https://doi.org/10.48047/AFJBS.5.4.2023.154-165

African Journal of Biological Sciences

Journal homepage: http://www.afjbs.com

Research Paper Open Access

FOOD SAFETY REGULATORY MODEL IN INDIA

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Volume 5, Issue 4, Aug 2023

Received: 09 Oct 2023

Accepted: 19 Nov 2023

Published: 02 Dec 2023

doi: 10.48047/AFJBS.5.4.2023.154-165

ABSTRACT:

The food processing sector in India has witnessed remarkable growth in recent years, driven by government initiatives aimed at promoting private investment and infrastructure development. This paper provides an overview of the evolving regulatory framework governing food safety in India, with a focus on recent developments, challenges, and proposed reforms and different new technologies to curb food adulteration. However, challenges such as delays in implementation and gaps in enforcement have highlighted the need for continuous improvement. The infamous "Nestle-Maggi" dispute catalysed reform, prompting the government to reassess existing regulations and strengthen enforcement mechanisms. Therefore, to protect human life new simple rapid approaches are needed to determine the concentration of adulterants in food products. In earlier, several approaches including spectroscopy, chromatography, ELISA are used for determination of adulterants. But these techniques are expensive, time-consuming, and require a skilled person to operate. Recently, nanotechnology-based techniques are successfully used for the identification of adulterates/contaminants. These techniques are simple and sensitive and avoid the use of costly instrumentation. Artificial Intelligence has been proved to be an advanced technology in food science and engineering. In this paper, we intend to proclaim the role of artificial intelligence in food adulteration detection in a systematic way. The potential for machine learning and deep learning in food quality has been analyzed through its applications. Various data sources that are available online to detect food quality have been discussed in this review. The different techniques used to detect food adulteration and the parameters considered while evaluating the food quality have been highlighted. The various comparisons have been done among the state-of-the-art methods along with their datasets sets and results. This study will assist the researchers in analysing the best method available to detect food quality. It will help them in finding the food products that are studied by different researchers along with relevant future research directions.

Keywords: Food safety, Regulation, FSSAI, India, Novel foods.

INTRODUCTION

Over the past several years, the food processing industry in India has witnessed a remarkable growth trajectory, emerging as a sector ripe with potential for lucrative investments. This transformation has been fuelled by concerted efforts from the Ministry of Food Processing Industries, which has rolled out a series of strategic programs aimed at catalysing private investment and fostering sustainable development within the sector. These initiatives, designed to enhance infrastructure, bolster processing capacity, and provide essential support mechanisms, have been pivotal in propelling the food processing industry towards sustained growth.

The Ministry's initiatives represent a multifaceted approach towards nurturing the food processing sector, encompassing various facets crucial for its holistic development. One of the primary objectives of these programs is to address infrastructural deficiencies and create an enabling environment conducive to industry expansion. By investing in infrastructure development, such as cold storage facilities, warehouses, and transportation networks, the government aims to mitigate logistical bottlenecks and enhance the efficiency of food supply chains. This strategic investment not only improves the storage and distribution capabilities of food products but also fosters greater integration with global markets, thereby bolstering the competitiveness of Indian food products on the international stage.

In addition to infrastructure development, the Ministry's initiatives focus on augmenting processing capacity across different segments of the food processing value chain. Through targeted interventions, such as the establishment of food parks, agro-processing clusters, and modernization of existing processing units, the government seeks to unlock the latent potential of India's agricultural produce and transform it into value-added products. By facilitating technology adoption, skill development, and innovation in food processing techniques, these initiatives aim to enhance productivity, quality, and profitability within the sector. Moreover, by promoting backward and forward linkages with farmers, agri-entrepreneurs, and retail chains, these programs foster greater inclusivity and equitable growth within the food processing ecosystem.[1]

A cornerstone of the Ministry's approach towards industry development is its emphasis on attracting foreign direct investment (FDI) to fuel sectoral growth. Recognizing the critical role of FDI in augmenting capital inflows, technological expertise, and global best practices, the government has adopted a liberalized policy framework to facilitate foreign investments in the food processing sector. Under the automated route, foreign investors can now avail themselves of 100 per cent FDI in the food processing industry, thereby unlocking new avenues for international collaboration, technology transfer, and market access. This proactive stance towards FDI underscores India's commitment to

