results of Wilcoxon signed-rank tests comparing customer WTP for infant formula under different certification scenarios. The certification scenarios used here are the same as those applied to salt.

Results Analysis:

1. **No Certificate vs. Normal Certificate:** The Z value of -6.118 and p-value of 0.0000 indicate a difference in WTP between these scenarios, suggesting that a normal certificate significantly increases customer WTP compared to no certification. This result ($p < 0.05$) indicates that the data are not consistent with the WTP coming from the same distribution.
2. **No Certificate vs. Blockchain Certificate:** With a Z value of -6.768 and a p-value of 0.0000, the test demonstrates a difference in WTP. The p-value of less than 0.05 shows that the data is not consistent with the null hypothesis.
3. **Normal Certificate vs. Blockchain Certificate:** The Z value of -4.782 and a p-value of 0.0000 show a difference between these scenarios. This suggests that data are not consistent with the null hypothesis.

Table 5 Wilcoxon Signed-Rank Test Results Comparing Customer WTP for Infant Formula Across Different Certification Scenarios

Compared Scenarios for Customer WTP for Infant Formula	Z	p
No Certificate / Normal Certificate	-6.118	0.0000
No Certificate / Blockchain Certificate	-6.768	0.0000
Normal Certificate / Blockchain Certificate	-4.782	0.0000

Overall Conclusion: Similar to the findings for salt, significant differences were noted across all pairs, with higher certification standards positively affecting customer willingness to pay for infant formula.

4.3 Analysis of Ratios of WTP Across Certification Types

To analyze consumer behavior regarding willingness to pay for various certification types across products with different sensitivity levels, we created ratio variables to normalize price differences. Comparing WTP ratios allows us to standardize the inherent differences in scale between these products and facilitates a clearer understanding of how different certification types, influence consumer preferences across varying sensitivity levels. Specifically, products like salt and infant formula exhibit distinct market characteristics and varying levels of importance to different consumer segments.

We generated three different ratios for each product: WTP for no certification / WTP for blockchain-based certification, WTP for no certification / WTP for standard certification, and WTP for standard certification / WTP for blockchain certification. Consequently, we have a total of six different ratios.

Once these ratio variables are created, non-parametric tests can be employed to identify differences in WTP for different certification types across varying sensitivity levels. Table 6 presents the descriptive statistics for these six variables.

Table 6 Descriptive Statistics for Ratio Variables Measuring Customer WTP Cross Product and Cross Certification

Variable	Observations	Mean	Median	Standard Deviation	Min	Max
Salt No Certification/ Blockchain Certification Ratio	73	0.4856	0.4	0.5400	0	4
Salt No Certification/ Normal Certification Ratio	73	0.5292	0.5	0.4523	0	2
Salt Blockchain Certification / Normal Certification Ratio	73	1.2824	1	0.6563	0.3333	5
Infant Formula No Certification/ Blockchain Certification Ratio	73	0.3956	0.3333	0.5093	0	3.3333
Infant Formula No Certification/ Normal Certification Ratio	73	0.4869	0.3333	0.6096	0	3.3333
Infant Formula Blockchain Certification / Normal Certification Ratio	73	1.3936	1.2	0.6732	0.5	4

4.4 Evaluating Statistical Significance for Ratio Variables and WTP

Table 7 displays the results of a Wilcoxon signed-rank test comparing customer WTP for three different certification scenarios compared to a benchmark for a sensitive (Infant Formula) and non-sensitive (Salt) product. The benchmark for each ratio is the denominator.

