FOOD SAFETY AND INFORMATION ASYMMETRY: IMPLICATIONS FOR THE AGRI-FOOD INDUSTRY

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Corresponding author:
Talía Gomez-Aguas
t.gomez@unizar.es

Talía Gómez-Aguas[1]

[1] Universidad de Zaragoza, España

Abstract

Aim: This study systematically organizes and critically analyzes the literature on food safety from the perspective of information economics. It identifies key informational issues, including information asymmetry, moral hazard, and adverse selection, and explores the proposed academic solutions to these problems. Additionally, the study highlights conceptual gaps in the existing research and proposes directions for future research. **Methodology:** The researcher conducted a literature review using the Scopus and Web of Science databases, focusing on academic studies related to food safety, economics, governance, and supply chain management. The review emphasized theoretical frameworks and coordination approaches, facilitating a structured mapping of the field's primary contributions and trends. **Results:** Food safety significantly influences the competitiveness of the agri-food sector. Effective management of food safety relies on the quality of inputs, the architecture of the value chain, and the implementation of control mechanisms. As the costs and complexities associated with safety measurements escalate, stakeholders must establish tighter coordination between public and private entities. Key mechanisms for ensuring food safety include Hazard Analysis and Critical Control Points (HACCP) systems, traceability tools, and voluntary certification schemes. Nonetheless, research remains limited regarding which governance approach is most effective in contexts characterized by varying degrees of information asymmetry. **Originality/value:** Despite the extensive research on food safety, few studies examine the issue through a structured lens of information economics. This study actively integrates concepts such as credibility, moral hazard, and adverse selection into a theoretical framework specifically designed for agri-food governance. By doing so, it provides analytical tools for researchers, policymakers, and practitioners who aim to enhance both efficiency and transparency in the management of food safety.

Keywords: food safety, food quality, asymmetric information, vertical coordination, co-regulation, safety and quality signals
JEL: D82, Q18, L15,L66.

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SEGURIDAD ALIMENTARIA Y ASIMETRÍA DE LA INFORMACIÓN: IMPLICACIONES PARA LA INDUSTRIA AGROALIMENTARIA

Resumen

Objetivo: este estudio organiza y analiza críticamente la literatura sobre seguridad alimentaria desde la perspectiva de la economía de la información. Se identifican los principales problemas informacionales, como la asimetría de la información, el riesgo moral y la selección adversa, junto con las soluciones propuestas en el ámbito académico. Además, se señalan vacíos conceptuales y se proponen líneas de investigación futuras. **Metodología:** se realizó una revisión de literatura en las bases de datos Scopus y Web of Science, considerando estudios académicos en las áreas de seguridad alimentaria, economía, gobernanza y gestión de cadenas de suministro, con foco en marcos teóricos y enfoques de coordinación. La revisión permitió mapear las principales contribuciones y tendencias en el tema. **Resultados:** la seguridad alimentaria es un factor clave para la competitividad en el sector agroalimentario. Su gestión depende de la calidad de insumos, la estructura de la cadena de valor y los mecanismos de control utilizados. A medida que la medición de la seguridad se vuelve más costosa y compleja, se requieren formas más estrechas de coordinación, tanto públicas como privadas. Entre los mecanismos más relevantes se destacan los sistemas HACCP, la trazabilidad y los esquemas de certificación voluntaria. Sin embargo, la evidencia sobre qué enfoque institucional es más eficaz ante distintos grados de asimetría informativa sigue siendo limitada. **Originalidad / valor:** aunque existen estudios sobre seguridad alimentaria, pocos han abordado el tema desde una perspectiva estructurada basada en la economía de la información. Este trabajo integra conceptos clave como credibilidad, riesgo moral y selección adversa en un marco teórico aplicado al análisis de gobernanza agroalimentaria. La propuesta ofrece herramientas útiles para investigadores, responsables de políticas públicas y actores del sector que buscan mejorar la eficiencia y la transparencia en los sistemas de control alimentario.

Palabras clave: seguridad alimentaria, calidad alimentaria, información asimétrica, coordinación vertical, corregulación, señales de seguridad y calidad

1. INTRODUCTION

Food safety significantly influences public health, consumer trust, and the global food economy. In this context, the agri-food system is undergoing a fundamental transformation. This transformation fosters stronger coordination among supply chain actors, including customers, processors, and producers. As a result, these actors enhance information exchange to align more effectively with consumer expectations (Barkema, 1993).

In today's dynamic landscape, food safety has emerged as a critical issue within the agri-food sector. Scandals such as Mad Cow Disease (BSE) or the mislabeling of beef as "best British beef" when it originated from South America have intensified public concerns regarding safety and transparency in the industry. The competitiveness of food companies in both national and international markets depends on their ability to adopt production processes that meet stringent food safety and quality standards (Holleran et al., 1999).

Furthermore, food safety has become more important than ever to consumers. Unnevehr (2003) identifies four reasons for this trend: Improved diagnostic techniques enable easier tracing of illnesses to food-borne pathogens; increasing consumer affluence has led to heightened demand for safer, higher-quality foods; new sources of food and new production practices have introduced additional risks into the food supply chain; and consumers are purchasing more prepared foods and dining out more frequently than ever before. As a result, the agri-food supply chain has emerged as a prominent subject of research in recent years (Chu & Pham, 2024)

Recent concerns, such as the widespread presence of microplastics in various food matrices, highlight the continuous emergence of complex food safety challenges that demand ongoing scientific scrutiny and effective mitigation strategies (Ziani et al., 2023). Despite the undeniable importance of food safety, academic research to date has predominantly focused on consumer perceptions and pathogen control processes implemented by producers, aiming to enhance safety through better pathogen management (see Clayton et al., 2003; Malcom et al., 2004; Marsh et al., 2004; Maruyama & Kikuchi, 2004; Nayga et al., 2003; Patil & Frey, 2004; Van der Gaag et al., 2004). Although scholars recognize the close relationship between food safety and the concept of a credence attribute (Starbird, 2007), this critical aspect has garnered limited attention. Among existing studies, Weiss (1995) emphasizes principal-agent theory as a suitable framework for analyzing food safety issues while discussing the challenges associated with its application. Additionally, Antle (2001) points out that the food safety market is characterized by imperfect information.

