Chapter

Global Trends Regarding Food Assurance

Marc Romina Alina, Crina Carmen Mureșan, Anamaria Pop, Georgiana Smaranda Marțiș, Alina Narcisa Postolache, Florina Stoica, Ioana Cristina Crivei, Ionuț-Dumitru Velescu and Roxana Nicoleta Rațu

Abstract

The chapter offers an in-depth examination of food protection, encompassing food safety, food security, food fraud, and food safety culture. The chapter commences with a brief introduction, followed by a subsection on food protection that encompasses concepts of food safety, food security, and food safety culture. The third section presents information on food availability, including access to food, Zero Hunger (SDG 2)—a sustainable development target, and local food systems. Section four examines recent papers on sustainable agriculture, encompassing climate change, harvesting practices, agricultural stability, and biosecurity. The final section discusses the problems of Sustainable Food Processing in the twenty-first century within a dynamic business context.

Keywords: food assurance, food protection, food security, food fraud, food safety

1. Introduction

Food production, climate change, and sustainability are currently the most popular topics, with a high research density and importance in food security. While water security, energy security, water footprint, and the environment have received a lot of attention, they are not closely related to food security. The number and importance of studies on food sovereignty, ecological agriculture, and childhood obesity were low, indicating that these are developing fields. Food sovereignty has received significant attention in recent years as a result of the impact of international conflicts and the COVID-19 pandemic [1].

Although there was a low number of published papers on topics closely related to food security, research on nutrition security, biodiversity, and aquaculture had a medium degree of centrality but a low degree of intensity. This suggests that there is a great deal of untapped potential for future research on these topics. In food security, the fundamental research directions are sustainable agricultural development and poverty eradication in Africa, Southeast Asia, and other regions [2].

Numerous topics are covered by research on food security, and in recent years, there has been a notable advancement in the field's body of knowledge. Research in this area is crucial for making logical and scientific assessments of the development trend in food security.

The meaning of food security has been expanded upon and refined over time, and the findings have progressively shifted from theoretical to practical. The primary focus of food security at first was on the adequacy of food supply and production. The balance of food supply and demand, as well as the overall amount and quality of food, was then given equal consideration in studies on food security [3, 4]. From the perspectives of food production, distribution, consumption, and reserves, scientists create the food security evaluation index system [5].

Food fraud is a persistent problem that presents changing challenges for Food Supply chain [6]. In addition to causing financial and reputational harm to the directly implicated food companies and industrial associations, food frauds can also erode public confidence in the authorities tasked with ensuring food safety by posing a genuine risk to public health. Food frauds are just one of the many food-related risks that worry consumers more than harmful bacteria or chemical residues [7].

Food safety culture (FS-culture) is recognized as a significant phenomenon in the context of food safety. In both the research and food sectors, increasing attention is being paid to food handlers' behavior and food safety, the significance of the elements of FS-culture (e.g., leadership, commitment, communication, risk awareness, work environment, and management system, styles, and process), and a holistic approach to food safety management systems (FSMS) that includes human behavior [8].

2. Food protection

Food safety is a fundamental requirement, but there is a chance it will not be given enough consideration when creating productive and successful systems. Food safety is still a major concern because foodborne illness outbreaks can be very expensive for consumers, the food industry, and the government [9]. A closely related but more general concept is "food safety," which refers to the absence of any potential contaminants or hazards from food. Both names can be used interchangeably in real life. Hazard identification and control are necessary for HACCP implementation in the food industry. Motivating food handlers to put what they have learned about food hygiene into practice is therefore a significant challenge in the food industry.

Food safety hazards are contaminants that can render a food product unsafe for production. A lack of proper food hygiene can result in food-borne diseases and death of consumers. Contaminated food is one of the most common causes and major contributors to gastrointestinal illness (e.g., acute diarrhea, nausea, vomiting, and abdominal pain), compromised nutritional status, decreased resistance to disease, and loss of productivity in the world today. Furthermore, food companies rely on food safety methodologies, such as the food Good Manufacturing Practices (GMP), Good Agricultural Practices (GAP), the Hazard Analysis and Critical Control Points (HACCP) system, and the ISO 22000 standard, to ensure the safety of their food products (**Figure 1**) [10–12].

Many barriers and factors (environmental, social, cultural, belief systems, etc.) can influence whether food handlers effectively implement food safety practices in their workplaces [13, 14], including a lack of adequate food safety training, time pressure,

Figure 1.
Ways for preserving food safety.

competing job tasks, lack of or inconvenient locations of equipment/resources, lack of managerial support, motivation/incentive, lack of reminders, or lack of clarity in food safety messages [13, 15].

Food security is concerned with the international community's stability and human well-being, and it plays an important role in sustainable development. Hunger eradication, achieving food security, and improving nutritional status are high-priority areas in the 17 Sustainable Development Goals [https://sdgs.un.org/2030agenda]. Nutrition, quality, and quantity security in food is the aim of food security research. It is still very difficult to ensure food security, and the situation is dire even though grain output is still steadily increasing and nutritional levels are improving. Numerous problems with food security are brought on by climate change. The productivity and sustainability of food, as well as achieving the dual goals of food security and sustainable development, are critical topics. Agriculture is responsible for 34% of greenhouse gas emissions, with the majority resulting from land-use changes caused by agricultural activities and the remainder from the food production supply chain [16].

Achieving the Sustainable Development Goals is critical for resolving the conflict between food production, greenhouse gas emissions, and resource depletion. Man Li et al. proposed a comprehensive ecological and economic model to analyze crop phenology and nitrogen fertilizer absorption capacity, demonstrating that improving nitrogen fertilizer efficiency can increase yield [17].

Agro-ecosystems rely heavily on water resources, and rising food demand will inevitably raise water demand [18]. Many scholars have assessed the importance of water resource security to food security [19]. Determining how to achieve food security while ensuring water resource security is an important research topic that involves technology, management, policy, and other factors [20].

When considering agricultural development in terms of sustainability, it is necessary to investigate ecological agriculture models while keeping environmental protection in mind. For example, Lucantoni et al. studied the transition of a Cuban farm to ecological agriculture, focusing on sustainable practices that integrate environmental protection into the agricultural development [21].

The Food Supply Chain (FSC) has faced one of the most emerging challenges and issues on a global scale over the last decade, specifically "food fraud" [6]. Food fraud refers to the deliberate and intentional misrepresentation, adulteration, substitution, or tampering of food products for economic gain, often involving deceptive practices such as mislabeling, falsification of documentation, or undisclosed ingredient modifications. This malpractice undermines consumer trust, compromises food safety, and disrupts the integrity of the Food Supply Chain [7].

Food products are heterogeneous because they come in various proportions from different geographical sources and are subject to different laws and regulations depending on their origin, destination, and manufacturing [22]. Thus, food commodities are vulnerable to fraud. Furthermore, FSCs contain a number of interconnected and intercorrelated elements and phases that should be considered in order to eliminate food fraud throughout the supply chain [6].

The main sources of public awareness regarding food fraud and authenticity are high-profile media discussions, such as those that are linked to health risks to the public or that occur when a large-scale operation is discovered and the ensuing scandal damages the reputation of businesses or government agencies [23]. But food fraud is pervasive and costs a significant amount of money, even when it is not current [24]. Its many forms include imitation, substitution, dilution, adulteration, mislabeling, and dilution [25]. Thus, establishing protocols and quality markers to identify food fraud remains a crucial and pressing undertaking. A variety of information databases are available for evaluating the incidence of food fraud. The Center for Food Protection and Defense in the United States (US) is home to the Economically Motivated Adulteration (EMA) database, which contains details about the food product, the year and country of origin, the type of fraud, the health effects, and how the incident was discovered [26].

Another platform for information exchange and collaboration on infractions of EU agri-food chain laws is the EU Food Fraud Network (EU-FFN), which is intended for use by Member States and other European nations. According to the Commission Implementing Regulation (EU) No 2019/1715, it has contact points in each Member State that are assigned by the network member and forwarded to the EU Commission contact point. Under the EU Commission's supervision, the Administrative Assistance and Cooperation System-Food Fraud (AAC-FF) facilitates the sharing of private information about the suspected food fraud cases and non-compliances. The documents, unapproved treatment and/or process, replacement, dilution, addition, or removal in product, mislabeling, and intellectual property rights infringement are the five primary categories into which they fall (EU-FFN, 2019) [7].

Food safety culture (FSC) has emerged as a critical factor influencing the behavior and practices of food handlers within organizations. It is defined by the Global Food Safety Initiative (GFSI) as the "shared values, beliefs, and norms that influence mindset and behavior toward food safety within and across an organization." This concept underscores the importance of aligning organizational attitudes and actions to prioritize food safety at every level.

In recent years, FSC has gained significant attention in the food industry, driven by its potential to enhance compliance with the safety standards, reduce risks, and

build consumer trust. Various tools and methodologies have been developed to assess and improve FSC, ranging from surveys and audits to behavioral observation techniques [8]. A strong FSC fosters accountability, proactive risk management, and continuous improvement, ensuring that food safety becomes a core organizational priority rather than a regulatory obligation. Given its far-reaching impact, fostering a robust food safety culture is now recognized as a cornerstone of sustainable and trustworthy food production [27].

