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Agricultural Product Quality and Safety Enhancement, Value Addition, and Market Linkages

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Agricultural Product Quality and Safety Enhancement, Value Addition, and Market Linkages - A Guidance Manual

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Foreword

The food processing industry plays a pivotal role in global food security, economic development, and public health. Small and medium-sized enterprises (SMEs) have become essential drivers of innovation, growth, and sustainability within this sector. However, SMEs often face unique challenges in maintaining high standards of food quality and safety, particularly when balancing cost-efficiency with the implementation of stringent safety protocols. This report, "Food Quality and Safety Enhancement and Value Addition in Small and Medium Enterprises," explores critical strategies for improving food safety practices, enhancing product quality, and adding value to agricultural products within the SME context. As consumer demands for safe, nutritious, and high-quality food continue to rise, SMEs must be equipped with the necessary tools and knowledge to meet these expectations. The adoption of robust food safety practices is no longer optional—it is a fundamental requirement for gaining consumer trust, maintaining market access, and meeting regulatory standards. In this report, we delve into key principles such as Hazard Analysis and Critical Control Points (HACCP), Good Manufacturing Practices (GMP), and other safety management systems that can help SMEs minimize risks and enhance the safety and integrity of their food products.

Moreover, value addition presents a powerful opportunity for SMEs to diversify their product offerings, increase profitability, and reduce waste. By transforming raw agricultural products into higher-value processed foods, SMEs can tap into new markets, extend product shelf life, and contribute to sustainable food systems. The report highlights innovative processing techniques, such as fermentation, drying, and fortification, alongside packaging strategies that preserve product quality and appeal to increasingly conscious consumers. The importance of training and capacity-building within SMEs cannot be overstated. Empowering employees with the knowledge and skills to follow food safety protocols, recognize hazards, and engage in value-added processing techniques is essential for the success and growth of small and medium enterprises. A well-trained workforce not only ensures food safety compliance but also fosters a culture of continuous improvement and innovation within the business. This report is intended as a comprehensive resource for SMEs in the food processing industry, offering insights into best practices, innovative solutions, and actionable recommendations for improving food quality, safety, and value addition. By adopting the strategies outlined in this report, SMEs can overcome challenges, meet market demands, and contribute to a safer, more sustainable global food system.

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Abbreviations

ADB	Asian Development Bank
AIT	Asian Institute of Technology
CAC	Codex Alimentarius Commission
CC	Climate Change
CCPs	Critical Control Points
CDC	Centers for Disease Control and Prevention
CPO	Certification Process Owner
DMS	Department of Medical Sciences
EFSA	European Food Safety Authority
EHEDG	European Hygienic Engineering & Design Group
ERS	Economic Research Service
FAO	Food and Agriculture Organization
FDA	Food and Drug Administration
FSIS	Food Safety and Inspection Service
FSMA	Food Safety Modernization Act
GFSI	The Global Food Safety Initiative
GHP	Good Hygiene Practices
GMOs	Genetically Modified Organisms
GMP	Good Manufacturing Practices
GTIN	Global Trade Item Number
HACCP	Hazard Analysis Critical Control Point (HACCP)
HD	Hygienic Design
HPP	High-pressure Processing
LAB	Lactic acid bacteria
MAP	Modified Atmosphere Packaging
MOPH	Ministry of Public Health
O3	Ozone
OHS	Occupational Health and Safety
PCR	Post-consumer Recycled
PEF	Pulsed Electric Field
PPE	Personal Protective Equipment

PRPs	Prerequisite Programs
QFD	Quality Function Deployment
R&D	Research and Development
RFID	Radio Frequency Identification
SFBs	Small Food Businesses
SMEs	Small and Medium-sized Enterprises
SPS	Sanitary and Phytosanitary
TFDA	Thai Food and Drug Administration
TPM	Total Productive Maintenance
UHT	Ultra-High-Temperature
USDA	U.S. Department of Agriculture
UV	Ultraviolet
WHO	World Health Organization
WTO	World Trade Organization' s

1. Food Quality and Safety Enhancement

1.1 Introduction

Food safety is a fundamental aspect of public health and essential for ensuring the integrity of the food supply. The importance of robust food safety standards cannot be overstated, as many countries face significant challenges in establishing and enforcing adequate microbiological criteria for food products. Ineffective enforcement mechanisms and insufficient consumer education on food hygiene exacerbate these issues, particularly in nations where hygiene practices are lacking. To implement and uphold effective safety standards, governments must allocate appropriate resources, strengthen regulatory frameworks, and foster international cooperation to facilitate the sharing of best practices. Developing nations encounter numerous barriers, such as inadequate infrastructure, limited financial resources, and a fundamental lack of knowledge about food safety practices (FDA et al., 2003). However, the implementation of food safety standards can significantly reduce the incidence of foodborne illnesses, enhance the quality of life for consumers, and provide access to international markets. In developed countries, the adoption of these standards is equally vital as it bolsters consumer confidence and promotes trade while also aiming to lower the prevalence of foodborne diseases. This report focuses on the global landscape of food quality, safety, and value addition, examining the complexities of implementing food safety standards across different contexts (Grace, 2015b; Powell et al., 2011). Key areas of analysis will include the effectiveness of Hazard Analysis Critical Control Point (HACCP) systems, the adherence to microbiological criteria, the importance of good manufacturing practices (GMP) and good hygiene practices (GHP), and the overall impact on public health and trade. By identifying both successful strategies and ongoing challenges, this report will highlight the crucial need for a comprehensive approach to food safety that addresses socio-economic, environmental, and regulatory factors influencing food operations worldwide (Mendis & Rajapakse, 2009; Okpala & Korzeniowska, 2023; Owusu-Apenten & Vieira, 2022).

Many countries lack comprehensive microbiological standards for food products, and even when such standards exist, they are often not properly enforced. Hygiene is a critical element of food safety, but in many regions, there is insufficient public education about food hygiene practices. To ensure that food safety regulations are effectively implemented and enforced, governments need to allocate sufficient resources, strengthen their regulatory systems, and encourage international cooperation to share information and best practices (Hutter, 2011; Odipe et al., 2019). Developing countries face several challenges in implementing food safety standards, such as poor infrastructure, limited financial resources, and a lack of knowledge about basic food safety principles. Key recommendations for addressing these challenges include allocating more funding for food safety enforcement, strengthening regulatory frameworks, training personnel, raising consumer awareness about hygiene and safety, and fostering international collaboration. In developing nations, implementing robust food safety standards can help reduce the incidence of foodborne illnesses, improve public health, and facilitate access to international export markets. Similarly, in industrialized countries, effective food safety standards can decrease the prevalence of infectious diseases, enhance consumer confidence, and promote international trade(S. Forsythe, 2012; Patil et al., 2005).

While many countries have made progress in implementing food safety standards, challenges persist. These challenges include the inconsistent application of Hazard Analysis and Critical Control Points (HACCP) systems and microbiological criteria. This study examined the global adoption of food safety standards, focusing on six key areas: food standards, HACCP, prerequisite programs, microbiological criteria, food hygiene, and process controls. The findings indicate that while food safety standards have been implemented in many countries, the quality of implementation and enforcement varies widely (Bacs et al., 2007; Kamboj et al., 2020). HACCP is widely recognized as a vital part of food safety, but the shortage of trained personnel remains a significant barrier to its effective use. Hygiene and process controls are also critical to ensuring food safety. The adoption of food safety standards helps reduce the risk of infectious diseases, improve product quality, enhance consumer trust, and open access to global markets. Governments are encouraged to invest in the implementation and enforcement of these standards, strengthen their regulatory frameworks, and train qualified personnel to uphold food safety protocols. Food safety standards, which include a set of rules and guidelines, are essential for ensuring that food products are safe for human consumption (Kotsanopoulos & Arvanitoyannis, 2017; Webb, 2015).

Developing nations face significant challenges when it comes to food safety, including poor infrastructure, lack of clean water, inadequate sanitation facilities, and limited financial resources (Grace, 2015a). Despite these obstacles, implementing food safety standards in these countries can help reduce the incidence of foodborne illnesses, improve the population's overall health, and increase access to international export markets (Buzby & Roberts, 2009). On the other hand, developed nations also encounter their own set of challenges, such as complex regulatory frameworks and constrained resources. However, when food safety standards are effectively implemented in developed countries, they can boost consumer confidence, facilitate international trade, and reduce the occurrence of infectious diseases. Over the past 30 years, the structure of agricultural trade in developing countries has shifted, with unprocessed food exports declining and processed food exports increasing. Processed food products from developing countries are primarily exported to developed nations, but access to these markets presents significant challenges. One key challenge is that many developing countries struggle to meet the increasingly stringent food safety regulations imposed by developed nations (Briones & Felipe, 2013; Jongwanich, 2009).

In recent years, concerns about food safety have expanded beyond the domains of food toxicology and microbiology to include economists and social scientists, who are examining the broader socio-economic implications of food safety. These concerns are driven by the real and growing incidence of foodborne illnesses globally, as well as consumer apprehension about the safety of the food they consume (Silbergeld et al., 2008). This anxiety is particularly pronounced in industrialized countries, where media coverage often amplifies fears about food safety. Another important aspect of food safety concerns is how regulations impact global trade in food and agricultural products (Adinolfi et al., 2016). While the incidence of foodborne diseases is significant in both industrialized and developing countries, the nature of the problem differs in each context. This article highlights these differences and similarities, with a primary focus on the economics of food safety in developing countries. In industrialized nations, food supplies are generally considered safe, but foodborne illnesses remain a prevalent issue. For instance, more than 40 different pathogens are known to cause foodborne illnesses. Although major outbreaks are relatively rare, incidents involving contaminated meat, dairy products, salads, or canned goods still occur, and when they do, they raise consumer concerns. Even though only a small number of consumers may be directly affected by these incidents, high-profile food safety scares can lead to widespread fear and anxiety through a process known as "social amplification," where concerns about food safety become magnified in public discourse. In developing countries, the prevalence of foodborne illnesses is high, but reliable data to track trends or pinpoint the specific causes is often scarce. In many of these countries, foodborne diseases are closely tied to broader issues of economic underdevelopment and limited capacity to monitor and ensure the safety of the food supply. Furthermore, food safety is not isolated from other environmental health challenges, such as inadequate sanitation, poor water quality, and substandard housing, all of which can exacerbate the risk of foodborne illnesses (Akhtar et al., 2014; Grace, 2015b; Käferstein, 2003; Newell et al., 2010).

Food safety regulations and legislation have long been shaped by a multitude of factors, including socioeconomic pressures, consumer demands, political dynamics, and legal considerations (Lang et al., 2009). At the dawn of the 20th century, several critical food safety issues emerged that galvanized public awareness. The horrific sanitation conditions in the meatpacking industry, brought to light by Upton Sinclair's *The Jungle*, were instrumental in the passage of the pivotal Federal Meat Inspection Act of 1906 (Demme, 2023). Similarly, widespread food adulteration—where hazardous chemicals were added to food, along with the proliferation of fraudulent and potentially dangerous remedies—spurred the enactment of the Pure Food and Drug Act in the same year. Fast forward to the 21st century, and food safety remains as urgent and paramount as it was more than a century ago (Uzdavines, 2017). Public concern continues to rise, particularly in response to high-profile foodborne illness outbreaks linked to pathogens such as *Salmonella*, *Escherichia coli* O157:H7, *Listeria monocytogenes*, and others. These pathogens pose significant risks, causing both immediate acute health issues and potentially long-term chronic complications, particularly for vulnerable populations, including the elderly, children, and immunocompromised individuals (Bolten et al., 2023). Moreover, outbreaks are now occurring in foods that were previously considered low risk, such as fruit juices, fresh produce, and deli meats. The Sanitary and Phytosanitary (SPS) Agreement, along with the World Trade Organization's (WTO) dispute resolution mechanism, provides a framework to ensure that food safety standards are not exploited as a form of protectionism (Gruszczynski & Scott, 2023). Although these standards are subject to frequent revisions, reflecting the ongoing advancements in scientific understanding of health hazards and improvements in food processing technology such changes are both inevitable and necessary. In fact, the implementation of stringent food safety standards can enhance market efficiency by lowering transaction costs and reducing trade frictions (Jongwanich, 2009; Sun et al., 2021; Unnevehr & others, 2003). These standards offer exporters a clear benchmark for meeting the expectations of importers regarding food quality and safety. However, in practice, there is growing concern that food safety standards are sometimes used as non-transparent, trade-restricting tools, rather than as genuine instruments designed to safeguard human, plant, and animal health. Developing countries face significant challenges in navigating these evolving standards. Their limited access to cutting-edge technology and expertise, coupled with inadequate resources, often places them at a disadvantage. Furthermore, perceived inequities in the global food safety system exacerbate these difficulties, making it harder for these nations to effectively implement and comply with international food safety requirements (P.-C. Athukorala & Jayasuriya, 2003; P. Athukorala & Jayasuriya, 2005).

1.2 Food safety and value addition enhance agricultural products, increasing economic possibilities.

Food safety is a complex and multifaceted issue. Despite years of educational campaigns, public health initiatives, and advances in microbiological research, foodborne illnesses continue to be a major source of human disease (Quinlan, 2013; Soon et al., 2011). Recent food safety incidents have drawn significant attention, leading to public confusion and diminished trust in both the food industry and regulators (Hallman, Cuite, & Hooker, 2009b, 2009a). One notable case occurred nearly two decades ago, when an outbreak of *Escherichia coli* O157:H7 in hamburgers from the Jack-in-the-Box fast-food chain in the U.S. led to four deaths and hundreds of illnesses, placing microbial food safety squarely in the public eye. Despite this heightened awareness, convincing food producers, processors, retailers, food service operators, and even home cooks to consistently adopt scientifically validated food safety practices remains an ongoing challenge, particularly when no outbreak is imminent. The concept of a "food safety culture" is still emerging, and effective ways to cultivate and sustain this culture across the entire food supply chain-spanning farms, processing facilities, distribution networks, retail, restaurants, and households are yet to be fully explored (Hallman, Cuite, Nucci, et al., 2009; Hallman & Cuite, 2009; Kinsey et al., 2009).

The idea of "safe food" can mean different things to different groups, with varying definitions depending on one's perspective (Behrens et al., 2015). Consumers, regulatory bodies, industry professionals, special interest groups, and academics all approach the concept of food safety from unique angles. Much of the information the public receives about food safety is mediated through the media, which can play a significant role in shaping public perceptions of the safety of the food supply (Organization & others, 2010). Consumers, as the final link in the food supply chain, are at the receiving end of food safety efforts, yet their understanding of what constitutes "safe food" is diverse and influenced by various factors such as age, health, cultural background, education, and media consumption (Grace, 2016; King et al., 2017). When educated consumers were asked to define safe food, their descriptions highlighted several key elements: food that has been handled properly, including the thorough washing of fish, poultry, and raw produce; food prepared on clean, sanitized surfaces with sanitized utensils; and the importance of hand washing during food preparation. Many consumers also emphasized the need to avoid reusing dirty clothes or sponges during food handling (Grace, 2015a; Isanovic et al., 2023; Nayak & Waterson, 2019).

For many well-informed consumers, common sense plays a key role in their understanding of food safety. They seek food that retains its nutritional value but is free from harmful chemicals such as pesticides, and they expect food to be stored and distributed under proper temperature controls to ensure its safety. Some consumers are familiar with the term "contamination" and define safe food as food that is free from contaminants. For others, the concept of safe food is more practical and straightforward: it simply means food that will not make them sick. For these individuals, safe food involves purchasing items like fresh chicken that are properly sealed and have no leaks, as any signs of compromised packaging can raise concerns about the product's safety (Frewer et al., 2009; Liang & Scammon, 2016; Wilcock & Ball, 2014). Consumers often rely on their senses if food looks or smells off, they assume it is unsafe to eat. Interestingly, few consumers explicitly mention food labeling as a central component of food safety, yet they tend to believe that they know how to handle food once it is in their possession, assuming that the food's safety has already been ensured by the time it reaches their hands. From an academic standpoint, the definition of safe food is more nuanced and encompasses a variety of scientific disciplines, such as biochemistry, microbiology, genetics, medicine, and food science, among others. Academics tend to focus on specific research areas, and their definitions of safe food are often shaped by the boundaries of their respective fields. One common scientific measure of food safety is the incidence of foodborne illnesses, which reflects the effectiveness of food safety measures and provides a benchmark for assessing the risk associated with different foods (Liang & Scammon, 2016; Nestle, 2010).

1.2.1 Food safety in corporate culture

An organization's culture is shaped by the shared values, beliefs, and behaviors of its employees and leaders. In the context of food safety, this culture refers to how an organization approaches food safety both in its mindset and actions and is a vital part of the broader organizational culture (Liggans & Kim, 2024; Yiannas, 2008). Food safety culture extends beyond just the technical components of a food safety management system, which include regulatory compliance, standard operating procedures, policies, training, and auditing. It also involves communication efforts, a clear understanding of roles and responsibilities, strong management commitment, and a recognition that the entire organization functions as an interconnected system that can impact food safety outcomes. Establishing a food safety culture requires combining the best scientific practices with effective management strategies and robust communication systems (Liggans & Kim, 2024).

Griffith & Motarjemi, (2023) identified six key factors that contribute to food safety performance within an organization: leadership, food safety management systems and style, commitment to food safety, the food safety environment, risk perception, and communication. According to Chris Griffith, formerly at the University of Wales Institute Cardiff, the development of food safety values, beliefs, and attitudes within an organization is largely influenced by the knowledge, standards, motivation, and leadership of those in charge, as well as how they communicate with and earn the trust of the staff.

Leaders within an organization play a critical role in shaping and nurturing a food safety culture. By exemplifying the values and behaviors they want to see in others, leaders can gain widespread support from employees. This can be achieved through their responses to critical situations, role modeling, mentoring, allocating resources, and reinforcing the organization's values through rituals, stories, and ceremonies. Leaders also influence organizational culture by how they recruit, select, promote, and remove employees. For a food safety culture to thrive, it's important that operators understand the risks associated with their products and how to effectively manage those risks. Having technical staff who stay informed about emerging food safety concerns, continually evaluate procedures, assess supplier practices, and monitor frontline staff behaviors is essential for establishing a strong food safety culture. Technical experts should be able to access the latest research and learn from past foodborne illness outbreaks to guide their decisions (Kim, 2009; Mak & Kim, 2017).

An example of a positive food safety culture can be seen in a long-term care facility. Here, the operator might provide clear guidelines for menu planning to reduce the risks of *Listeria monocytogenes*, such as advising against serving unheated cold cuts to vulnerable, immunocompromised residents. The guidelines would include not only safe menu choices and alternatives but also instructions for residents on how to properly handle food removed from the dining room and taken back to their rooms. In this scenario, everyone involved in the food safety system of the facility from kitchen staff to healthcare professionals would be provided with accurate, up-to-date information on the risks of *Listeria monocytogenes* and the best practices to minimize those risks (Coia et al., 2017; Darwin, 2011; Thomas et al., 2012).

1.3 Enhancing Food Safety in Food Production: Standards, Principles, and Applications for Small and Medium-Sized Enterprises

1.3.1 Introduction

In many modern economies, small and medium enterprises (SMEs) are the backbone of the economy, representing most businesses and employing a large proportion of the workforce. For instance, in the European Union, micro and small businesses (those with 1-50 employees) account for 98.7% of all enterprises and employ 50.2% of the workforce, while medium and large businesses (with over 50 employees) make up just 1.3% of the total number of businesses but employ nearly half of all workers (Chetty et al., 2024; Randrianarivelo et al., 2022). This pattern is also observed in countries like New Zealand, where 97% of businesses employ 20 or fewer people and account for about 30% of total employment. In smaller towns and rural areas, SMEs contribute significantly to local employment, representing about 32% of the workforce and around 33% of national sales and income (Legg et al., 2009) (Twinokwikiriza, 2018). This makes the management of safety and the creation of healthy work systems in SMEs an important issue for many nations, especially when existing regulations often fail to address the unique challenges SMEs face (Gamage et al., 2020; Kheni et al., 2010).

Despite efforts by local, national, and international organizations to support the development and growth of SMEs, resources and support systems remain insufficient. Research highlights the recurring challenges faced by employers, employees, enforcement agencies, and researchers when it comes to developing and implementing safety interventions in SMEs. These challenges arise because the characteristics of SMEs such as their small size, limited resources, and lack of specialized safety expertise often hinder the successful implementation of safety measures tailored for larger organizations. There is a consensus that safety intervention models designed for larger businesses are not effective in the context of SMEs. Difficulties such as reaching geographically dispersed businesses, their often-short lifespans, and their lack of safety expertise have left SMEs to manage food safety independently. However, some progress has been made with simple, low-cost solutions aimed at controlling specific hazards, particularly in relation to chemical exposures (Pingault et al., 2017).

To address these challenges, various models and preventive approaches have been developed at both national and international levels for use with small enterprises. Common strategies include the use of checklists, food safety management systems, and other preventive programs (Legg et al., 2015). These interventions aim not only to enhance safety but also to help owner-managers maintain their identity as responsible employers. By doing so, they can avoid negative criticism, improve employee satisfaction, set industry-accepted standards for acceptable working conditions, and increase legitimacy within their respective sectors. Masi et al. (2014) identified several key factors that drive safety performance in SMEs, including positive attitudes toward health and safety, availability of clear guidelines, active management involvement, access to economic resources, effective communication, and the presence of industry associations or consultants (Masi et al., 2014). Given the sheer number, geographic spread, and diversity of SMEs, reaching them with safety interventions remains a significant challenge. The model proposed for improving occupational health and safety (OHS) in SMEs should build on two fundamental principles: ensuring a high standard for acceptable working conditions and providing effective support systems (M. D. Oliveira et al., 2018; Ulu & Birgün, 2022).

The standards for safety need to be clearly defined and communicated through regulation, including inspections that target specific health and safety issues, offer practical solutions, and facilitate open dialogue between regulatory bodies and owner-managers. It is essential that social partners in the industry, such as trade unions and sector associations, are involved to ensure that safety standards are both practical and achievable. The support system should offer practical tools that are integrated into the business strategy and be delivered by intermediaries who have direct, personal contact with owner-managers and a deep understanding of the business context. Recent research has begun to explore how different types of intermediaries can be leveraged to help SMEs adopt and implement food safety practices effectively (Legg et al., 2015).

SMEs in the food industry, despite their significant role in production, are often influenced by various external and internal stakeholders, such as regulatory bodies, auditors, and industry groups. While microbiological food safety is not always inherent in the methods used by these smaller enterprises, many still rely on governmental guidance and third-party oversight to ensure that their products meet safety standards (Humphrey, 2012). However, outbreaks of foodborne illness have been traced to farms, processors, and retailers that were certified, highlighting that certification alone does not guarantee safety. A 2008 report by the U.S. Government Accountability Office emphasized that, although inspectors play a key role in monitoring compliance, the primary responsibility for food safety lies with food producers (Powell et al., 2013). Frank Yiannas, former president of the International Association for Food Protection, argues in his book *Food Safety Culture: Creating a Behavior-based Food Safety Management System* that an organization's food safety systems must be deeply integrated into its culture (Yiannas, 2008). He stresses that achieving food safety success requires a shift beyond traditional methods of training, testing, and inspections. Instead, food safety should focus on changing behaviors. As Yiannas puts it, "food safety equals behavior." This perspective aligns with the World Health Organization's (2006) identification of five primary factors contributing to foodborne illnesses: improper cooking, temperature abuse during storage, poor hygiene by food handlers, cross-contamination between raw and ready-to-eat foods, and sourcing food from unsafe suppliers. These behaviors can be influenced and changed through a shift in organizational culture, underlining the importance of fostering a strong food safety culture within all parts of the food production and supply chain (Isanovic et al., 2023; Yiannas, 2015)

1.3.2 The importance of food safety in food production

The concept of "safe food" is a complex and multifaceted one, shaped by the perspectives and definitions of various groups, including consumers, special interest groups, academics, regulatory bodies, and the food industry. Any attempt to define safe food in simple terms will inevitably fall short, as food safety encompasses a broad range of factors. According to the 1998 American Academy of Microbiology Colloquium on Food Safety, safe food is food that, when handled properly at every stage from production to consumption, is highly unlikely to cause illness or harm. While the goal of a safe food supply is universally shared, the criteria used to define food as "safe" are evolving and becoming more nuanced as safety standards improve. However, challenges arise when perceived risks, often fueled by media coverage, influence public opinion and lead to disproportionate resource allocation in response to those concerns. The perception of food as unsafe can quickly spread, particularly when politicians and regulators become involved, further amplifying the issue in the public's mind (Bazzan, 2019; Eruaga, 2024; Paul, 2009).

A good example of the evolving approach to food safety can be seen in the use of performance standards for pathogens like *Salmonella* and *Escherichia coli* in the U.S. food supply. These standards, based on microbial counts and prevalence data, reflect a growing trend among regulators to quantify food safety. However, there is consensus among food safety experts that microbial testing alone cannot guarantee food safety. Routine sampling reveals the limitations of testing as a definitive tool for ensuring safety. For instance, pathogens like *E. coli* O157:H7 in ground beef or *Listeria monocytogenes* in cooked foods often appear in very low concentrations, typically below 0.1%. Even with extensive testing (e.g., 60 samples per lot), the chances of detecting these pathogens remain under 10% (Ehuwa et al., 2021; Lammie & Hughes, 2016; Todd, 2004). Most companies conduct fewer tests (often 3-5 per lot) to verify that their Hazard Analysis and Critical Control Point (HACCP) systems are functioning properly, but this approach still leaves significant uncertainty regarding the safety of the food. Additionally, pathogens may not be evenly distributed in contaminated foods, which further limits the effectiveness of testing in guaranteeing safety. Differences in how food safety is judged around the world are also likely to persist. For instance, there are ongoing disagreements between the U.S. and the European Union regarding the safety of beef hormone treatments and genetically modified organisms (GMOs). These differences persist even with mechanisms like the World Trade Organization’s (WTO) dispute resolution system in place to address such conflicts. In general, the European and American approaches to food safety differ significantly, with cultural and historical factors often playing as much of a role in decision-making as scientific data (Anyshchenko & Yarnold, 2021; Carlarne, 2007; Fabrizi, 2021; Quintillhn, 1999).

The global food industry operates in an environment where policies, regulations, guidelines, and educational initiatives related to food safety are constantly being updated and developed. These updates can either enhance the efficiency and effectiveness of food supply chains or, if not harmonized globally and clearly communicated to consumers, can lead to increased complexity and confusion. One of the key drivers of food safety challenges in the coming decades is the projected doubling of global food demand and international trade. This growth is expected to significantly increase the risk of foodborne diseases (Quested et al., 2010; Van Boxstael et al., 2013). Other factors that pose substantial challenges to food safety include climate change, the emergence of new pathogens and toxins, an aging population, and the increasing prevalence of immuno-compromised individuals. Additionally, changing consumer preferences such as a growing demand for fresh and minimally processed foods further complicate food safety efforts (Dong et al., 2015; King et al., 2017).

Emerging technologies hold promises for transforming food production, processing, and packaging, yet concerns about their safety and public perceptions will continue to challenge both the food industry and regulators. The scale of changes needed to address these interconnected challenges is comparable to the transformations seen during past revolutions in agriculture and industry, such as the Industrial and Agricultural Revolutions of the 18th and 19th centuries, and the Green Revolution of the 20th century (Dutta et al., 2023; Hecht, 2014). As global food trade expands, food safety has become a critical concern for both developed and developing countries. Beyond the obvious impact on health and lives, foodborne diseases also negatively affect economies, trade, and industries. The costs of a foodborne illness outbreak can be substantial, including medical expenses, lost productivity, costs to the affected businesses (such as product recalls and brand damage), and expenses incurred by public health authorities at local, regional, and national levels (Dhurandhar et al., 2015; Kassebaum et al., 2017). Although food security is a shared concern for both importing and exporting nations, many countries, especially those with less developed food safety systems lack the necessary surveillance and reporting mechanisms to effectively track and manage foodborne illnesses. Strong enforcement of food safety standards, coupled with robust surveillance networks, is essential at the national, regional, and global levels to address these risks (Faour-Klingbeil & CD Todd, 2020; King et al., 2017). In small and medium-sized food enterprises (SMEs), a significant gap in food safety knowledge persists. Research has shown that 62% of food business owners in these enterprises lack knowledge during the compliance decision-making process, reinforcing findings from previous studies on environmental regulation in SMEs. Many small business owners are skeptical about the relevance and importance of certain food safety regulations, which often contribute to low compliance levels. In case studies of small and medium enterprises, 83% of owners expressed a lack of trust in the legislative requirements governing food safety (Ahinful, 2018; Fairman & Yapp, 2004).

1.3.3 International Food Standards and General Food Guidelines

According to the World Health Organization (WHO), foodborne illnesses impact a large portion of the global population, with an estimated 600 million people falling ill each year, resulting in approximately 420,000 deaths. Developing countries are disproportionately affected by these illnesses, as they often lack the infrastructure and resources needed to manage food safety effectively. Food recalls occur when a product is found to be unsafe, typically due to contamination or other hazards, and can be initiated by manufacturers, government bodies, or through consumer complaints. In developed countries, robust regulatory systems and monitoring agencies, such as the FDA in the United States and EFSA in the European Union, work to ensure food safety (Brown & Chan, 2010; Buckley & Riviere, 2012). However, in many developing countries, food safety systems may be less developed, leading to higher rates of foodborne illnesses and more frequent product recalls. Recent food recalls have included instances of Salmonella contamination in pet treats, onions, and peaches in the U.S., Listeria concerns in cheese and pork products in Europe, wheat flour contamination with metal fragments in India, and potential Salmonella contamination in milk powder in Nigeria (Lee et al., 2023). These cases highlight the critical need for strong food safety measures and effective monitoring systems to prevent and address contamination risks worldwide. Despite the availability of various resources aimed at improving food safety, including legislation, policies, standards, guidelines for implementing food safety systems, worker training programs, and audits, foodborne illnesses continue to occur with alarming regularity. These outbreaks lead to significant public health crises, costly product recalls, and a loss of consumer trust in both food manufacturers and brands. A food safety management system is a structured approach designed to manage and mitigate food safety risks within a food establishment to ensure that the food produced is safe for consumption. All food businesses are required to establish, implement, and maintain a food safety management system based on the principles of Hazard Analysis Critical Control Point (HACCP) (Hutter, 2011; Lufu et al., 2020).

