Anubodhan, Vol. 2, No. 2, April-June 2026, Pages: 41-49
Journal homepage: ISSN: 3049-4184 (Print) 3108-1185 (Online)
https://anubodhan.org https://doi.org/10.65885/anubodhan.v2n2.2026.057

Review

Application of Artificial Intelligence in Food Product Development in Small and Large Scale: A Review

Rinky Bhadra [1], Ratan Gachhui [1]

Received: 22 May 2026 / Accepted: 28 May 2026 / Published online: 4 June 2026

Abstract

Artificial intelligence has emerged as a transformative technology in the food industry, particularly through product development, quality assurance, and personalisation of consumers. As the need to increase innovative, safe, and personalised food products rises, AI has emerged as an essential means of solving the complexities of contemporary food systems. In this paper, the researcher discusses how AI has been used in the food product development process of small-scale businesses and large-scale industries and how technological advancements are forming new trends in the traditional practices.

Machine learning, predictive analytics, natural language processing, and computer vision, as parts of AI-based tools, are quite important to improve decision-making processes. They can be used to analyse big data on consumer preferences, ingredient properties, and market trends, which will help in the creation of new food products. AI also facilitates virtual experimentation by removing the need to use time-consuming and expensive physical experiments and making the development cycle more efficient overall.

The review also evaluates the role of AI in maximising resources, minimising food waste, and enhancing supply chain management, all of which help in sustaining the supply chain. At both small and large scales, AI can be used to make better predictions and manage stock and quality, which are needed to guarantee consistency and adherence to regulations. Besides, AI-based personalisation can enable businesses to adjust products to the individual demand of consumers, including dietary limitations and health allergies.

Although AI has many benefits, the introduction of the technology into the food industry is not immune to negative aspects. High implementation costs, worries over data privacy, and untechnical natures, as well as infrastructural constraints, especially impact small-scale enterprises. This study assesses these challenges critically and

[1] Department of Life science & Biotechnology, Jadavpur University, Kolkata-700032, West Bengal, India

✉ Rinky Bhadra, E-mail: rinkybhadra99@gmail.com

further projection of the future on AI integration in the development of food products. This research highlights that AI becomes increasingly significant as a strategic instrument to help organisations become more competitive, innovative, and adaptable to changing consumer demands, especially in a dynamic international market.

Keywords: Artificial Intelligence, Food Product Development, Computer Vision, Food Large-scale Manufacturing, Food Innovation.

Introduction

The world food market is undergoing a huge transformation due to the blistering technological speed, and one of the main processes that promotes innovation and performance is artificial intelligence. Using machines with capabilities to learn, reason, solve problems and make decisions, AI can be described as the simulation of human intelligence. The recent years have seen the provision of AI within the food systems revolutionise numerous areas within the food industry, especially in food product development.

Development of food products is an intricate, multidisciplinary procedure that entails ideation, formulation, testing and commercialisation. Conventionally, it was a manual process that was extremely dependent on expert knowledge and trial and error and was time-consuming and resource intensive (Ding et al. 2023). Nonetheless, the introduction of AI technologies is eliminating these traditional solutions in favour of data-intensive methods that are more accurate, fast and innovative. To produce insights that are used in influencing product development, AI systems have the potential to process enormous quantities of data that originate in various forms, such as consumer feedback, nutritional databases, and market trends.

Among the most relevant contributions of AI in the development of food products, one should mention the possibility of predicting the preferences of consumers and finding new tendencies. Machine learning algorithms can help companies to create products that resonate well with the expectations of consumers, which makes them more likely to succeed in the market (Azeem et al. 2025). AI can be used to optimize food formulations by proposing combinations of ingredients that enhance the taste, texture, nutritional value and shelf life. This increases the quality of the products besides minimising the cost and time of product development.

The utilisation of AI technologies is gaining popularity among both small-scale businesses and large-scale food manufacturers, but the scope and sophistication of their use differ significantly. Big companies have access to large volumes of data, sophisticated technologies and expertise-based personnel and could deploy sophisticated AI systems that are combined with automation and robotisation. It is used in end-to-end optimisation in these organisations, including research and development, production and distribution.

Conversely, small-scale firms tend to be limited by such factors as reduced finances, inadequate technical capabilities, and the availability of quality information. However, with the advent of cloud-based AI solutions, open-source software, and easy-to-use software, even small businesses can now make use of AI on a cost-effective basis. The main applications of AI used by these businesses include market analysis,

interpreting customer feedback, and incremental product improvements, which can greatly help these businesses increase their competitiveness in niche markets.