Several researchers have developed concepts for food safety culture [8, 28]. A specific FSC conceptual model by Spagnoli et al. 2023 [27] is used, in which food safety culture is comprised of three building blocks: the food safety management system (based on core control and assurance activities), the human-organizational, and the human-individual building block. The assessment reveals the maturity of the current food safety culture in a specific food processing organization. Maturity of FSC, or maturity of the dimensions that comprise FSC, is measured on a scale, with five-point maturity scales (with stages one through five representing the stages of doubt, react to, know of, predict, and internalize) and three-point maturity scales (with stages one through three representing a reactive, active, and proactive level of maturity) being the most common. A particular FSC dimension may be regarded as having a gap when it has a low maturity score. It is anticipated that a company with a developed food safety culture will produce products with the higher levels of (microbiological) food safety. Previous studies that looked into the relationship between food safety culture and *L. monocytogenes* control came to the conclusion that a more developed food safety culture is linked to a lower risk of *L. monocytogenes* contamination. This connection highlights the importance of fostering a strong food safety culture (FSC). Additionally, another study found that associated butcher shops achieve higher output levels for food safety due to a more developed safety climate and a food safety management system (both of which are the elements of FSC) [27, 28].

Food safety, food protection, sustainability, digitization, and retaining skilled personnel are just a few of the many issues and concerns that face the food industry today. Companies will now need to work toward developing their organizations' FSC as well, due to legislation, stricter private certification programs, and growing awareness of the topic.

3. Food availability

Food availability, a critical component of the Food Supply Chain (FSC), is directly influenced by practices that ensure product authenticity and prevent food fraud. When food fraud occurs, it not only impacts consumer trust but also disrupts the availability of safe and authentic products in the market. Strengthening food safety culture (FSC) and implementing effective management systems are vital strategies to enhance food availability by minimizing disruptions caused by adulteration, substitution, or other fraudulent practices. Thus, ensuring "food availability ties closely to maintaining food integrity and building resilience within the FSC."

This version aligns "food availability" with related themes like food fraud and food safety culture.

In its most basic form, food availability refers to the state in which food is produced to be consumed at local levels, where local people or households can easily find the food they need. It illustrates how different types of food are produced and

supplied. Furthermore, the process of food availability is taken into account, mainly focusing on the dietary preferences of the consumer. These important variables are convenience, cost, taste, and cultural norms. In addition to these, there exist other variables including socioeconomic position and food accessibility, which essentially impact food types and nutrient quality. Consumer decisions have a direct impact on nutrition and sustainability, both of which are impacted by the available food options, quantity, and variety, as well as disposable income [29].

Enough good food must physically exist in order for food to be available. Food availability on a global scale denotes adequate total food production. But at the local, regional, and national levels, this component is much more complex and consists of a mix of domestic food production, commercial food imports and exports (including food aid), intra- and international trade, international, national, and local transportation, storage capacity, logistics, and food stocks [30].

When sociocultural, physical, and financial resources come together to enable the purchase or acquisition of the right foods for a healthy diet, food access is the outcome. Three components are considered to be part of food access.

First, access refers to having actual physical access to food, which can be challenging in some locations. It also has to do with allocation problems, which arises for a variety of causes and takes many different shapes.

Second, a crucial component of food access is food affordability. The cost of food in relation to the disposable money available for food purchases is a significant factor in this regard. Food insecurity may rise if prices rise more quickly than earnings.

The third essential component is preference. Food choices are influenced by a variety of factors, including convenience and culinary abilities, cultural and religious contexts, food flavor and appearance, health and ethical considerations, and marketing and retail methods.

Food utilization includes healthy eating habits, a varied diet, appropriate intra-household food distribution, food preparation and cleanliness practices, and how the body uses the many nutrients found in food. Food use is frequently understood to refer exclusively to food's physiological nutritional value. Foods must also be safe, meaning they must be devoid of infections, parasites, and other pollutants as well as poisons. Although a lot of ultra-processed meals meet these requirements, consuming too many of these "empty calories" can also be considered "unsafe" because it may lead to obesity and overweight as well as linked diet-related illnesses.

The other three dimensions—consistency and dependability in food supplies/availability, access, and utilization—are referred to as stability. Households should not run the risk of losing access to food due to cyclical events or unexpected shocks. Therefore, stability entails lowering the possibility of unfavorable consequences on the other aspects of food security. It speaks of the temporal aspect of inclusivity and food security, or the period of time that takes into account the needs of every member of a specific population in terms of food security. Examples include universal access to agricultural inputs, steady physical market access, and pricing and policy stability [31].

According to Rahimov [32], a multitude of factors, such as population increase, agricultural practices, climate change, technological improvements, and trade dynamics, influence global patterns in food availability:

1. Increasing global food production: Over the past few decades, there has been a general increase in global food production, which can be attributed to advancements in agricultural technology, improved crop types, and the development of

cultivated territory. This has aided in supplying food to the world's expanding population. In an effort to increase yields, several areas have switched to more intense agricultural methods. This covers the application of herbicides, fertilizers, and irrigation—especially in the underdeveloped nations [33, 34].

2. Regional differences due to unequal distribution and reliance on imports: Despite a global increase in food supply, there are still large regional differences. Some regions, especially in sub-Saharan Africa and some parts of South Asia, still struggle to achieve adequate food supply because of things like unstable climate patterns, inadequate infrastructure, and conflict.

   Additionally, a lot of nations, particularly those in the Middle East and North Africa, mostly rely on food imports because their own domestic production capacities are restricted. One of the most important issues facing the globe today is food security. Natural disasters and geopolitical unrest have put strain on food systems in 2023, which has worsened access to food in the end. As per the most recent report from the World Bank Food Security Outlook, there is a significant increase in the gap between individuals and there is a possibility of 943 million people experiencing extreme food insecurity by 2025 [35].

3. Threats to crop yields and their adaptation and resilience: Extreme weather events, changing growing seasons, and increased pest and disease threats all contribute to climate change's substantial impact on crop yields across different locations. To lessen the effects of climate change on the supply of food, more attention is being paid to the development of climate-resilient crops and farming methods [36].

4. Technological innovations through precision agriculture and sustainable practices: Precision farming, genetically modified organisms (GMOs), and digital farming tools are examples of technological innovations that are improving food production efficiency while also helping to decrease food waste. Sustainable farming methods that preserve soil health, lessen their negative effects on the environment, and increase the supply of food over the long term are becoming more and more important [37].

5. Trade dependency: International trade has a significant impact on the availability of food worldwide. Trade enables food to be transferred from areas of surplus to areas of deficit, but it also exposes food supplies to supply chain interruptions, trade restrictions, and geopolitical unrest. While the COVID-19 pandemic brought attention to weaknesses in global supply chains and temporarily disrupted food supplies in certain areas, it also sparked initiatives to create more resilient and locally focused food systems [38–40].

6. Changing demand patterns and food waste: As urbanization accelerates and incomes rise, dietary preferences are shifting toward more processed and animal-based foods. While this transition reflects improved living standards in many cases, it also introduces challenges to food production systems by increasing the demand for resource-intensive products such as meat and dairy. This shift may strain agricultural resources and contribute to environmental degradation if not managed sustainably.

On the other hand, global food waste exacerbates the issue of food availability. A significant proportion of food is wasted not only in high-income nations, where consumer habits and overproduction play a role, but also in lower-income countries, where inadequate infrastructure, storage, and transportation lead to post-harvest losses. Addressing food waste requires a dual approach: improving efficiency and infrastructure in developing countries while promoting responsible consumption and reducing overproduction in the developed nations.

Moreover, the growing emphasis on plant-based diets and alternative protein sources presents an opportunity to balance demand patterns with environmental sustainability. Innovations such as lab-grown meat and plant-based substitutes may help reduce the burden on traditional food systems. By addressing food waste and diversifying dietary options, the global food supply chain can be made more resilient and equitable [41, 42].

3.1 Access to food

One aspect of food security, according to Campomanes et al. [43], is food access, which is the financial and physical capacity of individuals to obtain food. The physical component includes transportation choices, accessibility, and the distance and duration of travel to food-related services like markets. Economic access, which is determined by a number of factors including household income, food prices, and availability of financial assistance, is the capacity to buy food. Access to food affects other aspects of food security as well. For instance, greater dietary diversity may result from easier availability to food.

Access to food, a vital component in determining health and well-being, is influenced by a complex interplay of factors. These can be broadly categorized into two primary dimensions: economic accessibility and physical availability. Within these dimensions, critical determinants include infrastructure, affordability, purchasing power, and proximity to food sources. Additionally, access to food is shaped by cultural preferences, environmental factors, and governmental policies, all of which play a significant role in influencing food security at both individual and community levels. This discussion explores these interconnected factors, emphasizing their impact on ensuring equitable and sustainable access to food for all populations [44].

To stay healthy and avoid malnutrition, one must have access to enough food that is safe and nourishing. Nonetheless, there are a variety of factors that impact food access, which can be essentially classified into two categories: physical availability and economic accessibility. It is essential to comprehend these elements in order to create efficient solutions that guarantee food security for all people.

The presence and accessibility of food within a particular geographic area is referred to as physical availability. This availability is dependent on a number of important factors.

The physical availability of food is greatly influenced by infrastructure. Food must be moved from producing locations to markets *via* effective transportation networks that include ports, railroads, and roadways. In remote or underprivileged locations in particular, poor infrastructure can cause delays, increased food spoiling, and less access. Furthermore, keeping perishable food fresh requires having access to sufficient storage facilities like cold storage and warehouses. Food losses due to inadequate storage infrastructure can further reduce supply [45]. Another important component of physical food access is how close people live to food sources. A larger density of food retail establishments, such as supermarkets and grocery stores, is generally

advantageous for urban areas as it improves access to a wider range of foods. On the other hand, because there are fewer stores and a longer distance between food sources, those living in rural areas frequently have less access to a variety of fresh foods. The idea of "food deserts," which are places with little availability to reasonably priced and wholesome food, is especially pertinent to low-income urban and rural communities. Moreover, local food production—which includes farmer's markets, community gardens, and nearby farms—can greatly increase the availability of food, particularly in isolated or rural locations [46].