[1] Kohli, Charu, and Suneela Garg. "Food safety in India: an unfinished agenda." *MAMC Journal of Medical Sciences* 1, no. 3 (2015): 131-135.

fostering a business-friendly environment that incentivizes foreign participation and promotes economic prosperity.[2]

Moreover, alongside efforts to attract foreign investments, the Ministry has embarked on a journey of regulatory reform aimed at enhancing the governance and oversight of the food processing industry. Recognizing the importance of a robust regulatory framework in safeguarding consumer interests, ensuring food safety, and promoting industry compliance, the government has undertaken comprehensive measures to strengthen regulatory mechanisms and streamline regulatory processes. These efforts encompass a wide range of initiatives, including the revision of existing regulations, the introduction of new standards, and the deployment of advanced regulatory technologies to improve monitoring and enforcement capabilities.

The overarching objective of these regulatory reforms is to create a transparent, predictable, and investor-friendly regulatory environment that instils confidence among stakeholders and fosters responsible business conduct. By aligning regulatory frameworks with international best practices, harmonizing standards, and promoting industry self-regulation, the government aims to enhance the ease of doing business in the food processing sector while safeguarding public health and consumer interests.

The food processing industry in India represents a compelling investment opportunity, propelled by robust government support, favourable policy frameworks, and a conducive business environment. The Ministry of Food Processing Industries' strategic initiatives, encompassing infrastructure development, capacity augmentation, FDI promotion, and regulatory reform, underscore the government's unwavering commitment to unleashing the sector's full potential. As India embarks on its journey towards becoming a global food processing hub, investors stand to benefit from the myriad opportunities presented by this dynamic and rapidly evolving industry.[3]

BACKGROUND OF THE DEVELOPMENT OF FOOD SAFETY LAW IN INDIA

The national regulatory framework that oversees food standards and food safety has undergone significant modifications in recent years. These changes have been brought about by a number of factors. The first step of these adjustments may be the adoption of the Food Safety and Standards Act, of 2006. Before the implementation of the Food Safety Supply Act, the control of food was carried out by the Prevention of Food Adulteration Act, which was passed in 1954, in conjunction with other restrictions imposed by the government.[4] To consolidate the several pieces of law that deal with food and to exercise oversight over various aspects of the food sector, the Food Safety and Standards Act was put into effect. With the purpose of monitoring and regulating the manufacture, storage, import, and sale of food goods, the FSSAI was established under the Food Safety and Standards Act. The Food Safety and Standards Act made it easier to create the Central Advisory Committee, the Scientific Committee, and the Scientific Panel, all of which were responsible for formulating standards that were founded on scientific principles. Without a sure, it was a big step forward in terms of ensuring the

[2] Kristkova, Zuzana Smeets, Delia Grace, and Marijke Kuiper. “The economics of food safety in India: a rapid assessment.” Wageningen University & Research, (2017).
[3] Singh, S. P., S. Kaur, and D. Singh. "Toxicological profile of Indian foods—ensuring food safety in India." In Food Safety in the 21st Century, pp. 111-127. Academic Press, (2017).
[4] Shukla, Seema, Ravi Shankar, and Surya Prakash Singh. "Food safety regulatory model in India." *Food Control* 37 (2014): 401-413.

quality and safety of food that is intended for human consumption. The introduction of the regulations, on the other hand, slowed down the progress that had been accomplished with the implementation of the FSS Act to a certain degree. The primary reason for this was that the regulations were not implemented until after a delay of about five years, and even after that, they were insufficient since they did not correspond with the events that were occurring at the time. When the 'Nestle-Maggi disagreement developed, it became clear that the new limits were nothing more than surface constraints.

