

# The Role of Digital Technologies in Enhancing Food Safety and the Enforcement of Food Quality Control in Nigeria's AgriFood Industry

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**Abstract.** Food safety and the enforcement of food quality control are very critical concerns in Nigeria's agricultural food industry. The need for innovative solutions to address these challenges motivated this study. The study explores the potential of digital technologies to improve food safety and enhance the enforcement of quality control in Nigeria's AgriFood industry. The study's objectives are to assess the current state of food safety and quality control regulations in Nigeria's Agricultural and Food industry and to identify areas for improvement. The study also aimed to evaluate the potential of digital technologies to enhance food safety and quality control in Nigeria's AgriFood industry. The study relied on both primary and secondary sources of data. The researchers collected primary data through key informant interviews with six experts who have conducted studies on food safety and the enforcement of quality control in Nigeria's AgriFood industry. The collected data were analysed using thematic analysis. The study found that the current state of food safety and quality control in Nigeria's AgriFood industry poses serious challenges, including inadequate infrastructure, insufficient regulatory enforcement, and limited market access. It was also found that foodborne illnesses are prevalent in Nigeria, as evidenced by the high incidence of microbial contamination in everyday food products. A typical example is the widespread detection of aflatoxins in maize and peanuts. The evaluation of digital technologies demonstrates their potential to enhance food safety. The study shows that mobile-based reporting systems can improve real-time monitoring and reporting of food safety issues, thereby reducing reporting time. It also showed that digital market surveillance technology can accurately detect and track food safety risks. It also demonstrates that Blockchain technology can help to ensure supply chain transparency and accountability, thereby reducing the circulation of counterfeit products. Therefore, the study recommends adopting digital technologies to enhance food safety practices in Nigeria's AgriFood industry by integrating mobile-based reporting systems, digital market surveillance, and blockchain into existing food safety frameworks.

**Keywords:** Food Safety; Quality Control; Digital Technologies; AgriFood Industry; Nigeria.

## INTRODUCTION

The importance of food safety and quality control in the AgriFood industry cannot be overstated. Ensuring that food products are safe for consumption and meet quality standards is essential to protecting public health, building consumer trust, and promoting economic advancement [1]. The issue of Food safety, also known as quality control, comprises a wide range of activities, including hazard analysis, good manufacturing practices, quality management systems, and even supply chain management [2].

Ensuring food safety globally by enforcing food quality controls is a significant challenge. According to the World Health Organisation (WHO), one in ten people worldwide falls ill each year from contaminated food. Contaminated food causes approximately 420,000 deaths annually [3]. Foodborne illnesses can cause grave health-related consequences, such as kidney failure, mental illness, and in worst-case scenarios, death [4]. For example, in 1996, a large outbreak of *E. coli* O157:H7 occurred in Japan, affecting thousands of people [5]. Similarly, in the United States, the Centres for Disease Control and Prevention (CDC) estimated that foodborne illnesses cause about 128,000 hospitalisations and 3,000 deaths annually [6]. The foregoing statistics highlight the need for countries to develop more robust food quality control measures.

In addition to the health impacts, gaps in food safety and quality control also have significant economic consequences [7]. Foodborne illnesses can cause losses for farmers and processors, which, in turn, can affect the broader economy. For instance, a study by the U.S. Department of Agriculture (USDA) Economic Research Service (ERS) stated that the annual cost of foodborne illnesses in the United States is about \$17.6 billion [8]. In Australia, a study found that foodborne illnesses also cause severe economic losses, particularly in healthcare costs and lost productivity [9]. These again point to the need for countries to prioritise food safety quality control.

The Nigerian agric-food industry is a significant contributor to the country's economy, providing employment and income for millions of people [10]. Over the years, considerable government investment has been made to enhance agricultural and food production in Nigeria [11]. However, the issue of food safety, especially regarding

the enforcement of quality control guidelines, has received limited policy attention. In Nigeria, the adoption of digital technologies in the AgriFood industry is still in its infancy. The country's food safety gaps have many consequences, including the dangers posed by the spread of communicable diseases, which could lead to a public health disaster. It can also affect Nigeria's competitiveness and global reputation, making it challenging for the country to participate in international markets [12].