Regulatory authorities that oversee food production focus on the impact of factors such as agricultural chemicals, animal hormones, feed contaminants, and antibiotics in defining safe food. In processing environments, these authorities typically address the microbiological, chemical, and physical hazards associated with food manufacturing. Regulatory definitions of safe food are often based on standards established by global organizations like the World Health Organization (WHO), the European Commission, and the U.S. FDA, as well as international trade regulations. For instance, the food safety standards set by the Joint Food and Agriculture Organization/WHO Codex Alimentarius Commission (CAC) serve as international guidelines used to resolve trade disputes. Some regulators now also use quantitative risk assessments to define food safety and determine the most effective intervention strategies. Scientific risk assessments have become central to food safety practices worldwide, particularly following the adoption of the Sanitary and Phytosanitary Agreement by the World Trade Organization (WTO) (Fink, 2023; Fortin, 2023; Halabi, 2015). At the primary level of food production, farmers and ranchers play a foundational role in defining food safety. Their practices, such as the use of chemicals for soil treatment or hormones in animal production, are central to maintaining food safety at this stage. Safe food for these producers means applying practical production methods that balance economic pressures with the need to control hazards, often relying on government-approved chemicals to maximize production efficiency. Although microbiological safety has historically received less focus at this level, there is growing recognition of the importance of farmers and ranchers in ensuring food safety through their practices. Within the broader food industry, food safety is defined through specific guidelines for raw materials and finished products. These industry standards outline acceptable limits for chemical contaminants like pesticides and hormones, physical hazards such as bone or metal fragments, and microbiological risks such as *Listeria monocytogenes* and *Salmonella* (Mansour, 2011).

The food industry also defines safe food through pathogen reduction strategies employed during processing, whether through established methods like pasteurization or newer technologies such as pulsed high-energy light. This sector includes all stages of the food supply chain, from production and processing to distribution, retail, and food service, as well as industries that support plant and animal growth and use by-products for non-food purposes like healthcare and clothing (A. K. Das et al., 2019). Several small tech companies have developed product-specific solutions for traceability, with some retailers achieving success by implementing these solutions for individual products like mangoes or pork. However, full engagement from all parties in the supply chain is necessary to ensure the correct and complete entry of data, which remains a significant challenge in making traceability (whether via block chain or other methods) a standard practice. Some retailers conduct traceability challenges for specific products to assess the effectiveness of the systems they have in place. These challenges also help maintain ongoing relationships with suppliers and ensure continuous knowledge about the product and production processes (Khaliq et al., 2023).

The issue of customer and consumer relevance typically falls under the joint responsibility of the marketing and research and development (R&D) departments, although in retail and foodservice settings, Quality Assurance often takes on R&D duties. Methods for ensuring consumer relevance can vary from simple in-house product testing using externally provided samples to more advanced product design techniques and professional panels. In some cases, product development is done in collaboration with customers to better understand how a product performs in both professional kitchens and home environments. One structured approach used in the food industry, though not widely applied, is Quality Function Deployment (QFD). This methodology aims to translate the "voice of the customer" into product design characteristics, including raw materials, processing, packaging, distribution, and presentation, through various stages. Although QFD considers interactions among design elements using the "roof" of the "house of quality," its complexity has limited its widespread use. That said, large, branded manufacturers with more resources have successfully used QFD, viewing it as an essential investment in their brand's growth (Arcidiacono et al., 2024; Megel, 2011).

Once a product is on the market, customer feedback systems are widely used to track complaints, claims, and comments in a systematic way. These responses provide valuable insights for businesses, although the sophistication of data collection, analysis, and response systems varies greatly. A common challenge is trend analysis based on responses per unit sold, which can be difficult for manufacturers to track since they don't always know when products are sold to the end consumer. Some try to estimate an average lag period between production and consumer use, but this approach is imprecise. Additionally, complaint behavior differs across regions. For instance, complaints in Europe tend to be highest in the UK and much lower in Mediterranean countries. Globally, there can be a significant variation in complaint rates between countries for example, the United States versus Costa Rica or the Philippines despite the same products being sold (Beneria et al., 2012). These disparities indicate that complaint rates don't simply reflect product failure rates; they also reflect cultural and behavioral differences in how consumers react to product issues. Interestingly, consumers in countries with lower complaint rates may be just as unlikely to purchase a product after a negative experience as those in higher complaint rate countries.

Quality system certification, such as ISO 9001, typically requires companies to implement a system for tracking customer satisfaction that goes beyond just accepting designs and recording complaints. It involves ongoing monitoring and comparison against industry standards and consumer expectations, with appropriate follow-up actions. While these aspects like product design, customer feedback, and complaint tracking are crucial, they are not always standardized tools in certification schemes. However, the Global Food Safety Initiative (GFSI) standards do require companies to focus on new product development and customer feedback. Companies implementing a food quality and safety management system need to create their own approach, mixing these elements in a way that fits their operation. Transparency and accountability are key in ensuring the integrity of products and materials throughout the food value chain. This means that companies must provide clear, accessible information about all relevant parameters and conditions related to food safety, product quality, and traceability batch by batch. Many certification schemes are designed to help meet this transparency requirement. For example, GFSI-recognized certifications are widely seen as an indicator of a company's commitment to quality, safety, and hygiene. While no auditing or certification process can guarantee that conditions for every individual batch of product were perfect, the frequency of audits and built-in self-checks in the certification process offer a reasonable level of assurance (Crandall et al., 2012; Gerardi, 2023).

However, when precise control over parameters is necessary, customers will expect more detailed information. The level of transparency needed depends on the level of integration in the supply chain. For example, in fully vertically integrated operations, the final seller is part of a controlled supply chain where all relevant conditions and parameters are known and can be recorded as part of the product's history. In this case, acceptance testing is typically unnecessary because the records contain all the necessary details, such as whether certain chemicals were used on crops. If no chlorinated pesticides were used, there would be no need to test for them later. In contrast, in cases where uncontrollable variables exist (like mercury levels in wild-caught fish), testing might be done early in the supply chain, but only once. For products bought on the open market, traceability is often lost, making it difficult to know if a batch was produced under the same conditions. In such cases, acceptance testing becomes the primary method for ensuring safety and quality at each stage of the chain. For example, when buying vegetable oils on the global market, traceability can be challenging, but international regulations require ships carrying edible oils to maintain records of previous cargo, cleaning procedures, and acceptance testing. Testing in this case is made easier because contaminants are typically evenly distributed in oils, and advanced techniques like chromatography and mass spectrometry can quickly and comprehensively screen for impurities (Jennings et al., 2016; Shepherd et al., 2017).

The Global Food Safety Initiative (GFSI) is a business-driven platform aimed at improving food safety management systems globally. The GFSI brings together food safety experts from around the world to define food safety standards across the supply chain, benchmark various food safety systems, build the capacity of smaller businesses, and focus on enhancing auditor competency. Its goal is to ensure consumer confidence in the safety of food worldwide (see GFSI website).

GFSI recognized standards have been developed for certification by:

(1) BRC Global Standards: https://www.brcgs.com/
(2) CANADAGAP: https://www.canadagap.ca/
(3) Food Safety System Certification 22000: https://www.fssc22000.com/ and https://www.fssc22000.com/developmentprogram/
(4) Global Aquaculture Alliance Seafood Processing Standard: https://www.aquaculturealliance.org/
(5) Global GAP: https://www.globalgap.org/uk_en/

GFSI Food Safety and Environmental Practices
The GLOBALG.A.P. Harmonized Produce Safety Standard is a separate standard that covers food safety and traceability requirements for fruits and vegetables. The HPSS is similar to the GAP audit in the U.S. market and is a GFSI designed for producers selling domestically or in the U.S.
The GLOBALG.A.P. Produce Handling Assurance Standard is a facility audit that can be conducted as a stand-alone audit or in conjunction with an IFA or HPSS audit to assess packing facilities.
The GLOBALG.A.P. GRASP is a voluntary farm-level social/labor management tool for the global supply chain to be used in conjunction with Integrated Farm Assurance (IFA).

(6) Global red Meat Standard: https://www.grms.org/
(7) International Featured Standards: https://www.ifs-certification.com/index.php/en/
(8) Safe Quality Food: https://www.sqfi.com/
(9) Primus GFS: http://primusgfs.com/
(10) Japan Food Safety Management Association: https://www.jfsm.or.jp/eng/
(11) Asia gap: https://jgap.asia/en/certification-program-2/
(12) Fresh care: https://www.freshcare.com.au/about/
(13) China HACCP – GFSI: https://mygfsi.com/news_updates/china-focus-day-2019

Hazard Analysis and Critical Control Points (HACCP) is a food safety system developed in the United States, and over time, it has become the globally recognized standard for ensuring food safety. It is now a key component of food safety regulations in the European Union, the United States, and many other countries. The FAO/WHO Codex Alimentarius Commission has established guidelines for implementing the HACCP system. HACCP certification is widely available through certification bodies, typically under the ISO 22000 framework or the GFSI-recognized FSSC 22000 certification, which combines ISO 22000 with Prerequisite Programs (as outlined in ISO/TS 22002-1) (Pop et al., 2018). In the United States, the Food Safety Modernization Act (FSMA) introduced Hazard Analysis and Risk-based Preventive Controls (HARPC), which is an evolution of the HACCP system. The Codex Alimentarius HACCP principles are considered the most effective global tool for food safety and are mandatory in many countries. These principles form the basis of various voluntary food safety management standards, including ISO 22000, BRC, and IFS standards. HACCP-based approaches are also applied in tools like the Safer Food, Better Business packs and T-matrix diagrams (Dlamini & Adetunji, 2023; Dzwolak & Anim, 2025). Despite being implemented globally for several decades, challenges to the effective application of HACCP principles and food safety management systems (FSMS) persist. These obstacles include financial, technical, managerial, organizational, educational, and psychological barriers. Small food businesses (SFBs) often face significant difficulties in applying HACCP principles due to financial constraints, lack of technical expertise, and limited resources. The HACCP plan is a critical document in any structured FSMS and is essential for ensuring food safety, though these challenges can hinder its full implementation (Dzwolak, 2019; Nguyen & Li, 2022; Panghal et al., 2018).

ISO 9001, the global standard for quality management systems, is widely recognized, but its requirements are broad and not specifically tailored to the food industry. As a result, an ISO 9001 certification alone is generally not seen as sufficient evidence of good practices in food safety. Nonetheless, the management principles outlined in ISO 9001 are incorporated into food-specific quality standards (Hoyle, 2017).

ISO 22000, a food safety management standard from the International Organization for Standardization (ISO), is specifically designed for organizations in the food supply chain. The 2018 version of ISO 22000 provides a framework for food safety management but does not include the Prerequisite Programs (PRPs) required for the system. These are covered in the ISO/TS 22002 series. The FSSC 22000, a GFSI-recognized certification scheme, combines ISO 22000 with applicable PRPs, providing a comprehensive food safety management system (Chen et al., 2020; Gil et al., 2017).

Six Sigma is a methodology designed to minimize variability in both products and processes, striving for a near-perfect failure rate of 0.0003%. It heavily relies on statistical analysis across five key steps: Define, Measure, Analyze, Improve, and Control. Originally developed in the electronics sector, Six Sigma has since been adapted to other industries as well. While companies can apply Six Sigma principles, certification is typically given to individuals, not organizations, with different "belt" levels representing expertise (Costa et al., 2018).

European Hygienic Engineering & Design Group (EHEDG) works to promote the production of safe food by ensuring that food manufacturing equipment is hygienically designed. EHEDG is a global consortium comprising equipment manufacturers, food companies, research bodies, and public authorities, providing training and developing guidelines. Although it originated in Europe, EHEDG now has active chapters worldwide, with guidelines available in multiple languages (see http://www.ehedg.org/).

Prerequisite Programs (PRPs) refer to the essential operational conditions necessary for a HACCP program to be effective. These conditions cover a wide range of areas such as facility hygiene, equipment maintenance, pest control, personnel hygiene, and chemical management. In the food industry, many of these PRPs are derived from **Codex Alimentarius**. **ISO/TS 22002-1:2009** outlines the requirements for establishing and maintaining PRPs, which are often implemented alongside **ISO 22000** certification to control food safety hazards (Pop et al., 2018).

5S is a workplace organization method that originated in Japan. It focuses on: (1) removing unnecessary items, (2) assigning permanent homes for remaining items, (3) cleaning the workspace, (4) standardizing common tasks, and (5) maintaining and improving these practices. Although **5S** exceeds the requirements of food industry PRPs, it can complement them, creating synergy between the principles of food safety and the structured approach of 5S. Though many consultants offer training in 5S, it does not have a formal certification scheme like the ones discussed in this chapter (see 5S: https://www.5stoday.com/what-is-5s/).

Total Productive Maintenance (TPM) is a participatory approach where production workers take responsibility for both preventive and corrective maintenance of the equipment they use. The goal is to reduce various forms of loss, including downtime, off-spec production, safety hazards, and costs related to stock management, planning uncertainty, and morale. While TPM is widely adopted by many companies, it is not associated with a specific certification standard (see http://en.wikipedia.org/wiki/Total_productive_maintenance).

GS1 is an organization that develops and maintains global supply chain standards aimed at improving efficiency and visibility. Its system, which is used globally across many sectors, includes the Global Trade Item Number (GTIN), a unique identifier for products and services throughout the supply chain, from warehouses to retail checkouts. One of the primary benefits of GS1 standards is enabling traceability throughout the supply chain (see http://www.gs1.org).

RFID (Radio Frequency Identification) is a technology that uses radio waves to track and identify objects through embedded microchips and antennas. These RFID tags transmit identification data to a reader without needing direct contact or line-of-sight, unlike traditional barcode systems. RFID tags can be applied to various objects, such as livestock, where they allow for precise identification of animals. This technology is widely used in supply chains for real-time tracking (see http://www.rfid.org/).

1.3.4 National Food Safety Regulations

Food safety regulations in Thailand are crucial for protecting public health and ensuring the safety and quality of food products consumed by the population. The country's approach to food safety is a multifaceted endeavor that involves legislative frameworks, government agencies, and cooperative efforts among various stakeholders in the food production and distribution chain. Thailand's food safety regulations are primarily governed by the Food Act of 1979, which established the legal basis for food safety standards and oversight. The Act mandates the Ministry of Public Health, through the Food and Drug Administration (FDA), to regulate food products. The FDA is responsible for enforcing laws related to food safety, including labeling, hygiene, and the quality of food products. In 2017, Thailand enacted the Food Safety Act aimed at enhancing food safety management, which encompasses both domestic food safety practices and imported food products (Bassetti et al., 2023).

Regulatory Agencies

Several agencies play distinct roles in the regulation of food safety in Thailand. They are discussed hereafter.

Ministry of Public Health (MOPH): This ministry oversees food safety regulations and policies to protect public health. It implements various health initiatives and ensures that the food supply is safe for consumers.

Thai Food and Drug Administration (TFDA): As a division of the MOPH, the TFDA is primarily responsible for the registration and approval of food products, including dietary supplements and pharmaceuticals. It also oversees compliance with food safety standards.

Department of Medical Sciences (DMS): This department conducts research and laboratory testing to assess food safety, as well as support the regulatory process by offering scientific advice.

Local governments: Local authorities are responsible for enforcing food safety regulations at the community level. They conduct inspections and ensure compliance with health standards in food establishments.

The National Bureau of Agricultural Commodity and Food Standards (ACFS) Thailand became a founding member of the World Trade Organization (WTO) on December 28, 1994, alongside 80 other nations. By joining, Thailand committed to reducing customs tariffs and other trade barriers. To ensure active participation in international agricultural and food trade while fulfilling WTO obligations, Thailand required a new mechanism. As part of a restructuring of the Ministry of Agriculture and Cooperatives in 1997, the Bureau of Agricultural Commodity Standards and Inspection was established under the Office of the Permanent Secretary. This Bureau was tasked with addressing non-tariff trade barriers, serving as a national focal point for coordination with both domestic and international stakeholders, and developing national agricultural commodity standards in alignment with global standards. Key non-tariff barriers in agriculture and food trade fall under the Sanitary and Phytosanitary (SPS) and Technical Barriers to Trade (TBT) agreements. To provide well-coordinated and high-quality services to the agricultural and food industries, the Bureau collaborated closely with other relevant departments. In 2002, a major government restructuring led to the establishment of the National Bureau of Agricultural Commodity and Food Standards (ACFS), replacing the Bureau of Agricultural Commodity Standards and Inspection. ACFS serves as the central authority for regulating agricultural products, food, and processed agricultural goods by enforcing standards across the entire food supply chain. Additionally, ACFS is responsible for accrediting certification bodies for agricultural commodities and food, negotiating with international partners to reduce non-tariff trade barriers, and enhancing the competitiveness of Thai agricultural and food standards in the global market.

The National Bureau of Agricultural Commodity and Food Standards (ACFS) envisions becoming a globally recognized leader in the standardization of agricultural commodities and food products. The organization is dedicated to ensuring that Thailand's agricultural and food standards align with international best practices, thereby enhancing the country's competitiveness in the global market.

To achieve this vision, ACFS has established a clear and structured mission focusing on six key areas. First, the agency aims to strengthen the development of standards for agricultural commodities and food products, ensuring that they meet both domestic demands and international guidelines. By doing so, ACFS seeks to enhance the quality, safety, and sustainability of Thai agricultural exports.

Second, ACFS is committed to improving the inspection and certification systems for agricultural and food products. These efforts are designed to ensure compliance with both national and international requirements, fostering consumer trust and facilitating smoother trade relations.

Third, the agency emphasizes the implementation of standards throughout the entire production chain. This includes driving food safety strategies to guarantee that agricultural and food products maintain high quality from production to consumption.

Another critical aspect of ACFS's mission is strengthening Thailand's position in international negotiations regarding standards, as well as sanitary and phytosanitary measures. By actively engaging in these discussions, the agency helps protect the interests of Thai agricultural producers and ensures fair trade practices.

Furthermore, ACFS is responsible for overseeing and enforcing the Agricultural Standards Act of B.E. 2551. Through strict monitoring and control measures, the agency ensures that agricultural standards are effectively implemented and adhered to across the industry.

Lastly, ACFS aspires to be the national center for information on agricultural commodities and food products. By serving as a reliable and comprehensive source of data, the agency supports policymakers, industry stakeholders, and consumers in making informed decisions.

In conclusion, ACFS plays a vital role in shaping Thailand's agricultural and food industry. Through its commitment to standardization, quality assurance, and international collaboration, the agency continues to enhance the global reputation of Thai agricultural products while safeguarding consumer health and safety.

Accreditation Scope of the National Bureau of Agricultural Commodity and Food Standards

The National Bureau of Agricultural Commodity and Food Standards (ACFS) plays a crucial role in ensuring the quality and safety of Thailand's agricultural and food products through its accreditation services. By providing accreditation to Certification Bodies (CBs) and Inspection Bodies (IBs), ACFS ensures that products and processes comply with national and international standards.

Accreditation for Certification Bodies (CBs)[1]

ACFS currently accredits Certification Bodies under seven key scopes. First, the Good Manufacturing Practice (GMP) and Hazard Analysis and Critical Control Point (HACCP) scope ensures that food manufacturing processes adhere to strict hygiene and safety standards. Second, the Preventive Control for Human Food (PCHF) and Preventive Control for Animal Food (PCAF) focus on proactive measures to prevent contamination and ensure food safety for both human and animal consumption.

Additionally, the Food Safety Management System (FSMS) scope ensures comprehensive oversight of food safety practices within the industry. The Good Agricultural Practice (GAP) and Global G.A.P. scope establishes standards for safe and sustainable farming practices. Moreover, the Organic Agriculture scope verifies compliance with organic farming regulations to promote environmentally friendly and chemical-free agricultural production.

Furthermore, ACFS provides accreditation for the Agricultural Produce or Product scope, which ensures the quality and safety of raw agricultural goods. Lastly, the Geographical Indication (GI) Product scope protects and certifies products based on their unique regional origins, preserving Thailand's diverse agricultural heritage.

Accreditation for Inspection Bodies (IBs)

In addition to certifying CBs, ACFS also accredits Inspection Bodies across four scopes. The first is the Good Manufacturing Practice (GMP) and Hazard Analysis and Critical Control Point (HACCP) scope, which ensures that inspection procedures uphold stringent food safety standards. The second, Good Agricultural Practice (GAP), focuses on verifying safe and sustainable farming techniques.

The third accreditation scope, Organic Agriculture, ensures that inspection bodies evaluate compliance with organic production standards. Lastly, the Agricultural Produce or Product scope accredits the assessment of raw agricultural goods, ensuring their quality and safety.

1.3.5 Food Safety Standards

Food safety standards in Thailand are comprehensive, covering a range of aspects from production to consumption. The regulations address issues such as:

(1) **Hygiene practices**: Establishments in the food service industry are required to maintain high levels of cleanliness and sanitary conditions to prevent contamination. This involves regular inspections and adherence to guidelines regarding food handling, equipment cleanliness, and waste disposal.

(2) **Labeling and packaging**: Food products must include clear labeling that provides critical information for consumers, such as ingredients, allergens, expiration dates, and nutritional content.

(3) **Pesticide and chemical residues**: The government regulates the levels of pesticide residues allowed in food products to ensure they do not exceed safe limits. This is vital for the health of consumers and the prevention of chemical-related illnesses.

(4) **Food imports and exports**: Thailand closely monitors food products imported into the country, ensuring they comply with safety standards before entering the market. This strategy extends to exported products, helping to maintain the country's reputation as a trustworthy supplier of food products globally.

Despite the existing regulatory framework, Thailand faces several challenges in enforcing food safety regulations, including limited resources for inspections, a large informal food sector, and

[1] For more information on the list of accredited Certification Bodies (CBs) and Inspection Bodies (IBs), please visit the official website: https://www.acfs.go.th/#/

varying compliance levels among food producers. The rise of e-commerce and online food delivery services has also introduced new complexities regarding food safety enforcement. To address these issues, the Thai government has been working on improvements such as strengthening the Food Safety Act, enhancing public awareness campaigns about food safety, and increasing investments in food safety infrastructure. Collaboration with international organizations, such as the World Health Organization (WHO) and the Food and Agriculture Organization (FAO), also plays a vital role in adopting best practices and improving standards. Food safety regulation in Thailand is essential for safeguarding public health and ensuring the integrity of the food supply. Through a combination of legislation, regulatory oversight, and community involvement, the country aims to enhance food safety standards. Continuous improvements and adaptations are necessary to overcome challenges and keep pace with an evolving food landscape, ultimately aiming for a food system that protects both consumers and producers alike. As Thailand continues to develop its food safety regulations, fostering a culture of safety and awareness will remain fundamental to achieving these goals (Organization & others, 2010, 2022).

1.3.6 Advantages of Implementing Food Safety

Implementing food safety systems offers several key benefits, particularly in the context of hazard characterization and risk assessment. One advantage is the systematic identification and assessment of potential risks, which involves determining the nature of the hazard, understanding how it affects the body, and quantifying the severity of the impact at different exposure levels. This process is essential in identifying which hazards pose the greatest threat and helps set the stage for informed decision-making. For instance, in the case of chemical hazards, food safety systems use dose-response models to predict the potential effects on human health, even if the chemicals are present at very low levels in food. These models, while uncertain, are crucial for understanding how a substance might affect individuals and for shaping public health policies. Similarly, when dealing with biological or physical agents, dose-response assessments are important for understanding the effects of pathogens in food, although these assessments are only possible if sufficient data is available (Buchanan et al., 2000, 2009).

Despite the challenges, these food safety systems help bridge the gap between animal studies and human exposure by applying safety factors. For instance, even though high-dose animal studies are often used to assess toxicological effects, extrapolating these findings to humans remains difficult, especially at lower doses. The metabolism of chemicals can change depending on the dose, and adverse effects at higher doses may not be relevant at lower doses, making dose-response relationships complex to model (Slikker Jr et al., 2004). One of the main sources of uncertainty in hazard characterization is the variability among individuals, for example, how different animals or humans may respond to the same dose of a substance. This variability can make it harder to predict the exact health effects of low-dose exposure, and toxicologists often rely on threshold levels to assess the risk. For chemicals with long-term effects, such as carcinogens, this becomes even more challenging, as certain substances may cause persistent genetic mutations over time that lead to cancer. To address this uncertainty, conservative models and safety factors are often used in food safety systems, especially for biological hazards, which are more unpredictable (Havelaar et al., 2010). While this approach doesn't guarantee absolute safety, it provides a reasonable level of protection by identifying acceptable levels of risk and ensuring that food products meet stringent safety standards. In cases where data is insufficient, benchmark doses may be used to focus on lower, more precise risk levels, improving the accuracy of predictions regarding low-dose risks. Overall, food safety systems are crucial for assessing both chemical and biological hazards, allowing for better risk management and helping to ensure that food products are safe for consumption by identifying potential risks and mitigating them through scientifically backed safety measures (Fung et al., 2018).

1.4 Conclusion and Recommendation

1.4.1 Conclusion

The implementation of food safety standards in small and medium-sized food factories in Thailand is essential for ensuring public health, improving product quality, and enhancing competitiveness in local and international markets. However, these factories often face challenges such as limited financial resources, inadequate technical knowledge, and insufficient access to infrastructure and technology. Addressing these challenges requires collaborative efforts from the government, private sector, and industry stakeholders to provide support in the form of training, resources, and incentives.

By adopting food safety standards like Good Manufacturing Practices (GMP), Hazard Analysis and Critical Control Points (HACCP), and Good Agricultural Practices (GAP), these factories can establish safer and more efficient production processes. Compliance with such standards not only benefits consumers but also opens doors to export opportunities and long-term business growth.

1.4.2 Recommendations

Government Support and Incentives

(1) Provide financial assistance, such as subsidies, grants, or low-interest loans, to help small and medium food factories upgrade their facilities and adopt food safety systems.
(2) Simplify regulatory requirements and create user-friendly guidelines tailored to SMEs.
(3) The Department of Irrigation plays a vital role in helping small and medium-sized farmers adapt to climate change, with a particular focus on sustainable water management. Key initiatives include providing training, equipment, and consultations to educate farmers on efficient water usage, water-saving irrigation techniques, and irrigation system maintenance. To enhance water availability, the department develops small-scale water resources, such as constructing wells and improving natural water sources. Additionally, it encourages farmers to adopt rainwater harvesting systems, like storage ponds and check dams, to serve as supplementary water supplies during the dry season. The department also emphasizes the importance of farmer participation in water resource planning and management. This collaborative approach ensures efficient and equitable water usage, contributing to sustainable food production and climate resilience.

Capacity Building and Training

(1) Conduct nationwide training programs to educate factory owners and workers on food safety standards and practices.
(2) Collaborate with universities and technical institutions to offer specialized courses on food safety management for SME owners.

Access to Resources and Technology

(1) Promote the use of affordable and easy-to-implement technologies, such as mobile apps for record-keeping or low-cost monitoring systems for food safety.
(2) Encourage the establishment of shared-use processing facilities equipped with food safety-compliant infrastructure.

Strengthening Inspections and Certifications

(1) Ensure regular and consistent inspections of SMEs while offering constructive feedback and guidance for improvement.
(2) Provide affordable certification processes for small factories to encourage compliance with GMP, HACCP, or other relevant standards.

Collaboration and Networking

(1) Foster networks among small and medium food producers to facilitate resource sharing, best practice exchanges, and mutual support in food safety implementation.
(2) Build public-private partnerships to drive investment in SME capacity-building programs.

Consumer Awareness and Market Access

(1) Educate consumers about the importance of certified food products to create market demand for safety-compliant goods.
(2) Assist SMEs in meeting export requirements by providing market information and support for compliance with international food safety standards.

By adopting these recommendations, Thailand's small and medium food factories can overcome challenges, meet regulatory and market demands, and contribute to a safer and more reliable food supply chain.

2. Principle of Food Safety and its Application

2.1 Introduction

Food businesses around the world are required to develop and maintain effective food management systems. These "systems" serve as management tools that help implement key food safety principles. Essentially, a system selects the most essential methods, techniques, and knowledge relevant to a particular situation, making them concrete, measurable, and actionable. It also aims to define clear endpoints for achieving goals. For example, 6 Sigma is a management system designed to ensure consistency, providing a structured set of steps, specific methods, and a defined goal. Similarly, GFSI-recognized certification schemes (Global Food Safety Initiative) follow a similar approach (Crandall et al., 2012). These schemes typically include general quality management requirements based on ISO 9001, a HACCP module (based on the Codex Alimentarius guidelines), and various prerequisite programs (PRPs) focused on hygiene practices. The advantage of these schemes is that they offer a comprehensive, structured approach to managing food quality and safety. Their certifications are widely recognized and accepted by industry players and regulatory authorities, ensuring credibility. Moreover, these schemes can be updated or expanded as needed, with input from various stakeholders, ensuring they remain relevant and effective over time (Overbosch & Blanchard, 2023; Pop et al., 2018).