DEVELOPMENT - POST THE 'NESTLE-MAGGI' DISPUTE

Even though the 'Nestle-Maggi' issue initially centred on the integrity of the test results and breaches in labelling, it also attracted attention to a great deal of other problems with the regulation of food in India. In the wake of the 'Nestle-Maggi' dispute, the government admitted that there were flaws in both the legislation and the way it was handled throughout the whole situation. The government needed to perform important reassessments to regain momentum and realign it with the appropriate direction. Following that, the process of rebuilding started, and ever since then, the FSSAI has been making great strides towards its goals. At present, all-encompassing rules are being enacted to oversee almost every aspect of the food industry.

The vast majority of the products and additives have specifications that are in accordance with the standards that are used internationally. In addition, regulations have been put into place to offer in advance permission for food additives and foods that are not specifically mentioned. The implementation of separate standards for advertising and claims provides a more systematic approach to the process of permitting validated claims to be made on culinary products. The establishment of third-party auditing systems has been made possible in order to assist a gradual shift away from relying on regulatory inspections and towards encouraging self-compliance among food companies.

Furthermore, the FSSAI has enacted legislation concerning the labelling and certification of organic food. When it comes to addressing the concerns of the sector, the FSSAI exhibits a better degree of proactive communication. In order to illustrate, the Food Licencing and Registration System (FLRS) that is accessible online has been upgraded to become a Food Safety Compliance System (FoSCoS) that is unified and more user-friendly. FoSCoS will include a wider range of activities than just licencing and registration. The platform is presently being developed to serve as an all-encompassing information technology solution for all of India's food safety regulatory needs. Among the elements that are included in this are an online platform for filing annual returns, a system for clearing food imports, and an audit management system.

WORK-IN-PROGRESS

The Food Safety and Standards Act and the regulations that correspond to it include a number of parts that are inconsistent with one another. The conflicts may develop as a result of the fact that the implementation of the law takes place in a number of phases, with different groups of persons participating in each step. When it comes to its position, the FSSAI sometimes displays inconsistency. As an example, the FSSAI has modified its attitude on the registration and licencing requirements for exporters and e-commerce platforms, even though the current law has not been updated. The FSSAI is proven to be adaptable in its attitude, according to a different point of view, provided that sufficient justifications are supplied in advance. India, which is comprised of 28 states and eight union territories, poses a number of issues when it comes to the implementation of laws by the state food authorities. It

is because the state food authorities do not get enough training on the amended laws and regulations that food businesses are experiencing unnecessary difficulties. Because of this, it is essential to have a solid understanding of their constraints and to effectively handle the issue. As of right now, the process of upgrading state-level laboratories is still going on, and it may take some more time to finish. In addition, the permission of the Parliament is still being sought for other amendments that have been recommended in accordance with the FSS Act and its regulations. As a result of the adoption of these adjustments, it is envisaged that the regulatory framework will become much more simplified.

FSSAI PROPOSES OVERHAUL OF FOOD SAFETY REGULATIONS FOR STREAMLINED COMPLIANCE IN INDIA'S FOOD INDUSTRY

In order to improve the efficiency of business procedures within India's food industry, the FSSAI has suggested a significant revision of the regulations that govern food safety and standards to be implemented across the nation. It was a crucial step towards establishing the 'One Nation, One Commodity, One Regulator' framework that the proposals were considered during the 43rd meeting of the FSSAI, which was headed by Apurva Chandra, who is the Union Health Secretary.[5]

FSSAI Certification Takes Centre Stage: The FSSAI has taken a big step by announcing that its certification is the sole mandatory requirement for food goods throughout the country. This move is intended to simplify compliance procedures and expedite regulatory processes. Following the implementation of this key decision, food businesses will no longer be required to get additional certifications from organisations such as the Bureau of Indian Standards (BIS) or AGMARK.[6] Businesses in the food sector are anticipated to see a considerable decrease in complexity as a result of the simplification of their obligations in order to conform to the standards that have been developed by a single regulatory body.

Approval of Standards and Amendments: The significant gathering also saw the endorsement of many standards and modifications, covering areas such as mead (Honey wine), alcoholic ready-to-drink drinks, milk fat products, and rules for haleem, a traditional meal consisting of meat, pulses, grains, and other components.[7] The regulation amendments highlight the FSSAI's strong dedication to maintaining high standards of food safety for a wide range of food items.