Based on the foregoing, it is clear that Nigeria needs to develop innovative solutions to address its food safety challenges. Currently, there are few studies on the potential of digital technologies to enhance food safety and on the practical implementation of quality control standards in Nigeria's agric-food industry. Most researchers have focused on the food production dimension of food security, while paying little attention to food safety [13]. Therefore, this study aims to contribute to the existing body of knowledge on food safety and quality control in Nigeria's agric-food industry and to provide practical recommendations to policymakers and other stakeholders in the agric-food sector on how to address the safety gaps. The objectives of this study are as follows:

- 1) To assess the current state of food safety and quality control in Nigeria's agricultural and food industry, and to identify areas for improvement.
- 2) To evaluate the prospects of digital technologies, when it comes to enhancing food safety, as well as quality control in Nigeria's agricultural and food industry.

## METHOD

**Theoretical Framework: Technology Acceptance Model.** This study anchors its arguments on the Technology Acceptance Model. The Technology Acceptance Model (TAM) is an analytical framework introduced by Fred Davis in 1989 [14]. TAM is a widely used theoretical framework for analysing information systems, as it encourages the adoption of technology. According to TAM, the adoption and use of technology are influenced by two main factors: perceived usefulness and perceived ease of use [15].

The propositions of the TAM model provide insights into the potential benefits of adopting and using digital technologies to enhance food safety and implement quality control in Nigeria's agric-

food industry. The perceived usefulness of digital technologies, such as mobile-based reporting systems and digital market surveillance technology, can influence their adoption among stakeholders in the agric-food industry. If stakeholders perceive these technologies as helpful in improving food safety through quality control, they are more likely to adopt and use them. Similarly, perceptions of digital technologies can influence their adoption and use. In other words, if stakeholders see digital technologies as easy to use and to integrate into their existing systems and processes, they are more likely to adopt and promote their use. This study posits that digital technologies have the potential to enhance food safety and also adherence to quality control standards in Nigeria's agric-food industry.

*The Research Design and Method of Data Collection.* This study employed a qualitative research approach. It involved an in-depth examination of the current state of food safety and the enforcement of quality control regulations in Nigeria's agric-food industry, as well as the potential of digital technologies to enhance them. This study relied on both primary and secondary sources of data. The researchers collected primary data through key informant interviews with six researchers who have conducted studies on food safety or the implementation of food quality control measures in Nigeria's AgriFood industry. The Key Informants were selected based on their expertise and experience in food safety requirements and their implementation in Nigeria's agric-food industry. The interviews were used to gather in-depth insights into the challenges and opportunities associated with food safety and the enforcement of quality control requirements in Nigeria's agric-food industry, as well as the potential of digital technologies to enhance it.

To obtain secondary data, the researchers reviewed existing literature on food safety and the enforcement of food quality control standards in Nigeria's AgriFood industry. The literature review provided a comprehensive understanding of the current state of food safety and adherence to quality control in the industry, and the potential of digital technologies to address the challenges associated with them.

*Method of Data Analysis.* The data collected from the Key Informant interviews and secondary sources were analysed using thematic analysis, which involved identifying, coding, and categorising themes and patterns [16]. The researchers

chose the thematic analysis approach because it allows them to provide detailed explanations of the experiences and perceptions of the key informants, as well as of the information extracted from the existing literature. The researchers validated the study's findings through triangulation by comparing the key informant interview results with existing literature on food safety in Nigeria [17].

## RESULTS

### **The current state of food safety and quality control enforcement in Nigeria's agricultural and food industry, and identified areas for improvement.**

The analysis of the current state of food safety in Nigeria's agric-food industry, based on in-depth interviews with key informants and a review of secondary data sources, reveals several critical issues that require attention. They include: inadequate infrastructure, reflected in poor storage facilities and inefficient transportation systems; insufficient regulatory enforcement; limited access to markets; and even high incidences of foodborne illnesses arising from microbial contamination. Furthermore, our analysis showed limited capacity to enforce food safety testing and inspection standards, as well as a lack of transparency and accountability in supply chain operations. The challenges are further worsened by limited awareness and education about food safety in Nigeria, as well as inadequate funding and resources needed to enforce food safety standards. The data from the primary sources are first presented, then supported with information from secondary sources.

