

ARTIFICIAL INTELLIGENCE IN FOOD SAFETY GOVERNANCE: EMERGING APPLICATIONS, REGULATORY CHALLENGES, AND THE INDIAN EXPERIENCE

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Abstract

The integration of Artificial Intelligence into the governance of food safety in India is one of the most transformative developments in food safety regulation in the country in the 21st century. The Food Safety and Standards Act, 2006 (FSSA), and its regulatory body, the Food Safety and Standards Authority of India (FSSAI), provide the regulatory framework for food safety in India. The integration of AI into this framework will allow the authority to improve food safety through increased traceability of food products, increased efficiency in detecting food hazards, and reduced regulatory burdens on food businesses. This article aims to review how AI can be incorporated into food safety in India through the use of predictive analytics, machine learning to detect adulteration, computer vision to assess product quality, blockchain-AI systems to trace products, and natural language processing to monitor regulatory compliance. Furthermore, this article will review the gaps within current food safety regulations in India regarding AI. Finally, by comparing the approaches to AI regulation in the European Union, the United States, and China, this article will propose a framework for AI in food safety regulation in India that is compliant with the country's constitution, specifically Article 21 and Article 47.

Keywords: Artificial Intelligence, Food Safety, FSSAI, Machine Learning, Regulatory Governance, India, Food Adulteration, Traceability, Algorithm.

1. Introduction

Food safety has till now mainly been based on the idea of chemical testing and penal enforcement. The Food Safety and Standards Act, 2006 aimed to consolidate all the food laws of the country and place all the food regulatory authority under one body to regulate food and ensure its safety the Food Safety and Standards Authority of India (FSSAI).¹⁷⁵³ However, with the exponential growth of the food processing industry of India (valued at approximately USD 866 billion in 2025) and the increasing

complexities involved in the supply of food from farm to table, there is a need to improve upon the methods in place within the FSSAI to improve food safety.¹⁷⁵⁴

Artificial Intelligence in the form of machine learning, deep learning, computer vision, natural language processing, and predictive analytics has become part of various governance systems around the world. The World Health Organisation (WHO) has recognised that AI technology could be used to identify food safety hazards much faster and to trace the source of contaminated

¹⁷⁵³ Food Safety and Standards Act, 2006 (Act 34 of 2006), Preamble and Section 4; see also Preamble to the Food Safety and Standards Authority of India (FSSAI), established under Section 4(1) of the Act.

¹⁷⁵⁴ Ministry of Food Processing Industries, Government of India, Annual Report 2023-24 (MoFPI, New Delhi, 2024), available at <https://mofpi.gov.in>

food products in real time.¹⁷⁵⁵ Similarly, the Food and Agriculture Organisation of the United Nations (FAO) recognises that digitising food safety systems, including the implementation of Artificial Intelligence, is vital to achieving the Sustainable Development Goal 2 (Zero Hunger) and SDG 3 (Good Health and Well-Being) goals of the UN.¹⁷⁵⁶

While there are various technology-based initiatives within India by the FSSAI, such as the Food Safety on Wheels programme, the FLRS (Food Licensing and Registration System), and the integration of rapid testing kits, there is no significant deployment of Artificial Intelligence technologies yet within these programmes.¹⁷⁵⁷ Thus, the aim of this article is to review the various uses of Artificial Intelligence in food safety in India, recognise the regulatory lacunae of the FSSA 2006 Act, and propose a regulatory framework that can be implemented within the Indian legal system for the effective use and regulation of Artificial Intelligence in the food safety sector.

2. Understanding AI in the Food Safety Ecosystem

Artificial intelligence does not relate to a specific technology but refers to various tools that simulate the functions of the human brain such as learning, reasoning, recognizing patterns, and making decisions based on the information available to the tool.¹⁷⁵⁸ For instance, machine learning algorithms can detect anomalies in food analysis that humans could not identify.

