

# Artificial intelligence in the food industry

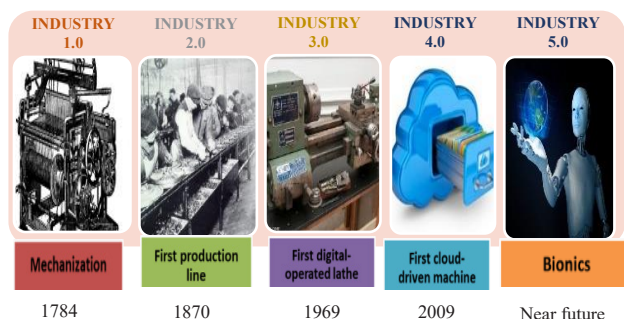
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**Abstract.** The growth of the planet's population requires the application of innovative technological solutions for its nutrition. Artificial intelligence, as part of the technological toolkit of Industry 4.0, having a strong transforming effect in modern society, is perceived as a strategic factor for increasing productivity, efficiency and innovation in a number of sectors, including the food industry. The global food and beverage artificial intelligence market in 2021 is valued at USD 4.49 billion. It is expected to grow at a CAGR (average annual rate) of 45.4% to reach US\$ 83.4 billion by 2029. The main goal of every industrial enterprise in the food industry is to produce high-quality products at the lowest possible cost. The application of AI can contribute to maintaining a higher quality of the manufactured product, through rapid quality control and visualization of the result. AI can aggregate and analyze data in real-time making recommendations to improve operational activities, can analyze data, uncover trends and recommend actions to increase efficiency. The result of the implementation of artificial intelligence in the food industry contributes to driving the growth of the market.

## 1 Introduction

Industrial development has been developing at an accelerated pace in recent years. [1] After the digital revolution at the end of the 1980s, today we are in the midst of another great revolution, the fourth industrial revolution or Industry 4.0. [2] If the first two industrial revolutions took 2 centuries, the last two were realized in the past 3-4 decades. This is the result of the accelerated development of technical, technological and digital innovations, which change the possibilities of carrying out studies, research, analysis, development, production and marketing, the generation of product value and related services.[3] Fig. 1 summarizes the evolution of the industrial revolution. [4]



**Fig. 1.** Stages of the industrial revolution over the years.

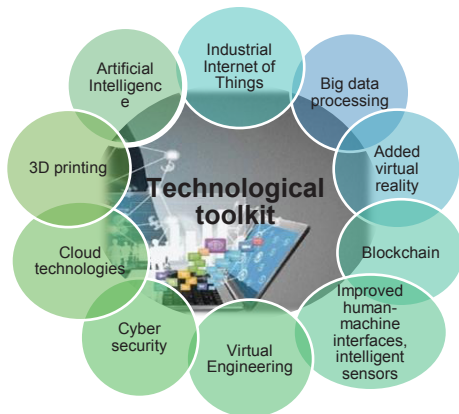
❖ *Industry 1.0* is the first industrial revolution in human history. It developed in the second half of the 18th century. The mechanization of manual labor, the

power of wind, water is connected. The steam engine was put into operation in production and transport.

- ❖ *Industry 2.0* developed at the end of the 19th century. It is associated with the introduction of electricity and the introduction of mass production.
- ❖ *Industry 3.0* is characterized by the application of electronics, electronic technologies and computers, in which the automation of production processes is achieved.
- ❖ The opening of local economies on a global scale is a stage known as *Industry 3.5*. It is characterized by relocation of production, i.e. export of production from developed to less developed economies.
- ❖ With the introduction of Internet technologies in production, the fourth industrial revolution in human history is formed - *Industry 4.0*. New technologies allow the use of various cloud solutions for processing big data, building smart factories, virtual copies of the real world, collaboration between people in real time via the Internet, making decentralized decisions to achieve organizational excellence. [5] The technological toolkit of Industry 4.0 is summarized in fig. 2.

Despite the fact that Industry 4.0 is at an initial stage of its development and its main achievements can be expected in the current decade, the image of the new industrial revolution - Industry 5.0, which includes the penetration of artificial intelligence into the everyday life of a person, can already be outlined.