The ability of individuals and households to obtain food on a financial basis is referred to as economic access to food. A number of variables pertaining to affordability, purchasing power, and general economic policies influence this access. One of the main factors influencing economic access to food is affordability. A person's ability to afford food is greatly influenced by their income; a higher income typically translates into more access to a more varied and nutrient-dense diet [47].

One of the most important components of economic access is purchasing power, which is impacted by variables including employment, earnings, and inflation. Over time, high inflation can reduce purchasing power and raise the cost of food. While underemployment or unemployment can significantly limit access to food, stable and sufficient wages are necessary to ensure constant access to food [48].

A number of other factors, such as cultural preferences and dietary needs, health and nutrition awareness, climate and environmental factors, and economic access, go beyond physical availability to influence food access.

The capacity of people to receive enough food that is safe and nutritious is known as food access, and it is greatly influenced by both international markets and state policy. The physical availability and cost of food are determined by these factors, which have an immediate impact on local and global food security [49].

Global markets and governmental regulations are closely related, and their combined influence has a significant impact on how people may get food. Trade agreements, tariffs, and subsidies all have both beneficial and bad effects on the availability and cost of food. Subsidies can improve access by bringing down the cost of food, but they can also damage local agriculture in developing nations and distort markets. Tariffs may shield homegrown businesses, but they may also make a variety of items less affordable and accessible. Trade agreements have the potential to enhance competitiveness for local farmers while also opening up markets and extending access [50].

Global markets can increase price volatility and interrupt the availability of food, which adds another layer of complexity. They also have an impact on commodity prices and supply chains. Policymakers must comprehend these processes in order to develop well-rounded strategies that promote local agriculture, guarantee food security, and preserve resilience to changes in the global market. To ensure that everyone has access to sufficient and nourishing food, careful policy planning and effective coordination are required to minimize risks and optimize the advantages of global market interactions and governmental policies [51].

Zero Hunger (SDG 2) - UN sustainable development goals:

As part of the 2030 Agenda for Sustainable Development, the United Nations established the 17 sustainable development goals (SDGs) in 2015, with "Zero Hunger" being the second objective. By 2030, this goal seeks to eradicate hunger, increase food security and nutrition, and advance sustainable agriculture throughout the world. Millions of people worldwide suffer from hunger, especially in developing nations where food insecurity, malnutrition, and poverty are pervasive. The Zero Hunger aim acknowledges that having access to enough food that is safe,

nourishing, and sufficient is both a fundamental human right and a prerequisite for human development [52–54]. The objective encompasses several aims, such as:

- Universal access to safe, nutritious, and sufficient food—implementing an end to hunger and making sure that everyone, especially the weak and impoverished, has year-round access to enough wholesome food (**Figures 2–4**).

- End all forms of malnutrition—lowering all types of malnutrition, such as obesity, wasting, and stunting, especially in young children, teenage girls, women who are pregnant or nursing, and the elderly.

- Double the productivity and incomes of small-scale food producers—encouraging environmentally friendly farming methods that protect ecosystems, boost productivity, and make food production systems climate change adaptable (**Figure 5**).

- Sustainable food production and resilient agricultural practices—increasing the earnings and output of small-scale food producers, particularly those who are female, belong to indigenous tribes, are family farmers, or are fishermen.

- Maintain the genetic diversity in food production—guaranteeing the genetic variety of seeds, domesticated animals, and grown plants (**Figures 6** and **7**).

By tackling every aspect of food security and utilizing both new and current uses of science, technology, and innovation throughout the food system, it will be possible to achieve zero hunger by 2030. This report calls attention to the need for nations, especially developing nations, to invest in the capacity for innovation in addition to highlighting tools and approaches for addressing particular problems (such as increasing productivity or reducing post-harvest loss). In addition to guaranteeing wholesome food at all times, innovative skills are essential for using agriculture and the larger food system as a catalyst for sustainable and prosperous growth [56].

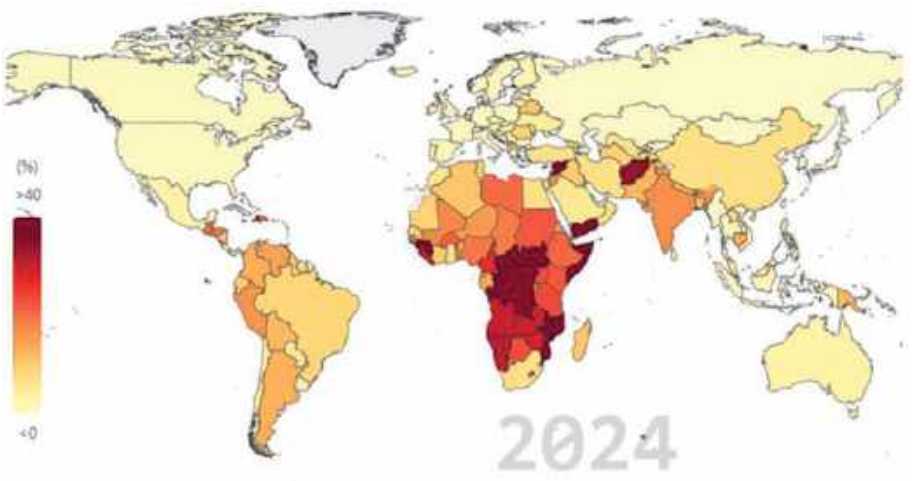

Figure 2.
Percentage of food insecure people globally in 2024 [35].

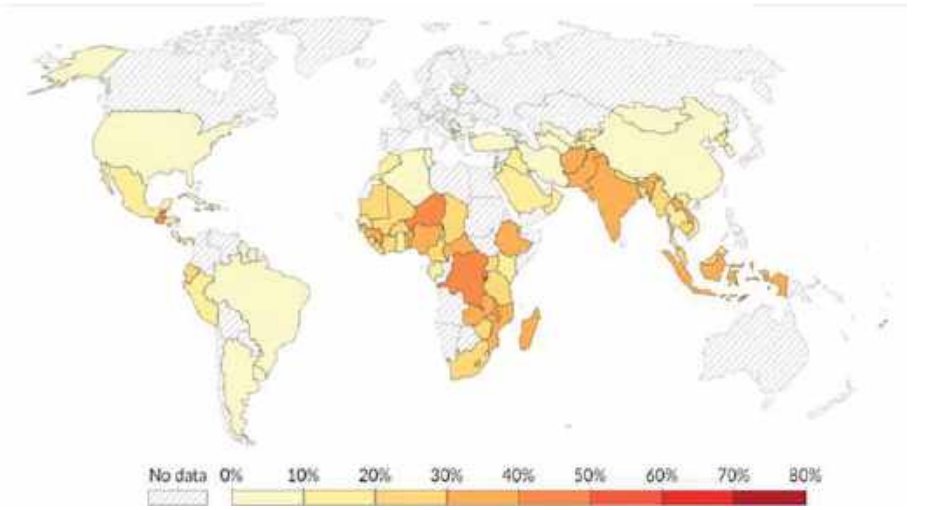

Figure 3.
Share of children younger than 5 years old that are defined as stunted. Stunting is when a child is significantly shorter than the average for their age, 2022 [35].

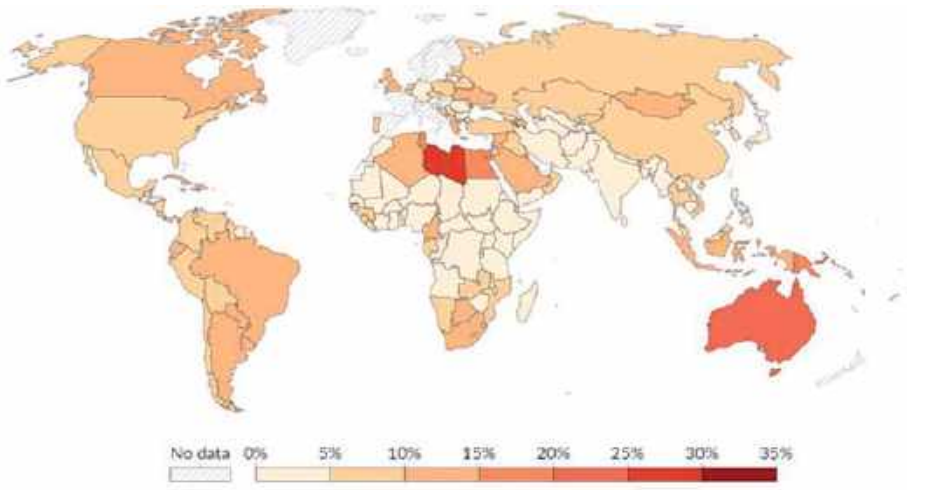

Figure 4.
Percentage of children under 5 years old who are defined as overweight, 2022 [55].

In order to achieve the "Zero Hunger" goal, food safety is essential since contaminated food negatively affects nutrition, health, and food security and exacerbates hunger and malnutrition [57]. For a variety of reasons, including the avoidance of foodborne illnesses, safeguarding food supplies, preserving nutritional value, promoting sustainable food systems, raising public awareness, and educating the public, it is imperative that food safety be maintained [58–60].