Regulatory Compliance and Stakeholder Engagement: Alongside these changes, the FSSAI approved extensive guides that provide detailed instructions on analysing various food items to guarantee compliance with regulations. These documents are essential tools for firms aiming to comply with FSSAI regulations. Prior to formalising these recommendations and notifying the gazette, they must undergo feedback from stakeholders. The iterative process demonstrates the FSSAI's commitment to openness and the active involvement of stakeholders in influencing the development of food safety standards.

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[5] Pillay, D. Padma Kumar, and TK Manoj Kumar. "Food security in India: Evolution, efforts and problems." *Strategic analysis* 42, no. 6 (2018): 595-611.

[6] Vasanthi, S. I. R. U. G. U. R. I., and Ramesh V. Bhat. "Management of food safety risks in India." *Procs Indian Nat Acad Sci* 84 (2018): 937-43.

[7] Singh, Rameshwar, and Anil Kumar Puniya. "Role of Food Safety Regulations in Protecting Public Health." *Indian Journal of Microbiology* (2024): 1-3.

The FSSAI's strategic plan signifies a significant advancement in the integration of food safety laws. If effectively executed, these suggested modifications possess the capability to initiate a novel period of effective and efficient regulation within India's food sector, hence benefiting companies via the reduction of regulatory duplications and the simplification of compliance procedures.

FUNCTIONING OF FOOD SAFETY AND STANDARDS AUTHORITY OF INDIA

Regulatory framework: The Committee observed that despite the Food Safety and Standards Act, 2006 being in effect for over ten years, FSSAI has not yet established regulations regarding the accreditation of food testing laboratories, food labelling standards, and genetically engineered food, among other matters. In addition, the FSSAI has not been able to identify the specific areas where standards still need to be developed or revised. A majority of states lack a distinct food safety agency to effectively enforce food safety regulations and standards. The consequences of this situation include (i) the absence of rigorous quality control measures, (ii) food contamination, (iii) deceptive packaging, and (iv) the distribution of faulty food items.[8]

The Committee advised that the FSSAI should establish and officially announce rules on all specified areas included in the Act within a one-year timeframe. In addition, it suggests the creation of an independent food safety agency in each state to enforce a strong food safety system.

Licensing and registration: in accordance with the Act, it is a violation of the law for any person to initiate or run a food business without first obtaining a licence. Based on their observations, the Committee found that a significant number of food enterprises were operating either without a valid licence or with licences that had expired. Furthermore, many national and state licencing organisations were issuing licences based on documents that were lacking in quality. Furthermore, it was noted that the percentage of licences that are refused for renewal is quite low throughout the renewal process. The Committee advised FSSAI to evaluate all licences granted under the previous system of product approvals and to revoke and reissue licences as necessary in accordance with the current mechanism of product approvals.

Food safety surveys: The Committee noted that FSSAI has delegated the responsibility of conducting surveys to states; however, governments lack the necessary resources and capabilities to carry out these surveys. Nevertheless, there has been no survey done to assess the implementation of the Act. FSSAI lacks a comprehensive database of food firms. Hence, FSSAI and state food agencies should carry out surveys of food enterprises under their jurisdiction.

Food recall plans: The Committee advised FSSAI to guarantee that every food firm have a food recall strategy, to be implemented in the event of a prohibition on any food goods. In addition, it is suggested that FSSAI should regularly issue recall reports every two weeks in order to inform customers of contaminated and misbranded goods.

Food testing laboratories: The Committee observed a scarcity of labs, personnel, and operational food testing equipment in the majority of food laboratories used by FSSAI and state food safety agencies. There is an insufficient amount of testing done on food samples. There are a total of 266 laboratories in the country; however, a sizeable portion of them do not possess the requisite equipment

[8] Kamboj, Sahil, Neeraj Gupta, Julie D. Bandral, Garima Gandotra, and Nadira Anjum. "Food safety and hygiene: A review." *International Journal of Chemical Studies* 8, no. 2 (2020): 358-368.

to analyse essential features such as the presence of heavy metals, pesticides, and microbiological contamination. To obtain accurate results, the Committee suggested implementing a uniform testing process throughout the whole country. Additionally, it is recommended that every state develop its hiring criteria and routinely oversee the administration of tests in order to fill open positions in laboratories.

