Food and Agriculture Organization of the United Nations

FOOD SAFETY AND QUALITY

IN THE NEAR EAST AND NORTH AFRICA

MAPPING DRIVERS, CHALLENGES AND IMPERATIVES

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Abbreviations

AMR	antimicrobial resistance
ARSO	African Organization for Standardisation
CA	competent authority
CAC	The Codex Alimentarius Commission of the FAO and WHO of the UN
CCFL	Codex Committee on Food Labelling
CoAHD	cost and affordability of a healthy diet
DALY	disability-adjusted life year
DPSIR	Driver-Pressure-State-Impact-Response Framework
EDCs	endocrine disrupting chemicals
EMRO	WHO's Eastern Mediterranean Region
ESCWA	United Nations Economic and Social Commission for Western Asia
ESF	Food Systems and Food Safety Division
EU	European Union
FAO	The Food and Agriculture Organization of the United Nations
FAOSTAT	The Statistics Division of the FAO
FBOs	Food Business Operators
FBD	foodborne disease
FLW	food loss and waste
GAP	good agricultural practice
GHP	good hygiene practice
GM	genetically modified
GSO	GCC Standardization Organization
HACCP	Hazard Analysis and Critical Control Points
HM	heavy metals
IDPs	internally displaced people
IFPRI	International Food Policy Research Institute
INFOSAN	International Food Safety Authorities Network
ILAC	International Laboratory Accreditation Cooperation
ISO	International Organization for Standardization
JECFA	Joint FAO/WHO Expert Committee on Food Additives and Contaminants
JEMRA	Joint FAO/WHO Expert Meeting on Microbiological Risk Assessment
JEMNU	Joint FAO/WHO Expert Meetings on Nutrition

JMPR	Joint FAO/WHO Meeting on Pesticide Residues
LAS	League of Arab States
LMICs	low- and middle-income countries
MAPs	medicinal and aromatic plants
MOU	memorandum of understanding
MRLs, MLs	maximum residue limits, maximum limits
NCDs	noncommunicable diseases
NENA	The Near East and North Africa
PAFTA	Pan-Arab Free Trade Agreement
POPs	persistent organic pollutants
PPP	public-private partnership
PTWI	provisional tolerable weekly intake
RASFF	Rapid Alert System for Food and Feed of the EU
RNE	Regional Office for the Near East and North Africa
SDGs	Sustainable Development Goals
SME	small and medium-sized enterprise
SMIIC	Standards and Metrology Institute for Islamic Countries
SNE	FAO Subregional Office for North Africa
SNG	FAO Subregional Office for the Gulf Cooperation Council States and Yemen
SPS	Sanitary and Phytosanitary Measures Agreement of the WTO
TBT	Technical Barriers to Trade Agreement of the WTO
UNEP	The United Nations Environment Programme
UNIDO	The United Nations Industrial Development Organization
WHO	The World Health Organization of the United Nations
WOAH/OIE	The World Organization for Animal Health
WTO	The World Trade Organization
WWTP	Wastewater Treatment Plants

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Executive summary

This report offers an assessment of the current state of food safety and quality in the Near East and North Africa (NENA) region from a One Health Approach perspective to identify the drivers and challenges in food safety governance.

The Driver-Pressure-State-Impact-Response Framework (DPSIR) was employed to dissect the causal factors and their interconnections, shedding light on how drivers collectively exert pressures that ultimately shape the current state of food safety in NENA countries.

The analysis revealed a complex web of drivers that influence the region's food safety landscape. Despite economic and political diversity across NENA countries, water scarcity has emerged as a shared challenge driven by rapid population growth and climate change. These factors, combined with global trade dynamics, exacerbate the spread of pathogens and diseases. Furthermore, as the demand for food and water continues to rise, the diminishing availability of water resources places considerable strain on agricultural production and supply. This situation often transforms agricultural practices, particularly in non-oil-producing countries where agriculture plays a pivotal role in the economy.

These challenges can lead farmers to adopt riskier agricultural practices, particularly considering prevailing poor water governance and institutional fragmentation in most countries. Specifically, countries such as Lebanon, Yemen, the Sudan, Iraq, and the Syrian Arab Republic are already grappling with economic and geopolitical turmoil and facing layered pressures on food safety. In almost all countries, governance across various sectors has been marked by weaknesses and inefficiencies, resulting in profound ecological consequences, contaminating water, soil, and air, which disrupts agrifood systems and results in critical economic and public health impacts.

Amid these dynamics, microbial and chemical contaminants in food have emerged as pressing concerns in the region. Existing data underline the significant and growing problem of pesticides and antimicrobial residues in food chains, aggravated by poor practices such as the misuse of antibiotics in livestock farming, excess and misuse of pesticides, lack of legislation, and weak policies. For instance, high rates of antibiotic residues have been reported in poultry meat, fish, and milk in several countries, raising concerns about the rising levels of Antimicrobial Resistance (AMR) and its impact on public health. Even relatively stable nations such as the UAE, Qatar, and Saudi Arabia respond with urgency to the well-documented problem of pesticide residues, given their substantial reliance on food imports. Moreover, frequent cases of smuggling of animal antimicrobials and illicit pesticides have been reported, raising the question of the effectiveness of border and domestic control measures.

Of equal concern is mycotoxins contamination; another widespread problem in many countries in the region affecting various food products including nuts, cereals, oilseeds, Medicinal and Aromatic Plants (MAPs), milk and dairy products and animal feed, with prevalence rates exceeding permissible limits. To effectively implement these regulations, reliable and continuous surveillance, and monitoring of emerged and regulated mycotoxins in food using sensitive state-of-the-art analytical techniques is needed, as well as further capacity-building initiatives in occurrence-data provision for exposure assessments.

With these ongoing challenges and pressures observed through trade dynamics, the exporting countries in the region face export limitations as they struggle to comply with the heightened food safety standards and controls imposed by global markets. As a result, NENA countries have been subject to numerous border alerts, seizures, and market withdrawals of food products due to violations of regulations in the importing countries, with foodborne pathogens, mycotoxins, violating, and prohibited pesticides being the primary reasons for rejection at borders. These barriers, in turn, prompt funded strategic initiatives to support the food industry and mobilizes the public sector to tackle the obstacles posed by rising food safety measures in importing countries.

The exploitation of regulatory gaps and weak enforcement and controls on supply chains has led to a surge in illicit cases where food can pose significant harm to consumers. Fraudulence of spoiled and expired meat and food mislabelling has been reported in Lebanon, the Syrian Arab Republic, Egypt, and the Sudan. Moreover, the exchange of information on the occurrence of allergic reactions and allergenic ingredients is required to establish a harmonized standard for labelling food allergens across the region and to be made accessible to consumers.

There is a pervasive lack of a food safety culture, coupled with neglected infrastructure and poor practices throughout the entire food supply chain.

Sporadic incidents and reports of foodborne illnesses, food poisoning, and waterborne diseases are frequent in many countries in the region. Key pathogens include *Salmonella spp.*, *Escherichia coli*, *Listeria spp.*, *Campylobacter spp.* Foodborne viruses (such as the hepatitis A virus and norovirus) are often implicated in sporadic cases or are detected in food, primarily through research efforts. These efforts have recently led to concerns being raised about antimicrobial-resistant food pathogens in the region and calls for urgent official monitoring programs and interventions at the policy and control levels. The region suffers from a general lack of comprehensive scientific data on food outbreaks, their associated risk factors, and the health burden of foodborne diseases. Additionally, there is limited information on serotypes and strains circulating in most countries, particularly in the GCC region. Consequently, the precise incidence of human infections resulting from foodborne exposure remains inadequately documented. Often, cases of food poisoning receive media coverage with limited subsequent investigation into the underlying factors. During research efforts, tracing such cases proves cumbersome, with information published by official health authorities generally lacking in detail.

Addressing the interplay of these various challenges, the changes they bring into food systems, and their impacts on food safety necessitates a holistic risk-based control system and a solid commitment to integrating the One Health approach principle encompassing animals, humans, the environment, and agricultural sectors (Figure 1). This approach hinges on the institutionalization of food safety by defining the mechanisms for establishing and enforcing standards and regulations, enhancing surveillance systems and conformity assessment capacities, fostering the culture of multi-sectoral partnerships and international collaboration, and empowering all Food Business Operators (FBOs) and stakeholders to assume their functions with clear mandates and education. It also involves proactive strategies and preventive measures (HACCP and GxPs) to promote good and safe practices, mitigate risks, and reinforce information sharing.

Within the context of the DPSIR framework, these key areas were examined in terms of response strategies in the process of adapting to uncontrolled challenges, preventing pressures affecting food safety, and reducing their adverse effects.

This notwithstanding, it is difficult to generalize shortfalls along the supply chains and system deficiencies uniformly across the region, as each nation has its own unique set of circumstances when it comes to government priorities, political stability, availability of resources and governance issues. For instance, oil-producing countries tend to have more advanced healthcare infrastructure and have usually undertaken substantial reforms within their national control systems, which places them in a relatively better position.

Conversely, non-oil-producing countries tend to grapple with severe economic crises, political conflicts, and recurrent wars. Such resource-poor nations often struggle with deteriorating conditions, governance challenges, and setbacks and delays in the establishment of functional systems.

Meanwhile, countries falling in the middle, such as Tunisia, Morocco, and recently Egypt, are taking gradual steps in transitioning towards adopting a risk analysis approach. Consequently, the prioritization of food safety issues and the identification of deficiencies in response strategies vary and are influenced by the availability of data at the local level.

While subsequent sections of this report tap into specific examples of progress, and challenges across individual countries in the region, this section outlines the general shortcomings in preventing current pressures and reducing their impacts.

These include a fragmented institutional framework, which, despite notable advancements and legislative reforms undertaken by many countries in the last decade, remains a prominent issue.

Fragmented governance structures weaken the enforcement of law by introducing various obstacles, such as internal conflicts and a lack of consensus among agencies involved in food safety. This hampers the instituting of clear mandates and communication mechanisms among FBOs and stakeholders, thereby deterring the transition process for established food safety agencies and Competent Authorities (CAs) to assume their full roles.

Poor coordination among local CAs involved in food safety leads to duplicated roles, ineffective monitoring, and enforcement of laws across the supply chain, a lack of coordination between local governments, and the ineffective utilization of limited resources, such as human resources. This in turn hampers thorough and routine official food safety inspections and national monitoring and surveillance activities.

There are few examples of countries embracing a holistic approach to food safety in this region. Significant shortfalls in food inspection and control, characterized by shortages of qualified inspectors and inadequate inspection resources, are common issues. Additionally, there is an unequal focus on food safety, with local and traditional markets - vital sources of food - often neglected, particularly in low- and middle-income countries.

Small and medium-sized enterprises (SMEs) prevalent in these markets frequently encounter challenges related to food hygiene and sanitary standards and are often overlooked. Consequently, many of the stages of the food supply chain lack robust monitoring and control programs. These disparities compound food safety and food fraud issues.

Hence continuous efforts are needed to integrate risk assessment into the food value chain and to leverage inspectors' capacities and knowledge of emerging risks and preventive controls.

Moreover, other issues hinder the transition toward sustainable solutions to these chronic challenges:

First, multi-sectoral collaboration as an instrument for the creation of inclusive, equitable, and appropriate regulatory and control frameworks in the region is yet to be strengthened. This issue of entrenched silo thinking may require significant reform to foster a mechanism for coordination, cooperation, and communication among key stakeholders and actors under the One Health approach and ensure functional reporting systems and rapid response capabilities to food safety emergencies and outbreaks of foodborne diseases.

Second, effective actions by policymakers to create a healthy food environment and develop coherence in national policies and investment plans, including trade, food, and agricultural policies, to promote a healthy diet and protect public health.

Third, many countries in the NENA region lack comprehensive surveillance and control programs for food chains related to microbiological, chemical, radiological, and physical hazards. Additionally, there is a need to strengthen the national capacity for outbreak detection, management, and prevention of all food safety risks. Despite the effectiveness of addressing food safety and zoonotic risks demonstrated by some countries, such as Qatar and the United Arab Emirates through the One Health approach, a multisectoral national control plan to ensure rapid response to food safety emergencies is still lacking in many countries. Furthermore, there is a notable deficiency in comprehensive data infrastructure and information exchange systems among various stakeholders in most NENA countries. This shortfall is compounded by the scarcity of official statistics and information on foodborne diseases, outbreaks, and surveillance and monitoring capabilities, including the challenges of conducting rapidly evolving analytical techniques, such as whole-genome sequencing, and performing complex tests on emerging food contaminants. As a result, this gap continues to impede the monitoring of food hazards and the timely identification of emerging food safety risks, hindering the effective implementation of risk-based policies.

Fourth, given that many NENA countries are actively working towards aligning with international food safety standards, particularly those set by the Codex Alimentarius Commission (CAC), the limited availability and sharing of data, along with disparities between national and international food safety standards, underscore the need for greater involvement from scientific communities and academia to address these challenges. Moreover, the development of regional food safety and quality standards under the Codex principles is required to include subjects related to guidelines for controlling certain bacteria in food products, the safe use and reuse of water in food production, principles for the use of remote audits and inspections in regulatory frameworks, responses to emerging global food safety challenges, and addressing issues such as antimicrobial resistance (AMR) in food production.

Fifth, establishing and strengthening science policy platforms at both the national and regional levels is essential for collaborating with intergovernmental organizations, providing scientific advice, enhancing surveillance programs, managing risks, and sharing knowledge.

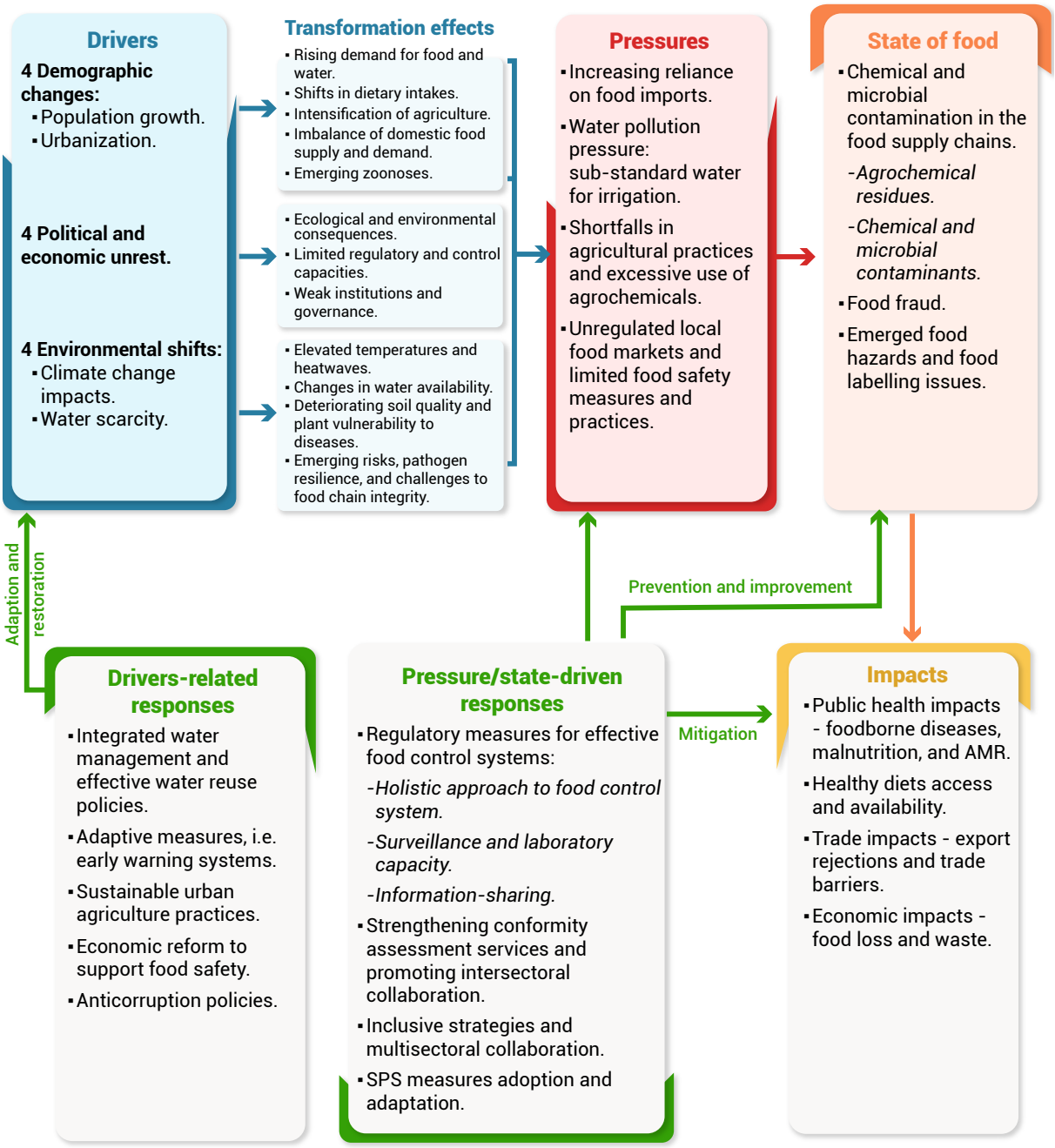
Sixth, identifying priority action areas and mobilizing funding sources for the following issues:

- Capacity-building programs to train food inspectors, develop inspection manuals, and apply risk-based controls.
- Support NENA countries in adopting sustainable food system concepts in two key areas: agrifood systems and healthy diet.
- Support the setup of infrastructure and logistics in terms of cold store chains, refrigerated transport systems, and air cargo space, and enhance the knowledge of the post-harvest handling of perishable products from the farm to factory to ports.
- Compliance with legal acts and the criteria for the traceability system of food supply chains (for both import and export agri-food crops) for effective tracing back to the farmer, packing house, and even to the plot.
- Consumer risk assessment studies for both short- (peak) and long-term intake of food hazards to enhance public awareness and protect health from adverse effects.
- Building a database on national and regional food consumption and collecting dietary surveys in conjunction with the residue levels found.
- Enhancing efforts to combat and prevent Illicit trade in food and food fraud by highlighting the challenges posed by smuggling, counterfeiting, and other fraudulent practices that undermine the global food system and put public health at risk.
- Tackling innovation in food production: Embracing technology and innovation, using biotechnology in crop development, and exploring sustainable alternatives in food production.
- Leveraging the Artificial Intelligence (AI) and robotics in food regulation and their application in product development, supply chain traceability, market trends, consumer preferences, and inspection of food establishments. AI-enhanced surveillance systems in food safety programs and the aggregation and analysis of data from various sensors across food production can help ensure food safety, labelling accuracy, traceability, and enforcement.
- Research studies in the field of microbiota-friendly diets and addressing the enhancement of gut health will substantially reflect various conditions, including inflammatory bowel disease, type 1 diabetes, obesity, and heart disease.

Finally, fostering collaboration between the government and industry through public-private partnerships (PPPs) in NENA countries is crucial for advancing research and development, facilitating information sharing, implementing effective training programs, and formulating and enforcing food fraud regulations. These partnerships also foster transparency and trust among stakeholders, ultimately enhancing risk communication and food safety measures.

To this end, restoring political stability in many NENA countries is crucial for achieving transparency, accountability, and a shared vision. Strengthening food safety governance and institutional capacities and creating a robust national food control system with clearly defined mechanisms for multi-sectoral and international collaboration is essential. These goals necessitate the development of a legal, institutional, and regulatory food safety framework that fosters a holistic, institutionalized culture of health values and promotes the rule of law throughout the entire food supply chain.

Figure 1. An illustration of DPSIR components and indicators, derived from a review of the literature in NENA countries



Source: Adapted from UNEP (2017a). Created by Dima, modified by Moustapha.

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1. CONTEXT OF THE REPORT

1.1 The landscape of global food safety: trends and risks

Despite significant advances in food production and distribution technology, food safety remains a critical public health issue worldwide, affecting the economy and global trade. The World Health Organization (WHO) reported estimates of 600 million cases of foodborne disease each year and 420 000 annual deaths resulting from foodborne illnesses (WHO, 2015a). Most of these illnesses were caused by foodborne pathogenic microorganisms, with thirty-one foodborne hazards identified as the primary causative agents. These figures are still an underestimation, yet they show the substantial health impacts of foodborne diseases (FBD), particularly on vulnerable populations, and those living at and under the poverty line, who cannot cope with FBD. Foodborne illnesses also have a significant economic impact, with estimated lost productivity and medical expenses in Low- and Middle-Income Countries (LMICs) reaching USD 110 billion (World Bank, 2018a).

Food can be contaminated at any step of the supply chain by microbiological, physical, and chemical hazards such as pesticides, veterinary drugs, heavy metals, mycotoxins, and industrial pollutants, which may pose risks to human health and the environment. In addition, several factors have been reported to contribute to food safety incidents, such as poor hygiene and food handling practices, manufacturing practices, agricultural practices, unsafe water used in food production, improper food storage and transportation, poor sanitation, and a lack of regulation or enforcement of food safety laws (FAO, 2022a; FAO, 2022b).

The past few decades have seen rapid changes to food safety risk, affected by complex global economic, environmental and policy developments such as the globalization of the food supply chain, changing food consumption patterns, the intensification of food production, climate change effects, advances in processing technologies, and economic and political shifts (FAO, 2022c; FAO, 2020b).

With the global population expected to reach 9.7 billion by 2050, ensuring a safe and secure supply in the global market is critical for global health and wellbeing. It is estimated that global food production will need to increase by 70 percent to meet the growing demand for food. However, it is argued and documented that the intensification of agricultural practices and livestock production leads to the intensive use of pesticides, antibiotics, hormones, and other chemicals to enhance crop yields and meat production. This raises concerns regarding the amplification of food safety risks and the emergence of antibiotic-resistant bacteria, which have potential health consequences for humans (FAO, 2020b; Godwin *et al.*, 2022).

Moreover, globalized food trade has grown significantly in volume and complexity, and foodborne illnesses and outbreaks are able to spread at an unprecedented rate (FAO, 2022c; Godwin *et al.*, 2022). An example is the 2011 sprout-associated EHEC O104:H4 outbreak in Germany, one of the most prominent foodborne illness outbreaks in history, which caused more than 4 000 cases linked to fenugreek seeds imported from Egypt, and which resulted in significant economic losses in Germany and beyond (Burger, 2012). In the same year, the Salmonella newport outbreak associated with the consumption of mung bean sprouts affected consumers in Germany and the Netherlands (Bayer *et al.*, 2014).

Furthermore, the annual EU report on zoonosis revealed an increase in zoonotic diseases in 2021, with campylobacteriosis – associated with chicken and turkey meat – being the most frequently reported zoonosis, followed by salmonellosis and listeriosis (EFSA and ECDC, 2022; Benaboud *et al.*, 2021; Jallow *et al.*, 2017a; Nasreddine *et al.*, 2016).

These, and many other cases, highlight the threat zoonotic agents and their toxins pose to global food safety (Johansen *et al.*, 2021; Waltenburg *et al.*, 2021; WHO EMRO, n.d.) and the need for robust systems to prevent and detect foodborne illnesses that could spread widely.

Along the same lines, food supply chains have become more challenging to monitor, which makes it easier for fraudulent activities to go undetected. Recent food fraud instances have exposed vulnerabilities in the supply chain. For example, in the case of carcinogenic substance ethylene oxide discovered in spices imported to Europe from India (Kowalska and Manning, 2022), and the discovery of horse meat in products advertised as containing beef (EC-DG Sante, n.d.). This food fraud exposed consumers to the risk of consuming meat that had not been subject to the same strict regulations as beef. These, and other incidences, hence, highlight the importance of a resilient supply chain, of a need for greater transparency and traceability throughout the system, and of the importance of rigorous testing and monitoring processes (FAO, 2022a; FAO, 2022c).

Among other significant issues that impact food safety are the effects of climate change. Frequent and severe extreme weather events have been implicated in food production disruption and distribution and play a role in food contamination. The latter in particular is an emerging issue resulting from global warming and changes in precipitation patterns, reportedly leading to an increase the prevalence of foodborne illnesses and the risk of aflatoxin contamination (FAO, 2020b; Warnatzsch *et al.*, 2020).

Equally concerning is the increasing challenge of water scarcity, that has led to the use of contaminated water sources in agricultural systems in many parts of the world, specifically in developing countries, and as such has increased the risk of waterborne illnesses (FAO, 2016a; FAO NERC, 2014; FAO, 2021a; Faour-Klingbeil and Todd, 2018).

Foodborne illnesses not only strain public health systems, but also constrain agricultural development, and reduce access to markets requiring higher safety standards and requirements such as the Sanitary and Phytosanitary (SPS) Measures.

Given the complexity and ever-changing nature of food safety, tackling the emerging risks and challenges requires a coordinated, multi-faceted strategy that takes into account the entire food supply chain and the complex interactions among various actors.

1.2 Agrifood systems transformations in the NENA region

The NENA region is not immune to these global challenges. Many countries have strengthened their food safety systems through various measures, including developing and enforcing new regulations and standards, increasing investment in food safety infrastructure, and promoting greater collaboration with other countries and international organizations (Faour-Klingbeil, Al-Busaidi, and Todd, 2022; FAO/WHO, 2003). However, FBD remains a significant public health problem in the region (WHO, 2015b).

The major foodborne diseases caused by microorganisms are Salmonellosis; which constitutes a major problem in most countries, Campylobacteriosis; which is a widespread infection caused by certain species of Campylobacter bacteria; infections due to enterohaemorrhagic (causing intestinal bleeding) *Escherichia coli* (e.g. *E. coli* 0157); and Listeriosis, which have emerged over the past few decades. Cholera is caused by the bacterium *Vibrio cholerae* – a major public health problem that leads to enormous economic losses.

Indeed, in recent years, the region has experienced significant shifts in its agrifood systems, driven partly by rapid population growth and urbanization, economic development, climate change, and changing dietary habits (UN ESCWA, 2019b). However, the phenomenon of climate change is also expected to substantially impact agricultural productivity, and its ramifications are especially pronounced in the water sector, posing food safety risks (FAO, 2020b; FAO, 2014; FAO, 2021a).

Other key predicaments that emerge as an inevitable consequence of the political and economic instabilities in some countries are the disruption of supply chains and limited access to safe food, water, and sanitation services, leading to food contamination and the spread of diseases. For instance, the displacement of millions of people in the Syrian Arab Republic led to the spread of typhoid fever, cholera, and hepatitis A due to deteriorating water and sanitation infrastructure, the exposure of communities to wastewater contaminants, and thus were a natural result of the increased risk of waterborne disease outbreaks (Eneh *et al.*, 2023).

The region reportedly suffers from dire malnutrition and food insecurity, compounded by the COVID-19 pandemic and the Russia-Ukraine conflict. These crises hindered access to essential foodstuffs, exacerbated disruptions in supply chains and contributed to a rise in the prices of critical commodities, such as grains, fertilizers, and energy (FAO, IFAD, UNICEF, WFP, WHO and UNESCWA, 2023).

The fragility of agrifood systems in the NENA region underscores the importance of building resilient local agrifood systems and adopting strategies to counter uncertainties and crises, to safeguard all food security and nutrition ensuring availability, accessibility, utilization, and stability. Reinforcing trade and food safety governance is key to achieving this goal.

These transformations in agrifood systems also highlight the vigilance required in the region and demonstrate that although overarching, common patterns are observed in agriculture, the food supply chain, and food safety risk, there are also distinct variations among nations. For instance, countries like Yemen and the Sudan are low-income, low-resource economies where basic subsistence is a struggle, and where food insecurities and malnutrition are prevalent. Thus, understanding these food safety issues, divergences, and the fundamental drivers is imperative for decision-makers and interested parties aiming to enhance the region's food security and safety capabilities. This report aims to cover these areas.

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2. PURPOSE AND SCOPE OF THE REPORT

The report aims to understand food safety and quality issues in the NENA region, their drivers, and challenges faced by national governments and value chain actors, and to support identifying opportunities to improve compliance with food safety and quality requirements of various markets.

To achieve these objectives, several fundamental questions guide this research endeavour:

1. Have the NENA region's food safety regulation and enforcement mechanisms developed in a robust and effective enough way to meet emerging challenges in the food supply chain?
2. Are there any trends and emerging food safety risks that must be addressed and controlled?
3. What are the barriers to implementing effective food safety measures in the NENA region?
4. What is the approach of NENA region countries towards international standards, and how do they incorporate them?

The Near East and North Africa (NENA) region comprises 19 countries, including Algeria, Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Occupied Palestinian Territory, Qatar, Saudi Arabia, the Sudan, the Syrian Arab Republic, Tunisia, the United Arab Emirates, and Yemen. These countries are named according to the multilingual database of Names of Countries and Territories (NOCS) and coded according to UNDP as follows:

Region		Subregion	Country	Code
Near East and North Africa (NENA) region	North Africa	SNE	**Algeria** (the People's Democratic Republic of Algeria)	ALG
		-	**Egypt** (the Arab Republic of Egypt)	EGY
		SNE	**Libya** (the State of Libya)	LIB
		SNE	**Mauritania** (the Islamic Republic of Mauritania)	MAU
		SNE	**Morocco** (the Kingdom of Morocco)	MOR
		SNE	**Tunisia** (the Republic of Tunisia)	TUN
		-	**Sudan** (the Republic of the Sudan)	SUD
	Middle East	-	**Iraq** (the Republic of Iraq)	IRQ
		-	**Jordan** (the Hashemite Kingdom of Jordan)	JOR
		-	**Lebanon** (the Lebanese Republic)	LEB
		-	**Syrian Arab Republic** (the-)	SYR
		-	**Palestine**	PSE
	Gulf Region	SNG	**Bahrain** (the Kingdom of Bahrain)	BAH
		SNG	**Saudi Arabia** (the Kingdom of Saudi Arabia)	SAU
		SNG	**Kuwait** (the State of Kuwait)	KUW
		SNG	**Oman** (the Sultanate of Oman)	OMA
		SNG	**Qatar** (the State of Qatar)	QAT
		SNG	**United Arab Emirates** (the-)	UAE
		SNG	**Yemen** (the Republic of Yemen)	YEM

Source: Moustapha, author's own elaboration.

The FAO Subregional Office for North Africa (FAO-SNE) was established in 1996 to provide assistance to the five Maghreb countries, namely Algeria, Libya, Morocco, Mauritania, and Tunisia. Additionally, the FAO Subregional Office for the Gulf Cooperation Council states and Yemen (FAO-SNG) was inaugurated in 2010 to support seven countries, including the GCC States (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates), as well as Yemen.

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3. CONCEPTUAL FRAMEWORK

3.1 An integrated approach to food safety

Addressing emerging food safety risks requires effective surveillance of FBDs and monitoring systems to identify pathogens, detect new risks, and respond quickly to food outbreaks. Epidemiological data on foodborne pathogens and their public health impacts, the development of new diagnostic tools, and other interventions are equally imperative to minimize the risks of FBDs. This includes food handler and consumer awareness and education on safe food handling practices and the promoting of sustainable good practices.

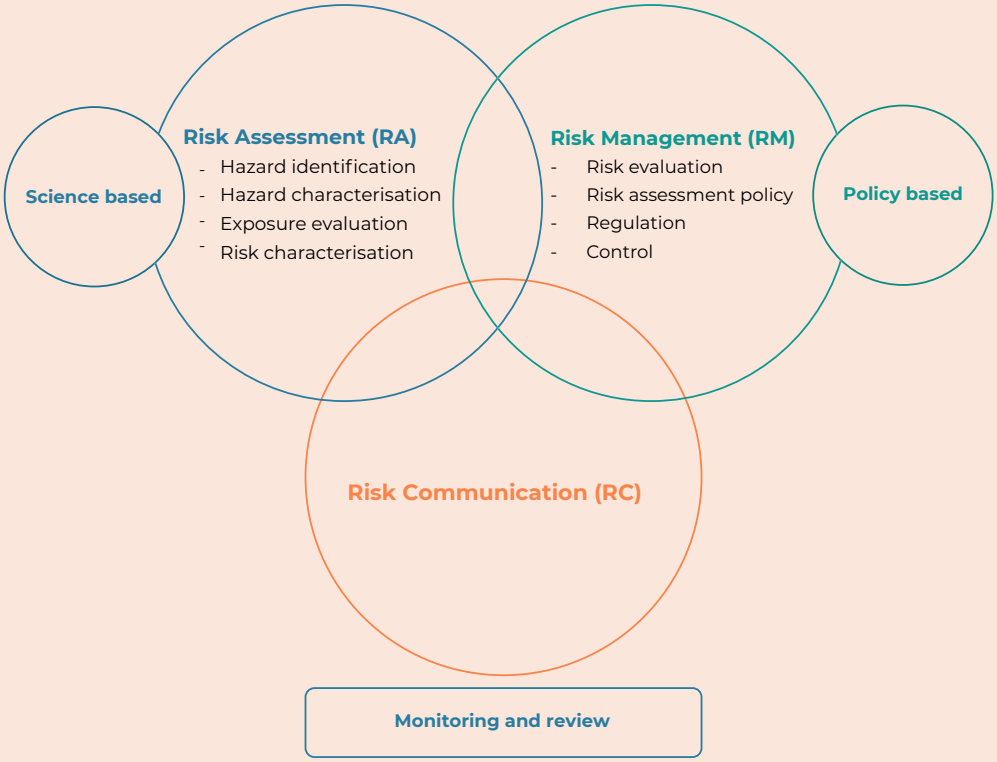
The One Health approach has become prominent in addressing both critical issues in food safety and significant pressures leading to devastating consequences for human health and the broader economy (Boqvist, Söderqvist, and Vågsholm, 2018). At its core, this approach is premised on the idea that the health of humans, animals, plants, and ecosystems are inseparable, and that no one component of this quartet can be considered in isolation of the others. To this end, the One-Health approach necessitates that several factors are integrated when studying the food safety status of a country.