Achieving zero hunger is closely related to food safety. Since contaminated food can worsen malnutrition and impair health, attempts to enhance nutrition and food security are hindered in the absence of safe food. To guarantee that food is not only available but also safe and nourishing, it is crucial to incorporate food safety into

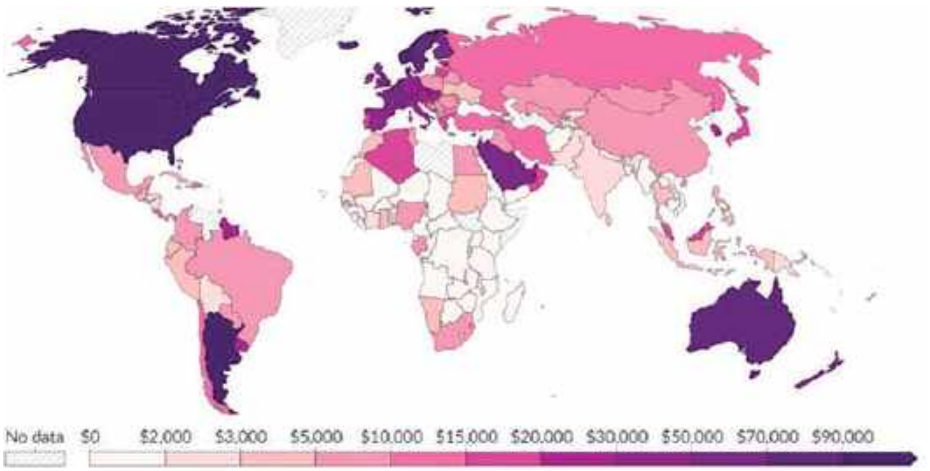

Figure 5.
Agricultural value added per worker, 2019 [55].

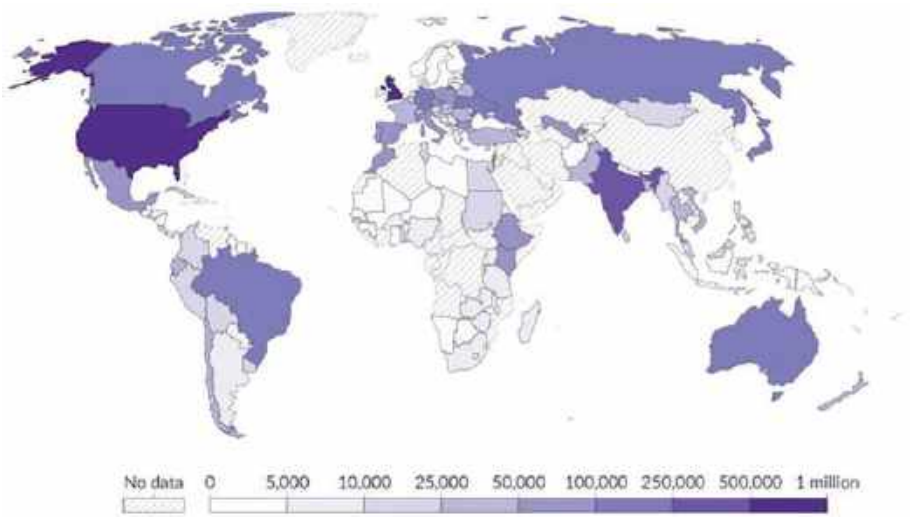

Figure 6.
Number of unique plant genetic samples in conservation facilities, 2021 [55].

agricultural practices, food processing, distribution, and public health regulations. A comprehensive strategy that acknowledges the critical role that food safety plays in advancing global food security and nutrition is needed to achieve the "Zero Hunger" goal [61].

3.2 Local food systems

Low-income households worldwide are disproportionately affected by food and nutrition insecurity, which raises the prevalence of chronic diseases in this demographic. Because there are so many variables influencing the accessibility and availability of nutrient-dense food, addressing this issue is difficult. Local food systems,

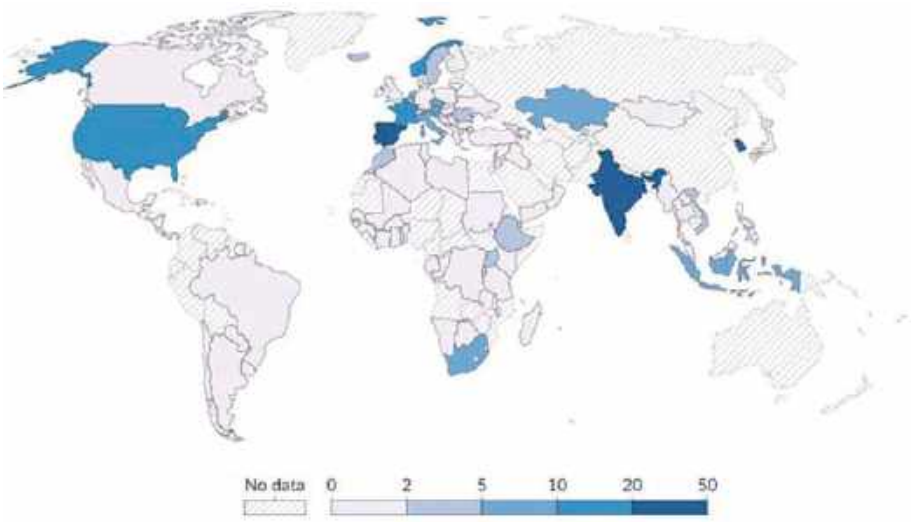

Figure 7.
Local animal breeds with the conserved genetic material, 2023 [55].

or short value chain models as they are more colloquially called, provide a systematic approach that seeks to optimize resources and align values both within and outside of the food supply chain [62].

In low-income areas, local food production is essential to food security. Local agriculture increases food availability and guarantees that communities have access to wholesome, culturally appropriate foods by lowering reliance on imports, strengthening local economies, and enhancing resilience to external shocks. Thus, it is imperative to support local food systems in order to reduce hunger in vulnerable areas and achieve sustainable food security [63]. According to research, households experiencing food insecurity frequently compromise food quality and variety in favor of quantity (e.g., by eating inexpensive, high-energy, and low-nutrient meals) [63, 64].

Enhancing food availability is mostly dependent on local food production, particularly in low-income areas where access to food may be hampered by a number of issues like poverty, poor infrastructure, and a reliance on imports. There are several advantages to encouraging local food production, and these benefits immediately improve the availability and security of food in these places.

Enthoven and Van den Broeck [65] related the fact that local food production provides fresher and more nutritious options, which is especially important in low-income areas with the limited storage facilities. It also reduces reliance on costly and unpredictable imports, enabling communities to attain greater self-sufficiency with a more stable food supply.

Local food production enhances nutritional outcomes by providing communities with culturally appropriate foods that align with their dietary needs and preferences, often offering more nutritious options than imported, processed foods. This is especially vital in low-income regions, where local production increases access to diverse, fresh, and nutrient-rich foods, playing a crucial role in combating malnutrition, particularly among vulnerable groups like children and the elderly [66].

By boosting food access, bringing communities out of poverty, and generating revenue and jobs for small-scale farmers and laborers, local food production promotes

economic growth. Additionally, it supports regional markets by enabling manufacturers to deal directly with customers, cutting expenses, and taking into account regional dietary preferences [67, 68].

The ability to produce food locally increases resistance to external shocks like natural catastrophes and international crises because it ensures a steady supply of basic foods even in the event that imports are disrupted. This is another benefit of eating locally. Furthermore, local farmers can employ techniques that more effectively adjust to environmental conditions, lowering the chance of crop failure and guaranteeing steady food supply, thanks to their in-depth knowledge of regional climates [69] . Local food production promotes sustainable agriculture by encouraging environmentally friendly practices like crop rotation, which preserves soil fertility and ensures long-term food availability. It also supports biodiversity by fostering the cultivation of diverse, locally adapted crops, enhancing food security, and reducing the risk of crop failure [70].

By teaching and training farmers in better agricultural techniques, food preservation, and market management, local food production empowers communities and increases food supply by improving farmers' productivity and quality [71]. Furthermore, local food systems improve community ties by encouraging collaboration between farmers, local authorities, and consumers. This results in improved resource management and communal food distribution.

Through a combination of regulations, financial aid, and instructional programs, local governments and communities can make a substantial contribution to the promotion of local food production. Financial incentives, such grants or tax exemptions, can be given to small-scale farmers and regional food enterprises as part of these initiatives. Additionally, governments have the authority to establish food hubs that streamline the distribution of regionally grown food and zoning regulations that give priority to urban agriculture. Furthermore, enhancing food security and empowering local farmers can be achieved through educational initiatives that teach sustainable farming practices and efficient food marketing strategies. Communities may boost local economies, increase access to food, and fortify themselves against disruptions to the global supply chain by combining these strategies [72, 73].

4. Sustainable agriculture

In recent years, sustainable agriculture has become vital for addressing global issues like climate change, food security, and environmental degradation. It combines the latest innovations with conventional techniques to increase productivity while preserving natural resources and supporting economies, cultures, and ecosystems [74]. Farming methods that satisfy present food needs while guaranteeing that future generations can do the same are commonly referred to as sustainable agriculture. Since sustainable agriculture usually places a higher priority on small-scale and family agricultural systems, supporting them can also help to boost local economy. Moreover, by encouraging diverse and resilient farming systems, sustainable agriculture, helps to maintain thriving rural communities and prevents huge businesses from monopolizing agricultural production [75].