Despite the recent attention on food safety, research within the economics of information remains poorly integrated. The existing literature has identified several distinct problems, including moral hazard and adverse selection. Moreover, various solutions to manage these issues have emerged. Unfortunately, a comprehensive review that organizes and summarizes the evidence regarding food safety issues and management is lacking, which this paper seeks to address. This fragmentation leads to uncertainty about key findings and leaves many questions unanswered.

This paper addresses this critical gap by providing a structured review of food safety research through the lens of asymmetric information. It explores key informational failures, assesses academic responses, and identifies avenues for future research. Specifically, we focus on the following crucial research questions: What are the primary information problems encountered in terms of food safety? Are there corrective mechanisms to mitigate such information problems? Finally, what are the main gaps in knowledge about this relationship?

Overall, this study contributes to theory by organizing and framing food safety within an information economics paradigm and offers valuable insights for industry stakeholders and policymakers to navigate and address food safety challenges. This article will present a brief overview of the concept of food safety and its origins. By addressing issues of asymmetric information, the article provides a comprehensive review that synthesizes and integrates the main problems and solutions identified in the literature. The discussion will conclude with unresolved theoretical issues in food safety and propose directions for further research.

2. LITERATURE REVIEW

2.1 Food Safety and the Supply Chain

Consumers and processors can effectively prevent food safety failures by ensuring the safety of inputs, ingredients, and raw materials at the point of purchase (Starbird, 2005).

Revisiting the concept of food chain reveals that the majority of the food we consume originates from a series of critical economic stages, including production, processing, and distribution. Each of these stages plays a vital role in adding value to the final product, as food can diminish in value over time during storage, raising significant safety concerns (Yin & Wang, 2017). This article conceptualizes the supply chain as the complete process that encompasses agricultural production, harvesting or slaughtering, primary production or manufacturing, and extends through to storage and distribution for retail sale or use in catering and consumer practices.

Although the supply chain concept is not new, recent interest has surged due to the imperative to meet customer demands and enhance competitiveness. Vertical coordination refers to the organization of activities, resources, and information flow between suppliers and purchasing firms. Effective vertical coordination is essential for maximizing the benefits of a safe, high-quality, and efficient food supply business (Stringer & Hall, 2007). Given the rising demand for food safety emphasizes the interdependence among various levels of the supply chain, a more closely coordinated system is essential for improving responsiveness and swiftly adapting to changing conditions, ultimately enhancing competitiveness (Ziggers & Trienekens, 1999).

2.2 Definition of Food Safety and Food Quality

Food safety and food quality assurance serve as essential forms of guarantees in the food industry. Safety is defined as the assurance that food will not cause harm to consumers when it is prepared and/or consumed according to its intended use (Raspor, 2008). In contrast, the assurance of quality entails a guarantee that agreed-upon specifications have been met (Holleran et al., 1999). Therefore, if safety-related standard specifications are included in the quality assurance system, then the assurance of quality inherently includes safety.

Quality and safety attributes in the food industry often pose challenges for identification and observation (Holleran et al., 1999). These attributes are classified as credence attributes because they are difficult or impossible to measure (Starbird, 2007). Consequently, they create information asymmetry between buyers and sellers, complicating the buyer´s task of determining quality. As a result, Shafieizadeh et al. (2023) argue that the perceived credibility of information hinges on its perceived quality, which can significantly influence how information is adopted. Additionally, Akerloff (1970) asserts that institutional guarantees, such as quality assurance standards, are essential for mitigating the effects of quality identification and uncertainty.

2.3 Asymmetric Information Between Buyers and Sellers

Consumers often lack information regarding the quality attributes of most goods available on the market (Yoo & Joo, 2012). As previously mentioned, even after making a purchase, they are unable to ascertain these properties. This situation constitutes a market failure, as the availability of information is essential for effective market functioning. A primary explanation for this deficiency is that information is typically treated as a public good, leading to its undersupply in the market (Henson & Traill, 1993). Recent conceptual frameworks underscore the complexities associated with food credence attributes and their influence on information asymmetry within supply chains (Schrobback et al., 2023).

Despite the public good’s inherent characteristics of being nonrival and nonexcludable, Antle (1999) argues that information can function as a club good that is nonrival but excludable. In this context, the role of government is to establish a legal framework that allows consumers to access and utilize information. However, two critical factors must be considered. First, producers may not possess superior information about a product's safety attributes compared to consumers. This situation can lead to a scenario where all participants in the food chain experience what is termed "symmetric imperfect information." Second, while producers may indeed have more information than consumers, disseminating this information throughout the food chain can incur significant costs.

Two critical problems in ensuring food safety are defining what is considered safe and determining how to measure it. Food safety is often compromised by contamination from physical agents such as metal and glass, chemical agents like toxins, and biological agents like bacteria. Despite this knowledge, we still lack a precise definition of an appropriate level of food safety. In recent years, the government has stepped in to establish food safety standards, but the issue remains unresolved. This lack of consensus partly stems from conflicting interests among various actors in the food chain and a shortage of scientific evidence that links contamination rates to illness (Starbird, 2005).

The ambiguous definition of safety creates uncertainty for firms operating within the supply chain regarding the economic consequences of their actions. Although firms can estimate the costs associated with a lot failing a safety inspection, they struggle to calculate the probability of such events due to the lack of a precise definition of safety. As a result, they cannot accurately assess various issues, such as the return on investments aimed at improving safety or the value of testing the safety of inputs.

Measuring safety offers several advantages. First, it enables buyers to monitor a supplier's ability to meet specifications related to food safety. Through repeated transactions, buyers can develop a statistical profile of the supplier's performance. Second, measuring allows for the differentiation of safe lots from unsafe ones prior to their movement through the supply chain. Third, when suppliers are aware that the buyer is measuring product safety, those who invest less effort in safety may be deterred from entering into contracts with the buyer. When this happens, testing effectively segregates safe suppliers from unsafe ones before any transaction takes place (Starbird, 2007).