Hygiene is generally understood as the practice of maintaining cleanliness to prevent illness and the spread of disease. However, for our purposes, hygiene is broader and also includes preventing foreign materials in food, following basic housekeeping rules, and managing chemicals like pesticides and lubricants. These aspects are typically addressed through what are called prerequisite programs (PRPs) within the context of HACCP (Mortimore & Wallace, 2013). Hygiene alone is not enough to ensure food safety or prevent disease; a comprehensive system is needed to manage potential risks, such as cross-contamination, and ensure proper labeling. For instance, many countries require that allergens be declared on food packaging. When designing hygiene management systems, it's important to consider the specific hygiene needs of the situation. For example, the requirement for food handlers to wear hairnets may not apply to workers harvesting lettuce by hand, as lettuce is later cleaned in a way that removes not just hair, but other foreign materials as well. However, other hygiene practices, like controlling contamination in the growing environment (e.g., protecting against bacteria such as Enterohemorrhagic Escherichia coli from untreated fertilizers or contaminated water), are critical, as subsequent food processing might not eliminate all harmful pathogens. In this sense, hygiene management systems complement HACCP by addressing risks that can be easily prevented or mitigated, streamlining the process before focusing on the more complex hazards that require specific HACCP interventions. A key resource for hygiene standards is Codex Alimentarius, which provides a wide range of internationally accepted hygiene practices. While Codex serves as a foundation for many food safety systems, it is not itself a certification system, and there is no global certification schemes directly based on Codex (Ripolles-Avila et al., 2020).

In the realm of hygiene management, the 5S methodology is an important approach to consider. Originally developed in Japan, 5S focuses on organizing the workplace by eliminating waste in various forms—such as unnecessary tools, parts, and instructions—and removing dirt and clutter. The goal is to create a standardized, clean, and efficient workspace that is always well-organized. Depending on how it's implemented locally, 5S can also contribute to safety, employee satisfaction, and product quality. Although 5S originated outside the food industry, it is easily adaptable to support hygiene management and improve operational reliability. Many organizations use 5S as a foundation for continuous improvement programs. For broader hygiene management systems, there are globally recognized certification schemes, such as those under the Global Food Safety Initiative (GFSI). For example, the FSSC 22000 standard includes a specific prerequisite program standard, ISO/TS 22002-1:2009 (updated in 2020), which enhances the ISO 22000 food safety management system to offer a comprehensive solution. Another important framework is the American Institute of Baking (AIB) certification, which places a strong emphasis on hygiene in food production—particularly where the baking process provides effective control over microbiological risks. Additionally, numerous local standards exist, often tailored to specific types of food products and their unique safety requirements (Bomba & Susol, 2020; Lokunarangodage et al., 2016).

2.2 Production building, design of facilities and equipment

In 2020, Hygienic Design (HD) was added to the scope of the GFSI Benchmarking Requirements, specifically in two areas: J1 (Hygienic Design of Food Buildings and Processing Equipment for building constructors and equipment manufacturers) and J2 (Hygienic Design of Food Buildings and Processing Equipment for users of the buildings and equipment). Hygienic Design focuses on creating food processing plants and equipment that are easy to clean, durable, and offer effective protection from hazards. As a result, HD can be seen as a prerequisite program (PRP) within the HACCP framework. At the time of writing, no GFSI-recognized Certification Process Owner (CPO) standards have been established for these HD requirements. The principle of prevention and risk reduction is generally considered the exclusive domain of the HACCP system. HACCP was originally developed by the Pillsbury company in the 1960s and was formalized by Codex in 1993. Since Codex Alimentarius serves as the foundation for national food safety laws and international trade, HACCP has been adopted by many countries as a legal requirement. ISO 22000 is the leading international standard for certifying HACCP systems, but it does not specifically address the necessary hygiene conditions (PRPs). This is where frameworks like the GFSI certification schemes come into play, which focus on hygiene and other prerequisites not covered in ISO 22000 (Overbosch & Blanchard, 2023).

Importantly, none of the mentioned standards or schemes specify hazards to be addressed or reduced. Instead, it is up to the expertise of those who design, implement, and verify the HACCP system to identify the relevant hazards and determine how to mitigate them. Auditors play a crucial role in assessing whether the system meets the required standards. Some large food manufacturers have developed a two-tier system, where each product category (such as canned pineapple, frozen vegetables, or smoked sausage) has a detailed process flow and specific hazard control measures. It is then the responsibility of the individual manufacturing site to implement the plan and add any additional controls as needed for local hazards. While this approach is generally effective, it requires high-level expertise to execute properly. The widespread legal requirement for HACCP throughout the supply chain has, in some cases, led to its misapplication. For example, businesses handling only pre-packaged, shelf-stable foods may feel pressured to create their own Critical Control Points (CCPs), even though they may not be necessary. To manage this complexity, especially when dealing with a broad range of products, risk matrices are often used. These matrices assess various factors, including the inherent risk of the product (such as its ability to support pathogen growth based on factors like water activity or pH), the likelihood of chemical contamination, and risks related to suppliers or product origins. Microbiological modeling is also increasingly used to support risk matrices. This modeling looks at the growth and death rates of relevant microorganisms under real-world conditions, considering product characteristics (such as packaging type), processing conditions, storage factors (temperature, time, humidity), and the expected consumer handling and preparation. This data helps in refining risk assessments and ensuring that food safety measures are both accurate and practical (Abate Reta & Hailu Addis, 2015; S. J. Forsythe, 2008).

2.3 Operation control

Food safety is a fundamental aspect of food operations, ensuring that products are safe, nutritious, and of high quality for consumers. Effective control of food operations involves a comprehensive range of practices, policies, and procedures that work together to minimize the risks of foodborne illnesses and contamination throughout the entire food supply chain, from farm to table. At the heart of food operations control is the application of Hazard Analysis Critical Control Point (HACCP) principles, which offer a structured method for identifying, assessing, and managing food safety hazards. HACCP begins with a thorough hazard analysis to identify potential biological, chemical, and physical hazards at each stage of food production, processing, and preparation. Once these hazards are identified, critical control points (CCPs) are established specific stages in the food operation where control measures can be applied to prevent or reduce the identified risks. Examples of CCPs might include monitoring cooking temperatures, chilling times, or ensuring proper storage conditions (Panisello & Quantick, 2001).

To ensure these control measures are working effectively, food operators develop monitoring procedures that track compliance with the established standards. Regular monitoring allows any deviations from the standards to be quickly detected, enabling corrective actions to be taken before unsafe food reaches consumers. Beyond HACCP, training and education are essential in creating a culture of food safety within food operations. It is important that all staff members, from management to kitchen workers, understand their role in maintaining food safety. Training programs should cover key topics like personal hygiene, cross-contamination prevention, correct food handling practices, and the importance of temperature control. By providing staff with the necessary knowledge and skills, food operations can significantly reduce the risk of human error, which is often a major factor in food safety failures. Clear communication of food safety protocols and individual responsibilities ensures that all team members uphold safety standards consistently. Record-keeping is another critical element of food operations control. Accurate records provide documentation of food safety practices and decisions made throughout the food handling process, helping to ensure compliance with regulations and offering a valuable resource for identifying trends or areas that need improvement. Maintaining logs for things like food temperatures, cleaning schedules, and training sessions creates accountability and transparency in food safety operations. Finally, regular internal audits and inspections are proactive measures that help identify potential weaknesses in the food safety system before they lead to contamination or illness. These audits serve as an essential tool for assessing the effectiveness of food safety controls and ensuring that food safety standards are consistently met (De Silva, 2007; Dlamini & Adetunji, 2023; Panisello & Quantick, 2001).

Collaboration with suppliers is also critical in food operations control, as food safety starts long before products reach the kitchen. Establishing strong relationships with suppliers ensures that they adhere to strict safety standards and practices, from sourcing raw ingredients to packaging. Food operators should conduct due diligence when selecting suppliers, including reviewing their food safety certifications and practices. Regular communication and partnership with suppliers can foster shared responsibility for food safety and help ensure that only safe and high-quality ingredients enter the operation. Technology plays an increasingly important role in enhancing food safety in operations control. Advancements in food safety technology, such as temperature monitoring devices, digital food safety management systems, and traceability tools, have improved the ability to monitor and manage food safety practices in real-time. These innovations can provide alerts for temperature fluctuations or deviations from safety protocols, allowing for immediate corrective actions. Additionally, technology can simplify documentation and record-keeping processes, making it easier for food operators to maintain compliance with food safety standards. It is essential to cultivate a positive food safety culture within the organization. This culture should emphasize the shared responsibility of all employees in maintaining food safety, recognizing that their actions directly impact consumer safety and public health. Management should lead by example, demonstrating a commitment to food safety through their actions and decisions. Encouraging open dialogue about food safety challenges and successes among staff members can also enhance engagement and continuous improvement within food operations control. By implementing HACCP principles, providing ongoing training and education, maintaining meticulous records, collaborating with suppliers, leveraging technology, and fostering a strong food safety culture, food operations can significantly reduce the risks of foodborne illnesses and ensure the safety and quality of the food served. These efforts are vital not only for protecting consumers but also for building trust and maintaining the integrity and reputation of food businesses in the competitive food industry (Gereffi & Lee, 2009; B. G. Smith, 2008; Trienekens & Zuurbier, 2008).

2.4 Sanitation

Food sanitation is a critical component of food safety in the food processing industry. It encompasses the practices and procedures that prevent contamination of food products at every stage of production, from raw material handling to the final packaging of food. Effective food sanitation ensures that food products are safe for consumption, free from pathogens, and in compliance with health and safety regulations. Given the complexity of food production, sanitation is not just about cleanliness but also involves the prevention of foodborne diseases, maintaining quality, and ensuring regulatory compliance. Food sanitation in food processing is a multifaceted concept that extends beyond simple cleanliness. It aims to prevent both microbial and chemical contamination, reduce cross-contamination, and maintain an overall safe environment for food production. Inadequate sanitation can lead to contamination, foodborne illnesses, or spoilage, which can have significant consequences for both consumers and producers. Foodborne illnesses caused by contaminated food are a serious public health concern. According to the Centers for Disease Control and Prevention (CDC), approximately 48 million people in the United States suffer from foodborne illnesses each year, resulting in 128,000 hospitalizations and 3,000 deaths (Ikpe, 2021; Kassem, 2018). Pathogens like *Salmonella*, *Escherichia coli* (E. coli), *Listeria*, and *Campylobacter* are common culprits of these illnesses, and many of these pathogens are spread through improper sanitation practices during food processing. Proper food sanitation helps mitigate these risks by ensuring that food is handled, prepared, and stored in a hygienic environment. In the context of food processing, sanitation is not only essential for consumer safety but also for maintaining the quality and shelf life of food products. Clean environments and equipment contribute to better food quality, preventing spoilage, off-flavors, and unwanted microbial growth (Akbar & Anal, 2011).

Food sanitation is governed by numerous regulations, which vary by country but are designed to protect consumers and maintain food safety standards. In the United States, several regulatory agencies enforce sanitation and food safety guidelines, including: The FDA enforces sanitation standards for food products that fall under its jurisdiction, including processed foods, beverages, and dietary supplements. The FDA's Food Code provides a comprehensive set of guidelines related to sanitation in food establishments, including cleaning, temperature control, and hygiene practices (Marriott et al., 2006). The FDA also conducts inspections and audits of food processing plants to ensure compliance. The USDA oversees the sanitation standards for meat, poultry, and egg products. The Food Safety and Inspection Service (FSIS), a branch of the USDA, sets standards for food sanitation in meat and poultry processing facilities. FSIS guidelines include regulations for pathogen control, temperature monitoring, and cleaning procedures. While OSHA primarily focuses on worker safety, its regulations also impact on food sanitation, particularly in ensuring that workers are protected from hazards such as chemicals used in cleaning and sanitation. OSHA mandates that food processing facilities provide adequate training, protective equipment, and safe handling procedures for cleaning chemicals. On a global level, organizations such as the Codex Alimentarius Commission (Codex), which was established by the World Health Organization (WHO) and the Food and Agriculture Organization (FAO), create international standards and guidelines for food safety, including sanitation. Codex provides recommendations on hygiene practices, including cleaning, sanitizing, and handling procedures for food processors. Effective sanitation in food processing requires the implementation of specific practices across different stages of production (Commission et al., 2007). The key sanitation practices are discussed below.

2.4.1 Cleaning and Sanitizing Equipment

Cleaning and sanitizing equipment and surfaces is one of the most important aspects of food sanitation. Equipment, machinery, tools, and utensils that come into direct contact with food must be thoroughly cleaned to remove dirt, grease, food residue, and any contaminants. Inadequate cleaning can provide breeding ground for bacteria and other pathogens, leading to contamination of the food product. Cleaning typically involves the removal of visible debris, while sanitizing aims to kill any remaining microorganisms that could pose a risk to food safety. Different types of sanitizers (e.g., chlorine-based, iodine-based, quaternary ammonium compounds) are used to reduce microbial contamination. The frequency of cleaning and sanitizing depends on the type of food product being processed, the nature of the equipment, and the specific risks associated with the production environment (Yemics & Harmanci, 2020).

2.4.2 Employee Hygiene and Training

Employees play a central role in food sanitation. Ensuring proper personal hygiene is essential to minimize the risk of food contamination. Workers must adhere to stringent hand-washing protocols, use protective clothing such as gloves, aprons, and hairnets, and avoid touching food or food contact surfaces with bare hands. Regular training programs are necessary to teach employees about proper food handling practices, the importance of hygiene, and how to recognize and prevent contamination risks. Food processors must also enforce policies that address illness reporting, ensuring that employees who are ill, especially with gastrointestinal symptoms, are excluded from food handling duties. This helps prevent the spread of pathogens, particularly from employees to the food products (Todd et al., 2010).

2.4.3 Temperature Control

Proper temperature control is critical for preventing the growth of harmful bacteria and pathogens. The "danger zone" for food safety is between 40°F (4°C) and 140°F (60°C), where bacteria multiply most rapidly. During food processing, it is important to maintain strict temperature controls during every step—whether it's in the refrigeration, freezing, cooking, or holding stages. For example, perishable items should be kept under refrigeration at or below 40°F (4°C) during processing and storage. Cooking should be done at temperatures high enough to kill pathogens (e.g., 165°F or 74°C for poultry). Similarly, foods that are hot held must be kept at 140°F (60°C) or above to prevent bacterial growth (Mutton, 2009).

2.4.4 Pest Control

Controlling pests such as rodents, insects, and birds is an essential part of food sanitation. These pests can contaminate food products directly or indirectly through their droppings, urine, or nesting. An effective pest control program involves regularly inspecting and maintaining the facility, sealing entry points, and using traps or bait systems. A clean environment is essential for minimizing pest infestations. Pests are attracted to areas where food scraps and waste accumulate, so maintaining cleanliness is a key preventive measure (Trematerra & Fleurat-Lessard, 2015).

2.4.5 Cross-Contamination Prevention

Cross-contamination occurs when harmful microorganisms or allergens are transferred from one food item or surface to another. This can happen through direct contact between contaminated and uncontaminated foods, or indirectly through food contact surfaces, equipment, or employees' hands. Preventing cross-contamination is an essential part of sanitation in food processing. Practices to prevent cross-contamination include using separate equipment for different food products (e.g., raw meat vs. ready-to-eat foods), color-coding utensils and cutting boards, and maintaining clear separation between raw and cooked foods throughout the production process (Starovoytova, 2019).

2.4.6 Waste Management

Proper waste disposal is a crucial element of food sanitation. All food waste, packaging material, and other refuse should be collected, stored, and disposed of in a hygienic and environmentally responsible manner. Organic waste should be kept away from food processing areas to reduce the risk of contamination and pest attraction. Additionally, waste bins should be regularly emptied and cleaned to prevent odor and contamination (Schuler et al., 1999).

2.5 Maintenance and cleaning

In addition to cleaning equipment and tools, maintaining the cleanliness of the entire facility is important. The floors, walls, ceilings, and ventilation systems of food processing plants must be kept clean and free from any potential sources of contamination. High-touch areas such as door handles, light switches, and restroom facilities should also be disinfected regularly (Resendiz et al., 2023). Failure to adhere to proper sanitation practices can have severe consequences for both food producers and consumers. The risks associated with inadequate sanitation include. Poor sanitation practices can lead to foodborne illness outbreaks. Bacteria, viruses, and parasites can thrive in unsanitary conditions, contaminating food products and making consumers ill. In severe cases, foodborne illness outbreaks can lead to hospitalization or deaths. A food processing company found guilty of poor sanitation practices can suffer irreparable reputational damage. News of a contamination incident or foodborne illness outbreak can spread quickly, eroding consumer trust and leading to a significant decline in sales. Food safety violations can lead to lawsuits, fines, product recalls, and even plant shutdowns. Companies may also face regulatory actions that lead to loss of operating licenses or legal liability for damage caused by contamination. Poor sanitation leads to higher operational costs. These costs can include increased product losses due to contamination, higher pest control costs, and the costs of cleaning up contamination incidents. Food sanitation is a cornerstone of food safety in food processing. Proper sanitation practices are essential for preventing contamination, safeguarding public health, maintaining product quality, and ensuring compliance with regulations. By adhering to stringent sanitation protocols, food processors can mitigate the risks associated with foodborne illnesses and contamination, protect their reputation, and contribute to a safer, healthier food supply. As consumer demands for safe, high-quality food continue to grow, so too will the importance of sanitation in the food processing industry. Effective sanitation not only reduces the risk of contamination but also promotes a culture of food safety that benefits everyone in the food supply chain (Madilo et al., 2024; Sousa, 2008; Yapp & Fairman, 2006).

2.6 Personal hygiene

Personal hygiene in food processing is a critical aspect of maintaining food safety and ensuring the health of consumers. It refers to the practices that food handlers and workers must follow to prevent contamination and ensure that food products remain safe, nutritious, and of high quality (Okpala & Korzeniowska, 2023). Since food processing environments are often high-risk areas for contamination due to the nature of raw materials, equipment, and machinery involved, maintaining strict personal hygiene standards is essential in preventing foodborne illnesses and ensuring compliance with food safety regulations. Food handlers play a direct role in safeguarding food safety, as they are in close contact with raw materials, utensils, processing machinery, and the final product. The first and most fundamental aspect of personal hygiene is regular handwashing, which is vital for removing bacteria, viruses, and dirt from the hands before and after handling food, especially raw food items like meats, vegetables, or eggs. It is essential that workers wash their hands thoroughly with soap and water for at least 20 seconds, paying attention to areas like nails, between fingers, and wrists, as these are common places for bacteria to accumulate. Workers should also use hand sanitizers if handwashing facilities are not immediately available (Bloomfield et al., 2012; Redmond & Griffith, 2003).

In addition to hand hygiene, food handlers must wear appropriate personal protective equipment (PPE), such as gloves, aprons, masks, hairnets, and closed-toe shoes, to reduce the risk of contamination. Hairnets and caps help prevent hair from falling into food, while gloves protect both the worker and the product from direct contact. Gloves should be regularly changed and used properly to avoid cross-contamination between different types of food. PPE should be clean and maintained regularly, and it should be replaced immediately if it becomes soiled or damaged. Food handlers must also ensure that their clothing and footwear are kept clean, as dirt or contaminants can be transferred from them to the food. Personal items such as jewelry, watches, or smartphones should not be worn in food processing areas, as they can harbor bacteria and pose contamination risks. In addition to physical hygiene, workers must follow proper procedures for illness reporting. Any worker who is ill, particularly with gastrointestinal symptoms like vomiting or diarrhea, should be excluded from food handling tasks until they have fully recovered to prevent spreading infectious diseases (Organization & others, 2020; Sarkar et al., 2020).

2.7 Transportation

The transportation of food is a critical phase in the food supply chain that directly impacts food safety and quality. Ensuring that food products are transported in conditions that preserve their integrity, prevent contamination, and maintain optimal freshness is essential for safeguarding consumer health and complying with food safety regulations. Whether transporting raw materials from farms to processing plants or finished goods from distribution centers to retailers, proper handling, temperature control, and sanitation during transportation are key factors that influence the final product's quality, safety, and shelf life. One of the most important factors in the safe transportation of food is temperature control. Many foods, especially perishable items like meat, dairy, fruits, and vegetables, require specific temperature ranges to remain safe for consumption and to preserve their nutritional value, texture, and taste. For instance, refrigerated foods should be transported in refrigerated vehicles, known as reefers, which are equipped with cooling systems that maintain a constant temperature. The temperature must be carefully monitored to avoid fluctuations that could lead to bacterial growth or spoilage. For frozen products, it is critical that the transportation temperature remains below -18°C (0°F) to prevent thawing and refreezing, which can compromise product quality and safety. Similarly, non-perishable foods, though less susceptible to temperature changes, should still be kept at appropriate temperatures to prevent damage to packaging or potential contamination (Aung & Chang, 2014; Haji et al., 2022).

Sanitation and hygiene during transportation are also paramount in preventing contamination. All food transport vehicles must be thoroughly cleaned and sanitized before use to eliminate the presence of dirt, pathogens, and allergens. Regular cleaning and disinfection of vehicles help to avoid cross-contamination between different food products (Moerman, 2017). For example, transporting raw meats in the same vehicle as fresh produce can lead to harmful cross-contamination, which is a significant risk factor for foodborne illnesses. Transporters should also ensure that food is properly packaged and secured to minimize movement during transit, which can cause physical damage, contamination, or spoilage. Sealed containers or pallets can prevent direct contact between food products and the transport vehicle, further reducing contamination risks. Traceability and documentation are critical aspects of food transportation that help maintain food safety and quality (Bryan, 1988; Carrasco et al., 2012). Proper documentation ensures that food can be traced back to its origin, allowing for transparency in the event of a food safety issue, such as a product recall. Transporters should maintain records of the temperature, time, and conditions under which food was transported, as well as the vehicle's cleaning and maintenance schedules. These records are important for both regulatory compliance and for reassuring consumers that the food they are purchasing has been handled in accordance with safety standards. Another vital consideration is the timeliness of transportation. Speed is essential for minimizing the time food spends in transit, reducing the opportunity for spoilage, and maintaining freshness. Perishable products should be delivered to their destination as quickly as possible to ensure that they reach retailers or consumers within their optimal shelf life. A well-organized, efficient logistics system that uses real-time tracking and route optimization technologies can help minimize delays and ensure timely deliveries. Moreover, vehicle maintenance and monitoring systems are essential for ensuring that transportation conditions remain stable throughout the journey. Vehicles should be regularly serviced to ensure that refrigeration units, air conditioning systems, and other temperature control mechanisms are functioning properly. In addition, the use of GPS tracking systems and temperature sensors within vehicles allows for constant monitoring, providing real-time data on location and temperature conditions, which helps identify potential issues before they become problematic (Robinson et al., 2013; Sharma et al., 2024).

2.8 Training

Food safety training is a vital element in ensuring the safe production of food in the processing industry. Given the complexities of modern food production from sourcing raw ingredients to packaging and distribution effective training ensures that workers at every stage of the process understand and adhere to rigorous safety standards. This training is crucial for minimizing the risk of contamination, preventing foodborne illnesses, and ensuring that food products meet the quality expectations of consumers and regulatory bodies. With increasingly globalized food supply chains and rising consumer expectations for safe, high-quality food, food safety training has become more important than ever. At the heart of food safety training is HACCP (Hazard Analysis and Critical Control Points), a preventive approach to food safety that identifies potential hazards at critical stages in the production process. Workers must be trained to understand and implement HACCP principles, recognizing hazards like biological, chemical, and physical contaminants that could affect food safety. They learn to identify critical control points (CCPs) places in the production process where risks are most likely to occur and how to monitor these points to ensure food safety is maintained. By understanding their role in this system, employees are empowered to take corrective actions when necessary, reducing the likelihood of contamination (Adesokan et al., 2015; McFarland et al., 2019; Park et al., 2010).

In addition to HACCP, training programs in the food processing industry cover Good Manufacturing Practices (GMP), which focus on maintaining cleanliness, hygiene, and proper handling of food materials. Training emphasizes the importance of personal hygiene, such as regular handwashing, wearing appropriate personal protective equipment (PPE), and maintaining a clean work environment. Contamination can easily occur if workers fail to follow these basic hygiene practices, making it crucial that employees understand their responsibility in preventing cross-contamination and ensuring that food remains safe throughout the production process. Employees must also be educated on the risks of illness, particularly foodborne pathogens like Salmonella or E. coli, and the importance of reporting illness or injury to prevent contamination. Another key area of food safety training is temperature control. Many food products, especially perishable items, require strict temperature regulation to prevent the growth of harmful bacteria and to maintain their quality. Workers are trained to monitor and control temperature throughout the food processing chain whether during storage, transportation, or cooking. Temperature logs must be maintained, and employees must be able to react swiftly if temperature deviations occur, which could compromise food safety. Ultimately, food safety training is an ongoing process. Regular refreshers and updated training on new regulations, technologies, and emerging risks are essential to ensure that employees remain aware of the best practices. By investing in comprehensive food safety training, the food processing industry can prevent contamination, maintain product integrity, and safeguard consumer health, while also avoiding costly recalls and reputational damage (C. A. F. De Oliveira et al., 2016; Meghwal et al., 2017; Mendis & Rajapakse, 2009).

2.9 Product information and consumer awareness

In the food processing industry, product information and consumer awareness are fundamental to ensuring food safety and fostering trust between manufacturers and consumers. As consumers become more health-conscious and informed, they increasingly seek transparency regarding the food they purchase, especially concerning its safety, ingredients, nutritional value, and sourcing (W. Wu et al., 2021). The role of clear and accurate product information is critical, as it empowers consumers to make informed decisions, while also ensuring that food safety regulations are met. Food processors have a responsibility not only to provide detailed product labeling but also to educate consumers on safe food handling, preparation, and storage practices. Product labeling plays a central role in food safety, providing essential information to help consumers understand what they are consuming and how to handle the product safely (Aung & Chang, 2014). According to food safety regulations in many countries, labels must include key information such as the ingredients list, nutritional information, allergen warnings, expiry dates, storage instructions, and country of origin. This information helps consumers avoid products that may pose risks to their health due to allergies, sensitivities, or dietary restrictions. For example, clear labeling of gluten, nuts, or dairy allergens is critical for individuals with food allergies, ensuring they can avoid potentially harmful products. In addition, labels should indicate use-by or best-before dates, which help consumers avoid consuming expired products that could pose a food safety risk. Proper storage instructions on labels, such as whether a product should be kept refrigerated or frozen, further help in preserving food quality and preventing contamination or spoilage (Cordeiro et al., 2024).

In addition to mandatory labeling requirements, traceability is another important aspect of product information in food safety. Food processors must ensure that their products can be traced back to their origins through clear documentation of their sourcing, processing, and distribution methods. This is especially vital in the event of a foodborne illness outbreak or contamination recall. Transparent product traceability enables consumers to trust that the food they are consuming has been handled safely at every stage of the supply chain. It also allows for quick responses in case of any safety issues, minimizing risks to consumers and enabling manufacturers to efficiently manage recalls (Aung & Chang, 2014). Consumer awareness is equally important for food safety, as it provides the public with the knowledge necessary to handle and prepare food safely at home. Many foodborne illnesses occur due to improper food handling, such as cross-contamination, undercooking, or improper storage. Therefore, food processors and regulatory bodies must play an active role in educating consumers about proper food safety practices. This can include safe cooking temperatures, the importance of washing hands and surfaces, and how to store food correctly to avoid spoilage or contamination. Food manufacturers and retailers can promote consumer education through campaigns, websites, and informational materials on safe food handling and storage, as well as providing clear instructions for preparation on product labels (Charan & Panghal, 2018; Dabbene et al., 2014).

Moreover, online platforms and social media are increasingly being used by food processors to communicate directly with consumers. By providing accurate and updated information on food safety, including new safety standards, ingredient sourcing, and production processes, food companies can build consumer confidence and foster stronger relationships. Social media can also be a venue for addressing consumer questions and concerns about food safety, enhancing the transparency of food production processes. Lastly, food safety training for consumers should not be limited to product labels alone. Collaboration between food processors, governments, and consumer organizations can help develop educational initiatives that raise awareness about the broader aspects of food safety. Programs aimed at teaching consumers how to handle food responsibly and be aware of potential risks, such as foodborne pathogens or contaminants, are critical in reducing the incidence of food safety issues at the consumer level (Bendeković et al., 2015; King et al., 2017; Lam et al., 2020).

2.10 Conclusion

Industry compliance with established procedures and practices is more likely when regulatory bodies communicate consistently about what is necessary to protect public health, why it matters, and which alternative methods of compliance may be acceptable. Model codes serve as a framework for determining what is required. They are beneficial for businesses by offering established standards that can be used in training and quality assurance programs. They also assist local, state, and federal agencies in developing or updating their own regulations. The model Food Code, for example, provides clear guidelines on food safety, sanitation, and ethical practices that can be uniformly adopted across the retail food sector. It reflects the collective input of many experienced individuals, agencies, and organizations, drawing from years of practical experience with previous editions (Fortin, 2022; Kotsanopoulos & Arvanitoyannis, 2017).

The code acknowledges that the quality of life, public health, and general welfare are closely tied to how we safely produce and protect our food. Its provisions are aligned with, and where applicable, incorporate federal performance standards for food products and processes. These federal standards define the expected safety outcomes for products, often in terms of reducing harmful microorganisms. By focusing on performance standards as the benchmark for regulatory compliance, businesses are allowed to adopt innovative methods for ensuring food safety, rather than being restricted to traditional techniques like specific cooking times or temperatures. Federally inspected establishments demonstrate compliance with these standards through a properly designed and validated HACCP plan. Similarly, retail processors can apply for a variance to use federal food safety performance standards as an alternative to the regular requirements in the Food Code, provided they can demonstrate that their processing methods meet the necessary safety standards. To secure such a variance, retail processors must present a validated HACCP plan and maintain proper records and verification, just as federally inspected businesses do (Hubbard, 2012; Humphrey, 2012).