In the context of climate change prevention, numerous studies emphasize the importance of reducing greenhouse gas emissions by sequestering carbon in soils, increasing biodiversity, and promoting agroecology. Techniques such as regenerative agriculture, climate-smart agriculture, and agroforestry have been shown

to enhance crop resilience, lower the carbon footprint of agricultural practices, and mitigate the adverse effects of climate change [76].

Additionally, sustainable agriculture is often highlighted as a pathway to transitioning toward alternative techniques like organic farming, integrated pest management, and biological control methods. These approaches aim to foster ecological balance and natural pest management, reducing dependency on the synthetic pesticide inputs.

However, it is important to approach this issue from a multifaceted perspective. While organic farming is frequently advocated as a solution to mitigate climate change, some studies argue that it can inadvertently contribute to climate challenges due to lower yields, which may necessitate the expansion of agricultural land and lead to deforestation or habitat loss. Therefore, the effectiveness of organic farming and other sustainable practices must be evaluated within the broader context of regional needs, resource availability, and potential trade-offs to ensure that their implementation is both environmentally and economically sustainable [75, 77].

It is generally believed that the perception of climate risks has become a significant factor in agricultural commodity price developments, with the important implications for regulators and market investors [78].

The focus of sustainable farming harvesting practices consists in increasing resource efficiency, reducing waste, and preserving ecosystems. Advancements include precision farming, drone technology, and intelligent irrigation systems ensure optimal crop yield with minimal resource usage. Agriculture without pesticides (inorganic drugs) and mulching crops increases soil health, water retention, and biodiversity, promoting long-term and predictable crop yields [79].

Nowadays agriculture is embracing modern monitoring methods, artificial intelligence, and sensor data is revolutionizing precision agriculture, allowing farmers to collect real-time information, make informed decisions, and optimize resource use to increase productivity and sustainability [80].

A few examples of emerging technologies are: edge computing and artificial intelligence; robotics and automation; data integration and decision support systems; personalized and prescriptive agriculture; closed-loop systems and predictive analytics; biosensors; LiDAR and radar sensors; soil sensors; IoT and wireless sensor networks; and hyperspectral and multispectral imaging sensors. These technologies offer information about crop health, stress levels, nutritional deficits, and crop management techniques. Machine learning capabilities enable real-time analysis and field-level decision-making closer to the data source.

While these advancements offer significant benefits, they also come with challenges and potential disadvantages. High implementation and maintenance costs can be prohibitive for small-scale farmers, creating a technology gap and exacerbating inequalities in access. Dependence on digital tools increases vulnerability to cybersecurity threats, such as hacking or data breaches, which can compromise farm operations. Additionally, the reliance on IoT and wireless networks requires robust infrastructure that may not be available in rural or underdeveloped regions. Environmental concerns related to the production and disposal of electronic components, as well as the energy consumption of these systems, could also undermine the sustainability goals if not properly addressed.

The development of sensor technology will be essential to maintaining environmental sustainability and food security for coming generations. However, addressing these limitations will be critical to ensuring equitable and sustainable adoption of these technologies across diverse agricultural systems [80, 81].

Agricultural stability focuses on achieving consistent yields while maintaining ecosystem health. Climate change and resource depletion pose significant challenges, but approaches like agroecology, diversified cropping systems, and regenerative farming offer pathways to resilient agricultural systems. These practices not only enhance soil fertility but also protect crops from disease and extreme weather, ensuring long-term stability and food security [82]. Studies conducted at the European level reveal the need for integrated land-use planning, including diversification and sustainable use of agricultural inputs. Furthermore, climatic instability reduces the temporal stability of production, and the stabilizing effect of crop diversity seems to be higher in areas with high thermal instability [83].

In order to protect agriculture against new dangers like diseases, invasive species, and pests—threats that are made worse by climate change, biosecurity is becoming more and more crucial. Biosecurity is defined by FAO as "a strategic and integrated approach that encompasses the policy and regulatory frameworks (including instruments and activities) for analyzing and managing relevant risks to human, animal and plant life and health, and associated risks to the environment" (https://www.fao.org/one-health/areas-of-work/biosecurity/en). Genetic engineering, better pest management techniques, and surveillance technologies are examples of contemporary biosecurity approaches that help minimize dangers while lowering the need for dangerous chemicals. With a wide range of advantages, including increased crop resilience and a decreased need for chemical inputs, biotechnology has had a revolutionary impact. New developments in integrated pest management, biotechnology, and plant breeding offer vital resources for maintaining ecological balance and sustainable productivity [84].

5. Twenty-first century challenges in sustainable food processing in a dynamic business environment

Sustainability has become an essential component of numerous company and supply chain strategies. Corporate enterprises are intensifying their endeavors to include sustainable practices in their operational procedures [85].

The United Nations 2030 Agenda recognizes the crucial role of the private sector, primarily observed in major firms [86, 87]. However, to accomplish substantial transformation and maintain long-term objectives, small and medium enterprises (SMEs) need to adjust. Nevertheless, incorporating sustainable principles into organizations is a complicated endeavor, as the impact of legislation and recommendations on organizational behaviors is influenced by numerous factors [88–90].

Hence, it is imperative for research on business transformation to explicitly integrate intra- and inter-organizational practices and skills for sustainability by adopting a multilevel or even multisystem approach [89, 90].

Organizational and managerial attitudes, contextual factors, and resource limitations influence the adoption of sustainable strategies that integrate sustainability into a firm's business model, despite the presence of mandatory provisions and regulations [91–93].

In recent years, numerous scholars have initiated discussions on sustainable transformation in the food business due to its crucial role in attaining the Sustainable Development Goals (SDGs) [94, 95].

Although numerous companies in the food industry encounter challenges when attempting to achieve sustainable change, such as opposition from employees and

other stakeholders, practitioners must clearly understand dynamic capabilities by explaining relevant practices and their evolution over time. Implementing sustainability practices in the food industry aims to reduce the potential risks associated with food production and processing. These risks include issues related to hygiene, arable farming, seasonal supply (such as the availability of temporary labor), perishable goods, antibiotics and hormones, and packaging and labeling [96].

Enhancing the sustainability of processes and products in the food business will assist in mitigating risks and adapting to evolving consumer demands. Smith [97] examined the potential for food businesses operating inside food supply chains to promote investment in environmentally friendly production and distribution systems. The aim was to establish a connection between sustainable business practices and customer purchases, as well as social value. Furthermore, attaining elevated environmental and ethical benchmarks might potentially lead to gaining a competitive edge. Additionally, the knowledge and understanding acquired can be utilized to establish mutually advantageous collaborations with suppliers. Moreover, Smith [97] contended that fostering interpersonal trust and adhering to standards is crucial for the development of more sustainable local and conserved food supply chains. In his study, the researcher also determined that multi-stakeholder efforts, which involve collaboration between food corporations, farmers, academics, innovators, governments, and non-government organizations (NGOs), play a crucial role in improving the overall sustainability of food supply chains [97].

Nevertheless, Beske et al. [98] emphasized that the majority of dynamic capabilities employed to support specific practices are tailored to individual partnerships, to enhance interactions between the different entities to permit more changes. Therefore, acquiring a more profound comprehension of dynamic capabilities and their correlation with associated practices will assist organizations in the food processing sector to shift toward sustainability.

Prior research has recognized the interconnectedness between sustainable practices and dynamic capabilities. Studies conducted by Beske et al. [98], Hong et al. [99], and Mousavi et al. [100] have explored this relationship. However, the recent study by Gruchmann et al. [101] empirically validated the specific relationships in the food processing sector. For example, they found that improved communication capabilities contribute to the organizational integration practices, indicating the presence of iterative cycles within the implementation phases. The specific dynamic capabilities highlighted in their study are sensing, seizing opportunities and threats, reconfiguration, employee empowerment, relational capital building, and risk management. These interconnected capabilities are crucial in enabling food processing enterprises to achieve the sustainable change. To summarize, the Gruchmann et al. [101] paper suggests that food processing companies should improve their ability to adapt to change, involve their employees, establish strong relationships with stakeholders, implement sustainability standards carefully, embrace ongoing learning, and make decisions based on long-term data. Implementing these tactics can greatly facilitate the attainment of long-lasting transformation within the industry.

Venturelli et al.'s [102] study provides noteworthy contributions to the domains of open innovation (OI) and sustainability, with a specific focus on the food business. The paper presents the "4SOI (For Sustainable Open Innovation) Framework," which offers a systematic method for comprehending the integration of OI with the sustainability goals. Components of the 4SOI Framework refer to stakeholder engagement, long-term vision, multi-dimensional approach, cooperative projects, adaptation to global challenges, and integration of sustainable practices. This framework aims

to guide small- and medium-sized firms (SMEs) in the food industry to help them achieve sustainability goals through the use of innovative practices. The study emphasizes the significance of engaging stakeholders in the process of innovation. It shows that involving stakeholders in decision-making processes can result in the creation of novel and effective practices that have a favorable influence on business models. This discovery highlights the significance of cooperation in promoting enduring innovation.

Globally, the food industry faces the significant challenges in terms of production and food safety, carbon footprint, food waste, water consumption, and biodiversity impact in the twenty-first century [103]. In this regard, companies must adhere to innovative solutions to ensure the most sustainable food processing. One of the major challenges is implementing GFSI food safety schemes, reducing food waste, using nanotechnology in the food industry, and developing sustainable packaging.