Despite a precise definition of safety, measuring it remains prone to significant error. The measurement process is subject to two types of error. Diagnostic error arises from misclassifying a sample as either contaminated or uncontaminated, which can be quantified through the sensitivity and the specificity of the test. Let alpha (α) represent the sensitivity of the test and beta (β) represent its specificity. Sensitivity refers to the probability that the test correctly identifies a contaminated sample, while specificity refers to the probability that the test accurately identifies an uncontaminated sample. Diagnostic error is linked to false positive and false negative test results. A false positive occurs when a test incorrectly indicates the presence of a pathogen, represented mathematically as $1-\beta$. Conversely, a false negative occurs when a test incorrectly indicates the absence of a pathogen, represented as $1-\alpha$.

Another source of error in food safety testing is sampling error. Due to the immense volumes of food that move through the supply chain daily, buyers must rely on sampling to assess the safety of purchase lots. Sampling error arises when the characteristics of the sampled portion do not accurately reflect those of the entire lot from which it is drawn. While random sampling can help mitigate this error, implementing effective random sampling techniques and ensuring their consistent application poses significant challenges. This difficulty persists despite recent advancements in microbial sampling and detection technologies (Yang et al., 2022).

An interesting conclusion stemming from the presence of diagnostic and sampling errors is that buyers often possess less knowledge about the safety of the products they purchase than suppliers do. This lack of information implies that an unsafe lot may occasionally pass inspection, while a safe lot may fail inspection. The potential impact of this risk on an individual producer's compensation affects the behavior of both suppliers and buyers, as it directly influences their profitability (Starbird, 2005, 2007).

3. METHODOLOGY

The researcher conducted a literature review on food safety from an informational perspective. To achieve the established objectives, the researcher utilized the major academic search engines, Web of Science and Scopus, which provide access to numerous indexed journals relevant to the study and are widely recognized by the international scientific community. In both databases, the researcher performed initial searches using general keywords such as "food safety," "food quality," and "asymmetric information." Subsequently, the author executed Boolean searches that combined terms such as "food safety and asymmetric information," "food quality and asymmetric information," "food safety and moral hazard," and "food safety and co-regulation." This methodology allowed the researcher to broaden the range of related articles and enhance the scope of the information available. Moreover, articles that fell beyond the scope of the study were excluded, such as those focused on medical or nutritional aspects. The research specifically targets management-related areas, aligning with the defined objectives.

4. RESULTS

4.1. Implications of Asymmetric Information

Measurement error has long been recognized as a source of imperfect or asymmetric information about food safety, which significantly impacts individual and institutional behavior. Specifically, when consumers lack accurate information regarding safety, it can result in either an oversupply of unsafe products or a complete halt in transactions (Starbird, 2005).

When suppliers have superior information about product quality compared to buyers, the market experiences three rather unpleasant economic phenomena: moral hazard, adverse selection, and significant transaction costs.

Moral hazard problems arise when the production of safer products incurs higher costs than those of less safe alternatives, while consumers are unable to directly observe the safety features of these products. In this context, suppliers may lack motivation to prioritize safety (Vosooghidizaji et al., 2019). Specifically, while a supplier may commit to enhancing safety, there are instances where they fail to fulfill this promise. Due to the inherent diagnostic and sampling errors associated with safety measurement, buyers cannot be confident that suppliers have delivered safe food ingredients. This uncertainty challenges stakeholders and drives ongoing research into supplier behavior and effective quality investment strategies (Wu et al., 2024).

When transactions occur between processors and consumers, food safety creates a double moral hazard problem. This issue arises from the assumption that both consumers and processors engage in unobservable preventive measures to reduce the risk of food-borne illnesses. Recent outbreaks of food-borne illnesses (Mead et al., 1999; Roe et al., 2000) have heightened consumer concerns about food safety. As a result, the potential costs of contracting a food-borne illness have motivated consumers to take preventive actions aimed at minimizing their likelihood of becoming ill (Buzby et al., 1996; Fein et al., 1995; Foster & Just, 1989; Roe et al., 2000; Swartz & Strand, 1981).

Producers actively seek to invest resources in safety due to consumer demand and the need to mitigate costs related to product recalls, disposal of harmful food, and damage to reputation resulting from outbreaks (Thomsen & McKenzie, 2001). This scenario creates a double moral hazard problem, resulting from risk-sharing and imperfect information on both sides of the transaction (Cooper & Ross, 1985; Holmström, 1979). On one side, consumers face challenges in verifying how a product is processed, packaged, distributed, or stored, rendering the precautions taken by processors unobservable. Conversely, processors frequently lack the ability to determine how consumers handle and prepare their food. As a result, both the efforts made by processors - information that consumers cannot see or access – and the handling practices of consumers – private information that producers cannot observe – create a dual moral hazard issue. Antle (2001) characterized this situation as one of symmetric imperfect information.

Elbasha and Riggs (2003) present a model of double moral hazard in which both consumers and producers engage in unobservable preventive measures to mitigate the risk of foodborne illnesses. A significant concern in this context is that the losses resulting from such illnesses are shared between consumers and producers in accordance with the existing tort law. They identify the solution that maximizes profits and demonstrate that this risk-sharing arrangement, coupled with imperfect information, leads to an incentive problem.

Adverse selection occurs when low-safety producers systematically drive out high-safety producers in markets where safety is not observable. This phenomenon arises from the inability to distinguish between suppliers who can provide safe food and those who cannot. Suppliers often assert that they possess specific skills or abilities related to safety upon hiring; however, due to the imperfect observability of safety, buyers cannot completely verify the type of supplier they engage with. As a result, buyers tend to offer prices that reflect the "average" quality or safety associated with the suppliers available. It means these average prices often fail to adequately compensate the highest-quality suppliers, leading them to exit the market (Akerlof, 1970).