Table 7 Wilcoxon Signed-Rank Test Results Comparing Customer WTP for varying certification types Across Different sensitivity levels

Compared Scenarios for Customer WTP for ratio variables	**Z**	**p**
Salt and Infant Formula ratios of No Certification/ Blockchain Certification	2.024	0.0430
Salt and Infant Formula ratios of No Certification/ Normal Certification	1.618	0.1057
Salt and Infant Formula ratios of Blockchain Certification / Normal Certification	-1.212	0.2254

4.4.1 Salt and Infant Formula Ratios of No Certification/Blockchain Certification

The null hypothesis (H0) proposed that the distribution of the ratios of No Certification/Blockchain Certification for salt and infant formula would be identical. However, the Wilcoxon signed-rank test resulted in a Z-value of 2.024 with a p-value of 0.0430, indicating a statistically significant difference in willingness to pay ratios between salt and infant formula for no certification versus blockchain certification. This significant result leads to the rejection of the null

hypothesis. Consequently, it is evident that consumers are willing to pay a higher premium for blockchain-certified infant formula compared to blockchain-certified salt when no certification serves as the benchmark. This outcome strongly suggests that people have a greater preference for blockchain certification in sensitive products compared to non-sensitive ones.

4.4.2 Salt and Infant Formula Ratios of No Certification/Normal Certification

The null hypothesis (H0) stated that the distribution of the ratios of No Certification/Normal Certification for salt and infant formula is the same. The Wilcoxon signed-rank test produced a Z-value of 1.618 with a p-value of 0.1057, suggesting that the difference in willingness to pay ratios between salt and infant formula for no certification versus normal certification is not statistically significant. This result indicates that the sensitivity of the products does not significantly influence the WTP for normally certified products.

4.4.3 Salt and Infant Formula Ratios of Blockchain Certification/Normal Certification

The null hypothesis (H0) posited that the distribution of the ratios of Blockchain Certification/Normal Certification for salt and infant formula is the same. The Wilcoxon signed-rank test yielded a Z-value of -1.212 with a p-value of 0.2254, indicating no statistically significant difference in WTP ratios between salt and infant formula for blockchain versus normal certification. This result implies that the shift from normal to blockchain certification does not significantly affect WTP.

4.5 Regression Analysis

To assess whether variables including age, gender, household income, and familiarity with blockchain impact customer willingness to pay, we conducted a regression analysis. To do so, we began by reshaping the data from a wide format to a long format. In the wide format, each individual's WTP values are stored in separate columns. By converting to a long format, all WTP values will be in one column (WTP), with another column (Certificate Type) indicating which certification or variable the WTP value corresponds to. Apart from simplifying the analysis, reshaping the data allows us to account for correlations within individuals more effectively (e.g., using clustered standard error). The regression model, based on 330 observations (after reshaping the data), is statistically significant with an F-statistic of 11.74 and a p-value of 0.0000, explaining approximately 48.18% of the variation in the dependent variable (WTP). Standard errors were clustered at

respondent level to account for correlated errors within a single respondent. Table 8 presents the results of the regression analysis.

Table 8 Regression Analysis Results of Factors (Certification type, Age, Gender, Household Income, Highest Education Degree, and Blockchain Familiarity) Influencing Customer WTP

WTP	Coefficient	Robust Standard Error	t	p > |t|
Certification Type				
Formula Normal Certification Scenario	695454.5	126983.4	5.48	0.000
Formula Blockchain Certification Scenario	1022727	138515.1	7.38	0.000
Salt No Certification Scenario	-694090.9	131943.5	-5.26	0.000
Salt Normal Certification Scenario	-676636.4	131563.3	-5.14	0.000
Salt Blockchain Certification Scenario	-673000	131553.9	-5.12	0.000
Age	6622.669	6392.639	1.04	0.304
Gender				
Male	192307.7	131502.1	1.46	0.148
Household Income				
20-40 M Toman	144137.1	131126.4	1.10	0.276
40-60 M Toman	165464.7	164207.5	1.01	0.317
More Than 60 M Toman	-139285.7	172770.3	-0.81	0.423
Highest Degree				
Bachelor's Degree	13874.93	203845.5	0.07	0.946
Master's Degree	104635	219073.4	0.48	0.635
Higher Degree	455457.6	320554.5	1.42	0.160
Constant	292265.6	298585.9	0.98	0.331

Age: Age was positively associated with customer WTP, but the relationship was not statistically significant (coefficient = 6622.669, p = 0.304).