1) Inadequate Infrastructure. Data from both primary and secondary sources indicate that inadequate infrastructure hampers the current state of food safety in Nigeria's AgriFood industry. In response to a question on food preservation challenges, one of the interviewed researchers stated:

*The lack of adequate storage facilities is a major challenge in Nigeria's agricultural and food industry. Most farmers and food processors lack access to modern storage facilities that can protect their products from contamination and spoilage. As a result, some farmers resort to harmful preservation techniques, such as using sodium benzoate to preserve fruits and vegetables (Interview with Researcher 3).*

There is also research evidence from the extant literature suggesting that poor storage facilities and food-handling practices are major contributors to food losses and contamination in Nigeria. For example, studies [18] noted that inadequate storage facilities and handling practices are major contributors to aflatoxin contamination in maize and peanuts in Nigeria. Furthermore, another researcher stated that:

*Some farmers use formaldehyde to preserve fish, which can be harmful to consumers. Formaldehyde is a known carcinogen, and its use in food preservation is prohibited in many countries (Interview with Researcher 2).*

Studies support this claim by showing that the use of formaldehyde and other chemical preservatives in food preservation poses a significant public health concern in Nigeria [19]. Note that formaldehyde is a toxic substance that can cause cancer and other health problems, while sodium benzoate (E211) can cause allergic reactions and other adverse health effects in some individuals [20].

Inefficient transportation systems glaringly reflect the inadequate infrastructure in Nigeria's AgriFood industry, and this inefficiency has become a defining feature of Nigeria's transportation sector. According to one of the researchers, he stated that:

*Nigeria's transportation systems are not designed solely to handle perishable food products, leading to significant losses during transport, especially for farmers in rural areas (Interview with Researcher 1).*

The above assertion is supported by studies showing that inefficient transportation systems are a significant constraint on food production and marketing in Nigeria [21]. The lack of refrigerated transportation and other specialised food preservation equipment can lead to spoilage and contamination of food products during transportation. In addition, outdated equipment and technology are also significant challenges in Nigeria's agric-food industry. According to one of the researchers interviewed, he argued that:

*Most food processing companies in Nigeria use outdated equipment and technology, which can lead to contamination and spoilage of food products. There is a need for investment in modern equipment and technology to improve food safety and implement quality control standards (Inter-*

*view with Researcher 4).*

The above assertion aligns with the arguments of scholars [22, 23].

2) Insufficient Regulatory Enforcement. The quest to enforce food quality control in Nigeria's agric-food industry also faces challenges due to insufficient regulatory enforcement. According to researcher 1, he noted that:

*The regulatory frameworks for food safety in Nigeria are weak and inadequate. There is insufficient enforcement of food safety regulations, leading to unsafe food products. For instance, the National Agency for Food and Drug Administration and Control (NAFDAC) is responsible for regulating food safety in Nigeria. Still, the agency lacks the necessary resources and capacity to effectively enforce food safety regulations (Interview with Researcher 1).*

The above assertions are also echoed in studies by scholars such as [12, 24, 25], which all show that weak regulatory frameworks and inadequate enforcement of food safety regulations remain the major contributors to food safety problems in Nigeria. The lack of effective enforcement of food safety regulations has also created a delicate situation, as it has enabled the contamination of many food products with harmful substances or organisms, including microbial contaminants and chemical preservatives, which remain prevalent [12]. The limited capacity of regulatory agencies has also posed many challenges in enforcing food safety in Nigeria. According to one of the researchers, he noted that:

*The regulatory agencies responsible for food safety in Nigeria lack the necessary resources, including personnel, equipment, and even technology, to carry out their mandate effectively; this has led to many food products being unsafe for human consumption (Interview with Researcher 3).*

3) Limited Access to Markets. This study also found that the quest for food safety in Nigeria has been hampered by farmers' limited access to formal markets, such as online marketplaces and supermarkets. That has posed serious challenges for the industry. According to one of the researchers interviewed, he said:

*Limited access to formal markets, such as supermarkets, poses a significant challenge to food safety and quality control in Nigeria's AgriFood industry. Many farmers and even food processors lack access to formal markets, making it difficult for*

them to sell their products at a fair price and comply with food safety regulations (Interview with Researcher 1).