The concept of risk analysis (Figure 2) that consists of three primary components (risk assessment, risk management, and risk communication) is taken in this report as the overarching systematic framework that establishes a roadmap for gathering data in the integrated production-to-consumption approach, based on the following reasoning:

The Risk Assessment step (RA) of the risk analysis involves a scientific process consisting of 4 steps: potential hazard identification, hazard characterization, exposure assessment, and risk characterization. It comprises identifying the common types of food hazard in the whole food production chain, the prevalence of contamination, and factors involved in these hazards, such as water pollution and agricultural practices, and their impact on public health. FAO and WHO promote the application of RA in all matters involving food safety based on sound scientific advice and evidence. Several committees provide technical advice to the Codex Alimentarius Commission (CAC), namely, the Joint FAO/WHO Expert Committee on Food Additives and Contaminants (JECFA), the Joint FAO/WHO Meeting on Pesticide Residues (JMPR), the Joint FAO/WHO Expert Meeting on Microbiological Risk Assessment (JEMRA), and the Joint FAO/WHO Expert Meetings on Nutrition (JEMNU).

Identifying suitable mitigation strategies and policies to address risks relies on the availability of national food safety information, including food outbreak statistics, national monitoring and surveillance reports, and data on the incidence of FBD and traded food shipment rejections. Hence an overview of this area will identify patterns, trends, and specific knowledge gaps that require action.

Figure 2. A risk analysis framework



Source: Adapted from Codex Alimentarius Commission (2007). Figure developed by Moustapha.

The Risk Management (RM) stage is distinct from the Risk Assessment stage and entails the process of weighing policy reform in consultation with all interested parties and taking into consideration risk assessment and other factors relevant to the protection of consumer health and the promotion of fair-trade practices. If needed, it entails selecting appropriate prevention and control operations to reduce or eliminate the risks identified in the risk assessment stage.

Gaining insight into the regulatory measures and the effectiveness of inspections and food control infrastructure, such as laboratories, surveillance systems, and trained personnel, is crucial to food safety governance and public health protection. Together with compliance with international food safety standards, such as those developed by the CAC, this identifies a country's food safety system maturity level and readiness to respond to food safety threats.

The last part of the risk analysis paradigm is Risk Communication (RC). Effective risk communication is the interactive exchange of information and opinions concerning food safety hazards and risks, risk-related factors, and risk perceptions by risk assessors, risk managers, consumers, industry, the academic community, and other interested parties, and includes risk assessment findings and an identification of the basis of risk management decisions.

Looking into current collaboration and cooperation between decision-makers or food regulators and stakeholders in addressing food safety issues in the NENA region will reveal each country's commitment to ensuring the safety of their food supply.

To achieve the objectives within this context, the DPSIR tool is employed to explore various socio-economic and environmental factors that impact food safety. The following section presents this research approach in detail.

3.2 Methodological approach

This report principally utilizes the DPSIR framework, which lays out a set of causal links – 'Driving forces,' 'Pressures', 'State', 'Impact', and 'Response' (Figure 1). This framework is widely used in environmental management, policy development, and scientific research to analyse complex environmental issues and identify the cause-and-effect relationships between the environment and various anthropogenic activities in a socio-economic context. Additionally, it is endorsed by international organizations such as the United Nations Environment Programme (UNEP, 2017a).

DPSIR has not been utilized in research related to food safety. Yet, as a versatile tool adapted for this work, an analysis of its five components can aid in structuring information and can make it possible to navigate the complex interlinkages of the diverse factors leading to food safety and quality problems. It can also help formulating evidence-based recommendations and appropriate responses to improve food safety outcomes. Hence, the focus of this report is on the forces that increase pressures on food safety.

In the context of food safety, the five DPSIR components are (1) Driving forces that increase cause or lead to (2) Pressures on food safety and quality. The food safety pressures would thus alter the (3) State of food and result in (4) Impact on human health, the food system, food trade, and the economy. These in turn lead to societal and regulatory (5) Responses to prevent or mitigate the impact of the identified forces, food safety pressures, and state of food.

These five components are defined as follows:

Drivers: Primary or secondary forces for an individual area that drive human activities to increase pressures on food safety. A typical question is 'What drivers exacerbate food safety issues'?

Pressures: Consequences of the driving forces. For instance, human activities that exert direct pressure on food safety. For example, misuse of pesticides and water pollution.

State: As the result of pressures, the state of food is affected. This element represents the state of food. It intersects with the first component of the paradigm of risk analysis, which involves examining the safety of food and its status in a broader context.

Impacts: What are the implications of the current state of food safety in the region? Examples of impact indicators are human health consequences – a challenging investigation due to the dearth of data.

Responses: Actions taken by groups or individuals in society (societal actions) and governments (policy makers). For instance, interventions and policies proposed to improve food safety and to control food pressures through regulation, mitigation, or prevention.

The DPSIR framework was proposed because it embeds the risk analysis, and can inform the risk assessment and risk management phases of the risk analysis process as follows:

- The **State** and **Impact** elements can be used to inform the risk assessment scale. In this context, it involves considering variables such as food contamination issues, types of hazards prevalent in the food chains and the potential for these, the prevalence of foodborne illnesses and deaths, and economic and health burdens.
- The **Response** element, which looks at the various cause-and-effect relationships, can inform the risk management strategy and curb any issues identified. Risk management involves developing and implementing measures to mitigate or prevent food safety risks, e.g. food safety policies and regulations, capacity building, surveillance and monitoring systems, risk communication strategies, and international cooperation on food safety.
- Risk communication is an element cutting across the DPSIR framework. Effective communication is essential for identifying and addressing food safety risks and ensuring stakeholders are informed and engaged in decision-making.

3.2.1 Data collection

3.2.1.1 Scoping review [1]

This report examines and synthesizes evidence on the different indicators of each DPSIR element through a scoping review of peer-reviewed articles, grey literature (i.e. government-produced reports, guidelines, official websites, similar media, etc.), key and flagship publications from international organizations such as the Food and Agriculture Organization of the United Nations (FAO), the World Health Organization (WHO), the World Organization for Animal Health (WOAH, founded as OIE), and policy and standards documents.

In this study, a comprehensive search was conducted across five electronic literature databases, namely Medline (PubMed), Scopus, Web of Science, ResearchGate, and Google Scholar, in addition to FAO databases such as FAOSTAT and Food Loss and Waste, to retrieve relevant articles, reports, and statistics. The search also included news media due to the limited availability of data in some areas. Additionally, a comprehensive review of existing literature has led to the identification of 258 citations and full-text papers published between 1991 and 2024, as well as 144 key and flagship publications from international organizations published between 2000 and 2024, along with a mapping of both quantitative and qualitative data related to food safety and quality topics. This research utilized a narrative synthesis approach to present a summary of the findings, identify gaps, and provide recommendations based on the compiled data.

[1] A six-stage methodological framework: identifying the research question (As 'fundamental' questions in section 2), searching for relevant studies, selecting studies, charting the data, collating, summarizing, and reporting the results, and consulting with stakeholders to inform or validate study findings.

3.2.1.2 Prioritization of food safety issues

Collaborative efforts were essential for identifying and prioritizing food safety concerns within each country. This necessitated active engagement from stakeholders across various sectors to address significant gaps in data and to verify the presently available information.

The objective was fulfilled by conducting key informant interviews and organizing a Delphi panel consisting of various actors and stakeholders including food safety regulators, public health officials, and food industry representatives from the region. Panellists were selected based on their extensive expertise and experience in food safety. The Delphi panel conducted a feedback loop and prioritized the current identified issues in the state of food safety in the NENA region, the main challenges and pressing issues that need to be addressed, and the interventions that need to be implemented. They then provided a compilation of invaluable insights into critical food safety concerns in the region, which are summarized and highlighted in this report.

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4. RESEARCH OUTCOMES

The review and analysis of available information identified key indicators to incorporate into each of the DPSIR elements.

4.1 DRIVERS

Improving the quality of food safety in the region is a critical objective, and understanding the underlying causes of safety concerns and emerging risks is a necessary first step towards achieving this goal. Emerging food safety risks refer to potential dangers that have been identified or have recently become more prevalent in the region, and that potentially constitute public health risks.

An emerging risk to human, animal, plant health and/or to the environment is a risk resulting from a newly identified hazard to which there may be significant exposure, or from an unexpected new or increased significant exposure and/or susceptibility to a known hazard. These may arise from various sources, such as changes in farming methods, advancements in food processing technologies, cross-contamination, international trade of food items, and the impact of climate change.

By identifying the drivers of food safety issues and their impacts, policymakers and stakeholders can create effective policies and implement solutions that address pressing issues by taking proactive measures to reduce their impacts. Examining these drivers is naturally intertwined with the resulting changes they bring about in food safety. Therefore, it is crucial to briefly touch upon the concept of pressures within the context of drivers.

Through this nuanced understanding of the interplay between the two, we can effectively highlight and elaborate on the diverse array of pressures on food safety.

The focus is on the driving forces that shape actions and their repercussions on food safety and public health, with a particular consideration to human activities that play pivotal roles in catalysing system change. While specific drivers may differ among countries, several overarching factors have been identified globally, including climate change, water scarcity, demographic changes, supply chain complexity, and resource depletion (FAO, 2022c; FAO, 2020b FAO, 2016a, EFSA *et al.*, 2020; Kendall *et al.*, 2018). These factors substantially influence food safety locally, and they interact with, and are influenced by, local dynamics.

To explore the relevance of these drivers to the NENA region, this report engages in comprehensive discussions backed by a thorough systematic literature review. Despite some commonalities, the region exhibits significant diversity in the realms of politics and governance, as well as in the state of its natural resources, the economy, and poverty levels.

This complexity poses challenges and drivers of food safety issues that may vary locally. Therefore, a comprehensive understanding necessitates consultation with relevant stakeholders who can provide insights into local contexts. For instance, ongoing conflicts in certain countries may undermine reform efforts, highlighting the need for tailored approaches. Furthermore, while delving into the drivers and changes that exert pressure on food safety, it is crucial to adopt a holistic perspective. These factors do not function in isolation; rather, they interact synergistically, exacerbating food safety challenges such as climate change and population growth.

4.1.1 Demographic changes driver

4.1.1.1 Population growth

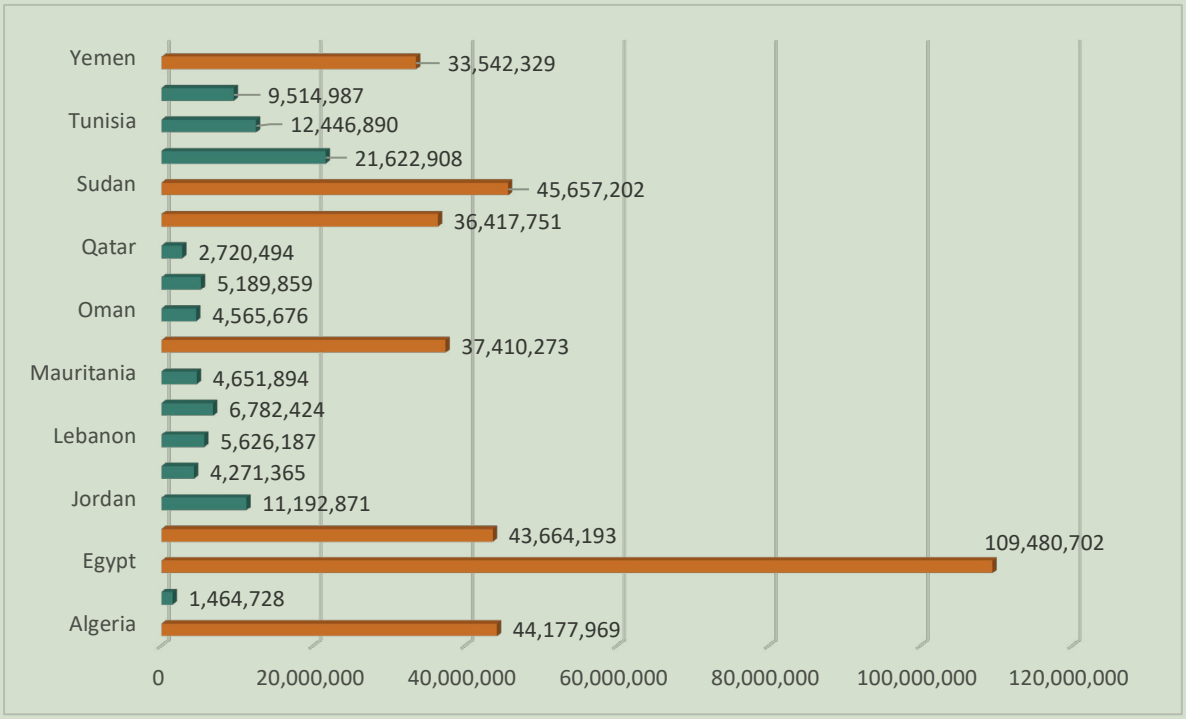
In the past 70 years, NENA's population has grown sixfold, compared to a threefold increase worldwide. Current projections indicate that NENA's population will reach more than 633 million by 2050, with almost three quarters living in the region's cities. Notably, Iraq, the Sudan, and Occupied Palestinian Territory are expected to undergo a remarkable doubling of their populations in the 35 years between 2015 and 2050 (FAO, 2022e; UNICEF, 2019).

With the region's population density increasing (Figure 3), there is a growing demand for food, necessitating the expansion of food production, processing, and distribution systems. This demand is linked to challenges in agricultural production and water availability, the increase in wealth of some countries, and the feasibility of international food trade (FAO, 2022e; FAO, 2014; Al-Rifai *et al.*, 2020). For instance, the Gulf states have experienced significant population growth, which puts pressure on food production, supply chains, and food safety systems.

The ability of countries to meet increasing demand for food and water, and their ability to achieve self-sufficiency varies, and depends on available resources, climatic conditions, and policies. In Egypt, Morocco, and Algeria, the quantity of vegetables produced within the region has risen by 14.7 percent over the past decade. Among these countries, Egypt, Jordan, and Tunisia have the highest self-sufficiency rates for vegetable production in the region, standing at 119 percent, 140 percent, and 110 percent respectively in 2020. Conversely, Bahrain, Mauritania, and Qatar have the lowest self-sufficiency rate in vegetable production (FAO, 2022e). According to the OECD-FAO report, the NENA region is projected to experience strong production growth driven by increased crop intensity, significant improvements in crop yield, and growth in poultry meat production (OECD and FAO, 2018).

In low-income and lower-middle-income countries, the growth in crop yield was expected to be achieved through the adoption of enhanced crop varieties, increased utilization of fertilizers and pesticides, as well as through improved farm management practices facilitated by mechanization and enhanced agricultural skills achieved through education and extension services.

Figure 3. Population densities in the NENA region



Source: Adopted from FAOSTAT (FAO Statistical Division). Figure developed by Moustapha. n.d. Food and Agriculture Organization Statistics (FAOSTAT Database). FAO, Rome. [Cited 2 May 2024]. https://www.fao.org/faostat/en/#data.

The degree of change in these practices, however, is influenced by changing trends in input costs, limited resources, and climatic conditions (OECD and FAO, 2021) and can have a significant impact on food safety. For instance, in the past few decades, Kuwait has made substantial investments in the development of innovative agricultural approaches, aiming to foster agricultural expansion and achieve a level of self-sufficiency in food production. As a result, there has been a surge of interest in agricultural endeavours, particularly in the cultivation of vegetables. However, the increased prevalence of insect pests and diseases has created a significant demand for pesticides (FAO, 2021b; Ebtisam *et al.*, 2013).

Furthermore, population growth and changing dietary preferences have led to increased demand for certain types of foods, particularly meat and dairy products, which has led to an increase in the production of livestock (OECD and FAO, 2018) (Table 1). Livestock and fish production was expected to increase by a further 20 percent due to fast growth, and poultry meat and milk yields are assumed to grow steadily in the region (OECD and FAO, 2021).

On the one hand, strategies for intensification of crop and livestock production bring numerous benefits, including improved food accessibility. However, they also increase the threat of emerging and re-emerging zoonoses and the excessive use of antibiotics, presenting potential risks to public health and wellbeing (OECD and FAO, 2018; FAO, IFAD, UNICEF, WFP and WHO, 2023). The NENA countries continue to face a heightened risk of zoonotic infections. This vulnerability is primarily attributed to the sizeable population residing in close proximity to animals in the region, as well as the amplified scale of international trade.

Furthermore, the movement of populations and livestock across neighbouring countries further contributes to this risk and is exacerbated by the impact of climate change and vector bionomics (Awaidy and Al Hashami, 2020; Chammem *et al.*, 2018; WHO EMRO, n.d.).

Table 1. Live and slaughtered animals in livestock production systems in the NENA region (unit 1000 animal)

Country	Items	Value
Algeria	Meat of sheep, fresh or chilled	18032.1
	Meat of goat, fresh or chilled	1923.9
	Meat of chickens, fresh or chilled	271810
	Meat of camels, fresh or chilled	48.9
	Meat of rabbits and hares, fresh or chilled	8353
	Meat of turkeys, fresh or chilled	104
Bahrain	Meat of sheep, fresh or chilled	1492.4
	Meat of goat, fresh or chilled	15.9
	Meat of chickens, fresh or chilled	9815
	Meat of camels, fresh or chilled	1.2
Egypt	Meat of chickens, fresh or chilled	1710320
	Meat of sheep, fresh or chilled	1253.0
	Meat of goat, fresh or chilled	642.7
	Meat of buffalo, fresh or chilled	598.0
	Meat of camels, fresh or chilled	87.2
	Meat of rabbits and hares, fresh or chilled	55445
	Meat of turkeys, fresh or chilled	2305
Iraq	Meat of sheep, fresh or chilled	1957.5
	Meat of goat, fresh or chilled	530.5
	Meat of chickens, fresh or chilled	144717
	Meat of buffalo, fresh or chilled	30.1
	Meat of camels, fresh or chilled	10.9
Jordan	Meat of sheep, fresh or chilled	1821.0
	Meat of goat, fresh or chilled	370.0
	Meat of chickens, fresh or chilled	260000
	Meat of camels, fresh or chilled	5.5
	Meat of turkeys, fresh or chilled	72
	Meat of rabbits and hares, fresh or chilled	23
Kuwait	Meat of sheep, fresh or chilled	3023.1
	Meat of chickens, fresh or chilled	50067
	Meat of goat, fresh or chilled	41.6
	Meat of camels, fresh or chilled	10.0
Lebanon	Meat of sheep, fresh or chilled	190.0
	Meat of goat, fresh or chilled	155.9
	Meat of chickens, fresh or chilled	57730

Continue ▶

Country	Items	Value
Libya	Meat of sheep, fresh or chilled	1985.7
	Meat of goat, fresh or chilled	838.1
	Meat of chickens, fresh or chilled	111485
	Meat of camels, fresh or chilled	18.8
Mauritania	Meat of sheep, fresh or chilled	2430.6
	Meat of goat, fresh or chilled	1234.8
	Meat of camels, fresh or chilled	137.6
	Meat of chickens, fresh or chilled	6149
Morocco	Meat of sheep, fresh or chilled	12829.1
	Meat of goat, fresh or chilled	2370.5
	Meat of chickens, fresh or chilled	732623
	Meat of turkeys, fresh or chilled	22433
	Meat of camels, fresh or chilled	16.0
Oman	Meat of sheep, fresh or chilled	1111.2
	Meat of goat, fresh or chilled	741.5
	Meat of camels, fresh or chilled	81.2
	Meat of chickens, fresh or chilled	8521
Palestine	Meat of sheep, fresh or chilled	396.5
	Meat of goat, fresh or chilled	211.0
	Meat of chickens, fresh or chilled	20866
Qatar	Meat of sheep, fresh or chilled	372.4
	Meat of goat, fresh or chilled	30.0
	Meat of chickens, fresh or chilled	25000
	Meat of camels, fresh or chilled	1.8
Saudi Arabia	Meat of sheep, fresh or chilled	5658.1
	Meat of goat, fresh or chilled	2354.7
	Meat of chickens, fresh or chilled	644014
	Meat of camels, fresh or chilled	469.8
The Sudan	Meat of sheep, fresh or chilled	15558.7
	Meat of goat, fresh or chilled	13220.2
	Meat of cattle with the bone, fresh or chilled	3595.6
	Meat of camels, fresh or chilled	551.2
	Meat of chickens, fresh or chilled	33674
Syrian Arab Republic	Meat of sheep, fresh or chilled	4690.2
	Meat of goat, fresh or chilled	480.6
	Meat of chickens, fresh or chilled	75963
	Meat of camels, fresh or chilled	3.2
	Meat of buffalo, fresh or chilled	2.5
	Meat of turkeys, fresh or chilled	28
	Meat of rabbits and hares, fresh or chilled	13

Continue ▶

Country	Items	Value
Tunisia	Meat of sheep, fresh or chilled	3700.0
	Meat of goat, fresh or chilled	713.3
	Meat of chickens, fresh or chilled	105342
	Meat of turkeys, fresh or chilled	12880
	Meat of camels, fresh or chilled	12.4
United Arab Emirates	Meat of goat, fresh or chilled	3578.0
	Meat of sheep, fresh or chilled	245.4
	Meat of camels, fresh or chilled	224.8
	Meat of chickens, fresh or chilled	44266
Yemen	Meat of goat, fresh or chilled	7848.8
	Meat of sheep, fresh or chilled	5800.0
	Meat of chickens, fresh or chilled	191070
	Meat of camels, fresh or chilled	16.3

Source: Adopted from FAOSTAT (FAO Statistical Division). Table developed by Moustapha. n.d. Food and Agriculture Organization Statistics (FAOSTAT Database). FAO, Rome. [Cited 2 May 2024]. https://www.fao.org/faostat/en/#data.

NENA aquaculture production reached a value of USD 2.3 billion in 2018. Egypt and Saudi Arabia contributed to approximately two-thirds and one-quarter of this amount, respectively. Production volume has had a rapid growth trajectory, resulting in a total production of 1.7 million tonnes in 2018. Egyptian fish farms were responsible for 92 percent of the region's output, with Saudi Arabia accounting for 4.2 percent. Other significant contributors included Iraq, Tunisia, Algeria, the United Arab Emirates, and the Syrian Arab Republic. Although current production levels are relatively low, all of these countries have ambitious plans to further develop their aquaculture sector, often with the goal of enhancing food self-sufficiency (FAO, 2022d).

A total of 43 species of finfish, shellfish, and aquatic plants were produced in the NENA region, with Tilapia being the most widely cultivated species, accounting for 63 percent of total production in 2018. Mullets and carp follow closely as the second and third most commonly farmed species, representing 14 percent and 12 percent of total production respectively (FAO, 2022d).

Efforts made to improve infrastructure with the goal of boosting local production are, for the vast majority of NENA countries, not sufficient to meet local needs (FAO, European Union, and CIRAD, 2022). The agricultural sector is profoundly affected by several factors such as soil limitations and constraints in agricultural policies (Mouël *et al.*, 2018), alongside the growing challenge of the reduced availability of water (FAO, 2022e; FAO, 2016a; Todd, 2016).

Contrary to the projected growth in food production, more recent information indicates that production has remained stagnant in Egypt, Jordan, Libya, and Occupied Palestinian Territory over the last decade. Morocco has experienced a considerable decrease, and production levels in Iraq, Lebanon, Saudi Arabia, and Yemen have substantially declined (FAO, IFAD, UNICEF, WFP, WHO and UNESCWA, 2023b).

According to Mouël *et al.* (2018), the sub-region most susceptible to the negative effects of land degradation on agriculture is the Maghreb, which is projected to witness a significant decline of nearly 50 percent in its cultivable land area by 2050. The Near East region would also face substantial consequences, with a quarter of its cultivated land expected to be lost.

Consequently, the imbalance between domestic supply and demand would be made up by increased agricultural imports, resulting in rising regional import dependence to almost 70 percent of domestic requirements, as discussed in the next section (FAO, 2022e).

4.1.1.2 Urbanization

Urbanization is contributing to changes in food production systems, with cities consuming 70 percent of all food produced globally and contributing significantly to greenhouse gas (GHG) emissions (World Bank, 2023). Urbanization impacts every aspect of the food chain system, from food production to processing, packaging, transportation, storage, marketing, and consumption, and even affects how food waste is managed.

During the past few decades, the NENA region has experienced significant shifts in agrifood systems driven partly by rapid population growth, urbanization, economic development, climate change, and changes in dietary habits (UN ESCWA, 2019b; FAO, European Union and CIRAD, 2022; Elgendy and Abaza, 2020). Internal displacement driven by war, such as in the Syrian Arab Republic, the Sudan, Iraq, Libya, and Yemen, disparities between urban and rural development, and the effects of climate change, such as droughts, are all factors that play into the diversity of urbanization trends in the region.

These factors collectively lead to the abandonment of agriculture-based livelihoods, prompting individuals to seek opportunities in urban settings (Diab, El Shaarawy, and Yousry, 2020). This demographic shift in the region is expected to increase the urban population to over 450 million (66 percent of the NENA population); with a projection of rise to 73 percent by 2050, placing immense strain on the NENA cities' existing urban supply chains, as well as their infrastructure, resources, and services (FAO, 2022e; FAO NERC, 2024). Moreover, the shift to urban living and industrialized economies in Africa and other developing countries has led to a rise in the release of pollutants into water, air, and soil. These pollutants encompass pesticides, heavy metals, toxic industrial chemicals, and hazardous wastes, including endocrine-disrupting chemicals (EDCs) (Miller *et al.* 2016).

On the other hand, urban development remains largely unregulated (FAO NERC, 2024, Elgendy and Abaza, 2020), which contributes to increased pollution, including contamination of food in urban supply chains (CoSAI, 2022).

On the other track, dominant food shops, small food retailers (grocers, butchers, fish sellers, dairy shops), and local ready-to-eat and ready-to-serve food outlets have become common in densely populated areas of NENA countries. Moreover, there has been a notable rise in informal food markets in recent years, referred to as traditional or informal street food markets, or open markets.

These venues offer a diverse range of affordable food choices at street food stalls in Egypt's Tahrir Square and Al-Hussein in Cairo, as well in the Sudan, Iraq, Jordan, and Lebanon. Food markets often flourish in the Hajj and Umrah seasons in Saudi Arabia when millions of Muslims make the pilgrimage to Mecca and Al Madinah. Similarly, Lebanon is known for its vibrant street food scene in Beirut and its suburbs. Although these popular markets provide economic opportunities for small-

scale vendors and affordable food options to the local population, they pose challenges to local authorities in terms of resource management and regulatory oversight. Many municipalities in the region have yet to integrate agrifood systems challenges and entry points into their planning (FAO NERC, 2024).

Moreover, a significant high level of food loss and waste (FLW) is reported in the region, and consideration specifically on developing more sustainable and healthier urban agrifood systems for a better environment as well. FLW accounts for 8-10 percent of global GHG emissions, contributing to an unstable climate and extreme weather events such as droughts and flooding (FAO NERC, 2024; FAO, 2022e; FAO, 2015b).

While official information is limited, it is widely known that urban markets, particularly in developing countries including in the NENA region, often operate with an absence of stringent regulatory controls and proper licensing. As such, the informal nature of these markets gives rise to food safety concerns due to instances of unhygienic handling practices, inadequate refrigeration, and the use of low-quality ingredients (as outlined in section 4.2).

At the same time, notable shifts in dietary intake influenced by social, cultural, and lifestyle transformations have been observed in the NENA countries. Economic growth and urbanization have led to increased trade and globalization, resulting in a preference for packaged food options and the proliferation of eateries, cafes, and fast-food chains. Hence, consumers are increasingly opting for ready-to-eat foods and modern restaurants and takeaways, which have flourished in the last few decades in middle- and high-income countries (Musaiger, 2014; Shaban and Alkazemi, 2019). This provides consumers with more choice (Al-Kandari *et al.*, 2019; Al-Shabib *et al.*, 2016; Yahia *et al.*, 2008) and greater convenience (FAO, IFAD, UNICEF, WFP, WHO and UNESCWA, 2023), but also elevates the risks associated with food contamination and the subsequent rise in foodborne illnesses (Todd, 2016), placing the burden on local authorities to not only enforce stringent regulations but also to conduct routine inspections and provide training to vendors.

4.1.2 Political and economic unrest

The NENA region has been plagued by numerous conflicts, which have had a profound impact on food safety issues. Internal conflicts, religious tensions, and economic downturns have long hindered the establishment of robust public health systems necessary for effectively combating and managing foodborne diseases in the region (FAO NERC, 2024; Todd, 2016, 2022).

Many countries face resource constraints, including limited funding and human resources constraints, which can limit their ability to implement effective food safety measures including laboratory testing, inspection, and monitoring systems. Unfortunately, these circumstances persist in certain nations within the region and make it difficult to detect and address food safety issues in a timely manner.

The profound and extensive impacts of conflicts and displacements in the Syrian Arab Republic, Iraq, Libya, Yemen, and Occupied Palestinian Territory extend beyond the countries directly affecting the entire region (FAO NERC, 2024; Zimmermann, 2022). These countries in addition to the Sudan and Lebanon are severely afflicted by high levels of food insecurity. The Syrian Arab Republic stands out, with heavy disruptions in farming, humanitarian aid, and food availability. Similarly, Yemen faces an alarming situation, and the situation in Gaza is critical, with the population experiencing catastrophic levels of conflict-induced food insecurity and malnutrition, and a substantial risk of famine.

Adverse regional developments, especially the crises in The Syrian Arab Republic and Iraq, have affected Jordan profoundly, leading to an unprecedented influx of refugees, disrupted trade routes, and a decline in investments and tourism. This ongoing regional uncertainty, coupled with reduced external assistance, adds further pressure on agrifood systems and food safety funds (The Economist Group, 2022).

Beyond human suffering, armed conflicts also have far-reaching ecological consequences and devastating impacts on the natural environment as well, resulting in the contamination of water, soil, and land, as well as causing air pollution (FAO NERC, 2024). This, in turn, has detrimental effects on nearly every aspect of the food system, from the production, harvesting, processing, and transportation of food to the supply of inputs, financing, marketing, and consumption.

The Global Food Security Index (GFSI) revealed a clear connection between armed conflict and water pollution. Conflict not only affects the quality of water but also hampers its availability as a crucial resource for agriculture. This indicates that conflicts can directly impact the agricultural sector, affecting its ability to sustainably produce food and meet the demands of a growing population (The Economist Group, 2022).

Consequently, the countries' limited natural resources, including insufficient water, land, petroleum, and natural gas supplies, along with the substantial number of refugees and regional turmoil, impede its economic growth(FAO NERC, 2024; Chanegriha, 2018).

In 2020, the NENA region hosted 41.2 million international migrants, along with an additional 9.6 million refugees and 14.8 million internally displaced people (IDPs) (United Nations Department of Economic and Social Affairs, Population Division, 2020; IMDC, 2021). Jordan and Lebanon are among the top 10 countries in globally in terms of hosting refugees. Syria has the highest number of IDPs worldwide with over 6.5 million. Sudan hosts 1.1 million refugees, primarily from South Sudan, and 2.73 million IDPs (UNHCR, 2021; IMDC, 2021). It is estimated that over 57 percent of Yemen's population, equivalent to 19 million individuals, experienced crisis-level, or even more severe levels of acute food insecurity in the latter half of 2022 (FAO/WFP, 2022). This may be due to the amount of conflict in the region and the lower level of rural transformation in the sub-region (Mauritania, the Sudan, Yemen) (FAO, 2019b).

In the recent UN ESCWA Forum, the Executive Secretary indicated climate change as one of the key challenges the Arab region faces, but also emphasized poor governance and rampant corruption. The political and economic instabilities in these countries pose serious difficulties rooted in complex political and social conflicts, and a lack of accountability and transparency renders institutions and regulatory enforcement fragmented or dysfunctional. This has far-reaching outreach to all sectors, including the food safety governance (UN ESCWA, 2023).

Moreover, conflicts have detrimental effects on food and water supply chains, leading to shortages, contamination, malnutrition, and vulnerability to climate change pressures on food safety, e.g. mycotoxins. For instance, the civil war in the Syrian Arab Republic resulted in infrastructure destruction and limited government capacity for regulation and enforcement. According to the representative of the Syrian Ministry of Agriculture, boycotts, along with the destruction caused by the war to the infrastructure and irrigation channels, have put 84 percent of Syrians under the threat of food insecurity (UN ESCWA, 2023). In Yemen, approximately 90 percent of food is imported through the nation's poorly maintained, war-damaged ports, with long delivery delays and rising costs (UNDP, 2021).

Essential food safety infrastructure, such as laboratories, inspection systems, and certification processes, may have been destroyed or rendered ineffective due to resource scarcity or lack of personnel. Consequently, this leads to deficiencies in food inspection, contamination monitoring, laboratory analysis, disease surveillance, and information dissemination, resulting in an increased risk of foodborne disease contamination, particularly in low and middle-income countries.

4.1.3 Environmental shifts

4.1.3.1 Climate change impacts

There is a growing recognition that climate change is a significant driver of emerging risks in food safety (FAO, 2020b; FAO, 2015b; EFSA; 2007; Maggiore *et al.*, 2020). However, its impact varies in different regions of the world (Kendall *et al.*, 2018).

The warming of surface seawater, coupled with increased nutrient input, has contributed to the proliferation of toxin-producing algae that results in outbreaks of seafood contamination. This poses a challenge to controlling the quality of the marine environment in countries relying on desalination for freshwater supply in food production (Richlen *et al.*, 2010). Additionally, various parasites, fungi, viruses, vectors, and invasive species thrive under these conditions, posing threats to the health of both plants and animals. The invasion and expansion of animal pests and pathogens have been attributed in part to climate change and to the globalization of agriculture (FAO, 2020b; Maggiore *et al.*, 2020).