Gender: Coefficient for male respondents was positive but not statistically significant (coefficient = 192307.7, p = 0.148), suggesting no significant difference in WTP between males and females.
Household Income: The effect of household income on WTP was assessed using three categories relative to a reference group (Lower than 20 M Toman). None of the income levels showed significant effects.
Highest Degree: The education level was categorized into bachelor's, master's, and higher degrees, with a base reference group (High School Diploma). No significant differences were found across education levels.
Constant: The constant term, representing the baseline WTP when all other predictors are zero, was not statistically significant (coefficient = 292265.6, p = 0.331).

The benchmark for the dummy variables representing shopping scenarios is the WTP for baby formula with no certification. The coefficients for the certification types are relative to this benchmark, indicating changes in WTP. The negative coefficients for salt products reflect that WTP for salt is generally lower than for baby formula. Among the salt products, no certification has the most negative coefficient, followed by normal certification with a slightly less negative coefficient. Blockchain certification has the smallest negative coefficient among the salt products, indicating the highest WTP in this category. WTP for blockchain certification in infant formula scenario is higher than normal certification. Overall, these results confirm the pairwise tests above.

5. Discussion and Conclusion

5.1 Discussion

The findings of this study offer a refined perspective on consumer preferences and willingness to pay for certified salt and infant formula in Iran. This research clarifies several critical areas, providing valuable insights when compared with existing literature.

5.1.1 Certification and Consumer Trust

The role of certification in influencing consumer purchasing decisions is well-documented in the literature. Hatanaka and Busch (2008) and UNDP (2021) highlighted the growing importance of third-party certifications in ensuring food safety and quality standards. This study corroborates these findings, demonstrating that consumers are willing to pay significantly more for certified products, whether standard or blockchain-certified, compared to uncertified ones. This reinforces the value consumers place on certification as a marker of quality and safety.

However, this study reveals a particularly strong preference for blockchain certification, especially for sensitive products like infant formula. This preference aligns with the observations of Lin et al. (2022) in China, where consumers showed a willingness to pay a premium for blockchain-traceable meat. The preference for blockchain certification may be attributed to the enhanced transparency and security that blockchain technology offers, as noted by Behnke and Janssen (2020) and Casino et al. (2021). The study's finding that consumers in Iran also value blockchain certification underscores its growing global appeal.

5.1.2 Impact of Consumer Demographics

The influence of consumer demographics on WTP for certified products has been a mixed area in the literature. Studies by Czine et al. (2020) and Liu et al. (2022) suggested that factors such as income, family structure, and trust in eco-labels significantly affect WTP. However, this study found that demographics such as age, gender, income, educational level, and familiarity with blockchain technology did not significantly impact WTP. This discrepancy could be due to

cultural or regional differences in consumer behavior, indicating that demographic factors may not uniformly influence WTP across different markets.

5.1.3 Trust and Transparency

The significant trust placed in blockchain certification by Iranian consumers aligns with broader trends in consumer behavior towards transparency and trust in the food supply chain. Blockchain's ability to provide a decentralized and immutable record of transactions enhances consumer confidence in the authenticity and safety of food products (Galvez et al. 2018; Bonneau et al. 2015). This study's results, which show a higher WTP for blockchain-certified products, support the idea that consumers value the transparency and reliability offered by blockchain technology.

5.1.4 Policy and Marketing Implications

The study's findings have important implications for policy and marketing strategies. The high WTP for blockchain-certified products suggests that regulatory bodies should consider promoting blockchain technology as a standard for product certification. This could enhance consumer confidence and ensure product authenticity and safety, as suggested by existing literature on the benefits of blockchain in food traceability (Ferris 2019; Kamble et al. 2020).