Computer vision systems based on convolutional neural networks can analyze the visual appearances of food products and determine whether they are adulged or spoiled with high accuracy of over 95%.¹⁷⁵⁹ Natural language processing applications can scan

food labelling and import documents and report anomalies to food regulatory authorities. Additionally, blockchain technology ensures that all the components of the supply chain are visible to food authorities in the case of foodborne illness outbreaks.¹⁷⁶⁰

Artificial intelligence can be implemented in food safety in five different areas: detecting food hazards and adulteration, tracing and ensuring supply chain transparency, predicting food safety issues for food inspections, monitoring food regulatory compliance, and creating systems to provide food information to consumers. Each of these areas has unique regulatory and ethical issues for the law of India to consider before artificial intelligence can be integrated into the FSSA.

3. Current and Emerging Applications in India

3.1 AI-Driven Adulteration Detection

Food adulteration is one of the primary food safety challenges in India. According to the FSSAI Annual Report (2022-23), over 1.5 lakh food samples were tested in the country, and a significant number of them failed the quality tests prescribed for the food products.¹⁷⁶¹ The use of AI-powered spectroscopy systems, such as near-infrared spectroscopy (NIRS) coupled with deep learning models, has been used to detect adulterants in food commodities such as detergent in milk, Sudan dye in chilli powder, and mineral oil in edible oils. The Indian Institute of Technology (IIT) Bombay developed an AI-assisted near-infrared spectroscopy-based system for the detection of milk adulteration. The system demonstrated 97.4% accuracy in the detection of adulterated milk samples.¹⁷⁶²

Food Testing Laboratories that are under the FSSAI are considering the use of automated image recognition systems for the inspection of

¹⁷⁵⁵ World Health Organisation, "WHO Five Keys to Safer Food" and "Digital Health and Food Safety" Technical Consultation Report (WHO, Geneva, 2023).

¹⁷⁵⁶ Food and Agriculture Organisation of the United Nations, "FAO Strategy on Digital Agriculture" (FAO, Rome, 2022), p. 14.

¹⁷⁵⁷ Food Safety and Standards Authority of India, Annual Report 2022-23 (FSSAI, New Delhi, 2023), Chapter 5 (Technology Initiatives).

¹⁷⁵⁸ Stuart Russell and Peter Norvig, Artificial Intelligence: A Modern Approach (4th edn, Pearson, 2021), p. 1.

¹⁷⁵⁹ K. Bhargava et al., "Deep Learning-Based Computer Vision for Food Quality Inspection: A Systematic Review" (2023) 182 Food Control 110486.

¹⁷⁶⁰ M.A. Salah Uddin et al., "Blockchain Leveraging in the Agri-Food Supply Chain: A Framework for the Future" (2021) 152 Food Control 109318.

¹⁷⁶¹ Food Safety and Standards Authority of India, Annual Report 2022-23 (FSSAI, New Delhi, 2023), Annexure III (State-Wise Testing Data).

¹⁷⁶² Indian Institute of Technology Bombay, Research Output Report 2022-23: AI Applications in Food Safety (IIT Bombay, Mumbai, 2023).

food samples. Furthermore, the Ministry of Agriculture is also using AI-based systems for the monitoring of the health of soil and crops that feed the Indian food supply.¹⁷⁶³

3.2 Traceability and Supply Chain Integrity

Traceability in the food supply chain is a cornerstone of food safety law. While Section 28 of the FSSAI 2006 requires all food business operators to keep proper records of the food articles that they purchase, manufacture, store, distribute, and sell, there seems to be a lack of implementation of this regulation. The integration of AI into blockchain technology offers a technological solution to the supply chain traceability challenge. The National Horticulture Board and a few private agri-food companies have implemented blockchain technology to trace the origin of mango, pomegranate, and processed food exports. These systems use AI algorithms to receive and analyze sensor data from the food products in transit to identify any deviations in food safety parameters during transit.¹⁷⁶⁴

The Food Safety Connect platform by the FSSAI and the National Food Safety Data Repository are efforts by the FSSAI to establish a data-driven food safety regulatory authority. The use of AI analytics on these data repositories holds the potential to allow the FSSAI to proactively ensure food safety rather than reactively dealing with food safety challenges.¹⁷⁶⁵