In conclusion, implementing food safety standards in small or medium-sized food factories is crucial for ensuring the production of safe, high-quality food products. By adopting internationally recognized food safety frameworks such as HACCP, these businesses can systematically identify, control, and mitigate potential hazards, reducing the risk of contamination and foodborne illnesses. Furthermore, regular staff training, proper hygiene management, and consistent monitoring of critical control points are essential to maintaining a culture of food safety. Small and medium-sized food factories can benefit from the structure and clarity provided by food safety standards, which not only ensure compliance with regulatory requirements but also enhance consumer trust and marketability. It is recommended that these businesses invest in the necessary resources, such as training programs, hygiene systems, and record-keeping practices, to build a robust food safety management system. Additionally, seeking certification through recognized programs like GFSI can provide added credibility and competitive advantage in the industry. With the right commitment to food safety, small and medium-sized food factories can thrive while safeguarding public health (Demmler, 2020; Mayett-Moreno & López Oglesby, 2018; Organization & others, 2022).

3. Agricultural Value Addition: Benefits, Processing Techniques, and Packaging Strategies for Small and Medium-Sized Enterprises

3.1 Introduction

Agricultural value addition is a pivotal strategy for enhancing the economic prospects of small and medium-sized enterprises (SMEs) in the food processing sector. It involves transforming raw agricultural products into finished or semi-finished goods through various processes, adding quality, appeal, and market value to these products. For small and medium-sized businesses, which often face challenges such as limited access to resources, technology, and markets, the practice of adding value to agricultural products is a promising way to improve profitability, extend product shelf life, reduce post-harvest losses, and tap into larger and more diverse markets. The benefits of agricultural value addition are far-reaching. It not only boosts the income and profitability of farmers and SMEs but also plays a critical role in rural development, poverty reduction, and food security. By processing raw agricultural commodities, businesses can extend the usability of these products, mitigate seasonal glut or scarcity, and create a variety of value-added products that can cater to changing consumer preferences. This approach not only provides a steady stream of income for agricultural producers but also opens doors for innovation in food product development and marketing, contributing to the sustainability of both SMEs and the agricultural industry (Chambo, 2009; Fan et al., 2013; Moyo, 2016).

Agricultural value addition brings a variety of advantages to both small and medium-sized enterprises (SMEs) and the broader agricultural economy. The most obvious benefit is the potential to increase the profitability of agricultural products. Raw agricultural commodities are often sold at lower prices, especially when there is a glut in supply or when the product is in its peak harvest season. By adding value through processing, SMEs can transform these raw materials into more marketable products, commanding higher prices and thereby improving their profitability. In addition to higher income potential, value addition helps SMEs differentiate their products in competitive markets. By offering processed and packaged goods that meet consumer demands for quality, convenience, and unique features, SMEs can carve out niche markets (Bennett & Smith, 2002; Ensari & Karabay, 2014; O. Jones & Tilley, 2009).

These markets could include organic foods, health-conscious products, or regionally inspired specialties. Value-added products also have longer shelf lives than their raw counterparts, reducing the risks of spoilage and wastage, which is particularly important in regions where food security is a concern. Moreover, value addition contributes to employment generation, especially in rural areas where agricultural SMEs are often based. Processing, packaging, and marketing of agricultural products require skilled labor and create job opportunities along the value chain. These jobs can have a significant impact on local economies, providing stable income sources for individuals who might otherwise depend solely on primary agriculture. By processing raw agricultural products, SMEs are also helping to address food security concerns. Value-added products tend to be more durable and storable, which helps ensure that food supplies are available year-round, even in the off-season. Furthermore, these products can be distributed over longer distances, including international markets, further strengthening the supply chain and promoting food trade (Gereffi et al., 2008; Minor et al., 2020).

Processing techniques are the backbone of agricultural value addition, and they vary widely depending on the type of raw material and the desired product. The right processing method not only affects the quality of the final product but also its nutritional content, shelf life, and marketability. One of the most common and simplest forms of value addition is drying, which reduces the moisture content of agricultural products, making them more stable and less susceptible to microbial growth. Drying techniques vary from solar drying to the use of mechanical dryers. Dried fruits, vegetables, and herbs are popular examples of value-added products that can fetch higher prices due to their extended shelf life and convenience. Fermentation is a time-tested method of food preservation that also enhances the flavor, texture, and nutritional profile of products. It is used widely in the production of dairy products, beverages (such as yogurt, kefir, and kombucha), and fermented foods like sauerkraut, kimchi, and pickles. For SMEs, fermentation presents an opportunity to create a variety of health-oriented products, as fermented foods are known for their probiotic benefits (Press, 2015).

Milling grains into flour is another common value addition technique that has been practiced for centuries. It enables raw grains like wheat, corn, and rice to be transformed into finished products used in baking and cooking. Small-scale millers can create specialty flours such as gluten-free or whole grain variants, catering to modern consumer preferences. For fruits, vegetables, and seeds, cold-pressing and extraction techniques are employed to produce juices, oils, and concentrates. Cold pressing preserves the nutrients and flavors in the raw material and is particularly popular in the production of healthy beverages and oils like olive oil, avocado oil, and fruit juices. For SMEs, this technique provides an opportunity to cater to the growing demand for natural, minimally processed foods (J. M. Jones et al., 2015; Pinheiro Pantoja et al., 2024).

Canning is a technique that involves sealing food in containers and heating them to destroy spoilage-causing microorganisms. This method has long been used for preserving fruits, vegetables, meats, and seafood. SMEs can use canning to create products like jams, pickles, sauces, and soups that can be sold in both local and international markets. Blanching involves briefly exposing products like vegetables to heat before rapidly cooling them, while pasteurization is a heat treatment that destroys harmful pathogens. Both methods help to increase the shelf life of fresh products while maintaining their nutritional value and safety. These techniques are commonly used in the production of ready-to-eat meals, soups, and sauces. Packaging plays a vital role in the success of value-added agricultural products. It serves as both a protective barrier and a marketing tool (Mohan et al., 2015; Rabiepour et al., 2024). Proper packaging ensures that the product remains fresh, safe, and appealing to consumers. For SMEs, adopting effective packaging strategies is essential for maximizing the shelf life of products, complying with regulations, and attracting customers. Packaging protects value-added products from physical damage, contamination, moisture, and oxygen, all of which can lead to spoilage. Vacuum-sealed bags, modified atmosphere packaging (MAP), and airtight containers are some packaging methods that can help extend the shelf life of products, particularly in the case of fresh produce, dairy, and meats (Opara & others, 2013).

With growing consumer concern over environmental sustainability, using eco-friendly packaging is becoming a key selling point for food products. SMEs can adopt biodegradable, recyclable, or compostable packaging materials to appeal to environmentally conscious consumers. This strategy aligns with global sustainability trends and can enhance the brand's reputation in the marketplace. Packaging also plays a crucial role in marketing. Clear, attractive, and informative packaging can help products stand out on the shelf and communicate their quality, origin, and unique features to consumers. SMEs can use labeling to highlight the benefits of their products, such as organic certification, health benefits, or local sourcing. Packaging innovations that enhance consumer convenience, such as re-sealable pouches, portioned servings, and ready-to-eat products, can increase product appeal. By focusing on convenience, SMEs can cater to the modern consumer's busy lifestyle and demand for quick, easy-to-use food options. Agricultural value addition presents an exciting opportunity for small and medium-sized enterprises to improve the profitability, sustainability, and competitiveness of their businesses. Through innovative processing techniques, SMEs can transform raw agricultural products into high-value goods that meet the demands of consumers and the marketplace. By using appropriate packaging strategies, SMEs can ensure the longevity, safety, and attractiveness of these products, while also promoting environmental sustainability. Value addition benefits not only individual businesses but also the broader agricultural sector, contributing to rural development, job creation, and food security. As demand for quality and diverse food products continues to grow, SMEs in agriculture have the potential to thrive by embracing value addition as a core business strategy (Grayna et al., 2022; Kutkaitis & Hlasha Al Sibai, 2024; Wandosell et al., 2021).

3.2 Benefits of agricultural value addition

The concept of food preservation has evolved significantly over the years. Initially, its main goal was simply to extend shelf life and ensure the safety of food products. However, consumer demand has shifted, and today's expectations go beyond just safety and longevity. Consumers increasingly seek food that retains fresh-like qualities, such as high levels of nutrients and antioxidants, all while maintaining food safety standards. Traditional methods like thermal sterilization and pasteurization, which are effective at reducing harmful microorganisms, often result in the loss of heat-sensitive nutrients and negatively impact the sensory, physicochemical, and nutritional properties of the food (Chiozzi et al., 2022). The global agricultural market has grown more complex due to various factors, including changing consumer preferences, advancements in technology, evolving food safety and quality standards, and shifts in the food industry structure along the entire value chain. As a result, a larger portion of the final price that consumers pay for food is now generated in the post-farm gate stages of the supply chain, rather than at the production level on the farm. Today, the input and production stages contribute roughly 16% of the final price of food, while the remaining 84% is attributed to processing, distribution, and marketing (Weis, 2007). This shift in the distribution of value along the food value chain highlights the growing importance of value addition in the post-farm segments of the industry.

The Food Dollar Series, a tool developed by the Economic Research Service (ERS), tracks how much of the consumer dollar is allocated at each stage of the agrifood value chain. This series has been used by researchers and policymakers since the 1940s to better understand the economic dynamics of the food industry (Jantjies, 2024). According to the Food Dollar analysis, there is often concern that farmers may be creating more value than they are capturing, with some policymakers suspecting the influence of anti-competitive forces along the value chain (Howard, 2021). Despite the relevance of value creation and capture in agribusiness, the concept of value is not always clearly defined or consistently measured in academic and managerial literature. Studies have shown that there is a lack of consensus on how to explicitly define or quantify "value" in the context of the agrifood value chain (Toussaint et al., 2022).

Historically, the agribusiness industry has been centered around a commodity-based model, prioritizing efficiency, standardized products, and economies of scale. In the past, companies could achieve profitability without focusing heavily on creating value, as they relied on factors such as controlled distribution channels, regulated markets, the acquisition of underperforming firms, or limited resource availability. While these markets were successful in producing large quantities of uniform products, shifts in consumer demand toward safer, higher-quality, and more convenient products, combined with technological advancements and increasing competition, have driven the need for more differentiated offerings. As a result, businesses have had to focus more on value-added activities to meet evolving consumer expectations and capitalize on emerging opportunities in the agribusiness sector. In recent years, value creation and value addition have become critical strategies for business survival in the agriculture and food industries (Ba & others, 2016; Baffes & Nagle, 2022; Webber & Labaste, 2009).

In the context of agribusiness, value creation, or "value adding," refers to the process through which a company modifies a product's place, time, and form to make it more desirable or preferred by consumers in the marketplace. Historically, value creation and value adding were considered synonymous, and the concept of value adding has been particularly useful in analyzing agricultural profitability (Kumar & Reinartz, 2016). The U.S. Farm Bill of 2002 defines value adding as any change in the physical state of an agricultural commodity through processing or handling that enhances its marketability (MacDonald et al., 2004). This process expands the potential customer base for the product and increases the revenue derived from its marketing, processing, or segregation by the producer. Since 2009, the U.S. Department of Agriculture (USDA) has provided 863 value-added producer grants, totaling $108 million, to assist businesses in transforming raw commodities into higher-value products. These grants underscore the importance of value addition as an integral part of agribusiness strategy (Olayemi & Olatidoye, 2024).

4. Thermal Processing Techniques for Food Preservation and Processing in Small and Medium-Sized Food Factory

4.1 Introduction

Thermal food processing and preservation play a crucial role in extending the shelf life of food products while maintaining their safety, flavor, and nutritional value. For small and medium-sized food factories, this process is essential for producing commercially viable products while ensuring food safety standards are met and operational costs are kept under control. Thermal processing, which includes techniques such as pasteurization, sterilization, and blanching, works by applying heat to food to destroy harmful microorganisms like bacteria, yeasts, molds, and enzymes that contribute to spoilage and foodborne illnesses (Deak & Mohácsi-Farkas, 2023). The fundamental goal is to achieve microbial inactivation while minimizing the negative effects on the quality of the food. The application of heat can be done through different methods, such as direct or indirect heat treatment, depending on the type of food and the desired outcome. In pasteurization, food is typically heated to temperatures below 100°C for a specific period, while sterilization requires higher temperatures, often above 100°C, to ensure the complete destruction of microorganisms. Blanching, on the other hand, involves briefly exposing food, such as vegetables, to boiling water or steam to inactivate enzymes that can cause quality degradation, particularly in frozen foods. For small and medium-sized food factories, the choice of thermal processing method depends on several factors including the type of food, the desired shelf life, production volume, and available equipment (Sruthy et al., 2022).

One of the key considerations in thermal processing is the heat penetration rate, as certain food products may have varying compositions that affect how evenly and quickly heat distributes throughout the product. This is especially important for thicker or denser foods such as meats, soups, or sauces, which may require specialized equipment like retort machines or autoclaves to ensure uniform heat distribution. Additionally, the duration of heat application is critical; overcooking or overheating food can result in a loss of flavor, texture, and nutritional quality, while under processing can leave microorganisms viable, posing health risks. For small and medium-sized enterprises (SMEs), the balance between efficiency and quality is essential (Manzoor et al., 2022). These companies often face constraints in terms of financial resources and technical expertise, which means that choosing the appropriate thermal processing technology is not only about food safety but also cost-effectiveness.

Smaller factories may opt for batch processing systems like batch pasteurizers, which are simpler and less expensive but can be less efficient for large volumes, while larger SMEs with higher production demands might invest in continuous systems for more consistent processing at a faster rate. Additionally, investment in energy-efficient equipment is critical, as thermal food processing can be energy-intensive. Reducing energy consumption without compromising product quality is a significant challenge for smaller factories, which often rely on traditional methods or outdated equipment that may have higher operational costs (Singh et al., 2023). Thermal preservation also involves cooling or refrigeration following the heating process to prevent the re-growth of microorganisms. For example, after pasteurization, food products such as juices, dairy products, and ready-to-eat meals are typically cooled to ensure that the food stays within safe temperature ranges and to retain its taste and texture. Another important aspect of thermal food processing is the potential impact on the nutritional value of the food. The application of heat can degrade certain vitamins, minerals, and antioxidants in foods, especially those sensitive to heat, such as vitamin C and certain B vitamins (Ottaway, 2012).

Small and medium-sized food processors must therefore weigh the trade-off between effective microbial inactivation and nutrient preservation. The adoption of more advanced techniques, such as high-pressure processing (HPP) or sous-vide cooking is becoming increasingly popular in some sectors, as these methods can achieve microbial inactivation without the need for excessive heat, preserving both the quality and nutritional content of the product. Nevertheless, these methods require significant capital investment, which may not always be feasible for SMEs. Additionally, packaging technologies also play a key role in thermal food preservation. Vacuum sealing, modified atmosphere packaging (MAP), and other advanced packaging techniques help to extend shelf life by creating an optimal environment that inhibits microbial growth and minimizes oxidation. In combination with thermal treatments, these technologies provide a comprehensive approach to food preservation that can be tailored to the specific needs of different food products.

Furthermore, regulatory compliance is a significant consideration for small and medium-sized food factories, as they must meet local and international food safety standards (Amit et al., 2017). These regulations often require documented procedures and validation studies to demonstrate that the thermal processing methods used are effective in ensuring the safety of the food. Many SMEs may not have the resources to conduct expensive research or testing in-house, which can make compliance with food safety standards more challenging. Therefore, collaboration with external laboratories, food safety consultants, or universities may be necessary to validate their thermal processing methods. Moreover, with increasing consumer demand for healthier, more natural food products, there is growing pressure on small and medium-sized food factories to adopt thermal processing methods that preserve the organoleptic qualities of food, such as flavor, texture, and color, while avoiding the use of chemical preservatives (Lisboa et al., 2024). This trend towards "clean label" products, which feature minimal processing and fewer additives, is encouraging SMEs to explore more innovative thermal processing technologies that minimize the negative effects on food quality. The right choice of technology, equipment, and methods is crucial for achieving food safety, maintaining product quality, and meeting consumer expectations. By balancing cost, quality, and safety, SMEs can position themselves to compete effectively in the global food market while responding to consumer demands for higher-quality, safer, and more nutritious food options (Nguyen, 2023).

4.2 Drying

Food drying is one of the oldest and most widely used methods of food preservation, particularly important for small and medium-sized food factories looking to extend the shelf life of their products, enhance storage stability, and reduce dependency on refrigeration or freezing. Drying, as a preservation technique, involves the removal of moisture from food products, thus inhibiting the growth of microorganisms and preventing enzymatic and oxidative degradation that contribute to spoilage (Amit et al., 2017). For SMEs in the food industry, drying offers a versatile and cost-effective means of preserving a wide variety of foods, from fruits, vegetables, and meats to herbs, spices, and ready-to-eat meals. The process of drying reduces the water activity of food, making it inhospitable for bacteria, molds, and yeasts that typically thrive in moist environments. Moreover, the dehydration process helps concentrate the flavors, nutrients, and sugars of the food, potentially enhancing its taste and texture, which is particularly beneficial in sectors such as snacks, dried fruits, and even powdered food products (Ogwu & Ogunsola, 2024).

There are several methods of drying employed in small and medium-sized food factories, each with its unique advantages and challenges. These methods include air drying, sun drying, freeze drying, spray drying, and tunnel drying, and the choice of method depends on several factors, including the type of food, energy efficiency, cost constraints, and the desired product quality. Air drying, one of the simplest and most accessible methods, relies on the circulation of hot air around food to remove moisture. This method can be applied to various products, including fruits, vegetables, and meats. In small-scale operations, air drying is often conducted in low-cost, small-scale dehydrators, which can be manually or automatically controlled to regulate temperature, humidity, and airflow. Although air drying is energy-efficient, it can sometimes result in uneven drying, particularly for larger or thicker food pieces, which may lead to variations in quality and shelf life (Snyder, 2017).

Furthermore, air drying is limited by environmental conditions and may not be suitable for all food types, especially those with high moisture content, which may require more specialized drying techniques. Sun drying, a traditional method that has been used for centuries, is another cost-effective technique for small and medium-sized factories, particularly in regions with abundant sunlight and dry climates. This method involves spreading food products, such as tomatoes, fruits, or herbs, under the sun's heat for extended periods. Sun drying has the advantage of using natural energy, reducing operational costs, and being simple to implement (Snyder & Worobo, 2018). However, it has significant drawbacks, including the potential for contamination from dust, insects, and animals, as well as inconsistencies in drying due to fluctuating weather conditions. Sun-dried products often have a shorter shelf life compared to those dried using controlled, mechanized methods. In contrast, freeze drying, also known as lyophilization, is a more advanced and capital-intensive drying method that involves freezing the food, followed by a process in which the frozen water is sublimated directly into vapor under a vacuum. This method preserves the food's structure, flavor, and nutritional content more effectively than other drying techniques and results in a product that is light, airy, and highly shelf stable. Freeze-dried foods can be rehydrated quickly, making them ideal for applications in the foodservice industry, camping foods, and emergency preparedness (Hayashi, 1989; Inyang et al., 2017).

However, for small and medium-sized food factories, the high cost of freeze-drying equipment, as well as the significant energy requirements, can pose barriers to widespread adoption, particularly for operations with limited budgets. Spray drying, on the other hand, is a method widely used in the dairy, coffee, and powdered food industries, which involves spraying a liquid food product into a hot air stream, where the moisture rapidly evaporates, leaving behind dry powder. Spray drying is highly efficient for products that are initially in liquid form, such as fruit juices, milk, and soups, as it allows to produce fine powders that retain much of the original taste, color, and nutritional value (Bhandari et al., 2008; Schuck et al., 2016).

However, this method requires specialized equipment, which can be expensive, and the drying process must be carefully controlled to avoid the degradation of sensitive compounds, such as vitamins and flavors, in the food product. Additionally, spray drying can result in the loss of some volatile compounds, such as certain aromatic components in herbs or spices, and may not be suitable for high-moisture foods such as meat or leafy vegetables. Tunnel drying, commonly used for large-scale production, involves passing food through a long, heated tunnel where hot air is circulated around the product to remove moisture in a controlled, continuous flow. This method is widely used for the drying of fruits, vegetables, and herbs and is suitable for medium to large production runs. For small and medium-sized food factories, tunnel dryers can be a good choice if they have the capacity to handle large volumes of raw materials, as they allow for consistent drying across batches (Banozic et al., 2023).

However, tunnel dryers can be more costly, and space-consuming compared to other drying methods, and they require careful calibration to ensure uniformity and prevent over-drying, which can lead to product shrinkage, loss of flavor, and lower nutritional value. In choosing the most appropriate drying method, small and medium-sized food factories must also consider factors such as energy consumption, scalability, and the impact of drying on the final product's sensory qualities. Energy use is a major consideration, as drying can be an energy-intensive process, particularly for methods such as freeze-drying or spray drying. Smaller operations with limited budgets may be drawn to methods like air drying or sun drying, which require less initial investment and lower energy costs but might not offer the same level of consistency or shelf stability as more advanced methods (El-Abidi et al., 2024; Ioannou Sartzi et al., 2024; Jangam, 2011). Additionally, drying can affect the texture, color, and nutritional value of food products, and small manufacturers must balance the cost and efficiency of the drying process with the quality and appeal of the finished product. In many cases, SMEs may need to invest in equipment that balances energy efficiency with product quality and may also need to adopt strategies such as pre-treatment of food with blanching, acidulants, or antioxidants to preserve color, texture, and flavor during drying. In addition to traditional packaging methods, more innovative solutions such as biodegradable films, smart packaging with oxygen scavengers, or moisture-absorbing packets are becoming increasingly popular, especially in markets where sustainability and consumer health are prioritized (T. Das et al., 2024; Mediani et al., 2022; Sethupathy & Anandharamakrishnan, 2025).

With the growing demand for organic, natural, and minimally processed foods, small and medium-sized food manufacturers are under increasing pressure to produce dried products without the use of artificial preservatives, colors, or additives. This trend has driven the development of new drying technologies and techniques that minimize the impact of drying on the flavor, color, and nutritional value of food, while still ensuring effective microbial control and preservation. Moreover, as the global food industry faces increasing competition, small and medium-sized manufacturers are seeking ways to differentiate their dried food products by focusing on quality, uniqueness, and sustainability, which can be achieved through methods such as organic certification, the use of local ingredients, or innovative flavor profiles. Finally, food drying for preservation in small and medium-sized food factories also requires adherence to food safety regulations and quality control standards (Liu et al., 2022; Michel et al., 2024). Manufacturers must ensure that the drying process is consistent and reliable, as improper drying can lead to incomplete moisture removal, which may not effectively inhibit microbial growth, leading to spoilage or foodborne illness. Regulatory authorities in many countries require that manufacturers document and validate their drying processes, conduct regular testing for moisture content, and comply with microbiological and shelf-life testing to demonstrate product safety. For smaller operations without in-house laboratories or extensive resources, partnering with external food safety experts or third-party testing labs can be critical to ensuring compliance with regulations and maintaining consumer trust. As small and medium-sized food factories continue to evolve, the role of drying as a preservation technique will remain a cornerstone of the food processing industry, offering a wide range of opportunities for innovation, efficiency, and product differentiation (Lisboa et al., 2024; Tkaczewska, 2020).

4.3 Frying

Food frying as a preservation method in small and medium-sized food factories plays a significant role in extending the shelf life of various food products, enhancing their flavor, texture, and visual appeal, while providing a unique way of preserving both the organoleptic qualities and safety of food. The process of frying involves cooking food by submerging it in hot oil or fat, which facilitates the rapid absorption of heat, leading to the evaporation of moisture within the food. This moisture loss is a key factor in food preservation, as reducing water activity limits the growth of microorganisms, such as bacteria, molds, and yeasts, which are the primary causes of food spoilage. In many ways, frying is a form of dehydration that also creates a barrier to microbial contamination, allowing food to remain safe for consumption for a more extended period compared to fresh, uncooked alternatives. For small and medium-sized food factories, frying is especially attractive because it is an efficient method that can be applied to a wide variety of food products, including snacks, vegetables, meats, and bakery items, among others. At the same time, frying enhances the palatability of food by creating desirable textural characteristics such as crispiness and golden-brown color, which are highly prized by consumers. However, while frying can contribute to food preservation, it also presents several challenges that small and medium-sized food factories must manage, including the control of frying parameters, oil management, quality control, and regulatory compliance, all which impact product safety, consistency, and cost-effectiveness (Abate Reta & Hailu Addis, 2015; Man, 2002; Saguy & Sirotinskaya, 2014; Siddiqui et al., 2024).

In small and medium-sized food manufacturing operations, one of the most significant advantages of frying is its ability to achieve rapid preservation with relatively low capital investment compared to other preservation methods like freezing or freeze-drying, which require more sophisticated and expensive equipment. The basic equipment needed for frying, such as fryers, deep fryers, or shallow fryers, is widely available and can often be purchased at a lower cost than other processing machinery. This is especially appealing for SMEs that may not have the financial resources to invest in high-tech processing equipment. Frying also allows for high throughput, enabling manufacturers to process large batches of food in a relatively short time, making it a suitable technique for high-demand production environments. However, the main challenge with frying for preservation is achieving the correct balance between moisture removal, oil absorption, and the maintenance of food quality. The heat used in frying causes a rapid outer layer of the food to form a crispy, golden-brown crust, which acts as a barrier to further moisture loss and protects the interior of the product. This outer crust not only helps preserve the food but also improves the sensory qualities, including flavor, texture, and mouthfeel (Frakolaki et al., 2023; Oke et al., 2018).

The speed of the frying process is critical because prolonged exposure to high temperatures can result in excessive oil absorption, which leads to a greasy, unappealing product and may even introduce unhealthy trans fats if oils are overheated or reused too many times. Additionally, overheating during frying can cause the breakdown of food's nutrients, particularly sensitive compounds like vitamins A and E, and the formation of undesirable compounds such as acrylamide, which is a potential carcinogen that forms when certain foods are fried at high temperatures. A higher frying temperature typically leads to faster moisture evaporation, which results in a crispier product and faster preservation. However, too high a temperature can led to the burning or charring of food, resulting in undesirable flavors and the formation of harmful compounds. Most frying is done within a temperature range of 160°C to 190°C (320°F to 375°F), with the exact temperature depending on the food being fried, the desired texture, and the type of oil used. To maintain consistency in frying, small and medium-sized manufacturers need to invest in equipment that allows for precise temperature control, as well as systems to monitor and adjust the frying process in real-time. Advances in fryer technology, including computerized systems and temperature sensors, have made it easier for even smaller operations to maintain the correct frying parameters (Kerr, 2017; Liu, 2020).

Oil management is another critical aspect of frying, especially in the context of food preservation. Frying oil degrades over time due to the high temperatures, the presence of food particles, and the breakdown of fats, which can lead to the formation of off-flavors, unpleasant odors, and a decline in the overall quality of the food. Some modern fryers are designed with oil filtration and recycling systems that help to reduce waste, optimize oil usage, and lower operating costs. Additionally, the type of oil used for frying can also impact on the quality and healthfulness of the final product. Oils high in unsaturated fats, such as olive oil or canola oil, are often preferred for their lower levels of saturated fats and healthier lipid profile, whereas oils that are more stable at high temperatures, like palm oil, may be used for longer frying cycles in larger-scale operations (Zhang et al., 2020). Choosing the right oil depends on several factors, including the intended product, desired flavor, and cost-effectiveness, as well as consumer demand for healthier, more sustainable options. Another consideration in food frying is the development of an efficient cooling and storage system after frying, which is essential for maintaining product safety and shelf life. Some fried food products, such as potato chips, French fries, or fried snacks, benefit from being packaged in gas-flushed or vacuum-sealed bags to protect the food from exposure to air, which can lead to staleness or rancidity. In terms of shelf life, fried food products typically last longer than fresh foods due to the reduced moisture content, but their longevity can still be affected by the quality of the oil used, the temperature at which they are fried, and the conditions under which they are stored. For small and medium-sized food factories, optimizing these post-frying processes is crucial to ensuring that the final product remains safe and appealing to consumers over time (Cui et al., 2024; Sukaew, 2024).

Despite its numerous benefits, frying as a preservation method for small and medium-sized food factories also faces some significant challenges, particularly when it comes to maintaining high product quality while keeping production costs low. One such challenge is balancing the desire for crispy, flavorful products with the need to meet growing consumer demands for healthier, lower-fat food options. The concern over the health implications of fried foods has led to increased demand for alternatives that use less oil or employ healthier frying oils. Air frying, for example, has become an increasingly popular method of cooking, as it uses hot air circulation to cook food with little to no oil, which results in a lower fat content. However, air frying technology typically involves more specialized equipment, which can be expensive and may not yet be viable for many small and medium-sized food factories. The market for healthier fried foods has also led to the development of new frying oils that are designed to withstand high temperatures without breaking down or forming harmful compounds (Zaghi et al., 2019).

Some manufacturers have opted for using oils that are high in monounsaturated fats or even oils derived from non-traditional sources, such as avocado or coconut oil, which are often marketed as healthier alternatives. These innovations are responding to the growing consumer awareness of health risks associated with excessive consumption of fried foods, particularly concerning heart disease, obesity, and other chronic conditions linked to high-fat diets. In addition to health concerns, the environmental impact of frying also presents a challenge for small and medium-sized food factories. Moreover, there is a growing focus on sustainability in the food industry, and frying technology has seen advancements designed to reduce energy consumption and improve the efficiency of the process. Some frying equipment now includes energy-saving features such as heat recovery systems, which help capture and reuse the heat generated during frying, thereby reducing the overall energy consumption and environmental footprint of the operation (Nantapo et al., 2015).