The Committee made the observation that just thirteen of the sixty-two state food labs that are now in operation have accomplished the task of obtaining accreditation from the National Accreditation Board for Testing and Calibration Laboratories. Taking into consideration this specific framework, the Committee has said that it is essential to mandate certification for all laboratories in order to provide efficient quality control of food for consumption.

Amendments to the Act: The Committee proposed many revisions to the current Food Safety and Standards Act, 2006 in order to create a consistent regulatory system for food safety across the nation. The proposals pertain to three areas: (i) the regulation of food colour use, (ii) the regulation of pesticide usage in primary production by farmers and fishermen, and (iii) the modification of the procedure for selecting the Chairman and CEO of FSSAI to include experts and scientists from the food industry.

Shortage of manpower: The Committee noted a severe deficiency of personnel at both FSSAI and state safety agencies, resulting in a detrimental impact on food safety measures across the states. The Ministry of Health and Family Welfare should develop a coordinated action plan with the states to address the scarcity of workforce.

EVOLVING REGULATORY FRAMEWORK FOR NOVEL FOOD IN INDIA

The proliferation of global connections has initiated a fresh surge in the market for innovative food products. Novel foods, including genetically modified foods, cell-based meat, eggs, and dairy substitutes, as well as plant-based and fermentation-derived proteins, have been introduced into the Indian market. Hence, it is crucial to comprehend the regulatory framework established for innovative food products.

In the Indian plant-based food sector, Good Dot and One Good are prominent companies offering a diverse array of innovative food items, such as soy milk, coconut milk, almond cheese, and plant-based animal substitutes. Furthermore, Clear Meat, an Indian start-up, has achieved success in creating and conducting trials on its first lab-grown chicken mince. The company intends to release its market-ready product by 2023. Myoworks' objective is to provide components and scaffolds for the cultivated meat sector. They have secured INR 50 lakhs from the Department of Biotechnology, India to showcase an initial proof of concept.[9]

Plant-based alternatives are seeing a surge in popularity globally, thanks to companies like Zero Egg and Vly Foods that provide a broad range of goods. In December 2020, Eat Just, a firm based in California, achieved a significant milestone by obtaining regulatory clearance in Singapore for their cultured chicken, making it the first cultured meat product to do so.[10]

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[9] Giacalone, Davide, and Sara R. Jaeger. "Consumer acceptance of novel sustainable food technologies: A multi-country survey." *Journal of Cleaner Production* 408 (2023): 137119.

[10] Raju P, “Evolving Regulatory Framework For Novel Food In India” (Food and Drugs Law - India, August 25, 2023) https://www.mondaq.com/india/food-and-drugs-law/1359028/evolving-regulatory-framework-for-novel-food-in-india-

The FSSAI issued the Food Safety and Standards (Approval of Non-Specified Food and Food Ingredients) Regulations, 2017 (2017 Regulations) on 11 September 2017. According to the 2017 Regulations, certain food items or ingredients must get prior clearance before they may be introduced into the market.[11]

Furthermore, the 2016 Regulations regulate eight specific types of foods, which also include innovative foods. The laws provide a roster of permissible ingredients and additions that may be used in designated food categories. Food Business Operators (FBOs) who want to produce, import, or sell the designated foods must rigorously comply with these requirements.

In March 2022, the Food Safety and Standards (Health Supplements, Nutraceuticals, Food for Special Dietary Use, Food for Special Medical Purpose, and Prebiotic and Probiotic Food) Regulations, 2022 ("2022 Regulations") were introduced, replacing the 2016 Regulations. However, the 2022 Regulations do not apply to novel foods, which means that the 2016 Regulations and 2017 Regulations still govern novel foods.