3.3 Predictive Analytics for Risk-Based Inspections

Currently, the process of conducting food safety inspections in India is marked by certain constraints in terms of resources, geographical coverage, and the scheduling of these inspections. AI-based prediction models of food

safety risks, trained with past inspection and violation reports, can determine which food establishments are at the most significant risk of violating food safety regulations far more efficiently than manual inspection schedules. FSSAI has included in its Strategic Plan 2020–2025 a plan to shift towards risk-based inspection systems, which can be enabled with the implementation of these AI-based predictive models of food safety.¹⁷⁶⁶ The United States Food and Drug Administration (FDA) has implemented a system called PREDICT (Predictive Risk-based Evaluation for Dynamic Import Compliance Targeting) that uses machine learning to determine which imported foods are at the most significant risk of violating food safety regulations and has seen a substantial improvement in the rate of FDA inspections of food products.¹⁷⁶⁷ As the regulating authority of food imports in India, FSSAI is mandated under Section 16(3)(e) of the FSSAI 2006 to regulate all food imports into the nation.¹⁷⁶⁸

3.4 Consumer-Facing AI Applications

Beyond the regulatory aspects of food safety, there are also consumer-focused AI applications. For instance, the FSSAI has developed the Food Safety Connect mobile application that uses AI to allow consumers to check the licence of a food establishment, file a complaint against a food business, and access information regarding the safety of food products. Furthermore, there are chatbots and AI applications that can read food labels and identify food allergens and additives.¹⁷⁶⁹ These types of applications are especially relevant to the Indian country as food literacy among the population is not universally high and Article 47 of the Indian constitution states that the state shall take care to raise the standard of living of

¹⁷⁶³ Ministry of Agriculture and Farmers Welfare, Government of India, National e-Governance Plan in Agriculture 2.0: Digital Agriculture Mission 2021–2025 (MoA, New Delhi, 2021).

¹⁷⁶⁴ National Horticulture Board, Government of India, "Traceability Pilot Project Report: Mango and Pomegranate Export Chains" (NHB, Gurugram, 2023).

¹⁷⁶⁵ Food Safety and Standards Authority of India, "Digital Transformation Strategy 2022–2025" (FSSAI Policy Document, New Delhi, 2022).

¹⁷⁶⁶ Renata Clarke, Rea Tresa Jojo and Astrid von Meijenfildt, "Artificial Intelligence and Risk-Based Food Safety Inspection: Opportunities and Challenges" (2023) 38(2) Food Policy 102523.

¹⁷⁶⁷ Food Safety and Standards Authority of India, Strategic Plan 2020–2025 (FSSAI, New Delhi, 2020), Strategic Pillar 3 (Regulatory Modernisation).

¹⁷⁶⁸ US Food and Drug Administration, "PREDICT: Predictive Risk-based Evaluation for Dynamic Import Compliance Targeting" (FDA, Silver Spring, 2022); Food Safety and Standards Act, 2006, Section 16(3)(e).

¹⁷⁶⁹ Food Safety and Standards Authority of India, Food Safety Connect Mobile Application: User Manual (FSSAI, New Delhi, 2023), available at <https://fscos.fssai.gov.in>.

its people and ensure that they are adequately provided for.¹⁷⁷⁰

4. The Regulatory Framework and Its AI-Related Lacunae

The FSSA 2006 is a comprehensive Act that establishes the FSSAI, providing it with the power to prescribe food standards, license food businesses, regulate the import and export of food, and adjudicate cases of violation of food safety regulations.¹⁷⁷¹ However, the Act was established well before the emergence of AI in food production and safety industries. The Act does not provide for the challenges that will be posed by AI in food safety regulations. Some of the lacunae in the Act include:

4.1 Absence of Legal Framework for AI-Generated Evidence in FSSA Enforcement: The Act provides no provisions regarding the use of AI-generated evidence in food safety regulations. While Section 46 of the Act provides for the taking of food samples, and Section 47 provides for the analysis of these samples in accredited laboratories, there is no provision for the acceptance of evidence generated from the analysis of food by AI algorithms in hearings before adjudicating officers of the FSSAI or in appeals tribunals under Sections 68 and 70 of the Act.