4.4 Smoking

Food smoking as a preservation method has been utilized for centuries, with its origins tracing back to ancient civilizations that discovered the benefits of smoke not only for flavor enhancement but also for prolonging the shelf life of food (Joardder et al., 2019). In small and medium-sized food factories, smoking remains a popular method of preserving meats, fish, cheeses, and even certain vegetables by imparting unique flavors, textures, and colors while simultaneously providing antimicrobial and antioxidative properties that help inhibit spoilage and bacterial growth (Akharume et al., 2021). The process involves exposing food to smoke from burning or smoldering wood, typically in a controlled environment like a smokehouse or smoker, where the food is either suspended in the air or placed on racks to absorb the compounds produced by the combustion of wood. These compounds, such as phenols, aldehydes, and acids, are deposited on the surface of the food, where they contribute not only to flavor but also to the preservation process. The antimicrobial effect of smoke, due to the presence of phenolic compounds, helps to kill or inhibit the growth of bacteria and molds, while the reduced moisture content and increased acidity of smoked foods provide further resistance to microbial contamination (Kaloti, 2022).

Furthermore, the antioxidants present in the smoke, including certain phenolic compounds and volatile organic compounds, help to slow down oxidative rancidity, which is particularly important for preserving the quality of fats in foods like smoked meats or fish. For small and medium-sized food producers, food smoking offers several distinct advantages, including its relatively low cost, scalability, and ability to enhance the organoleptic qualities of food, all of which make it an attractive choice in the competitive food industry. Smoking also allows for differentiation in product offerings, as smoked foods are often associated with premium quality, traditional craftsmanship, and distinctive flavor profiles, which can appeal to niche markets or health-conscious consumers looking for alternatives to more heavily processed or chemically preserved foods. While traditional methods of smoking, such as cold smoking, hot smoking, and smoke roasting, have been in use for centuries, the modern small or medium-sized food factory can adapt these methods with new technologies and innovations to increase efficiency, safety, and product consistency, while still preserving the artisanal characteristics of smoked products. However, despite its benefits, food smoking also poses significant challenges for small and medium-sized producers, especially in terms of quality control, regulatory compliance, equipment costs, and labor-intensive processes, which must be carefully managed to ensure that the final product is both safe for consumption and meets consumer expectations in terms of flavor and appearance (Eze & Mena, 2024; Maga, 2018).

The primary mechanism by which smoking preserves food is through the drying effect that occurs when food is exposed to smoke at varying temperatures. The drying process, akin to dehydration, reduces the water activity in food, which is essential for limiting the growth of microorganisms (Andrés et al., 2007). Low water activity prevents bacteria, molds, and yeasts from thriving, thus extending the shelf life of smoked foods. In traditional smoking methods, such as cold smoking, temperatures are kept below 30°C (86°F), which prevents cooking the food but still allows it to be dried and exposed to smoke. Cold smoking is often used for products such as sausages, hams, cheeses, and fish, where the primary purpose is to impart flavor, texture, and preservative properties (Ledesma et al., 2017). For meat and fish, cold smoking often follows a curing or salting process, which further draws moisture out of the product and enhances its preservation. The extended exposure to smoke in cold smoking creates a layer of protective compounds on the surface of the food, which act as a barrier to microbial attack (Ledesma et al., 2017). While cold smoking is highly effective for preservation, it is a slow process and typically requires days or even weeks to fully impart the desired flavor and achieve the necessary preservation effects. Hot smoking is commonly used for a range of products, including smoked poultry, ribs, and certain types of fish, and is particularly favored by smaller producers who need a more efficient method of preserving and preparing their products for quick distribution or retail. Hot smoking is also useful in applications where the smoking process is combined with other preservation methods, such as brining or marinating, to further enhance the product's shelf life and flavor profile (Rabiepour et al., 2024).

Smoke roasting is another form of food smoking used in some small and medium-sized food factories, particularly for meat and poultry. In smoke roasting, the food is cooked in a smoke-filled chamber, where the combination of smoke and heat contributes to the development of the desired texture, flavor, and preservative qualities. The cooking temperatures for smoke roasting typically range from 120°C to 150°C (248°F to 302°F), which ensures that the food is both smoked and cooked to a safe internal temperature, making it ideal for products that require a more rapid production cycle, such as ready-to-eat meals or pre-cooked meats (Kubiak & Polak-Sliwinska, 2015). The speed of this process allows manufacturers to achieve a more consistent and quicker production turnaround compared to cold smoking, but it also requires careful temperature control to ensure that the food does not become overcooked or lose its desired quality. With smoke roasting, small and medium-sized food factories can produce large volumes of smoked products more efficiently, while still achieving the flavor, color, and preservation benefits associated with traditional smoking methods (Weber, 2012). One of the key considerations for any smoking process, whether cold smoking, hot smoking, or smoke roasting, is the type of wood used to generate the smoke. The choice of wood significantly impacts the flavor and aroma of the final product. Hardwoods such as hickory, oak, mesquite, and applewood are often used for smoking, as they produce dense, flavorful smoke that imparts rich, smoky notes to food. Different woods create different flavor profiles, and small and medium-sized food factories often experiment with various wood types to create unique products or cater to specific market demands (Shanley et al., 2015). For example, oak may be used for more robust flavors, while fruitwoods like apple or cherry are typically used for lighter, milder smoked products. The use of different wood chips, sawdust, or logs also allows for innovation in smoked food offerings, enabling manufacturers to differentiate their products in an increasingly crowded market. However, sourcing high-quality wood for smoking can present challenges in terms of cost and availability, particularly for small operations, as wood suppliers may vary in quality, consistency, and price (Jahnke, 2012).

Despite the many advantages of food smoking for preservation, small and medium-sized food factories must address several challenges related to the consistency, safety, and scalability of the process. One of the main challenges in smoking food is maintaining a consistent level of smoke penetration and temperature control throughout the entire smoking cycle. This is particularly important in small-scale operations that may rely on traditional or semi-automated smoking equipment, which can be more prone to temperature fluctuations, uneven smoke distribution, or longer smoking times (Michel et al., 2024). Consistency is essential to ensure that each batch of smoked food meets the desired flavor profile, texture, and preservative characteristics, and small manufacturers must invest in equipment that helps maintain uniformity in the smoking process. Automated or computer-controlled smokehouses, which allow for precise regulation of temperature, humidity, and smoke flow, can help alleviate some of these challenges and improve the efficiency of the smoking process, but they may represent a significant investment that could be prohibitive for small and medium-sized operations (Barbut, 2020). To counteract potential inconsistencies in smoking, many manufacturers implement strict quality control procedures, including regular monitoring of smoking temperatures, humidity levels, and smoke density, as well as regular sampling for microbiological testing to ensure the safety of the smoked food.

In addition to ensuring product consistency, safety is a paramount concern in food smoking. The potential for foodborne illnesses, particularly from pathogens such as Listeria, Salmonella, and Clostridium botulinum, is a critical issue for smoked products, especially those that are consumed without further cooking. In the past, the primary method for ensuring the safety of smoked foods was using salt, which inhibited microbial growth. However, the modern smoking process often involves combining smoking with other preservation methods, such as curing, brining, or vacuum sealing, to enhance food safety (Jain & Anal, 2017). For small and medium-sized food producers, ensuring compliance with food safety regulations, including those set forth by organizations such as the U.S. Food and Drug Administration (FDA), the European Food Safety Authority (EFSA), or local health authorities, is essential to minimize the risk of contamination and spoilage. These regulations often require rigorous testing of smoking parameters, proper labeling, and documentation of safe processing practices (Groenleer, 2014).

4.5 Baking

Baking, as a method of food processing and preservation, has long been integral to the food production industry, with its application spanning a wide variety of baked goods such as bread, cakes, cookies, pastries, and other products that form the cornerstone of many small and medium-sized food factories worldwide (Augustin et al., 2016). The significance of baking in these smaller-scale operations cannot be overstated, as it serves not only to produce a diverse range of desirable food items, but also as an essential method for preserving food by reducing moisture content, enhancing flavor, and increasing shelf life through the combination of heat, time, and ingredients in specific proportions (W. Zhou et al., 2014). The baking process itself typically involves the application of dry heat in an enclosed oven, which causes the ingredients to undergo chemical and physical transformations that result in the desired texture, color, and flavor. This dry heat works through a combination of conduction, convection, and radiation, which causes the water in doughs and batters to evaporate, thereby reducing water activity and creating a more shelf-stable product that is less susceptible to microbial growth. For small and medium-sized food producers, the versatility and relatively low capital cost of baking equipment, along with its ability to create a broad range of consumer-friendly products, make it an attractive and feasible option in the highly competitive food manufacturing industry (Cappelli et al., 2021).

From the production of staple products like bread and rolls to specialty items such as artisanal pastries, cookies, and gluten-free or vegan alternatives, baking provides a fundamental means of creating food that appeals to diverse consumer preferences while also offering the ability to preserve products for longer periods, making them more suitable for distribution and storage (Siddiqui et al., 2022). Furthermore, baking enhances the sensory properties of foods, such as aroma, flavor, texture, and visual appeal, creating products that not only meet the basic nutritional needs of consumers but also contribute to the overall eating experience. These sensory qualities are crucial to small and medium-sized food businesses, as they aim to distinguish themselves in crowded marketplaces where consumer preferences are continuously evolving, particularly with an increasing demand for convenience, indulgence, and quality in everyday food choices (Mesly & Réthoré, 2024). The process of baking for food preservation is particularly effective because it involves reducing the moisture content of the food, which is a primary factor in microbial spoilage (Saranraj & Geetha, 2012). This reduction in moisture slows down the growth of microorganisms, including bacteria, molds, and yeasts, which thrive in environments with higher water activity.

These processes contribute to the creation of the characteristic structure and texture of baked goods, with the heat of the oven causing the dough or batter to expand, rise, and solidify into a final product. In addition to this physical transformation, the Maillard reaction and caramelization contribute to the golden-brown color and the development of complex flavors during baking (Panghal & Khatkar, 2007). This reduction in moisture, combined with the structural changes during baking, creates a protective barrier that helps preserve the food by limiting the availability of water for microbial activity. While the specific baking time and temperature vary depending on the type of product being made, the general range of temperatures for baking foods usually falls between 160°C to 220°C (320°F to 430°F) (Sarion et al., 2021). At these temperatures, the moisture in the food is rapidly evaporated, creating a more shelf-stable product, which is especially important for small and medium-sized food manufacturers who seek to extend the shelf life of their products without resorting to the use of chemical preservatives or refrigeration. The versatility of baking also allows for the incorporation of various preservation techniques in conjunction with heat treatment, such as the use of natural preservatives like salt, sugar, vinegar, and certain acids, which further improve the preservation qualities of the final product (Ogwu & Ogunsola, 2024). Small and medium-sized food producers can enhance the shelf life of their baked goods by utilizing certain ingredients, such as emulsifiers, dough conditioners, and stabilizers, which improve the texture, moisture retention, and freshness of the product, thereby allowing it to remain palatable for longer periods.

In small and medium-sized food factories, the baking process is often carried out using a variety of ovens, each with specific advantages depending on the scale of production, type of food being produced, and desired output. For smaller operations that produce smaller batches, countertop ovens, convection ovens, or deck ovens are commonly used, as these allow for greater control over the baking environment and are suitable for more artisanal or handcrafted baked goods (Bramsiepe et al., 2012). Convection ovens, which use fans to circulate hot air, are especially useful for producing baked goods that require even heat distribution, such as cookies, cakes, or pastries, as they ensure that the food is baked uniformly. These ovens are generally more energy-efficient than traditional static ovens, and they allow smaller food manufacturers to produce higher volumes with less risk of uneven baking (Konur et al., 2023). On the other hand, deck ovens, which are typically used for more traditional or artisanal baking, offer the benefit of direct heat from stone or ceramic decks, resulting in a more rustic and crunchy texture, particularly for bread, pizza, and other yeast-leavened products. For larger-scale production, rotating rack ovens or tunnel ovens may be used in medium-sized food factories to provide continuous baking with consistent results, which is ideal for mass production of products like packaged bread, rolls, and cakes.

These ovens are designed to accommodate larger volumes of baked goods and provide greater efficiency in terms of time and energy consumption, which is critical for meeting high demand in larger production settings. Although these larger ovens are more expensive and complex, their ability to handle higher capacities with minimal oversight makes them suitable for medium-sized food factories aiming to scale their operations while maintaining product consistency and quality (Masanet et al., 2012). Regardless of the size of the oven or the scale of production, the baking process itself remains rooted in the fundamental principles of heat transfer and moisture reduction, which are crucial for both preserving the food and achieving the desired final product. Baking in small and medium-sized food factories also enables the creation of products with diverse textures, which can greatly enhance consumer appeal. For instance, the high temperatures involved in baking allow for the crisping of crusts in products such as bread, rolls, and pastries, while simultaneously softening the interior (Davidson, 2024). This contrast between the crispy exterior and soft, airy interior is highly sought after by consumers and is often a key selling point for baked goods.

The baking process is not only about producing products with desirable textures and flavors, but it also involves a set of challenges and considerations related to food safety, product consistency, and quality control. One of the key factors in ensuring the safety and quality of baked goods is controlling the baking environment. Fluctuations in temperature, humidity, or airflow can lead to inconsistencies in the final product, such as uneven browning, improper rising, or undesirable textures (J. P. Smith et al., 2004). To address these concerns, small and medium-sized food manufacturers must invest in proper equipment maintenance, as well as implement procedures for monitoring and controlling the conditions inside the baking oven. The consistency of ingredients also plays a critical role in producing high-quality baked goods. Even slight variations in ingredient quantities or properties, such as flour quality, moisture content, or yeast activity, can result in noticeable differences in the finished product. As a result, food manufacturers must establish strict ingredient sourcing and quality control procedures to ensure that the materials they use meet the required specifications and will yield consistent results across batches (W. B. Zhou & Therdthai, 2007).

4.6 Pasteurization and sterilization

Food pasteurization and sterilization are two critical thermal processing methods used to extend the shelf life of food products while maintaining safety and preserving nutritional value. These techniques are of particular significance for small and medium-sized food factories, where they enable the mass production of a wide array of consumable goods, including dairy products, beverages, soups, sauces, jams, canned foods, and ready-to-eat meals (Slavov et al., 2019). Both pasteurization and sterilization work through the application of heat to destroy or inactivate harmful microorganisms, such as bacteria, yeasts, molds, and viruses, which could lead to spoilage or foodborne illness. However, these two methods differ in their temperature, duration, and the extent of microorganism destruction they achieve. Pasteurization is a milder form of heat treatment, typically applied at temperatures below 100°C (212°F), designed to eliminate harmful pathogens while preserving the food's taste, texture, and nutritional content. It is commonly used for products like milk, juices, beer, canned vegetables, and some meats, where a balance between safety and product quality is paramount (Chiozzi et al., 2022).

Sterilization, on the other hand, involves higher temperatures, generally above 100°C, and is used for products that require complete microbiological safety, such as canned foods, sauces, and certain pre-packaged meals, where a more intense heat treatment is necessary to destroy a broader range of microorganisms, including spores that can survive lower temperatures. The challenge for small and medium-sized manufacturers is that both pasteurization and sterilization are complex processes that require precise control of temperature, pressure, and time to ensure the safety, quality, and shelf life of the final product (Huang et al., 2019). These manufacturers often lack the resources of larger companies to invest in highly automated or large-scale thermal processing equipment, so they must rely on smaller, more cost-effective solutions that can still meet stringent food safety standards without compromising on the quality of their products.

For small and medium-sized food factories, the decision between pasteurization and sterilization often comes down to the type of product being produced and its intended shelf life. Pasteurization, which was developed by French scientist Louis Pasteur in the 19th century, works by heating food to a temperature between 60°C and 85°C (140°F to 185°F) for a specific period (Mouritsen & Styrbæk, 2017). This method does not cook the food, but instead, it aims to eliminate or reduce the load of harmful bacteria and pathogens that could cause spoilage or illness, such as *Salmonella*, *E. coli*, and *Listeria monocytogenes*. Because pasteurization is less intense than sterilization, it helps retain more of the food's original flavor, texture, and nutritional content, which is especially important for products like milk, fruit juices, yogurt, and other sensitive foods (Raut et al., 2023). Pasteurization also helps to preserve the vitamins and minerals in these products, particularly those that are sensitive to heat, like vitamin C. In small and medium-sized food factories, pasteurization is often achieved using either batch or continuous processes. In batch pasteurization, food is placed in large tanks or containers and heated for a predetermined time to achieve the desired temperature. Once the pasteurization cycle is complete, the food is rapidly cooled to stop further thermal degradation (Ottaway, 2010). This type of pasteurization is often used for smaller production runs, as it allows for precise control over the pasteurization process, making it ideal for artisanal or specialty products that require a more hands-on approach. Continuous pasteurization, on the other hand, involves the use of heat exchangers or other automated systems to rapidly heat and cool food products as they move through pipes or conveyor belts. This system is more suitable for higher-volume production, allowing small and medium-sized factories to process larger quantities of food more efficiently while still maintaining safety and quality (Ramesh, 2020)

While pasteurization is sufficient for many foods, there are certain products, especially those that require extended shelf life or are prone to contamination by heat-resistant microorganisms, that necessitate a more intense processing method: sterilization. Sterilization involves applying much higher temperatures, typically in the range of 115°C to 135°C (239°F to 275°F), for longer periods (Widmer & Frei, 2011). The higher temperature and longer duration of heat exposure in sterilization processes are necessary to kill heat-resistant bacterial spores, such as those produced by *Clostridium botulinum*, which can cause botulism, a potentially fatal form of food poisoning. This makes sterilization critical for foods that have a high risk of contamination with such spores, including canned vegetables, meats, poultry, and ready-to-eat meals, as well as some sauces and gravies (Anderson et al., 2011).

For batch retort systems, food containers, such as cans or jars, are loaded into the retort, where they are heated to the required temperature for a specified time before being rapidly cooled. Continuous retorts, on the other hand, use a conveyor system to move food through different temperature zones, allowing for continuous processing and higher throughput. Retorts have become a widely used option in small and medium-sized factories because they offer scalability and flexibility for a range of food products. However, despite their advantages, retort sterilization can also pose challenges related to cost, energy consumption, and the potential for product degradation if not properly controlled (Awuah et al., 2007). Overheating during sterilization can lead to undesirable changes in the food's color, texture, and flavor, which are particularly problematic for products that are intended to retain a fresh-like appearance and taste, such as certain ready-to-eat meals, soups, or sauces. As a result, it is crucial for small and medium-sized food manufacturers to carefully calibrate their sterilization processes to balance microbial safety with the maintenance of product quality (Ramesh, 2020).

One of the most significant challenges faced by small and medium-sized food manufacturers in the pasteurization and sterilization process is the ability to control the thermal treatment effectively and ensure consistency across large batches. This involves not only achieving the correct temperature for the right amount of time but also ensuring that the food reaches the required temperature throughout its entire mass. Uneven heating can result in under-processed areas where pathogens remain viable, or over-processed zones where the product quality deteriorates. For smaller operations, where resources may be limited, manual monitoring and frequent testing are often required to ensure the process is working as intended. These small factories must often rely on relatively simple, yet effective technologies, like temperature sensors, to provide real-time feedback during the process. In addition, proper calibration and regular maintenance of pasteurization and sterilization equipment are essential to maintain consistent results. For example, the use of automated temperature controls, steam injectors, and pressure gauges in retorts can provide more precise control and reduce the likelihood of errors, improving both the safety and quality of the food product. Similarly, in pasteurization systems, the use of plate or tubular heat exchangers with automated flow and temperature control can help to achieve optimal pasteurization conditions, ensuring a consistent product across every batch. With increasing demand for high-quality, safe food products, many small and medium-sized manufacturers are exploring automated or semi-automated systems that not only reduce the reliance on manual labor but also help to improve product quality and consistency (Saravacos et al., 2002; Skjöldebrand, 2013).

4.7 Essential oil extraction process

Essential oil extraction is a critical process in the production of high-quality natural oils, often used in the food, cosmetic, and pharmaceutical industries, and plays an increasingly important role in small and medium-sized food factories. These oils, derived from plants through distillation, cold-pressing, or solvent extraction methods, are valued for their strong aromatic qualities and potential health benefits, making them highly sought after in both food and beverage production as well as in the development of natural flavorings and fragrances (Pandey et al., 2023). The extraction process itself involves separating the essential oil from plant materials, such as leaves, flowers, roots, or peels, to obtain a concentrated liquid that retains the plant's aromatic compounds. For small and medium-sized food manufacturers, essential oils are often incorporated into food products as natural flavor enhancers, preservatives, or even functional ingredients, given the growing consumer demand for natural, organic, and holistic food options. The appeal of these oils lies in their ability to add distinct, potent flavors to a wide array of products, ranging from confectionery, baked goods, beverages, and dairy items to sauces, marinades, and ready-to-eat meals (Parvin et al., 2023). Essential oils are often used in the food industry for their antimicrobial properties, their ability to prolong shelf life, and to provide consumers with a more "natural" eating experience free from artificial flavorings and additives. However, the extraction process itself presents unique challenges, especially for small and medium-sized food factories that lack extensive resources or large-scale equipment available to larger operations. These smaller producers must balance the cost of extraction with the need for quality, scalability, and efficiency, often navigating financial and logistical hurdles while trying to remain competitive in an increasingly crowded market (Mollik & Ananna, 2024). Additionally, the volatile nature of essential oils, which can vary in potency and composition depending on factors such as the plant's origin, environmental conditions, and harvesting methods, poses a challenge in maintaining consistency and quality control in food products.

The most common method of essential oil extraction is steam distillation, which is widely used in both large and small-scale production due to its efficiency, cost-effectiveness, and ability to produce high-quality oils. Steam distillation works by passing steam through plant material, which causes the plant cells to rupture and release essential oil vapors. These vapors are then condensed back into liquid form, separating the oil from the water. The process is typically carried out in a distillation apparatus that includes a boiler for generating steam, a still where plant material is placed, a condenser for cooling the vapor, and a separator to collect the essential oil (Rao et al., 2021). For small and medium-sized food factories, distillation units are available in various sizes, ranging from laboratory-scale equipment suitable for research and product development to larger-scale industrial units capable of processing significant quantities of plant material. These systems can be relatively inexpensive and easy to operate, making them accessible to smaller manufacturers who wish to produce essential oils for food applications (Kholiya et al., 2023). For example, delicate flowers like lavender or jasmine may require lower temperatures and shorter distillation times to preserve the integrity of their essential oils, while tougher plant materials like citrus peels or cinnamon bark may require higher temperatures and longer distillation periods. Additionally, plant material must be of high quality, free from contaminants such as pesticides or disease, to ensure the purity and safety of the final essential oil product (Prosche & Stappen, 2024). For small and medium-sized producers, sourcing high-quality raw materials is crucial, and many turn to local farmers or specialty suppliers to obtain the plants needed for essential oil extraction, often forming relationships with growers who share an interest in producing high-quality, sustainable ingredients.

In addition to steam distillation, cold-press extraction is another popular method for extracting essential oils, particularly from citrus fruits like oranges, lemons, and grapefruits, where the oil is found in the peel. Cold pressing, also known as expression, involves mechanically pressing the fruit peel to release the oil without the application of heat, thus preserving the oil's delicate aromatic compounds. This method is ideal for producing citrus oils with vibrant, fresh flavors, and it is often preferred for use in the food industry, where the integrity of the oil's flavor profile is essential (Cakaloglu et al., 2018). The process involves using a machine called a "decanter" or "citrus press," which applies pressure to the peel, separating the essential oil from the fruit's juice and pulp. For small and medium-sized manufacturers, cold-press extraction equipment is typically available in both manual and automated versions, with the latter offering higher efficiency and consistency for larger production volumes. While cold pressing is generally gentler on the oil, it does have its limitations. For example, it is not suitable for extracting oils from most other plant materials, and the oil yield can be relatively low compared to other methods like steam distillation. Additionally, cold-pressed oils tend to be more susceptible to oxidation, which can shorten their shelf life and impact the quality of the final product. To address this, small food manufacturers often incorporate antioxidants, such as vitamin E or rosemary extract, into the oil or the final food product to help extend its shelf life (Ferhat et al., 2007; Pinheiro Pantoja et al., 2024). Another challenge associated with cold-press extraction is the significant amount of raw material required to produce a relatively small amount of oil, particularly in the case of citrus fruits, which may need to be processed in large quantities to obtain a commercially viable yield.

For small and medium-sized food factories, one of the key considerations when incorporating essential oils into food products is ensuring that the oils are both safe and compliant with food safety regulations. Since essential oils are highly concentrated substances, they must be used in precise quantities to avoid overwhelming the flavor profile of the food product or posing any health risks to consumers. For example, essential oils like oregano, cinnamon, or clove contain potent compounds that can be toxic if consumed in large amounts, and even some oils that are considered safe in small quantities may cause allergic reactions or irritation in certain individuals. As a result, many small and medium-sized manufacturers work with food safety experts and regulatory bodies, such as the U.S. Food and Drug Administration (FDA) or the European Food Safety Authority (EFSA), to ensure that the oils they use are safe for consumption and are properly labeled (Hasnan et al., 2022). This may involve testing essential oils for purity, potency, and contamination, as well as ensuring they meet specific quality standards related to their chemical composition, storage, and handling. Additionally, because essential oils are volatile, they can degrade over time when exposed to heat, light, or air, which can negatively impact both their flavor and aroma. Therefore, small and medium-sized manufacturers must take care to store essential oils in dark, cool places and use airtight containers to preserve their integrity. Proper packaging and labeling are essential for maintaining the quality and safety of essential oils in food products, as well as ensuring transparency for consumers who are increasingly interested in knowing the origin and composition of the products they consume (Konudula & Kuruvanparamb Krishnan, 2024).

5. Non-thermal Processing Techniques for Food Preservation and Processing in Small and Medium-Sized Food Factory

5.1 Introduction

Non-thermal food processing technologies have emerged as a significant innovation in the food industry, particularly for small and medium-sized food factories, offering them an opportunity to process food in ways that preserve its nutritional value, flavor, and sensory qualities, all while extending its shelf life without the application of high temperatures. Non-thermal processing techniques are particularly important in smaller-scale food manufacturing, where the demand for high-quality, fresh, and safe food products is increasingly critical to competing in an expanding market. These innovative methods allow food producers to achieve high levels of microbial inactivation, reduce spoilage, and enhance food safety while preserving key nutrients that might otherwise be destroyed by heat treatments. Moreover, non-thermal methods can offer a competitive edge for small and medium-sized food factories by providing options for processing a wide range of products, from juices and dairy products to meats, ready-to-eat meals, and snacks, thus helping to diversify their product portfolios and meet evolving consumer preferences (Khouryieh, 2021).

One of the most well-known non-thermal food processing techniques is High Pressure Processing (HPP), which involves subjecting food to extremely high levels of pressure, typically in the range of 400 to 600 MPa, in a water-filled chamber. This pressure is applied for a specified period, typically from a few seconds to several minutes, and is effective at inactivating microorganisms like bacteria, yeasts, molds, and viruses, while preserving the food's organoleptic properties, such as color, texture, and taste. HPP is considered a cold pasteurization technique, as it does not require the application of heat but can achieve similar effects in terms of microbial safety and shelf-life extension (Reardon, 2018). For small and medium-sized food manufacturers, HPP is particularly attractive because it can be applied to a wide range of food products, including juices, ready-to-eat meals, dips, sauces, meats, seafood, and fruits, while maintaining their fresh-like characteristics. The primary barrier is the initial cost of the equipment, as HPP machines can be expensive to purchase and maintain. While the technology is becoming more affordable, especially with advancements in more compact and energy-efficient designs, the high upfront cost can still be a significant barrier for small-scale food producers. Moreover, the need for specialized packaging that can withstand the high pressures applied during processing adds another layer of complexity and cost to the process. Nevertheless, for those small and medium-sized manufacturers who can afford the investment, HPP offers a way to process food in a way that meets growing consumer demand for safe, high-quality, and minimally processed products (Elamin et al., 2015).

Another promising non-thermal processing technology is Pulsed Electric Field (PEF) treatment, which uses short bursts of high-voltage electricity to create electric fields that disrupt the cell membranes of microorganisms, rendering them inactive while having minimal impact on the food's flavor, texture, and nutritional content. In PEF treatment, the food is subjected to electric pulses in a liquid or semi-solid state, which causes electroporation, a process where the electric field induces temporary pores in the microbial cell membranes, leading to cell death. PEF is particularly effective for liquid foods such as fruit juices, smoothies, and milk, but it can also be applied to certain solid foods, such as vegetables and meats, depending on the specific application. PEF also helps to preserve the natural color, flavor, and texture of foods, providing manufacturers with a method that maintains the sensory quality of the product while ensuring food safety. Small and medium-sized food manufacturers may find PEF to be a cost-effective solution, as the equipment required for this technology is generally more affordable than other non-thermal processing methods like HPP. However, the scalability of PEF remains a challenge for smaller factories, as high-voltage systems that can treat large volumes of food may still require substantial investments, both in terms of capital and energy. As the technology matures, however, there is potential for more scalable and efficient PEF systems that can be integrated into the production lines of small and medium-sized food businesses, particularly as demand for high-quality, minimally processed food grows (Niu et al., 2020).