The growing focus on health, sustainability, and transparency in the food industry has provided new use cases for AI. Today, consumers are increasingly aware of their food choices and expect products that are, in addition to being tasty, healthy, safe, and environmentally friendly (Bidyalakshmi et al. 2025). AI is essential to fulfil these expectations since AI will allow analysing food to identify nutrients more accurately, decrease food waste, and enhance supply-chain traceability.

The purpose of this study is to present an in-depth analysis of the use of AI in the development of food products and focus specifically on the comparison of its application on small- and large-scale. It aims to single out the main advantages, issues, and perspectives of AI implementation in the food sector. Through the analysis of the existing tendencies and technological innovations, the research will lead to further insight into how AI is influencing the future of food innovation and production.

Role of AI in food product development

AI has an important and complex role in the many phases of developing food products, including premise planning and idea formation, formulation, production and subsequent commercialisation. In the initial phases, AI systems can analyse huge amounts of structured and unstructured data, such as consumer preferences, eating habits, cultural factors, and buying patterns. Using machine learning algorithms, companies can find the latent patterns and correlations, which can hardly be observed using traditional research methods. Through this, innovative ideas of products can be produced that are closely associated with existing and new needs in the market.

AI technologies can be used to experiment with flavours and ingredient profiles using chemical formulas, sensory characteristics, and historical data on formulations. AI can anticipate the relationship of various ingredients with each other (taste, texture, aroma, and appearance) and, thus, create novel and appealing food products (Addanki et al. 2022). This foresight ability is a great creativity boost, and it decreases the uncertainty that involves developing new products.

Besides ideation, AI is also crucial in the product development formulation and testing stages. The simulation tools being developed by artificial intelligence enable researchers and developers to perform virtual experiments to test various formulations under various conditions without conducting the exercise physically. This does not only speed up the development process but also saves costs on the raw materials, labour, and time. Additional factors included in these simulations can be shelf life, stability and environmental conditions, which will guarantee quality and safety of the final product.

AI is a part of nutritional optimisation and the creation of health-centric products. Through nutritional databases and dietary guidelines, AI systems can make recommendations on substituting ingredients and making modifications in them to promote the nutritional content of food products without compromising the sensory characteristics. This is especially significant considering the growing awareness of consumers of health and wellness (Canatan et al. 2025). AI also helps in regulatory compliance, whereby the formulations of the products comply with food safety and food labelling requirements.

AI implementation in food product development results in a more successful, data-driven, and innovative process. It lessens dependence on conventional trial-and-error procedures and assists businesses in responding better to evolving customer likes and market trends.

Applications in large-scale food industries

The food industries, particularly large-scale food industries, have been leading the adoption of artificial intelligence technologies to make their operations more efficient, to become innovative and to stay at a competitive advantage in the global market. These organisations have all the infrastructure, financial capacity, and technical skills to have advanced AI systems that are deployed in many parts of the value chain (Mavani et al. 2022). Advanced data analytics is one of the key uses of AI in large-scale industries to enable companies to solve and analyse large volumes of consumer and operational data in real-time.

Big food companies can understand the behaviour patterns, preferences and buying habits of their consumers using the power of machine learning and big data analytics. This allows them to come up with highly individualised and intensive product offerings that attend to selected market segments. As an example, AI can recognise the taste preferences in a region and suggest the differences in products, which will result in heightened customer satisfaction and market penetration.

Along with product development, robotics and automation based on AI are increasingly involved in large-scale food manufacturing. These technologies also increase the efficiency of production as they are used to perform repetitive tasks with high precision and consistency, less prone to human error. Automation is also better to enhance workplace safety, as the minimal human participation in hazardous workplaces is reduced. Consequently, companies would be able to attain greater productivity levels whilst being able to ensure high levels of stringency in quality.

Predictive maintenance is another area of the critical application of AI in large-scale industries. Through sensors and data analytics, AI systems keep an eye on the functionality of machinery and equipment on a continuous basis. These systems can anticipate the need to perform maintenance prior to its actual occurrence, hence eliminating any unexpected failures as well as minimising downtimes by detecting patterns that show possible failures. This results in tremendous cost savings, and production processes are not interrupted.

It has a wide application in computer vision technologies in quality inspection and quality control. These systems can identify the presence of defects, contamination and variation of food products with a high degree of accuracy, making them comply with safety measures and quality levels (Onyijen et al. 2024). Another vital role of AI in the supply chain involves optimisation of its operations, such as demand forecasting, supply chain inventory management, and supply chain logistics. Companies can reduce the waste of food and enhance sustainability by effectively forecasting demand and reallocating resources.