With global warming, extended hot and dry summers necessitate indoor livestock housing, enabling disease spread and increasing the demand for veterinary medicines, which in turn potentially fosters antibiotic-resistant bacteria. Considering these changes, the abundance of disease-carrying vectors and secondary hosts is projected to rise, and climate change may introduce emerging or new pathogens (FAO, 2020b; Boxall *et al.*, 2009), requiring governments in the region to rapidly detect and control infectious animal diseases and monitor veterinary drug residues in animal products.

Climate change has a critical role in impacting the various stages of fungi's life cycle. They directly affect the fungi's ability to colonize crops, survive, and produce toxins (Ganesan *et al.*, 2021). As temperatures continue to rise, we can anticipate a general rise in mycotoxigenic fungi that thrive in warmer climates. One example is the Aspergillus species, which is known for producing Aflatoxins. Aflatoxins pose substantial risks to both human and animal health. Consequently, while global warming will render certain regions unsuitable for crop cultivation, in areas where farming remains feasible, plants will be exposed to suboptimal climatic conditions, making them more vulnerable to fungal contamination. At the same time, warmer climates will provide favourable conditions for thermotolerant species, leading to the dominance of Aspergillus over Penicillium species (Zingales *et al.*, 2022), and prevalent mycotoxin contamination in food and animal feed.

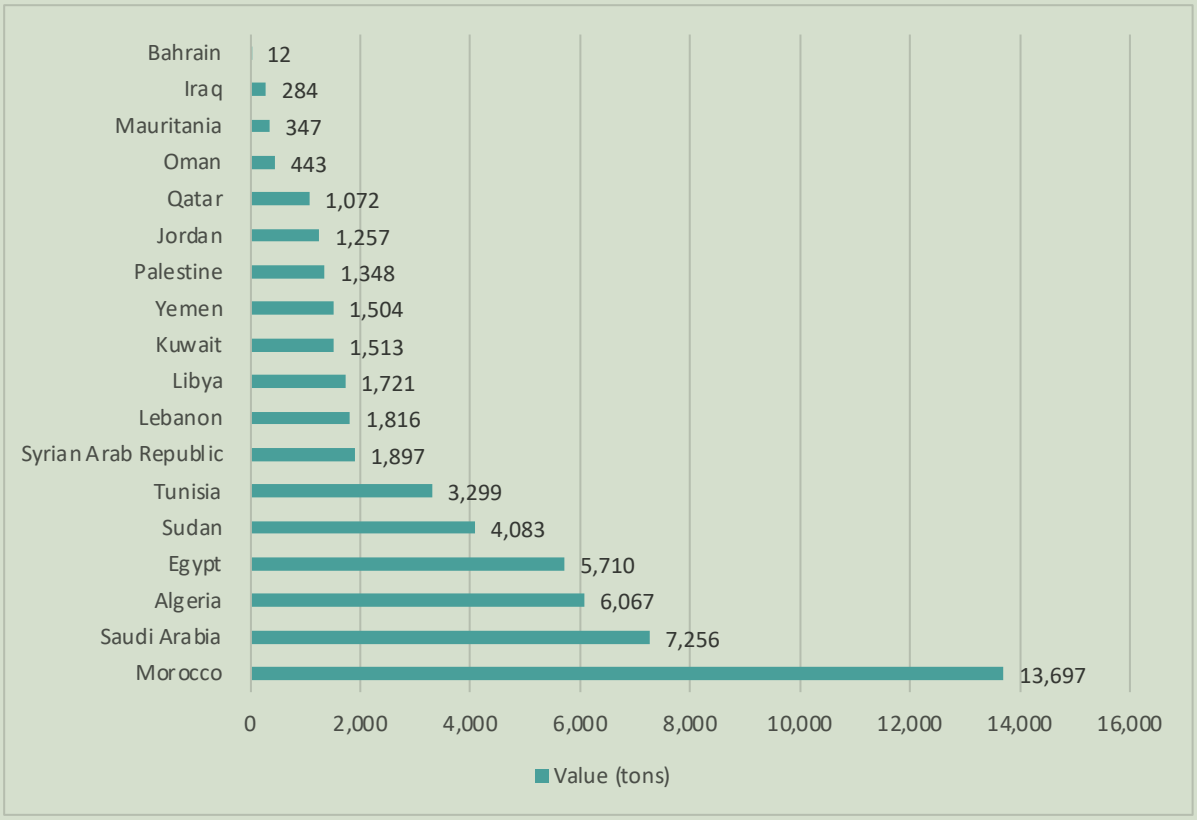
The effect of temperature variations on waterborne and FBD and their prevalence in the Arab region is well documented. Diarrheal diseases caused by bacteria like *Salmonella spp.* and *Campylobacter spp.* tend to thrive in warmer temperatures, and climate change is expected to further contribute to their proliferation in the future (Al-Rifai *et al.*, 2020; Cissé, 2019; El-Fadel *et al.*, 2012).

The NENA region, known for its aridity, is particularly vulnerable to climate influences and the impact of escalating temperatures, and is expected to see a significant surge of 150 percent in the frequency of droughts between 2020 and 2070. The Arab region is projected to experience an average mean temperature increase of 1.7˚ to 2.6˚C under Representative Concentration Pathways (RCP) at RCP8.5, making it one of the most heavily affected regions globally (UN ESCWA, 2017). The Regional Knowledge Hub Data Portal (FAO RICCAR, 2024), looking at the change in the number of tropical night signals, highlighted that Egypt, Jordan, Libya, Mauritania, Oman, Somalia, the Sudan, and the Syrian Arab Republic might be particularly affected by climate change by 2081-2100.

Over the long term, changes in temperature, humidity, rainfall patterns, and extreme weather events have been known to put pressure on natural resources and agricultural production. The degradation of natural resources and biodiversity across land and water is common in the NENA region. For example, in 2015, degraded land in Kuwait and Iraq accounted for 64 percent and 26 percent the total, respectively. Freshwater stress levels are high in all NENA countries (except Mauritania). Meanwhile, weather extremes – variable temperatures and rainfall (heat, drought, and aridity) – are already affecting agrifood systems and natural resources (FAO NERC, 2024).

Climate change in the region may result in a projection of the frequency and intensity of FBD caused by pathogens including toxigenic microorganisms and may promote the uptake of toxic heavy metals in stable crops, spreading fungal infections in plants and driving plant pests into new areas. Left unmitigated, these changes may lead to harmful changes in agricultural practices, such as the increased use of pesticides (Figure 4), rendering crops and livestock highly susceptible to disease and threatening the overall safety of food supply and therefore public health.

Figure 4. Annual agricultural pesticide usage in the NENA region



Source: FAOSTAT (FAO Statistical Division). n.d. Food and Agriculture Organization Statistics (FAOSTAT Database). FAO, Rome. [Cited 2 May 2024]. https://www.fao.org/faostat/en/#data.

According to the World Bank Group's Climate Change Knowledge Portal (World Bank, 2024), countries in the NENA region are becoming increasingly more vulnerable to the risk of flooding, for example, the devastating floods in Yemen in 2008 that took an immense economic toll, and the 2009 floods in Jeddah, Saudi Arabia, that inflicted substantial damage. Flash floods have also been known to affect Iraq and the Syrian Arab Republic, triggered by heavy rainfall (EUMETSAT, 2019; World Bank, 2018a), and the Mediterranean storm Daniel passed through eastern Libya over 2023, bringing heavy rainfall and flooding that resulted in large-scale destruction. Such changes in rainfall patterns forge new transport pathways for contaminants (e.g. microbes, heavy metals, and dioxins), and increases the ability of disease-causing microbes to spread, leading to marked changes in water quality.

Moreover, these climate effects may have consequences on the levels of residues found in food crops and animals due to the increased volume of run-off, leading to the transportation of sediment, nutrients, pollutants, refuse, animal waste, and various other substances into water sources (Schwanen *et al.*, 2023). During severe flooding events, wastewater treatment plants (WWTPs) may become overwhelmed, polluting both human and animal or farm environments with bacteria found in human sewage and antimicrobial-resistant pathogens, further jeopardizing the integrity of the environment and food crops (Boxall *et al.*, 2009).

4.1.3.2 Water scarcity

Water resources in the region have been under significant strain due to rapid industrial development, population growth, and poor management, further exacerbated by the impact of climate change. Many countries are currently experiencing water scarcity as a result of inefficient water usage and the exploitation of resources. Furthermore, urbanization is becoming a serious challenge, as evidenced in Yemen by the rapid growth of cities like Sanaa, Aden, Mukalla, and Taiz over the past few decades. Particularly in Sanaa, increasingly irrigated farmland has suffered from a deficit of water relative to growing demand (FANACK, 2017; FANACK, 2021).

Additionally, ongoing conflicts have also contributed to the crisis. The Syrian Arab Republic, for instance, has faced increasing water scarcity, aggravated by the destruction of water supply infrastructure during the war, disruption of transboundary flows, the lack or absence of power and energy resources, and corruption. Furthermore, the damage to wastewater treatment plants (WWTP) has resulted in a decline in access to water, with at least 70 percent of sewage being discharged untreated and no less than half of sewerage systems being out of order (Dagher *et al.*, 2021).

The availability of fresh water per capita declined in NENA by 78 percent between 1962 and 2018; much higher than the global figure of 59 percent. Nine NENA countries have suffered declines in per-capita freshwater availability of more than 80 percent. (FAO, 2022e). Consequently, the demand for water to sustain food production will put additional strain on water resources due to decreasing precipitation, pollution, uncontrolled pumping, and wastewater seepage (FAO, 2022e; Daher, 2022). This scarcity poses a significant threat to food safety as it leads to changes in agricultural practices, including the use of substandard water sources to overcome shortages. This, in turn, adds to food safety pressures as crops, soil, and groundwater are exposed to microbial and chemical contamination (FAO, 2022c; Faour-Klingbeil and Todd, 2018).

Variances exist in water resources across NENA countries, with some countries facing significant constraints that affect agricultural and fishing practices, and food production (Table 2). While certain countries primarily rely on river sources for their agricultural water supply, others, such as Lebanon, predominantly use groundwater as a primary source, followed by rivers (FAO, 2022e; Jaafar and Kharroubi, 2021). Conversely, the GCC countries rely on shrinking aquifers and desalination processes to meet their water needs, with groundwater being primarily used for agriculture (Abdulrahman, 2020; Qureshi, 2020). These practices have proven to be unsustainable, either due to their adverse effects on the environment or the depletion of water reserves.

Faced with the increasing water usage rates, several countries, including Egypt, Morocco, Tunisia, and Jordan, have been compelled to diversify their water sources and reduce their dependence on natural resources. One of these alternative solutions is wastewater reuse for irrigation (USAID DAI, 2009; FAO, 2021a; GIZ, 2016). Algeria, the Sudan, Iraq, and Mauritania also practice reclaimed water reuse for irrigation. However, there are concerns over the quality of treated wastewater used for irrigation given the constrained capacities of WWTPs (ACWUA, 2011; USAID DAI, 2009; GIZ, 2016; Neamatallah, 2018) and the limited efficacy of available treatment technologies in eliminating harmful pollutants (Abu Qdais, Abdulla and Kurbatova, 2019; Alkhamisi and Ahmed, 2014; Aydin *et al.*, 2016; Caucci and Hettiarachchi, 2018; Djemil, Hannouche and Belksier, 2018; Dzhumagulova and Abdulameer, 2021; Elmeddahi *et al.*, 2016; Hajjami *et al.*, 2012; N'Diay and Ahmed, 2014; Qadir *et al.*, 2010).

Capacity overload in existing WWTPs is a prominent issue in the region, as untreated or inadequately treated wastewater has been found to be discharged into water bodies such as rivers, canals, and coastal areas, impacting water quality and the environment (Caucci and Hettiarachchi, 2018; Tawfik *et al.*, 2021; Mateo-Sagasta, Al-Hamdi and AbuZeid, 2022). Nevertheless, ongoing efforts are being made to explore the feasibility of water reuse in agriculture and the integration of WWT technologies in countries such as Lebanon, Egypt, Tunisia, and Morocco. These reports often point to intersectoral collaboration as a condition for implementation of complex initiatives involving diverse technologies and strategies.

But many countries grapple with institutional fragmentation, limited infrastructure, inadequate coordination among stakeholders involved in water governance, and ineffective resource management, which hinders the effective regulation of water resources and agricultural practices (FAO, 2022e; Breulmann *et al.*, 2019; GIZ, 2016; Bannaga, 2016). Therefore, despite formulating policies and plans to enhance WWT, practical execution of these measures often falls short (GIZ, 2016). Effective partnership and communication to address the legal, technical, and cultural obstacles continue to be a common weakness (Frascari *et al.*, 2018). Furthermore, the unequal ramifications of climate change on farmers in resource-poor nations and conflict zones are evident due to their limited adaptive capabilities (OECD and FAO, 2021).

In the absence of proactive adaptation strategies and robust policies, farmers often resort to risky agricultural practices, such as using WWTP effluents, sewage channels, or polluted rivers for irrigating vegetables (Dagher *et al.*, 2021), which present significant risks to public health and food safety.

Similarly, the Gulf countries have undertaken WWTP initiatives in response to diminishing aquifers and to reduce reliance on desalinated water for their industrial and agricultural water needs, minimizing environmental deterioration (Abdulrahman, 2020; Paleologos *et al.*, 2019; Qureshi, 2020). However,

significant risks persist, stemming from the absence of a well-defined systemic risk management approach and the need for regulatory framework enhancements (Paleologos *et al.*, 2019).

In response to these challenges, FAO and WHO developed a series of normative guidelines as an authoritative assessment of the health risks of water, whether used for drinking, irrigation, or recreational purposes (WHO, 2022; FAO and WHO, 2021; FAO, 2021a; FAO NERC, 2014).

Table 2. Main agricultural systems and relevant subsystems in the NENA region

Agricultural systems	Length of growing period	Main production	Distribution of rural population (%)	Rural population density (persons/ km2)	Distribution of area excluding desert (km 2)	Key issues
Major Agricultural Systems						
Irrigated	Year-round	Wheat, fruits, vegetables, sugar cane, sugar beet, fodder	32.6	170	8.9	Access to water, pollution, input misuse
Rainfed	<150 days	Cereals (wheat), olive, fruit trees	21	45	21.7	Droughts, temperature increase
Dryland	90-150 Days	Cereals (barley, millet), beans, livestock: goats, sheep	15.7	35	20.8	Droughts, access to markets, finance, and inputs
Pastoral	30-90 days	Livestock: sheep, goats, camels	20.5	25	38.2	Access to basic services, heatwaves
Forest-based	<150 days		10.1	45	10.3	Deforestation, land degradation
Relevant Subsystems						
Oases	30 > days	Dates, vegetables				Water overuse, market access, income diversification
Mountains		Vegetables, fruit trees, legumes, cereals, livestock				Low investments, small size of plots, water scarcity, high production costs, lower productivity, market access
Urban/ peri-urban agriculture	Vegetables, fruits, dairy products		Urban encroachment, land tenure, access to quality water			
Fisheries and aquaculture	Fish		Competition for land and water			
Deltas and coastal areas	Rice, vegetables, cereals		Seawater intrusion, urban encroachment on arable land			

Source: Adapted from FAO (2022e). Table developed by Moustapha.

4.2 PRESSURES

This section discusses the key pressures on food safety inferred from the earlier discussions on drivers (section 4.1), and identified from the available reports, studies, and research in the region (as outlined in section 3.2.1.1 and represented in Figure 1).

4.2.1 Increased reliance on food imports

Achieving food security remains a complex challenge requiring sustained investment and long-term planning. Some countries have prioritized food security and self-sufficiency through investments in domestic agriculture, sustainable farming practices, and diversification of food sources.

While there have been some improvements in food production, the region's reliance on food imports is expected to continue due to rapid population growth, limited natural resources and arable land, and the impacts of climate change (FAO, IFAD, UNICEF, WFP, WHO and UNESCWA, 2023; FAO, 2022e).

In 2020, the region witnessed a substantial increase in net food imports, with a total bill of USD 61 billion, indicating a significant surge compared to the previous decade, in order to meet the population's needs (FAO, 2022e). On average, imports provided 62 percent of the region's food supply between 2017 and 2019, with a population-weighted import dependency of around 50 percent. In several countries, such as Algeria, Iraq, Lebanon, and Tunisia, import dependency exceeded 50 percent, while in Jordan, Kuwait, Saudi Arabia, the United Arab Emirates, and Yemen, more than 80 percent of total domestic calorie availability came from imports (Berekaa, 2021; DKA, 2022; IFAD, UNICEF, WFP, WHO and ESCWA, 2021).

Overall, GCC countries exemplify the region's heavy reliance on food imports, which amount to 33 million tons of food every year, estimated to be 90 percent of their food demands (FAO, 2022e; Alrobaish *et al.*, 2021). Given the region's dependence on food imports, many countries are vulnerable to price fluctuations.

Many NENA countries depend heavily on imported foodstuffs. Wheat, a staple food, is no exception, with much of it coming from the Russian Federation and Ukraine (Table 3). More than 70 percent of the wheat supply in Lebanon and Egypt comes from Ukraine and the Russian Federation. Libya imports more than 60 percent of their wheat, in Mauritania the proportion exceeds 50 percent, Saudi Arabia and Oman import almost half their wheat, and in Tunisia and Yemen, more than 40 percent of the total wheat supply is imported. The NENA region's average wheat import dependency on Ukraine and the Russian Federation is around 45 percent (FAO, 2022e; WITS, 2024).

The extensive importation, transportation, and distribution of large quantities of food products over long distances poses additional challenges to quality control, traceability, and compliance with food safety standards (Al-Kandari, Al-Abdeen and Sidhu, 2019; Alrobaish *et al.*, 2021).

In the GCC countries for instance, with food consumption projected to rise by 55 percent in Saudi Arabia in 4 years (WITS, 2024; Berekaa, 2021), the country imports an estimated 80 percent of its overall food products from 157 countries worldwide (Alrobaish *et al.*, 2021). Hence, having the appropriate capacity and capability to ensure the safety of these substantial amounts of imported

food and their compliance with local regulations as well as religious Halal standards can be challenging in these nations (Abdulsalam and Bakarman, 2021; Berekaa, 2021; El Sheikha, 2016). The situation becomes even more challenging when considering fresh food imported and distributed over long distances, often facing extensive waiting times at entry ports for sampling, testing, and border controls (Alrobaish *et al.*, 2021). This development represents an incredibly demanding operational environment for food safety interventions, particularly in the GCC countries (Berekaa, 2021; AlKandari & Jukes, 2009; Al Mutairi *et al.*, 2015).

Table 3. Wheat import volumes in NENA countries (tonnes); list in descending order

Country	Quantity (1000 tonnes)
Egypt	8010.427
Algeria	7017.241
Morocco	6007.647
Yemen	2851.728
Tunisia	1891.272
Saudi Arabia	1879.023
United Arab Emirates	1664.95
Jordan	771.5939
Mauritania	750.0895
Iraq	710.4181
Lebanon	552.357
Oman	474.5492
Kuwait	429.8089
Libya	245.4659
Bahrain	133.7205
Qatar	83.5822
Syrian Arab Republic	81.67494
Palestine	61.77

Source: Adopted from FAOSTAT (FAO Statistical Division). Table developed by Moustapha. n.d. Food and Agriculture Organization Statistics (FAOSTAT Database). FAO, Rome. [Cited 2 May 2024]. https://www.fao.org/faostat/en/#data.

Hence, the increase in food imports requires governments and regulatory institutions to dedicate significant resources, i.e. finances and policies, towards instituting proactive regulatory strategies and fostering effective traceability systems (FAO, 2023e).

The necessity of this proactive approach arises from the persistent threat of emerging infectious diseases, including zoonoses. The risks associated with these diseases are amplified by globalized trade, unplanned urbanization, and climate change (Awaidy and Al Hashami, 2020; Brooks *et al.*, 2022) and the Gulf countries are particularly vulnerable to this trend due to a large workforce and frequent air travel, which increases the risk of introducing airborne and exotic zoonotic diseases (Todd, 2017).

These ongoing transformations create a pressing need within the region to adopt risk management strategies capable of swiftly responding to the evolving food safety risks within the global food market. A case in point is the growth poultry imports which is influenced by population and urbanization trends in many developing economies and emerging markets (Miller *et al.*, 2022). Eventually, that means more antibiotics are needed to keep the animals healthy and to drive production.

The reliance on antibiotics in food animal production, along with the misuse and abuse of these drugs, is known to have at least partially contributed to the emergence and spread of antibiotic-resistant foodborne bacterial pathogens (Miller *et al.*, 2022). Such outcomes present a serious and elevated risk to consumers, thus positioning AMR as a central issue in food safety.

Other concerns extend to the subtle forms of food fraud that remain a complicated problem in complex food supply chains, and which necessitate competent laboratories, ample resources, adept personnel, and qualified inspectors for detecting these deceptive activities.

4.2.2 Water pollution: substandard water for irrigation

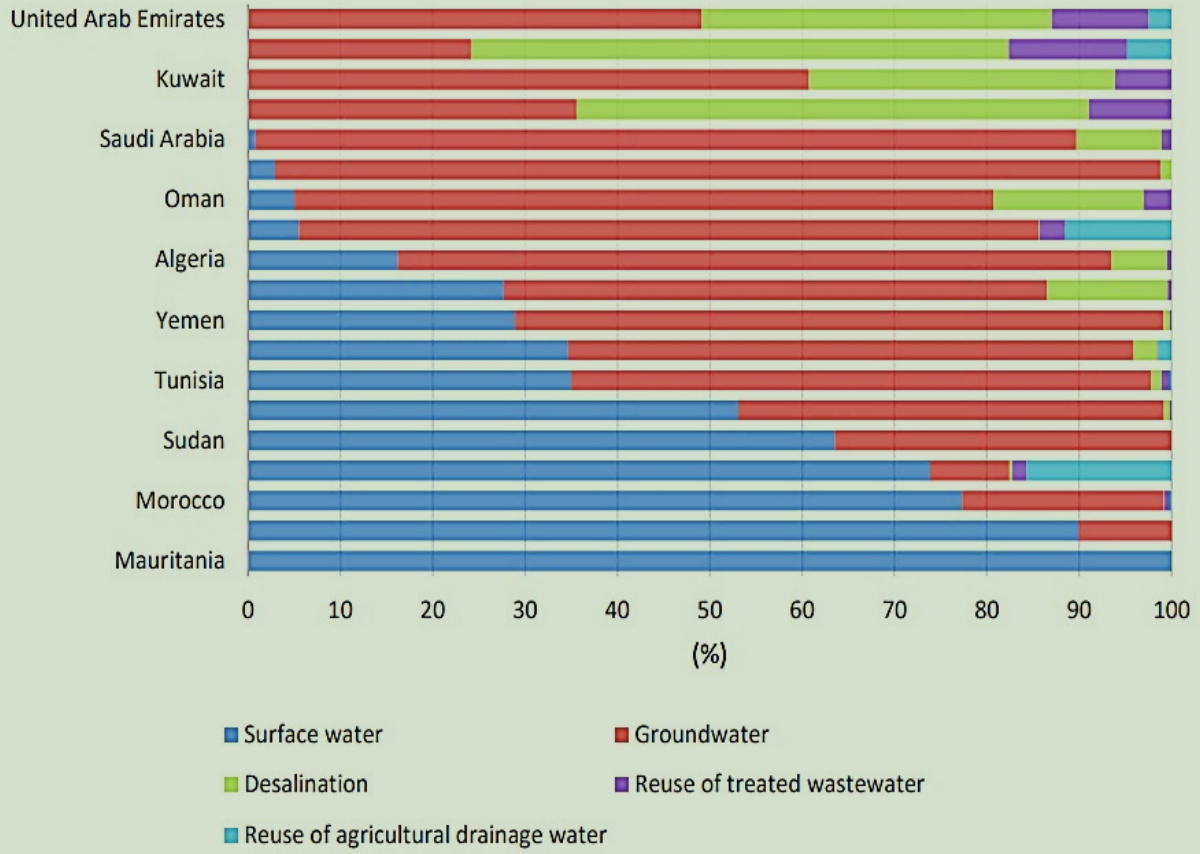
Evidence from across the region shows that there is a widespread problem of water pollution which could have ramifications on the quality and safety of food. The rapid pace of industrial development and population growth, as well as climate change, have significantly strained water resources in the region, primarily as a result of poor management.

In the Gulf region, water pollution is a major concern due to increasing industrialization and urbanization. Furthermore, an increase in the use of groundwater for irrigation has led to a decrease in water quality and availability, and the disposal of chemicals has contributed to pollution.

For instance, industrial pollution from oil fields, oil spills and seepage from oil pipelines, is causing pollution in Libya and Iraq, with the latter being implicated as a potential source of a drinking water contamination event that caused more than 100 000 people to be hospitalized. Also, in Kuwait, groundwater remains contaminated after the destruction of oils wells during the Gulf War (de Waal *et al.*, 2023).

Similarly, water from the Euphrates is polluted as a consequence of damage to oil infrastructure, with thousands of barrels of oil leaking out into creeks in the area and ending up in a 160 km-long river (Dagher *et al.*, 2021). Consequently, there are challenges in finding safe alternatives to freshwater given the increased groundwater salinity resulting from excessive extraction and use of fertilizers and climate change (Lahham *et al.*, 2022).

Figure 5. Water withdrawals by source per total water withdrawal, NENA, 2015 and 2017



Source: Elmahdi, A., Badawy, A., Alejandro Paltan Lopez, H. 2022. Addressing the water challenges in the agriculture sector in Near East and North Africa. Cairo, FAO. https://doi.org/10.4060/cc0349en

Several laws and regulations have been established to protect water resources from pollution and exploitation. Countries like Lebanon, Morocco, the Syrian Arab Republic, and Tunisia, have adopted a forward-looking approach in the formulation of agricultural development strategies to address deficiencies in water policies and environmental legislation, aiming to reduce the pollution of groundwater quality and consequent deterioration of its quality (El-Haddad *et al.*, 2011). However, notable issues persist in the form of inadequate institutional mechanisms to enforce these laws and rules, resulting in weak water governance and a lack of accountability measures (FANACK, 2017; Dagher *et al.*, 2021; Eid-Sabbagh *et al.*, 2022; Tawfik *et al.*, 2021).

Human activity has significantly impacted the quality of surface and groundwater. Due to state dysfunction and misallocated funds for WWTP rehabilitation in Lebanon, water resources have become contaminated with untreated sewage, domestic waste, industrial solid waste, and effluents. In Lebanon, 60-70 percent of natural sources of water are affected by bacterial contamination and the untreated effluents of industry, chicken farms, and slaughterhouses that leach into the sea and rivers, the latter of which are used as water sources for irrigation and crop washing. For example, the Litani River, a crucial water irrigation source in the Bekaa Valley, suffers from significant levels of chemical and bacterial contamination (Shaban and Hamzé, 2018).

Lack of access to advanced wastewater technologies is among the key issues in the water sector in the region. Moreover, the operations and monitoring of wastewater treatment plants in countries such as Egypt (Tawfik *et al.*, 2021), Tunisia (Caucci and Hettiarachchi, 2018), and Lebanon (Eid-

Sabbagh *et al.*, 2022), Oman (Al-Riyami *et al.*, 2018) are known to be deficient, with limited capacities to eliminate pathogens and hazardous chemicals, as well as a shortage of skilled operators.

These conditions are particularly alarming in countries where agriculture plays a vital role in the economy, e.g. in Morocco, Tunisia, the Syrian Arab Republic, Lebanon, Jordan, and Egypt. In these nations, many farmers are forced to rely on low-quality water for crop irrigation, which poses serious agricultural safety and quality risks. Countries affected by conflict face additional challenges due to their limited capacity to adapt (FAO, 2022e).

The use of untreated or partially treated wastewater for agricultural purposes in and around urban areas persists, despite its prohibition (Figure 5). The most usual form of water reuse in the region is indirect water reuse, where treated or untreated wastewater is discharged into freshwater streams and utilized downstream after dilution. Similar practices have been reported in Lebanon, the Syrian Arab Republic, Morocco, and Egypt (FAO, 2022e; Faour-Klingbeil and Todd, 2018; Lahham *et al.*, 2022; Habbari *et al.*, 1999; Melloul *et al.*, 2001; Mourad and Berndtsson, 2020; Qadir *et al.*, 2010; Tawfik *et al.*, 2021).

Also in Tunisia, water quality has long been a concern due to the pollution of most water resources, with many of these pollutants stemming from wastewater discharge, industrial effluents, and agricultural activities. Although efforts have been made within the last decade to create wastewater facilities, overall, the water quality remains poor and could continue to worsen if more is not done to reverse rising pollution (Borgen Project, 2017). In Egypt, institutional fragmentation and overlapping responsibilities encourages the utilization of untreated wastewater for enhancing crop yields. There are occasions when the state chooses to overlook the informal discharge of sewerage and wastewater effluents and reuse practices in the Delta (Tawfik *et al.*, 2021).

Meanwhile, in the Syrian Arab Republic, the continual degradation of, and damage to, water treatment networks, irrigation canals, and water stations, has forced farmers to resort to illegal exploitation of groundwater, purchasing water in tankers, and utilizing untreated wastewater, resulting in serious risks to public health. As a result, water pollution and tankers selling unlicensed water have led to the outbreak of numerous diseases such as leishmaniasis in Aleppo and Deir al-Zor, and typhoid fever around Damascus (Daher, 2022).

There are growing concerns regarding the potential health risks associated with the long-term accumulation of emerging contaminants such as estrogenic hormones and pharmaceutical compounds (antibiotics) due to deficiencies in water and wastewater management.

In Jordan, Al-Mashaqbeh *et al.* (2020) found various levels of pharmaceutical compounds in the influent & effluent of the As-Samra treatment plant in Jordan, specifically: 1,7-dimethylxanthine, acetaminophen, sulfamethazine, sulfamethoxazole, and trimethoprim. It was also discovered that the treatment plant could not completely remove the pharmaceuticals and personal care products from its wastewater; therefore, some of these compounds remained in treated wastewater used in the irrigated farming of vegetables such as parsley. (National Academy of Science, 2016).

Furthermore, a total of 290 environmental pollutants (EP) have been observed in different water matrices across the MENA countries, stemming mainly from industrial effluents, agricultural practices, and the discharge or reuse of treated wastewater. Pharmaceutical compounds figure among the most frequently reported compounds in wastewater, treated wastewater, surface water, and drinking water. Nevertheless, pesticides are the most frequently detected pollutants in

groundwater. More concerning is that there have been 57 cases exceeding thresholds set by the WHO and European Commission (EC). Overall, pesticides, organic compounds, and pharmaceuticals are the most concerning EP groups. Negative removals of some EPs such as carbamazepine, erythromycin, and sulfamethoxazole were recorded, suggesting their possible accumulation or release during treatment (Haddaoui and Mateo-Sagasta, 2021).

Moreover, antibiotics like sulphonamides, erythromycin, and macrolides were found in the aquifer of the irrigated area of Oued Souhil, in Tunisia (unpublished results) at concentration levels similar to those in wastewater, confirming the pressures of poor treatment and inadequate agricultural practices on the environment and the food chain. The transfer of hormones and pharmaceutical compounds has been raised as a major concern in some irrigated areas as a result of antibiotic transfer to groundwater following the use of wastewater in irrigation. (Caucci and Hettiarachchi, 2018).

Negligence in this critical area of the supply chain increases the risk of food and waterborne illnesses, such as cholera, due to poorly managed water and sewage systems, inadequate sewage disposal strategies, and farmer use of untreated wastewater (Qamar *et al.*, 2022). This precarious situation not only presents significant health risks but also contributes to the alarming rise of antibiotic-resistant strains (Al-Riyami *et al.*, 2018).

4.2.3 Shortfalls in agricultural practices – excessive use of agrochemicals (pesticides and veterinary medicines)

Almost all countries in the NENA region have established regulations to control pesticide residues in foodstuffs; however, several reports have consistently highlighted a significant shortfall in national inspection and monitoring programmes, traceability, enforcement, and policy, which contributes to continued excessive use and abuse of pesticides and to non-compliance with safety regulations (Abou Zeid *et al.*, 2020; Benaboud *et al.*, 2021; Khaled, 2012; Osaili *et al.*, 2022) (Table 4). This issue is further compounded by the inadequate emphasis on promoting farm control programs and enhancing pesticide safety education among farmers, and food producers.

A key challenge faced by farmers, particularly in greenhouse environments, is heavy reliance on chemical pesticides due to the limited availability of non-synthetic methods of pest control, which restricts their options for sustainable farming practices. Studies have shown that in most countries, farmers have poor awareness of the regulations governing pesticides or the significance of adhering to these rules due to their limited access to training and educational resources. Additionally, they lack information about the health and environmental impacts of pesticides, protective measures, and trade implications. There are cases where instructions for proper pesticide use are not easily understood due to language barriers and social constraints (FAO, 2021b; FAO, 2022a; Abdelbagi *et al.*, 2020; AEEFG, 2020; Benaboud *et al.*, 2021; Jallow *et al.*, 2017a). Furthermore, significant gaps in pesticide management were reported in Tunisia, such as non-compliance with regulations at various stages, e.g. marketing, storage, application, residue management, protection, and pesticide waste management. This also includes ineffective post-approval control procedures, and inadequate efforts to raise awareness of pesticide risks and crop protection in small and medium-sized agricultural producers and efforts to supervise these (AEEFG, 2020).

With ineffective border controls, these conditions have collectively rendered the supply chain vulnerable to inadequate labelling and the smuggling of counterfeit and restricted pesticides into the local markets in many countries, including Yemen, Lebanon, Algeria, Morocco, and the Gaza Strip, further complicating the situation (Houssari, 2023; Benaboud *et al.*, 2021; CEOBS, 2020; El-Haddad *et al.*, 2011; Holm Akhdar, 2022).

The illicit trafficking of restricted pesticides is a growing challenge, with an increase in the reported cases of suppliers exploiting regulatory gaps along the supply chain. Suppliers from the EU also export banned pesticides to countries in the global South, a trend that could potentially extend to the region in the absence of vigilant state oversight and monitoring. Consequently, unsafe levels of pesticide residues are frequently detected in the region (Robertson, 2016).