In the context of adverse selection, Starbird and Amanor-Boadu (2007) explore how contracts that include traceability can help processors select against producers who fail to meet safety specifications. They assert that the motivation to exclude unsafe producers depends on the magnitude of failure costs and the proportion of these costs allocated to producers. Transaction costs, which encompass expenses associated with conducting an economic exchange - such as search, selection, bargaining, monitoring, and enforcement – play a crucial role in this relationship (Madhok, 2002). Consequently, transaction costs encompass every aspect of the contractual relationship between customers and suppliers (Hobbs, 1996). Since production costs remain stable across different methods of organizing exchanges (Williamson, 1996), TCE predicts that the processors will opt for the organizational structure that minimizes transaction costs (Van Hoek, 2000). Williamson (1979) identifies market contracting as the most efficient governance mechanism due to the inherent benefits of competition. He further explains that the incentive for vertical integration increases as the transaction costs associated with using the marketplace transactions rise (Klein et al, 1978; Williamson, 1974, 1975, 1986).

Spot markets can encounter several issues that hinder their effectiveness in ensuring food safety to consumers. One major concern is that traditional spot market pricing systems may not adequately respond to shifts in consumer demand if prices fail to reflect the specific attributes of products that consumers prioritize. When the pricing system does not accurately represent consumer preferences for food safety, producers lack the necessary incentives to prioritize the production of safer food options or are penalized for producing inferior products. Given that food safety incurs higher costs, producers lack incentives to incorporate the desired attributes (Ward, 2001). To ensure that production is driven by product attributes that cannot be effectively priced, an alternate coordination system is needed, such as contracting and vertical integration.

In the context of food safety and quality assurance, transaction costs play a significant role as they are influenced by food safety regulations and customer requirements. For instance, food safety technical regulations may mandate that a firm trace products through the production process and identify potential sources of contamination, thereby impacting transaction costs.

Measuring the costs associated with identifying and approving competent food suppliers poses significant challenges. After identifying potential suppliers, auditors must assess their production systems and evaluate their products and processes. Transaction costs include supplier expenses related to supplier identification, contract negotiation, and the verification and enforcement of contracts.

To assess a product's safety, a buyer should verify that the seller employs a "safe" production process. However, this verification process incurs a significant search cost, particularly when the buyer requires a diverse range of suppliers or seeks products that pose a higher risk of safety hazards. During contract negotiations, buyers establish product and process specifications and insist on supplier compliance with these standards. Once both parties agree on the product specifications, buyers typically request supplier site visits or audits prior to finalizing the contract. These visits aim to confirm that all product and process specifications are effectively implemented.

Additionally, contract verification and enforcement are crucial elements of the exchange process. Although buyers and sellers seem to mitigate risks associated with exchange, such as incomplete contracts, they cannot foresee all potential issues at the time of drafting contracts. Consequently, emphasizing contract verification and enforcement becomes essential (Holleran et al., 1999).

4.2. Correcting Problems Associated with Imperfect Information

Several effective strategies exist to address the issues stemming from imperfect safety information. The most straightforward approach involves obtaining more comprehensive information about suppliers and the quality of their products. While this method can reduce some of the informational asymmetry, it is essential to recognize that acquiring precise information can be costly and is sometimes infeasible.

Another viable strategy is implementing an intermediate degree of vertical coordination, through contracts or higher levels of vertical integration. Specifically, this approach entails designing contracts that attract safe suppliers while deterring those that are unsafe. Such contracts may specify bid prices, product specifications, and inspection protocols that differentiate between safe and unsafe suppliers. If the buyer is unable to effectively segregate these suppliers, they can engage in vertical integration by acquiring or merging with a supplier to ensure product safety.

A third strategy focuses on enhancing the value of revealed information, encouraging suppliers to demonstrate their safety standards through various signals. These safety and quality signals can include the adoption of process standards, guarantees, warranties, and third-party certifications.

Finally, a fourth strategy is co-regulation, where collaboration between producers and regulatory bodies enhances safety oversight. The subsequent sections will analyze the solutions for imperfect information, which encompass (i) acquiring information about the supplier´s product, (ii) implementing vertical coordination, (iii) establishing signalling mechanisms, and (iv) engaging in co-regulation.

4.3. Acquiring Information About the Supplier´s Product

The first strategy to enhance the safety of the food supply focuses on implementing inspections and traceability systems. Hobbs (2004) asserts that one crucial function of traceability within a food supply chain is to verify credence quality attributes, a process known as ex ante quality verification[1]. Research on information asymmetry in agri-food supply chains further supports this argument (Schrobback et al., 2023). Inspection systems utilize samples and tests to collect information regarding safety and quality. Consequently, buyers analyse inspection results to determine whether a supplier´s product meets safety standards.

All traceability systems share the common element of accumulating information about product attributes, including safety and origin, as products move through the supply chain. The breadth, depth, and precision of the accumulated information define the effectiveness of a traceability system. According to Golan et al. (2004), the breadth of information pertains to the varied product attributes being monitored, the depth reflects how far information extends throughout the supply chain, and the precision indicates the specificity and accuracy of this information. The New Era of Smarter Food Safety initiatives, combined with the growing adoption of digital technologies such as Artificial Intelligence (AI), blockchain, and the Internet of Things (IoT), significantly enhance the capabilities of these systems. These advancements enable more efficient monitoring, real-time decision-making, and proactive risk management (Aslam et al., 2024; Lin et al., 2022; U. S. Food and Drug Administration, 2023). As a result, without effective inspection mechanisms, unsafe food can enter the supply chain unchecked, and without traceability, it becomes impossible to identify the supplier responsible for unsafe products.