For businesses, the insights from this study can inform targeted marketing strategies. Emphasizing the benefits of blockchain certification, such as enhanced safety and authenticity, can attract more consumers and justify premium pricing. This aligns with the recommendations of Duckworth et al. (2022) and Dionysis et al. (2022), who highlighted the importance of promoting specific product attributes to enhance consumer appeal.

It is important to note that our results may be influenced by both false negatives and false positives due to the sample size used in our study. This underscores the need for repeating our analysis with a larger sample size to more thoroughly investigate the impact of consumer demographics and familiarity with blockchain technology on these findings.

5.2 Concluding Remarks

This study reveals several key insights into consumer preferences and their WTP for certified salt and infant formula in Iran. In the following, we describe the primary conclusions drawn from the research findings:

Certification plays a crucial role in influencing consumer purchasing decisions, as evidenced by research showing that the presence of any certification, whether standard or blockchain, notably increases the willingness to pay for products like salt and infant formula. Statistical analysis, such as the Wilcoxon signed-rank tests,

confirms that consumers are prepared to pay significantly more for certified goods compared to uncertified ones, highlighting the value they place on product certification.

Consumer demographics such as age, gender, income, and educational level generally showed no statistically significant impact on the willingness to pay.

Lastly, Ratios of WTP for different certification types highlighted consumer preferences for blockchain certification over no certification and normal certification, particularly for sensitive products like infant formula. This suggests a higher perceived value and trust in blockchain certification.

The findings of this study have several important implications for consumer trust, policy considerations, and marketing strategies. First, the significant increase in willingness to pay for blockchain-certified products indicates that consumers place higher trust and value on the transparency and security provided by blockchain technology. This suggests a potential market advantage for companies that adopt blockchain certification in their supply chains, particularly for products that require high safety standards, such as infant formula specifically in the case that companies do not already have a certification.

Additionally, these findings have important policy and regulatory considerations. Regulatory bodies might consider promoting blockchain technology as a standard for product certification to enhance consumer confidence and ensure product authenticity and safety. Such measures could lead to the broader acceptance and implementation of blockchain solutions across various industries.

Finally, businesses can leverage these insights to develop targeted marketing strategies that emphasize the benefits of blockchain certification. By highlighting the enhanced safety and authenticity of blockchain-certified products, companies can attract more consumers and justify premium pricing. This approach not only addresses consumer concerns but also capitalizes on the trust and value associated with blockchain technology.

5.3 Future Research

The subject offers several opportunities for further research, particularly in areas that could substantially improve our understanding and application of technology in various contexts. One key area for expansion is consumer demographics. By incorporating a broader demographic sample, research could be generalized across various consumer groups internationally, offering insights with global applicability.

Another essential area for exploration is the cost-benefit analysis of blockchain technology in the food industry. Detailed studies on the economic feasibility of implementing blockchain at different scales of operations could illuminate potential financial challenges or advantages. This information is crucial for businesses that are considering adopting blockchain to enhance transparency and efficiency in their operations.

Additionally, technological acceptance is a crucial research domain. Investigating the factors that influence consumer trust and acceptance of blockchain

technology in food safety is essential. Understanding these factors will facilitate the development of more effective educational programs and marketing strategies, ultimately promoting broader acceptance and utilization of this promising technology.

Finally, Additional studies could investigate the impact of other variables such as cultural factors, brand loyalty, and individual consumer concerns. Such studies could further explain consumer behaviours in willingness to pay for certified products.

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Popular science summary

The Power of Blockchain: Ensuring Food Safety and Transparency

Imagine walking into a grocery store and knowing exactly where your food comes from and how it was handled along the way. This dream is becoming a reality thanks to blockchain technology, a revolutionary tool originally designed for cryptocurrencies but now transforming the way we trace and ensure the safety of our food.

The Problem: Trust and Safety in the Food Supply Chain

Food safety is a critical issue worldwide. Contaminated food can cause severe health problems and even death. Traditional methods of ensuring food safety, like paper-based tracking systems, are often inefficient and prone to errors or fraud. This lack of reliable information has eroded public trust in the food supply chain.