The Global Food Safety Initiative (GFSI) has developed into an extensive, international multi-stakeholder collaboration that unites the important participants in the food industry to collectively promote ongoing improvements in food safety management systems (FSMS) and practices globally. To ensure safe food for consumers worldwide, professionals in the food industry established GFSI in 2000 to address the common challenges, particularly to minimize food safety hazards, eliminate redundant audits and expenses, and build confidence across the supply chain [104]. The GFSI recognized standards, including Global Gap, BRC, and IFS Food, encompass the fundamental characteristics that define the certification of the production process. Global Gap encompasses the main production activities, while IFS and BRC are designed for the management and regulation of production processes. FSSC22000 is a food safety management system that incorporates globally recognized and autonomous standards such as ISO22000, ISO9001, ISO/TS 22003, and sector-specific technical specifications for prerequisite programs (PRPs), such ISO/TS22002-1. Furthermore, alongside these standards, the FSSC scheme incorporates certain FSSC criteria known as FSSC Additional Requirements, which is included in the FSSC22000 scheme documents [103].

The food sector is crucial in the manufacturing, logistics, and consumption of food, and traditional methods have resulted in environmental issues including greenhouse gas emissions, deforestation, land clearance, and excessive water usage [105]. The concept of sustainability in the food sector encompasses economic feasibility, environmental conservation, and social fairness. To achieve this shift, it is necessary to collectively rethink manufacturing techniques, supply chain management, consumption trends, and the regulatory structure [103]. Through an analysis of the environmental consequences, social effects, economic factors, and technical advancements that influence the sector's dynamics, it becomes evident that there is a pressing need to synchronize industry operations with the sustainable principles, and this need is not simply a matter of personal preference, but also an ethical responsibility toward the planet [106].

Sustainability in the food business refers to a comprehensive framework that seeks to achieve a harmonious equilibrium between economic feasibility, environmental preservation, and social fairness across the entire food chain [103]. The conversion of by-products from the food industry (such as molasses, eggshells, and citrus peels) into the value-added products is an example of a sustainable, circular, economical, and safe approach to the food chain [107, 108]. A study by Fahmy et al. [109] mentions introducing molasses as a novel ingredient in papermaking, for the first time in history. The inclusion of molasses in papermaking resulted in a paper composition

with the extended breaking lengths and significantly increased water retention values compared to paper without molasses. Environmental management is the key aspect of sustainability in the food sector, primarily emphasizing decreasing greenhouse gas emissions, minimizing chemical usage, strengthening soil health, preserving water resources, and safeguarding biodiversity. This includes regenerative and ecological farming practices, sustainable land use management, and responsible management of waste [110].

Rabbi et al. [111] conducted a study that emphasized the potential of the circular economy for reshaping the food industry through adopting sustainable waste management strategies, supply chain optimization, and resource use to enhance the environmental sustainability. Furthermore, the study findings revealed that using circular economy approaches in the food sector can greatly decrease waste and enhance resource efficiency by converting food waste into high-value products, such as biogas and materials made from biomass. Agricultural wastes contain significant amounts of complex carbohydrates, proteins, fibers, polyphenolic components, bioactive chemicals, and other similar substances. Although organic chemical wastes constitute an environmental hazard, they have the potential to serve as a valuable raw resource in various agricultural, food, and healthcare products [112, 113]. Owing to their abundant nutrients, the agro-residues are not classified as waste; instead, they serve as a raw material to produce new goods. Optimizing pretreatment techniques for agro-waste biomass, considering its biochemical properties and implementing modern conversion methods can enhance the cost-efficiency of conversion operations to produce bioproducts. Microbial biotechnology and nanotechnology are crucial in converting agricultural waste into enzymes and other bioactive chemicals for use in the pharmaceutical industry, as well as in the production of vermicompost, organic fertilizers, biofuels, medicinal products, and some food-related goods [114–116]. Given its multiple possible uses, nanotechnology is being extensively investigated in the food and healthcare sectors. Owing to the improvements in the bioavailability and concentrations of bioactive substances, the ability to deliver bioactive substances to particular tissues or organs is also enhanced. The distinctive characteristics and extensive surface area of nanostructured materials can deeply transform the food industry, and although the considerable advantages of nanotechnology for society have been well acknowledged, the domain of food science has now started to examine its practical uses [117]. Nanoencapsulation is a technique that utilizes a matrix or inert substrate to retain coated matters, such as food, taste molecules or ingredients, in a liquid, solid, or gaseous state. The use of nanoencapsulation to stabilize the bioactive substances enables enhanced regulation of their release at physiologically active sites [118].

Environmental concerns about pollution from plastics, greenhouse gas emissions, and the decreasing number of natural resources are the driving forces behind the need for sustainable packaging. Biodegradable plastics, materials made from plants, and recycled materials are among the many sources from which sustainable food packaging materials can be derived. These materials have advantages such as decreased material waste, decreased carbon emissions, and the capacity to be reused or composted [119].

An investigation conducted by Mishra et al. [120] aimed to analyze the attributes, efficiency, and environmental implications of biodegradable nanomaterials employed in the sustainable packaging of food. The study demonstrated the enhanced mechanical properties of biodegradable nanocomposites, including tensile strength, elongation at break, and puncture resistance, in comparison with conventional packaging

materials. Barrier testing has shown that biodegradable nanoparticles are effective in providing the necessary barrier properties against water vapor, oxygen, and oil to preserve the quality of food and prolong its shelf life. Furthermore, biodegradation studies have emphasized the ecological feasibility of biodegradable nanomaterials, as they decompose into nontoxic compounds in the natural environments. The experimental findings validated that biodegradable nanoparticles can effectively tackle environmental concerns associated with the traditional packaging materials, while also satisfying the requirements for food packaging. Biodegradable nanoparticles present a feasible solution to enhance the sustainability of the food packaging industry by offering environmentally friendly alternatives that minimize the ecological consequences and promote the preservation of important resources.

To enhance the efficiency of recycling and composting, researchers are now developing novel materials and methods, including biodegradable and compostable polymers as well as plant-based materials. Another encouraging development is the utilization of biodegradable and sustainable materials, which includes cellulose, starch, and lignin, derived from agricultural waste or other agricultural byproducts. This mitigates the reliance on fossil fuels and virgin resources. Furthermore, the adoption of reusable and refillable packaging is becoming increasingly popular, particularly in the food service sector, as it has the potential to tremendously decrease the environmental waste and expenses. The future also presents opportunities for innovative materials that embody intelligence and interactivity, such as sensors capable of detecting spoilage of food, prolonging shelf life, or enhancing freshness, thereby mitigating food waste and advancing food safety [119].

6. Conclusion

In a constantly changing world, ensuring food safety and agricultural sustainability is becoming a major challenge. Factors such as climate change, population growth, and the globalization of supply chains require the implementation of innovative solutions and coherent policies to protect the integrity of food products. By promoting a strong food safety culture, using advanced technologies and adopting sustainable agricultural practices, the food industry can reduce the risks associated with contamination, food fraud and food insecurity. At the same time, the development of local food chains and the implementation of efficient resource management strategies can contribute to an equitable distribution of food and reduce waste. The future of food safety depends on the collaboration between authorities, producers and consumers, as well as on the integration of protective measures to guarantee access to safe and nutritious food for all.

DOI: http://dx.doi.org/10.5772/intechopen.1014033

Author details

Marc Romina Alina[1*], Crina Carmen Mureșan[1], Anamaria Pop[1], Georgiana Smaranda Marțiș[1], Alina Narcisa Postolache[2], Florina Stoica[3], Ioana Cristina Crivei[2], Ionuț-Dumitru Velescu[2] and Roxana Nicoleta Rațu[2]

1 Faculty of Food Science and Technology, Food Engineering Department, University of Agricultural Science and Veterinary Medicine Cluj-Napoca, Cluj-Napoca, Romania

2 Faculty of Agriculture, Department of Food Technology, "Ion Ionescu de la Brad" University of Life Sciences, Iasi, Romania

3 Faculty of Agriculture, Department of Pedotechnics, "Ion Ionescu de la Brad" University of Life Sciences, Iasi, Romania

*Address all correspondence to: romina.vlaic@usamvcluj.ro

IntechOpen

References

[1] Legwegoh AF, Fraser EDG. Food crisis or chronic poverty: Metanarratives of food insecurity in sub-Saharan Africa. Journal of Hunger & Environmental Nutrition. 2015;**10**(3):313-342

[2] Li J, Song W. Food security review based on bibliometrics from 1991 to 2021. Foods. 2022;**11**(23):3915

[3] de Souza Ferreira Filho JB, Horridge M. Land use change, ethanol production expansion and food security in Brazil. In: Khanna M, Zilberman D, editors. Handbook of Bioenergy Economics and Policy: Volume II: Modeling Land Use and Greenhouse Gas Implications. New York, NY: Springer; 2017. pp. 303-320

[4] Guo Z, Hu Y, Zheng X. Evaluating the effectiveness of land use master plans in built-up land management: A case study of the Jinan municipality, eastern China. Land Use Policy. 2020;**91**:104369

[5] Coates J. Build it back better: Deconstructing food security for improved measurement and action. Global Food Security. 2013;**2**(3):188-194

[6] Kyrgiakos LS et al. The food fraud landscape: A brief review of food safety and authenticity. In: The 17th International Conference of the Hellenic Association of Agricultural Economists. Basel, Switzerland: MDPI; 2024

[7] Visciano P, Schirone M. Food frauds: Global incidents and misleading situations. Trends in Food Science & Technology. 2021;**114**:424-442