In 2022, the FSSAI introduced the Food Safety and Standards (Vegan Foods) Regulations, 2022 ("Vegan Regulations"). These regulations specifically regulate plant-based food items that are considered novel foods. The Vegan Regulations provide the precise meaning of the term "vegan," as well as the necessary conditions for obtaining prior permission and the specific labelling requirements, among other provisions.[12]

Novel food businesses must acquire a central licence from the licencing authorities in accordance with the Food Safety and Standards (Licencing and Registration of Food Business) Regulations, 2011 ("2011 Regulations"). On the other hand, small-scale food businesses engaged in the production of novel foods only need to register themselves under the regulations. FBOs must adhere to hygiene and safety standards, in addition to following the appropriate requirements for licence application. The 2011 Regulations require that all renewals and modifications in the company be informed and authorised by the licencing authority in a suitable manner. Prior clearance from the FSSAI is required for a new food maker or importer in accordance with the 2017 Regulations, before they may apply for a central licence.[13]

Plant-based meals, including burgers manufactured from plant-based beef, are becoming more popular worldwide because of their environmentally favourable characteristics. Indian enterprises are also creating inventive dairy products made from plants to meet the preferences and nutritional requirements of customers, especially those who are unable to digest lactose. Nevertheless, the existing legal framework for innovative foods in India is riddled with difficulties. The FSSAI has significant

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[11] "Novel Foods Regulations And Their Approval Process In India - Food Safety Mantra Blog" (Food Safety Mantra Blog, January 29, 2021) https://www.foodsafetymantra.com/regulatory-insight/food-supplements/novel-food-products/novel-foods-regulations-and-their-approval-process-in-india/#:~:text=According%20to%20these%20regulations%2C%20manufacture,to%20the%20FSSAI%20for%20approval.

[12] Legal P, "Ensuring Food Safety in India: A Comprehensive Overview of Laws, Regulations, and Current Challenges - Prime Legal" (Prime Legal, January 14, 2024) https://primelegal.in/2024/01/14/ensuring-food-safety-in-india-a-comprehensive-overview-of-laws-regulations-and-current-challenges/

[13] Agronfood, "FSSAI Proposes Overhaul of Food Safety Regulations for Streamlined Compliance in India’s Food Industry" (Agro & Food Processing, February 6, 2024) https://agronfoodprocessing.com/fssai-proposes-overhaul-of-food-safety-regulations-for-streamlined-compliance-in-indias-food-industry/

latitude in the regulation process at several stages. For instance, FSSAI has the authority to conduct further evaluations, such as safety assessments and clinical studies, specifically on the Indian population. Currently, there are no explicit protocols established for these clinical studies. In addition, FSSAI specifies the need for post-market monitoring on a case-by-case basis, without providing any standards for determining the necessity of such surveillance. Furthermore, the 2017 Regulations do not provide a set timeframe for the prior licencing of innovative foods, resulting in delays for food business operators (FBOs). Therefore, the broad discretionary powers of FSSAI lead to ambiguity and complicate the regulatory process.[14]

AI'S ROLE IN IMPROVING FOOD SAFETY

AI is significantly enhancing food safety and regulatory frameworks in various areas of the food supply chain, including production, processing, distribution, and consumption. AI plays a crucial role in identifying and stopping harmful substances by combining high-resolution photography with AI to detect foreign items, spoilage, and flaws beyond existing methods. Manufacturing lines install AI-enabled cameras and sensors to oversee and scrutinize food products for impurities or harmful substances, ensuring prompt identification and elimination of dangerous goods. AI models use predictive analytics to examine past and current data, forecasting possible instances of contamination and enabling proactive actions to avert epidemics.[15]

AI enhances food safety by improving traceability throughout the supply chain, a crucial aspect for effectively monitoring the origin of contamination and handling recalls. Combining AI with blockchain technology creates a secure and unalterable record of the entire food item process, improving transparency and responsibility. AI-driven “radio-frequency identification” (RFID) and Internet of Things (IoT) sensors monitor and record environmental conditions, ensuring adherence to safety regulations and maintaining product quality.

AI assists regulatory agencies and enterprises in adhering to food safety laws by automating and optimizing monitoring procedures. AI technologies provide automated reports that analyze large volumes of data to verify ongoing adherence to food safety requirements. AI's Natural Language Processing (NLP) skills enable it to analyze and comprehend new legislation, ensuring organizations remain updated on changes and can adjust promptly.