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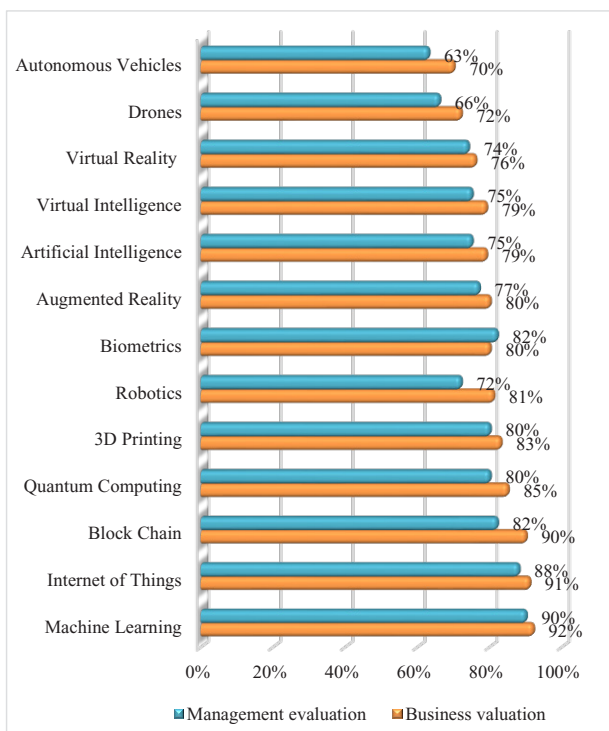


**Fig. 2.** Technological toolkit of Industry 4.0.

❖ *Industry 5.0* is associated with the entry of bionics and biotechnology into production processes. This allows the application of biological sensors for the organization and control of production.

Each new stage of industrial development is the result of scientific, technical and technological progress. The rapid development and implementation of new digital innovations that change the possibilities of conducting research, research, analysis, production and marketing, generating value of products and related services. [6]

The results of a conducted survey related to the expectations of business and public administration for the technologies of Industry 4.0, which are going to have the strongest impact on their development in the next few years, are summarized in fig. 3. [7]

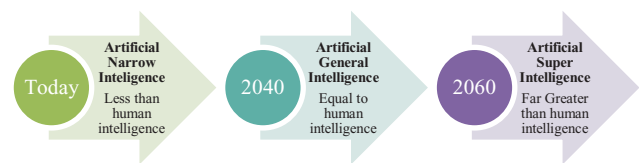


**Fig. 3.** Ranking of the technologies with the strongest impact in the next decade.

The research shows that artificial intelligence is considered to be the tool of Industry 4.0 that has the strongest transformative effect in modern society.

## 2 Literature review

Artificial intelligence (AI) is a branch of computer science that has been developing extremely rapidly in recent years. It is used to develop software that performs tasks instead of human intelligence. [8] AI is widely used in various areas of the modern world. The term was first used by the American John McCarthy in 1956. [9] With it, he described an area of computer science that aims to give machines a human image and capabilities. The Oxford Dictionary defines the term as [10] "Computer systems capable of performing tasks that normally require human intelligence such as visual perception, speech recognition, decision making, and translation between languages." For Haenlein and Kaplan, [11] AI represents "The ability of a system to correctly interpret external data, learn from such data, and use that knowledge to achieve specific goals and objectives through flexible adaptation". In the European Commission's artificial intelligence strategy, [12] the term is defined as "systems that exhibit intelligent behavior by analyzing their environment and taking action, with some degree of autonomy, to achieve specific goals. AI-based systems can be software-only, operating in the virtual world (e.g. voice assistants, image analysis software, search engines, speech and face recognition systems) or AI can be embedded in hardware devices (eg robots, autonomous cars or drones, IoT applications, etc.). AI enables machines to learn from experience, adapt to new data, and perform human-like tasks. [13] Using these technologies, computers can be trained to perform specific tasks by processing large amounts of data and recognizing patterns in the data." Experts' expectations for the evolution of AI in the next 40-50 years [14] are presented in fig. 4.

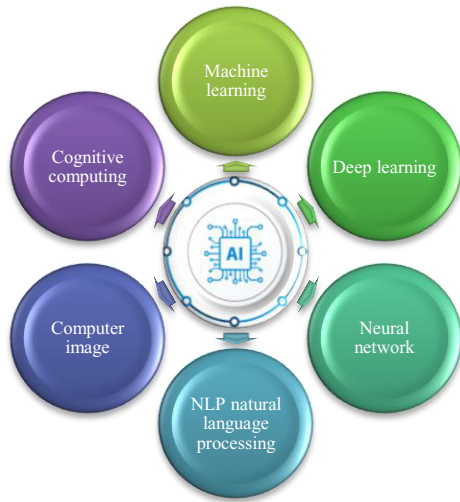


**Fig. 4.** Trends in the evolution of AI type.

At the current stage, we rely on the so-called weak or narrow AI. It is created to perform limited, singular tasks. This type has already been achieved and is a reality. On the one hand, it reinforces human capabilities, and on the other, it dismisses the concern about AI superiority over humans and the possible consequences of this. The expectation by 2040 is to use systems with intelligent knowledge and cognitive abilities. These systems create an AI that is indistinguishable from a human, although the speed and ability to process data is much faster and with unparalleled volume and capacity.

