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THE MODERN FOOD INDUSTRY: TRENDS, CHALLENGES, AND INNOVATIONS

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ABSTRACT

New product development and improvement of existing ones, design as the creation of new food formulations, and the production process of foodstuffs are a major challenge for modern food companies in a competitive environment, in which the ability to identify consumer preferences more accurately becomes more urgent. It is an integral part of the technological activities of the modern food industry. Creating a new kind of food product is not only a scientific but also a commercial component, in which the development of the commercial aspect is extremely important for food companies in terms of the cost of creating a technological market environment. But in planning, studying, market analysis, defining, and targeting the audience, fear is considered one of the main driving forces of economic activity in both the market and the real economy. Its role is to encourage potential buyers of a product or service from a practical point of view to avoid market failure, every company has a detailed market study that helps determine the precise market limits and specify the most important activity to achieve commercial success.

Keywords: new food products, company success, development, consumer satisfaction.

صناعة الأغذية الحديثة: الاتجاهات، التحديات والابتكارات

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الخلاصة

إن تطوير المنتوجات الغذائية الجديدة وتحسين المنتوجات الحالية، والتصميم مثل إنشاء تركيبات غذائية جديدة، وكذلك إنشاء عملية إنتاج المواد الغذائية يمثل تحديًا كبيرًا لشركات الأغذية الحديثة في بيئة تنافسية، تصبح القدرة على تحديد تفضيلات المستهلك بدقة أكثر إلحاحًا. إن هذا الامر أصبح جزء لا يتجزأ من الأنشطة التكنولوجية لصناعة الأغذية الحديثة في الشركات الغذائية. إن إنشاء نوع جديد من المنتوجات الغذائية ليس مكونًا علميًا فحسب، بل هو مكون تجاري أيضًا، اذ إن تطوير الجانب التجاري أمر في غاية الأهمية بالنسبة لشركات الأغذية من حيث تكلفة خلق بيئة السوق التنافسية. ولكن في عملية التخطيط والدراسة وتحليل السوق وتحديد الجمهور المستهدف لها، يعد الخوف أحد القوى الدافعة الرئيسية للنشاط الاقتصادي في كل من السوق والاقتصاد الحقيقي. ويتمثل دورها في تشجيع المشترين المحتملين لمنتج او خدمة معينة من تجنب فشل السوق، ويكون لدى كل شركة دراسة سوقية تفصيلية تساعد على تحديد حدود السوق بدقة وتحديد النشاط الأكثر أهمية لتحقيق النجاح التجاري.

الكلمات المفتاحية: منتوجات غذائية جديدة، نجاح الشركة، تطوير، إرضاء المستهلك.

INTRODUCTION

The modern food industry is a broad and diverse subject encompassing many topics relevant to how food is produced, processed, distributed, marketed, sold, prepared, and eaten,

and the factors affecting all of these. The modern food industry is growing in complexity due to new developments. These developments include shifts in how food is produced (for example, vertical farming, smart agriculture, animal-less food production, alternative proteins, bioengineering food products), processed (for example, automation), distributed (for example, online grocery stores, drone deliveries), marketed (for example, social media marketing), and eaten (for example, meal kits, food delivery apps). These developments also include factors such as population growth, distributed and urbanized populations, growing concern for food safety and quality, environmental impacts of food production, processing, and distribution, and a growing desire for convenience and novel experiences (**Aguilar *et al.*, 2019**). The modern food industry is also a constantly changing subject, and as new developments are adopted and new factors emerge, innovations will be created in response to these developments and factors.
The food industry has witnessed rapid and dramatic changes due to the food industry revolution in recent years (**Ding *et al.*, 2023**). These changes involve the introduction of new technologies that revolutionize food processing and distribution to improve food quality and safety, provide personalized nutrition and diet, support sustainability, and conserve energy and resources (**Alkhafaji M. & Herrara R., 2021**). In this part of the article, the processing, distribution, and consumption of food products are examined and advancements in machine learning, artificial intelligence, big data, blockchain, the internet of things, and biotechnology, all of which address challenges in the food industry and help create a new generation of food industry equipment are explored.