In 2017, the former Minister of Agriculture in Lebanon permitted the re-importation of 18 out of 36 pesticides which were previously banned due to their association with cancer risks and hazards to pregnant women. This decision was justified by the absence of viable alternatives for combatting weed and insect control, which had significantly impacted production costs and yields (Mohsen, 2022); this case underscores the erratic nature of policies in one of the most critical areas of the food chain.

Along the same lines, food safety governance in Jordan has faced recent criticism by the former Director of the Food and Drugs Laboratories at the Jordanian Food and Drugs Authority over the haphazard use of pesticides and rising levels of chemical contamination, which are potentially linked to the rising number of cancer cases in the country (Mauvais, 2021). Adding to these concerns, the elevated temperatures and arid climate prevalent in the region can exacerbate the persistence of agrochemical residues in the environment, posing greater challenges in managing the associated risks.

A review published by Merhi *et al.* (2023) reported the presence of antibiotic residues of public health concern in dairy products, meat products and honey. These residues vary in composition and were found to be present in many food samples at various concentrations. Some results were alarming and required the rapid action of local authorities to monitor and manage. Contributing to this problem are misuse of antibiotics and a disregard for their withdrawal periods.

There is a dearth of data regarding husbandry practices tied to veterinary medicine. Existing information already points to a critically widespread use of antibiotic drugs in food production, which raises serious public health concerns. In Algeria, Berghiche *et al.* (2018) revealed significant antibiotics abuse, with more than half of surveyed poultry farmers not adhering to withdrawal periods for antibiotics. Furthermore, veterinarians reported a 96 percent failure rate in antibiotic treatments, suggesting that antibiotics were often used ineffectively (ibid). A study in Khartoum state reported that farmers have poor knowledge and inadequate awareness of the proper application of antibiotics, the potential health risks, and the economic repercussions of their misuse. Their application of antibiotics was indiscriminate, applied to both ailing and healthy animals. Furthermore, additional data indicated a lack of awareness of common zoonotic infections. (Eltayb *et al.*, 2012). Similarly, a substantial proportion of surveyed farmers (97 percent) in Morocco have resorted to extensive antibiotic use, primarily due to the accessibility of smuggled antibiotics (El-Youbi *et al.*, 2016). Considering these findings, it is plausible to assume that indiscriminate antibiotic use in animal husbandry might be widespread in the region, exacerbating the emergence of antibiotic-resistant strains within the agricultural environment. This is discussed in the next section.

Promoting safe agricultural practices is pivotal to ensuring food products meet safety standards and regulations; however, it is undermined by poor extension services and educational support, and the problem of farmer illiteracy (UN ESCWA, 2019a; Wilfred L. Mushobozi, 2010; Benaboud *et al.*, 2021; Jallow *et al.*, 2017a; Nasreddine *et al.*, 2016). Moreover, efforts to enhance farmer education and training are hindered by a shortage of skilled technical staff, low farmer participation in seminars and agricultural lectures, and limited awareness of the pivotal role played by agricultural extension services.

Additionally, weak enforcement of food safety regulations at the national level can further impede the effectiveness of cooperatives and extension services, underscoring the need for comprehensive reforms and greater support for these vital support systems within the food supply chain. For instance, in Lebanon, monopoly laws pose obstacles to small farmers organizing into marketing cooperatives, limiting their ability to access vital support. Additionally, farmers and agricultural operators in Iraq and Lebanon often have lower levels of education, which can act as a barrier to their intake of information and use of digital technologies, potentially hindering their access to modern agricultural practices and food safety improvements (Bahn *et al.*, 2021; Dalgamoni, 2018; Hamdan Al-Zahrani *et al.*, 2021).

Table 4. Pesticide use challenges in the NENA countries

Country	Potential pesticide challenge	Source
Egypt	Unregistered distribution networks evade regulatory oversight. Proliferation of fraudulent and counterfeit pesticides. Ineffective government oversight and monitoring mechanisms. Inappropriate use and disposal of pesticides, poor farmer awareness. Misuse of pesticides and non-compliance with safety regulations (maximum residue levels of pesticide in food).	El-Safoury, 2020; Kassem *et al.*, 2021; Khaled, 2012
Lebanon	Excessive use of pesticides. Absence of adequate testing laboratories and testing methodologies. Limited funding and resources to improve the capabilities of laboratories to detect a wider range of pesticide residues. Lagging surveillance system. Illegal access to and use of banned pesticides	FAO, European Union and CIRAD, 2022; Abou Zeid *et al.*, 2020; Nasreddine *et al.*, 2016
Kuwait	Lack of effective enforcement mechanisms. Significant illiteracy and limited knowledge. Unsafe disposal of pesticides.	Jallow *et al.*, 2017b, 2017a, 2017c
Morocco	Overuse of pesticides. Poor farmer knowledge and awareness.	Benaboud *et al.*, 2021
Saudi Arabia	High rate of detection of pesticide residues in locally traded food.	N.M. Al-Daghri *et al.*, 2024; Faraj, 2019

Source: Dima, author's own elaboration.

4.2.4 Unregulated local food markets and limited food safety measures and practices

Food trading in many LMICs is dominated by the informal sector. Numerous micro- and small businesses, which are not legally registered and compete mostly on price, handle much of the food that people eat (Henson *et al.*, 2023). Insufficient awareness, inadequate operational conditions, and disincentives often lead to subpar food safety practices among those operating in the informal food sector. In many cases, this stems from an excessive number of vendors relative to the consumers. These food vendors are drawn to areas with heavy human traffic, even if it means being exposed to dust and vehicle exhaust fumes and lacking access to clean water.

Hygiene is not always prioritized at these locations, and the presence of animals (both domestic and wild) in traditional food markets can pose a threat to public health if not managed properly. Zoonotic pathogens can spread to humans through direct contact with infected animals (Henson, 2023; Henson *et al.*, 2023). However, consumers are not entirely passive in their exposure to unsafe food; they can take action to protect themselves through their food choices and food preparation practices. Nevertheless, many types of food safety hazards cannot be effectively recognized by consumers when making food choices, especially when consumers focus on price rather than the conditions of hygiene (Henson. *et al.*, 2023).

The NENA region faces significant challenges in terms of economic growth and governance, which are essential elements affecting the transformation of agrifood systems. There is inadequate capacity to produce enough food to meet the rapid increase in food demand, in particular due to scarcity of natural resources and the socio-economic constraints that have profound implications for food security, compounded by degraded infrastructure such as water supply, poor post-harvest storage conditions, and the absence of adequate agricultural policies (FAO, IFAD, UNICEF, WFP, WHO and UNESCWA, 2023; FAO, 2022c; FAO NERC, 2024; FAO, 2019d; UN ESCWA, 2019b; Khader *et al.*, 2019).

Informal food markets play a critical role in linking the urban poor to key markets selling fruits, vegetables, fish, and meat products. This offers critical opportunities for income generation, especially for women, young people, and those with less education (FAO, 2019d).

Rapid urbanization and changing economic structures in many NENA countries have led to a rise in domestic markets, including informal food markets and street vendors, traditional local food shops, roadside stands, and food stalls/kiosks. These markets provide livelihoods for many and serve as essential resources for budget-constrained consumers who constitute a significant portion of the population. Most of these venues sell a variety of high-risk foods, including meat, fish, and dairy products. However, while they provide economic opportunities and cultural experiences, they are often characterized by poor infrastructure and overcrowding (FAO, 2013b; FAO, 2013a; FAO, 2019d).

Inadequate market structures compromise food safety and heighten the risks associated with food spoilage. The Economic and Social Commission for Western Asia (ESCWA) report (2019) emphasized the prevalence of inadequate agricultural practices and suboptimal post-harvest handling in the Arab region, leading to damage during transportation and processing, as well as pest infestation during storage (UN ESCWA, 2019b). In the NENA region, each year, over 14.8 percent of food produced is lost from in the supply chain post-harvest up to, but not including the retail stage.

Significantly high levels of food loss and waste (FLW), above the global average, are reported in the region. (FAO, 2023b; UNEP, 2021a; FAO NERC, 2024; UN ESCWA, 2019b).

These issues are further exacerbated by deficiencies in market infrastructure, including the lack of cold chain facilities, inadequate transportation, and the prevalence of open-air stalls, exposing food to detrimental environmental factors like heat and humidity (FAO, 2015b; FAO, 2015c; UN ESCWA, 2019b). At the same time, such conditions accelerate the deterioration of food items, contributing to microbial growth and contamination.

Evidence from many localized studies indicates that such poor practices, unhygienic operating conditions, and the use of low-quality ingredients, among other factors, result in high levels of microbial pathogens in food produced, processed, and/or managed by informal food processors and vendors. High levels of microbial pathogens have been found in street-vended salads, 75 percent of meat samples taken from the city's traditional markets were contaminated with antibiotic-resistant Salmonella strains, 40 percent of lettuce and herb samples were contaminated with Lead (Pb) and Arsenic (As), while 40 percent of other green vegetable samples had unsafe microbial pathogen levels. (Henson *et al.*, 2023)

In Lebanon, inadequate storage facilities and poorly maintained post-harvest washing facilities and transportation systems have contributed to the pathogenic contamination of fresh produce. Conflict-related infrastructure damage in the Syrian Arab Republic and Iraq has made it difficult to transport and store food safely, while the West Bank and Gaza have severely limited access to resources and infrastructure (Lin *et al.*, 2022). There is a growing body of research in this area that consistently emphasizes the lack of government policies, strategic initiatives, and investments, and the absence of effective inspection and control in this informal food businesses sector to promote the post-harvest handling, transportation, storage, and serving practices to evade the risks associated with food spoilage, compromised food safety requirements, and food losses (Table 5). This is a critical sector considering the significant number of people who rely on these sources for their food needs.

It is widely known that these markets often operate without formal licenses and outside the purview of government policies, resulting in poor environmental and sanitary standards, inadequate waste disposal, and limited access to potable water. With the clear deficiency in legal requirements related to the safe transportation, storage, and handling of food, these conditions create an environment conducive to pest infestations and microbial contamination, leading to frequent food safety challenges stemming from inadequate unsafe and risky practices throughout the entire supply chain. Moreover, tackling the food safety problem requires a fundamental shift in thinking and practice and the involvement of local governments and municipalities where informal markets are based (Henson *et al.*, 2023; WHO, 2023a). The focus should be on multisectoral interventions that combine food safety measures with attention to animal health, environmental health, nutrition, safe water, and sanitation. For this purpose, WHO has recommended five key actions for safer markets to mitigate risk in traditional food markets (WHO, 2023a).

Of greater concern is the well-documented inadequacy of food operator and street food vendor knowledge and practice of food safety, particularly in LMICs (Desye *et al.*, 2023), including NENA countries (Table 5). Adding to these challenges, vendors often struggle to meet established hygiene standards due to the lack of basic food service infrastructure and equipment. This trend is similarly observed in Saudi Arabia, a resource-rich state known be making progress in addressing food safety issues.

One of the biggest concerns for Saudi Arabia is the health oversight of millions during the annual Hajj, and despite much care taken to restrict pilgrims with illnesses and attention paid to food safety and hygiene, occasional outbreaks have been reported (Todd, 2017). The majority of food handlers and workers in these regions are foreigners who may not be adequately trained in food handling processes and hygienic practices, and in some cases may be carriers of foodborne diseases (Todd, 2017).

The exposure of pilgrims to outdoor food stalls/kiosks in and around Mecca has also been identified as a contributing factor to food poisoning incidents during the Hajj and Umrah seasons. During the Hajj pilgrimage, the street-food trade often flourishes, as many pilgrims with limited financial resources rely on the affordability of food found in these stalls. While food handlers typically undergo medical examinations before employment, during peak seasons such as Hajj and Umrah, temporary food handlers are often hired without proper training in food handling procedures and hygiene. Researchers have observed these actors are handling food in unhygienic conditions, and improperly cooling or heating food (Moutz *et al.*, 2012).

Similarly, in Iraq, millions of pilgrims attend the Arbaeenia mass gathering each year, and temporary rest areas called Mawakib are set up to provide food and other services to attendees. However, the potential for improper handling of food at these Mawakibs increases the risk of waterborne and foodborne diseases (Radhi *et al.*, 2019).

In countries where artisanal fisheries and small-scale fishermen operating compact vessels dominate the fishing industry, traditional and simple techniques for harvesting, handling, and processing are still prevalent. Unfortunately, these methods often lack the necessary infrastructure for proper handling and storage, compromising the quality and safety of harvested fishery products.

While some large transportation trucks are equipped with refrigeration systems and can transport significant quantities of seafood products in insulated boxes filled with ice, a substantial majority of trucks lack the required cold storage capabilities, leading to food safety concerns. Although legislation and standards have been introduced to regulate transportation conditions, comprehensive implementation of these regulations has been lacking (Al-Busaidi *et al.*, 2016). These circumstances are likely prevalent elsewhere in the region, due to deeply rooted governance issues.

Table 5. Food safety challenges in local food markets in the NENA region

Country	Context	Findings	Source
Iraq	Street food vendors	Poor education on food safety requirements. Poor cleanliness in food production and utensils and tools. Lack of awareness of personal hygiene.	Khaleefah *et al.*, 2020
	Mawakibs during mass gatherings*	Fair to unsatisfactory practices toward safe food handling and personal hygiene. Non-licensed operators.	Lami *et al.*, 2019
Lebanon	Street food vendors	Unsatisfactory levels of *Escherichia coli*, *Staphylococcus aureus*, *Listeria spp.*, and *Salmonella spp.* in vended food. Inadequate sanitary conditions.	Loukieh *et al.*, 2018
Morocco	Local markets incl. slaughterhouses	Critical shortfalls in personal hygiene. Inadequate storage conditions.	Montet *et al.*, 2020
Oman	Seafood retail outlets	Lack of personal hygiene. High contamination of food contact surfaces.	Sudheesh *et al.*, 2013
Saudi Arabia	Restaurants, public kitchens, and street food vendors	Cross-contamination risks. Improper handling and storage practices. Lack of refrigeration facilities. Inadequate cooking utensils and tools. Critical food control violations and fraud.	Bakri *et al.*, 2017
		Scarce resources. Poor environmental conditions and lack of basic facilities (toilets, water, …).	Moutz *et al.*, 2012
Sudan	Street food vendors	Poor food safety knowledge and practices. Poor personal hygiene. *Escherichia coli*, *Staphylococcus Aureus*, and *Bacillus spp.* in cooked meals and beverages.	Abdalla *et al.*, 2008
Tunisia	Street food vendors	No specifications regulating the sanitary conditions of street food. Lack of legislation.	The Rejbi 2022; Maghreb Times, 2022

Source: Dima, author's own elaboration.

* Faith-based organizations and the public provide water, food, shelter, accommodation, and to a certain extent, health services for pilgrims.

Food workers have been responsible for FBD outbreaks, as microbial agents can be transferred to and from workers through contact with raw foods, especially those of animal origin. Transmission can occur via hands (including dirty fingernails, rings, fabrics, currency, and jewellery), clothing, aerosols, vomit, dust, exposed hand lesions. Transmission depends on the species of microbial agents, inoculum delivery route, type of surface contact, time-temperature control, and relative humidity (Abdalla *et al.*, 2009; Todd *et al.*, 2009).

To mitigate potential risks associated with disease transmission via food handlers, it is imperative to provide comprehensive training programs for food vendors, restaurant staff, and all individuals involved in food preparation and service.

Government entities responsible for food safety have joined forces with external consultants to design and implement training initiatives. These programs aim to equip workers with the knowledge and skills necessary to prevent the transmission of enteric diseases to consumers, thereby safeguarding public health (Cortas, 2017; Food Watch, 2023; Government of Dubai, n.d; Todd, 2016, 2017). Such programs yield successful results when paired with governmental commitment, as exemplified by the United Arab Emirates. In line with global best practices, the country, notably the emirate of Dubai, has formalized and mandated food safety training for food handlers.

Comparable initiatives and regulations can be observed regionally through the development of regional standards to regulate street-vended foods (see Table 19), underscoring the significance of regional food safety education and training within the food industry. Vocational education institutions have the potential to bridge this crucial gap in many countries by offering specialized training programs in food safety and related fields. Nevertheless, this sector remains underdeveloped, with disparities persisting in the quality and availability of vocational training programs across different countries.

4.3 STATE OF FOOD

Several reports from the region have highlighted the substantial effects of the complex interplay of drivers and the various pressures from human activities in NENA countries (as outlined in section 4.2, and Figure 1), such as the indiscriminate use of agrochemicals in farming and livestock production, agricultural practices, and food safety measures. These factors collectively affect the safety and quality of food, in terms of chemical and microbial contamination and food frauds. In this context, the studies presented below could be used to inform the risk assessment scale and to guide regulators to further consider these potential hazards, food contamination issues, types of hazards prevalent in the food chains, and fraudulent practices. They can further be used to discuss the possible application of additional requirements in the form of labelling standards or codes of practice.

4.3.1 Chemical and microbial contamination in the food supply chains

4.3.1.1 Agrochemical residues in food

A. Pesticide residues in foodstuffs

Pesticide residues exceeding the legal maximum residue limits (MRLs) have been detected in various foodstuffs, including fruits, vegetables, and grains, in different NENA countries, raising significant legal and health-related concerns. While the existing body of research on pesticide residues is generally limited in the region, with some sources dating back a decade, there is a noticeable recent trend of growing research interest, highlighting the increasing significance of this issue (Table 6).

Based on the available data and considering the prevailing conditions, i.e., widespread availability of illicit pesticides, insufficient training, and lax enforcement of regulations, it becomes evident that the actual extent of pesticide contamination in food could be worse than currently known. Studies have shown that even countries with relative stability and ample resources are not immune to this issue. For instance, fruits and vegetables in local markets in Qatar were found to contain pesticide residues that exceeded the MRLs set by the country's regulatory authorities, with dates and fruiting vegetables found to be likely to pose high health risks to consumers (Elobeid *et al.*, 2021).

Furthermore, the overuse and indiscriminate mixing of pesticides in greenhouse vegetable cultivation in Saudi Arabia has contributed to contamination, with most samples exceeding the MRLs. According to a study by Osman *et al.* (2010), the most frequently identified pesticides were carbaryl and carbofuran, among others. Furthermore, some vegetable samples contained prohibited pesticides, such as (lindane, methoxychlor, paraquat, and azobenzene). Similarly, in the United Arab Emirates, a comprehensive study conducted by Osaili *et al.* (2022) shed light on the alarming prevalence of pesticide residues in imported vegetables.

The research analysed 5 560 vegetable samples that entered the United Arab Emirates via the ports of Dubai Emirate during the years 2018 and 2019. A total of 79 different pesticides were identified and approximately 26.8 percent of the fruit samples exceeded the MRLs, with chlorpyrifos, carbendazim, cypermethrin and azoxystrobin consistently being detected at rates above the MRLs. The Emirate of Dubai, being one of the largest net importers of fresh fruits and vegetables in the MENA region, is particularly susceptible to an influx of unsafe products. The study underscored the critical need for the United Arab Emirates to institute regular monitoring programs for pesticide residues to ensure the safety of imported food intended for human consumption (Osaili *et al.*, 2022). This echoed a similar scenario in Qatar, where 90 percent of imported fruit and vegetables contained hazardous levels of pesticide residues (Al-Shamary *et al.*, 2016). Moreover, Jallow *et al.* (2017c) reported a substantial percentage of fruit samples exceeding the MRLs in Kuwait, with some contaminated with more than 4 types of pesticide residues. Conversely, earlier studies showed reduced levels of pesticides in fruits and vegetables, which were attributed to the ongoing pesticide monitoring programs.

Of particular concern was the detection of chlorinated pesticides in the breast milk of lactating women, posing potential risks to breastfed infants. Chlorpyrifos-methyl was the most frequently detected pesticide, primarily found in wheat flour (Bu-Abbas *et al.*, 2009; Saeed *et al.*, 2000, 2001).

In Tunisia, pesticides have emerged as the second most prevalent cause of poisoning, trailing only medications. The National Agency for Sanitary, Environmental, and Occupational Control (ANCSEP) conducted two crucial studies— a 'total diet assessment' of dietary exposure to pesticide residues, and a study on pesticide residues in the food chain. The results of these studies have not yet been made public. Overall, the conditions surrounding pesticide use in the country remain at high risk, with farmers being aware of the associated health risks, yet continuing to face health-related issues themselves (AEEFG, 2020).

Similarly, pesticide residues pose a persistent challenge in the shipments of fresh fruit and vegetables from Morocco, as highlighted by Salghi (2012), and have been frequently notified at EU borders (Dumpis, 2021; Food Business Africa, 2023; Salghi *et al.*, 2012). Also in Egypt, elevated pesticide contamination levels were reported (Saleh *et al.*, 2020; Ibrahim *et al.* 2022).

The misuse of pesticides and fertilizers in Lebanon, combined with their persistent presence in the environment, has led to substantial contamination levels in soil, water, and agricultural products. Sixty per cent of the examined agricultural products contained pesticide residues at levels that pose significant threats to human health. For example, an investigation conducted on sediment samples from northern Lebanon revealed detectable quantities of DDT and DDE in all samples collected. This suggests an ongoing use of DDT parent compounds, despite their banned status (Nasreddine *et al.*, 2016).

Table 6. Key findings on pesticide residues in food in the NENA region

Country	Sample type	Key findings	Source
Algeria	N=40, Tomatoes grown in greenhouses in Boudouaou and Douaouda	Five pesticides were detected (Douaouda): Chlorpyrifos, fenitrothion, metalaxyl procymidone, and triadimenol. Three pesticides were detected: Chlorpyrifos, triadimenol, and procymidone.	Saidi Mouhouche and Abri, 2017
Egypt	N=175, Fresh fruits and vegetables	Eighty percent were contaminated, out of which 42 percent contained residues above the MRLs. Chlorpyrifos, cypermethrin, and carbendazim are the most frequently detected. No health risk according to the Health Index.	Ibrahim *et al.*, 2022
	N=70, Fruits and vegetables	88.6 percent contaminated, out of which 42.8 percent had pesticide residues above the MRLs	Saleh *et al.*, 2020
	N= 2318, Fresh fruits and vegetables	18.5 percent contained detectable residues, and1.9 percent of the contaminated samples had concentrations above MRLs.	Dogheim *et al.*, 2002
Jordan	N=158, Fresh Fruits and Vegetables	54 percent contained residues. Among the tested samples, 22 percent contained residues above MRLs. Out of the 113 pesticides, 22 pesticides were above the permissible limit.	Algharibeh and AlFararjeh, 2019
Kuwait	N=150, Fresh fruits and vegetables	21 percent contained residues above the MRLs.	Jallow *et al.*, 2017c
	N=140, Core samples and additional samples (n= 90) of a typical Kuwaiti diet	Chlorpyrifos, vinclozolin, procymidone, and captan residues were significantly below the MRLs.	Saeed *et al.*, 2001

Continue ▶

Country	Sample type	Key findings	Source
Lebanon	N=387, Foods of plant origin	Over 50 percent of the positive samples for 14 residues were above the EU MRLs. The presence of chlorpyrifos in cucumbers raised health concerns.	Khazaal *et al.*, 2022
	N=212, Apples	77 percent of the samples were contaminated, out of which 61 percent exceeded the MRLs. No risk to human health based on Hazard Quotient 0.1-8 percent.	El Hawari *et al.*, 2019
	N=1860, Individual foods (prepared and cooked) and exposure assessment study	- Chlorpyrifos, procymidone, primiphos-methyl, doimethoate, and dieldrin most frequently detected and quantified pesticide residues. - Mean estimated daily exposures were below the acceptable ADIs* for all investigated residues. - Using the UB approach, the mean estimated daily exposures were below the ADIs for all residues except for Dieldrin.	Nasreddine *et al.*, 2016
Morocco	N=51, Fresh fruits	69 percent of the samples were below the MRLs for some pesticides.	Choubbane *et al.*, 2022
Qatar	N=49, Fresh fruits, and vegetables N=42, Water, and soil	- 18 percent of all samples exceeded the MRLs, with Methoxychlor posing health risks due to daily intakes. - Organochlorine pesticides in soil and water below the MRLs or were residue-free.	Elobeid *et al.*, 2021
	N=127, Fresh fruits and vegetables	90 percent of imported samples contained residues above the MRLs, with heptachlor most frequently detected.	Al-Shamary *et al.*, 2016
Saudi Arabia	N=21, Fresh fruits and vegetables	20.9 percent contained pesticide residues above MRLs. Methomyl, imidacloprid, metalaxyl, and cyproconazole are most frequently detected.	Ramadan *et al.*, 2020
	N=160, Fresh vegetables	53 samples were above the MRLs. The most frequently detected pesticides were carbaryl followed by carbofuran.	Osman *et al.*, 2010
Sudan	N=19, Fresh vegetables	All samples were above the MRLs set by Codex Alimentarius.	Mohamed *et al.*, 2018
Tunisia	Table grapes - predicted short-term intake expressed as percent of ARfD*	For at least one chemical compound, 94 percent of the samples exceeded EU MRLs.	Bouagga *et al.*, 2019

Source: Dima, author's own elaboration.

* Acceptable Daily Intake (ADI); Maximum Residue Level (MRL); Acute Reference Dose (ARfD)

In a recent study in Lebanon, over half of fruit and vegetable samples examined contained prohibited pesticides. Moreover, a fifth of the samples exceeded the statutory pesticide MRLs.

Notably, one sample surpassed the permitted limit for banned pesticides by an alarming 18 times, while in another instance, residues were four times higher than the limit established for a non-prohibited pesticide. Even though this non-prohibited pesticide is not banned, the WHO classifies it as extremely hazardous due to its suspected effects on fertility and its potential to cause foetal deformities and malformations (Mohsen, 2022).

In 2003, Consumers Lebanon initiated a campaign in collaboration with FAO and the Ministry of Agriculture to decrease pesticide usage. Nonetheless, no improvements have been seen since, primarily due to the lack of action from the Lebanese government. Despite all efforts made and recommendations shared during discussions with the Ministry of Agriculture and the Parliamentary Agriculture Committee, progress has been elusive. The obstacles hindering solutions are often referred to as the 'pesticide mafias,' which include individuals within legislative and executive authorities, as well as supporting merchants (Mohsen, 2022).

In general, findings within the region, and even within the same country, exhibit variability, making it plausible to anticipate the worst-case scenario, for two reasons: One, the existing studies differed in their methodologies and had limitations, as they may not have accurately represented the actual pesticide residue levels at the time of consumption compared to when the samples were taken for exposure assessment. Additionally, certain population groups, such as children, and specific regions may be excluded from these studies. And two, the health risks of pesticide residues may be under-represented due to the limited scale of work, samples, and in many cases, studies excluding animal-derived food products which result in a suboptimal coverage of pesticides that are characterized by a very high solubility in fat and a tendency to accumulate in fatty animal tissues (Nasreddine *et al.*, 2016). Studies on pesticide residues in animal-derived food are scant in the region. These limitations highlight the crucial need for further research and a larger-scale national monitoring programme, as well as exposure assessment studies, which are currently lacking across the region.

B. Veterinary drugs and antimicrobial residues in foodstuffs

Antimicrobial residues in food have gained significant attention in recent years due to increasing concerns about food safety and public health. The primary public health implication associated with antimicrobial residues is the emergence of AMR as an emerging global issue, driven by the world's interconnected nature, where humans, animals, water, and food function as conduits for resistant microorganisms.

AMR is the ability of a microorganism (like bacteria, viruses, and some parasites) to stop an antimicrobial (such as antibiotics, antivirals, and antimalarials) from working against it. Antimicrobial misuse and overuse in animal production for non-therapeutic purposes, such as for prophylaxis, and to promote growth, reduces the effectiveness of antimicrobial therapies, and excessive use or misuse are recognized as major drivers of AMR. In 2019, 1.3 million human deaths were attributable to bacterial AMR (Murray *et al.*, 2022). Currently, 27 different antimicrobial classes are used in animals (FAO, 2021c).

The Eastern Mediterranean Region (EMRO), which includes NENA countries, has been identified as particularly vulnerable to AMR due to a lack of national action plans, limited awareness, fragmented information systems, irregular monitoring and surveillance, weak laboratory capacity, inadequate national programs for infection control and patient safety, inappropriate prescription practices, and

the presence of counterfeit drugs and medicines (FAO NERC, 2024; WHO, 2015c). AMR results in persistent illness and increased mortality and has a significant impact on regional public health and healthcare costs. Changes in the state of AMR since this study was undertaken are discussed further in section 4.5. Furthermore, general understanding of the status of AMR in foodborne pathogenic bacteria across the region is limited, although some reports indicate varying trends at the food-human interface (FAO NERC, 2024; Habib and Mohamed, 2022).

The excessive and indiscriminate use of veterinary drugs by farmers, insufficient withdrawal periods for antibiotics, poorly treated wastewater, and the absence of robust surveillance systems to monitor antibiotics are commonly reported as factors contributing to the prevalence of antibiotic residues (FAO NERC, 2024; Al-Bahry *et al.*, 2009; Mohammadzadeh *et al.*, 2022; Qadir *et al.*, 2010).

For example, in Meknes, Morocco, the misuse of antibiotics in poultry farming has led to alarming levels of antibiotic residues (36.15 percent) (Chaiba *et al.*, 2017). Prior findings from Saudi Arabia suggested a widespread misuse of tetracycline agents, including the layered use of drugs belonging to the same pharmacological group and a lack of adherence to recommended withdrawal times, resulting in tetracycline levels above the MRLs in eggs (Al-Ghamdi *et al.*, 2000).

Furthermore, local fresh milk samples in Kuwait exceeded the MRL for tested residues, with tetracycline being the predominant residue. Antimicrobial residues in imported pasteurized milk samples were more prevalent than in local samples. However, imported powdered and condensed milk samples from EU countries did not contain any residues except for tetracyclines.

Sulfonamides residues were found to be widespread, and to a lesser extent, chloramphenicol residues were detected in tested feed and feedstuff samples. In addition, 5.6 percent of poultry samples exceeded the MRLs for tetracycline residues, with contaminated poultry originating from local sources (Al-Mazeedi, 2015).

Raw milk samples (n=200) were collected from markets and farms in Saudi Arabia and Egypt and tested to assess the presence of antibiotic residues. The study revealed that 40 samples were positive for 29 antibiotic residues antibiotics belonging to five groups: Tetracyclines, sulfonamides, fluoroquinolones, macrolides, and lactamases (Al-Shaalan *et al.*, 2022).

Food studies have highlighted a critical issue with AMR foodborne pathogens. The indiscriminate use of antibiotics has also been implicated in the widespread presence of antimicrobial resistance in *E. coli* contaminating fresh green produce. This trend could potentially amplify the reservoir of AMR in the intestinal tract of human populations (Burjaq and Shehabi, 2013; Hassan *et al.*, 2011). Similar concerns extend to dairy products (Harakeh *et al.*, 2012). Multiple resistance to four or more antimicrobial agents, along with plasmids of various sizes, were documented among bacterial isolates found on raw vegetables in Saudi markets (Hassan *et al.*, 2011).

Additionally, 70.8 percent of the *E. coli* isolates from humans, fresh vegetables, water, and air displayed antibiotic resistance, primarily to amoxicillin and ampicillin. At the same time, a high percentage of multidrug resistance was observed in all human isolates (Aabed et.al, 2021).

Water quality plays a pivotal role in transmitting AMR throughout the food chain. In Lebanon, the pervasive consumption of water contaminated with human and animal faeces has been identified as a significant contributor to the development of multiple drug resistance (MDR) in 60 percent of the *E. coli* isolates on fresh produce cultivated in the Bekaa Valley (Faour-Klingbeil *et al.*, 2016a; Halablab*et al.*, 2010).

Moreover, Al-Bahry *et al.* (2014) identified elevated levels of pathogens in both wells and treated sewage effluent. This contamination was attributed to several factors, such as the reuse of sewage effluent, deteriorating septic systems, the use of fertilizers, and the recycling of treated sewage. The presence of trihalomethanes and antimicrobial-resistant strains suggested inadequate sewage water treatment, posing significant risks to public health. In this regard, the risk of infectious diseases was evident, as exemplified by the 2012 shigellosis outbreak (Abaidani *et al.*, 2015).

Since 2010, WHO, FAO, and WOAH/OIE have established a formal tripartite alliance to address risks at the human-animal-ecosystem interface and to enhance global coordination and promote intersectoral collaboration between the public health and animal health sectors, as well as in food safety (WHO, 2015c; FAO, 2021c). In 2022, the Tripartite became formally the Quadripartite as it welcomed the United Nations Environment Programme (UNEP) in the alliance to accelerate coordinated strategies on human, animal, and ecosystem health that are essential in addressing AMR risks related to the environmental sector. The WHO/FAO/WOAH/UNEP Quadripartite alliance has identified AMR as one of the 3 priority topics for joint action (FAO, WHO, WOAH, and UNEP, 2022; WHO, 2023b; WHO, 2023c).

This global initiative published guidelines and a call to action to food safety authorities to prevent and control AMR in the food chain (FAO, UNEP, WHO, WOAH, 2024; WHO, 2024).

A regional One Health platform will be established by the Regional Quadripartite Organizations in collaboration with all relevant stakeholders to enhance NENA countries' efforts to implement the activities outlined in the regional One Health Action Plan under the guidance of the Quadripartite One Health Approach (FAO NERC, 2024). Few countries in the region have ongoing surveillance of AMR in food-producing animals and food or integrated surveillance of AMR in foodborne bacteria. There is a need to build capacities and encourage NENA countries to initiate surveillance programs to gain a better understanding of AMR transmission mechanisms through food chains to humans and their impact on human populations.