[8] Zanin LM, Stedefeldt E, Luning PA. The evolvement of food safety culture assessment: A mixed-methods systematic review. Trends in Food Science & Technology. 2021;**118**:125-142

[9] Kamboj S et al. Food safety and hygiene: A review. International Journal of Chemical Studies. 2020;**8**(2):358-368

[10] Kotsanopoulos KV, Arvanitoyannis IS. The role of auditing, food safety, and food quality standards in the food industry: A review. Comprehensive Reviews in Food Science and Food Safety. 2017;**16**(5):760-775

[11] Trienekens J, Zuurbier P. Quality and safety standards in the food industry, developments and challenges. International Journal of Production Economics. 2008;**113**(1):107-122

[12] Varzakas TH, Arvanitoyannis IS. Application of ISO22000 and comparison to HACCP for processing of ready to eat vegetables: Part I. International Journal of Food Science and Technology. 2008;**43**(10):1729-1741

[13] Insfran-Rivarola A et al. A systematic review and meta-analysis of the effects of food safety and hygiene training on food handlers. Foods. 2020;**9**(9):1169

[14] Seaman P. Food hygiene training: Introducing the food hygiene training model. Food Control. 2010;**21**(4):381-387

[15] Mohammad ZH et al. Food safety challenges and barriers in southern United States farmers markets. Foods. 2019;**9**(1):12

[16] Aggarwal P et al. How much does climate change add to the challenge of feeding the planet this century? Environmental Research Letters. 2019;**14**(4):043001

[17] Man, Li ZG, Zhang W. Balancing food security and environmental sustainability through seasonal crop allocation in Bangladesh. In: Selected Poster Prepared for Presentation at the 2020 Agricultural & Applied Economics Association Annual Meeting (Virtual) August 10-11, 2020. Milwaukee, WI, USA: Agricultural and Applied Economics Association (AAEA); 2020

[18] Mekonnen MM, W. Gerbens-Leenes the water footprint of global food production. Water. 2020;**12**(10):2696. DOI: 10.3390/w12102696

[19] Cansino-Loeza B, Munguía-López ADC, Ponce-Ortega JM. A water-energy-food security nexus framework based on optimal resource allocation. Environmental Science & Policy. 2022;**133**:1-16

[20] Jones AD, Fink Shapiro L, Wilson ML. Assessing the potential and limitations of leveraging food sovereignty to improve human health. Frontiers in Public Health. 2015;**3**:263

[21] Lucantoni D. Transition to agroecology for improved food security and better living conditions: Case study from a family farm in Pinar del Río, Cuba. Agroecology and Sustainable Food Systems. 2020;**44**(9):1124-1161

[22] Vasileiou M et al. Transforming weed management in sustainable agriculture with artificial intelligence: A systematic literature review towards weed identification and deep learning. Crop Protection. 2024;**176**:106522

[23] Marvin HJP et al. Global media as an early warning tool for food fraud; an assessment of MedISys-FF. Food Control. 2022;**137**:108961

[24] Ulberth F. Tools to combat food fraud - a gap analysis. Food Chemistry. 2020;**330**:127044

[25] Robson K et al. A comprehensive review of food fraud terminologies and food fraud mitigation guides. Food Control. 2021;**120**:107516

[26] Bouzembrak Y et al. Development of food fraud media monitoring system based on text mining. Food Control. 2018;**93**:283-296

[27] Spagnoli P et al. The relationship between food safety culture maturity and cost of quality: An empirical pilot study in the food industry. Foods. 2024;**13**(4):571

[28] Nyarugwe SP et al. Determinants for conducting food safety culture research. Trends in Food Science & Technology. 2016;**56**:77-87

[29] Ogot N. Chapter 7 - metrics for identifying food security status. In: Galanakis CM, editor. Food Security and Nutrition. London, UK: Academic Press; 2021. pp. 147-179

[30] Avermaete T et al. Chapter 71 - food and nutrition security: Challenges for farming, procurement, and consumption. In: Knowles ME et al., editors. Present Knowledge in Food Safety. London, UK: Academic Press; 2023. pp. 1100-1112

[31] Nitzko S, Spiller A. Comparing "leaf-to-root", "nose-to-tail" and other efficient food utilization options from a consumer perspective. Sustainability. 2019;**11**(17):4779. DOI: 10.3390/su11174779

[32] Rahimov N. The role of global trends in stimulating food production. Acta Universitatis Danubius Economica. 2024;**20**(3/2024):7-14

[33] Mc Carthy U et al. Global food security – Issues, challenges and technological solutions. Trends in Food Science & Technology. 2018;**77**:11-20

[34] Galanakis CM. The future of food. Food. 2024;**13**(4):506

[35] Group W.B. Food Security Update. The Bank's Response to Rising Food Insecurity. Washington, DC, USA: World Bank; 2024. Available from: https://www.worldbank.org/en/topic/agriculture/brief/food-security-update

[36] Gomez-Zavaglia A, Mejuto JC, Simal-Gandara J. Mitigation of emerging implications of climate change on food production systems. Food Research International. 2020;**134**:109256

[37] Karunathilake EMBM et al. The path to smart farming: Innovations and opportunities in precision agriculture. Agriculture. 2023;**13**(8):1593

[38] Smith VH, Glauber JW. Trade, policy, and food security. Agricultural Economics. 2020;**51**(1):159-171

[39] Fan S, Brzeska J. Sustainable food security and nutrition: Demystifying conventional beliefs. Global Food Security. 2016;**11**:11-16

[40] Campi M, Dueñas M, Fagiolo G. Specialization in food production affects global food security and food systems sustainability. World Development. 2021;**141**:105411

[41] Lopez Barrera E, Hertel T. Global food waste across the income spectrum: Implications for food prices, production and resource use. Food Policy. 2021;**98**:101874

[42] Sanders R. Dynamic pricing and organic waste bans: A study of grocery retailers' incentives to reduce food waste. Marketing Science. 2023;**43**(2):289-316

[43] Campomanes F, Marshall M, Nelson A. A method for estimating physical and economic food access at high spatial resolution. Food Security. 2024;**16**(1):47-64

[44] Bondemark A. The relationship between accessibility and price – The case of Swedish food stores. Journal of Transport Geography. 2020;**82**:102615

[45] Wudad A, Naser S, Lameso L. The impact of improved road networks on marketing of vegetables and households' income in Dedo district, Oromia regional state, Ethiopia. Heliyon. 2021;**7**(10):e08173

[46] Cattaneo A, Nelson A, McMenomy T. Global mapping of urban-rural catchment areas reveals unequal access to services. Proceedings of the National Academy of Sciences of the United States of America. 2021;**118**(2):e2011990118

[47] Garcia X, Garcia-Sierra M, Domene E. Spatial inequality and its relationship with local food environments: The case of Barcelona. Applied Geography. 2020;**115**:102140

[48] Salima W et al. The impact of credit access on household food security in Malawi. Journal of Agriculture and Food Research. 2023;**11**:100490

[49] Clapp J et al. Viewpoint: The case for a six-dimensional food security framework. Food Policy. 2022;**106**:102164

[50] De Schutter O, Jacobs N, Clément C. A 'common food policy' for Europe: How governance reforms can spark a shift to healthy diets and sustainable food systems. Food Policy. 2020;**96**:101849

[51] Candel JJL, Biesbroek R. Policy integration in the EU governance of global food security. Food Security. 2018;**10**(1):195-209

[52] Blesh J et al. Development pathways toward "zero hunger". World Development. 2019;**118**:1-14

[53] Biermann F et al. The sustainable development goals as a transformative force?: Key insights. In: Biermann F, Hickmann T, Sénit C-A, editors. The Political Impact of the Sustainable Development Goals: Transforming Governance through Global Goals? Cambridge: Cambridge University Press; 2022. pp. 204-226

[54] Sorooshian S. The sustainable development goals of the United Nations: A comparative midterm research review. Journal of Cleaner Production. 2024;**453**:142272

[55] Team O.W.I.D. End Hunger, Achieve Food Security and Improved Nutrition and Promote Sustainable Agriculture. Oxford, UK: Our World in Data, Global Change Data Lab; 2023. Available from: https://ourworldindata.org/sdgs/zero-hunger

[56] United Nations Conference on Trade and Development (UNCTAD). The Role of Science, Technology and Innovation in Ensuring Food Security by 2030. Geneva, Switzerland: UNCTAD; 2017

[57] Fanzo J et al. Sustainable food systems and nutrition in the 21st century: A report from the 22nd annual Harvard nutrition obesity symposium. The American Journal of Clinical Nutrition. 2022;**115**(1):18-33

[58] Chauhan C et al. Food loss and waste in food supply chains. A systematic literature review and framework development approach. Journal of Cleaner Production. 2021;**295**:126438

[59] Vizzoto F, Testa F, Iraldo F. Strategies to reduce food waste in the foodservices sector: A systematic review. International Journal of Hospitality Management. 2021;**95**:102933

[60] Mokrane S et al. Exploring the global scientific literature on food waste and loss. Sustainability. 2023;**15**(6):4757

[61] Manzoor S et al. Sustainable development goals through reducing food loss and food waste: A comprehensive review. Future Foods. 2024;**9**:100362

[62] Garrity K et al. Local food system approaches to address food and nutrition security among low-income populations: A systematic review. Advances in Nutrition. 2024;**15**(4):100156

[63] Bezuneh M, Yiheyis Z. Household food insecurity, coping strategies, and happiness: The case of two public housing communities. Journal of Agriculture, Food Systems, and Community Development. 2020;**9**(3):215-226