AI-powered apps are enabling customers to make more secure food choices and stay well-informed about food safety concerns. AI-driven mobile applications provide up-to-date data on food recalls, allergy notifications, and nutritional details, empowering customers to make well-informed choices. However, there are challenges to AI's extensive use, such as maintaining superior and uniform data across the supply chain, implementation being prohibitively expensive, and ethical and privacy concerns arising from the use of AI in surveillance and data gathering.[16]

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[14] “Committee Reports” (PRS Legislative Research) https://prsindia.org/policy/report-summaries/functioning-of-food-safety-and-standards-authority-of-india

[15] Qian, C., S. I. Murphy, R. H. Orsi, and M. Wiedmann. "How can AI help improve food safety?" *Annual Review of Food Science and Technology* 14 (2023): 517-538.

[16] Karanth, Shraddha, Edmund O. Benefo, Debasmita Patra, and Abani K. Pradhan. "Importance of artificial intelligence in evaluating climate change and food safety risk." *Journal of Agriculture and Food Research* 11 (2023): 100485.

The production of food from agricultural products requires the use of both rigorous scientific principles and precise technical techniques. Food processing enterprises generate vast quantities of data during their operations. Data is essential for the efficient functioning of logistical networks, processing equipment, and ensuring food safety. Statistical approaches may be used to analyse daily data, and the findings can be succinctly summarised for various purposes.

This data can be divided into three types:

1. Structured data such as numerical information, times and dates, serial numbers, etc.
2. Unstructured data such as text, email correspondence, machine data, survey replies, and transcripts
3. Semi-structured data such as tables, graphs, PowerPoint presentations, transcripts, audio and video files, XML documents, etc.

All three categories of data together have some traits in common, such as:

- Volume: Every food processing plant and every food-related corporation has enormous amounts of data stored in their databases.
- Value: The resident data contains a lot of useful information, in order to be useful to operations and decision-makers, these insights must be found, extracted, and processed.
- Variety: A wide range of big data types can be analyzed separately or collectively to look for any more significant patterns, trends, or correlations
- Velocity: Large data can be examined historically, but depending on the situation, it can also be examined in real-time. For example: Sensors are being installed in food processing plants to collect data at very high speeds. For quick answers, traditional analytical methods are frequently insufficient.

Insider threats are becoming increasingly dangerous for enterprises because they may have a negative effect on physical security, food defence, brand reputation, and food product safety. For instance, enterprises may employ real-time or nearly real-time data updates to identify system abnormalities and potentially uncover any attempts by a disgruntled employee to disrupt an ongoing operation. A method of managing data involves using AI to assist those responsible for data analysis.[17]

Using AI to Process Data for Food Safety

- Machine learning: The systems are able to improve with time as a result of their ability to learn. It is useful for sifting through large datasets in search of patterns, outliers, and trends pertaining to food safety. As a result, it may be used to predict potential food poisoning epidemics by analysing past data and current environmental conditions.
- Natural language processing: Computers can now understand, interpret, and even create their own language thanks to this development. This aids in the detection of possible food safety and

[17] Awuchi, Chinaza Godswill. "HACCP, quality, and food safety management in food and agricultural systems." *Cogent Food & Agriculture* 9, no. 1 (2023): 2176280.

consumer sentiment issues by use of text data analysis from sources including social media, reviews, and regulatory regulations.

- Computer vision technology: It helps in interpreting and comprehending visual data, including images and videos. It can also be used for checking food contaminants, and spoilage.
- Deep learning: It can be applied to enhance predictive models for food safety incidents and to improve image recognition during food quality inspections.