The predominant measure of food safety identified in the literature is the proportion of a producer´s output that complies with all government safety standards (Baiman et al., 2001; Lim, 2001; Starbird, 2005; Starbird & Amanor-Boadu, 2007). This definition inherently assumes that government standards effectively distinguish between safe and unsafe food. Traceability entails identifying the source of a product responsible for a food safety failure. Since many food safety failures result from sequential errors within a supply chain, it is unlikely there would be only one responsible party (Buzby et al., 2001). Starbird and Amanor-Boadu

[1] Hobbs (2004) also identifies two other distinct functions for traceability in a food supply chain: (a) as a reactive traceback mechanism when contamination problems occur, and (b) as a means to strengthen liability incentives.

(2007) developed a measure called the cost allocation factor, which quantifies the proportion of costs associated with food safety failure costs that can be attributed to the producer of unsafe food. It is important to recognize that information obtained from inspection and traceability systems alone does not enhance food safety. Rather, stakeholders must actively use information to remove unsafe food that is already present in the supply chain and to prevent unsafe food from ever entering the supply chain in the first place.

What drives systems to prevent unsafe food from entering the supply chain? What incentives motivate suppliers to produce and deliver safer food? Inspection systems enhance food safety by imposing significant costs when a lot fails inspection, while traceability systems enable the allocation of costs associated with unsafe food back to its source. A critical concern is that not every unsafe lot that passes inspection will cause illness, but the associated costs of illness from harmful food are likely to be substantial.

Starbird and Amanor-Boadu (2006) make an important contribution to understanding this issue. They argue that the effectiveness of inspection and traceability systems hinges on the accuracy of inspections. Errors in inspection – encompassing both diagnostic and sampling mistakes -- can result in safe products failing inspections and unsafe products passing them. Such errors directly impact supplier profits and, in turn, the ability of inspection and traceability to incentivize suppliers effectively.

An important question explores the impact of inspection error on motivation, which remains unclear. On the one hand, inspection serves as a powerful incentive only if safe products pass and unsafe products fail inspections; this outcome is more likely when inspection error is low. Conversely, traceability offers significant incentives primarily when unsafe products pass inspection, a scenario that becomes more probable when inspection error is high. Ultimately, the effectiveness of inspection and traceability systems depends on the characteristics of the inspection policy. These inspection policies can be negotiated directly between buyers and suppliers or established by an independent third party.

4.4. Vertical Coordination

Various governance mechanisms effectively coordinate the transformation of farm products into food products. These coordinating structures create a continuum, with external coordination positioned at one extreme and internal coordination at the other. For example, agricultural cooperatives demonstrate that vertical coordination linearly enhances cooperative performance; however, the relationship between this coordination and the distribution of internal benefits among members often reveals a more nuanced, frequently inverted U-shaped pattern (Zhong et al., 2018).

External coordination refers to the exchange of information and goods between adjacent stages of the food market that occurs independently of any single firm. The most extreme form of this coordination is open production, where the production process concludes before marketing commitments are established, leading to sales in spot markets (Barkema & Drabenstott, 1995).

The increasing recognition of food safety's importance among food providers, juxtaposed with rising consumer dissatisfaction regarding food safety, suggests a significant failure within the current market system (Boehlje et al., 1995; Hanf & Wright, 1992). Consequently, this dynamic indicates a market structure shift from open production to more structured practices such as contracting and vertical integration.

Contracts have emerged as a prevalent method in the food industry for the production and marketing of agricultural products. To deter suppliers from delivering unsafe food, these contracts frequently incorporate specific food safety standards.

A contract qualifies as a safe contract when it is accepted by safe suppliers and rejected by unsafe suppliers (Starbird, 2005). Safe suppliers are those who have adopted and implemented advanced food safety methods, resulting in a minimal failure rate of their lots in meeting food safety standards. In contrast, unsafe suppliers do not employ these sophisticated food safety practices, l resulting in a higher incidence of failure to meet safety standards in their lots. Consequently, a greater proportion of lots from unsafe suppliers are likely to be contaminated (Starbird, 2007).

The selection of appropriate contract parameters is a central challenge that buyers encounter when implementing effective safe contracts. A well-designed safe contract should persuade reliable suppliers to engage in the transaction while deterring those that are unsafe. Key contract parameters[2] related to safety are included in the bid price, safety standards, premiums, or discounts associated with deviations from these standards, the sampling plan, the diagnostic test employed to measure safety, and provisions for sharing the costs of food safety failures.

Starbird (2007) emphasizes that contract provisions significantly influence food safety by affecting the costs associated with delivering contaminated products. Suppliers of contaminated food incur two types of costs. The first type, known as inspection failure costs, arises when a contaminated lot is delivered and subsequently fails inspection. This cost encompasses the expenses related to disposing of the contaminated food, any penalties or fines imposed on the supplier, and the additional production costs required to replace the rejected lots.

The second type of cost, known as the safety failure cost, arises when a contaminated lot is delivered and passes inspection. This cost pertains to the consequences of contaminated food entering the buyer´s production system, potentially resulting in illness when the product reaches the consumer. Estimates of the costs associated with safety failures are notably challenging to obtain (see Buzby et al., 2001). Furthermore, these costs vary significantly between private firms, which aim to maximize profits, and public agencies, which focus on enhancing consumer welfare and public health. Additionally, a crucial characteristic of safety failure costs is that they impact suppliers only when the party responsible for the failure can be identified and held accountable for a portion of the associated costs.

The probability that a supplier incurs inspection failure costs or safety costs depends on the accuracy of the inspection procedure. Specifically, a false positive test result increases the likelihood that a supplier has to pay inspection failure costs. Similarly, a false negative test result affects the likelihood that a contaminated lot successfully passes inspection. Consequently, if a contaminated lot passes inspection, the supplier is likely to bear a portion of the safety failure costs.

Ultimately, a contract's effectiveness in attracting safe suppliers and deterring unsafe ones is contingent upon several factors, including the supplier's production costs, the likelihood of inspection failure, the probability of a safety failure, and the costs associated with both inspection and safety failures. When the testing procedure is accurate and leads to the

[2] Of course, supply chain contracts include many other provisions in addition to those that influence safety.

rejection of non-compliant lots and incurs substantial failure costs, it serves as a significant deterrent to unsafe suppliers (Starbird, 2007).