4.3.1.2 Chemical and microbial contaminants in food

A. Heavy metals in foodstuffs

Heavy metals (HM) are an area of concern in some parts of the NENA region, and should be a key area of focus given the pollution issues in many of the NENA countries resulting from industrialization, polluted environment (i.e. presence of mines in grazing areas, sewage, industrial effluents, and emissions from vehicles), tainted animal feed, direct contamination from agricultural activities, and transmission of contaminants via inadequately treated wastewater (Al-Musharafi, Mahmoud and Al-Bahry, 2012).

A comprehensive review focused on HM in red meat in Algeria, Egypt, Iraq, Kuwait, Lebanon, the West Bank in Occupied Palestinian Territory, Saudi Arabia, the Syrian Arab Republic, Jordan, and the Sudan revealed elevated levels of HM exceeding the recommended MLs set by the FAO/WHO Codex Alimentarius Commission (Emami *et al.*, 2023).

In Jordan, several types of vegetables (such as cabbage, green onion, lettuce, parsley, rocket, spinach, carrot, onion, potatoes, and cauliflower) obtained from a market were found to contain heavy metals, including Lead (Pb) in onions, exceeding Codex MLs.

While the daily intake of HM from these tested vegetables fell below the MLs (Osaili *et al.*, 2016), these findings reveal environmental contamination within the food chains, potentially posing long-term health risks, emphasizing the magnitude of heavy metal contamination in food sources.

In the Gulf countries, a range of findings on local and imported food products were of concern. For example, an examination of imported rice in Qatar uncovered Arsenic (As) levels exceeding the ML concentration by 5.5-fold (Elobeid *et al.*, 2019). Moreover, earlier studies highlighted health concerns related to elevated Cadmium (Cd) levels in crustaceans consumed in Qatar, considering consumers' consumption patterns (Aboul Dahab, 1991).

According to Costelna (2014), persistent Arsenic (As) contamination in molluscs and crustaceans consistently exceeded the MLs, particularly in Qatar and the UAE. In Kuwait, all samples contained Lead (Pb), Cadmium (Cd), and Mercury (Hg), while Bahrain's samples exceeded permissible Lead (Pb) limits. Significantly, coastal areas of Oman and Qatar showed elevated Cadmium (Cd) concentrations in shellfish. Additionally, the weekly intake estimations of Arsenic (As) and Cadmium (Cd) from shellfish were alarmingly high, exceeding the Provisional Tolerable Weekly Intake (PTWI). More recently, concerns arose in Qatar regarding the health risks of Mercury (Hg) in fish consumption (Al-Sulaiti *et al.*, 2023).

Tunisia was reported as being among the top 10 origin countries flagged by the Rapid Alert System for Food and Feed (EU RASFF) between 2000 and 2022 for having Mercury (Hg) in exported food shipments (Eissa *et al.*, 2023). In Saudi Arabia, elevated concentrations of heavy metals were found in various vegetables, including roots, stems, leafy greens, fruits, cereals, and legumes, grown in four major industrial and urban cities (Tabouk, Riyadh, Dammam, and Jazan). These concentrations were attributed to air pollution resulting from industrial activities, particularly in the central and eastern districts (Ali and Al-Qahtani, 2012).

Due to variations in food consumption habits and limited research on heavy metals contamination across these countries, drawing definitive conclusions about the extent of this issue is challenging. However, the data shed light on the crucial role of risk assessment and underscored the critical need for more research to integrate scientific insights into legislative decisions. This integration can guide risk management interventions and provide advisory measures to address this complex and evolving concern.

B. Occurrence of mycotoxins in the food chain

Mycotoxins contamination is influenced by several critical factors, including climate change, agricultural and processing methods, storage/transportation practices, the nature of animal feed, and improper use of food waste in animal feed (Rodrigues, Handl, and Binder, 2011; Wu and Turna, 2019; Kolawole *et al.*, 2024). The widespread nature of this problem in the region is well-documented, with a recent review revealing significant trends in mycotoxins contamination, most notably affecting dry bread, cereal products, and nuts.

Among the countries surveyed, Algeria stands out with an alarming 87 percent contamination rate in animal feed. When considering regional prevalence, the countries with the highest occurrences of mycotoxins in animal feed are as follows: Algeria (87 percent), Yemen (72 percent), Jordan (63 percent), Qatar (46 percent), the Sudan (45 percent), Tunisia (31 percent), Morocco (31 percent), Egypt (29 percent), and Saudi Arabia (15 percent) (Jalilzadeh-Amin *et al.*, 2023). Animal feed plays

a pivotal role in the food chain as it directly impacts the safety of animal-derived food products, thereby influencing human health.

Notably, the widespread presence of Aflatoxin M1 (AFM1) in milk is of widespread concern in the region, with numerous studies reporting levels exceeding permissible limits (Wu and Turna, 2019), representing an increased health risk. The high prevalence of AFM1 in raw, pasteurized, and ultra-high temperature (UHT) processed milk in certain countries has been linked to elevated levels of AFB1 in animal feed.

Specifically, the prevalence rates of AFM1 in raw milk in Lebanon, Occupied Palestinian Territory, Egypt, and the Syrian Arab Republic were 67 percent, 85 percent, 38 percent, and 14 percent, respectively. In pasteurized milk, Lebanon reported a prevalence rate of 36 percent. Furthermore, in UHT milk, Saudi Arabia recorded a prevalence rate of 82 percent (Rahmani *et al.*, 2018).

Spices, and nuts represent another avenue for aflatoxins contamination. Research studies conducted in Saudi Arabia and Egypt have shown that a wide range of spices are highly contaminated with mycotoxigenic fungi. Consequently, recommendations have been made to reduce the use of heavily contaminated spices like ginger in food processing (Hashem and Alamri, 2010).

Data from Oman also showed that certain types of spices (n=105) harboured fungi that could pose health risks to humans. Although the initial fungal levels were relatively low, the risk factor is elevated when these spices are introduced into food and left for an extended period. Under such conditions, certain types of fungi can proliferate and generate mycotoxins (Elshafie *et al.*, 2002).

Research undertaken in Morocco uncovered the prevalence of ochratoxin A (OTA) in corn, wheat, and barley samples, with contamination rates ranging from 40 percent to 55 percent. Subsequent studies by the same researchers revealed that 10 percent of cornflour samples sold in Rabat exceeded the PLs for aflatoxins in 2007 (Zinedine *et al.*, 2007b, 2007a).

In addition to spices, nuts, seeds, herbs, dried vegetables, and cereal grains are recognized as significant sources of mycotoxins in Egypt. These contaminants are commonly found in cereal and cereal products in Morocco and Tunisia.

In the Sudan, mycotoxins prevalence is particularly pronounced in foods such as sesame seeds and various nut products (Darwish *et al.*, 2014). These foods require appropriate drying during processing and adequate storage conditions.

Recently, substantial advances in mycotoxin analytical methods have led to an increasing number of studies investigating the occurrence and toxicity of emerging mycotoxins in food crops, where the most frequently detected emergent mycotoxins worldwide include fusaric acid (FUS), enniatins (ENNs), culmorin, apicidin, butenolide, fusaproliferin, alternaria toxins, aurofusarin, emodin, nivalenol (NIV), beauvericin (BEA), diacetoxyscirpenol (DAS), patulin (PAT), moniliformin (MON) and sterigmatocystin (STG) (Kolawole *et al.*, 2024).

Considering the persistent challenge of ensuring the safety and availability of cereal grains in the region, significant progress has been made in the regulatory frameworks of NENA countries, particularly in the establishment of regulatory maximum limits for mycotoxins. However, the effective implementation of these regulations requires robust and continuous surveillance systems, the application of advanced analytical methodologies, and sustained capacity-building efforts. These measures are essential to generate reliable occurrence data to support exposure assessments (Abdallah *et al.*., 2023; Kolawole *et al.*, 2024).

C. Prevalence of foodborne pathogenic microbes

Foodborne microbial contamination is a result of unforeseen events or undesirable conditions that lead to the presence of microbial agents such as bacteria, viruses, fungi, parasites, or their toxins in the food supply chain. Some microorganisms are known for their pathogenicity when digesting contaminated food. Commonly identified microbial hazards in food include pathogenic and spoilage bacteria (such as *Salmonella spp.*, *Listeria spp.*, *Campylobacter spp.*, *Clostridium spp.*), viruses (such as hepatitis A and E viruses, norovirus), parasites (such as Trematodes, Cyclospora, Cryptosporidium) as well as toxins produced by bacteria (such as shigatoxin-producing *Escherichia coli* [STEC]). A recent study revealed that hepatitis A and E, and noroviruses are among the main viruses that cause millions of cases of foodborne illness and tens of thousands of human deaths annually (JEMRA, 2023).

In 2015, following an inspection campaign by the Lebanese Ministry of Public Health, 28.7 percent of all tested samples were deemed unacceptable due to microbial contamination. A recent review, which analysed these publicly disclosed results indicated the predominant biological contaminants were sulphate-reducing bacteria (34.7 percent), *Escherichia coli* (32.1 percent), coliforms (19.6 percent), *Staphylococcus aureus* (12.8 percent), and *Salmonella spp.* (11.6 percent). The persistent shortcomings in hygiene and sanitation systems within Lebanon's food supply chain were found to pose significant threats to public health. Foodborne viruses and parasites, including norovirus, hepatitis A virus (HAV), and Cryptosporidium, were not included in the tests conducted by local authorities, despite their global as well as local significance. Norovirus stands as the leading cause of foodborne gastroenteritis worldwide. Moreover, Lebanon reported 10 400 cases of HAV between 2005 and 2017, alongside recent accounts of Cryptosporidium and other parasitic infections within the Lebanese population (Kharroubi *et al.*, 2020).

In Libya and Jordan, reports have highlighted concerning contamination levels of pathogenic bacteria including enteropathogenic *E. coli*, and *Salmonella spp.* in minced meat and beef burgers (Hamad and Saleh, 2019; Nimri, Abu Al-Dahab and Batchoun, 2014). These findings suggest potential cross-contamination during the processes of slaughter, transportation, and retailing, exacerbated by poor hygiene practices among sellers (Hamad and Saleh, 2019).

Similarly, Egypt and Saudi Arabia have witnessed a high rate of food contamination, with the dominant causative agents being *Salmonella spp.*, *Staphylococcus aureus*, *Bacillus cereus*, *Clostridium perfringens*, and *E. coli*. Notably, Staphylococci were implicated in 41 percent of bacterial food poisoning cases in Saudi Arabia (El Sheikha, 2016).

In general, the literature provides evidence emphasizing the health risks associated with the prevalence of *Salmonella spp.*, *Campylobacter spp.*, *Listeria monocytogenes*, and *Brucella spp.* in the food systems of many countries in the region, which is compounded by the emergence of multidrug-resistant strains. A recent comprehensive review by Habib and Mohamed (2022) highlights the frequent presence of these bacterial pathogens in animal-derived food products, while the available information regarding these pathogens in fruits and vegetables remains notably scarce. These bacteria have the potential to infiltrate the human food chain at various stages, from primary production to food consumption.

The emergence of multidrug-resistant strains, as evidenced in several countries including Egypt and Saudi Arabia, has added to growing public health concerns, and underscores the urgency of responsible antibiotic use in primary production.

The review also demonstrated the prevalence of *Campylobacter spp.* in various food products in many countries, particularly in poultry and dairy. It highlights the limited surveillance programs in the region and the dearth of nationally representative data on *Campylobacter spp.* levels in chicken.

Furthermore, the prevalence of *Listeria monocytogenes* has been well-documented in several studies, specifically in meat and meat products in North African countries like Egypt, as well as in raw milk and meat in Morocco, and ready-to-eat chicken meat products in the Sudan. In GCC countries such as Saudi Arabia, the presence of *Listeria monocytogenes* has also been reported in raw beef, chicken, fish, and camel milk. There remains a noticeable research gap when it comes to *Listeria spp.* in plant-based foods.

In this context, the studies from Jordan and Egypt have revealed AMR in *Listeria monocytogenes* isolates, with some strains showing resistance to multiple antibiotics, including those commonly used in treating listeriosis. This high level of resistance raises concerns about the efficacy of empirical listeriosis therapy. Understanding the pathways of *Listeria monocytogenes* transmission and its antimicrobial resistance profiles throughout the food chain, from farm to farm, is crucial for effective risk management in human health. Nevertheless, information regarding the specific serotypes and strains circulating in the region remains limited (Habib and Mohamed, 2022).

The widespread contamination of water sources presents a direct and pressing threat to food safety. Water serves as an indispensable element in food production and preparation, and when it becomes polluted, it can introduce harmful pathogens into the food chain. This risk is further compounded by inadequate sanitation practices across various stages of food processing and handling. Data illustrating the consequences of unregulated contaminated water application in agricultural practices have shown a high prevalence of Salmonella in strawberries (28 percent) and lettuce (39 percent), as well as in soil (42 percent) and water used for irrigation or washing (42 percent) (Uyttendaele *et al.*, 2015).

In Lebanon, *Listeria monocytogenes* was detected in 20 percent of vegetable samples from the fields and post-harvest areas after washing. Additionally, *Salmonella spp.* was detected in 6.7 percent of the raw vegetables collected from post-harvest washing areas (Faour-Klingbeil *et al.*, 2016b).

Generally, the lack of clean water generates a situation fertile for the propagation of waterborne and communicable diseases, including polio, HAV, impetigo, scabies, and diarrheal diseases (Daher, 2022). Given that this issue remains a significant challenge in countries with weak governance and in places where reduced international aid has hindered the implementation of vital development plans and strategies (UN ESCWA, 2019b), it is anticipated that the risk of food contamination may be significant in many countries.

In general, the scarcity of information regarding the economic and health burdens of FBD and the investigations into the sources of etiological agents represent a critical deficit of the surveillance and reporting systems in the region.

4.3.2 Food fraud

The multitude of challenges in many countries across the region, including environmental degradation and water pollution, severely impact the quality and safety of food products. Adding to these concerns is lax regulatory oversight and insufficient inspections, creating an environment ripe for fraudulent activities.

Food fraud is a situation in which food business operators or suppliers deliberately mislead, deceive, cheat or adulterate customers about the quality and ingredients of the food they are buying. Often driven by economic gain, these fraudulent acts can also pose serious private- or public-health risks when they involve intentional adulteration with a variety of chemicals, ingredients, biological agents, or any other unsafe substances to consumers (FAO, 2021d; FAO, 2022a; Roberts, *et al.*, 2022) (Table 7 and Table 8).

Table 7. Explanation of common fraud and deception in foodstuffs (FAO, 2021d)

Term	Definition	Example
Adulteration	A component of the finished product is fraudulent (intentionally debasing the quality of food by adding or replacing food substances with undeclared alternative components).	Melamine added to milk.
Counterfeit	All aspects of the fraudulent product and packaging are fully replicated (copying the appearance and characteristics of another legitimate food).	Copies of popular foods not produced with the same food safety guarantees.
Mislabelling and Tampering	Legitimate products and packaging are used in a fraudulent way (food packaging does not accurately reflect the product contents).	Changing expiry information or adding fraudulent description of production method or origin.
Simulation	An illegitimate product is designed to look like, but not exactly copy, the legitimate product.	'Knock-offs' of popular foods not produced with the same food safety guarantees.
Diversion	The sale or distribution of legitimate products outside of intended markets.	Relief food is redirected to markets where aid is not required.

Source: Adapted from FAO (2021d). Table developed by Moustapha.

The risk of food fraud has been welldocumented in recent years. Illegal trade and fraud in the agricultural food sector have far-reaching consequences for numerous stakeholders, including consumers, FBOs, and regulators. Despite the challenges of determining the global cost of fraud in the food industry due to the secretive nature of these activities, annual estimates typically fall within the range 30 to 50 billion USD a year (WTO, 2024). According to the U.S. Congressional Research Service, there have been 60 percent as many incidents of food adulteration from 2011 to 2012 than had been identified in the 30 years between 1980 and 2010 (Figure 6) (CRS, n.d.).

Table 8. Common types of food fraud and fraudulent practices

Type	Product-related	Process-related
Safety-relevant	Melamine and urea in milk powder. Peanuts in hazelnut powder.	Technical fats in fats fit for human consumption. Rework of non-marketable food. Methanol in spirits.
Not Safety-relevant	Hazelnut oil in olive oil. Blending spices. Organic labelling of conventional products. Farmed fish instead of wild catch. Incorrect animal species identification in fish or meat. Honey (origin, blossom, added syrups).	Increase of foreign water content. Expansion of specification tolerances.

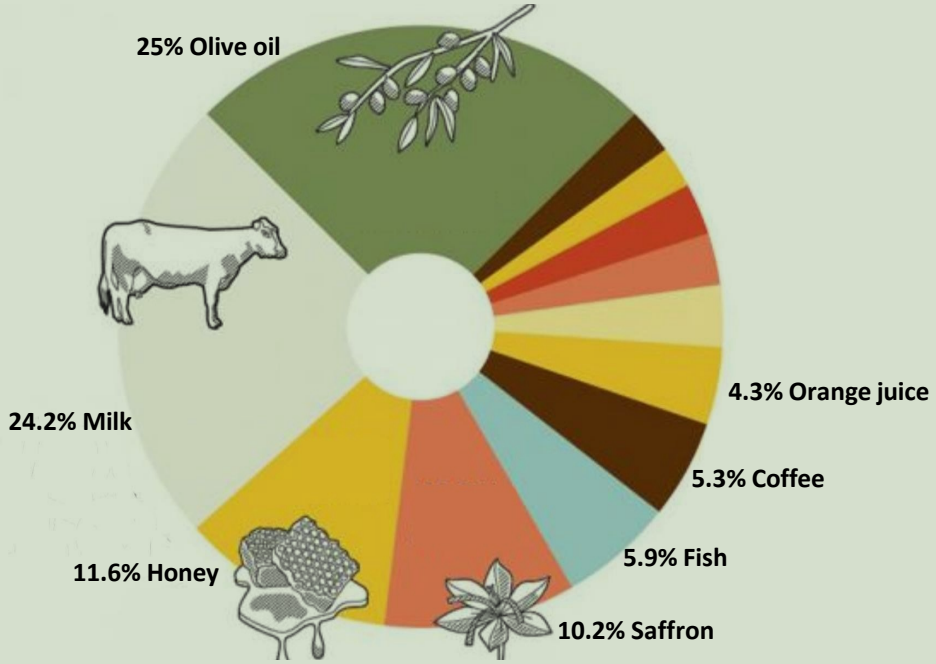
Source: Table developed by Moustapha.

Globally, regulatory agencies and industrydriven food safety initiatives have developed additional requirements specifically targeting food fraud prevention (FAO, 2021d; FAO, 2022a). Nonetheless, food fraud remains a challenging problem due to the global nature and complexity of food supply networks, difficulties in testing and detection strategies, and the often-unconventional nature of fraudrelated adulterants(FAO, 2021d; Roberts, *et al.*, 2022; Hellberg, Everstine, *et al.*, 2021). Vital to ensuring the safety, integrity, and fairness of the global food supply chain is addressing food fraud, which is essential for achieving the UN SDGs (WTO, 2024).

According to a Journal of Food Sciences study (Moore, Spink and Lipp, 2012), olive oil is the food most subject to fraud, representing 16 percent of all fraud cases, followed by honey (7 percent), then orange juice (4 percent), and apple juice (2 percent) of cases, as reported in the US Pharmacopeial Convention's Food Fraud Database.

For herbs, a recent study found that 25 percent of 78 samples of dried oregano bought from UK retailers contained ingredients other than oregano. Food fraud in spices occurs in saffron (representing 5 percent), vanilla extract (2 percent), turmeric, star anise, paprika, chili powder, and paprika, each accounting for another 1 percent. Midamar Corporation and Islamic Services of America were ordered to pay 600,000 USD in a US District Court, when three of the defendants' corporations admitted to a scheme to falsify export certificates in order to ship Halal beef to customers in Malaysia and Indonesia. In another incident that occurred in the British consumer marketplace in 2013, horse meat was illegally mixed into beef products. The product was prepared in Romania and was trans-shipped through several European countries. This represents a case of adulterant-substance food fraud because horsemeat was not authorized as an ingredient or as a substitute for beef. Additionally,

Figure 6. Most adulterated foodstuffs in the USA (2013)



Source: CRS, n.d. CRS Reports. In: Congress.gov. [Cited 2 May 2024]. https://crsreports.congress.gov/

Food fraud has proliferated in many NENA countries, including in the sale of spoiled and expired products and the practice of selling frozen and thawed meat as fresh. This troubling situation has consistently raised consumer concerns in Lebanon, the Syrian Arab Republic, Egypt, and Sudan (Doueiry, 2023; Independent Arabia, 2023; Shalaby, 2024). Rising meat and poultry prices have pushed Lebanese consumers to seek more affordable products from unreliable sources. This problem extends to the Syrian Arab Republic, where meat retailers and distributors have been caught selling expired goods in markets and smuggling meat beyond the purview of local authorities (Abd El-Razzak, 2022).

Similarly, Sudan faces a widespread issue of spoiled and expired goods, often attributed to the exploitation of citizens facing economic hardships. The need for budget-friendly consumer products, without regard for safety or quality, or expiration dates, provides fertile ground for fraudulent activities, such as tampering with expiration dates. This situation is further exacerbated by a lack of vigilant oversight from CAs (Independent Arabia, 2023).

Egypt's food markets are also vulnerable to intentional mislabelling and species substitution in popular meat cuts (Hassab El-Nabi, Hussein, and Khallafa, 2021). A recent report from Egypt has highlighted violations of quality and hygiene standards, involving the use of unauthorized tissues in meat products (Abd-Elhafeez *et al.*, 2022). Other investigations have unveiled instances of food adulteration involving genetically modified (GM) soybeans and maize, and meat from diverse animal species (Mostafa *et al.*, 2022).

Several news publications have reported the discovery of toxic chemicals added to commercial olive oil in Lebanon (Olive Oil Times, 2011), and the sale and distribution of fake and toxic olive oil in Morocco (Morocco World News, 2018 and 2019). It is important and necessary to authenticate olive oil to prevent fraud and to determine purity, and to ensure the health and safety of consumers.

Moreover, the identification of adulterated foods requires fast and reliable testing (FAO, 2021d). Tests are performed for animal species identification, to determine nutritional content, and to ensure compliance with labelling regulations. The main hurdles in food fraud control in this region include the lack of competent testing laboratories equipped with targeted and non-targeted multi-parameters detection techniques, as well as underdeveloped inspection criteria and monitoring mechanisms, and non-robust enforcement actions.

4.3.3 Emerged food hazards and food labelling issues

Over the past years, food safety and quality issues in the NENA have become extremely controversial and research findings have drawn an elevated level of public attention. Several food contaminants that lack extensive regulation in the NENA region are constantly emerging. These chemical and microbial hazards may either occur naturally in the raw materials of food products or can be present by their deliberate or unintentional addition during processing. The health effects of these hazards are determined to be in a range from benign to acutely toxic or carcinogenic.

Moreover, efforts to ensure the 'generic quality and authenticity of food' have been the foundation and justification for food legislation and its recent development. Initially, these efforts focused on regulations and/or standards for food safety, food authenticity, the prevention of fraud, consumer deception, and malpractice. Later, the scope was extended to guarantee the proper functioning of the food mass market. The first stage of regulating fraud involved establishing a regulatory framework for production, with prohibitions and obligations imposed on FBOs. The second stage focused more directly on market regulations, addressing the characteristics, manufacturing rules, composition, and sensory properties of foodstuffs. This stage helped determine the market presentation of foods, such as the classification of olive oils or the shape and fat content of cheeses.

Guarantees of general quality extend the connection between food and public health by providing consumer information on nutritional characteristics (food facts on informative labelling) and guarantee the proper functioning of supply channels and markets by ensuring and recognizing overall quality through standardization and corporate certification. This approach allows for voluntary actions to continuously improve the manufacturing of products and customer-supplier relations in intermediate markets. Considering the geographical and cultural origins and internal diversity of consumer needs, it is essential that FBOs leverage these actions and that support is provided for product marketing (European Commission on Agriculture, 2004).

The regional risk analysis initiative is required to provide a framework in which both the scientific assessment of these emerging foods and the relative importance of their risks, with particular regard to consumer perception, are combined in a system that properly recognizes the need to take regional management actions.

4.3.3.1 Chemical pollutants

Persistent organic pollutants (POPs) are pollutant chemicals that share a common characteristic: persistence in the environment. These chemicals include polychlorinated dibenzo-p-dioxins (PCDDs), dibenzofurans (PCDFs), biphenyls (PCBs), perfluoro octane sulfonic acid (PFOS), per- and polyfluoroalkyl substances (PFAS), and brominated flame retardants (BFRs), such as polybrominated diphenyl ethers (PBDEs).

Over the past few years, the risks posed by POPs have become of increasing concern to many countries, resulting in actions to protect human health and the environment being taken or proposed by countries. UNEP provides technical expertise and tools to assist countries in reviewing and updating their National Implementation Plan (NIP) to comply with obligations under the Stockholm Convention.[2] All NENA countries are among the 186 parties ratified in the Stockholm Convention.

The WHO has been collecting and evaluating information on levels of POPs in foods, including in breastmilk, since 1976. The biomonitoring of breastmilk data can provide information on the exposure of mothers as well as their infants, and it has been recognized as an ideal matrix to monitor levels of POPs in the environment. Moreover, breastmilk data can serve as a measure of the effectiveness of compliance with the convention's requirements for reducing or eliminating emissions of specific POPs (UNEP, 2017b).

In Lebanon, a total of 44 breast milk samples were collected from lactating mothers to assess the prevalence of POPs. The laboratory results revealed that dichlorodiphenyldichloroethylene (DDE), a metabolite of DDT (a POP compound), was detected in 17.9 percent of the samples. Similarly, in Saudi Arabia, a total of 50 milk samples were collected from four cities in eastern and central regions of the country in 2021. Several organochlorine pesticides classified as POPs were reported, including aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, and hexachlorobenzene (HCB) (El-Saeid *et al.*, 2021). In Morocco, POPs concentrations in a pooled sample of 59 donors of human milk were determined for the first time to provide a baseline and allow for future trend monitoring. The results showed that DDT (sum of o,p'-DDD, p,p'-DDD, o,p'-DDE, p,p'-DDE, o,p'-DDT, and p,p'-DDT) represented 94 percent of all detected organochlorine levels. Cis-heptachlor epoxide, HCB, HCHs, and indicator PCBs were found at much lower levels, with a dominance of PCB 138, PCB 153, and PCB 180, which accounted for 98.3 percent of the total. Among the 25 PBDE congeners quantified, BDE-47, BDE-153, BDE-197, and BDE-207 were the dominant congeners, accounting for 15.4 percent of the total concentration of PBDE (Ait Lhaj *et al.*, 2022).

In addition, the presence of polyaromatic hydrocarbons (PAHs), pesticides, and PCBs at elevated levels in the ambient air of Riyadh, Saudi Arabia, triggered the need for multisectoral actions to reduce such emissions (El-Mubarak *et al.*, 2015). Moreover, hexachlorobenzene (HCB) and the insecticide p,p'-DDT, along with its derivative products p,p'-DDE, and p,p'-DDD, were detected at significant concentrations in soil samples collected from 5 Syrian agricultural field soils, including potatoes, gherkins, and olives (Mohamad and Lorenz, 2009). Also, a study on the levels of POPs in irrigation water canals adjacent to industrial areas in 6 Egyptian governorates, namely Bani Swef, El-Giza, El-Sharkeya, El-Menoufeya, El-Gharbeya, and Alexandria, revealed low levels of PCDDs/PCDFs and indicator PCBs (M. F. El-Shahat *et al.*, 2019).

The persistence of such chemicals in soil, air, and water, in addition to their natural leaching through rainfall and flooding, results in their widespread distribution in the environment. This can lead to soil and water pollution, as well as to the eventual proliferation of these chemicals in food chains and their bioaccumulation in humans. There has been growing concern recently in many countries about the risks associated with POPs, particularly as a result of the identification of several POPs compounds as endocrine and reproductive hormone disruptors (EC-DG Sante, 2024a; Mansour, 2009).

[2] The Stockholm Convention is a global treaty (May 2001) to protect human health and the environment from chemicals that remain intact in the environment for long periods, become widely distributed geographically, accumulate in the fatty tissue of humans and wildlife, and have harmful impacts on human health or on the environment.

Several sources of POPs pollution have been identified, including the improper use and/or disposal of agrochemicals, industrial goods waste, combustion and open fires, and the disposal of industrial chemicals (UNEP, 2017b). In order to protect human health and the environment, it is necessary to strengthen national and regional actions and support initiatives to strengthen institutional capacities for monitoring POPs compounds, managing existing obsolete pesticide stockpiles, and managing industrial chemicals in general.

4.3.3.2 Marine foodborne toxins

Marine toxins, also known as biotoxins, are chemicals that are produced naturally by certain types of toxic algae. These toxins can accumulate in fish and shellfish, posing a risk to human health when consumed. Most of these toxins are produced by species of marine algae, with over 4 000 species existing, but with only approximately 70-80 species (or 2 percent) known to produce toxins (FAO, 2003).

Consuming fishery products such as with bivalve molluscs like mussels, clams, and oysters contaminated with these toxins can result in a variety of gastrointestinal and neurological illnesses associated. Paralytic shellfish poisoning, for instance, can be caused by several genera of dinoflagellates that produce saxitoxin, a heat-resistant and lethal toxin. Amnesic shellfish poisoning, or domoic acid poisoning, can be caused by fish genera that produce domoic acid (FAO, 2004; FAO, 2003; WHO, n.d.). Finfish poisoning, such as ciguatera poisoning, is associated with approximately 400 species of tropical fish and is caused by ciguatoxin. Scombroid (or histamine) poisoning, which is commonly associated with tuna and mackerel, occurs when fish contain high levels of free histidine in their flesh. Pufferfish (fugu) poisoning is caused by tetrodotoxin, which is produced in the liver or internal organs of pufferfish (FAO, 2004; FAO, 2003).

Each group of biotoxins comprises several analogues, and the maximum limit is expressed in terms of the reference toxin for each group as specified in the Codex standards. Current research efforts aim to assess the relative toxicity of each analogue to determine the overall toxicity of material in shellfish extracts. This requires the determination of toxicity equivalency factors (TEFs) (FAO and WHO, 2016). Furthermore, other studies have suggested the use of bio-accessibility information as a means of establishing more accurate and realistic estimates of seafood hazard identification and risk assessment, thereby constituting a crucial tool in the refinement of regulatory limits for the presence of biotoxins in seafood (Alves *et al.*, 2019).

Marine toxins have been reported in several main marine foods, leading to human poisoning incidents in African countries and coastal countries on the Indian Ocean and Red Sea. Saudi Arabia has published studies pertaining to the occurrence of Harmful Algal Blooms along the Red Sea (Tamele *et al.*, 2019). Climatic and environmental conditions such as changes in salinity, rising water temperatures, and increased nutrient levels and sunlight can influence population bloom growth. Data are scarce in the region regarding the levels of marine toxins in fishery products originating in the Red Sea, Mediterranean Sea, Gulf Sea, and the boundary oceans.

Accurate and complete data collection on biotoxins in fish and fishery products would be of great benefit to the region. The increase in consumption of fishery products as a healthy protein source, as well as the rise in the volume of fish imports in the region, have heightened the potential for human exposure to these hazards.

Based on the results of EU audits regarding food safety control systems in NENA countries for food exports to the EU market, it is required control marine biotoxins and prevent foodborne intoxications by supporting risk assessment studies on marine toxin, as well as to establish monitoring programs to evaluate the occurrence of these toxins and their sources and to address food safety issues by the authorities. Moreover, it was reported that notable shortage of laboratories in the NENA region that are capable of detecting marine biotoxins, and there are significant challenges in instituting these, particularly due to the limited availability of reference pure toxin materials for the development of laboratory methods (Table 15).

4.3.3.3 Plant inherited toxins

Tropane alkaloids (TAs) are naturally occurring toxins produced by various plants, primarily those in the *Solanaceae* family, which can result in poisoning when ingested by humans. Over 200 distinct TAs have been identified and can be found in various parts of the plant, such as the seeds, fruits, flowers, leaves, and stems. The harvesting of TA-producing weeds together with plants intended for food production is one of the main factors contributing to the presence of TAs in food. Well-known TAs include atropine and scopolamine.

Since 2018, there has been a significant increase in the number of studies on TAs in food and their impact on human health, which is considered an emerging trend. The RASFF report revealed that cereal and baking products, particularly buckwheat, are frequently reported to have elevated levels of atropine and scopolamine (RASFF, n.d.; Zile *et al.*, 2024). Baking bread from wheat flour contaminated with jimsonweed seeds (*Datura stramonium*) does not affect the content of tropane alkaloid. Furthermore, there have been numerous cases of *Datura* intoxication reported in various farm animals (Adamse and Egmond, 2010).

Pyrrolizidine alkaloids (PAs), naturally occurring toxins, are secondary metabolites produced by plants as a defence mechanism against insects and herbivores. More than 660 PAs have been identified. Leafy vegetables, herbs, spices, pollen products, and borage oil are well-known to be frequently contaminated with PA. These alkaloids also make their way into food via pollen from PA-contained plants, and through the use of raw materials that themselves contain PA. PA contamination is a prevalent issue in several African countries, with the sources of contamination attributed to the consumption of PA plants as herbs in food preparations (Letsyo *et al.*, 2024).

Ergot alkaloids (EAs) are another class of toxins produced by fungi, mainly members of the *Claviceps spp* that infect cereal grains, such as wheat, rye, barley, millet, and oats. Currently, there are over 40 known EAs.

Plant-based alkaloids are attracting the attention of the Codex Committee on Contaminants in Foods (CCCF), especially TAs and PAs. Discussion papers addressing the issue of PAs and draft guidance to contain TAs in foods have been developed.