Here are some instances of how various AI can be applied to big data analytics for food safety utilizing currently accessible technologies

1. Analytical prediction
2. Quality assurance and verification
3. Transparent supply chain
4. Social media monitoring and sentiment analysis
5. Adherence to regulations
6. Tailored food safety guidelines

AI Bio surveillance:

In the future, artificial intelligence will have an increasing impact on food safety. Biological threats may emerge inadvertently or intentionally. Biomonitoring is beneficial for both public safety (by preventing deliberate food adulteration and bioterrorism) and public health (by preventing foodborne disease). Using logistical networks, AI-assisted bio surveillance systems have the potential to integrate into all stages of the food chain, including pre-harvest and post-harvest. Every sensor or analyser that interacts with a human-consumed agricultural product will produce a unique set of data. AI may then merge and analyse this data. We may design the application to search for specific patterns and correlations, thereby identifying tainted product molecules. Additionally, it can detect new abnormalities in processes or outputs that may have gone unnoticed before.[18] Subsequently, Subject Matter Experts (SMEs) and system operators would be able to promptly access the real-time AI discoveries and evaluate them. Human participation is essential for determining analysis using logic, experience, and judgement. The AI-powered analytical system can integrate structured, unstructured, and semi-structured data to facilitate analysis. Ultimately, we can accurately state that AI-assisted analytics is a rapidly advancing domain that, with proper attention, can protect public health, reduce the likelihood of foodborne diseases, and maintain brand excellence and profitability. Exercising prudence is necessary when adopting this technology. However, with successful deployment and appropriate calibration, AI can help users gain deeper insights into their own products and processes. This offers the opportunity to uncover concealed problems and identify new ways to enhance efficiency. [19]

[18] Holzinger, Andreas, Katharina Keiblinger, Petr Holub, Kurt Zatloukal, and Heimo Müller. "AI for life: Trends in artificial intelligence for biotechnology." New Biotechnology 74 (2023): 16-24.
[19] Agrebi, Said, and Anis Larbi. "Use of artificial intelligence in infectious diseases." In *Artificial intelligence in precision health*, pp. 415-438. Academic Press, 2020.

CONCLUSION

The regulatory landscape governing food safety in India has undergone significant evolution over the years, reflecting the nation's commitment to ensuring the quality and safety of food products consumed by its citizens. From the enactment of the Food Safety and Standards Act, of 2006, to the recent proposals for regulatory overhaul by the FSSAI, the journey has been marked by both challenges and progress.

The foundation of the modern regulatory framework was laid with the introduction of the Food Safety and Standards Act, of 2006, which replaced the fragmented system of regulations previously governing the sector. This landmark legislation led to the establishment of the FSSAI, tasked with monitoring and regulating various aspects of food production, storage, import, and sale. However, the initial implementation of the Act faced hurdles, including delays in issuing regulations and challenges in aligning with evolving industry practices. The infamous 'Nestle-Maggi' dispute served as a wake-up call, highlighting gaps in the regulatory framework and prompting a re-evaluation of existing practices.

In response to these challenges, the FSSAI embarked on a journey of reform, aiming to streamline compliance procedures and enhance regulatory efficiency. The proposals put forth by the FSSAI, including the centralization of certification requirements and the endorsement of new standards and amendments, signify a proactive approach towards addressing industry concerns. Moreover, efforts to strengthen enforcement mechanisms, such as the establishment of independent food safety agencies in each state, underscore the commitment to ensuring rigorous quality control measures across the nation. However, challenges persist, including the shortage of manpower and the need for enhanced surveillance and monitoring capabilities.

The evolving regulatory framework also addresses the emergence of novel food products, including plant-based alternatives and genetically modified foods. While these innovations hold promise for addressing various consumer needs and preferences, they also pose unique regulatory challenges.

The introduction of specific regulations, such as the Food Safety and Standards (Vegan Foods) Regulations, 2022, demonstrates a willingness to adapt to changing market dynamics while ensuring consumer safety. However, concerns remain regarding the discretionary powers wielded by regulatory authorities and the need for greater clarity and transparency in the regulatory process.

Moving forward, collaboration between industry stakeholders, regulatory authorities, and policymakers will be crucial for navigating the complex regulatory landscape and fostering innovation while upholding stringent safety standards. This includes continued investment in infrastructure, capacity building, and technology adoption to enhance regulatory oversight and ensure compliance. While India's food safety regulatory model has made significant strides in recent years, there is still work to be done to address existing challenges and adapt to evolving industry trends. By embracing a holistic approach that balances innovation with safety, India can establish itself as a global leader in ensuring the quality and integrity of its food supply chain.