In recent years, several food scandals have highlighted these vulnerabilities, from mislabeled products to outbreaks of foodborne illnesses. These incidents underscore the urgent need for a more transparent and reliable system to track food from farm to table.

The Solution: Blockchain Technology

Blockchain technology offers a promising solution to these challenges. At its core, blockchain is a decentralized ledger that records transactions across multiple computers. This makes the information tamper-proof and easily accessible to all stakeholders, ensuring transparency and trust.

In the context of food safety, blockchain can provide a complete, immutable record of a product's journey through the supply chain. From the moment it's harvested to the time it reaches the consumer, every step is documented and can be verified. This level of transparency can significantly reduce the risk of contamination and fraud, and enhance consumer confidence.

Our Study: Measuring Consumer Willingness to Pay

To understand how much consumers value this enhanced transparency, we conducted a study focusing on two products: infant formula and salt. We chose

these products because they represent different levels of sensitivity regarding safety. Infant formula is highly sensitive due to its direct impact on infant health, whereas salt is less so.

We surveyed 73 participants in Iran, asking them how much they would be willing to pay for these products under three conditions: no certification, conventional certification, and blockchain-based certification.

Key Findings

Our findings were clear: consumers are willing to pay more for products certified through blockchain technology, especially for sensitive items like infant formula. This indicates a strong demand for transparency and safety in food products. Interestingly, demographic factors such as age, gender, and income did not significantly impact willingness to pay, suggesting broad support across different consumer groups.

Why It Matters

These results have significant implications for producers, retailers, and policymakers. For producers and retailers, adopting blockchain technology can differentiate their products in the market and justify higher prices. For policymakers, promoting blockchain as a standard for food certification can enhance food safety and restore public trust.

Moreover, as more consumers become aware of and demand blockchain-certified products, we can expect a shift towards more transparent and trustworthy food supply chains globally.

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Thank you all for making this achievement possible.

Appendix 1

Questionnaire

Informed Consent

Welcome to the research study!

Introduction: Thank you for considering participation in our survey. We are interested in understanding how consumers value different aspects of food items. The feedback you provide is crucial for our research.

Survey Overview: This survey is designed to be concise, requiring approximately 15 minutes of your time. Please be assured that all responses will be treated with the utmost confidentiality and will solely be utilized for academic research purposes.

Your participation in this research is voluntary. You have the right to withdraw at any point during the study. If you have any inquiries or require further information about the survey, please do not hesitate to reach out via email to the investigator of the study, Sara Ershadrad, at: saed0011@stud.slu.se.

By clicking the button below, you acknowledge:
- Your participation in the study is voluntary.
- You are at least 18 years of age.
- You are aware that you may choose to terminate your participation at any time for any reason.

Options:

- I consent, begin the study.
- I do not consent; I do not wish to participate.

**** If the participant does not consent: Skip to End of Survey**

Background Information

Blockchain technology can be utilized to trace food from farm to fork ensuring authenticity and quality throughout the entire food supply chain. Utilizing blockchain technology can help decentralize product information to store and trace

back where the products come from. It means that at every step of production to the moment it arrives at your table, the food journey can be tracked.

**** Shopping Scenario 1 and Shopping Scenario 2 was randomized**

Shopping Scenario 1

Q1. Imagine a close friend of yours who has a 3-months old baby asked you to buy infant formula powder. You find a product that meets all their nutritional requirements. What is the price you are willing to pay for an 800g canister from a generic brand without safety label? This product offers no specific information about its source or the processes it has undergone before reaching the store. (The price is stated in Iranian Toman.)
Slider Options:
0, 450000, 900000, 1350000, 1800000, 2250000, 2700000, 3150000, 3600000, 4050000, 4500000