Researchers have long recognized that poor contract design leads to significant problems. One such challenge arises when the costs associated with safety failures and inspection failures are excessively high, resulting in market failure due to a lack of supplier participation. Conversely, when these costs are too low, segregation becomes impractical, as all suppliers are likely to accept the contract.

Even in cases where a contract successfully segregates suppliers, adverse selection may still occur among those suppliers whose contamination rates fall below the maximum allowable limit. If the buyer cannot differentiate between suppliers with nearly zero contamination and those whose contamination levels approach the maximum permitted rate, the buyer tends to offer a price that fails to satisfy the safest suppliers. In this scenario, the safest suppliers may be inclined to relax their food safety efforts. Furthermore, if suppliers find ways to evade inspection, it creates perverse incentives that foster dishonest practices, ultimately leading to the introduction of unsafe food into the supply chain (Starbird, 2005; Van Ravenswaay & Bylenga, 1991).

The increasing adoption of contracts in food supply chains primarily stems from the heightened demand for traceability (MacDonald et al., 2004, p. 62). Traceability refers to the capability to track a product's origins as it moves through the supply chain. This concept serves several purposes, including enhancing supply management, improving safety and quality, and differentiating finished goods based on credence attributes (Golan et al., 2004). By enabling the identification and recall of products from unsafe sources, traceability plays a crucial role in promoting food safety and allows for the allocation of costs associated with unsafe food to the responsible parties.

Several researchers have analyzed the influence of supply chain contract provisions on quality and safety. Among the earliest studies, Lim (2001) examines a market characterized by n types of suppliers, each differentiated by the quality of their products. This study identifies the optimal inspection and warranty policies for buyers navigating this heterogeneous yet competitive market. In his model, the price remains fixed, and inspection is flawless. However, both the probability of a lot being inspected and the proportion of the warranty cost allocated to the supplier are variable. Lim concludes that suppliers of lower-quality products are more frequently offered contracts that include inspection provisions, while high-quality suppliers are more likely to receive contracts with warranty provisions.

In another study, Chalfant and Sexton (2002) investigated the issue of inaccurate quality grading in the California prune industry. They analyze how faulty testing affects a market populated by heterogeneous suppliers. Notably, their research does not explicitly address the issue of traceability. Their findings reveal that errors in the grading process exacerbate the adverse selection problem, leading to the undervaluation of high-quality products and the overvaluation of low-quality ones. Additionally, Hobbs (2004) examined how traceability systems can rectify information asymmetries related to food safety and other attributes of food quality.

Balachandran and Radhakrishnan (2005) develop a double-moral hazard model to examine the dynamics of supply chain relationships, specifically highlighting the buyer's ability to impose inspection failure costs and/or external failure costs on the supplier. They assume both the inspection process and the ability to accurately assign responsibility for external failures (traceability) are flawed. Their findings indicate that the accuracy of the inspection procedure significantly influences the fulfillment of fairness criteria within the supply chain.

More recently, Starbird and Amanor-Boadu (2007) analyze how specific contract provisions—namely, traceability and cost allocation—affect the behavior of buyers and sellers concerning food safety. Their model, which accounts for heterogeneous producers and imperfect testing by processors, indicates that for contract selectivity to succeed, food safety failure costs must be substantial, with a significant proportion allocated to producers. In contrast, low or unallocated costs result in adverse selection that disadvantages safe producers. Although contracting provides benefits, it also incurs costs. Contracts often limit producers' control, necessitating compensation for lost autonomy (Key, 2005). Additionally, writing and enforcing contracts can be expensive, which typically makes them practical only for significant product volumes (Lambert & Wilson, 2003). Finally, contracts introduce strategic risks for sellers, particularly the risk of hold-up, wherein reliance on a single buyer due to specific investments may diminish bargaining power and disincentivize further investment.

Given these disadvantages, buyers may find that spot markets provide the most effective means of organizing transactions. Consequently, they can choose among spot markets, contracts, and vertical integration based on which method best governs a specific set of transactions.

Vertical integration represents the highest level of vertical coordination between production and handling activities required to transform a product from its primary form and location to its consumer-ready state in the retail market (Kilmer et al., 2001). Agricultural economists attribute the recent increase in vertical integration within the food supply system to heightened consumer awareness of product safety (Caswell et al., 1994; Hennessy, 1996; Roberts et al., 1997; Streeter et al., 1991).

Hennessy (1996) constructed a model that demonstrates the incentives for integrating food production and processing. In this model, producers opt to invest in quality control, while processors conduct quality tests on the products they purchase from producers. Hennessy concludes that when testing is costly and imperfect, the market prices between producers and processors reflect these testing imperfections. He also finds that in the absence of informative tests or when the testing costs are prohibitively high, buyers are reluctant to pay a premium for quality, leading producers to hesitate in investing in quality control.

In this scenario, vertical integration can effectively eliminate the need for testing to ascertain quality, thereby removing the externality associated with asymmetric information and facilitating the efficient provision of high-quality product. The advantages of vertical integration, particularly in addressing information imperfections and minimizing the need for expensive external verification, are further enhanced by the incorporation of modern technologies such as blockchain in food supply chains (Chu & Pham, 2024).

Antle (1998) presents an alternative perspective on vertical integration by questioning how imperfect testing contributes to asymmetric information between producers and processors. Traditionally, it is assumed that the supplying firm is aware of its reliable quality control technology, while the processor lacks this knowledge. However, since most quality control technologies are fallible and necessitate testing to validate their performance, it is uncertain whether producers can genuinely know if their quality control is "reliable." Consequently, when both producers and processors have access to the same testing technology, which is inherently less than 100 percent accurate, they operate with imperfect information, creating a scenario of symmetric imperfect information.

When tests yield no informative value, vertical integration fails to address the challenge of delivering high-quality products. In such scenarios, producers and processors do not have access to any reliable information about quality and vertical integration is not a viable solution to the provision of safer products (Antle, 1996). The only feasible solutions to this issue lie in advancements in testing methodologies or other quality control technologies.