Ultraviolet (UV) light treatment is another non-thermal processing method that has gained popularity in recent years for its ability to inactivate pathogens and spoilage microorganisms in liquid foods, as well as on food surfaces. In UV processing, food products are exposed to ultraviolet light at specific wavelengths (typically in the range of 200 to 300 nm), which disrupts the DNA and RNA of microorganisms, preventing them from replicating and rendering them inactive. This method is widely used in the treatment of beverages, such as fruit juices, milk, and water, but can also be applied to sauces, salsas, and other liquid-based food products. Additionally, UV treatment is a non-invasive method that does not require preservatives, which is an attractive option for producers seeking to meet consumer demand for clean-label products. However, one of the limitations of UV light treatment is its penetration depth, as UV light is most effective on the surfaces of liquids or foods. This means that thicker products or foods with complex structures may require extended treatment times or the use of more advanced systems, such as pulsed UV light or UV-C light, to achieve the desired microbial inactivation. Furthermore, UV treatment may not be as effective against all types of microorganisms, particularly those that are more resistant to light, such as certain molds or spores. Nevertheless, UV light remains a promising non-thermal processing technique that is accessible to small and medium-sized food manufacturers, particularly in applications where mild microbial inactivation is needed without compromising the food’s sensory or nutritional qualities (Koutchma, 2009).

Another exciting non-thermal method is Ozone (O3) treatment, which involves the use of ozone gas to eliminate microorganisms in water, on food surfaces, or in the air. Ozone, a highly reactive form of oxygen, is an effective antimicrobial agent that can be used to disinfect food products, food contact surfaces, and processing environments. Ozone treatment has been successfully applied to a variety of food products, including fruits, vegetables, meats, and seafood, where it works by breaking down the cell walls of microorganisms, including bacteria, viruses, yeasts, and molds. One of the advantages of ozone treatment is that it does not leave chemical residues on the food, making it an attractive option for manufacturers aiming for organic or clean-label products. Additionally, ozone treatment can be performed at low temperatures, preserving the flavor, texture, and nutritional profile of the food. Small and medium-sized food manufacturers can benefit from ozone technology because it is relatively inexpensive and can be integrated into food processing operations without requiring substantial capital investment. Moreover, ozone is a versatile technology that can be used for multiple applications, including washing, sanitizing, and even controlling spoilage during storage. However, the effectiveness of ozone treatment depends on several factors, including the concentration of ozone, the exposure time, and the type of food being processed. The challenge for small and medium-sized food producers is ensuring that the ozone is applied in a controlled and consistent manner, as overexposure to ozone can potentially lead to unwanted changes in the food’s quality, such as a reduction in flavor or texture (Prabha et al., 2015).

5.2 Fermentation

Food fermentation is one of the oldest and most widely practiced methods of food preservation and enhancement, and its application in small and medium-sized food factories is growing as consumer demand for natural, probiotic-rich, and flavorful foods increases. Fermentation, which involves the conversion of carbohydrates (like sugars) into alcohol, gases, and acids by microorganisms such as bacteria, yeasts, and molds, is a process that not only extends the shelf life of food products but also enhances their taste, texture, and nutritional profile (Shakya et al., 2024). The practice of fermenting food dates back thousands of years, and today, it remains central to the production of a wide variety of foods, including dairy products like yogurt and cheese, fermented vegetables like sauerkraut and kimchi, beverages like beer and wine, and bakery products like sourdough bread. For small and medium-sized food manufacturers, fermentation offers an attractive method for producing high-quality, differentiated products with distinct flavors and textures that cater to a growing consumer preference for natural, minimally processed, and functional foods. The demand for probiotics—live microorganisms that, when consumed in adequate amounts, confer health benefits to the host—has driven the growth of fermented food markets, making fermentation not only a means of preservation but also a valuable tool for creating products with health-enhancing properties (Anagnostopoulos & Tsaltas, 2019). Fermented foods are often associated with gut health, immunity, and overall well-being, as certain strains of bacteria, such as Lactobacillus and Bifidobacterium, are known to support the balance of gut microbiota, thereby promoting digestive health. Additionally, fermentation can increase the bioavailability of nutrients by breaking down compounds that may otherwise inhibit nutrient absorption, such as phytates in grains and legumes, or by synthesizing essential vitamins, such as B vitamins, during the fermentation process. For small and medium-sized food manufacturers, fermentation offers an opportunity to create premium products that align with current health trends and differentiate themselves in a competitive marketplace (Thanzami & Lalhlenmawia, 2020; Todorov & Holzapfel, 2015).

One of the most significant benefits of fermentation for small and medium-sized food factories is its ability to extend shelf life and preserve food without the need for artificial preservatives or thermal processing. Unlike methods such as pasteurization, which involve the application of heat, fermentation relies on the growth of beneficial microorganisms to produce organic acids (such as lactic acid), alcohols, or gases that inhibit the growth of spoilage-causing microbes (Anand & Sati, 2013). Lactic acid bacteria (LAB), which are the primary microorganisms involved in the fermentation of dairy products, vegetables, and meats, play a crucial role in producing the sour, tangy flavors associated with many fermented foods, as well as in preventing the growth of pathogenic bacteria by lowering the pH of the food environment. For small and medium-sized manufacturers, this natural preservation method reduces the need for chemical additives, making fermented foods an attractive option for consumers seeking clean-label, minimally processed products (Ashaolu et al., 2023). Additionally, fermentation enhances the organoleptic qualities of food, contributing to more complex, layered flavors and textures that can be difficult to replicate with other processing methods. The production of fermented foods also requires relatively simple and low-cost equipment, especially when compared to the sophisticated machinery required for other food processing technologies like high-pressure processing (HPP) or ultra-high-temperature (UHT) pasteurization. For small food producers, the ability to ferment food using minimal equipment—such as fermentation tanks, pH meters, and incubators makes it a scalable and accessible method for producing high-quality products. Whether the product is a small batch of artisanal sauerkraut or a large batch of fermented dairy, the fermentation process can be adapted to suit the scale and needs of the operation, making it an ideal choice for manufacturers with varying production capacities (Mujahid et al., 2024; Senanayake et al., 2023).

In dairy production, fermentation plays a key role in creating a variety of popular products, including yogurt, kefir, and cheese. These products are typically fermented by the action of specific strains of bacteria, such as *Lactobacillus bulgaricus* and *Streptococcus thermophilus* in yogurt or *Lactobacillus* and *Bifidobacterium* in kefir, which convert milk sugars (lactose) into lactic acid, resulting in a thickened texture and a characteristic tangy flavor. For small and medium-sized dairy producers, the fermentation process is particularly valuable, as it not only preserves the milk but also enhances its nutritional value by increasing the bioavailability of calcium and other minerals (Maicas, 2020). Yogurt and kefir are also rich in probiotics, making them highly sought after for their gut-health benefits. The demand for probiotic-rich products has led to a surge in the popularity of fermented dairy among health-conscious consumers, presenting opportunities for smaller manufacturers to cater to this niche market. The fermentation process for dairy products can be carefully controlled to achieve desired textures and flavors, allowing small producers to create artisanal-style products that stand out in the marketplace. For instance, the use of traditional cultures, extended fermentation times, or unique strains of bacteria can result in products with distinctive flavors, appealing to consumers looking for more authentic or gourmet options (Popa et al., 2019).

However, the success of fermented dairy products depends on the precise management of temperature, pH, and humidity during the fermentation process, which can present challenges for small-scale producers with limited resources. The need for consistent fermentation conditions means that quality control and monitoring are critical, and small food manufacturers may need to invest in specialized equipment, such as temperature-controlled incubators or automated fermentation tanks, to ensure product consistency and safety. Additionally, small-scale dairy producers may face challenges in scaling their fermentation processes while maintaining the same level of quality and safety, requiring careful planning and attention to detail in production (Tamang et al., 2020).

Fermented vegetables represent another key category of products that benefit from the fermentation process. Sauerkraut, kimchi, pickles, and other fermented vegetables rely on the action of lactic acid bacteria, such as *Lactobacillus plantarum* and *Leuconostoc mesenteroides*, to preserve the vegetables and create a tangy, sour flavor. These products are particularly attractive to small and medium-sized food manufacturers because they align with consumer preferences for plant-based, probiotic-rich foods that support gut health and overall wellness (Varzakas et al., 2017). The process of fermenting vegetables typically involves submerging raw vegetables in a brine solution (saltwater), where the naturally occurring bacteria initiate the fermentation process. The high salt concentration in the brine draws moisture out of the vegetables, creating an environment in which the beneficial bacteria can thrive while preventing the growth of harmful microorganisms. In addition to preserving vegetables, fermentation enhances their flavor, texture, and digestibility, while also enriching them with additional beneficial compounds, such as B vitamins and organic acids. For small manufacturers, the ability to ferment vegetables with minimal equipment, such as fermentation crocks, jars, or small fermentation tanks, makes it an attractive option for producing artisanal, locally sourced products. Small-scale producers can experiment with different vegetable varieties, fermentation times, and flavorings (such as garlic, ginger, or chili) to create unique products that appeal to consumers seeking diversity in their fermented food offerings. However, as with dairy fermentation, maintaining consistent fermentation conditions is essential for product quality and safety, and small producers may need to invest in quality control measures, such as monitoring the salt concentration, temperature, and pH levels throughout the fermentation process (Taormina, 2010).

5.3 Chilling and freezing

Food chilling and freezing are essential techniques for preserving the quality, safety, and shelf life of perishable food products, particularly in small and medium-sized food factories, where maintaining product freshness and meeting consumer demands for convenience are critical. These methods, although distinct in terms of temperature ranges and processes, both rely on reducing the temperature of food products to slow down the activity of microorganisms, enzymes, and other spoilage agents that contribute to food degradation (James & James, 2023). Chilling typically involves lowering the temperature of food to just above freezing (0°C to 5°C), while freezing involves lowering the temperature to below freezing (usually between -18°C to -30°C or lower), thus transforming water in the food into ice. For small and medium-sized food producers, chilling and freezing offer significant advantages in terms of food preservation, allowing them to extend the shelf life of fresh foods, reduce waste, and enable the transportation of perishable goods over long distances. Moreover, these methods can preserve the sensory properties, nutritional value, and texture of food products, making them critical to maintaining consumer satisfaction and ensuring food safety (Kader, 2013).

Chilling is commonly employed in the storage and distribution of a variety of fresh food products, including fruits, vegetables, meats, poultry, dairy, and ready-to-eat meals. By slowing down microbial growth and enzymatic activity, chilling helps maintain the freshness of these products for extended periods. For small and medium-sized food manufacturers, chilling can be applied both during the processing and distribution phases to ensure that products remain safe for consumption while retaining their flavor, texture, and nutritional qualities. However, chilling is typically not sufficient to halt microbial growth entirely, especially with highly perishable foods like fresh seafood or raw meats, which may still have a limited shelf life even when kept at low temperatures. Despite this, chilling is often seen as a more cost-effective and energy-efficient method than freezing, as it requires less energy to maintain temperature and does not involve the complexities associated with freezing, such as ice crystal formation and thawing. Small and medium-sized food factories often utilize blast chillers, refrigerated storage rooms, or refrigerated trucks to chill food products quickly, helping to preserve product quality and prevent spoilage during processing and distribution. The speed at which food is chilled is crucial, as slower chilling processes can lead to uneven cooling and the potential for bacterial growth in areas that remain at higher temperatures for too long. Therefore, for small food producers, it is vital to monitor and control the chilling process using temperature-controlled equipment, automated systems, and temperature logging devices to ensure consistent product quality and food safety (Drummond & Sun, 2010; James & James, 2023).

Freezing, on the other hand, is a more intense preservation method that is widely used in the food industry, especially for products that need to be stored for extended periods. By reducing the temperature to below freezing, freezing transforms the water content in food into ice, which effectively halts microbial activity and significantly slows down the chemical processes that lead to food spoilage. For small and medium-sized food manufacturers, freezing offers a powerful means of extending the shelf life of products such as meat, poultry, fish, fruits, vegetables, and prepared meals. By freezing foods at the peak of freshness, manufacturers can offer consumers high-quality, convenient products that retain much of their original flavor, texture, and nutritional value. Freezing also enables the production of foods that are not seasonally available, allowing manufacturers to meet consumer demand for certain ingredients or products year-round. For example, small food producers that specialize in frozen fruits or vegetables can source ingredients when they are in season and freeze them for sale throughout the year. Similarly, small bakeries can freeze dough or finished bread products to extend their availability and meet fluctuating demand. In these cases, freezing allows food manufacturers to maintain a consistent supply of high-quality products, even when fresh ingredients are not readily available (Amit et al., 2017; X.-F. Wu et al., 2017).

In the context of small and medium-sized food factories, freezing offers several operational advantages, particularly in terms of scalability and storage flexibility. Unlike chilled products, which must be sold or consumed relatively quickly, frozen products have a significantly longer shelf life, which allows for greater flexibility in production and distribution schedules. Small food manufacturers can produce frozen products in batches, storing them in freezers until demand increases or until they are ready to be shipped to customers. This flexibility helps smooth out fluctuations in demand and reduces the pressure on production schedules, which is particularly valuable for small businesses that may not have the capacity for continuous, high-volume production. Moreover, freezing allows small food producers to offer a variety of convenience-oriented products, such as frozen meals, snacks, or frozen ingredients that can be used in cooking. The growing demand for convenient, ready-to-eat frozen meals presents an opportunity for small and medium-sized food manufacturers to tap into the expanding frozen food market, providing nutritious, gourmet options that align with consumer preferences for convenience, quality, and sustainability (Assegehegn et al., 2019; Rahman et al., 2006).

5.4 Food packaging for enhancing value

Food packaging plays a crucial role in preserving the quality, safety, and shelf life of food products, making it an indispensable part of the food production process, particularly for small and medium-sized food factories. It is not just a means of containing and protecting food; packaging also has the potential to enhance the overall value of the product by improving its appeal, convenience, sustainability, and consumer perception. As food manufacturers face increasing consumer demand for products that are not only fresh and safe but also convenient, sustainable, and visually appealing, the importance of effective food packaging cannot be overstated. Small and medium-sized food factories benefit significantly from packaging innovations as they strive to differentiate their products in a highly competitive market, expand their consumer base, and build brand loyalty. Through the strategic use of packaging materials, designs, and techniques, these producers can not only improve the preservation of their products but also create an enhanced consumer experience that contributes to higher perceived value and market success (Dora et al., 2013; Saguy & Sirotinskaya, 2014).

The primary function of food packaging is to protect food from physical damage, contamination, and spoilage, ensuring that it reaches consumers in the best possible condition. This protection is particularly important for perishable items such as fruits, vegetables, dairy, meats, and prepared foods, which are vulnerable to damage from handling, transportation, and environmental conditions. Packaging helps prevent moisture loss, oxidation, microbial contamination, and exposure to light, all of which can degrade the quality and safety of food. For small and medium-sized food producers, the right packaging solution is critical for ensuring product integrity and maximizing shelf life, especially when dealing with products that need to be transported over long distances or stored for extended periods. By selecting appropriate packaging materials, such as vacuum-sealed bags, modified atmosphere packaging (MAP), or barrier films, manufacturers can significantly extend the shelf life of their products while maintaining freshness, texture, and nutritional value (Robertson, 2009). For instance, vacuum sealing removes air from the package, thereby reducing the potential for bacterial growth and oxidation, which are major contributors to spoilage. Similarly, MAP involves adjusting the atmosphere inside the package—typically by replacing oxygen with gases like nitrogen or carbon dioxide—to slow down the degradation of food and maintain product quality over time. This is particularly effective for fresh produce, meat, fish, and ready-to-eat meals, which are prone to rapid spoilage if not properly packaged. These packaging methods are widely used by small food factories that need to maintain the freshness and quality of their products for a longer shelf life, helping them compete with larger brands that may have more extensive resources (Guillard et al., 2018; Ogwu & Ogunsola, 2024).

Beyond its role in preservation, food packaging plays a vital part in enhancing the value of a product by contributing to its overall appearance and marketability. In a crowded marketplace, packaging serves as the first point of contact between a product and the consumer, making it a critical tool for attracting attention and creating a lasting impression. Small and medium-sized food factories can use packaging to communicate key product attributes, such as quality, freshness, and authenticity, which are important factors for consumers when making purchasing decisions. The design, color scheme, and imagery on the packaging can evoke a sense of trust, quality, and craftsmanship, all of which are crucial for small brands trying to stand out against larger, more established competitors (Ahmed et al., 2017). For example, the use of premium packaging materials such as glass jars, kraft paper, or eco-friendly pouches can signal to consumers that the product is of high quality, natural, or artisanal in nature, which is a strong selling point in today's market where consumers are increasingly interested in clean-label, organic, and locally sourced products. Additionally, packaging that is designed with care and attention to detail can communicate the brand's commitment to quality and customer satisfaction, fostering consumer loyalty and repeat business. For small producers, creative and well-thought-out packaging is an effective way to enhance product value without necessarily increasing production costs. This is particularly important for businesses that are competing with larger brands but may not have the same level of marketing budget or resources (Ritika & Rizwana, 2024).

Sustainability has become a central focus for consumers and manufacturers alike, and packaging plays a significant role in this shift toward more environmentally conscious consumption. The rising demand for sustainable packaging solutions is driven by consumers' growing awareness of the environmental impact of plastic waste and their desire to support brands that prioritize eco-friendly practices (Dangelico & Pujari, 2010). Small and medium-sized food factories, which are often more agile and flexible in their operations, are in an excellent position to respond to this trend by adopting more sustainable packaging materials and practices. By choosing recyclable, biodegradable, or compostable materials, manufacturers can reduce their environmental footprint and appeal to eco-conscious consumers. Packaging made from post-consumer recycled (PCR) materials or plant-based plastics, such as biopolymers derived from corn or sugarcane, offers a sustainable alternative to traditional petroleum-based plastics and helps to address concerns over plastic pollution. In addition to using sustainable materials, small food factories can also implement packaging designs that minimize waste, such as reduced packaging sizes, minimalist designs, or concentrated formats that require less packaging per unit. Not only does sustainable packaging enhance the perceived value of a product by demonstrating a commitment to environmental responsibility, but it can also improve brand image, attract environmentally conscious consumers, and help food manufacturers meet regulatory requirements related to packaging waste. In many markets, the regulatory landscape is becoming stricter in terms of packaging sustainability, and small food manufacturers who adopt sustainable packaging solutions early on can gain a competitive edge by being ahead of regulatory changes and consumer demands (Coghlan et al., 2020; A. D. Smith, 2012).

Furthermore, food packaging plays a critical role in food safety and traceability, which are of increasing importance in today's food industry. Consumers are more concerned than ever about the safety of the food they purchase, and packaging that provides clear and reliable information about the product's origin, ingredients, allergens, and expiration date can enhance the perceived value of the product by instilling confidence in its quality and safety. For small and medium-sized food manufacturers, packaging is a powerful tool for ensuring transparency and building trust with consumers. Packaging labels that clearly indicate certification, such as organic, gluten-free, or fair trade, can differentiate products from competitors and create a stronger connection with health-conscious and socially responsible consumers. Additionally, modern technologies such as QR codes, RFID tags, and smart packaging are increasingly being integrated into food packaging, offering new ways to provide traceability, authentication, and real-time information about product freshness and quality. This type of packaging innovation enhances the overall value of the product by offering consumers a higher level of transparency and confidence, which is particularly important in an era of increasing food recalls and consumer concern about food safety. Smart packaging solutions can also be used to monitor temperature and freshness during transit and storage, alerting consumers or suppliers to any deviations from optimal conditions and ensuring the product remains safe and high-quality (Suhaimi et al., 2024).

The cost of packaging is a key consideration for small and medium-sized food manufacturers, and it is important to strike a balance between functionality, aesthetics, and cost-effectiveness. While premium packaging can elevate a product's perceived value, small producers must carefully consider their production and packaging costs to ensure that the packaging does not become a financial burden. Fortunately, advancements in packaging technology have made it easier for smaller manufacturers to access cost-effective yet high-quality packaging solutions. Flexible packaging, for example, offers an affordable and lightweight alternative to traditional rigid packaging, while still providing protection, convenience, and branding opportunities. Pouches, stand-up bags, and shrink wraps are often more affordable and easier to handle than glass jars or plastic containers, making them an attractive option for small food manufacturers who need to maintain competitive pricing. Additionally, the growing trend toward digital printing technologies has made it possible for small and medium-sized food factories to print high-quality, full-color packaging designs in small runs without incurring the high costs associated with traditional printing methods like offset printing. This has enabled smaller brands to create professional-looking packaging that helps them compete with larger companies on store shelves, without the need for large minimum order quantities or significant upfront investment (Ji & Han, 2022; Rooney et al., 2023; M. T. Smith, 2001; Sukumaran & Jano, 2024).

6. Conclusion

Enhancing food quality and safety, alongside agricultural value addition, is critical for the growth and sustainability of small and medium-sized enterprises (SMEs) in the food production sector. As global demand for safe, nutritious, and high-quality food continues to rise, SMEs must adopt stringent food safety standards, innovative processing techniques, and effective packaging strategies to remain competitive and meet consumer expectations. Food safety standards and principles are foundational to building consumer trust, ensuring public health, and gaining access to both local and international markets. By adhering to established guidelines such as Hazard Analysis Critical Control Points (HACCP) and Good Manufacturing Practices (GMP), SMEs can mitigate food safety risks and minimize the likelihood of contamination. Food safety is also inextricably linked to operational efficiency and product consistency, both of which contribute to long-term business success. Simultaneously, agricultural value addition offers significant economic and social benefits for SMEs. It enables the transformation of raw agricultural products into higher-value goods, improving profitability, reducing food waste, and contributing to food security. Techniques such as canning, freezing, fermentation, and drying, paired with innovative packaging solutions, allow SMEs to meet diverse consumer demands, extend product shelf life, and enter new markets. Effective packaging not only preserves the quality of processed products but also enhances their marketability, creating a strong brand identity and facilitating consumer loyalty.

By integrating food safety practices with value addition strategies, SMEs can unlock new business opportunities, ensure sustainability, and positively impact the broader agricultural and food sectors. SMEs should invest in modern food processing technologies that improve product consistency, quality, and safety. Automation and smart technologies can streamline production, enhance food safety monitoring, and reduce labor costs. Implementing digital solutions for traceability can improve transparency in food production, allowing businesses to track raw materials and processed products from farm to table. This can be crucial for ensuring food safety and meeting regulatory requirements, especially in export markets. Ongoing education and training on food safety regulations and best practices are essential for the workforce. SMEs should ensure that staff are regularly trained on food safety standards, hygienic practices, and the correct handling of food. SMEs should consider implementing comprehensive food safety management systems, including HACCP and GMP. These systems can help identify and control potential hazards at every stage of production. SMEs can invest in sustainable practices to reduce food waste, such as repurposing by-products for animal feed, bioenergy, or further value-added products. This not only contributes to sustainability but also helps to maximize profits from all parts of the agricultural output. With increasing consumer demand for eco-friendly options, SMEs should focus on adopting sustainable packaging materials, such as biodegradable plastics, compostable packaging, and reusable containers. By taking these proactive steps, SMEs can enhance their food safety and quality management practices, leverage value addition to diversify their product offerings, and position themselves for long-term success in a rapidly changing global food market.

7. References

Abate Reta, M., & Hailu Addis, A. (2015). Available online. In *International Journal of Food Science and Microbiology* (Vol. 2, Issue 6). www.internationalscholarsjournals.org

Adesokan, H. K., Akinseye, V. O., & Adesokan, G. A. (2015). Food safety training is associated with improved knowledge and behaviours among foodservice establishments' workers. *International Journal of Food Science*, *2015*(1), 328761.

Adinolfi, F., Di Pasquale, J., & Capitanio, F. (2016). Economic issues on food safety. *Italian Journal of Food Safety*, *5*(1).

Ahinful, G. (2018). *The relationship between environmental management practices and financial performance of Ghanaian SMEs.* Bournemouth University.

Ahmed, I., Lin, H., Zou, L., Brody, A. L., Li, Z., Qazi, I. M., Pavase, T. R., & Lv, L. (2017). A comprehensive review on the application of active packaging technologies to muscle foods. *Food Control*, *82*, 163–178.

Akbar, A., & Anal, A. K. (2011). Food safety concerns and food-borne pathogens, Salmonella, Escherichia coli and Campylobacter. *FUUAST Journal of Biology*, *1*(1 June), 5–17.

Akharume, F. U., Aluko, R. E., & Adedeji, A. A. (2021). Modification of plant proteins for improved functionality: A review. *Comprehensive Reviews in Food Science and Food Safety*, *20*(1), 198–224. https://doi.org/10.1111/1541-4337.12688

Akhtar, S., Sarker, M. R., & Hossain, A. (2014). Microbiological food safety: a dilemma of developing societies. *Critical Reviews in Microbiology*, *40*(4), 348–359.

Amit, S. K., Uddin, M. M., Rahman, R., Islam, S. M. R., & Khan, M. S. (2017). A review on mechanisms and commercial aspects of food preservation and processing. *Agriculture \& Food Security*, *6*, 1–22.

Anagnostopoulos, D. A., & Tsaltas, D. (2019). Fermented foods and beverages. In *Innovations in traditional foods* (pp. 257–291). Elsevier.

Anand, S. P., & Sati, N. (2013). Artificial preservatives and their harmful effects: looking toward nature for safer alternatives. *Int. J. Pharm. Sci. Res*, *4*(7), 2496–2501.

Anderson, N. M., Larkin, J. W., Cole, M. B., Skinner, G. E., Whiting, R. C., Gorris, L. G. M., Rodriguez, A., Buchanan, R., Stewart, C. M., Hanlin, J. H., & others. (2011). Food safety objective approach for controlling Clostridium botulinum growth and toxin production in commercially sterile foods. *Journal of Food Protection*, *74*(11), 1956–1989.

Andrés, A., Barat, J. M., Grau, R., & Fito, P. (2007). Principles of drying and smoking. *Handbook of Fermented Meat and Poultry*, *1*, 37–50.

Anyshchenko, A., & Yarnold, J. (2021). From 'mad cow'crisis to synthetic biology: challenges to

EU regulation of GMOs beyond the European context. *International Environmental Agreements: Politics, Law and Economics*, *21*(3), 391–404.

Arcidiacono, G., Risaliti, E., & Del Pero, F. (2024). Design for Six Sigma in the Product Development Process Under a Sustainability Point of View: A Real-Life Case Study. *Sustainability*, *16*(23), 10387.

Ashaolu, T. J., Khalifa, I., Mesak, M. A., Lorenzo, J. M., & Farag, M. A. (2023). A comprehensive review of the role of microorganisms on texture change, flavor and biogenic amines formation in fermented meat with their action mechanisms and safety. *Critical Reviews in Food Science and Nutrition*, *63*(19), 3538–3555.

Assegehegn, G., la Fuente, E., Franco, J. M., & Gallegos, C. (2019). The importance of understanding the freezing step and its impact on freeze-drying process performance. *Journal of Pharmaceutical Sciences*, *108*(4), 1378–1395.

Athukorala, P.-C., & Jayasuriya, S. (2003). Food safety issues, trade and WTO rules: A developing country perspective. *World Economy*, *26*(9), 1395–1416.

Athukorala, P., & Jayasuriya, S. (2005). Liberalisation and Industrial Growth: Lessons from Sri Lanka. In *Economic Growth, Economic Performance and Welfare in South Asia* (pp. 102–118). Springer.

Augustin, M. A., Riley, M., Stockmann, R., Bennett, L., Kahl, A., Lockett, T., Osmond, M., Sanguansri, P., Stonehouse, W., Zajac, I., & others. (2016). Role of food processing in food and nutrition security. *Trends in Food Science & Technology*, *56*, 115–125.

Aung, M. M., & Chang, Y. S. (2014). Traceability in a food supply chain: Safety and quality perspectives. *Food Control*, *39*, 172–184.

Awuah, G. B., Ramaswamy, H. S., & Economides, A. (2007). Thermal processing and quality: Principles and overview. *Chemical Engineering and Processing: Process Intensification*, *46*(6), 584–602.

Ba, M. N., & others. (2016). Strategic agricultural commodity value chains in Africa for increased food: the regional approach for food security. *Agricultural Sciences*, *7*(09), 549.

Bacs, M., Yüksel, M., & Çavucsouglu, T. (2007). Difficulties and barriers for the implementing of HACCP and food safety systems in food businesses in Turkey. *Food Control*, *18*(2), 124–130.

Baffes, J., & Nagle, P. (2022). *Commodity markets: evolution, challenges, and policies.* World Bank Publications.

Banozic, M., Vladic, J., Banjari, I., Velic, D., Aladic, K., & Jokic, S. (2023). Spray drying as a method of choice for obtaining high quality products from food wastes--A review. *Food Reviews International*, *39*(4), 1953–1985.

Barbut, S. (2020). Meat industry 4.0: A distant future? *Animal Frontiers*, *10*(4), 38–47.

Bassetti, E., Blankenship, J., White, J. M., Sweet, L., Threapleton, D., & Pries, A. M. (2023).

Benchmarking the nutrient composition and labelling practices of dry or instant cereals for older infants and young children across seven Southeast Asian countries. *Maternal & Child Nutrition*, *19*, e13603.

Bazzan, G. (2019). *EFFECTIVE GOVERNANCE DESIGNS OF FOOD SAFETY REGULATION: EVIDENCE FROM 15 EU COUNTRIES*.

Behrens, J. H., Vedovato, G. M., Cervato-Mancuso, A. M., & Bastos, D. H. M. (2015). Social representations of safety in food services. *Food Research International*, *74*, 324–328.

Bendeković, J., Naletina, D., & Nola, I. (2015). Food safety and food quality in the supply chain. *Trade Perspectives*, *151*, 1–13.

Beneria, L., Diana Deere, C., & Kabeer, N. (2012). Gender and international migration: Globalization, development, and governance. *Feminist Economics*, *18*(2), 1–33.

Bennett, R. J., & Smith, C. (2002). Competitive conditions, competitive advantage and the location of SMEs. *Journal of Small Business and Enterprise Development*, *9*(1), 73–86.