As a result of the combination of the region's dependence on imported cereals, a high consumption rate of herbal infusions, and the need to protect public health, it is essential to focus on policies and regulations that address plant-inherited toxins (FAO, 2022c; WITS, 2024). This includes conducting further study on plants containing these alkaloids and eliminating their use in food (Letsyo *et al.*, 2024). Additionally, there is a need to assess the risk of these alkaloids in foods, particularly wheat,

tea, herbal infusions, and cereal-based infant food. While Egypt has developed regulatory limits for alkaloids in foodstuffs, only a handful of other countries in the region have taken similar steps.

Detecting plant-based alkaloids presents a further challenge due to their diverse chemical structures and low concentrations in food products, making it necessary to use highly sensitive analytical methods (Tábuas *et al.*, 2024; Casado *et al.*, 2024; Letsyo *et al.*, 2024). To address this, laboratories in the region need to be supported in their efforts to analyse plant-based alkaloids.

4.3.3.4 Processing contaminants

Processing contaminants are undesired chemical by-products that are produced during food processing, especially during food heating, drying, smoking, or fermenting. Processing contaminants include chloropropanols, such as 3-monochloropropane diol (3-MCPD), glycidyl fatty acid esters (GEs), polycyclic aromatic hydrocarbons (PAHs), and acrylamide (FAO, 2024b). Several RNE countries were notified of the detection of both 3-MCPD and GEs as food hazards in shipments of fats, vegetable oil, cereal and bakery products, and confectionaries exported to EU countries (Table 12).

The Codex has established codes of practice and permissible limits for 3-MCPD and GEs in oils and products containing acid hydrolysed proteins (CXC 79-2019; CXC 64–2008; CXS 193-1995/2023). However, few countries in the region have taken action to regulate such contaminants by developing regulatory limits or codes of practice.

4.3.3.5 Food packaging and food contact materials

Food packaging (FP) plays a critical role in ensuring the quality and freshness of food remain intact until it reaches the end user during the sale process. On the other hand, Food contact materials (FCM) can contain chemicals that could migrate from the material itself to the foodstuffs, posing health concerns if ingested in non-safe quantities by the consumer.

A wide range of materials are used for packaging and come into contact with food during the entire production process, including plastics, recycled plastics, cardboard, silicones, printing inks, rubber, metals, glass containers, and ceramic objects; or kitchenware such as pots, pans, plates, bowls, and wooden materials. These materials can leach hazardous chemicals as product moves through the supply chain. Moreover, agricultural plastics (AGP) are increasingly being used in agriculture to improve collection and transportation efficiency, and as a result reducing food loss, preserving the quality, and maintaining the safety of food products, and acting as contamination prevention, thus prolonging the product's shelf-life.

Several countries have established FCM legislations with compliance requirements to ensure the safety of these materials. These legislations are commonly covering three aspects: Overall Migration Limits (OML), which describe the amount of all substances that can be transferred from FCM into food; Specific Migration Limits (SML), which examine the inertness of FCM by testing the presence of specific substances in FP materials that can potentially migrate to food, such as heavy metals, phthalates, bisphenol A, formaldehyde, and polyaromatic hydrocarbons (PAHs); and Non-intentionally Added Substances (NIAS), which are chemicals that are present in an FCM but have not been added for technical reasons during the production process. NIAS can originate from various sources, such as impurities, as well as from contaminants in the manufacturing process, such as recycled materials, or through indirect food contact sources, such as printing inks. Chemicals that

can migrate from plastics (whether recycled or virgin), and are identified to be of particular concern, include poly-fluoroalkyl substances (PFAS), phthalates, and mineral oils (FAO, 2022c).

In this regard, Egypt and the GCC countries have made progress in improving their FCM regulations and conformity actions. The lack of monitoring and enforcement to ensure product compliance and to safeguard consumers is a common issue in the region.

A 2021 UNEP report stated that the world is "drowning under the weight" of plastic pollution, with more than 430 million tonnes of plastic produced annually, of which two-thirds becomes waste, filling the ocean and, often, working its way into the human food chain (UNEP, 2021b). A Moroccan study of microplastic ingestion in edible fish from the mediterranean coast indicated an elevated level of microplastics in all the species studied, with polypropylene (PP) and polyethylene terephthalate (PET) being the most abundant polymers (Bouzekry A. *et al.*, 2023). Another report (Hamed *et al.*, 2023) drew similar conclusions, finding elevated levels of microplastics PET, PP, and nylon polymers in market fish from the Red and Mediterranean Seas in Egypt.

The study of human dietary exposure to microplastics, and the impact of microplastics on the ecosystem – with a focus on marine organisms – are important emerging areas of study, in order to better understand the threats posed by these pollutants (UNEP, 2021b; Bouzekry A. *et al.*, 2023; Hamed *et al.*, 2023; FAO, 2022c). To exploit synergies on this topic, the FAO, since 2021, has released a report titled 'Assessment of Agricultural Plastics and their Sustainability' that calls for international dialogue to develop guidance on the use of agricultural plastics, while also supporting countries in managing and reducing their AGPs.

4.3.3.6 Endocrine disruptors

Endocrine disruptors, aka endocrine disrupting chemicals (EDCs), are substances that can cause adverse effects by interfering in some way with the body's hormones or chemical messengers.

EDC effects can include (i) developmental malformations; (ii) interference with reproduction; (iii) increased cancer risk; and (iv) disturbances in immune and nervous system function (EC-DG Sante, 2024a).

Many pesticides have now been found to function as 'reproductive hormone disruptors' with oestrogenic activity (such as ortho-phenylphenol and DDT) or anti-androgenic activity (like methoxychlor; chlordecone; dieldrin, endosulfan; chlordane; and toxaphene), and some bind to the androgen or oestrogen receptors. Other pesticides and chemicals are defined as 'thyroid hormone disruptors' (such as amitrole and dithiocarbamates). Several research articles revealed that plasticizers like phthalates and bisphenol A (BPA) that are used in many industrial products, some naturally occurring plant oestrogens, polychlorinated biphenyls (PCBs), and dioxins are categorized as EDCs (Fabrizia Carli *et al.*, 2022; EC-DG Sante, 2024a; EPA, 2024). Since 1997, the UNEP, WHO, and ILO have worked together to address the issue of EDCs and their impacts on humans and wildlife and to strengthen international collaborative efforts to control areas of high priority (UNEP, 2024a; IPCS, 2002).

Regional synergistic interventions to assess the risk of EDCs are required to provide a powerful justification for regional safety actions to control these high-risk substances in the food chain.

4.3.3.7 Radiation (radionuclides and radioactivity)

Food irradiation is an authorized technique used on a commercial scale in many countries to preserve several types of foodstuffs from deterioration caused by microorganisms, insects, and metabolic activities. A 2023 study reviewing 488 RASFF notifications led to the identification of the most frequently flagged irradiated products globally, and the cause of the notifications. The products identified most frequently were food supplements, fruits, and vegetables, followed by herbs and spices. The reasons for border impositions of these products included the unauthorized application of irradiation, excessively high levels of radioactivity, and mislabelling of irradiated products (Eissa and Ezz El-Dein, 2023). Codex has established guidelines and codes of practice on the radiation and irradiation of food and methods of detecting irradiated food (CXC 19-1979; CXS 106-1983; CXS 231-2001).

On the other track, radionuclides are potential hazards from fish and food that originate from an area that has experienced nuclear incidents. Nuclear and radiation accidents can result in the release of substantial amounts of radioactive matter into the environment. In 2011, the Fukushima nuclear incident in Japan was triggered by a tsunami that flooded and damaged the 3 active reactors at the Fukushima Daiichi nuclear power plant. In 1986, the Chernobyl disaster in Ukraine left about 320 000 km^2 of land across Ukraine, Belarus, and Russia exposed to radiation. Most exposed plants did not reproduce for years. Many of these occurrences on land can be a result of the distribution of radioactive isotopes through water (Banach, Hoekvan den Hil and van der FelsKlerx, 2020). In response to the Chernobyl nuclear power station accident, the EU has implemented a regulation governing the import of foods to control radioactive contamination originating in third countries including Ukraine. Considering Ukraine's status as one of the main suppliers of sunflower oil, maize, barley, and wheat to countries in the region, several NENA countries require support to strengthen their capacities in meeting the radionuclide contamination and radioisotope limits as outlined in the Codex standard (FAO and WHO, 2011).

4.3.3.8 Food allergens

Food allergies are immune-mediated adverse reactions to naturally occurring antigenic proteins. Even limited exposure to the antigen protein can induce hypersensitivity or immunological responses in sensitive individuals, causing rashes, itching, swelling in the mouth, nausea, vomiting, and asthma. Food allergies are the leading cause of anaphylaxis, which is an acute and potentially deadly allergic reaction. The prevalence and severity of food allergies are increasing, with approximately 150 million adults and children worldwide suffering from food allergies. Allergens are principally of concern in products and their presence may not be expected. Therefore, complete ingredient labelling is imperative. Undeclared food allergens are among the top sources of food recall and withdrawal.

Since 2020, a series of meetings of the Joint FAO/WHO Expert Consultation on Risk Assessment of Food Allergens have been held to update the list of foods and ingredients known to cause immune-mediated hypersensitivity. The committee recommended a list of priority allergens, including cereals containing gluten (e.g. wheat and other *Triticum* species, rye and other *Secale* species, barley and other *Hordeum* species and their hybridized strains), crustaceans, eggs, fish, milk, peanuts, sesame, and specific tree nuts (almond, cashew, hazelnut, pecan, pistachio, and walnut). The committee also recommended that some of the allergens, such as buckwheat, celery,

lupin, mustard, and some tree nuts (Brazil nut, macadamia, and pine nuts) should not be listed as global priority allergens but may be considered for inclusion in priority allergen lists in individual countries. Due to the low prevalence, low allergenic potency, and generally low severity of soybean allergies, soybean was not included in the list of global priority allergens. However, it may still be considered for inclusion in priority allergen lists for individual countries (FAO and WHO, 2022a). The scientific recommendations regarding the priority allergens with proposed threshold levels were raised to the corresponding codex committees including the Codex Committee on Food Labelling (CCFL) to discuss the requirement of mandatory declaration for these food allergens and to set an international food safety standard (FAO and WHO, 2022a; FAO and WHO, 2022b; FAO and WHO, 2023a; FAO and WHO, 2023b).

The USA has regulated eight types of foods that are thought to account for over 90 percent of food allergies in the country, including tree nuts (almonds, walnuts, pecans, Brazil nuts, etc.); eggs; milk (dairy products); soybeans; wheat; sesame; fish (salmon, tuna, halibut); and crustaceans/shellfish (shrimp, lobster, crab) (FALCPA, 2004 via FAO, 2021e). In the EU, fourteen allergens are recognized as the most common causes of food allergies and intolerances: peanut products; nuts (almond, hazelnut, walnut, cashew, pecan nut, Brazil nut, pistachio, macadamia and their products); egg and egg products; milk and products (including lactose); soybeans and products; cereals containing gluten (wheat, rye, barley, oats and products); fish and products; crustaceans and products (prawns, lobster, crabs); celery and products; mustard and products; sesame seeds and products; sulphur dioxide and sulphites; lupin and products and molluscs and products (clams, oysters, scallops, snails and squid).

Given the increasing dietary patterns shifting towards plant-based diets, the need to exercise caution to avoid unintentionally introducing allergens into diets becomes ever more important. For instance, replacing cow's milk with almond milk can be challenging and problematic, particularly for infants and children who require a diverse range of foods and may be allergic to almond products (FAO, 2022a).

Data regarding the occurrence of allergenic reactions and potential sources are scarce across the entire region. This suggests the need to establish an information exchange and review mechanism that comprises a list of priority allergenic ingredients in food with the target of establishing a harmonized regional standard for the labelling of food allergens.

4.3.3.9 Biotechnology and food safety concerns

Modern biotechnology has tremendous potential for increasing food production and improving food processing. However, it can pose food safety challenges. Developments in food biotechnology need to be carefully evaluated to determine scientific basis for policy decisions regarding consumer health and safety.

Genetically modified foods are an example of biotechnology that refers to crops that have been modified by the insertion of gene(s) from the same or unrelated organism using food biotechnology with the aim to induce pest resistance through the incorporation of antimicrobial markers/genes. These genetically- engineered crops contain beneficial traits with examples of pest and disease resistance without the use of chemical pesticides or with increased nutrient levels. Many GM food crops have been developed, such as the *Bacillus thuringiensis* BT-corn which contains genes from

several proteins that render it toxic to insects; the GM herbicide-tolerant soybeans and maize that allow for a reduction in herbicide application; and non-browning apples that can resist browning after being cut (FAO, 2022f).

Different applications of agricultural biotechnologies in the areas of livestock, aquaculture, crops, and forestry were highlighted where these biotechnologies can be used to serve the needs of smallholders in developing countries (Ruane *et al.*; FAO, 2023d). Currently, several technical and policy-related discussions are actively addressing the most appropriate forms of regulations and standards for gene editing techniques and their impact on the safety of gene-edited food products, including the applicability of existing Codex Alimentarius principles and guidelines for relevant food safety assessments (FAO, 2023d). The FAO GM Foods Platform was established to facilitate the sharing of information on the safety assessment of foods derived from recombinant-DNA plants authorized in accordance with the Codex guidelines for the conduct of food safety assessment of foods derived from recombinant-DNA plants (CAC/GL 45-2003/2008). Most countries in the region reported their ongoing process of developing a regulatory framework for conducting safety assessments of GM foods.

Public health concerns regarding the potentially altered allergenicity of genetically modified (GM) crops were raised. In the interest of due diligence, the biosafety assessment needs to be conducted for all new GM applications (including assessing the risks to humans (food safety), animals, and the environment) (FAO, 2022f; Biosafety, n.d.). On the other side, the GM food crops need to be addressed by considering the international instruments, agreements, and texts that are relevant to biosecurity and biosafety; including the CAC texts, the provisions of WTO SPS and TBT agreements, and the Convention on Biological Diversity (CBD) including its Cartagena Protocol on Biosafety to which NENA countries are parties (FAO, 2000; Biosafety, n.d.).

Major regulatory difficulties in the region can be caused by the need to segregate GM from non-GM crops and the labelling of GM-incorporated foods (Mostafa *et al.*, 2022; FAO, 2022f), given countries' reliance on the importation of cereals, grains, and oilseed stable products. Moreover, in considering food trade, countries are challenged to base their GM-food decisions on acceptable levels of risk/ appropriate levels of protection (ALOP) to justify their decisions on acceptance and/or restrictions of such products (FAO, 2007) according to the WTO SPS provisions.

Cultivated meat (aka cultured meat, lab-grown meat, biotech meat, cell-based meat), is a genuine animal meat that is produced by cultivating animal cells in a factory or laboratory rather than on a farm. Singapore in 2020 was the first country to approve the sale of cultured meat in the market.

Cell-based food production is expected to present a potential alternative source of animal-based food products, including land and aquatic animal meat (raw and processed) and milk lipids (FAO, 2023a; FAO, 2022a; FAO, 2024a; FAO and WHO 2024).

Given its controlled production environment, the chance of infectious zoonotic and FBD occurrence in cultivated meat is considerably low when compared to conventional livestock production. However, as in the case of all food processing techniques, strict adherence to GHP and GMP are critical to avoid microbiological contamination. Countries have started to adopt these modern technologies to avoid intensification of large-scale animal farming and slaughter (FAO, 2023a; FAO, 2022a; FAO, 2024a; FAO and WHO 2024). The safety of such cell-based products is a key factor to ascertain before regulating and licensing these products. (FAO, 2024a; FAO and WHO 2024).

With the increasing number of countries that demonstrated interest in supporting these scientific innovations in order to achieve food security goals and sustainable food production and considering the rapid proliferation of gene-editing and cell-based technologies, multi-sectoral CAs and stakeholders dialogue is required, as is work on identifying and assessing the safety of these products and their implications (FAO, 2024a; FAO and WHO, 2023c).

The conclusion of a recent initiative in 2023 on the topic of food safety aspects of cell-based food within the context of Codex work in the Near East region was announced during a side event to the FAO/WHO Coordinating Committee for the Near East (CCNE). This event aimed to exchange scientific information and raise public awareness about cell-based food, as there is currently limited data available on the subject. Considering the lack of data, regulations, and enforcement of food safety in the region, several recommendations were made for regional collaboration on collecting accurate scientific information and sharing regulatory updates (FAO and WHO, 2024; FAO and WHO, 2023c). Additionally, it is important to engage in proactive discussions on technical capacities to support risk assessments and establish effective communication mechanisms at the national and regional levels to determine appropriate regulatory actions for these biotechnology-derived foods (aka biological products) (FAO, 2022; FAO and WHO, 2024).

4.3.3.10 Unregulated novel foods

There is a growing global interest in alternative proteins as a new food source for sustainable protein supply (Figure 7). These alternative proteins, also known as novel food proteins, consist of different sequences of amino acids that are essential for building lean body tissue and promoting overall health (FAO, 2022c; FAO, 2022f).

These novel foods could provide a substantial amount of protein that requires fewer natural inputs (such as water) compared to conventional protein sources like livestock meat and fish. As a result, the demand for alternative protein sources is on the rise globally, with the market expected to reach at least USD 290 billion by 2035. Europe accounts for almost 40 percent of the total global revenue, mainly due to increased consumption of high-protein products (such as snacks and sports nutrition products) over meat alternatives (Liu, 2018; Quintieri *et al.*, 2023; FAO, 2022c; FAO, 2022f).

Plant-based protein products include soybean protein, rice protein, hemp seed protein, chia seed protein, and plant protein hydrolysates, while insect-based protein includes over 2 000 identified insect species that are edible, with crickets, mealworms, and locusts being the most reported used for food applications. Microbial protein refers to protein derived from the dried cells of micro-organisms such as yeasts, microalgae, and fungi, which are grown in large-scale culture systems.

More recently, lab-grown meat, also known as in-vitro meat or cultured meat, has emerged as a potential source of protein, with cells grown in laboratories through tissue engineering technology. According to recent studies, the use of algae, insects, and fungi as non-meat protein sources is increasingly being explored and has been found to be promising due to its perceived environmental friendliness and positive impact on the climate (FAO, 2022c; FAO, 2022f; Liu, 2018; Government of Alberta, 2020; Quintieri *et al.*, 2023).

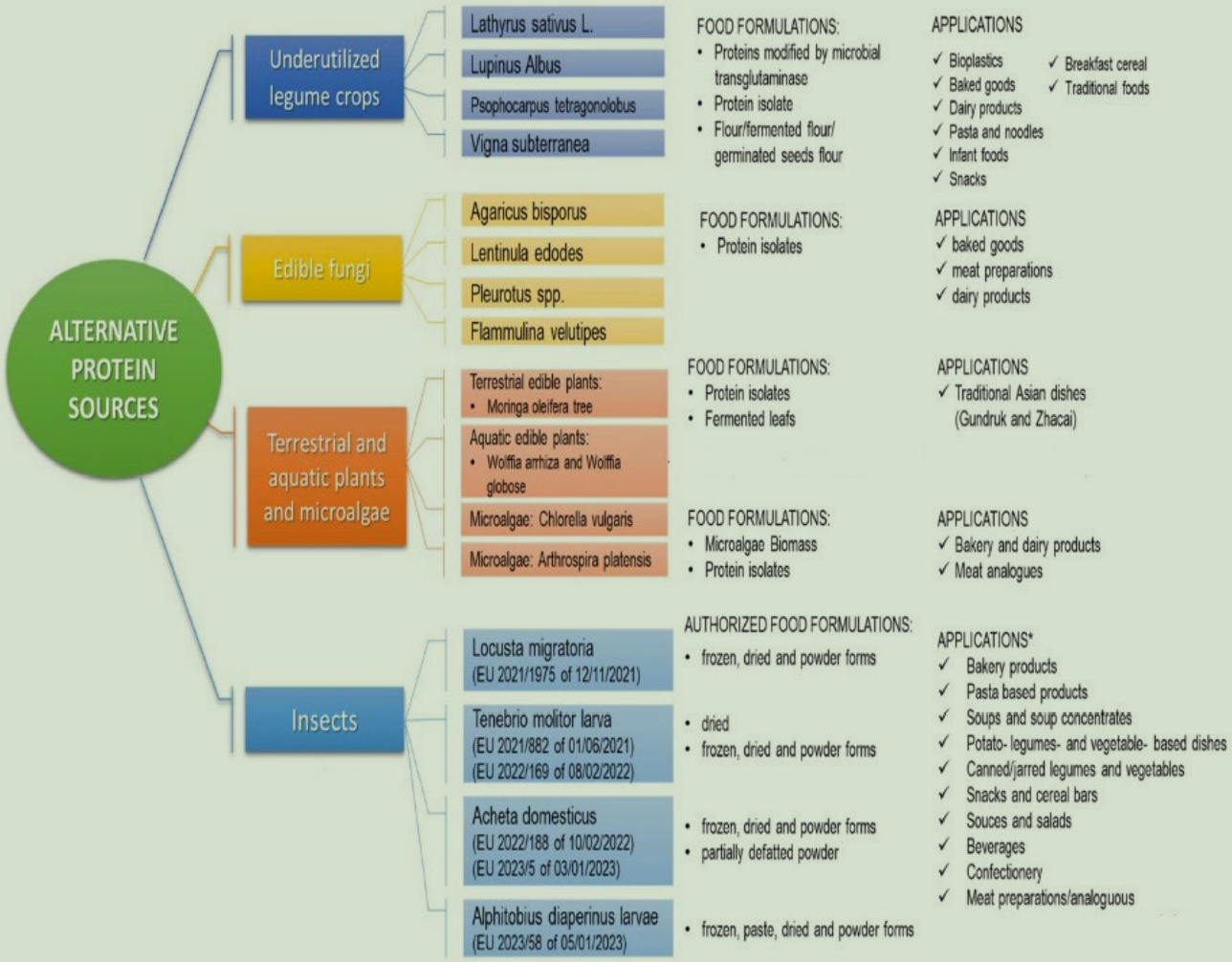
Several recent research studies have recognized the mainstreaming of algae-based foods among consumers due to their benefits.

To date, various vegan and microbial-based proteins, including those sourced from algae, fungi, and bacteria through single-cell technologies, have been legally approved and are being deployed in food products in the EU market. Although insects have not yet been fully approved as food in the EU and the United States of America, they are currently being supplied by Asian countries. Recently, the European Commission announced that over 20 algae species have been granted EU 'Novel Food' status (FAO, 2022c; FAO, 2022f; Liu, 2018; Quintieri *et al.*, 2023).

Certain food beliefs and practices in the region are rooted in religion. Consumers often connect with their religious and ethnic groups through distinct food patterns, dietary preferences, and prohibitions, and most religions have restrictions on the consumption of certain foods. Understanding the religious and cultural aspects of food on a global scale is crucial for defining, classifying, and labelling food to avoid obstacles in the approval processes of new food sources.

The conceivable shift in protein consumption has sparked regional initiatives to review the scientific studies on novel foods in general and alternative proteins in particular and has led to calls for a more in-depth investigation of their quality and authenticity, as well as for risk assessments, development of best practices, technical recommendations, and consumer acceptance criteria.

Figure 7. Food formulations and applications of different sources of alternative proteins



Source: Quintieri, L., Nitride, C., De Angelis, E., Lamonaca, A., Pilolli, R., Russo, F. & Monaci, L. 2023. Alternative Protein Sources and Novel Foods: Benefits, Food Applications and Safety Issues. Nutrients, 15(6): 1509.

The following are therefore key factors in the successful introduction of safe and compliant novel foods: (i) the development of a new system for naming novel foods and alternative protein sources, (ii) the identification of good practice in the production and cultivation chain, and (iii) measures taken to mitigate or prevent safety hazards that may affect consumer health (FAO, 2022c; FAO, 2022f).

4.3.3.11 Halal food certificate

'Halal' refers to any act or object sanctioned by Islamic law. Halal foods are foods that meet specific requirements and conditions under Islamic Law. To establish a consensus on the definition of halal and to recommend guidelines for its use in food labelling, the Codex's interested members have endorsed general guidelines for use of the term halal (CAC/GL 24-1997). However, differences in interpretation regarding 'lawful' and 'unlawful' animals and the method of slaughter still arise among the different Islamic schools of thought. As a result, the Codex halal guidelines are subject to the interpretation of the relevant authorities in each individual country, and halal certificates issued by the religious authorities of the exporting country are generally accepted by the importing country, unless the latter has specific requirements on its definition of halal.

Furthermore, nearly all NENA countries, excluding Bahrain and the Syrian Arab Republic, have joined the Standards and Metrology Institute for Islamic Countries (SMIIC). SMIIC has developed approximately 17 regional standards related to halal food.

Regional endeavours to establish a consensus on the definition of halal that is acceptable to all Islamic sects are conducive to facilitating regional trade and to integrating the principles and provisions of Islamic law into a mutual understanding. Such initiatives can also address the adoption of common border control measures, actions, and conformity assessment procedures for halal certificates.

4.4 IMPACTS

This section examines the consequences stemming from the drivers and pressures previously discussed (sections 4.1 and 4.2, respectively), in light of the current food safety and quality picture in the region, and its broader implications (as outlined in section 4.3 and represented in Figure 1).

This section specifically details the various impact indicators, including (1) the consequences for human health, such as indicators of malnutrition, the prevalence of FBD and food poisoning, AMR cases, and the impact of unhealthy diets, (2) the trade impact stemming from barriers global market access, and (3) the economic impact, encompassing food loss and waste and the intersection of health and economic factors, as measured by disability-adjusted life years (DALYs).

4.4.1 Public health impact

The WHO Eastern Mediterranean Region (EMRO), which geographically includes NENA countries, has the third-highest estimated burden of FBDs per population, after the African and Southeast Asia regions. Based on the annual estimation, 100 million people contract food-related infections and 32 million of those are children under five years old (WHO, 2015b; WHO, 2015a; WHO EMRO, n.d.).

In December 2015, WHO published the first global and regional estimates of the effects of FBD in terms of DALYs resulting from 31 foodborne hazards (WHO, 2015a).

According to this report, the most frequent causes of foodborne and waterborne illness were non-typhoidal *Salmonella spp.*, *Escherichia coli*, norovirus, hepatitis A, *Shigella spp.*, *Vibrio spp.*, and *Campylobacter spp.* accounting for 70 percent of the burden of FBDs in the region. Diarrheal disease agents, particularly Norovirus and *Campylobacter spp.*, and non-typhoidal *Salmonella spp.* were the major causes of death (WHO, 2015b; WHO, 2015a; WHO EMRO, n.d.; Todd, 2016). These 31 foodborne hazards were reported to cause 33 million DALYs every year, of which 40 percent of this burden was borne by children under 5 years of age. Diarrheal disease agents were responsible for half the global burden, and non-typhoidal *Salmonella spp.* and enteropathogenic *Escherichia coli* contributed the most (WHO, 2015a; Todd, 2016).

In the NENA region, countries with LMIC profiles often face challenges with their public health infrastructure, resulting in the development of less robust prevention and control strategies. Consequently, they are notably vulnerable to the threats posed by foodborne and waterborne diseases (Todd, 2022), potentially experiencing a higher risk of illnesses than currently known.

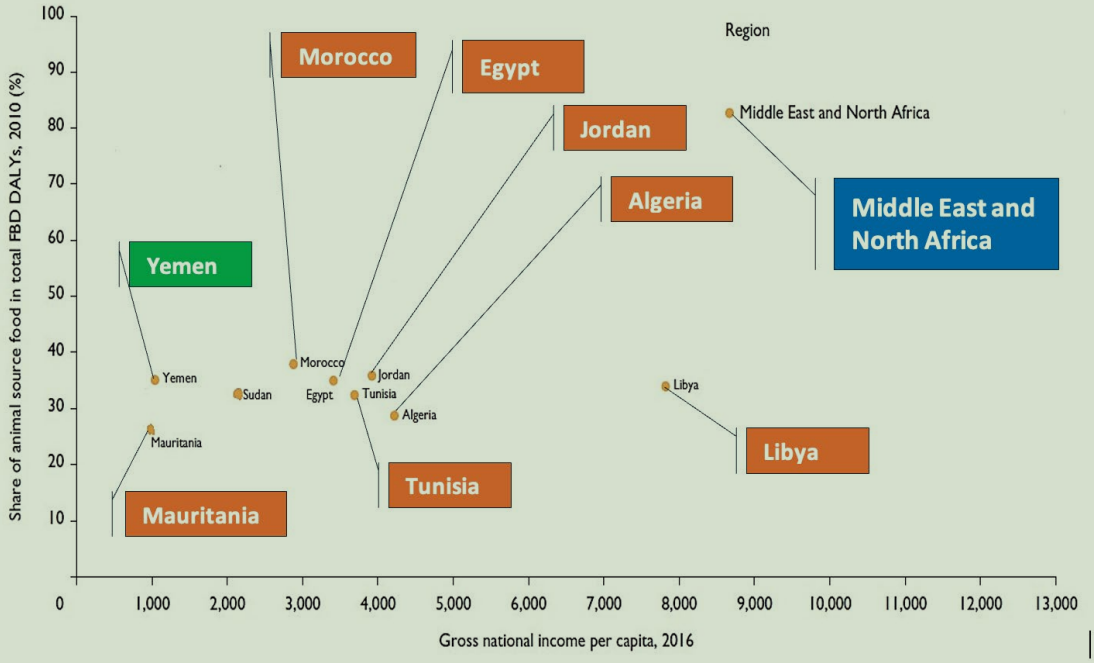
Where epidemiological information is available, the incidence of FBDs has reportedly been linked to the safety of water used during food processing and production, as well as to practices in agriculture and food handling, a lack of adequate food storage infrastructure, and poor enforcement of regulatory standards (FAO, 2016a). This situation is particularly pronounced in countries such as Yemen, Iraq, the Sudan, the Syrian Arab Republic, and currently, Lebanon, which is experiencing an economic and political crisis that has not only paralysed the nation but also devastated its water sources and environment.

The measure of the burden of FBDs attributable to animal source foods in NENA countries is demonstrated in Figure 8.

Additionally, issues like global warming, the large-scale displacement of people, and inadequate oversight of water sources have further compounded the issue. Recent reports have indicated a resurgence of Cholera cases, transmitted through contaminated water and food (Eneh *et al.*, 2023; Jalabi, 2022; Ng *et al.*, 2020; Qamar *et al.*, 2022). Moreover, Mauritania, situated in one of the regions vulnerable most to climate change, faces significant challenges related to food and waterborne diseases. These include bacterial and protozoan diarrhea, hepatitis and typhoid fever (Cissé, 2019).

Meanwhile, Libya has witnessed recurrent incidences of food poisoning in the past years (Ash, 2017; Hamad and Saleh, 2019; Libyan Cloud News Agency, 2020), with the number of cases constantly increasing in the country (Assad, 2022). Of particular concern is the alarming state of drinking water in Libyan schools, which poses a substantial threat to the health of school children. Due to ineffective investigations and management measures, widespread contamination of water sources has led to outbreaks of disease among students (Al-Boom, 2021).

Figure 8. Foodborne disease burden attributable to animal source foods in the NENA countries



Source: Adapted from WHO (2015a). Figure developed by Moustapha.

Similarly, Iraq has witnessed numerous food poisoning outbreaks, particularly in colleges. However, many of these outbreaks remain inadequately investigated and unpublished (Asaad *et al.*, 2014). Foodborne outbreaks often originate at food service establishments, highlighting the need for improved health inspection efforts and local laboratory capabilities. Iraq's reliance on low-quality water from the Tigris and Euphrates rivers, coupled with its proximity to neighbouring countries with frequent disease outbreaks, increases its vulnerability to waterborne and infectious diseases (Qamar *et al.*, 2022; Zolnikov, 2013).

Moreover, frequent incidents of foodborne illness have been reported in universities and schools across Egypt, Morocco, and Tunisia (Food Safety News, 2013; Herriman, 2015; Ibrahim and Abdel-Haleem, 2017; Sinaee, 2022).

Over the past three years, Lebanon has experienced a notable increase in recorded cases of food poisoning. The ongoing economic crisis, frequent power cuts, and warm climate have exacerbated food safety issues (Doueiry, 2023; Khzam, 2022). With the proliferation of AMR, food contaminants in Lebanon's food systems have the potential to inflict significant mortality and morbidity on vulnerable populations (Kharroubi *et al.*, 2020).

Similarly, there has been a notable increase in reports of food safety incidents in Tunisia, particularly those related to food of animal origin. These incidents are attributed to the operation of unregulated and haphazard food establishments and slaughterhouses that function in unsanitary conditions (The New Arab, 2019).

Egypt is facing a series of food quality and safety crises. Studies have found cases of botulism poisoning and unsanitary practices in Egyptian slaughterhouses. Both local and global organizations, such as WHO and the Centre for Disease Control and Prevention (CDC), have issued warnings to individuals visiting Egypt, alerting them to the increased risk of contracting various foodborne

illnesses like hepatitis A and typhoid. They advise against consuming tap water, ice cubes, street vendor food, and dairy items, particularly those that have not undergone pasteurization (AmCham, 2008).

In addition, reports revealed the presence of DDE and PCBs in the blood serum samples of females diagnosed with invasive adenocarcinoma in Egypt. The mean concentrations of DDE were significantly higher in breast cancer cases and benign breast disease cases than in healthy females, suggesting a potential link between DDT contamination and cancer development in Egypt (Ahmed *et al.* 2002).

Egypt's reputation has also been marred by recurring incidents of deadly food poisoning, for example, the fatalities in 2018 (Mallinson, 2018). Also, in 2021, at least 47 European travellers were hospitalized after dining in the city of Hurghada on Egypt's Red Sea coast (Whitworth, J. 2023). More recently, there has been a notable rise in cases of *E. coli* infections and associated hemolytic uremic syndrome among travellers. Visitors to Egypt have been advised to take precautions, such as avoiding non-potable tap water and opting for bottled water. Additionally, practicing safe food hygiene measures, like consuming thoroughly cooked food and peeled fruits, was recommended (Whitworth, J. 2023).