Historical Overview of the Food Industry

The history of the food industry dates back to ancient times when mankind began to cultivate crops. While early agricultural activities were largely associated with nature, civilizations grew and food was processed within cities. At the same time, food processing techniques were improved, and methods such as curing, drying, and smoking were developed to extend the shelf life of food and facilitate storage and transport. Before the 18th century, the food industry was limited in scale and mostly operated in the form of small workshops within cities, producing raw and simple food items such as flour and salt. The lack of close collaboration and information sharing between raw material producers, processors, and retailers led to inefficiencies in supply chain management, generating excessive inventory and food waste. The food industry originated in ancient times when mankind first began to cultivate crops. While early agricultural activities were largely associated with nature, civilizations grew and food was processed within cities. Simple food processing took place, such as roasting grains and corn, boiling tubers, filtering oil from seeds, etc. The food industry then went through several development stages, from food processing being determined by nature to food processing being determined by communities and cities. During the nascent stages in certain regions, food processing was thus initiated in the form of small-scale processing. As agricultural production evolved, machinery and equipment such as stone mills and presses were gradually introduced to make processing more efficient and to maintain the freshness and quality of food. As agricultural techniques improved, the production and processing of food, as the most important commodity, gradually expanded into a larger scale. Food processing technology was gradually developed with industrial characteristics, including salting, curing, pickling, etc. Meanwhile, to ensure the quality of food, brewing and food

preservation technology was innovated, including fermentation, cooling, smoking, and carbonating. (**Pilcher, 2023**)

Key Players in the Modern Food Industry

The modern food industry is a complex and vast network that involves multiple players and stakeholders, each having a distinct role in various operations. Each of these entities contributes significantly to the overall functioning and dynamics of this network, directly or indirectly influencing its constituents and operation. These players are primarily associated with food production, processing, preservation, packaging, distribution, marketing, and selling of food items, including a range of services endowed to them (**Aguilar *et al.*, 2019**).

Food producers, food processors, food distributors, food retailers, and food service establishments are among the major contributors to the modern food industry. Other influential actors include importers, exporters, wholesalers, brokers, resellers, and logistics service providers, such as trucking companies, railroads, shipping companies, and airlines. Some companies undertake a combination of these roles. Moreover, companies in the modern food industry are also in competition with producers, quality assurance technicians, grading and sorting facility managers, food quality assurance managers, restaurant managers, food service managers, food marketing managers, and food advertising personnel (**Green *et al.*, 2018**). Various government regulators oversee food safety and security, food trade, and food service guidelines, such as the Food and Drug Administration (FDA), US Department of Agriculture (USDA), Federal Trade Commission (FTC), and Environmental Protection Agency (EPA).

Globalization and the Food Industry

The profound impact of globalization on the modern food industry is thoroughly examined. The food industry, which provides food for humans and animals, is dedicated to collection, processing, preserving, packaging, marketing, and distribution. The food industry is a major pillar in any society or region; the globalization of the food industry is now equally evident. The globalization of the food industry is concerned with the production, processing, storage, and distribution of food, which changes the food supply, consumption, and demand patterns in a country through international trade (**Aguilar *et al.*, 2019**).

The early globalization of the food industry can be traced to the new world discovery by Christopher Columbus and the later establishment of the Columbian Exchange. Still, the food available in a country would mainly depend on the climate, agricultural products, and technology. The industrial revolution in the 1820s and consequently the advancement of agricultural technology narrowed the gap in food availability, supply, and consumption patterns among countries. Nevertheless, land provided equal agricultural products in a region. Land use was maximized by transportation technology in distant land, and eventually, comparative advantages in the agricultural products were created among different regions and countries. The agricultural product trade based on the comparative advantage is the earliest form of food industry globalization, which later expanded to raw materials and processed food. The modern globalization of the food industry resulted from advances in transportation and communication technologies, which radical changes were made to the distribution, supply, demand, and consumption of food. The Internet and satellite technologies enhanced food advertisement, marketing, and retailing. In addition to the McDonaldization world, the food tradition and culture of other countries have also gained acceptance and recognition, such as the tea culture and sushi culture. The food preference, custom, and behavior are dramatically

reshaped by the modern world food culture in addition to changing the food supply and consumption pattern (**Ding *et al.*, 2023**).