AI implementation in big food production thus improves operating efficiency and the quality of products and allows companies to react quickly to the evolving market environment, which contributes to their competitive advantage.

Applications in Small-Scale Food Enterprises

Small-scale food businesses are often limited in terms of financial resources, the absence of advanced infrastructure, and a continued lack of technical skills, which may prevent the use of complex AI technologies. Nevertheless, the fast evolution of the technological industry and the appearance of cloud-based AI solutions, open-source applications, and affordable programmes have turned it into a possible endeavour that small businesses can now implement AI in their software. These advances have greatly reduced barriers to entry, allowing small-scale businesses to utilise AI to enhance efficiency and innovation.

Market analysis and the generation of consumer insights are some of the major uses of AI in small-scale food businesses. The needs and preferences on social media, online reviews, and customer feedback can be analysed with AI-driven tools, allowing for learning about trends and areas of improvement. This enables small businesses to make sound decisions concerning product development and strategy in the market. These enterprises can learn the needs of consumers in third-best ways, hence coming up with products that are more consistent with the market demand.

AI is involved in simple product optimisation and improvement of quality. The analysis of ingredient proportions, cooking conditions, and sensory qualities can be helped by simple machine learning models to refine recipes. This will assist in having uniformity and the overall quality of their products (Yang et al. 2025). The production processes can also be controlled with the help of AI to identify errors or deviations and decrease the amount of waste to increase efficiency.

Another important application of AI in small-scale enterprises is cost optimization. AI can assist businesses in creating a more efficient inventory management system by forecasting demand and determining the best stock levels. This will decrease the possibility of too much production and spoilage, especially in the case of perishable food products. Also, AI can be used in pricing strategies due to its ability to analyse the market conditions and competitors' behaviour, which will help the small business to be competitive.

Another important aspect of AI implementation, although it is fraught with difficulties (lack of access to quality information and technical knowledge), is the tremendous advantages for small-scale businesses. Applying AI may result in better decision-making, enhanced innovation, and competitiveness in local as well as niche markets (Khan, 2022). The solution to successful implementation is to choose AI solutions that are scalable and user-friendly and have a reasonable cost, depending on the nature of the business and its performance.

AI applications might be larger or more complex in small and big businesses; the potential benefits of their usage are considerable to both. As technology keeps improving and becomes more accessible, AI is likely to become a more significant force that will allow small-scale food businesses to become much more empowered and, thus, able to compete in the fast-changing industry.

Benefits of AI in Food Product Development

The development of food products through the integration of artificial intelligence has a vast pool of advantages that positively impact the efficiency, accuracy and capability to develop new products in the food industry. One of the most prominent advantages is the ability of AI to enable data-driven decision-making. Through analysing big and

intricate data, AI systems will be able to pinpoint patterns, trends, and linkages that can be used to make informed and strategic decisions. This minimises the use of the traditional trial and error method, with the likely saving of time and resources and enhancing the overall effectiveness of the development process.

The other critical advantage of AI is that it can speed up innovation in food product development. AI will be able to create new product ideas based on the analysis of consumer tastes, trends, and compatibility of ingredients. This enables the companies to create innovative products in a better fashion to make sure the products are suited to the changing consumer needs. Also, AI-powered simulations allow testing a host of product formulations in a short period of time, thus saving much time to launch new products to the market. This reduced time-to-market is a vital element in the retention of competitiveness in an ever-evolving food market.

AI is also critical towards product improvement in terms of quality and consistency. By applying machine learning algorithms and monitoring solutions in real-time, businesses will have an opportunity to make sure that food products can meet set quality standards. Substantial risks of substandard and contaminated products or irregularities can be identified with great accuracy through AI-qualified quality control systems, which facilitate the prevention of product recalls and consumer safety (Dhal & Kar, 2025). This especially plays a vital role in the preservation of brand reputation and adherence to regulations.

AI also helps in personalisation and consumer satisfaction as it helps to create individual food products. Through analysis of individual preferences, nutrient needs and health status, AI systems can suggest or create products based on the needs of a consumer. Such personalisation not only boosts customer experience but also brand loyalty and market engagement. Besides these advantages, AI can aid food industry sustainability by improving resource management and minimising waste. AI systems are capable of accurately forecasting demand, leveraging inventory systems, and streamlining the supply chain processes, reducing food wastage. They are also able to propose green product formulations, which help in the sustainable production processes. Altogether, the development of AI enhances efficiency, minimises expenses, recovers innovation, and allows developing food products in a more sustainable way.