In Morocco, an average of 100 FBD episodes are reported annually, corresponding to 1500 affected cases across all provinces and regions of the kingdom. However, the laboratory confirmation rate remains very low, not exceeding the 10 percent threshold. In fact, according to the Department of Epidemiology and Disease Control, during the period 2007 to 2017, 13 778 cases of FBD were identified, of which 57 percent were declared in a family environment, and 42.9 percent of these outbreaks were reported in communities (Moumni Abdou *et al.*, 2019). In 2016, the estimated incidence rate of FBD was 4 cases per 100 000 population. When compared to nearby regions, this rate ranged from a low of 0.06 cases per 100,000 in Greece to the highest in Malta at 8.98 cases per 100,000 (ibid).

Healthcare infrastructure in the GCC states is more developed, but it is also impacted by significant episodes of FBD (Berekaa, 2021; Todd, 2017). However, data on occurrences and factors contributing to foodborne illnesses are limited, which hampers the ability of governments to formulate preventive policies (Todd, 2017). Some isolated instances of foodborne illnesses were documented in Dubai, while in Abu Dhabi, the Abu Dhabi Food Control Authority (ADFCA) recorded sporadic cases of food poisoning, including 561 cases in 2010, 667 in 2011, and 627 cases in the first six months of 2012 (Todd, 2017).

Saudi Arabia, renowned for its well-maintained healthcare system, faces various food safety challenges. These include the application of risk analysis, a lack of academic programs, limited scientific organizations, a shortage of specialized training programs, and a scarcity of food safety science programs. Furthermore, the absence of coordination and consistency between organizations undermines the efficacy of food safety systems in the kingdom (Berekaa, 2021). Over the years, Saudi Arabia has suffered from several foodborne outbreaks occurring in various locations and caused by various pathogens, resulting in cases of gastroenteritis and food poisoning (Box 1).

Furthermore, Saudi Arabia's meticulous management of the annual Hajj pilgrimage, which accommodates millions, involves rigorous health oversight. Despite precautions in food handling and the restriction of infected individuals, occasional outbreaks have been reported due to

microbial contamination during the Hajj and Umrah seasons in Mecca and other cities (Berekaa, 2021; Todd, 2017). For example, during the annual Hajj pilgrimage in 2006, a group of Saudi soldiers were diagnosed with gastroenteritis following a rice lunch contaminated with *Bacillus cereus* and *Clostridium perfringens* (Bakri *et al.*, 2017).

One common factor across Gulf states is the substantial presence of expatriate labour, a significant portion of which works in the food industry and may originate from parasite-endemic countries (Todd, 2017). While multinational corporations adhere to international standards, Gulf states rely on expatriate workers primarily in food service roles in small and medium-sized enterprises, restaurants, and hotels.

Over the past decade, numerous studies have investigated the prevalence of parasitic diseases among food handlers in Saudi Arabia, providing valuable insights into the health risks associated with these infections. For example, a study involving 194 food handlers found 11 percent to be infected with intestinal helminths, 7 percent with protozoa, and 5 percent with bacteria. Specific pathogens identified included *Ascaris lumbricoides*, affecting 47 percent of handlers, *Giardia lamblia* in 43 percent, and *Salmonella spp.*, which was the most common, affecting 87 percent of cases. Similarly, Zaglool (2011) reported a high prevalence of intestinal parasitic infections among food handlers during the Hajj season, and Wakid (2009) also observed an elevated prevalence of such infections in this population.

Furthermore, between 2005 and 2015, there were reported cases of foodborne hepatitis A virus (HAV) in Saudi Arabia, underscoring the urgency of implementing comprehensive surveillance and preventative measures. Embracing a One Health approach can be a pivotal strategy in tackling these pressing issues in Saudi Arabia, as emphasized by Al-Seghayer and Al-Sarraj (2021).

Box 1. Cases of reported gastroenteritis and food poisoning in Saudi Arabia

2006:

- During Hajj, a group of Saudi soldiers suffered from gastroenteritis after consuming rice contaminated with *Bacillus cereus* and *Clostridium perfringens*.
- In the Qassim area, a foodborne outbreak led to gastroenteritis in 65 percent of both males and females afflicted. *Salmonella spp.* and *Staphylococcus aureus* were the main causative agents.
- In Taif City, an extended family reported gastroenteritis symptoms. Thirty-nine out of 64 family members fell sick, and one patient died. The outbreak was attributed to *Escherichia coli* in raw milk.

2007:

- In Bisha, 55 people suffered from food poisoning after consuming a Russian salad contaminated with *Salmonella enteritidis*.
- In Riyadh, an outbreak of food poisoning was caused by *Salmonella enteritidis* group D.

2008:

- In Najran city, an outbreak affected 92 people, with *Salmonella enteritidis* group D emerging as the causative agent.
- In Ahad Rafidah in the Asir region, an outbreak of gastroenteritis was caused by *Salmonella spp.* and amoeba.

2009:

- In the Khaiber Valley, about 55 cases of gastroenteritis were reported after a meal in a restaurant.
- In a college restaurant in Riyadh, 200 students were infected with *Salmonella enteritidis* after eating Umm Ali, a dessert.
- Another outbreak in Al-Ahsa involved 33 cases associated with *Salmonella enteritidis* group D.

2010:

- A foodborne outbreak during a wedding ceremony in Sulyyel was caused by *Salmonella spp.*

2011:

- In Hail City, an outbreak of gastroenteritis affected 47 patients who ate shawarma from the same restaurant. *Salmonella enteritidis* group D was identified.
- Workers in Hail were affected by an outbreak associated with *Staphylococcus aureus* in green salad.
- An incident in Abha affected visitors from the Qassim House of Social Education. About 26 cases developed gastroenteritis after eating in two restaurants. The outbreak was associated with *Salmonella enteritidis*, though the source of infection was unknown.

Source: See References

4.4.1.1 Healthy diets: access and availability

A healthy diet helps to protect against malnutrition in all its forms, as well as noncommunicable diseases (NCDs), including diabetes, heart disease, stroke, and cancer. Healthy dietary practices start early in life – breastfeeding fosters healthy growth and improves cognitive development. The region faces a triple burden of malnutrition, including high rates of overweight, obesity, and diet-related NCDs, alongside stunting and micronutrient deficiencies (FAO NERC, 2024). Tables 9 and 10 map out food security, food availability and nutrition in the NENA region (The Economist Group, 2022; FAOSTAT, n.d.; WHO, 2020).

Table 9. NENA countries and the global food security index

Rank (Among 113 countries)	Country	Overall Score %	Affordability %	Availability %	Quality and Safety %	Sustainability and Adaptation %	Prevalence of undernourishment %	Percentage of children stunted %	Percentage of children underweight %	Prevalence of obesity %
23rd	**United Arab Emirates**	75.2	86.7	73.8	81.3	55.2	5.60	N/A	N/A	29.90
30th	**Qatar**	72.4	88.6	72.9	71.7	51	N/A	4.60	N/A	33.90
35th	**Oman**	71.2	88.6	64.3	73.2	53.6	9.80	12.20	11.20	22.90
38th	**Bahrain**	70.3	91.3	60.1	76.3	47.3	N/A	5.10	N/A	28.70
41st	**Saudi Arabia**	69.9	83.2	67.2	71.6	53.7	3.70	3.90	5.30	35
47th	**Jordan**	66.2	85.3	59.8	55.4	58.9	16.90	7.30	3	33.40
50th	**Kuwait**	65.2	80	62.9	67.8	45.5	2.70	6	3	37
57th	**Morocco**	63	74.6	42.9	73.1	60	5.60	12.90	2.60	25.60
62nd	**Tunisia**	60.3	74.5	54.1	58.8	49.7	3.10	8.60	1.60	27.30
68th	**Algeria**	58.9	66.8	57.3	54.7	54.2	2.50	9.30	2.70	26.60
77th	**Egypt**	56	65.2	54.2	45.9	55.8	5.10	22.30	7	31.10
105th	**Sudan**	42.8	35.2	48.2	53.9	35.7	12.80	33.70	33	7.40
111th	**Yemen**	40.1	46.4	26.9	48.7	37.8	41.40	37.20	39.90	14.10
113th	**The Syrian Arab Republic**	36.3	32	26.6	50.8	38.4	N/A	29.60	10.40	25.80

Source: Adopted from The Economist Group, 2022. Table developed by Moustapha Global Food Insecurity Index 2022. In: The Economist, London, UK. [Cited 1 May 2024]. https://impact.economist.com/sustainability/project/food-security-index/reports/Economist_Impact_GFSI_2022_Global_Report_Sep_2022.pdf

The inability of agrifood systems to provide households with adequate access to nutritious foods that contribute to healthy diets has amplified the call for a transformation of food system to make healthy diets available and affordable to all. Moreover, trends including the increased production of processed foods, rapid urbanization, and changing lifestyles have led to a shift in dietary patterns. People are now consuming more foods high in energy, fats, free sugars, and salt/sodium, and many do not have enough fruit, vegetables, and other dietary fibre such as whole grains in their diet (FAO, IFAD, UNICEF, WFP and WHO, 2023; FAO, 2010).

The exact makeup of a diversified, balanced, and healthy diet will vary depending on individual characteristics (e.g. age, gender, lifestyle, and degree of physical activity), cultural context, locally available foods, and dietary customs. However, the basic principles of what constitutes a healthy diet remain the same (FAO, IFAD, UNICEF, WFP and WHO, 2023).

Table 10. Prevalence of undernourishment, severe food insecurity, and selected forms of malnutrition

Country	Prevalence in the total population (2020 to 2022)		Prevalence in children (<5 Y) (2022)		Prevalence in adults (2016)	Prevalence in women (15-49 y) (2019)
	Undernourishment (%)	Severe Food Insecurity (%)	Stunting (%)	Overweight (%)	Obesity (%)	Anaemia (%)
Algeria	<2.5	5.6	8.6	11.9	27.4	33.3
Bahrain	n.a.	n.r.	5.0	n.a.	29.8	35.4
Egypt	7.2	8.8	20.4	18.8	32	28.3
Iraq	16.3	n.r.	9.9	6.4	30.4	28.6
Jordan	n.a.	n.r.	6.6	9.5	35.5	37.7
Kuwait	<2.5	4.5	6.9	11.7	37.9	23.7
Lebanon	n.a.	12.6	7.4	8.3	32	28.3
Libya	8.4	21.2	52.2	28.7	32.5	29.9
Mauritius	6.8	10.5	8.6	6.8	10.8	23.9
Morocco	6.3	n.r.	12.8	4.9	26.1	29.9
Oman	2.8	n.a.	12.7	6.5	27	29.1
Palestine	n.a.	4.0	7.5	8.3	n.a.	31
Qatar	n.a.	n.a.	4.4	11.7	35.1	28.1
Saudi Arabia	3.8	n.r.	12.4	10.1	35.4	27.5
Sudan	11.9	18.1	36	2.7	n.a.	36.5
Syrian Arab Republic	27.8	n.a.	25.4	11.7	27.8	32.8
Tunisia	3	12.6	8.6	19	26.9	32.1
United Arab Emirates	<2.5	1.2	n.a.	n.a.	31.7	24.3
Yemen	34.5	12.8	35.1	1.7	17.1	61.5

Source: Adopted from FAOSTAT (FAO Statistical Division). Table developed by Moustapha n.d. Food and Agriculture Organization Statistics (FAOSTAT Database). FAO, Rome. [Cited 2 May 2024]. https://www.fao.org/faostat/en/#data.

Box 2. Constituents of a typical healthy diet for adults

1. Fruits and Vegetables 400 gm/d, in varieties from all subgroups, and preferably in season (reduces the risk of NCDs).
2. Whole grains (e.g. wheat, brown rice, unprocessed maize, millet, and oats), avoid refined grains.
3. Legumes (e.g. beans and lentils).
4. Nuts (rich in omega-3 fatty acids).
5. Sugars <50 gm/d (less than 10 percent of daily calorie intake) free sugars besides sugars naturally present in honey and fruit juices. Consuming free sugars increases the risk of dental caries (tooth decay). Excess calories from foods and drinks high in free sugars also contribute to unhealthy weight gain, which can lead to overweight and obesity. Recent evidence also shows that free sugars influence blood pressure and serum lipids and suggests that a reduction in free sugar intake reduces risk factors for cardiovasculardiseases as well as increasing the risk of diabetes.
6. Salts <5 gm/d (equivalent to sodium intake of <2 gm/d) in iodized form. Most salt comes from processed foods (e.g. ready meals, processed meats, cheese, and salty snacks) or from foods consumed frequently in large amounts (e.g. bread). High sodium intake and insufficient potassium intake contribute to high blood pressure, which in turn increases the risk of heart disease and stroke. Potassium can mitigate the negative effects of elevated sodium consumption on blood pressure. Intake of potassium can be increased by consuming fresh fruit and vegetables.
7. Fats <30 percent of total energy intake to prevent unhealthy weight gain (preferably unsaturated fats - in particular, polyunsaturated fats [lean protein sources] - found in fish, chicken, beans, nuts, corn oil, sunflower oil, olive oil). Less preferable are saturated fats found in fatty meat, butter, palm oil, ghee, and lard). It is suggested that the intake of saturated fats be reduced to <10 percent of total energy intake and trans-fats to <1 percent of total energy intake (in particular, industrially produced trans-fats found in baked and fried foods, and pre-packaged snacks and foods, such as frozen pizza, pies, cookies, biscuits, wafers, and cooking oils and spreads which do not form part of a healthy diet and should be avoided.). Use low- or reduced-fat milk (1 to 2 percent fat) instead of full cream milk (4 percent fat). (Nishida *et al.*, 2009; WHO 2018). The general recommendation is to shift fat consumption away from saturated fats and trans-fats to unsaturated fats, with the goal of eliminating industrially produced trans-fats.
8. Drinking 8 glasses of water/d.

Source: See References

Box 3. Constituents of a typical healthy diet for infants and young children

1. In the first 2 years of a child's life, optimal nutrition fosters healthy growth, improves cognitive development, and reduces the risk of becoming overweight or obese and developing NCDs.
2. Advice on a healthy diet for infants and children is similar to that for adults, but the following elements are also important:
    a. Infants should be breastfed exclusively during the first 6 months of life.
    b. Infants should be breastfed continuously until 2 years of age and beyond.
    c. From 6 months of age, breast milk should be complemented with a variety of adequate, safe, and nutrient-dense foods. Salt and sugars should not be added to complementary foods.

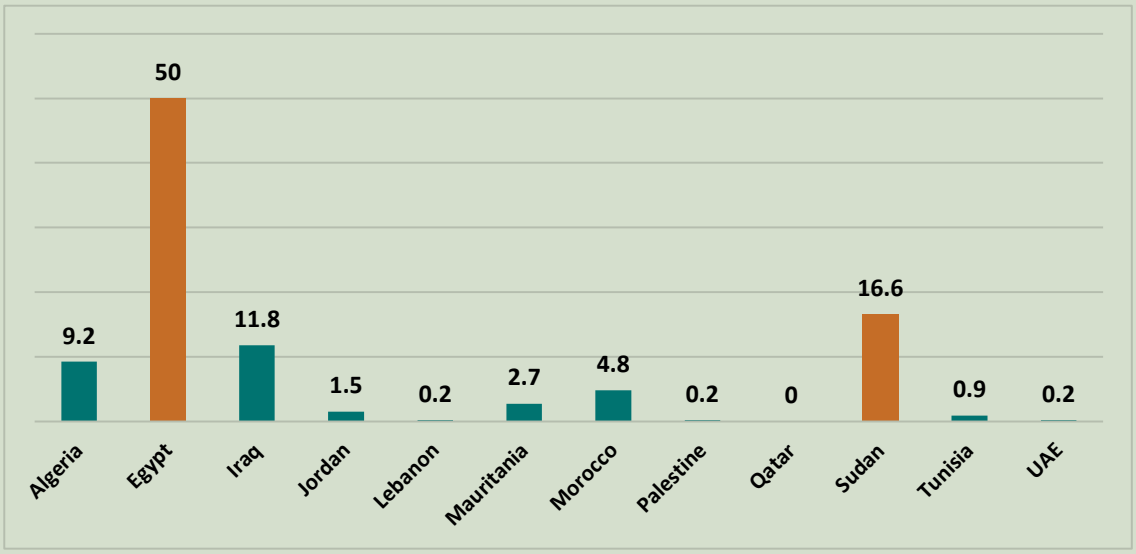
Source: See References

In November 2014, WHO, together with FAO, organized the Second International Conference on Nutrition (ICN2). ICN2 adopted the Rome Declaration on Nutrition (17), and the Framework for Action (18) that recommended a set of policy options and strategies to promote varied, safe, and healthy diets at all stages of life. Fostering a healthy food environment requires the involvement of stakeholders in both the public and private sectors. (FAO, IFAD, UNICEF, WFP and WHO, 2023).

Agrifood systems in the NENA region have struggled to deliver safe, healthy, and affordable foods in adequate quantities. This is due to gaps in institutional, regulatory, and inclusion-related aspects. Strengthening food safety measures can help mitigate these issues by enhancing the efficiency of food supply chains and preventing contamination and spoilage, thereby improving the overall quality and availability of nutritious food (FAO NERC, 2024).

The cost and affordability of a healthy diet continue to be challenging. The cost of a healthy diet in the Arab states in 2022 was USD 3.77 PPP up by 6.8 percent from the year before and only 0.19 PPP dollars below the global average. . Since 2017, the cost of a healthy diet in the Arab states has increased annually, with a 6.8 percent increase observed between 2021 and 2022 (Figures 9 and 10).

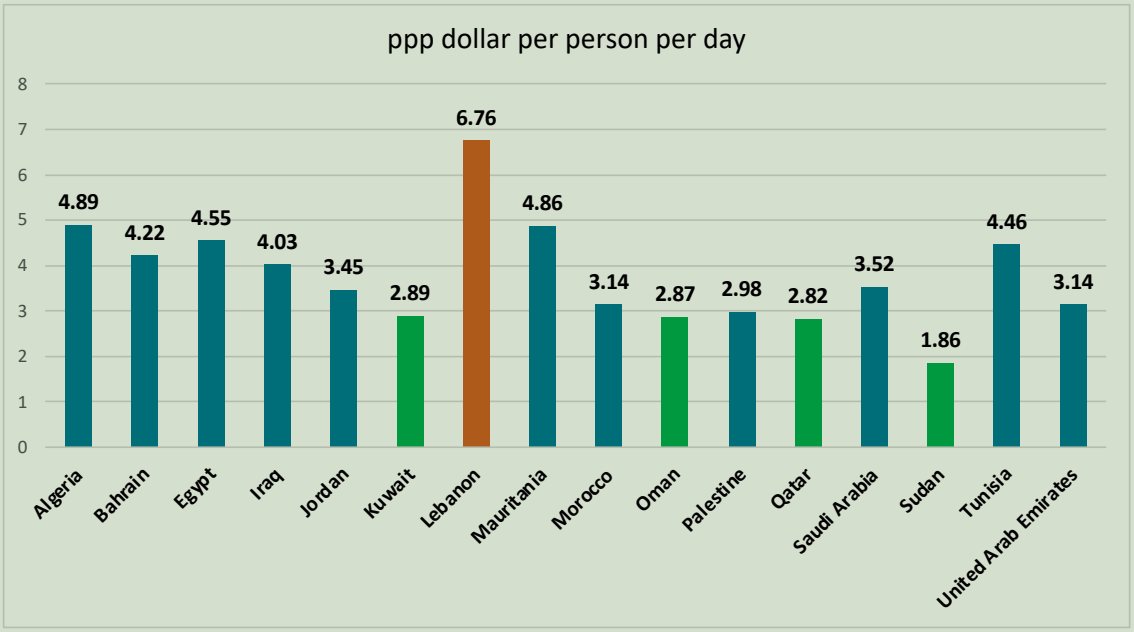
Figure 9. Number of people unable to afford a healthy diet in the NENA countries, in millions



Source: Adopted from FAOSTAT (FAO Statistical Division). Figure developed by Moustapha. n.d. Food and Agriculture Organization Statistics (FAOSTAT Database). FAO, Rome. [Cited 2 December 2024]. https://www.fao.org/faostat/en/#data

The lower-middle-income countries group saw the most significant increase between 2021 and 2022, rising from 3.85 PPP dollars to 4.48 PPP dollars, a 16.4 percent increase. In contrast, the group of countries affected by conflict showed no notable change between 2017 and 2022, remaining at 2.95 PPP dollars. Historically, high-income countries have had the lowest CoHD on average, but this trend shifted in 2021 when their costs began to rise, reaching 2.93 PPP dollars compared to 2.89 PPP dollars in conflict-affected countries (FAO, IFAD, UNICEF, WFP, WHO and ESCWA, 2024).

Figure 10. Cost of a healthy diet (USD per person per day)



Source: Adopted from FAOSTAT (FAO Statistical Division). Figure developed by Moustapha. n.d. Food and Agriculture Organization Statistics (FAOSTAT Database). FAO, Rome. [Cited 2 July 2024]. https://www.fao.org/faostat/en/#data

4.4.2 Trade impact and food export performance

The economic foundations vary significantly across the NENA countries. While Gulf states have built substantial economic pillars through oil production, others rely heavily on agriculture exports. Those countries, like Lebanon, Jordan, Tunisia, Morocco, the Syrian Arab Republic, and Egypt, look to the EU and US markets as major destinations for their food products (Taghouti, Martinez Gómez and García Alvarez-Coque, 2015).

Data obtained from FAOSTAT reveals that the volume of agrifood exports in NENA countries has increased substantially in recent years. Several foodstuffs that are produced in the region are more competitive in terms of price, production schedule (i.e. off-season), cuisine preferential, and nutritional value when compared with other international suppliers (Table 11). However, several trade-related incidences have signalled the challenges NENA countries face in complying with food safety, quality, and other requirements in foreign markets, whether specified by technical regulations or by commodity and market standards (Henson and Olale, 2011).

Table 11. Overview of the main food products exports by country and region

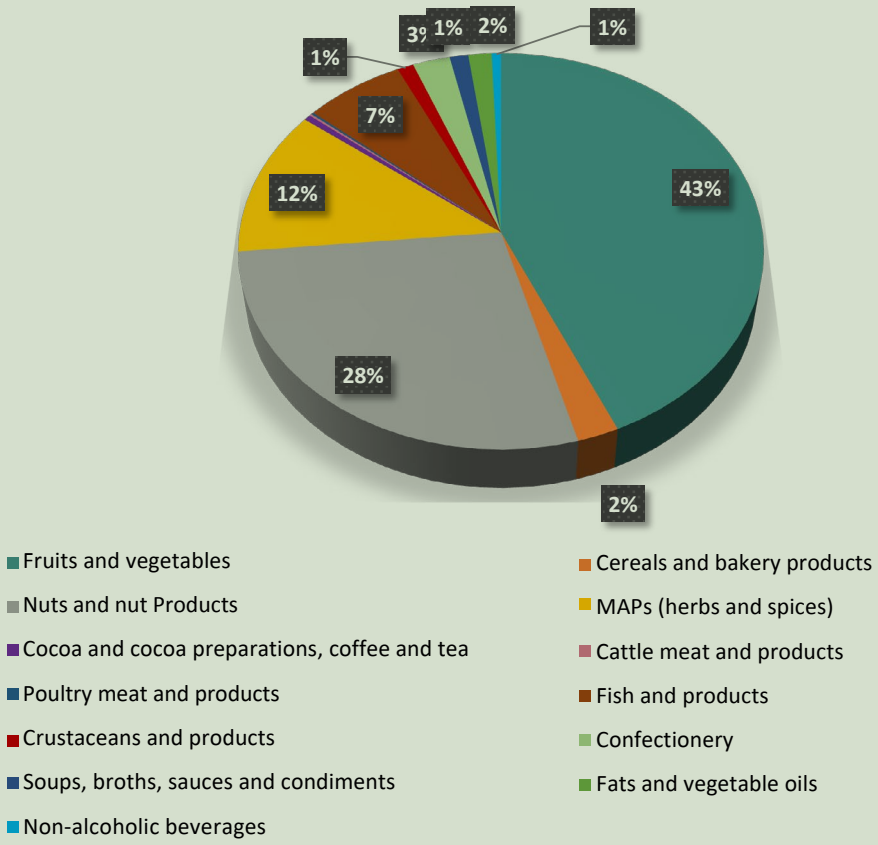
Exported agrifood product	Main exporting countries
Fruits and vegetables (total)	Egypt, Morocco, Tunisia, Algeria, United Arab Emirates, Syrian Arab Republic, Saudi Arabia, Jordan, Iraq, Lebanon
Oranges	Egypt, Morocco, United Arab Emirates, Lebanon, Saudi Arabia, Tunisia, Syrian Arab Republic
Apples	Lebanon, United Arab Emirates, Syrian Arab Republic, Saudi Arabia, Jordan
Potatoes	Egypt, Lebanon, Morocco, United Arab Emirates, Syrian Arab Republic, Jordan, Algeria
Dates	Iraq, United Arab Emirates, Algeria, Saudi Arabia, Tunisia, Egypt, Oman, Jordan, Palestine
MAPs	United Arab Emirates, Syrian Arab Republic, Egypt, Morocco
Nuts and nut products (peanuts, almonds, chestnuts, walnuts, cashew nuts, groundnuts, hazelnuts, pistachios)	United Arab Emirates, Syrian Arab Republic, Egypt, Tunisia, Morocco
Olive oil	Tunisia, Syrian Arab Republic, Oman, Morocco, Iraq, United Arab Emirates, Lebanon, Egypt, Palestine, Jordan
Honey	United Arab Emirates, Saudi Arabia, Yemen, Oman
Fish and fishery products	Algeria, Egypt, Mauritania, Morocco, Oman, Saudi Arabia, Tunisia, Yemen

Source: Adopted from FAOSTAT (FAO Statistical Division). Figure developed by Moustapha. n.d. Food and Agriculture Organization Statistics (FAOSTAT Database). FAO, Rome. [Cited 2 May 2024]. https://www.fao.org/faostat/en/#data

However, importing countries have progressively tightened their regulations, imposing rigorous food safety standards on imported goods due to growing concerns for public health. Consequently, exporters, especially small and medium enterprises, struggle to comply with regulations given the substantial financial burden and the requirement for specialized technical expertise. Eventually, both the public and private sectors incur significant financial costs in attempting to adhere to these standards, as well as to establish laboratories, deploy training, and to seek technical assistance for compliance (Todd, 2016).

Between 2020 and February of 2024, the RASFF issued a total of 637 alert notifications originating in the NENA region. A diverse range of food categories were subject to official controls or were found to violate EU regulations.

Figure 11. The categories of food products rejected entry or withdrawn from the EU markets due to food safety and quality violations



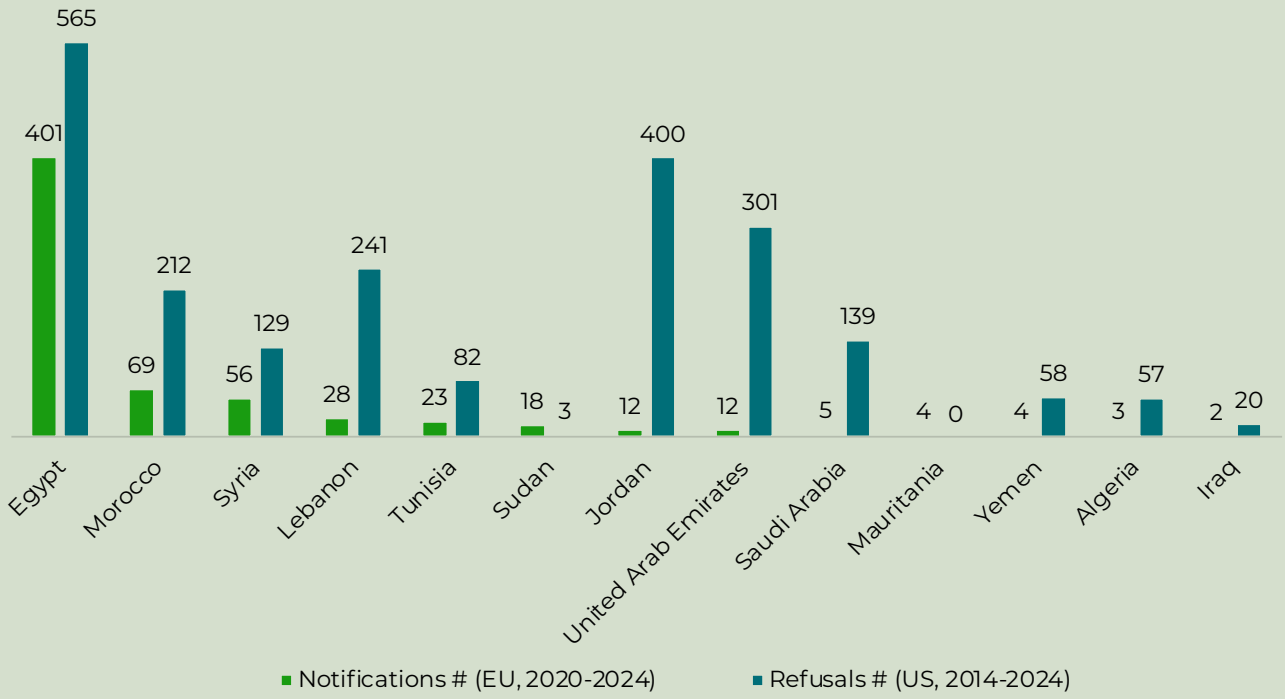
Source: Adopted from RASFF. Figure developed by Moustapha. n.d. RASFF Window. EC-DG Sante, Brussels. [Cited 2 May 2024]. https://webgate.ec.europa.eu/rasff-window/screen/search.

The investigation revealed a consistent pattern in the types of rejections within the five-year timeframe. Fruits and vegetables, nuts, and MAPs were the primary products found unsuitable for human consumption, followed by fish and fish products, and others (Figure 11, Table 12).

These notifications have resulted in various actions such as border rejection, seizure, market withdrawal, and, in certain instances, bans on the sale of these products within the respective countries, which results in significant financial losses for exporters and a decline in their market

share. Egypt tops the list in terms of the number of border alerts, followed by Morocco, the Syrian Arab Republic, Lebanon, Tunisia, and other countries as shown in Figure 12.

Figure 12. Top NENA countries in the number of EU and US border impositions



Source: Adopted from RASFF. Figure developed by Moustapha. n.d. RASFF Window. EC-DG Sante, Brussels. [Cited 2 May 2024]. https://webgate.ec.europa.eu/rasff-window/screen/search.

Moreover, mycotoxins and prohibited pesticides, including excessive pesticide residues, consistently emerged as frequent violations and primary reasons for EU border notifications (Table 12).

The prominence of Egypt in these notifications is noteworthy, with a considerable proportion of alerts attributed to unauthorized pesticides and aflatoxins in fresh fruits and vegetables, nuts and nut products and seeds. Similarly, Algerian fish products were rejected due to poor temperature control. Meanwhile, besides Aflatoxins, chemical adulteration, notably the use of banned colorants in food, was frequently linked to the rejection of Lebanese and Syrian shipments.

Additionally, heavy metals, aflatoxins, and histamine found in fish and other products were the leading reasons for the rejection of Tunisian and Moroccan products, followed closely by excessive sulphite levels.

As for Oman's and Saudi Arabia's products, these exhibited contaminants such as glycidyl esters (GE) in processed foods. A number of notifications registered concerning levels of chlorates and Mercury (Hg) in fish products from Yemen products, while issues like inadequate temperature control of fish products, microbial contamination, and histamine contributed to rejections from Mauritania and Morocco. On the other hand, the Sudan faced significant contamination issues in sesame seeds tainted with *Salmonella spp.*, while the remaining rejections were due to a lack of official certificates.

Similarly, earlier data from 2002 to 2011 showed a consistent rise in the number of notifications issued by the EU for products originating from Algeria, Egypt, Jordan, Lebanon, Morocco, the Syrian Arab Republic, and Tunisia. Fruits and vegetables were the most susceptible exported goods (Taghouti, Martinez Gómez and García Alvarez-Coque, 2015).

Egypt has also faced issues in the past decades, with some of its agricultural exports, such as groundnuts, being flagged for high aflatoxins content in EU notifications (Torayeh, 2013). In 2011, the EU imposed a ban on the import of Egyptian fenugreek seeds for being a potential source of the *E. coli* O104:H4 outbreak, which affected approximately 3134 individuals and tragically claimed the lives of at least 47 (Foley *et al.*, 2013). Another incident occurred in 2016, this time in the United States of America, due to strawberries implicated in a multistate outbreak of hepatitis A (CDC, 2016).

Recently, the European Commission has released Implementing Regulation (EU) 2023/1110 concerning the temporary increase in officials and emergency measures for certain goods from specific countries. This decision was triggered by recent notifications received through the RASSF on serious direct or indirect risks to human health in certain food and feed products from several countries, including Egypt, the Syrian Arab Republic, and the Sudan. These risks are specifically related to high rates of non-compliance with respect to pathogenic contamination and excessive pesticide residues.