[64] Savoie-Roskos M et al. Reducing food insecurity and improving fruit and vegetable intake among farmers' market incentive program participants. Journal of Nutrition Education and Behavior. 2016;**48**(1):70-76.e1

[65] Enthoven L, Van den Broeck G. Local food systems: Reviewing two decades of research. Agricultural Systems. 2021;**193**:103226

[66] Brunori G et al. Are local food chains more sustainable than global food chains? Considerations for Assessment. 2016;**8**(5):449

[67] Ahearn M, Liang K, Goetz S. Farm business financial performance in local foods value chains. Agricultural Finance Review. 2018;**78**(4):470-488

[68] Clark-Barol M, Gaddis JE, Barrett CK. Food agency in low-income households: A qualitative study of the structural and individual factors impacting participants in a community-based nutrition program. Appetite. 2021;**158**:105013

[69] Adalja A et al. An examination of consumer willingness to pay for local products. Agricultural and Resource Economics Review. 2015;**44**(3):253-274

[70] Bauman A, Thilmany D, Jablonski BBR. Evaluating scale and technical efficiency among farms and ranches with a local market orientation. Renewable Agriculture and Food Systems. 2019;**34**(3):198-206

[71] Calloway EE et al. Development of new measures to assess household nutrition security, and choice in dietary characteristics. Appetite. 2022;**179**:106288

[72] Zerbian T et al. The role of local authorities in shaping local food systems. Sustainability. 2022:**14**

[73] Barbosa MW. Government support mechanisms for sustainable agriculture: A systematic literature review and future research agenda. Sustainability. 2024;**16**(5):2185

[74] Rosli MN et al. Navigating the environmental, economic and social impacts of sustainable agriculture and food systems: A review. Frontiers of Agricultural Science and Engineering. 2024;**11**:652-673

[75] Telo da Gama J. The role of soils in sustainability, climate change, and ecosystem services. Challenges and Opportunities. 2023;**4**(3):552-567

[76] Bennetzen EH, Smith P, Porter JR. Agricultural production and greenhouse gas emissions from world regions—The major trends over 40 years. Global Environmental Change. 2016;**37**:43-55

[77] Pretty J et al. Global assessment of agricultural system redesign for sustainable intensification. Nature Sustainability. 2018:**1**

[78] Guo K et al. How are climate risk shocks connected to agricultural markets? Journal of Commodity Markets. 2023;**32**:100367

[79] Garcia-Garcia G, Stone J, Rahimifard S. Opportunities for waste valorisation in the food industry – A case study with four UK food manufacturers. Journal of Cleaner Production. 2019;**211**:1339-1356

[80] Kumar V et al. A comprehensive review on smart and sustainable agriculture using IoT technologies. Smart Agricultural Technology. 2024;**8**:100487

[81] Shahab H et al. IoT-based agriculture management techniques for sustainable farming: A comprehensive review. Computers and Electronics in Agriculture. 2024;**220**:108851

[82] Muhie SH. Novel approaches and practices to sustainable agriculture. Journal of Agriculture and Food Research. 2022;**10**:100446

[83] Egli L et al. Crop diversity effects on temporal agricultural production stability across European regions. Regional Environmental Change. 2021;**21**(4):96

[84] Dönmez D et al. Green horizons: Navigating the future of agriculture through sustainable practices. Sustainability. 2024;**16**(8):3505

[85] Chowdhury MMH, Agarwal R, Quaddus M. Dynamic capabilities for

meeting stakeholders' sustainability requirements in supply chain. Journal of Cleaner Production. 2019;**215**:34-45

[86] Scheyvens R, Banks G, Hughes E. The private sector and the SDGs: The need to move beyond 'business as usual'. Sustainable Development. 2016;**24**(6):371-382

[87] United Nations. Transforming our World: The Agenda 2030 for Sustainable Development. New York, NY, USA: United Nations; 2015

[88] Bartolacci F, Caputo A, Soverchia M. Sustainability and financial performance of small and medium sized enterprises: A bibliometric and systematic literature review. Business Strategy and the Environment. 2020;**29**(3):1297-1309

[89] Pizzi S, Corbo L, Caputo A. Fintech and SMEs sustainable business models: Reflections and considerations for a circular economy. Journal of Cleaner Production. 2021;**281**:125217

[90] Pizzi S, Leopizzi R, Caputo A. The enablers in the relationship between entrepreneurial ecosystems and the circular economy: The case of circularity. com. Management of Environmental Quality An International Journal. 2021;**33**:26-43

[91] Alassaf D et al. The impact of open-border organization culture and employees' knowledge, attitudes, and rewards with regards to open innovation: An empirical study. Journal of Knowledge Management. 2020;**24**:2273-2297

[92] Schaltegger S, Hansen E, Lüdeke-Freund F. Business models for sustainability: Origins, present research, and future avenues. Organization & Environment. 2016;**29**:3-10

[93] Schaltegger S, Lüdeke-Freund F, Hansen E. Business models for sustainability. A co-evolutionary analysis of sustainable entrepreneurship, innovation and transformation. Organization & Environment. 2016;**29**:264-289

[94] FAO. Tracking Progress on Food and Agriculture-Related SDG Indicators. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO); 2020

[95] Jouzdani J, Govindan K. On the sustainable perishable food supply chain network design: A dairy products case to achieve sustainable development goals. Journal of Cleaner Production. 2021;**278**:123060

[96] Spence L, Bourlakis M. The evolution from corporate social responsibility to supply chain responsibility: The case of waitrose. Supply Chain Management: An International Journal. 2009:**14**

[97] Smith BG. Developing sustainable food supply chains. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences. 2008;**363**(1492):849-861

[98] Beske P, Land A, Seuring S. Sustainable supply chain management practices and dynamic capabilities in the food industry: A critical analysis of the literature. International Journal of Production Economics. 2014;**152**: 131-143

[99] Hong J, Zhang Y, Ding M. Sustainable supply chain management practices, supply chain dynamic capabilities, and enterprise performance. Journal of Cleaner Production. 2018;**172**:3508-3519

[100] Mousavi S, Bossink B, van Vliet M. Dynamic capabilities and organizational routines for managing innovation towards sustainability. Journal of Cleaner Production. 2018;**203**:224-239

[101] Gruchmann T et al. Dynamic capabilities for sustainable change in the food processing industry: A multilevel perspective. Journal of Cleaner Production. 2021;**311**:127534

[102] Venturelli A et al. A dynamic framework for sustainable open innovation in the food industry. British Food Journal. 2022;**124**:1895-1911

[103] Prasanna S, Verma P, Bodh S. The role of food industries in sustainability transition: A review. Environment, Development and Sustainability. 2024;**27**:15113-15133

[104] Gerardi A. Chapter 70 - global food safety initiative (GFSI): Underpinning the safety of the global food chain, facilitating regulatory compliance, trade, and consumer trust. In: Knowles ME et al., editors. Present Knowledge in Food Safety. London, UK: Academic Press; 2023. pp. 1089-1098

[105] Rejeb A et al. Blockchain technology in the food industry: A review of potentials. Challenges and Future Research Directions. 2020;**4**(4):27

[106] Lau JD et al. Morals and climate decision-making: Insights from social and behavioural sciences. Current Opinion in Environmental Sustainability. 2021;**52**:27-35

[107] Fahmy T. Introducing molasses as a new additive in papermaking. Tappi Journal. 2007;**6**:23-25

[108] Abouzeid R et al. Preparation and properties of novel biocompatible pectin/silica calcium phosphate hybrids. Cellulose Chemistry and Technology. 2022;**56**:371-378

[109] Fahmy T. Molasses as a new additive in papermaking: For bagasse and kaolin filled bagasse pulps. Professional Papermaking. 2017;**14**:26-29

[110] Giller K et al. Regenerative Agriculture: An agronomic perspective. Outlook on Agriculture. 2021;**50**(1):13-25

[111] Rabbi MF, Amin MB. Circular economy and sustainable practices in the food industry: A comprehensive bibliometric analysis. Cleaner and Responsible Consumption. 2024;**14**:100206

[112] Chojnacka K et al. Recovery of fertilizer nutrients from materials - contradictions, mistakes and future trends. Renewable and Sustainable Energy Reviews. 2019;**110**:485-498

[113] Dwivedi S et al. Agro-wastes for cost effective production of industrially important microbial enzymes. Microbial Biotechnology: Role in Ecological Sustainability and Research. 2022:435-460

[114] Reshmy R et al. Lignocellulose in future biorefineries: Strategies for cost-effective production of biomaterials and bioenergy. Bioresource Technology. 2022;**344**:126241

[115] Bala S et al. Nanomaterials based sustainable bioenergy production systems: Current trends and future prospects. Nano. 2022;**7**:1-11

[116] Gupta VK et al. Microbes in valorisation of biomass to value-added products. Bioresource Technology. 2022;**347**:126738

[117] Kim DY et al. Recent developments in nanotechnology transforming the agricultural sector: A transition replete with opportunities. Journal of the Science of Food and Agriculture. 2018;**98**(3):849-864

[118] Pateiro M et al. Nanoencapsulation of promising bioactive compounds to improve their absorption, stability, functionality and the appearance of the final food products. Molecules. 2021;**26**(6):1547

[119] Hussain S, Akhter R, Maktedar S. Advancements in sustainable food packaging: From eco-friendly materials to innovative technologies. Sustainable Food Technology. 2024;**2**:1297-1364

[120] Mishra M et al. Biodegradable nanomaterials for sustainable food packaging applications. E3S Web of Conferences. 2024:**547**