Bhandari, B. R., Patel, K. C., & Chen, X. D. (2008). Spray drying of food materials-process and product characteristics. *Drying Technologies in Food Processing*, *4*, 113–157.

Bloomfield, S. F., Exner, M., Signorelli, C., Nath, K. J., & Scott, E. A. (2012). The chain of infection transmission in the home and everyday life settings, and the role of hygiene in reducing the risk of infection. *International Scientific Forum on Home Hygiene*.

Bolten, S., Belias, A., Weigand, K. A., Pajor, M., Qian, C., Ivanek, R., & Wiedmann, M. (2023). Population dynamics of Listeria spp., Salmonella spp., and Escherichia coli on fresh produce: A scoping review. *Comprehensive Reviews in Food Science and Food Safety*, *22*(6), 4537–4572.

Bomba, M. Y., & Susol, N. Y. (2020). Main requirements for food safety management systems under international standards: BRC, IFS, FSSC 22000, ISO 22000, Global GAP, SQF. *Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies. Series: Food Technologies*, *22*(93), 18–25.

Bramsiepe, C., Sievers, S., Seifert, T., Stefanidis, G. D., Vlachos, D. G., Schnitzer, H., Muster, B., Brunner, C., Sanders, J. P. M., Bruins, M. E., & others. (2012). Low-cost small scale processing technologies for production applications in various environments—Mass produced factories. *Chemical Engineering and Processing: Process Intensification*, *51*, 32–52.

Briones, R., & Felipe, J. (2013). Agriculture and structural transformation in developing Asia: review and outlook. *Asian Development Bank Economics Working Paper Series*, *363*.

Brown, P. N., & Chan, M. (2010). An overview of functional food regulation in North America, European Union, Japan and Australia. *Functional Food Product Development*, 257–292.

Bryan, F. L. (1988). Risks associated with vehicles of foodborne pathogens and toxins. *Journal of Food Protection*, *51*(6), 498–508.

Buchanan, R. L., Havelaar, A. H., Smith, M. A., Whiting, R. C., & Julien*, E. (2009). The key events dose-response framework: its potential for application to foodborne pathogenic microorganisms. *Critical Reviews in Food Science and Nutrition*, *49*(8), 718–728.

Buchanan, R. L., Smith, J. L., & Long, W. (2000). Microbial risk assessment: dose-response relations and risk characterization. *International Journal of Food Microbiology*, *58*(3), 159–172.

Buckley, G. J., & Riviere, J. E. (2012). *Ensuring safe foods and medical products through stronger regulatory systems abroad*.

Buzby, J. C., & Roberts, T. (2009). The economics of enteric infections: human foodborne disease costs. *Gastroenterology*, *136*(6), 1851–1862.

Cakaloglu, B., Ozyurt, V. H., & Otles, S. (2018). Cold press in oil extraction. A review. *Ukrainian Food Journal*, *7*, *Issue 4*, 640–654.

Cappelli, A., Lupori, L., & Cini, E. (2021). Baking technology: A systematic review of machines and plants and their effect on final products, including improvement strategies. *Trends in Food Science & Technology*, *115*, 275–284.

Carlarne, C. (2007). From the USA with love: sharing home-grown hormones, GMOs, and clones with a reluctant Europe. *Envtl. L.*, *37*, 301.

Carrasco, E., Morales-Rueda, A., & Garc\'\ia-Gimeno, R. M. (2012). Cross-contamination and recontamination by Salmonella in foods: A review. *Food Research International*, *45*(2), 545–556.

Chambo, S. A. (2009). Agricultural co-operatives: Role in food security and rural development. *A Paper Presented to Expert Group Meeting on Co-Operatives on 28th to 30th April*.

Charan, S., & Panghal, A. (2018). Importance of traceability in food supply chain for brand protection and food safety systems implementation. *Ann Biol*, *34*(2), 111–118.

Chen, H., Liu, S., Chen, Y., Chen, C., Yang, H., & Chen, Y. (2020). Food safety management systems based on ISO 22000: 2018 methodology of hazard analysis compared to ISO 22000: 2005. *Accreditation and Quality Assurance*, *25*, 23–37.

Chetty, D. R. V., Boojhawon, R., Bhagwant, S., & Levy, L. (2024). Factors affecting the occupational safety and health of small and medium enterprises in the Construction Sector of Mauritius. *Social Sciences \& Humanities Open*, *10*, 100964.

Chiozzi, V., Agriopoulou, S., & Varzakas, T. (2022). Advances, applications, and comparison of thermal (pasteurization, sterilization, and aseptic packaging) against non-thermal (ultrasounds, UV radiation, ozonation, high hydrostatic pressure) technologies in food processing. *Applied Sciences*, *12*(4), 2202.

Coghlan, C., Labrecque, J., Ma, Y., & Dube, L. (2020). A biological adaptability approach to innovation for small and medium enterprises (SMEs): Strategic insights from and for health-promoting agri-food innovation. *Sustainability*, *12*(10), 4227.

Coia, J., Barker, G., McDowell, D., Nuttall, D., Glazebrook, R., Davies, R., Larkin, L., Lane, C., Upadhyay, M., & Butler, S. (2017). *Ad Hoc ACMSF Group on eggs*.

Commission, J. F. C. A., Programme, J. F. F. S., & Organization, W. H. (2007). *Codex Alimentarius Commission: Procedural Manual*. Food \& Agriculture Org.

Cordeiro, M., Fernandes, V., Curado, J., & Ferreira, J. C. (2024). Enhancing Agriculture Products Traceability towards Sustainability. *Journal of Network and Innovative Computing*, *12*, 15.

Costa, L. B. M., Godinho Filho, M., Fredendall, L. D., & Paredes, F. J. G. (2018). Lean, six sigma and lean six sigma in the food industry: A systematic literature review. *Trends in Food Science \& Technology*, *82*, 122–133.

Crandall, P., Van Loo, E. J., O'bryan, C. A., Mauromoustakos, A., Yiannas, F., Dyenson, N., & Berdnik, I. (2012). Companies' opinions and acceptance of global food safety initiative benchmarks after implementation. *Journal of Food Protection*, *75*(9), 1660–1672.

Cui, T., Gine, G. R., Lei, Y., Shi, Z., Jiang, B., Yan, Y., & Zhang, H. (2024). Ready-to-Cook Foods: Technological Developments and Future Trends—A Systematic Review. *Foods*, *13*(21), 3454.

Dabbene, F., Gay, P., & Tortia, C. (2014). Traceability issues in food supply chain management: A review. *Biosystems Engineering*, *120*, 65–80.

Dangelico, R. M., & Pujari, D. (2010). Mainstreaming green product innovation: Why and how companies integrate environmental sustainability. *Journal of Business Ethics*, *95*, 471–486.

Darwin, M. (2011). *Induction of Hypothermia in the Cryonics Patient: Theory and Technique, Part 2*.

Das, A. K., Nanda, P. K., Das, A., & Biswas, S. (2019). Hazards and safety issues of meat and meat products. In *Food safety and human health* (pp. 145–168). Elsevier.

Das, T., Nonglait, D. L., Rajput, D., & Arya, S. S. (2024). Packaging of Freeze-Dried Products. *Freeze Drying of Food Products: Fundamentals, Processes and Applications*, 203–228.

Davidson, I. (2024). *Biscuit, cookie and cracker production: process, production and packaging equipment*. Elsevier.

De Oliveira, C. A. F., Da Cruz, A. G., Tavolaro, P., & Corassin, C. H. (2016). Food safety: good manufacturing practices (GMP), sanitation standard operating procedures (SSOP), hazard analysis and critical control point (HACCP). In *Antimicrobial food packaging* (pp. 129–139). Elsevier.

De Silva, T. (2007). Hazard analysis and critical control point (HACCP). In *Handbook of Food Preservation* (pp. 987–1028). CRC Press.

Deak, T., & Mohácsi-Farkas, C. (2023). Thermal treatment. In *Food safety management* (pp. 405–419). Elsevier.

Demme, K. (2023). *The Effect of Upton Sinclair's The Jungle in the Progressive Era*. Tokoha University, Tokoha University Junior College Repository.

Demmler, K. M. (2020). The role of small and medium-sized enterprises in nutritious food supply chains in Africa. *Global Alliance for Improved Nutrition (GAIN)*, *2*.

Dhurandhar, N. V, Schoeller, D., Brown, A. W., Heymsfield, S. B., Thomas, D., Sørensen, T. I. A., Speakman, J. R., Jeansonne, M., & Allison, D. B. (2015). Energy balance measurement: when something is not better than nothing. *International Journal of Obesity*, *39*(7), 1109–1113.

Dlamini, B. C., & Adetunji, A. I. (2023). Hazard Analysis and Critical Control Point (HACCP) and Food Safety Management Systems. *Food Safety and Toxicology: Present and Future Perspectives*, *243*.

Dong, Q. L., Barker, G. C., Gorris, L. G. M., Tian, M. S., Song, X. Y., & Malakar, P. (2015). Status and future of quantitative microbiological risk assessment in China. *Trends in Food Science \& Technology*, *42*(1), 70–80.

Dora, M., Kumar, M., Van Goubergen, D., Molnar, A., & Gellynck, X. (2013). Food quality management system: Reviewing assessment strategies and a feasibility study for European food small and medium-sized enterprises. *Food Control*, *31*(2), 607–616.

Drummond, L., & Sun, D.-W. (2010). 11 effects of chilling and freezing on safety and quality of food products. *Processing Effects on Safety and Quality of Foods*, 295.

Dutta, S., Bhattacharya, S., Sadhukhan, R., Sengupta, S., Chatterjee, R., Roy Choudhury, M., & Das, S. (2023). Transforming Agriculture and Securing Food Using Digital Technologies: Past Evolution, Present Practices and Challenges, and Future Perspectives. *Present Practices and Challenges, and Future Perspectives*.

Dzwolak, W. (2019). Assessment of HACCP plans in standardized food safety management systems--The case of small-sized Polish food businesses. *Food Control*, *106*, 106716.

Dzwolak, W., & Anim, B. (2025). Barriers hindering maintenance of standardised HACCP-based food safety management systems in small Polish food businesses. *Food Control*, *168*, 110849.

Ehuwa, O., Jaiswal, A. K., & Jaiswal, S. (2021). Salmonella, food safety and food handling practices. *Foods*, *10*(5), 907.

El-Abidi, A., Yadir, S., El Bazi, W., Bideq, M., Bousseta, H., Kriraa, M., & Elfezazi, S. (2024). Experimental study and mathematical modeling of drying kinetics of mint leaves under forced convection. *Chemical Engineering Communications*, 1–12.

Elamin, W. M., Endan, J. B., Yosuf, Y. A., Shamsudin, R., & Ahmedov, A. (2015). High pressure processing technology and equipment evolution: a review. *Journal of Engineering Science & Technology Review*, *8*(5).

Ensari, M. \cSebnem, & Karabay, M. E. (2014). What helps to make SMEs successful in global markets? *Procedia-Social and Behavioral Sciences*, *150*, 192–201.

Eruaga, M. A. (2024). *Enhancing global food safety standards through international collaboration* *and policy harmonization*.

Eze, C. C., & Mena, B. (2024). The Role and Importance of Consumer Perception. In *Consumer Perceptions and Food* (pp. 3–22). Springer.

Fabrizi, R. (2021). *Chlorinated chicken, hormone beef and Genetically Modified Organisms (GMOs). A critical discourse analysis of news and tweets regarding the GMO debate during the political uncertainty represented by Brexit negotiations.* University of Sheffield.

Fairman, R., & Yapp, C. (2004). Compliance with Food Safety Legislation in Small and Micro Business: Enforcement as an External Motivation. *Journal of Environmental Health Research*, *3*(2), 40–48.

Fan, S., Brzeska, J., Keyzer, M., & Halsema, A. (2013). *From subsistence to profit: Transforming smallholder farms* (Vol. 26). Intl Food Policy Res Inst.

Faour-Klingbeil, D., & CD Todd, E. (2020). Prevention and control of foodborne diseases in Middle-East North African countries: Review of national control systems. *International Journal of Environmental Research and Public Health*, *17*(1), 70.

FDA, U. S., for Disease Control, C., Prevention, & others. (2003). Quantitative assessment of relative risk to public health from foodborne Listeria monocytogenes among selected categories of ready-to-eat foods. *US Food and Drug Administration Center for Food Safety and Applied Nutrition, College Park, Md: US FDA*.

Ferhat, M. A., Meklati, B. Y., & Chemat, F. (2007). Comparison of different isolation methods of essential oil from Citrus fruits: cold pressing, hydrodistillation and microwave 'dry'distillation. *Flavour and Fragrance Journal*, *22*(6), 494–504.

Fink, B. A. (2023). Codex Alimentarius at home and abroad: the regulatory costs of developing and implementing international and national food-safety standards. In *Research Handbook on International Food Law* (pp. 347–367). Edward Elgar Publishing.

Forsythe, S. (2012). *Food hygiene, microbiology and HACCP*. Springer Science \& Business Media.

Forsythe, S. J. (2008). *The microbiological risk assessment of food*. John Wiley \& Sons.

Fortin, N. D. (2022). *Food regulation: law, science, policy, and practice*. John Wiley \& Sons.

Fortin, N. D. (2023). Global governance of food safety: the role of the FAO, WHO, and Codex Alimentarius in regulatory harmonization. In *Research Handbook on International Food Law* (pp. 227–242). Edward Elgar Publishing.

Frakolaki, G., Kekes, T., Bizymis, A.-P., Giannou, V., & Tzia, C. (2023). Fundamentals of food frying processes. In *High-Temperature Processing of Food Products* (pp. 227–291). Elsevier.

Frewer, L., de Jonge, J., & van Kleef, E. (2009). Consumer perceptions of food safety. *Medical Science*, *2*, 243.

Fung, F., Wang, H.-S., & Menon, S. (2018). Food safety in the 21st century. *Biomedical Journal*, *41*(2), 88–95.

Gamage, S. K. N., Ekanayake, E. M. S., Abeyrathne, G., Prasanna, R., Jayasundara, J., & Rajapakshe, P. S. K. (2020). A review of global challenges and survival strategies of small and medium enterprises (SMEs). *Economies*, *8*(4), 79.

Gerardi, A. (2023). Global Food Safety Initiative (GFSI): underpinning the safety of the global food chain, facilitating regulatory compliance, trade, and consumer trust. In *Present Knowledge in Food Safety* (pp. 1089–1098). Elsevier.

Gereffi, G., & Lee, J. (2009). A global value chain approach to food safety and quality standards. *Global Health Diplomacy for Chronic Disease Prevention Working Paper Series, February*.

Gereffi, G., Lee, J., Christian, M., Fernandez-Stark, K., Hovsepian, M., Kindman, A., Liang, T., Lowe, M., Meltzer, E., Wintersteen, K., & others. (2008). The governance structures of US-based food and agriculture value chains and their relevance to healthy diets. *Healthy Eating Research Program, Robert Wood Johnson Foundation*, 1–86.

Gil, L., Ruiz, P., Escrivá, L., Font, G., & Manyes, L. (2017). A decade of Food Safety Management System based on ISO 22000: A global overview. *Revista de Toxicologia*, *34*(2), 84–93.

Grace, D. (2015a). *Food safety in developing countries: an overview*.

Grace, D. (2015b). Food safety in low and middle income countries. *International Journal of Environmental Research and Public Health*, *12*(9), 10490–10507.

Grace, D. (2016). *Influencing food environments for healthy diets through food safety*.

Grayna, K. Ä., Turek, J., & others. (2022). What Hinders the Development of a Sustainable Compostable Packaging Market? *European Journal of Sustainable Development*, *11*(4), 180.

Griffith, C. J., & Motarjemi, Y. (2023). Human Factors in Food Safety Management. In *Food Safety Management* (pp. 919–941). Elsevier.

Groenleer, M. L. P. (2014). Agency autonomy actually: Managerial strategies, legitimacy, and the early development of the European Union's agencies for drug and food safety regulation. *International Public Management Journal*, *17*(2), 255–292.

Gruszczynski, L., & Scott, J. (2023). *The WTO Agreement on Sanitary and Phytosanitary Measures: A Commentary*. Oxford University Press.

Guillard, V., Gaucel, S., Fornaciari, C., Angellier-Coussy, H., Buche, P., & Gontard, N. (2018). The next generation of sustainable food packaging to preserve our environment in a circular economy context. *Frontiers in Nutrition*, *5*, 121.

Haji, M., Kerbache, L., & Al-Ansari, T. (2022). Food quality, drug safety, and increasing public health measures in supply chain management. *Processes*, *10*(9), 1715.

Halabi, S. F. (2015). The Codex Alimentarius commission, corporate influence, and international trade: A perspective on FDA's global role. *American Journal of Law \& Medicine*, *41*(2–3), 406–421.

Hallman, W. K., & Cuite, C. L. (2009). *Food recalls and the American public: Improving communications*.

Hallman, W. K., Cuite, C. L., & Hooker, N. H. (2009a). *Consumer responses to food recalls: 2008 national survey report*.

Hallman, W. K., Cuite, C. L., & Hooker, N. H. (2009b). *Understanding Consumer Reponses to Food Recalls*.

Hallman, W. K., Cuite, C. L., Nucci, M. L., & Hooker, N. H. (2009). *Consumers and food recalls: what does the public want to hear?*

Hasnan, N. Z. N., Basha, R. K., Amin, N. A. M., Ramli, S. H. M., Tang, J. Y. H., & Ab Aziz, N. (2022). Analysis of the most frequent nonconformance aspects related to Good Manufacturing Practices (GMP) among small and medium enterprises (SMEs) in the food industry and their main factors. *Food Control*, *141*, 109205.

Havelaar, A. H., Brul, S., De Jong, A., De Jonge, R., Zwietering, M. H., & Ter Kuile, B. H. (2010). Future challenges to microbial food safety. *International Journal of Food Microbiology*, *139*, S79--S94.

Hayashi, H. (1989). Drying technologies of foods-their history and future. *Drying Technology*, *7*(2), 315–369.

Hecht, S. B. (2014). Forests lost and found in tropical Latin America: the woodland 'green revolution.' *The Journal of Peasant Studies*, *41*(5), 877–909.

Howard, P. H. (2021). Concentration and power in the food system. *Concentration and Power in the Food System*, 1–232.

Hoyle, D. (2017). *ISO 9000 Quality Systems Handbook-updated for the ISO 9001: 2015 standard: Increasing the Quality of an Organization's Outputs*. Routledge.

Huang, M., Zhang, M., & Bhandari, B. (2019). Recent development in the application of alternative sterilization technologies to prepared dishes: A review. *Critical Reviews in Food Science and Nutrition*, *59*(7), 1188–1196.

Hubbard, M. R. (2012). *Statistical quality control for the food industry*. Springer Science \& Business Media.

Humphrey, J. (2012). Food safety, private standards schemes and trade: the implications of the FDA food safety modernization act. *IDS Working Papers*, *2012*(403), 1–65.

Hutter, B. M. (2011). *Managing food safety and hygiene: governance and regulation as risk management*. Edward Elgar Publishing.

Ikpe, B. C. (2021). *Contaminated Raw Produce as a Major Source of Foodborne Salmonellosis*. Walden University.

Inyang, U., Oboh, I., & Etuk, B. (2017). Drying and the different techniques. *International Journal of Food Nutrition and Safety*, *8*(1), 45–72.

Ioannou Sartzi, M., Drettas, D., Stramarkou, M., & Krokida, M. (2024). A Comprehensive Review of the Latest Trends in Spray Freeze Drying and Comparative Insights with Conventional Technologies. *Pharmaceutics*, *16*(12), 1533.

Isanovic, S., Constantinides, S. V, Frongillo, E. A., Bhandari, S., Samin, S., Kenney, E., Wertheim-Heck, S., Nordhagen, S., Holdsworth, M., Dominguez-Salas, P., & others. (2023). How perspectives on food safety of vendors and consumers translate into food-choice behaviors in 6 African and Asian countries. *Current Developments in Nutrition*, *7*(1), 100015.

Jahnke, A. D. (2012). *Understanding the External Firm Factors Impacting Innovation in the Hardwood Veneer Industry*.

Jain, S., & Anal, A. K. (2017). *Production and characterization of functional properties of protein hydrolysates from egg shell membranes by lactic acid bacteria fermentation*. *54*(5), 1062–1072. https://doi.org/10.1007/s13197-017-2530-y

James, S. J., & James, C. (2023). Chilling and freezing. In *Food Safety Management* (pp. 453–474). Elsevier.

Jangam, S. V. (2011). An overview of recent developments and some R&D challenges related to drying of foods. *Drying Technology*, *29*(12), 1343–1357.

Jantjies, H. (2024). *An enquiry into the competitive performance of the South African deciduous fruit canning industry*. Stellenbosch University.

Jennings, S., Stentiford, G. D., Leocadio, A. M., Jeffery, K. R., Metcalfe, J. D., Katsiadaki, I., Auchterlonie, N. A., Mangi, S. C., Pinnegar, J. K., Ellis, T., & others. (2016). Aquatic food security: insights into challenges and solutions from an analysis of interactions between fisheries, aquaculture, food safety, human health, fish and human welfare, economy and environment. *Fish and Fisheries*, *17*(4), 893–938.

Ji, Y., & Han, J. (2022). Sustainable Home Meal Replacement (HMR) consumption in Korea: Exploring service strategies using a modified importance--performance analysis. *Foods*, *11*(6), 889.

Joardder, M. U. H., Hasan Masud, M., Joardder, M. U. H., & Masud, M. H. (2019). A brief history of food preservation. *Food Preservation in Developing Countries: Challenges and Solutions*, 57–66.

Jones, J. M., Adams, J., Harriman, C., Miller, C., & der Kamp, J. W. (2015). Nutritional impacts of different whole grain milling techniques: A review of milling practices and existing data. *Cereal Foods World*, *60*(3), 130–139.

Jones, O., & Tilley, F. (2009). *Competitive advantage in SMEs: towards a conceptual framework*. SSRN.

Jongwanich, J. (2009). The impact of food safety standards on processed food exports from developing countries. *Food Policy*, *34*(5), 447–457.

Kader, A. A. (2013). Postharvest technology of horticultural crops-An overview from farm to fork. *Ethiopian Journal of Applied Science and Technology*, *1*, 1–8.

Käferstein, F. (2003). Foodborne diseases in developing countries: aetiology, epidemiology and strategies for prevention. *International Journal of Environmental Health Research*, *13*(sup1), S161--S168.

Kaloti, S. (2022). *Effect of cold smoking on polycyclic aromatic hydrocarbon content and sensory properties in selected foods*.

Kamboj, S., Gupta, N., Bandral, J. D., Gandotra, G., & Anjum, N. (2020). Food safety and hygiene: A review. *International Journal of Chemical Studies*, *8*(2), 358–368.

Kassebaum, N., Kyu, H. H., Zoeckler, L., Olsen, H. E., Thomas, K., Pinho, C., Bhutta, Z. A., Dandona, L., Ferrari, A., Ghiwot, T. T., & others. (2017). Child and adolescent health from 1990 to 2015: findings from the global burden of diseases, injuries, and risk factors 2015 study. *JAMA Pediatrics*, *171*(6), 573–592.

Kassem, A. Z. E. (2018). Cost of Foodborne Illnesses: A literature Review. *Food Safety Science, Health and Behaviour*, 1–10.

Kerr, W. (2017). Implications of non-equilibrium states and glass transitions in fried foods. In *Non-equilibrium states and glass transitions in foods* (pp. 209–239). Elsevier.

Khaliq, A., Ahsan, S., Chughtai, M. F. J., Liaqat, A., Mehmood, T., Sameed, N., Saeed, K., & Rahman, S. J. U. (2023). Food Hazards and Their Risk Management. In *Food Microbial and Molecular Biology* (pp. 99–130). Apple Academic Press.

Kheni, N. A., Gibb, A. G. F., & Dainty, A. R. J. (2010). Health and safety management within small- and medium-sized enterprises (SMEs) in developing countries: Study of contextual influences. *Journal of Construction Engineering and Management*, *136*(10), 1104–1115.

Kholiya, S., Chauhan, A., Kumar, D., KT, V., Upadhyay, R. K., & Padalia, R. C. (2023). Essential oils, applications, and different extraction methods. *Essential Oils: Sources, Production and Applications*, 25.

Khouryieh, H. A. (2021). Novel and emerging technologies used by the US food processing industry. *Innovative Food Science \& Emerging Technologies*, *67*, 102559.

Kim, C. W. (2009). *The Relationships Among Gender, Work Experience, and Leadership Experience in Transformational Leadership*.

King, T., Cole, M., Farber, J. M., Eisenbrand, G., Zabaras, D., Fox, E. M., & Hill, J. P. (2017). Food safety for food security: Relationship between global megatrends and developments in food safety. *Trends in Food Science \& Technology*, *68*, 160–175.

Kinsey, J., Harrison, R. W., Degeneffe, D., Ferreira, G., & Shiratori, S. (2009). Index of consumer confidence in the safety of the United States food system. *American Journal of Agricultural Economics*, *91*(5), 1470–1476.

Konudula, S., & Kuruvanparamb Krishnan, M. (2024). *A Case Study on Sustainability Certifications and Governance in the IndianEdible Oil MSMEs-Fostering Commitment to Organizational Sustainability*.

Konur, S., Lan, Y., Thakker, D., Morkyani, G., Polovina, N., & Sharp, J. (2023). Towards design and implementation of Industry 4.0 for food manufacturing. *Neural Computing and*

Applications, 1–13.

Kotsanopoulos, K. V, & Arvanitoyannis, I. S. (2017). The role of auditing, food safety, and food quality standards in the food industry: A review. *Comprehensive Reviews in Food Science and Food Safety*, *16*(5), 760–775.

Koutchma, T. (2009). Advances in ultraviolet light technology for non-thermal processing of liquid foods. *Food and Bioprocess Technology*, *2*, 138–155.

Kubiak, M. S., & Polak-Sliwinska, M. (2015). The level of chosen polycyclic aromatic hydrocarbons (PAHs) in meat products smoked by using an industrial and a traditional method. *Polish Journal of Natural Sciences*, *30*(2), 137–147.

Kumar, V., & Reinartz, W. (2016). Creating enduring customer value. *Journal of Marketing*, *80*(6), 36–68.

Kutkaitis, M., & Hlasha Al Sibai, A. (2024). *Navigating Compliance: Sustainable Packaging Challenges for SMEs in the EU: A study of the sustainable packaging compliance challenges that SMEs face when operating within the EU*.

Lam, T. K., Heales, J., Hartley, N., Hodkinson, C., & others. (2020). Consumer trust in food safety requires information transparency. *Australasian Journal of Information Systems*, *24*.

Lammie, S. L., & Hughes, J. M. (2016). Antimicrobial resistance, food safety, and one health: the need for convergence. *Annual Review of Food Science and Technology*, *7*(1), 287–312.

Lang, T., Barling, D., & Caraher, M. (2009). *Food policy: integrating health, environment and society*. OUP Oxford.

Ledesma, E., Rendueles, M., & Diaz, M. (2017). Smoked food. In *Current developments in biotechnology and bioengineering* (pp. 201–243). Elsevier.

Lee, J. C., Neonaki, M., Alexopoulos, A., & Varzakas, T. (2023). Case studies of small-medium food enterprises around the world: Major constraints and benefits from the implementation of food safety management systems. *Foods*, *12*(17), 3218.

Legg, S. J., Olsen, K. B., Laird, I. S., & Hasle, P. (2015). Managing safety in small and medium enterprises. In *Safety Science* (Vol. 71, pp. 189–196). Elsevier.

Liang, B., & Scammon, D. L. (2016). Food contamination incidents: what do consumers seek online? Who cares? *International Journal of Nonprofit and Voluntary Sector Marketing*, *21*(4), 227–241.

Liggans, G., & Kim, S. R. (2024). How Food Safety Culture Is Operationalized for Retail Food Settings: A Systematic Literature Review. *SAGE Open*, *14*(1), 21582440241236584.

Lisboa, H. M., Pasquali, M. B., dos Anjos, A. I., Sarinho, A. M., de Melo, E. D., Andrade, R., Batista, L., Lima, J., Diniz, Y., & Barros, A. (2024). Innovative and Sustainable Food Preservation Techniques: Enhancing Food Quality, Safety, and Environmental Sustainability. *Sustainability*, *16*(18), 8223.

Liu, X. (2020). *Modeling Analysis on Deterioration Characteristics of Frying Oil Using*

Metabolomics Approach.

Liu, X., Le Bourvellec, C., Yu, J., Zhao, L., Wang, K., Tao, Y., Renard, C. M. G. C., & Hu, Z. (2022). Trends and challenges on fruit and vegetable processing: Insights into sustainable, traceable, precise, healthy, intelligent, personalized and local innovative food products. *Trends in Food Science & Technology*, *125*, 12–25.

Lokunarangodage, C. V. K., Wickramasinghe, I., & Ranaweera, K. (2016). *Review of ISO 22000: 2005, Structural synchronization and ability to deliver food safety with suggestions for improvements*.

Lufu, R., Ambaw, A., & Opara, U. L. (2020). Water loss of fresh fruit: Influencing pre-harvest, harvest and postharvest factors. *Scientia Horticulturae*, *272*, 109519. https://doi.org/10.1016/J.SCIENTA.2020.109519

MacDonald, J. M., Perry, J., Ahearn, M. C., Banker, D., Chambers, W., Dimitri, C., Key, N., Nelson, K. E., & Southard, L. W. (2004). Contracts, markets, and prices: Organizing the production and use of agricultural commodities. *USDA-ERS Agricultural Economic Report*, *837*.