The food industry is an indispensable component of the modern economy, providing basic human requirements for survival. The food industry also employs many people and makes substantial contributions to gross income, especially for developing countries. The food industry is one of the results of industrialization, which supplies processed food to wholesalers or retailers to meet the demand for huge quantities and variety of food products in urbanization. The modern food industry is based on an interdependent and tightly coupled system spanning from farm production to consumer consumption with increasingly shrinking food supply chains. (**Crippa *et al.*, 2021**)

Sustainability and Environmental Impact in Food Production

Canada's food production and distribution systems are under scrutiny. Safety precautions are required to ensure wholesomeness in foods and beverages offered for sale. The American, European, and to a lesser extent Canadian food production systems are being evaluated and re-evaluated to ensure environmental sustainability. The criticisms include growing foods with artificial fertilizers and pesticides, implementing intensive livestock operations and applying hormones and antibiotics, and concentric venture to food package transactions, all with proposed negative contributions to the ecological footprint (**López-Gálvez *et al.*, 2021**). It is a deliberate universal effort to overcome environmental degradation by curtailing or putting limits to industrial emissions, using the fear of global warming, or climate change. The chemical nitrous oxide is about 300 times more potent than carbon dioxide for the greenhouse effect; the excessive use of nitrogen fertilizers is its principal anthropogenic source. Out of the dimension, current agriculture is not sustainable, at least with present uses and rates of resources (N and P fertilizers, fossil fuels, and various pesticides). Therefore, it is understandable that better use of agricultural resources can reduce "waste" with environmental impacts and sustainability labels (**Kusch-Brandt, 2020**).

Food Safety Regulations and Standards

Food safety regulations and standards are necessary to protect the consumer's health and ensure the quality of food products. Food safety regulations refer to the set of laws, regulations, and government-mandated guidelines that help control the production and distribution of food products. Standards, on the other hand, refer to industry-mandated guidelines, which are also important but are not necessarily enforced by regulations (**Henson & Caswell, 1999**). To ensure compliance with regulations and standards, food processors are expected to monitor the production and distribution of their products through quality assurance programs. The consequences of violations can range from warnings and fines to cessation of production and criminal prosecution. Often, packaging for products includes disclaimers and cautionary messages indicating that the product is not responsible for certain risks (**Abu Bakar, 2012**).

Food safety regulations and standards are extremely complex. In the food industry, the distribution of products is often coordinated through just-in-time delivery systems where many ingredients are outsourced and transported over long distances. This requires food processors to maintain rigorous records of the food product's history throughout the production process, including where ingredients were received, how the product was processed, storage conditions,

and shipping information. These records can be very extensive, especially for large firms that process many different products and are sometimes several inches thick for a single batch of a product. In the event of a food safety violation or perceived violation, state or federal authorities may review the records in an attempt to trace the problem back to the source. Because processors have a legal obligation to maintain these records, companies that do not comply with this requirement can face serious penalties including the loss of business licenses and criminal prosecution.

Technology and Innovation in Food Production

The food industry includes five distinct sectors: crop cultivation, animal husbandry, fishery, food processing, and food consumption (**Aguilar *et al.*, 2019**). At the same time, contemporary food production processes have been revolutionized by novel types of machinery and production techniques based on new technologies within all sectors of the food industry. The food industry along the entire food production chain from farm to table is experiencing gradual digitalization and smarter operation with control, monitoring, data acquisition, optimization, and even designation processes carried out by computer software, digital, and interconnected devices (**Hassoun *et al.*, 2023**).