Another researcher did note that:

*The high cost of market access is also a significant challenge to food safety and quality control in Nigeria's agricultural and food industry. Many farmers and food processors lack the resources and capacity to access formal markets, making it difficult for them to comply with food safety regulations and sell their products at a fair price (Interview with Researcher 2).*

The limited access of Nigerian food products to formal markets has led many farmers and food processing businesses to sell their products in informal markets, where food safety regulations are rarely implemented or enforced [26].

3) High Incidence of Foodborne Illnesses and the Prevalence of Microbial Contamination. A high incidence of foodborne illnesses also emerged as a serious challenge in the food industry. According to one of the researchers interviewed, he said:

*Foodborne illnesses are a significant public health concern in Nigeria. The lack of adequate food safety, food regulations, and enforcement has led to many food products being contaminated with harmful substances, including microbial contaminants and chemical preservatives (Interview with Researcher 1).*

To provide more depth to the discussion on microbial contamination, researcher 2 said:

*Microbial contamination of food products is a significant challenge to food safety in Nigeria. Many food products are contaminated with harmful microorganisms, such as bacteria, viruses, and parasites, which can cause foodborne illnesses (Interview with Researcher 2).*

Extant studies support this view, showing that microbial contamination of food products remains a significant food safety concern in Nigeria. For example, authors [27] report that many food products in Nigeria contain microbial pathogens such as Salmonella and E. coli. In addition, limited awareness of food safety practices has further complicated Nigeria's existing food safety situation. According to researcher 4, he said:

*Many people in Nigeria, including farmers, food handlers, and consumers, lack awareness of food safety practices. And this lack of understanding*

*can lead to food safety problems, including the foodborne illnesses we are talking about (Interview with Researcher 4).*

Researcher 1 also notes that:

*Microbial contamination is a significant problem in Nigeria's food supply. Many food products are contaminated with harmful microorganisms, including bacteria, viruses, and even parasites, which can cause foodborne illnesses (Interview with Researcher 1).*

Some observations about Aflatoxins were also shared by researcher 2. Below are the observations:

*Aflatoxins are a big problem in Nigeria's maize and peanut industries. Aflatoxins are toxic and carcinogenic, and can cause serious health problems in humans and animals (Interview with Researcher 2).*

Studies such as those by the authors [28] support this assertion by showing that aflatoxins often contaminate many maize and peanut samples in Nigeria. Note that the causes of microbial contamination in Nigeria's agricultural and food industry are complex and multifaceted. Based on insights from researchers, the study identifies poor handling and storage practices, inadequate sanitation, poor hygiene, weak food safety regulations, and enforcement gaps as the leading causes of microbial contamination in Nigeria's food supply; authors [12, 29] also highlight these factors.

4) Limited Capacity for Food Safety Testing and Inspection. The limited capacity for food safety testing and inspection has also emerged as a serious impediment to the enforcement of food quality control in Nigeria's agric-food industry. The limited laboratory testing capacity is a severe limitation for food safety testing and inspection in Nigeria. One of the researchers interviewed noted that:

*The laboratory capacity for food safety testing in Nigeria is limited. There appear to be no or limited laboratories that have the necessary equipment to conduct adequate testing of food products (Interview with Researcher 5).*

The extant literature also supports this assertion by showing that laboratories in many African countries, including Nigeria, lack the necessary equipment and personnel to conduct adequate testing and inspection of food products [30]. Inadequate testing and inspection provisions also

pose a significant challenge to food safety testing and inspection in Nigeria. The available literature indicates that the testing and inspection protocols for food safety in Nigeria are inadequate [25]. Regulatory authorities often fail to test or regularly inspect many food products, leading to food safety problems. There are also issues associated with the limited certification and accreditation of food safety testing laboratories. Certification and accreditation of food safety testing laboratories in Nigeria are limited [25].