Q2. Imagine a close friend of yours who has a 3-months old baby asked you to buy infant formula powder. You find a product that meets all their nutritional requirements. What is the price you are willing to pay for an 800g canister with conventional certification? The product is certified by a recognized food safety authority ensuring it meets standard quality and safety requirements. (The price is stated in Iranian Toman.)
Slider Options:
0, 450000, 900000, 1350000, 1800000, 2250000, 2700000, 3150000, 3600000, 4050000, 4500000

Q3. Imagine a close friend of yours who has a 3-months old baby asked you to buy infant formula powder. You find a product that meets all their nutritional requirements. What is the price you are willing to pay for an 800g canister blockchain certified infant formula? This product comes with a new feature - blockchain-based traceability. This system allows you to access detailed information about the product's journey from production to the table, including sourcing of ingredients, manufacturing processes, and quality control checks. (The price is stated in Iranian Toman.)
Slider Options:
0, 450000, 900000, 1350000, 1800000, 2250000, 2700000, 3150000, 3600000, 4050000, 4500000

**** Q1 to Q3 was randomized**

Q4. How realistic were the infant formula powder shopping scenarios? Considering your daily life and shopping habits, how likely is it that you would encounter such a situation?
Options:

- Extremely unlikely

- Somewhat unlikely
- Neither likely nor unlikely
- Somewhat likely
- Extremely likely

Shopping Scenario 2

Q5. Imagine a close friend of yours asked you to buy salt, an essential ingredient used daily in cooking. You find a product that meets all their nutritional requirements. The product is offered in a 1kg package. The product is from a generic brand without safety label. This product offers no specific information about its source or the processes it has undergone before reaching the store. What is the price you are willing to pay for this product? (The price is stated in Iranian Toman.)
Slider Options:
0, 6000, 12000, 18000, 24000, 30000, 36000, 42000, 48000, 54000, 60000

Q6. Imagine a close friend of yours asked you to buy salt, an essential ingredient used daily in cooking. You find a product that meets all their nutritional requirements. The product is offered in a 1kg package. The product has conventional certification. The product is certified by a recognized food safety authority ensuring it meets standard quality and safety requirements. What is the price you are willing to pay for this product? (The price is stated in Iranian Toman.)
Slider Options:
0, 6000, 12000, 18000, 24000, 30000, 36000, 42000, 48000, 54000, 60000

Q7. Imagine a close friend of yours asked you to buy salt, an essential ingredient used daily in cooking. You find a product that meets all their nutritional requirements. The product is offered in a 1kg package. This salt comes with a new feature - blockchain-based traceability. This system allows you to access detailed information about the product's journey from production to the table, including sourcing of ingredients, manufacturing processes, and quality control checks. How much are you willing to pay for this product? (The stated price is in Iranian Toman.)
Slider Options:
0, 6000, 12000, 18000, 24000, 30000, 36000, 42000, 48000, 54000, 60000

**** Q5 to Q7 was randomized**

Q8. How realistic were the salt shopping scenarios? Considering your daily life and shopping habits, how likely is it that you would encounter such a situation?
Options:
- Extremely unlikely
- Somewhat unlikely
- Neither likely nor unlikely
- Somewhat likely
- Extremely likely

Socio-Demographic Information

Q9. How old are you?

Q10. What is your highest education degree?
Options:

- High school diploma
- Bachelor's degree
- Master's degree
- Higher degrees
- I do not want to respond.

Q11. What is your gender?
Options:

- Female
- Male
- Other
- I do not want to respond.

Q12. How high is your monthly household income? (In million Toman)
Options:

- Lower than 20 M Toman
- 20-40 M Toman
- 40-60 M Toman
- More than 60 M Toman
- I do not want to respond.

Q13. How much are you familiar with blockchain technology from 0 to 10? (0 stands for "Not at all" and 10 stands for "very much familiar.")
Slider Options:
0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Q14. Have you heard about how blockchain can help to ensure the safety and authenticity of the food supply chain before participating in this survey?
Options:

- No
- Yes

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