It has a significant impact on product development, food safety, food quality, and energy/chemical usage during food production and is influencing global competition across contemporary food industries worldwide. States of the art food industry innovations, particularly in production machinery and food processing, flavor, functionality, and healthy enhancement of foods, as well as innovative packaging and storage techniques, digitalized food industry equipment, big data usage for food monitoring, and control, optimization of food production will be discussed in this research.

Supply Chain Management in the Food Industry

Supply Chain Management (SCM) is a complex network of various activities that provide the flow of goods. The food industry is considered one of the most complex systems in that respect. It includes such activities as sourcing, purchasing, transportation, production, processing, packaging, and distribution. The food industry should consider the specific characteristics of food products in the implementation of Supply Chain Management. The agricultural production is highly dependent on factors like climate and weather conditions. The vegetables harvested at a particular place cannot be substituted by the other products. Operations are performed by agricultural cooperatives or by producing and processing companies in combination. The food supply chains are widely exposed to shocks, e.g. climatic shocks, industrial accidents, or terrorist attacks. The strength of impact largely depends on the food product type and on the country level (**Gusarova *et al.*, 2019**). The aim is to provide a segmentation based on vulnerability against various hazards so as to support the decision making in counter-measure design.

Reliable information flows are critical for effective Supply Chain Management. Food products have a great number of intrinsic characteristics influencing the selected distribution channels, e.g. storage and transport temperatures, shelf life, volatility, perishability, quality specifications, size, tariff classification codes, value, etc. Food safety and quality are the top priority of consumers that require validation of safety and quality specifications of food products in each link of the food supply chain. Knowledge about food supply chains is often

inadequate or asymmetrical at some supply chain levels causing a lack of transparency (**Soysal et al., 2012**). The reviewed experience of managing food supply chains demonstrates that the following problems in managing food supply chains can occur: absence of methodology ensuring uninterrupted supplies and durable relations with suppliers; insufficient quality of information flow along the supply chain; high costs, underutilization of storage facilities, excess stocks and chronic shortages of raw products by product types, suppliers, delivery periods, etc. Problems concerning transportation both during raw material delivery from suppliers to processing enterprises and during product distribution from processing enterprises to consumers, including the execution of contracts on the food products delivery are also revealed. The introduction of the proposed methodology in enterprises will create a methodological basis for the selection and effective implementation of decision-making tools in Supply Chain Management (SCM).

Marketing and Consumer Behavior in the Food Industry

The food industry is not only vast and complex, but it is also an economic powerhouse with a monumental impact on food policy. As mentioned in the introduction, nowhere is the relationship between the human population and its survival more apparent than in food issues, most especially in the modern food system. Food issues constitute a fascinating and bewildering array of topics and questions about various aspects of how to survive, and many of the complexities of the modern food industry are illustrated in these questions. The food industry involves more than the people, firms, and farms involved in the production and processing of food, the industry also includes everyone involved with feeding people, from people who visit restaurants to those who put ready-to-eat meals in microwaves. This tremendously diverse group of people, firms, and farms are brought together by one thing: they transform food, for example, take it from a field or container and prep it in some way so that it is more desirable. Because there are so many different aspects of food, food trends, and people involved with food, an equally diverse set of questions can be asked about food topics that touch the modern food industry. Examining these questions sheds light on how food and the food industry shape how we view, engage with, perceive, and think about the world, and food issues highlight the importance of food in many aspects of life, from politics to geography, sociology, economics, and culture. Since the way that somebody eats, what types of food they eat, and how these divorces and purchases are made reflect one's life experiences, upbringings, beliefs, relationships, and social class, this foodiness. (**Sovacool et al., 2021**)

Food Waste and Loss Management

Food waste and loss is an issues that is receiving increased attention and action from governments, organizations, and companies worldwide. According to estimates from the United Nations, Food and Agriculture Organization (FAO), about one-third of global food production is wasted or lost each year. This amounts to about 1.3 billion tonnes of food. Food waste and loss have economic, environmental, and social consequences. On the economic side, food wastage costs the global economy about US$940 billion annually. For developing countries, it amounts to losses of approximately US$310 billion, whereas industrialized countries incur losses of about US$680 billion. Food waste and loss also contribute to environmental degradation. Reducing food waste and loss could mitigate pressures on land, water, and biodiversity (**Centre for Agricultural & Rural Cooperation, 2016**).