5) Lack of Transparency and Accountability in the Supply Chain. It was also found that the lack of transparency and accountability in the supply chain is a concerning issue that affects food safety in Nigeria's agricultural and food industry. According to one of the researchers interviewed, he noted that:

*The supply chain in Nigeria's AgriFood industry lacks transparency and accountability. It is difficult to track and trace food products, and that can lead to food safety problems and make it challenging to identify the source of contamination (Interview with Researcher 1).*

Evidence from secondary sources also indicates that limited visibility into supply chain operations negatively impacts Nigeria's agric-food industry. The lack of visibility into supply chain operations makes it quite challenging to track and trace food products [31]. This situation further complicates matters, as fragmented, poorly coordinated supply chains make it difficult to identify the exact source of contamination. As a result, regulators and producers face greater food safety and public health challenges, since these limitations hinder the timely recall of contaminated products. Similarly, given the limited accountability for food safety breaches in Nigeria [32], it is even more difficult to hold individuals and organisations accountable for the food safety problems they cause.

6) Limited Awareness and Education on Food Safety. Finally, limited public awareness and education on food safety have also emerged as a serious barrier to food safety and to the enforcement of quality control in Nigeria's agric-food industry. Researcher 1 notes that:

*Many farmers, food handlers, and consumers in Nigeria lack awareness of food safety practices. This lack of awareness can lead to food safety problems and make it challenging to improve food safety and quality control (Interview with Re-*

*searcher 1)*

There appears to be limited awareness of food safety practices or expectations amongst farmers and even food Handlers. Many farmers and food handlers in Nigeria lack awareness of food safety practices, such as proper handling and storage of food products [25]. This creates challenges for improving food safety and enforcing quality control. Part of the reason for the poor awareness is the limited education and training on food safety. Many farmers, food handlers, and even food consumers in Nigeria lack access to proper education or training on the requirements for ensuring food safety. For instance, many farmers in Nigeria have limited awareness of the risks associated with microbial contamination. There is also the issue of inadequate funding and limited resources required to enhance food safety in Nigeria [33]. There appear to be few adequately funded food safety initiatives, and the existing regulatory agencies lack the resources to perform their duties effectively.

### **The potential of digital technologies to enhance food safety and improve the enforcement of quality control in Nigeria's agricultural and food industry.**

This section presents an evaluation of the potential of digital technologies to enhance food safety and enforce quality control in Nigeria's AgriFood industry. The review focuses on how technology can improve real-time monitoring and reporting of observed food safety concerns to ensure supply chain transparency and accountability. The ultimate goal is to minimise the prevalence of poor-quality food products in the market.

1) Mobile-Based Reporting System. The potential of digital technologies to enhance food safety and ensure effective quality control in Nigeria's AgriFood industry is quite extensive; this is particularly true when stakeholders consider the benefits of mobile-based reporting systems. The systems can improve real-time monitoring and even food safety reporting, thereby reducing reporting time [34]. In Nigeria, where inadequate infrastructure and insufficient regulatory enforcement hamper the timely execution of tasks, mobile-based reporting systems can play a pivotal role by providing a faster, more efficient food monitoring and reporting system.

Other studies have shown that mobile-based reporting systems improve the real-time reporting of food safety issues. For example, studies on the impact of mobile-based reporting systems on food safety in Kenya found that mobile phones can shorten the time to report food safety issues, thereby reducing the incidence of foodborne illnesses [35]. Hence, policymakers and regulatory agencies in Nigeria can also apply this approach to improve the reporting of food safety concerns, especially in rural areas where access to formal reporting systems is quite limited. Also, using mobile-based reporting systems in Nigeria will improve transparency and accountability of operations in the AgriFood industry, which, in turn, will help build trust amongst consumers, especially in the formal markets. The use of mobile-based reporting systems in Nigeria's AgriFood industry will also be quite helpful in addressing the challenges faced by farmers and other food processing firms in accessing markets [36]. In Ghana, for instance, a mobile-based reporting system was adopted to track and report food safety issues in the poultry sector [37]. The system allowed farmers and poultry processors to report food safety impediments in real time, enabling swift action when needed to contain the spread of foodborne illnesses. Note that Ghana and Kenya are both sub-Saharan African countries that share many similarities with Nigeria. Hence, the successful implementation of mobile-based technology in the two countries indicates that it also has a high potential for succeeding in Nigeria.