Kilmer et al. (2001) conducted the first study to quantify the relationship between food safety and vertical integration in agricultural markets. Their results provide strong evidence supporting the hypothesized positive relationship between food safety and vertical integration, particularly in the contexts of fungicide and insecticide residues found in Florida strawberries and the insecticide residues in Florida tomatoes.

However, it is important to recognize that complete vertical integration entails several disadvantages, including high capital demands and reduced flexibility (Ziggers & Trienekens, 1999). Additionally, significant scale differences often exist between successive stages of the value chain. Therefore, vertical coordination frequently emerges as a more suitable strategy than vertical integration.

4.5 Safety and Quality Signals

In the context of food safety, consumers find information about raw materials and production processes essential when making decisions regarding the purchase, handling, and consumption of food (see, e.g., Caswell, 1998; Collins, 1997; Ippolito & Mathios, 1990, 1995; Roe et al., 2000; Petrescu et al., 2022). When the market does not sufficiently incentivize producers to disclose relevant information, implementing quality assurance systems proves valuable in enhancing market efficiency.

Governments and the private sector have actively responded to the growing interest in food safety, resulting in a new paradigm for food safety and quality regulation and management.At the public level, authorities have revised regulations and implemented significant institutional changes to enhance the oversight of food safety and quality (Jaffee & Henson, 2004). Specifically, the government has updated national-level food legislation and technical requirements for food processing, handling, and production processes, as well as product liability law. These revised technical requirements and liability laws directly influence the costs associated with transactions, thereby creating private incentives for the adoption of voluntary quality assurance systems.

In response to changes in public standards, the private sector has increasingly taken steps to address the food safety and quality concerns of consumers. A primary motivation for this trend has been to mitigate reputational and commercial risks associated with food product safety, which often relates to the nature of regulatory requirements. Consequently, in addition to the incentives derived from food and liability law, private incentives compel small and medium-sized enterprises (SMEs) to implement quality assurance systems (Karipidis et al., 2009). Furthermore, companies are moving beyond merely adhering to approved practices that meet technical requirements; they are also adopting quality assurance practices and systems. Ricker-Gilbert et al. (2025) illustrate this trend in their study, showing that companies adopting minor safety measures, like the use of measures already considered best practices, like the use of airtight bags, receive favorable reactions from consumers. These customers are often willing to pay a premium for the enhanced assurance of quality and safety these measures offer.

Quality assurance systems play a crucial role in exchanges where food safety and quality attributes are not directly observable. Their primary objective is to assure customers that the agreed-upon product characteristics and production processes are consistently met. By establishing technical requirements and contractual arrangements, these systems define the expectations of both contracting parties in advance. Subsequently, the quality assurance system verifies that the agreed-upon characteristics and attributes are delivered post-production.

A quality system consists of an organizational structure, defined responsibilities, processes, procedures, and resources that collectively facilitate effective quality management ("Nederlands Normalisatie Instituut Normcommissie Standaarprocedures en Criteria voor Evaluatie van Kwaliteitsbeheersingssystemen", 1989). In the food industry, food safety and quality assurance systems can manifest in various forms: (1) private voluntary international quality assurance standards, such as ISO 9000; (2) national farm-level assurance systems; (3) and proprietary quality assurance systems (Holleran et al., 1999).

Voluntary quality assurance standards establish internationally accepted procedures and guidelines aimed at maintaining consistent quality (Zaibet, 1995). One prominent example is ISO 9000 (International Organization for Standardization), which certifies organizations to ensure a uniform production process. This system consists of three primary standards, ranked from the most to least comprehensive: ISO 9001, ISO 9002, and ISO 9003. ISO 9001 encompasses all aspects of design, development, production, installation, and servicing. In contrast, ISO 9002 provides guidance for developing a quality management system when design control is not necessary. ISO 9003 focuses exclusively on final inspection and testing.

The certification of a voluntary quality assurance standard communicates to external parties that a firm has implemented a documented quality management system. In contrast,national assurance systems provide consumers with the assurance that a nation's farms produce products according to established guidelines. Typically, these systems prescribe production practices that extend from the farm level through the retail level, encompassing aspects such as transportation and storage.

The United Kingdom specifies unique safety and quality requirements that commonly involve reliance on third-party auditing and certification. These private or public certifiers assess, evaluate, and certify claims based on defined standards and methods (Deaton, 2004). Their emphasis on independence, objectivity, and transparency fosters trust and limits liability (Tanner, 2000; Zuckerman, 1996). While traditional perspectives view third-party certification as objective technical tools (Fagan, 2003; Golan et al., 2001; Sanogo & Masters, 2002; Tanner, 2000), there are arguments suggesting that it also reorganizes and disciplines the supply chain, resulting in various social and economic implications (Busch, 2000; Hatanaka et al., 2005).

Food manufacturers must select and implement the most appropriate quality assurance (QA) system, a process complicated by the unique characteristics of agri-food production (Luning et al., 2002). However, measuring the extent to which these systems truly assure food quality poses significant challenges, hindering effective selection and application (Van der Spiegel et al., 2003). Nonetheless, the adoption of QA systems can reduce transaction costs (Holleran et al., 1999). While suppliers may face short-run sunk costs during implementation, the adoption of these systems is likely to improve market access and potentially lower costs in both operational and buyer-supplier transactions (Bredahl et al., 1997).

4.6 Co-Regulation

The rising public concern about food safety has compelled government agencies to adopt more prescriptive and proactive regulatory measures within the food industry. This trend is evident in the substantial increase in government oversight of food safety over the past decade, which includes the introduction of ex ante direct regulations and ex post indirect controls (Henson & Caswell, 1999). Concurrently, as previously noted, private mechanisms for food safety control have emerged robustly and now play an important role in ensuring a higher level of food safety. As a result, a complex network of both public and private incentives has developed to promote the implementation of enhanced food safety controls (Gao et al., 2023).