Food waste and loss occur throughout the supply chain from primary production to consumption. To decrease waste and loss in the food supply chain, it is essential to identify and understand the reasons for the waste and losses. For farm and harvest practices, these reasons can be poor agronomic practices, resulting in low productivity and quality. Poor field selection, incorrect seeding, inadequate irrigation, and insufficient fertilizer application can also lead to crop damage and wastage (**Papargyropoulou *et al.*, 2014**). Careless handling of crops can result in crop damage during harvesting and transport. Distributional losses can occur due to poor infrastructure and the ability to transport only for a limited distance. During the processing stage, losses may occur due to process inefficiencies. Packaging and storage losses may occur due to inappropriate or inadequate packaging. Transportation losses may occur due to damage during transport or vehicles not meeting food safety requirements.

Emerging Food Trends and Future Directions

Consumers desire healthy, high-quality food with minimal additives, preservatives, and processing (**Aguilar *et al.*, 2019**). Active edible food packaging has recently become a promising food preservation technology. This packaging includes biopolymers, antimicrobial agents, and antioxidants that maximize food shelf life. The herbal field's evolution has sparked significant interest in edible packaging development using natural plant components. Essential oils, due to their antimicrobial activity, can inhibit gram-positive and gram-negative bacteria and fungi. However, incorporating the oil in edible films can lead to biopolymer solubility reduction. The objective of these innovations is to maximize processing efficiency, preservation times, and food safety to minimize food waste (**Ding *et al.*, 2023**).

Consumer profiles have evolved in line with these new processing and packaging technologies. New food platforms for ready-to-eat meals and on-the-go food demand the fast preparation of nutritious, tasty foods with minimal cooking time. Other consumer needs, such as health knowledge, personalized service, food security, and access to groceries, have emerged. The industry has control over food composition and quality to meet these challenges through nutrient bioengineering tools, agricultural techniques, and precision farming technologies.

Challenges and Opportunities in the Food Industry

More than twenty years have passed since the food industry entered the 21st century, setting the stage for another series of changes to meet the new demands of a growing global population with changing economic and social characteristics. With the emergence of a new generation of technologies, a new model of economic development, the rapid integration into the world economy, and the seemingly endless pursuit of benefits and convenience, the global food industry has faced a wide array of challenges, including alternative food networks, the twisting of food trade regimes, and a mismatch between regional policy architecture and food value chains. Borders are becoming more porous; the boundaries between agriculture, food processing, food retailing, and consumer life are increasingly blurred and converged. Farm production is no longer just farm production; it is redefined as a part of a global value chain driven by food processors, retailers, and consumers, while food processors are transforming from manufacturing-centric firms into lifestyle purveyors and brand securities.

Globalization presents challenges, but it also opens up opportunities for innovation. The convergence of economic, social, and technological factors is inspiring a redefinition of the

busyness of the food industry and generating a new series of mega technological trends in food processing, storage, distribution, transportation, trading, hazard prevention, and control. The food industry is in the midst of an inevitable transformation, with a scope of technological trends in and after the 2020s expected to change the industry in a way comparable to the global Green Revolution and Food Chemistry Revolution in the past half century (**Aguilar *et al.*, 2019**). It is no longer possible to fulfill the usage of stable and affordable food for the population over decades because of rising food prices, jarring public grievances on food safety, security hazards, food scares, and the suffering of over 950 million undernourished individuals.