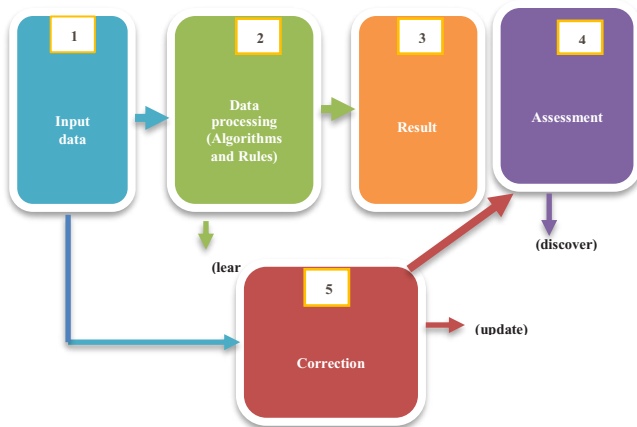
By 2060, AI is expected to surpass human intelligence in all parameters, from creativity to wisdom and problem solving.

The main components of AI are summarized in fig.5 [15]



**Fig. 5.** Key components of AI.

Among them are machine learning, deep learning, neural network, natural language processing (NLP), computer image and cognitive computing. In the case of artificial intelligence systems, a sequence of actions is observed, presented in fig.6. [16]

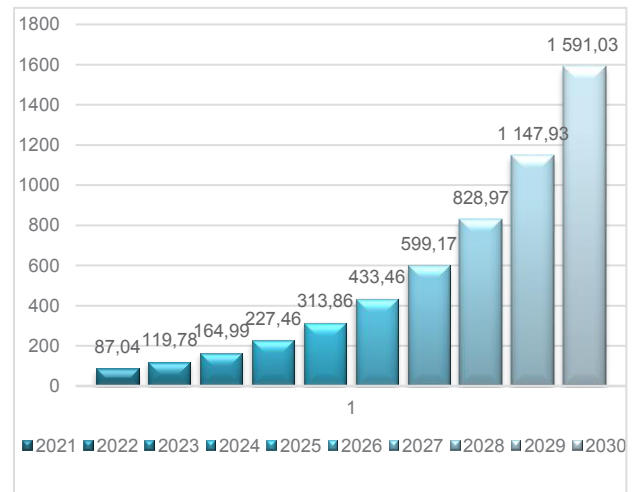


**Fig. 6.** AI work algorithm.

1. Initially, the system accepts data input (in the form of speech, text, image, etc.).
2. The system processes the data by following various rules and algorithms, interprets, predicts and processes the entered data.
3. After processing, the system provides a result, which can be success or failure.
4. The result is evaluated through analysis, discovery and feedback.
5. Finally, the system uses input correction scores, rules, and algorithms to output a result. This cycle continues until the desired result is achieved.

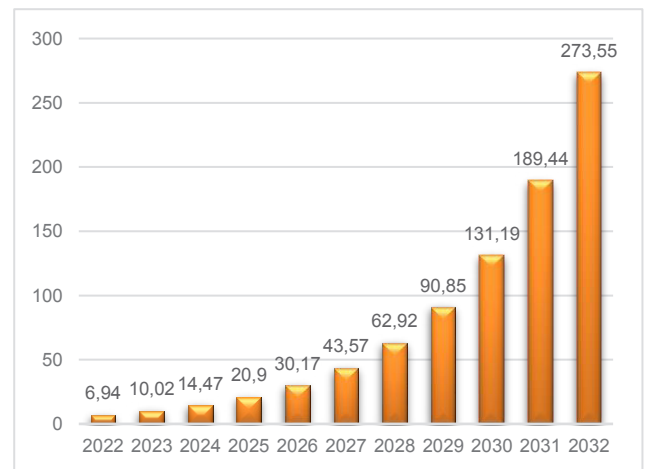
### 3 Analysis and discussions

Expectations of the impact of artificial intelligence on the economy are mixed. They are related to increasing productivity, improving efficiency, creating and implementing innovations. [17,18] AI has the ability to analyze large amounts of data, build models, predict and analyze with high accuracy, etc. It is expected to develop capabilities, foster creativity, enable interaction from the synergy between man and machine. The size of the global artificial intelligence market for 2022 is estimated to be \$119.78 billion (Fig.7), and to reach \$1`591.03 billion by 2030. [18]



**Fig. 7.** Trends in the development of the global market for Artificial Intelligence to 2030.

Artificial intelligence (AI) is creating significant transformations in the food industry as well. Forecasts for its penetration into the food and beverage business are on the rise. The growth expectations in the market for AI in the food industry are presented in fig. 8. [19]



**Fig. 8.** AI sales value (\$ in Billion).

Forecasts for the dynamics of the global size of artificial intelligence in the food and beverage market in the next decade is to continue to grow. The market size in