2) Digital Marketing Surveillance. Digital Market Surveillance Technology is also another potential solution to Nigeria's many food safety concerns. This technology can detect and track food safety risks with an impressive high accuracy rate, thereby enabling rapid action to eliminate low-quality products [38]. In a country like Nigeria, where inadequate infrastructure and insufficient regulatory enforcement are enduring challenges, digital market surveillance technology will play a paramount role in improving food safety and strengthening quality control enforcement. A study on the use of digital market surveillance technology to ensure food safety in South Africa also found that the technology can detect and track food safety risks with high accuracy [39]. Again, that does indicate a high potential for success if introduced in Nigeria as well.

The benefits of adopting digital market surveillance technology in Nigeria's AgriFood industry

are numerous. First, it will help to improve the detection and tracking of food safety risks. Secondly, it will enhance transparency and accountability in the agricultural and food industry, which can, in turn, help build trust amongst consumers. Finally, adopting digital market surveillance technology in Nigeria can help reduce economic losses associated with food contamination by enabling regulatory agencies to take swift action to prevent the spread of foodborne illnesses and increase access to global formal markets.

3) Blockchain Technology. Blockchain Technology is another potential solution that can help enhance supply chain transparency and accountability in Nigeria's AgriFood industry. This technology can ensure supply chain transparency and accountability, thereby reducing the circulation of low-quality food products [40]. In Nigeria, where the circulation of low-quality food products is a significant problem, Blockchain Technology will be a game-changer in improving supply chain transparency and accountability. It will enable real-time tracking and tracing of products [41].

Many studies on the use of Blockchain Technology in supply chain management found that the technology helps ensure supply chain transparency and accountability [42–44]. In Ghana, stakeholders implemented a blockchain-based system to track and trace cocoa beans, which has been successful [45]. Adopting Blockchain Technology in Nigeria's agricultural and food industry will help address the challenge of limited market access by granting Nigerian products access to formal domestic markets and improving access to international markets.

## CONCLUSIONS

This study aimed to show that digital technologies, such as mobile-based reporting systems, digital market surveillance technology, and Blockchain Technology, have the potential to enhance food safety and the enforcement of quality control in Nigeria's AgriFood industry. The study did highlight the need for the government. Also, business owners need to invest in digital technologies to enhance food safety and implement food quality standards. It also highlights the need for regulatory agencies to develop more robust frameworks to support the adoption and use of digital technologies in the enforcement of quality control. Based on the foregoing, the following recommendations are made:

1) The National Agency for Food and Drug Administration and Control (NAFDAC) should invest more in the development of mobile-based reporting systems, which can enable real-time reporting of food safety issues; this can help improve the reporting of food safety issues and reduce the incidence of foodborne illnesses.

2) The Federal Ministry of Agriculture and Rural Development should put more effort into the development of digital market surveillance technology, which can help to detect and track food safety risks with a high accuracy rate, and also enable the taking of swift action to prevent the circulation of low-quality food products.

3) The Nigerian government should invest in Blockchain Technology, as it can help to ensure supply chain transparency, accountability and even efficiency, in the Agric-food industry; this will help to reduce the circulation of counterfeit or low-quality products.

4) The National Universities Commission (NUC) should develop a curriculum which guides the provision of training and education on digital technologies in the area of food safety and the enforcement of quality control standards; this can help to build the capacity of food safety professionals in Nigeria, thereby enabling them to use digital technologies to enhance food safety effectively. There is also a need to develop informal teaching platforms or mechanisms to educate farmers and market traders on food safety and quality.

5) Government agencies and civil society organisations should use the media to sensitise the public and create awareness about food safety concerns and quality control gaps in Nigeria. They should also leverage social media platforms to promote sensitisation campaigns. In contrast, platforms such as X (Twitter) should host and sustain critical debates on the need to prioritise food safety and enforce food quality control standards in Nigeria.

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