Food Industry and Social Responsibility

The food and agriculture industry, comprising agribusiness, food/beverage processing, retailing and marketing, restaurants, catering services and catering food service industries, is an important part neither only in economic growth but also in social change. In addition to the economic dimension of semi-globalisation, there are social, political, cultural, environmental and demographic dimensions which have important implications for the food production-consumption continuum. The food and agriculture industry has been a key driver of social change as countries become more urbanized and engage in the global economy. This is the case in emerging economies and developing countries but also in developed countries. This paper highlights five key social change issues which are considered important future research opportunities. These key issues pertaining to food safety, health and nutrition, food price inflation, food quality and convenience, and food waste (**Dellios *et al.*, 2009**). To tackle the above issues, the food and agriculture industry has an important role to play in terms of contributing to a more sustainable and equitable food production-consumption continuum, adapting to and mitigating climate change, addressing global poverty and inequitable food price inflation, enhancing food safety and compliance, and ensuring food quality, affordability and accessibility (**Jae Morgan, 2016**).

The social responsibility of the food industry pertains to all business activities that concern ethical conduct at social, environmental, and related issues. Corporations recognize that they are responsible before their stakeholders (employees, consumers, suppliers, investors, and the wider community); and the community where their enterprise has been established. To be socially responsible, organizations must assume a commitment to conduct their business following laws, as well as with ethical and social expectations. Corporate social responsibility is a business strategy with growing acceptance in the food industry. Many food and agribusiness corporations developed and implemented strategies of corporate social responsibility. In some cases, companies consider social responsibility as a task of corporate image marketing.

The Role of Artificial Intelligence in Food Production

In enhancing various aspects of food production/distribution, artificial intelligence (AI) is growing in influence. With the powerful capabilities of machine learning, the food industry can become more efficient, and the issues of food safety and quality can also be resolved. Aspects dominated by AI include food safety and quality control. The aim is to apply AI in the food industry that guarantees food safety and quality and discuss the challenges involved in it, including the ethical aspects. In recent years, with the boost from the pandemic, agriculture and the food industry have turned to automation and robotics technology. Within this new model,

there are also great demands for using AI in the abovementioned aspects (**Ding *et al.*, 2023**). AI can be used in agriculture to predict the emergence of crop pests through image analysis, and management systems can be developed to optimize resource use and climate control, hence enhancing the yield of crop production (**Min *et al.*, 2023**). Moreover, in food production, it can be used to support automatic defect inspection and analysis via different sensing methods, hence ensuring product safety and quality. The food packaging industry is also being dominated by AI because of the advent of intelligent robots capable of automatically packing food according to the object detected in an image by an artificial vision system. Processed food production is another aspect where AI can be used in understanding the various mechanistic models in food processing. In the quality control of processed food, smart sensors and data analysis techniques can be explored to develop online automatic systems for quality inspection in food processing and packaging machines.

CONCLUSION

The food industry has undergone fast-paced changes in recent years due to influences from the overall food industry revolution. The development of artificial intelligence, big data, the internet of things, and other information and communication technologies gives more chances and opportunities to the food industry. The futures of the food industry will be based on technologies such as smart agriculture, robotic agriculture, drones, 3D printing, and digital twin technologies. With the considerate development of industrial AI and big data, food manufacturing now shifts from traditional manual production to an automated production phase. Packaging, warehousing, distribution, marketing, and consumer service will also move toward an automated phase. The emergence of these new production and service models brings more innovations and opportunities for the food industry but also higher requirements for the workforce of the food industry (**Ding *et al.*, 2023**). Regarding the food industry, food safety issues have become a serious global concern.

Technologies for food processing have gained much attention in recent years. These new technologies have transformed various aspects of the food industry, such as food processing and inspection. The integration of intelligent systems into traditional industries can enhance the safety and quality of processed food, standardize food production processes and formulation, lower the production cost and time, conserve energy and resources, and minimize food loss and waste. Inspired by the successful application of AI in the other sectors, and the fact that food industries are mostly traditional manual-based industries, more researchers started to conduct in-depth research in the food sector, leading to a startup of a large number of AI applications in the food industry (**Aguilar *et al.*, 2019**). The latest AI technologies in the food industry include, but are not limited to, synthetic food, food production & energy efficiency management, supply chain management, sales forecasting, assisted cooking, and personalized nutrition. Besides, applying biotechnology along with AI creates food with new attributes either by a new processing technique or combination resource that has not been combined before using technologies similar to 3D printing.

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