Madilo, F. K., Kunadu, A. P.-H., & Tano-Debrah, K. (2024). Challenges with food safety adoption: A review. *Journal of Food Safety*, *44*(1), e13099.

Maga, J. A. (2018). *Smoke in food processing*. CRC press.

Maicas, S. (2020). The role of yeasts in fermentation processes. In *Microorganisms* (Vol. 8, Issue 8, p. 1142). MDPI.

Mak, J. Y., & Kim, C. (2017). Relationship among gender, athletic involvement, student organization involvement and leadership. *Women in Sport and Physical Activity Journal*, *25*(2), 89–95.

Man, D. (2002). Food Industry briefing series: Shelf life. *Blachwell Science Ltd Ed. UK*.

Mansour, S. A. (2011). Chemical pollutants threatening food safety and security: an overview. *Advances in Food Protection: Focus on Food Safety and Defense*, 73–117.

Manzoor, A., Jan, B., Zahoor, I., Anjum, N., Nabi, A., Allai, F. M., Rizvi, Q. U. E. H., Shiekh, R. A., Sheikh, M. A., & Ahmad, S. (2022). Thermal treatment of foods: science, shelf life, and quality. In *Shelf Life and Food Safety* (pp. 165–180). CRC Press.

Marriott, N. G., Gravani, R. B., & Schilling, M. W. (2006). *Principles of food sanitation* (Vol. 22). Springer.

Masanet, E., Therkelsen, P., & Worrell, E. (2012). *Energy Efficiency Improvement and Cost Saving Opportunities for the Baking Industry: An ENERGY STAR®Guide for Plant and Energy Managers*.

Masi, D., Cagno, E., & Micheli, G. J. L. (2014). Developing, implementing and evaluating OSH interventions in SMEs: a pilot, exploratory study. *International Journal of Occupational Safety and Ergonomics*, *20*(3), 385–405.

Mayett-Moreno, Y., & López Oglesby, J. M. (2018). Beyond food security: challenges in food safety policies and governance along a heterogeneous agri-food chain and its effects on health measures and sustainable development in Mexico. *Sustainability*, *10*(12), 4755.

McFarland, P., Checinska Sielaff, A., Rasco, B., & Smith, S. (2019). Efficacy of food safety training in commercial food service. *Journal of Food Science*, *84*(6), 1239–1246.

Mediani, A., Hamezah, H. S., Jam, F. A., Mahadi, N. F., Chan, S. X. Y., Rohani, E. R., Che Lah, N. H., Azlan, U. K., Khairul Annuar, N. A., Azman, N. A. F., & others. (2022). A comprehensive review of drying meat products and the associated effects and changes. *Frontiers in Nutrition*, *9*, 1057366.

Megel, A. J. (2011). *Utilizing quality function deployment to create a quality requirement matrix for biofuel refinery inputs via voice of customer techniques*. Oklahoma State University.

Meghwal, M., Heddurshetti, U., & Biradar, R. (2017). Good manufacturing practices for food processing industries: Principles and practical applications. In *Food technology* (pp. 3–28). Apple Academic Press.

Mendis, E., & Rajapakse, N. (2009). GMP AND HACCP. *The Ceylon Chamber of Commerce*.

Mesly, O., & Réthoré, C. (2024). *Commercial Space Design and Customer Experience*. Cambridge Scholars Publishing.

Michel, M., Eldridge, A. L., Hartmann, C., Klassen, P., Ingram, J., & Meijer, G. W. (2024). Benefits and challenges of food processing in the context of food systems, value chains and sustainable development goals. *Trends in Food Science & Technology*, 104703.

Minor, T., Astill, G., Raszap, S., Thornsbury, S., Buzby, J. C., Hitaj, C., Kantor, L., Kuchler, F., Ellison, B., Mishra, A. K., & others. (2020). *Economic drivers of food loss at the farm and pre-retail sectors: a look at the produce supply chain in the United States*.

Moerman, F. (2017). Personal hygiene and good maintenance practices for the servicing of food processing equipment. In *Food protection and security* (pp. 267–327). Elsevier.

Mohan, C., Ravishankar, C., & Gopal, T. (2015). Canning of fishery products. *Handbook of Food Processing*, 57–86.

Mollik, M. A., & Ananna, A. K. (2024). *The impact of globalization on technology-oriented small and medium-sized enterprises (SMEs) in the Bangladeshi market*.

Mortimore, S., & Wallace, C. (2013). *HACCP: A practical approach*. Springer Science \& Business Media.

Mouritsen, O. G., & Styrbæk, K. (2017). *Mouthfeel: how texture makes taste*. Columbia University Press.

Moyo, S. (2016). *Family farming in sub-Saharan Africa: its contribution to agriculture, food security and rural development*.

Mujahid, M., Wakeel, M., Ali, A. M., Saeed, S., Nawaz, A. S., & Hafeez, K. (2024). Food fermentation: Traditional practices and modern applications in food industry. *International Journal of Food and Fermentation Technology*, *14*(1), 239–273.

Mutton, B. (2009). *Thermal Death of Bacteria Associated with*. University of Khartoum.

Nantapo, C. W. T., Muchenje, V., Nkukwana, T. T., Hugo, A., Descalzo, A., Grigioni, G., & Hoffman, L. C. (2015). Socio-economic dynamics and innovative technologies affecting health-related lipid content in diets: Implications on global food and nutrition security. *Food Research International*, *76*, 896–905.

Nayak, R., & Waterson, P. (2019). Global food safety as a complex adaptive system: Key concepts and future prospects. *Trends in Food Science \& Technology*, *91*, 409–425.

Nestle, M. (2010). *Safe food: The politics of food safety* (Vol. 5). Univ of California Press.

Newell, D. G., Koopmans, M., Verhoef, L., Duizer, E., Aidara-Kane, A., Sprong, H., Opsteegh, M., Langelaar, M., Threfall, J., Scheutz, F., & others. (2010). Food-borne diseases—the challenges of 20 years ago still persist while new ones continue to emerge. *International Journal of Food Microbiology*, *139*, S3--S15.

Nguyen, T. T. B. (2023). How do well-performed food businesses manage suppliers in emerging economies? *International Journal of Physical Distribution & Logistics Management*, *53*(10), 1129–1157.

Nguyen, T. T. B., & Li, D. (2022). A systematic literature review of food safety management system implementation in global supply chains. *British Food Journal*, *124*(10), 3014–3031.

Niu, D., Zeng, X.-A., Ren, E.-F., Xu, F.-Y., Li, J., Wang, M.-S., & Wang, R. (2020). Review of the application of pulsed electric fields (PEF) technology for food processing in China. *Food Research International*, *137*, 109715.

Odipe, O. E., Raimi, M. O., Deinkuro, N. S., Funmilayo, A. A., innocent Edewor, O.-P., Lateefat, H. M., & Fadeyibi, M. (2019). Assessment of environmental sanitation, food safety knowledge, handling practice among food handlers of Bukateria Complexes in Iju Town, Akure north of Ondo-State, Nigeria. *Acta Scientific Nutritional Health*, *3*(6).

Ogwu, M. C., & Ogunsola, O. A. (2024). Physicochemical Methods of Food Preservation to Ensure Food Safety and Quality. In *Food Safety and Quality in the Global South* (pp. 263–298). Springer.

Oke, E. K., Idowu, M. A., Sobukola, O. P., Adeyeye, S. A. O., & Akinsola, A. O. (2018). Frying of food: a critical review. *Journal of Culinary Science \& Technology*, *16*(2), 107–127.

Okpala, C. O. R., & Korzeniowska, M. (2023). Understanding the relevance of quality management in agro-food product industry: From ethical considerations to assuring food hygiene quality safety standards and its associated processes. *Food Reviews International*, *39*(4), 1879–1952.

Olayemi, W. A., & Olatidoye, O. P. (2024). Understanding the Agribusiness Model and Agricultural Value Chain (Africa). In *Agripreneurship and the Dynamic Agribusiness Value Chain* (pp. 257–272). Springer.

Oliveira, M. D., Lopes, D. F., & e Costa, C. A. (2018). Improving occupational health and safety risk evaluation through decision analysis. *International Transactions in Operational Research*, *25*(1), 375–403.

Opara, U. L., & others. (2013). A review on the role of packaging in securing food system: Adding value to food products and reducing losses and waste. *African Journal of Agricultural Research*, *8*(22), 2621–2630.

Organization, W. H., & others. (2010). *FAO/WHO expert meeting on the application of nanotechnologies in the food and agriculture sectors: potential food safety implications: meeting report*. World Health Organization.

Organization, W. H., & others. (2020). *Personal protective equipment*.

Organization, W. H., & others. (2022). *WHO global strategy for food safety 2022-2030: towards stronger food safety systems and global cooperation*. World Health Organization.

Ottaway, P. B. (2010). Stability of vitamins during food processing and storage. In *Chemical deterioration and physical instability of food and beverages* (pp. 539–560). Elsevier.

Ottaway, P. B. (2012). *The technology of vitamins in food*. Springer Science \& Business Media.

Overbosch, P., & Blanchard, S. (2023). Principles and systems for quality and food safety management. In *Food safety management* (pp. 497–512). Elsevier.

Owusu-Apenten, R., & Vieira, E. (2022). Food safety management, GMP \& HACCP. In *Elementary food science* (pp. 217–236). Springer.

Pandey, V. K., Tripathi, A., Srivastava, S., Dar, A. H., Singh, R., Farooqui, A., & Pandey, S. (2023). Exploiting the bioactive properties of essential oils and their potential applications in food industry. *Food Science and Biotechnology*, *32*(7), 885–902.

Panghal, A., Chhikara, N., Sindhu, N., & Jaglan, S. (2018). Role of Food Safety Management Systems in safe food production: A review. *Journal of Food Safety*, *38*(4), e12464.

Panghal, A., & Khatkar, B. S. (2007). Process optimization for test baking of chapati. *Indian Food Packer*, *61*(5), 98.

Panisello, P. J., & Quantick, P. C. (2001). Technical barriers to hazard analysis critical control point (HACCP). *Food Control*, *12*(3), 165–173.

Park, S.-H., Kwak, T.-K., & Chang, H.-J. (2010). Evaluation of the food safety training for food handlers in restaurant operations. *Nutrition Research and Practice*, *4*(1), 58–68.

Parvin, S., Reza, A., Das, S., Miah, M. M. U., & Karim, S. (2023). Potential Role and International Trade of Medicinal and Aromatic Plants in the World. *European Journal of Agriculture and Food Sciences*, *5*(5), 89–99.

Patil, S. R., Cates, S., & Morales, R. (2005). Consumer food safety knowledge, practices, and demographic differences: findings from a meta-analysis. *Journal of Food Protection*, *68*(9), 1884–1894.

Paul, K. T. (2009). Food safety: a matter of taste. *Food Safety Policy in England, Germany, the Netherlands, and at the Level of the European Union*.

Pingault, N., Caron, P., Kalafatic, C., Allahoury, A., Fresco, L. O., Kennedy, E., Khan, M., Kliksberg, B., Mei, F., Murphy, S., & others. (2017). *Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security*.

Pinheiro Pantoja, K. R., Melo Aires, G. C., Ferreira, C. P., Lima, M. da C. de, Menezes, E. G. O., & Carvalho Junior, R. N. de. (2024). Supercritical Technology as an Efficient Alternative to Cold Pressing for Avocado Oil: A Comparative Approach. *Foods*, *13*(15), 2424.

Pop, S. Z., Dracea, R., & Vl\uadulescu, C. (2018). Comparative study of certification schemes for food safety management systems in The European Union context. *Amfiteatru Economic*, *20*(47), 9–29.

Popa, M. E., Mitelut, A. C., Popa, E. E., & Matei, F. (2019). Creating products and services in food biotechnology. *Introduction to Biotech Entrepreneurship: From Idea to Business: A European Perspective*, 141–178.

Powell, D. A., Erdozain, S., Dodd, C., Costa, R., Morley, K., & Chapman, B. J. (2013). Audits and inspections are never enough: A critique to enhance food safety. *Food Control*, *30*(2), 686–691.

Powell, D. A., Jacob, C. J., & Chapman, B. J. (2011). Enhancing food safety culture to reduce rates of foodborne illness. *Food Control*, *22*(6), 817–822.

Prabha, V., Barma, R. D., Singh, R., & Madan, A. (2015). Ozone technology in food processing: A review. *Trends in Biosciences*, *8*(16), 4031–4047.

Press, R. (2015). *DIY Fermentation: Over 100 Step-By-Step Home Fermentation Recipes*. Sourcebooks, Inc.

Prosche, S., & Stappen, I. (2024). Flower Power: An Overview on Chemistry and Biological Impact of Selected Essential Oils from Blossoms. *Planta Medica*, *90*(07/08), 595–626.

Quested, T. E., Cook, P. E., Gorris, L. G. M., & Cole, M. B. (2010). Trends in technology, trade and consumption likely to impact on microbial food safety. *International Journal of Food Microbiology*, *139*, S29--S42.

Quinlan, J. J. (2013). Foodborne illness incidence rates and food safety risks for populations of low socioeconomic status and minority race/ethnicity: a review of the literature. *International Journal of Environmental Research and Public Health*, *10*(8), 3634–3652.

Quintillhn, S. P. (1999). Free Trade, Public Health Protection and Consumer Information in the European and WTO Context—Hormone-treated Beef and Genetically Modified, Organisms. *Journal of World Trade*, *33*(6).

Rabiepour, A., Zahmatkesh, F., & Babakhani, A. (2024). Preservation Techniques to Increase the Shelf Life of Seafood Products: An Overview. *Journal of Food Engineering and Technology*, *13*(1), 1–24.

Rahman, M. S., Ahmed, M., & Chen, X. D. (2006). Freezing-melting process and desalination: I.

Review of the state-of-the-art. *Separation \& Purification Reviews*, *35*(02), 59–96.

Ramesh, M. N. (2020). Pasteurization and food preservation. In *Handbook of food preservation* (pp. 599–608). CRC Press.

Randrianarivelo, F., Badri, A., Gauthier, F., & Boudreau-Trudel, B. (2022). Prevention of occupational diseases in small and medium-sized manufacturing enterprises in QUEBEC (CANADA)--Study of prevention management practices. *International Journal of Safety and Security Engineering*, *12*(3), 279–289.

Rao, M. V., Sengar, A. S., C K, S., & Rawson, A. (2021). Ultrasonication - A green technology extraction technique for spices: A review. *Trends in Food Science & Technology*, *116*, 975–991. https://doi.org/https://doi.org/10.1016/j.tifs.2021.09.006

Raut, M. R. R., Gupta, S., Gargelwar, M. A. P., & others. (2023). *Principles Of Microbiology*. Academic Guru Publishing House.

Reardon, L. R. (2018). *Safety and stability of high pressure processed blue cheese dressing*.

Redmond, E. C., & Griffith, C. J. (2003). Consumer food handling in the home: a review of food safety studies. *Journal of Food Protection*, *66*(1), 130–161.

Resendiz, M., Blanchard, D., & West, G. F. (2023). A systematic review of the germicidal effectiveness of ultraviolet disinfection across high-touch surfaces in the immediate patient environment. *Journal of Infection Prevention*, *24*(4), 166–177.

Ripolles-Avila, C., Martinez-Garcia, M., Capellas, M., Yuste, J., Fung, D. Y. C., & Rodriguez-Jerez, J.-J. (2020). From hazard analysis to risk control using rapid methods in microbiology: A practical approach for the food industry. *Comprehensive Reviews in Food Science and Food Safety*, *19*(4), 1877–1907.

Ritika, & Rizwana. (2024). Edible Packaging: Extension of Shelf Life and Improvement of Food Quality. *Food Coatings and Preservation Technologies*, 167–210.

Robertson, G. L. (2009). *Food packaging and shelf life: a practical guide*. CRC Press.

Robinson, J. L., Thomas, R. W., & Manrodt, K. B. (2013). Food for thought in the transportation carrier-selection decision. *Transportation Journal*, *52*(2), 277–296.

Rooney, K., Dong, Y., Pramanik, A., & Basak, A. K. (2023). Additive Manufacturing in Australian Small to Medium Enterprises: Vat Polymerisation Techniques, Case Study and Pathways to Industry 4.0 Competitiveness. *Journal of Manufacturing and Materials Processing*, *7*(5), 168.

Saguy, I. S., & Sirotinskaya, V. (2014). Challenges in exploiting open innovation's full potential in the food industry with a focus on small and medium enterprises (SMEs). *Trends in Food Science & Technology*, *38*(2), 136–148.

Saranraj, P., & Geetha, M. (2012). Microbial spoilage of bakery products and its control by preservatives. *International Journal of Pharmaceutical & Biological Archives*, *3*(1), 38–48.

Saravacos, G. D., Kostaropoulos, A. E., & others. (2002). *Handbook of food processing equipment* (Vol. 2012). Springer.

Sarion, C., Codin\ua, G. G., & Dabija, A. (2021). Acrylamide in bakery products: A review on health risks, legal regulations and strategies to reduce its formation. *International Journal of Environmental Research and Public Health*, *18*(8), 4332.

Sarkar, S., Nandi, K., Bakshi, P., Sen, D. J., & Mahanti, B. (2020). *Personal protective equipment for biohazards as a cascade for safety measures*.

Schuck, P., Jeantet, R., Bhandari, B., Chen, X. D., Perrone, Í. T., de Carvalho, A. F., Fenelon, M., & Kelly, P. (2016). Recent advances in spray drying relevant to the dairy industry: A comprehensive critical review. *Drying Technology*, *34*(15), 1773–1790.

Schuler, G. A., Nolan, M. P., Reynolds, A. E., & Hurst, W. C. (1999). *Cleaning, sanitizing and pest control in food processing, storage and service areas*.

Senanayake, D., Torley, P. J., Chandrapala, J., & Terefe, N. S. (2023). Microbial fermentation for improving the sensory, nutritional and functional attributes of legumes. *Fermentation*, *9*(7), 635.

Sethupathy, P., & Anandharamakrishnan, C. (2025). Challenges and opportunities. In *Conductive Hydro Drying of Foods* (pp. 445–471). Elsevier.

Shakya, B., Liu, R., Aryal, K., Thomas, S., Shaoliang, Y., & Chettri, N. (2024). *Ethnic cuisines from the eastern Himalaya: Revitalising and sustaining mountain food systemsICIMOD*. by International Centre for Integrated Mountain Development GPO Box 3226~….

Shanley, P., Pierce, A. R., Laird, S. A., Binnqüist, C. L., & Guariguata, M. R. (2015). From lifelines to livelihoods: Non-timber forest products into the twenty-first century. *Tropical Forestry Handbook*, 1–50.

Sharma, A. M., Batra, D., & Sharma, S. (2024). Documentation in logistics sustainability--challenges and opportunities. *Supply Chain Management*, 231–250.

Shepherd, C. J., Monroig, O., & Tocher, D. R. (2017). Future availability of raw materials for salmon feeds and supply chain implications: The case of Scottish farmed salmon. *Aquaculture*, *467*, 49–62.

Siddiqui, S. A., Mahmud, M. M. C., Abdi, G., Wanich, U., Farooqi, M. Q. U., Settapramote, N., Khan, S., & Wani, S. A. (2022). New alternatives from sustainable sources to wheat in bakery foods: Science, technology, and challenges. *Journal of Food Biochemistry*, *46*(9), e14185.

Siddiqui, S. A., Singh, S., Bahmid, N. A., Ibrahim, S. A., & Sasidharan, A. (2024). Applying innovative technological interventions in the preservation and packaging of fresh seafood products to minimize spoilage-A systematic review and meta-analysis. *Heliyon*.

Silbergeld, E. K., Graham, J., Price, L., Liebler, J., Evans, S., Vailles, R., Lackey, L., Peterson, A., Davis, M., Arriola, C. S., & others. (2008). Industrial food animal production: food safety, socioeconomic, and environmental health concerns. *Epidemiology*, *19*(6), S15--S16.

Singh, B., Pavithran, N., & Rajput, R. (2023). Effects of food processing on nutrients. *Current Journal of Applied Science and Technology*, *42*(46), 34–49.

Skjöldebrand, C. (2013). Food-processing equipment. In *Handbook of food factory design* (pp. 51–77). Springer.

Slavov, A. M., Denev, P. N., Denkova, Z. R., Kostov, G. A., Denkova-Kostova, R. S., Chochkov, R. M., Deseva, I. N., & Teneva, D. G. (2019). Emerging cold pasteurization technologies to improve shelf life and ensure food quality. In *Food quality and shelf life* (pp. 55–123). Elsevier.

Slikker Jr, W., Andersen, M. E., Bogdanffy, M. S., Bus, J. S., Cohen, S. D., Conolly, R. B., David, R. M., Doerrer, N. G., Dorman, D. C., Gaylor, D. W., & others. (2004). Dose-dependent transitions in mechanisms of toxicity. *Toxicology and Applied Pharmacology*, *201*(3), 203–225.

Smith, A. D. (2012). sGreen manufacturing in the packaging and materials industry: case study of small-to-medium sized corporate eco-friendly initiative. *International Journal of Logistics Systems and Management*, *11*(4), 429–449.

Smith, B. G. (2008). Developing sustainable food supply chains. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*(1492), 849–861.

Smith, J. P., Daifas, D. P., El-Khoury, W., Koukoutsis, J., & El-Khoury, A. (2004). Shelf life and safety concerns of bakery products—a review. *Critical Reviews in Food Science and Nutrition*, *44*(1), 19–55.

Smith, M. T. (2001). *Eco-design innovation in small and medium sized enterprises*. Open University (United Kingdom).

Snyder, A. B. (2017). *DISPERSE, SURVIVE, PROPAGATE: MICROBIAL RESILIENCE IN THE SPOILAGE OF COMMERCIALLY PROCESSED FOODS*.

Snyder, A. B., & Worobo, R. W. (2018). Fungal spoilage in food processing. *Journal of Food Protection*, *81*(6), 1035–1040.

Soon, J. M., Singh, H., & Baines, R. (2011). Foodborne diseases in Malaysia: A review. *Food Control*, *22*(6), 823–830.

Sousa, C. P. de. (2008). The impact of food manufacturing practices on food borne diseases. *Brazilian Archives of Biology and Technology*, *51*, 615–623.

Sruthy, G. N., Sandhya, K. R., Kumkum, C. R., Mythri, R., & Sharma, M. (2022). Thermal processing technologies for food. In *Current Developments in Biotechnology and Bioengineering* (pp. 263–300). Elsevier.

Starovoytova, D. (2019). Universal design to limit food cross-contamination: Incased set of kitchen utensils with five color-coded food chopping boards and knifes. *Innovative Systems Design and Engineering*, *10*(5), 1–26.

Suhaimi, A., Othman, A. A., Ghazali, A. F., & Kaliani Sundram, V. P. (2024). The Effect of Trust in Food Safety, Perception, Product Features and Consumers' Characteristics on Consumers' Purchase Decision for Safe Food: A Systematic Literature Review. *Pertanika Journal of Social Sciences \& Humanities*, *32*(2).

Sukaew, T. (2024). The Current and Emerging Research Related Aroma and Flavor. *Aroma and Flavor in Product Development: Characterization, Perception, and Application*, 329–369.

Sukumaran, L., & Jano, N. A. (2024). Edible Biopolymer Coatings/Films Used for Packaging and Preserving Foods. *Food Coatings and Preservation Technologies*, 301–338.

Sun, D., Liu, Y., Grant, J., Long, Y., Wang, X., & Xie, C. (2021). Impact of food safety regulations on agricultural trade: Evidence from China's import refusal data. *Food Policy*, *105*, 102185.

Tamang, J. P., Cotter, P. D., Endo, A., Han, N. S., Kort, R., Liu, S. Q., Mayo, B., Westerik, N., & Hutkins, R. (2020). Fermented foods in a global age: East meets West. *Comprehensive Reviews in Food Science and Food Safety*, *19*(1), 184–217.

Taormina, P. J. (2010). Implications of salt and sodium reduction on microbial food safety. *Critical Reviews in Food Science and Nutrition*, *50*(3), 209–227.

Thanzami, K., & Lalhlenmawia, H. (2020). Ethnic fermented foods and beverages of Mizoram. *Ethnic Fermented Foods and Beverages of India: Science History and Culture*, 435–457.

Thomas, D. J. I., Strachan, N., Goodburn, K., Rotariu, O., & Hutchison, M. L. (2012). A review of the published literature and current production and processing practices in smoked fish processing plants with emphasis on contamination by Listeria monocytogenes. *Final FSA Report*.

Tkaczewska, J. (2020). Peptides and protein hydrolysates as food preservatives and bioactive components of edible films and coatings-A review. *Trends in Food Science & Technology*, *106*, 298–311.

Todd, E. C. D. (2004). Microbiological safety standards and public health goals to reduce foodborne disease. *Meat Science*, *66*(1), 33–43.

Todd, E. C. D., Michaels, B. S., Greig, J. D., Smith, D., Holah, J., & Bartleson, C. A. (2010). Outbreaks where food workers have been implicated in the spread of foodborne disease. Part 7. Barriers to reduce contamination of food by workers. *Journal of Food Protection*, *73*(8), 1552–1565.

Todorov, S. D., & Holzapfel, W. H. (2015). Traditional cereal fermented foods as sources of functional microorganisms. In *Advances in fermented foods and beverages* (pp. 123–153). Elsevier.

Toussaint, M., Cabanelas, P., & Muñoz-Dueñas, P. (2022). Social sustainability in the food value chain: what is and how to adopt an integrative approach? *Quality & Quantity*, 1–24.

Trematerra, P., & Fleurat-Lessard, F. (2015). Food industry practices affecting pest management. *Stewart Postharvest Review*, *11*(1), 1–7.

Trienekens, J., & Zuurbier, P. (2008). Quality and safety standards in the food industry, developments and challenges. *International Journal of Production Economics*, *113*(1), 107–122.

Twinokwikiriza, I. (2018). *The contribution of small scale enterprises on employment creation*.

Kampala International University, College of Economics and Management.

Ulu, M., & Birgün, S. (2022). A New Model Proposal for Occupational Health and Safety. *Digitizing Production Systems: Selected Papers from ISPR2021, October 07-09, 2021 Online, Turkey*, 347–356.

Unnevehr, L., & others. (2003). *Food safety in food security and food trade* (Vol. 10). International Food Policy Research Institute Washington, DC.

Uzdavines, M. (2017). Dying for a Solution: The Regulation of Medical Devices Falls Short in the 21st Century Cures Act. *Nev. LJ*, *18*, 629.

Van Boxstael, S., Habib, I., Jacxsens, L., De Vocht, M., Baert, L., de Perre, E., Rajkovic, A., Lopez-Galvez, F., Sampers, I., Spanoghe, P., & others. (2013). Food safety issues in fresh produce: Bacterial pathogens, viruses and pesticide residues indicated as major concerns by stakeholders in the fresh produce chain. *Food Control*, *32*(1), 190–197.

Varzakas, T., Zakynthinos, G., Proestos, C., & Radwanska, M. (2017). Fermented vegetables. *Minimally Processed Refrigerated Fruits and Vegetables*, 537–584.

Wandosell, G., Parra-Meroño, M. C., Alcayde, A., & Baños, R. (2021). Green packaging from consumer and business perspectives. *Sustainability*, *13*(3), 1356.

Webb, M. (2015). Overview of food safety standards. *Food Safety, Market Organization, Trade and Development*, 45–58.

Webber, C. M., & Labaste, P. (2009). *Building competitiveness in Africa's agriculture: a guide to value chain concepts and applications*. World Bank Publications.

Weber, D. (2012). *The Food Truck Handbook: Start, grow, and succeed in the mobile food business*. John Wiley \& Sons.

Weis, A. J. (2007). *The global food economy: The battle for the future of farming*. Zed Books.

Widmer, A. F., & Frei, R. (2011). Decontamination, disinfection, and sterilization. *Manual of Clinical Microbiology*, 143–173.

Wilcock, A., & Ball, B. (2014). Food safety: consumer perceptions and practices. *Practical Food Safety: Contemporary Issues and Future Directions*, 11–29.

Wu, W., Zhang, A., van Klinken, R. D., Schrobback, P., & Muller, J. M. (2021). Consumer trust in food and the food system: a critical review. *Foods*, *10*(10), 2490.

Wu, X.-F., Zhang, M., Adhikari, B., & Sun, J. (2017). Recent developments in novel freezing and thawing technologies applied to foods. *Critical Reviews in Food Science and Nutrition*, *57*(17), 3620–3631.

Yapp, C., & Fairman, R. (2006). Factors affecting food safety compliance within small and medium-sized enterprises: implications for regulatory and enforcement strategies. *Food Control*, *17*(1), 42–51.

Yemics, F., & Harmanci, N. Y. (2020). Classification, uses and environmental implications of disinfectants. *Pakistan Journal of Analytical \& Environmental Chemistry*, *21*(2), 179–192.

Yiannas, F. (2008). *Food safety culture: Creating a behavior-based food safety management system*. Springer Science \& Business Media.

Yiannas, F. (2015). Food safety= behavior. *New York: Springer Science Business Media. Doi*, *10*, 971–978.

Zaghi, A. N., Barbalho, S. M., Guiguer, E. L., & Otoboni, A. M. (2019). Frying process: From conventional to air frying technology. *Food Reviews International*, *35*(8), 763–777.

Zhang, X., Zhang, M., & Adhikari, B. (2020). Recent developments in frying technologies applied to fresh foods. *Trends in Food Science & Technology*, *98*, 68–81.

Zhou, W. B., & Therdthai, N. (2007). Manufacturing of bread and bakery products. *Handbook of Food Products Manufacturing*, 265.

Zhou, W., Therdthai, N., & Hui, Y. H. (2014). Introduction to baking and bakery products. *Bakery Products Science and Technology*, 1–16.