2022 is estimated to be USD 6.94 billion. It is expected to reach about US\$273.55 billion by 2032. This shows growth at a CAGR of 44.4% during the forecast period. The ability of artificial intelligence to drive the realization of higher efficiency and profits, reduce losses and protect against disruptions in supply chains is recognized by a growing number of industrial enterprises. All this also applies to traditional industries such as food. Challenges facing the food industry are summarized in fig. 9

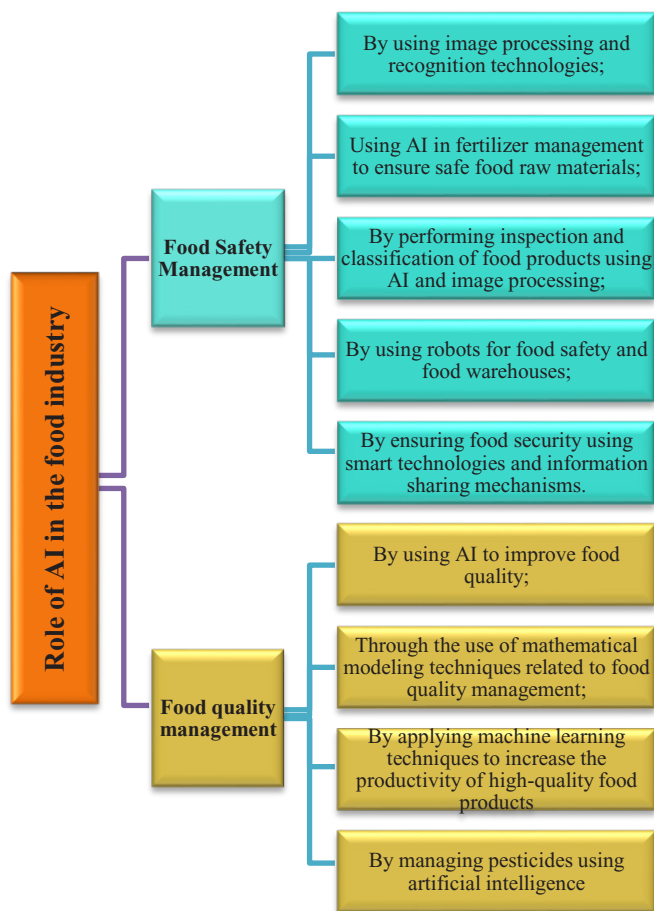


**Fig. 9.** Challenges for the food industry

They are related to the influence of a number of factors. Sustainability and local tastes, as well as changes in people's food and health consciousness, are important to the modern consumer. Errors and omissions are unacceptable in the fast-moving, consumer-oriented food and beverage market. Brand reputation can be seriously damaged if the company is unable to manage food and safety regulatory compliance, inventory and quality. The role of artificial intelligence in these challenges is to assist both in overcoming these difficulties and in creating, diversifying and improving products. (fig. 10)

Applications of artificial intelligence in the food industry are expressed in the following areas:

- ✓ Sales forecasting. Artificial intelligence can track customer preferences and purchases to predict sales.
- ✓ Predicting consumer preferences and purchasing methods by tracking customer emotions on social media processes and analyzes data to sort their posts and label them as positive, negative or neutral.
- ✓ Improvement of food products. Many food brands are improving their product offerings by using artificial intelligence and deep learning technologies to create flavor combinations that will be popular with consumers.
- ✓ Inventory forecasting. Artificial intelligence can provide accurate guidance for better market analysis.



**Fig. 10.** Role of AI in the food industry

This will facilitate pricing, inventory forecasts and more accurate planning.

- ✓ Supply chain improvement. Food safety regulations are becoming more and more stringent, requiring full transparency in supply chain management for food industry businesses. The need for AI-driven supply chain tracking can optimize the supply chain to increase enterprise profitability.
- ✓ Sorting for quality assurance. Sorting is one of the most labor-intensive operations in the production process. It can be facilitated with the help of artificial intelligence. This will contribute to increased productivity, reduced scrap and higher quality.
- ✓ Food security. The food industry is faced with the challenge of meeting the increased demand for food, due to the growing world population, climate change, decreasing areas of agricultural land, etc. Food safety. With artificial intelligence, practices that are not in line with the corporate policy for healthy and safe production can be identified

## 4. Conclusion

The rapid development of digital technologies and technique led to the achievement of the fourth industrial revolution in human history - Industry 4.0. Although the technological toolset of Industry 4.0 has not reached its full potential, the image of the next industrial revolution - Industry 5.0, which is characterized by the penetration of artificial intelligence into business, people's everyday life and society as a whole - can already be outlined. From the technological toolkit of Industry 4.0, artificial intelligence has the strongest transformative effect in society. Trends in the growing volume of the artificial intelligence market over the next decade attest to its pervasive penetration across sectors of the economy. The food industry is no exception. The role of AI in the sector is associated with improvement in two main areas - security and quality.

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