4.2 Digital Record-Keeping and Evidential Integrity in AI-Enabled Traceability Systems: The Food Safety and Standards (Licensing and Registration of Food Businesses) Regulations, 2011 require food businesses to maintain certain records of their food production processes. However, there are no provisions of the Regulations that provide for the standards of digital records generated by AI-enabled traceability systems of food products.¹⁷⁷²

4.3 Lack of Comprehensive Data Protection and AI Governance Framework: There is no

comprehensive data protection and AI governance framework in the country that would provide for the use of consumer data, supply chain data, and health data in the implementation of AI systems in food safety. While the Digital Personal Data Protection Act, 2023 establishes data protection principles that would apply to the collection of consumer and health data, it does not include provisions relating to AI in the context of food safety regulations.¹⁷⁷³ Additionally, the proposed National Data Governance Framework Policy does not include provisions relating to food safety.

4.4 Algorithmic Accountability and Constitutional Concerns in Food Safety Regulation: The Act provides no provisions relating to algorithmic accountability. As the Act provides for the use of algorithms to rate food businesses (or their products) it does not provide for mechanisms by which those food business operators may challenge those decisions of the FSSAI. This raises concerns regarding both Article 14 and Article 19(1)(g) of the Constitution of India that relate to the equality of all individuals and the right to engage in any economic activity.

5. Comparative Regulatory Perspectives

The General Food Law Regulation (EC No. 178/2002) and the recently adopted EU Artificial Intelligence Act (Regulation (EU) 2024/1689), which entered into force in August 2024, include AI as a crucial component of food safety and require assessments of the risks that such AI systems may present to food safety.¹⁷⁷⁴ Furthermore, the EU's Rapid Alert System for Food and Feed (RASFF) uses machine learning algorithms to identify the potential risks to food

¹⁷⁷⁰ Constitution of India, Article 47 (Duty of the State to Raise the Level of Nutrition and the Standard of Living and to Improve Public Health).

¹⁷⁷¹ Food Safety and Standards Act, 2006, Sections 16-29 (Functions and Powers of FSSAI).

¹⁷⁷² Food Safety and Standards (Licensing and Registration of Food Businesses) Regulations, 2011, Schedule 4 (Record-Keeping Requirements for Food Business Operators).

¹⁷⁷³ Digital Personal Data Protection Act, 2023 (Act 22 of 2023), Sections 4-12 (Obligations of Data Fiduciaries).

¹⁷⁷⁴ Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 Laying Down Harmonised Rules on Artificial Intelligence (Artificial Intelligence Act) [2024] OJ L 2024/1689; Regulation (EC) No. 178/2002 of the European Parliament and of the Council of 28 January 2002 Laying Down the General Principles and Requirements of Food Law.

and feed within the EU from various suppliers and countries.¹⁷⁷⁵

In the United States, the FDA has included information within its Technology Modernisation Action Plan regarding the use of AI and machine learning methods as a means of modernising food safety within the framework of the FDA Food Safety Modernisation Act (FSMA), 2011. Furthermore, the agency has published an AI and machine learning (AI/ML) action plan that details its intentions to address issues related to the validation of AI and ML tools used in food analysis, the transparency of those analyses, and the monitoring of those AI systems after they are released into food regulatory and safety applications.¹⁷⁷⁶

China's Food Safety Law (as amended in 2021) and its Interim Measures for the Administration of Generative AI Services, 2023, both express an awareness of the role that AI may play in food safety governance. For instance, the law requires food enterprises to implement traceability systems, and includes provisions that assign accountability to the algorithms that are used in the food production and management process.¹⁷⁷⁷

Each of these regulations and data points on AI and food safety regulations within the EU, the United States, and China indicate the various options available for the design of India's AI and food safety regulations.

6. Constitutional and Human Rights Dimensions

The integration of AI into food safety governance in India occurs within the constitutional framework of the country. The relevant Articles include Article 21, which provides the right to life, Article 47, which requires the government to provide nutritious food to its citizens, and Article 14, which provides the right to equality.

Furthermore, the Supreme Court of India has recognized that the right to health is provided for under Article 21¹⁷⁷⁸. The decision of the Court implies that the government must use the best available technology to ensure that there is no foodborne disease and that the food available to the citizens is safe to eat.