Although the potential benefits of co-regulating food safety are apparent, co-regulation remains a relatively novel concept in many parts of the world. A lack of trust among participants in the food supply chain, coupled with concerns about the risks associated with allowing market forces to influence food safety regulation, discourages closer coordination between private and public resources in controlling food safety.

Recent evidence indicates that co-regulation is emerging as a valid approach for enhancing food safety regulation (Liu et al., 2019), influenced by both regulatory change and the evolving structure and operations of food supply chains. In the European Union, recent developments in the regulatory environment are fostering greater collaboration between regulatory agencies and the private sector in the management of food safety. In the United States, this is evident in the implementation of the Hazard Analysis Critical Control Points (HACCP) across a number of key product sectors. This is shifting the responsibility for monitoring food safety to business operators. Additionally, Canada is adopting risk-based enforcement and monitoring strategies as a means to improve the efficacy of enforcement efforts at both the federal and provincial levels.

Garcia Martinez et al. (2007) examine the potential for co-regulation of food safety in the UK and North America, highlighting the distinct differences in established regulatory processes between these regions. Their study concludes that opportunities for co-regulation exist, albeit to varying degrees across the countries analysed, yet significant obstacles hinder the widespread adoption of co-regulatory practices in food safety. In Australia, Arup et al.(2020) argue that large supermarket chains serve as the primary agents of co-regulation, while civil society's influence diminishes due to a lack of government support and legal backing.

5. DISCUSSION

This literature review addresses a critical gap in food safety research by integrating an information economics perspective to systematically organize and synthesize the main challenges and solutions. Food and agribusiness firms increasingly operate in competitive markets where food safety plays a decisive role in maintaining competitiveness (Holleran et al., 1999; Unnevehr, 2003). Establishing food safety within the agri-food sector requires careful attention to the quality of raw materials, production practices, and the overall structure of the value chain.

The feasibility and cost associated with measuring product safety significantly influence the structure of market relationships (Hobbs, 1996). When safety measurement is straightforward and inexpensive, firms can maintain less stringent vertical links. Conversely, when measurement proves challenging or costly, tighter vertical coordination may be required. Furthermore, the rise of differentiated product specifications has intensified the challenge of ensuring that the desired product, complete with the requisite safety attributes, is indeed the one being transacted.

Institutional responses to food safety problems differ, ranging from minimal public intervention that allows market mechanisms to operate independently, to direct regulation, such as the establishment of national farm-level assurance systems (Henson & Caswell, 1999). In addition to public measures, numerous private strategies exist, including the adoption of voluntary international quality assurance schemes and contractual arrangements that promote vertical coordination (Gereffi et al., 2005; Trienekens & Zuurbier, 2008).

6. THEORETICAL AND PRACTICAL IMPLICATIONS

This study makes a significant contribution to theoretical discussions by organizing and systematizing the fragmented literature on food safety through the lens of information economics. By explicitly incorporating key concepts such as credibility, moral hazard, and adverse selection (Akerlof, 1970; Weiss, 1995; Starbird, 2007),the study enhances our understanding of how informational problems influence food safety outcomes and governance structures. This unified analytical framework lays the groundwork for future academic research exploring the intersection of food safety and economic information theory.

The study provides valuable insights for stakeholders throughout the agri-food sector. For businesses, it suggests strategies to manage information asymmetry, including certifications, vertical coordination, and digital traceability systems. For policymakers, it underscores the necessity of adaptive regulations that correspond to the informational risks present at each stage of the supply chain. Ultimately, the findings promote the development of more efficient and transparent governance mechanisms to ensure food safety across diverse contexts.

7. LIMITATIONS AND FUTURE RESEARCH LINES

While this study offers a comprehensive conceptual review, it is limited by its theoretical nature. It does not include empirical evaluation of the mechanisms discussed, nor does it distinguish between different regions, sectors, or levels of risk. These aspects represent fertile ground for further research. Future studies could empirically investigate whether advanced technologies, such as artificial intelligence, blockchain, the Internet of Things, and remote sensing, can improve traceability, reduce information asymmetry, and lower transaction costs in food supply chains (Bermeo-Almeida et al., 2018; Galvez et al., 2018; Queiroz et al., 2020; Rogerson & Parry, 2020). It is also relevant to examine how increased transparency, such as consumer access to full product histories, influences consumer confidence in both the short and long term. Finally, comparative studies on the effectiveness and efficiency of different governance mechanisms under varying risk scenarios could help determine which approach is most appropriate depending on the context.

8. CONCLUSIONS

An effective and credible food safety regulatory system plays a fundamental role in shaping public policy. The inherent uncertainty surrounding food safety necessitates an integrated chain approach that actively incorporates both safety and quality assurance (Caswell & Johnson, 1991). This approach must begin with clear specifications for raw materials and ingredients, ensuring that they adhere to established safety and quality standards prior to further processing.

Food safety management systems should be grounded in a comprehensive understanding of the production process and its inputs. A widely recognized methodology for achieving this is Hazard Analysis and Critical Control Points (HACCP), which focuses on identifying critical control points at each stage of production, distribution, storage, and consumption (Campden & Chorleywood Food Research Association, 2003; Zhou et al., 2022). Moreover, implementing robust traceability, particularly concerning raw materials, is essential for verifying the effectiveness of control procedures (Stringer & Hall, 2007). By integrating these elements across the value chain. organizations can significantly enhance food safety and strengthen consumer confidence.

STATEMENTS

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Use of Artificial Intelligence

No generative artificial intelligence tools were used in the preparation, analysis, or writing of this manuscript.

Conflict of Interest

The author declares that there are no conflicts of interest related to this research or its publication.

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Author Contributions (CRediT)

TGM: conceptualization, methodology, formal analysis, writing, original draft, review & editing.

Ethical Approval

Not applicable.

Declaration of Originality

The author declares that this manuscript is original, has not been published previously, and is not under consideration in any other journal. All information, interpretations, and conclusions are the result of the author’s independent academic work.

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