Challenges and Limitations

Even though the application of artificial intelligence development in the food industry has a lot of advantages, there are a number of challenges and constraints that make this trend difficult to embrace, especially among small and medium enterprises. Among the major obstacles lies the expensive implementation. The creation and implementation of AI systems involve hefty expenditure on the infrastructure, software and professional resources. They are prohibitive to small-scale businesses that might not have many financial resources and could deter the use of AI technologies.

The absence of technical skills and diversity of skills to implement and maintain AI systems are another significant constraint. Knowledge in fields like data science, machine learning and software engineering is necessary to implement AI successfully. Such expertise may not be available to many organisations and may restrict their capacity to make full use of AI capabilities. Also, the nature of AI systems may pose difficulties when adapting them to the current processes and technologies.

Another major challenge in AI applications is the quality and availability of data. Use of AI systems is greatly dependent on bulk data of high quality to operate successfully. In most instances, an organisation might encounter challenges in data gathering, data manipulation and data processing. Imprecise or unfinished data may combine to attain inaccurate outcomes and ineffective decision-making. Besides, issues associated with data privacy and security are gaining more importance, especially where the sensitive data of consumers is involved.

The absence of a standard set of rules and systems to control the application of AI in the food industry is another major problem. Lacking clear guidelines might introduce a lack of transparency and cause a lack of widespread acceptance of AI technologies. Compliance with the regulations, especially in food safety and labelling, can be complicated and may differ in one region from another, which makes the problems of organisations more complicated.

Another aspect that may hinder the introduction of AI is resistance to change. The management and workers might be reluctant to use the new technologies, fearing a job change or being unaware of AI systems. This opposition can delay the process of implementation and decrease the possible benefits of AI.

Thus, despite the high benefits of AI, it is necessary to tackle these issues to guarantee the successful implementation of AI in the development of food products. The cost reduction, increased accessibility, technical aptitude, and well-defined regulatory frameworks should be put in place to help in the effective application of AI to the food industry.

Future Prospects

The testability of artificial intelligence in the development of food products is quite optimistic, and the technology is likely to be improved continuously, leading to an improved application of AI and its limits. With the development of AI technologies, they should increasingly gain significance in the promotion of innovation, enhanced efficiency, and focus on global issues in the food industry. The combination of AI with other emerging technologies, including the Internet of Things (IoT), blockchain, and big data analytics, is likely to produce more intelligent and connected food systems.

Among the major developments in the future, personalised nutrition should be brought up. AI can transform the process of designing food products to meet the personal dietary requirements, health status, and genetic backgrounds. This may result in more personalised food solutions enhancing health and wellness that deal with such problems as obesity, malnutrition and chronic diseases.

Another field where AI is likely to exert a significant impact is sustainability. As the issue of environmental degradation and food security becomes more pressing than ever, AI will be used to optimise the use of resources, minimise waste, and encourage sustainable production methods. AI has the potential to help in creating alternative protein sources, optimising agriculture, and improving the efficiency of supply chains. With these developments, we will have a more resilient and sustainable food system.

Smaller-scale businesses are also likely to benefit as a result of the democratisation of AI technology. With the availability of AI devices at a lower price, which are user-friendly and can be hosted on cloud computing platforms, smaller companies can achieve good adoption and implementation of AI solutions. This will help them to

compete with bigger organisations and introduce innovations in every sphere of the industry.

Obstacles in the aspects of data privacy, security, and morality are likely to be resolved in the context of ongoing research and development in AI. Standardised regulations and best practices will additionally make the introduction of AI in the food sector more feasible. Training and education programmes will also be very instrumental in acquiring the skills and expertise that are needed to make use of AI.

The future of AI in food product development is thus huge and revolutionary. With ever-changing technology, AI will be at the centre of creating a more innovative, efficient and sustainable food sector. Its capacity to mend the divide between consumer needs and the production capabilities will guarantee its relevance and significance in the future.

Conclusion

AI is transforming the way food products are developed into faster, more efficient and data-driven development processes. Though the advanced AI systems have already been implemented in large-scale industries, small-scale enterprises are slowly adapting to solutions available to improve their capabilities. Although AI has limitations due to cost, data needs and technical skills, its advantages supersede its shortcomings. Further development of AI technologies will also change the food industry, making it more innovative, sustainable and consumer-friendly in product development. AI is an efficient solution that will address the future of food product development, on small and large scales, through bridging the disparity between consumer needs and industrial capacities.

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