The use of AI by the government to regulate food businesses must comply with Article 14 of the constitution. This right to equality was established by the Supreme Court of India in *E.P. Royappa v. State of Tamil Nadu*¹⁷⁷⁹. The use of AI to rate food businesses without the availability of mechanisms for transparency, audits, or grievance redressal may violate the rights of the affected businesses. Thus, the government's obligation to ensure that the implementation of AI to regulate food safety in India is not discriminatory, auditable, and under the oversight of human authorities is both significant and constitutionally mandated.

7. Towards a Regulatory Framework for AI in Indian Food Safety

Drawing on the above analysis, this article proposes a framework for the governance of AI in food safety in India based on five principles.

7.1 Risk-Proportionate Regulation: The risk-based regulation of AI systems in food safety. The degree of regulation that is placed upon AI systems should be based upon the extent of their impact upon food safety and food businesses.

7.2 Data Governance and Interoperability: A Food Safety Data Architecture should be established within FSSAI that provides governance over the data collected by AI systems in food safety while also ensuring that it is interoperable with the Digital Personal Data Protection Act, 2023.

7.3 Algorithmic Accountability: The FSSA 2006 should be amended to include a provision that

¹⁷⁷⁵ European Food Safety Authority, "RASFF — The Rapid Alert System for Food and Feed: Annual Report 2023" (EFSA, Parma, 2024).

¹⁷⁷⁶ US Food and Drug Administration, "Artificial Intelligence/Machine Learning (AI/ML)-Based Software as a Medical Device Action Plan" (FDA, 2021); FDA Food Safety Modernisation Act (FSMA), Pub L. No 111-353 (2011).

¹⁷⁷⁷ Food Safety Law of the People's Republic of China (as amended 2021), Chapter III (Food Safety Standards); Interim Measures for the Administration of Generative Artificial Intelligence Services, 2023 (promulgated by the Cyberspace Administration of China).

¹⁷⁷⁸ *Consumer Education and Research Centre v. Union of India* (1995) 3 SCC 42

¹⁷⁷⁹ (1974) 4 SCC 3

requires the registration and auditing of all AI systems that are used by either FSSAI or food businesses in the regulation of food safety.

7.4 Capacity Building and Inclusive

Deployment: The building of digital infrastructure and capacity within food safety authorities. FSSAI should invest in the digital infrastructure of its officers at the state and district levels. The State Food Safety Index can incorporate indicators related to digital infrastructure to incentivise state governments to invest in such digital infrastructure.

7.5 Consumer Rights and Transparency: The rights of consumers to be informed and to have an explanation for certain decisions of AI systems related to food safety. The right to an explanation should be incorporated into food safety regulations to ensure that consumers and food businesses are made aware of the reasons behind any decisions made by AI systems in food safety.

8. Conclusion

The use of artificial intelligence in the area of food safety governance is not a futuristic concept. The integration of AI into the food safety laws of India is a necessity. Though the FSSA 2006 provides for a robust legal framework for the protection of food safety in India, it is a law conceived well before the advent of the AI revolution. Given the size of India's food economy and the constitutional obligation to provide citizens with the right to food and health, it is imperative that amendments are made to the FSSA 2006 to incorporate AI into food safety governance.

AI presents many opportunities to transform the food safety industry from the detection of adulteration to the traceability of the food supply chain, from the regulation of food safety risks to the empowerment of consumers. However, integrating AI into the food safety governance framework also presents many challenges for the FSSAI. The regulatory strategies of other food-producing giants of the world, such as the EU, the US, and China, provide valuable insights

into the approach that can be taken by India in the formation of its AI in food safety regulations. However, the federal structure of India and its constitution also play essential roles in the formation of the AI in food safety regulatory framework.

To effectively implement AI in the area of food safety, the FSSAI will need to amend the FSSA 2006 to create a governance framework for AI in food safety. Furthermore, the federal government will also have to develop a food safety data architecture, significantly improve the food safety administration's capacity, and ensure that AI is used to uphold the citizens' constitutional right to safe food. By doing so, India will be able to position itself as a leader in the governance of food safety using AI to support its rising role in the food economy of the world.