Table 12. Exported food products and notified food hazards in EU RASFF (2020-2024)

Food category (no. of notifications)	Type of food hazard (frequency)
Fruits and vegetables (276) (inc. orange (99), mandarin (7), table grapes (20), strawberry (13), date (11), bell pepper (19), lemon (2), apple (6), beans (11), vine leaves (14), olives (6), chili pepper (1), okra (4), guava (5), turnip (3), tomato (4), jute mallow (2), carrots (7), herbal tea (2), peas (3))	Pesticide residues (241), Aflatoxins (9), Heavy metals (Lead (1), Cadmium (3)), Inherited plant toxins (Pyrrolizidine Alkaloids (PAs) (1)), Food additives (E122-Azorubine (2), E210-Benzoic Acid (3), Rhodamine B (1)), Allergens (Undeclared Sulphites (11), Foodborne microbes and enterotoxins (Shigatoxin-producing Escherichia coli (1), Norovirus (4)).
Cereals and bakery products (15) (inc. rice, wheat flour, couscous, biscuits, cookies, freekeh, sesame paste)	Pesticide residues (Thiamethoxam (2), Tricyclazole (2), Chlorpyrifos (1), Chlorpyrifos-methyl (2)), Processing contaminants (3-monochloro-1,2-propanediol (3-MCPD) (1), Glycidyl Esters (GEs) (2)), Chemical contaminants (Polycyclic Aromatic Hydrocarbons Inc. Benzo(a)pyrene (4) Mineral Oils (1)), Allergens (Undeclared Sulphite, Wheat) (3), Foodborne microbes (*Salmonella spp.* (inc. Havana, Mbandaka) (4)).
Nuts and nut products and seeds (177) (inc. peanuts, ground nuts, pistachio, tahini, and sesame paste)	Pesticide residues (Propamocarb (1), Chlorpyrifos (1)), Aflatoxins (129), Inherited plant toxins (Quinolizidine Alkaloids (1)), Food additives (E110-Sunset Yellow (1), E124-Ponceau (1), Cochineal Red (1)), Foodborne microbes (*Salmonella spp.* [inc. enteritidis, Amsterdam, Mbandaka, Orion, Rissen, Senftenberg, Salamae, Aberdeen, Adelaide, Braenderup, Karamoja, Herston, charity, Livingstone, Singapore, gaminara, Tennessee] (58)).

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Food category (no. of notifications)	Type of food hazard (frequency)
MAPs (herbs and spices) (76) (inc. marjoram (7), dill (7), anise seeds (2), basil (6), black pepper (1), chili pepper (2), cumin seeds (1), dry mint (1), fennel seeds (1), ginger (1), parsley (3), peppermint & spearmint (8), rosemary (2), turmeric (1))	Pesticide residues (41), Aflatoxins (2), Inherited plant toxins (Pyrrolizidine Alkaloids (PAs) (8)), Foodborne microbes (*Salmonella spp.* (inc. infantis, enteritidis, typhimurium) (21)).
Teas (3) (inc. herbal and mate tea)	Pesticide residues (Anthraquinone (1), Perchlorate (1)), Inherited plant toxins (Pyrrolizidine Alkaloids (PAs) (1)).
Cattle meat and products (1) (salted beef casings)	Heavy metals (Lead (1))
Poultry meat and products (1)	Foodborne microbes (*Salmonella infantis* (1))
Fish and products (43) (inc. seabream, tuna, monkfish, Xiphias gladus, sardine, Helicolenus dactylopterus, mackerel, swordfish, breams, pagro, anchovies, dolphinfish)	Pesticide residues (Chlorate (3)), Heavy metals (Mercury (29)), Histamine (9), Foodborne microbes (Listeria monocytogenes (1), Parasitic Infestation (1)).
Crustaceans and products (7) (Shrimps)	Heavy metals (Cadmium (1)), Food additives (E220-Sulfur Dioxide (6)).
Confectionery (16) (inc. Halawa, tahini, and jam)	Food additives (E210-Benzoic Acid (2), E407-Carrageenan (1)), Allergens (undeclared Sulphite (1)), Processing contaminants (Glycidyl Esters (GEs) (1)), Foodborne microbes (Salmonella (inc. Amsterdam, Montevideo, Orion (12)).
Soups, broths, sauces, and condiments (8) (inc. tomatoes paste, and sesame paste)	Food additives (E200-Sorbic Acid (2), E210-Benzoic Acid (5)), Allergens (undeclared peanuts (2), Sulphites (1)).
Fats and vegetable oils (10) (inc. ghee and vegetable fat)	Pesticide residues (Chlorpyrifos (1)), Processing contaminants (3-monochlor-1,2-propanediol (3-MCPD) (3), Glycidyl Esters (GEs) (8).
Non-alcoholic beverages (4) (inc. orange fruit drink, soft drink)	Food additives (Color E110-Sunset Yellow FCF (2), E 210-benzoic Acid (2)).

Source: Adopted from RASFF. Table developed by Moustapha. n.d. RASFF Window. EC-DG Sante, Brussels. [Cited 2 May 2024]. https://webgate.ec.europa.eu/rasff-window/screen/search.

Total of 83 pesticide residue types were frequently detected including: 2-chloroethanol (n=1), Acetamiprid (n=14), Azoxystrobin (n=13), Benomyl (n=1), Bifenthrin (n=3), Boscalid (n=13), **Carbendazim (n=24)**, Carbofuran (n=3), Chlorate (n=1), Chlorfenapyr (n=8), Chlorothalonil (n=2), Chlorpropham (n=6), **Chlorpyrifos (n=123)**, Chlorpyrifos-methyl (n=9), Clofentezine (n=1), Clothianidin (n=2), Cyflufenamid (n=2), Cyflumetofen (n=1), Cyfluthrin (n=11), Cypermethrin (n=7), Cyproconazole (n=1), Deltamethrin (n=1), Diazinon (n=1), Difenoconazole (n=8), Diflubenzuron (n=2), **Dimethoate (n=33)**, Dimethomorph (n=12), Diniconazole (n=1), Dithiocarbamates (n=2), Emamectin (n=6), Ethephon (n=2), Famoxadone (n=1), Fenamiphos (n=5), Fenazaquin (n=1), Fenbutatin oxide (n=1), Fenhexamid (n=2), Fenitrothion (n=2), Fenpropathrin (n=1), Fenpyroximate (n=1), Fipronil (n=6), Fluazifop-P (n=1), Flumetralin (n=1), Fluopyram (n=1), Flusilazole (n=4), Flutriafol (n=1), Fosthiazate (n=1), Imazalil (n=7), **Imidacloprid (n=13)**, Indoxacarb (n=6), Iprodione (n=6), **Lambda-cyhalothrin (n=17)**, Linuron (n=3), Lufenuron (n=10), Malathion (n=2), Metalaxyl (n=5), Methiocarb (n=1), Methomyl (n=9), Methoxyfenozide (n=1), Monocrotophos (n=1), Myclobutanil (n=4), Omethoate (n=13), Oxamyl (n=6), Penconazole (n=6), Phosmet (n=1), Profenofos (n=7), Propamocarb (n=1), Propargite (n=9), Propiconazole (n=18), Pyraclostrobin (n=5), Pyrimethanil (n=3), Spirotetramat (n=3), Sulfur (n=3), tau-fluvalinate (n=1), Tebuconazole (n=6), Teflubenzuron (n=3), Tetraconazole (n=1), Tetramethrin (n=1), Thiabendazole (n=1), Thiamethoxam (n=9), **Thiophanate-methyl (n=16)**, Tolfenpyrad (n=1), Triadimenol (n=2), Trifloxystrobin (n=5).

In general, several agricultural products from NENA countries are not authorized to enter potential export markets due to food safety and sanitary concerns. For instance, several NENA countries cannot export dairy and animal-based products to the EU due to the lack of the mandatory residues monitoring and control plans required by EU regulations (FAO, 2024c). Additionally, differences in standards within the region have led to the United Arab Emirates imposing a ban in 2016 on the import of fruits and vegetables, including apples, from Egypt, Oman, Yemen, Jordan, and Lebanon due to elevated levels of pesticide residues (Namrouqa, 2017; Al Mukrashi, 2017). Egypt also announced a similar suspension in 2019, involving a shipment of 700 tons of apples from Lebanon, for the same pesticide-related reasons (Mohsen, 2022). Furthermore, Qatar implemented bans on specific Lebanese vegetables over the past year due to high contamination rates.

The challenges related to food exports to the US are equally significant, especially considering recent reforms in food legislation that have significantly emphasized risk-based official controls and inspections. These controls are now applied not only within the US but also to food facilities beyond its borders.

The enactment of the Food Safety Modernization Act (FSMA) in 2011 introduced an additional level of responsibility for importers, who are now responsible for verifying exporter adherence to US food laws, including establishing proactive food safety systems. This, in turn, presents technical and scientific challenges to food exporters.

In 2001, 27 percent of food exports from Egypt, Jordan, Lebanon, and the Syrian Arab Republic to the United States were rejected by the FDA due to their noncompliance with US regulations. In addition, some shipments from Egypt were routinely rejected on the grounds of pesticide contamination (e.g. okra, frozen strawberries, olives), dirt (e.g. juices), mislabelling, leaking/swelling of containers, Salmonella contamination, and Aflatoxins contamination (AmCham, 2008).

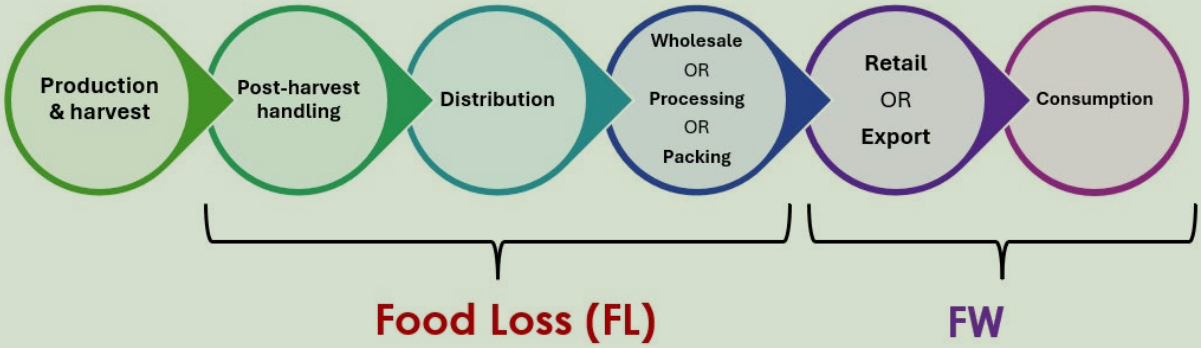
Overall, the period 2014 and February 2024, a total of 2 230 border entry refusals to US food markets were recorded for a wide range of products from various countries in the NENA region, including nuts (n=55), confectionary products (n=67), cocoa-based products (n=89), olives (n=121), other vegetables (n=125), dates (n=202), other Fruits (n=39), beverages (n=137), MAPs (n=71), rice (n=97), sesame products (n=106), and fishery products (n=70). There are currently no published statistics detailing the specific nature of these violations linked to each county. However, these refusals were mainly attributed to mislabelling or misbranding, unsanitary manufacturing conditions, or product contamination (FDA, 2024) (Figure 12).

With these ongoing trade challenges and pressures, exporting countries in the region are grappling with significant challenges due to increasing food safety standards and measures enforced by their trading counterparts. These challenges could be a driver to support export enhancement programmes and bolster the food industry with cooperation from governmental agencies to address these SPS and TBT-related barriers.

4.4.3 Economic impact: food loss and waste

Around one-third of all food produced in the world is lost and/or wasted (Figure 13). FAO's Food Loss Index estimates the amount lost from post-harvest to handling, processing, and distribution at 14 percent based on the emergent Food Loss Index.

Figure 13. Food loss within the supply chain



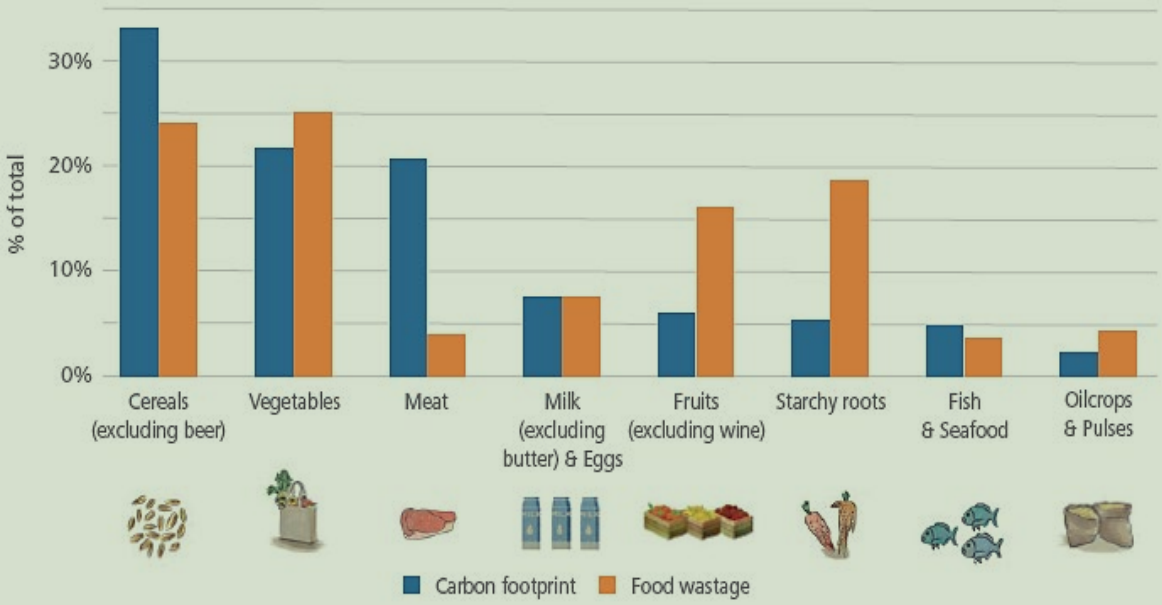
Source: Adopted from FAO (2015c). Figure developed by Moustapha.

Global food loss and waste has a tremendous economic and environmental cost, accounting for roughly one-quarter of the total global use of cropland, freshwater resources, and fertilizers for food production, without accounting for the loss and waste of animal products. It also generates a total of 4.4 gigatons of CO_2e, eq, or about 8 percent of total anthropogenic GHG emissions (carbon footprint)[3] annually. FLW in 2010 was among the largest carbon emitters globally (FAO, 2015b; FAO, 2015c; UNEP, 2024b).

Although meat only contributes a small percentage of the total volume of food waste (less than 5 percent), it has a considerable effect on climate change, accounting for more than 20 percent of the carbon footprint of food waste overall (Figure 14). This is because the carbon footprint of meat includes emissions resulting from the production of one kilogram of meat (e.g. methane emitted by ruminants), emissions related to feed production (e.g. fertilizer used for feed production), and emissions generated by manure management (FAO, 2015b).

[3] The carbon footprint of a food product is the total amount of GHG emitted throughout its lifecycle, expressed in kilograms of CO2-equivalents (FAO, 2015b). Carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) are GHGs that contribute to global warming and climate change and are emitted at all stages of the food life cycle.

Figure 14. Contribution of food commodities to carbon footprint and food wastage



Source: Source: Adopted from FAO (2015b). Figure developed by Moustapha.

Food loss and waste is a widespread problem that affects every stage of the food supply chain, from production to consumption. Inefficient production practices and poor supply chain management are major contributors to food waste. Several factors, including overproduction, inadequate cold chain infrastructure, ineffective harvesting techniques, and logistical challenges, lead to significant food loss (FAO, 2015b).

In the NENA region, around 39 percent of the population in the region is in moderate or severe food insecurity, while 66.1 million or 14 percent of the population are undernourished. There is inadequate capacity to meet rapidly increasing food demand, particularly due to the scarcity of natural resources in the region (FAO, IFAD, UNICEF, WFP, WHO and ESCWA, 2024).

Over 360 million hectares of land and 42 cubic km/year of water are used to produce food that is lost or wasted. Every year, over 14.8 percent of food produced is lost from post-harvest up to, but not including the retail stage (FAO, 2013b; FAO, 2013a; FAO, 2015b).

Significantly high levels of FLW are reported in the region (FAO, 2023b), with annual household food waste found to be 76 kg/capita in Libya (extrapolated), 105 kg/capita in Saudi Arabia and Lebanon (measured), 120 kg/capita in Iraq (average of measured data), and 132 kg/capita in Bahrain (measured) (FAO, 2015c; FAO, 2023b; UNEP, 2021a). These numbers are higher than the global average. FLW in the region can be attributed to a variety of factors including poor and insufficient post-harvest transport, storage and processing capacity, lack of cold chain capacity, and inappropriate production, harvesting, and handling practices (FAO, 2023b). These challenges point to the need for a holistic, integrated, and systemic approach across all levels of the food supply chain to address the gaps that have prevented effective FLW reduction (FAO, 2015b; FAO, 2015c; UNEP, 2024b).

Some countries in the region such as Jordan, Occupied Palestinian Territory, Saudi Arabia, and the United Arab Emirates have set strategic objectives for FLW reduction in alignment with their national agrifood system, food security, and sustainable development objectives (FAO, 2023b).

Many NENA countries have internalized FLW in their national pathways that emerged from the UN Food Systems Summit (UNFSS 2021; FAO, 2019a). However, strengthening the food control system is still needed for significantly reducing FLW through preventing contamination and spoilage throughout the supply chain. This requires the implementation of good agricultural and manufacturing practices, as well as proper storage and transportation conditions. Additionally, effective redistribution, upcycling, or repurposing of FLW and by-products necessitates the adoption of circular agrifood systems-based policies. These policies should address potential food safety issues and ensure the elimination of pathogens (FAO, 2024d).

4.5 RESPONSES

The 'response' component within the DPSIR framework identifies the actions and measures that policymakers, institutions, and governance authorities have taken to prevent, adapt to, or mitigate the impacts on food resulting from various drivers and pressures (as outlined in sections 4.1, 4.2, 4.3, and 4.4, respectively). Although not all impacts can be controlled or avoided, it is crucial to implement measures that focus on improving governance, preserving resources, and safeguarding the safety and integrity of the food supply chain.

Collaboration between risk assessors, food regulators, FBOs, and other stakeholders is essential for enhancing food safety and quality, which requires a robust regulatory framework and surveillance mechanisms to monitor trends in risks and adopt strategies to prevent the recurrence and spread of FBDs, among other things. In the following section, two types of responses will be addressed and reviewed in the literature to gain insights into their status in the region, identify gaps, and explore potential solutions.

1- Pressure- and state-driven responses:

- Regulatory measures for effective food control systems.
- Strengthening conformity assessment services and promoting intersectoral collaboration.
- Inclusive strategies and multisectoral collaboration towards engaging all stakeholders.
- SPS measures adoption and adaptation for harmonizing food safety standards and facilitating regional and global trade.

2- Drivers-related responses:

- Integrated water management and effective water reuse policies to promote sustainable resource use.
- Adaptive measures such as early warning systems for providing timely alerts on emerging food issues.
- Sustainable urban agriculture practices: encouraging sustainable and urban agriculture practices for safer and more resilient agrifood systems.
- Economic reform: setting economic policies to support food safety initiatives and fostering a culture of compliance with food safety and quality requirements.
- Anti-corruption policies: reducing corruption to ensure that food safety regulations are enforced fairly and effectively.

Each of these response strategies can play a role in creating a safer food environment and can steer current efforts in the region to strengthen food regulatory and control systems. This section sheds light on the actions taken by governments and highlights areas where preventive strategies can be reinforced.

4.5.1 Pressure- and state-related responses

4.5.1.1 Regulatory measures for effective food control systems

Establishing a robust and comprehensive food safety system necessitates the inclusion of critical components, including advanced food safety measures, established standards and guidelines, codes of practice, effective control management practices, reliable food inspection and enforcement services, robust food monitoring and surveillance systems, adequate laboratory resources, FBD surveillance systems, comprehensive food safety education and training, and timely communication and information sharing (FAO, 2017; Al-Kandari D *et al.*, 2009; Elmi M., 2004; Hegarty, 2006)..

In the region, microbiological hazards, as well as chemical hazards like pesticide residues, antibiotic residues, AMR, and mycotoxins, have been identified as pressing concerns.

The emergence of antimicrobial-resistant food pathogens in animal-derived food products adds a new layer of complexity to the food safety equation due to the rampant overuse and misuse of antimicrobials in both human medicine and agriculture. Furthermore, with the upsurge in food imports and the complexities of the food supply chain, CAs are under increasing pressure to strengthen their food control strategies and assume greater responsibility for safeguarding consumers.

To this end, policies, laws, and regulations play pivotal roles as pressures-related responses to enhance national control programs aimed at regulating practices around and safety of foodstuffs along the entire food chain, from production to disposal.

Several countries in the region have undertaken reforms to their food laws to align their national food regulations and standards with international requirements, such as in Jordan, Egypt, Lebanon, Morocco, Tunisia, the Syrian Arab Republic, and the GCC countries. The enactment of new legislation has led to the reorganization of food safety control functions and the establishment of independent food safety agencies (Table 13). In general, these efforts have been supported by international organizations, such as FAO and WHO, financial institutions such as the US Agency for International Development (USAID) and the World Bank, as well as the German Federal Institute for Risk Assessment (BfR) and Federal Office of Consumer Protection and Food Safety (BVL).

The review of regulatory frameworks in NENA countries revealed persistent gaps that hinder effective responses to current food safety issues. Food safety regulations in the area are primarily developed based on international Codex standards and/or top regulatory practices of the European Commission. Only a handful of NENA countries are continuously updating their mandatory technical regulations or voluntary standards regarding the establishment of a maximum residue limit (MRL) for agrochemicals and a permissible limit (PL) for chemical and microbial contaminants. Constant efforts are needed to integrate risk assessment systematically into the food chain to prioritize and address the potential sources of emerging risks and set effective preventive control actions.

4.5.2 Institutional framework for food safety control

Despite the recent initiative of instituting CAs for food safety control in some countries in the region (Table 13), there are persisting weaknesses within the institutional framework responsible for ensuring food safety in many countries, mostly resulting from a lack of coordination among various sectors involved and the significant gap between the creation of these agencies and the complete transfer of their mandates. While limitations in financial resources are often cited as the primary reasons for these shortcomings, poor governance, planning, and corruption have been well-documented as major obstacles to establishing sustainable systems in the region (UN ESCWA, 2023).

Table 13. Status of the independent food safety competent authorities in the NENA region

Country	Competent Authority (CA)	Year of establishment	Mission
Jordan	Jordan Food and Drug Administration (JFDA)	2003	Sole national CA for food safety and quality and drug safety and efficacy.
Saudi Arabia	Saudi Food and Drug Authority (SFDA)	2003	Independent CA tasked with ensuring the safety of food, drugs for humans and animals, and biological and chemical substances.
United Arab Emirates	Abu Dhabi Agriculture and Food Safety Authority (ADAFSA)	2019	The local authority in charge of agriculture, food safety, food security, and biosecurity.
Morocco	Morocco's National Office for Food Safety (ONSSA)	2009	Responsible for food safety and compliance of imported and traded food.
Kuwait	Public Authority for Food and Nutrition (PAFN)	2013	National CA in the field of food safety, security, and enhancing community nutrition.
Egypt	National Food Safety Authority (NFSA)	2017	Solely undertakes the functions of control and handling of food (ex-farm control).
Oman	National Centre for Food Safety and Quality (NCFSQ)	2019	CA responsible for the implementation of quality and safety standards throughout the food supply chain.
Tunisia	National Food Safety Authority (INSSPA)	2019	Controlling foodstuffs on import, export, feed, and agricultural inputs, monitoring drinking water supply systems, bottled water, and treated wastewater for agricultural use.
	National Risk Assessment Agency (ANCSEP/ANER)	2019	Effective risk analysis, and policy advice.
Mauritania	Mauritanian Food Safety Agency (AMSSA)	2023	Assessing the sanitary and nutritional risks of all food products and ensures these products meet safety standards to protect public health.

Source: author's own elaboration.

It is well recognized that many NENA countries exhibit fragmented governance structures across various ministries and agencies, albeit to varying degrees within the region. Yet, this lack of coordination affects multiple sectors, including the water sector and public administration.

Often, internal political conflicts and competition for resources delay the transition process, resulting in the duplication of roles among various ministries and municipalities and leading to conflicts over jurisdiction as well as a fragmented regulatory framework, such as in Algeria, Iraq, Lebanon,

Libya, Morocco, the Syrian Arab Republic, Oman, Egypt, and Tunisia (Al-Busaidi and Jukes, 2015; Al-Mazeedi *et al.*, 2015; Chanegriha, 2018; Cortas, 2017; FAO, 2019c; Ibrahim and Abdel-Haleem, 2017; UN ESCWA, 2023).

A limited awareness of the importance of interdependencies between sectors impedes the effective implementation of newly enacted laws and the exchange of critical information, hence perpetuating gaps in law enforcement and lax enforcement, allowing for impunity and food safety risks throughout the supply chain. This may be exemplified by the general lack of a centralized body, authority, or entities, vested in a risk assessment, and the gathering and sharing of data from diverse sources with relevant bodies (Kharroubi *et al.*, 2020; Moumni Abdou *et al.*, 2019; Todd, 2022).

In turn, it puts the region at a disadvantage in terms of producing research related to emerging diseases and generating quality data vital for effective risk management. As a result, acquiring accurate and up-to-date information on zoonotic, foodborne diseases, emerging food hazards, and AMR, their underlying causes, and common food hazards continues to be a challenging task (FAO, 2022c; Faour-Klingbeil and C. D. Todd, 2019; Todd, 2022; WHO EMRO, 2023).

Institutional deficiencies vary in intensity between countries, with the GCC states demonstrating significant progress in reforming their national food safety strategies. Given their reliance on food imports (discussed in the upcoming section) and the influx of international travellers, whether for work as expatriates, tourism, business, or religious visits, the GCC region is vulnerable to recurring outbreaks and novel infectious diseases (WHO EMRO, 2023), as well as to potential risks posed by inadequately trained food handlers from other countries (WHO EMRO, 2023; Todd, 2017; WHO, 2017b; WHO, 2018b).

Consequently, significant efforts have been directed toward transitioning from a reactive to a proactive management approach for food safety. An example of this is the United Arab Emirates, which made a remarkable shift by developing an integrated food control system and maintaining a robust food safety surveillance system that involves multiple stakeholders (Faour-Klingbeil, Al-Busaidi and Todd, 2022).

On the other hand, the task of institutionalizing food safety within the NENA region encounters additional challenges compounded by limited resources, conflicts, and political unrest in certain countries. Hence, the integration of a risk-based preventive approach into national food safety systems remains an area that has seen limited development.

Furthermore, several reports revealed that across most NENA countries, inspection activities predominantly rely on reactive sampling strategies and are limited to the evaluation of sanitary conditions, personal hygiene, and food labelling (Al-Busaidi and Jukes, 2015; Alomirah *et al.*, 2010; Todd, 2016, 2017). The scarcity of competent inspectors equipped with essential resources and guidelines for effective routine inspections further hampers the assurance of regulatory compliance along the entire food chain and amplifies pressures on food safety (Shalaby, 2024; Tajkarimi, Ibrahim, and Fraser, 2013; EC-DG Sante, 2015; EC-DG Sante, 2023).

While this section does not analyse the national control systems of each nation exhaustively, it offers an overview of regulatory gaps by drawing insights from specific examples within subregions. It is worth noting that literature sources are limited for most GCC countries and notably scarce for Algeria, Iraq, Libya, the Sudan, Occupied Palestinian Territory, and Mauritania.

A. FAO-SNG countries (the Gulf Cooperation Council states and Yemen)

Saudi Arabia has made a significant transition from fragmented organizations to a centralized food safety administration with the establishment of the SFDA in 2003. The agency plays a crucial role in regulating, inspecting, and monitoring food and drug safety, with various regulations revised to align with the Codex Alimentarius. Recently, it has established sampling and analytical laboratory facilities at all ports of entry within the country to conduct comprehensive physical, chemical, and microbiological analyses based on risk assessment (Alrobaish *et al.*, 2021).

However, the ongoing process of centralization has led to overlapping legislative and monitoring tasks among multiple entities, presenting challenges in ensuring the safety, quality, and authenticity of both local and imported food, as well as compliance with Halal standards (Alrobaish *et al.*, 2021). This is compounded by the limited communication and collaboration between non-governmental institutions and public institutions involved in the food supply chain, such as government ministries of the environment, agriculture, and others. This lack of cooperation hampers the effective implementation of inspection controls on food service establishments and local markets (Alsubaie and Berekaa, 2021). Moreover, research has found that most inspectors in the GCC countries, including Saudi Arabia, lack adequate training and qualifications in public health and food inspection (Alsubaie and Berekaa, 2021). As such, food inspectors often lack motivation and have inadequate knowledge of emerging risks and practical implementation of the HACCP system due to limited training opportunities. These conditions may compromise the efficacy of regulatory oversight and the enforcement of food safety regulations (Al-Mazeedi, 2015; Alsaleh, 2021).

Similarly, in Oman, the Food Safety and Quality Center (FSQC) was established in 2019 to ensure consistent inspections and to oversee the implementation of standardized quality and safety norms across the food supply chain. However, challenges in food control persist due to a shortage of qualified inspectors, coordination gaps, and duplications of responsibilities among different authorities (Faour-Klingbeil, Al-Busaidi and Todd, 2022).

In Kuwait, since 2013, the Public Authority for Food and Nutrition (PAFN) has been tasked with overseeing food safety across the supply chain through food inspection measures. However, this initiative faced hindrances due to limited resources that were insufficient to match the surge in food imports (Al-Mazeedi *et al.*, 2015).

The observed inadequacy of food inspectors' skills, many of whom held secondary school diplomas, was not limited to Kuwait alone but was also noted in Oman (Al-Busaidi and Jukes, 2015; Alomirah *et al.*, 2010). Nevertheless, recent information highlights Kuwait's adoption of a proactive approach. This is exemplified through the establishment of national risk profiling and focal points, which enable swift responses during foodborne outbreaks.

The utilization of risk assessment for targeted inspections is also on the rise. However, the enhancement of multisectoral cooperation, particularly with stakeholders from the agricultural sector, remains a priority to foster effective risk-based management for locally produced food (WHO, 2018b).

Yemen serves as another illustrative case, where an ongoing civil war has plunged the nation into turmoil since 2015. Consequently, the conflict has had a profound impact on Yemen's food and health systems (UNICEF, 2021). The consequent absence of effective governmental oversight has

contributed to a surge in foodborne diseases, such as cholera outbreaks. Furthermore, the conflict has posed significant challenges to the enforcement of food safety regulations, prompting the emergence of fraudulent and contaminated food items within the market.

B. FAO-SNE countries (FAO subregional office for North Africa)

Tunisia has embarked on an initiative to assess the gaps in its national food control system as part of an effort to embrace a risk analysis approach and enhance risk communication and intersectoral collaboration. This initiative led to the establishment of two agencies in 2019, namely, the National Food Safety Authority (INSSPA) as CA, and the National Risk Assessment Agency (ANCSEP/ANER) as a leading risk assessment agency in the region. However, until 2021, progress had been deterred by multiple factors, as previously recognized by the Minister of Health. These include a lack of coordination between different stakeholders, limited skilled human resources and analytical capacity, and a scattered legal and institutional framework.

On another front, Tunisia and Mauritania have joined efforts to ensure food safety standards are met and maintained and to share best practices, technical expertise, and knowledge exchange in areas such as food production, handling, storage, and distribution. Strengthening cooperation between the two countries can lead to strengthening regulatory frameworks and quality control systems, and effective monitoring mechanisms to guarantee the safety of their food supply chains (BNN, 2023).

Meanwhile, in Morocco, the CA responsible for regulating, implementing, and controlling conformity of imported and locally traded food is the National Office for Food Safety (ONSSA). Its mandates are extensive and instituted designed to implement the government's policy on the safety of plants, animals, feed, and food products, from raw materials to the final consumer. Since 2009, ONSAA as an independent food safety authority has faced significant challenges in addressing food safety inspection and monitoring activities at various points of the food chain. These gaps were particularly prominent in wholesale fruit and vegetable markets and slaughterhouses. The limited coordination among stakeholders engaged in food control and the inadequate staff capacity to cover expansive territories do not match the magnitude of the tasks entrusted to ONSSA (Morocco World News, 2022).

C. Other countries in the North Africa and Middle East

There have been notable efforts to enhance and standardize inspection controls in Egypt (FAO, 2019c). However, despite the law's enactment in 2017, NFSA has encountered difficulties fully exercising its mandates as the sole authority responsible for the oversight of all aspects of food manufacturing and distribution in the Egyptian market. This is due to conflicting roles and overlapping responsibilities with other local entities reluctant to relinquish authority. Instances of overlapping control functions and animal product testing have led to confusion among traders (Shalaby, 2024). This encroachment by different government bodies upon NFSA's domain and decision-making processes results in a lack of autonomy, impairing its effectiveness (FEI, 2020). Consequently, the inadequate coordination and communication among the involved agencies hinder their ability to promptly address foodborne hazards and to conduct routine inspections and surveillance efficiently (Shalaby, 2024).

The regulatory shortfalls are exacerbated by constrained technical capabilities, including food inspectors, a shortage of personnel to execute mandated duties, and inadequate resources for inspection controls (Shalaby, 2024). Recently, the European Commission auditing program in Egypt has raised concerns regarding the skills of food inspectors and their limited access to standardized procedures or instructions necessary to perform official control tasks (Whitworth, J. 2023). The rising threat of food fraud within the supply chain necessitates heightened proficiency and expertise among food inspectors in detecting fraudulent practices. Past incidents have revealed discrepancies in outcomes among various entities engaged in food control (Shalaby, 2024).

Currently, NFSA leadership has put in place a contemporary risk-based approach to food import control. This system mirrors those systems implemented in Jordan and the United Arab Emirates, where food categories are linked with a verified history of adherence to food safety standards, resulting in reduce the delays during border sampling and testing, and consequently, a reduction in food shipments clearance time. NFSA streamlined the inspection process and allocated resources based on the varying levels of risk associated with different food categories to enhance efficiency and ensure compliance with food safety standards. The authorities and stakeholders are aware of the importance of integrating the risk analysis concept into the national system (FEI, 2020; Ibrahim and Abdel-Haleem, 2017). NFSA also established a whitelist of qualified food importers, who benefit from streamlined clearance protocols for imported food consignments, resulting in the reduction of customs hold periods, and the application of reduced sampling frequencies (less than 100 percent) to these consignments, following a risk determination approach adopted to create distinct clearance lanes for food import consignments.

In the Sudan, and before the recent conflict, the food safety control system has undergone significant improvements. The country has set up several regulations and laws to ensure the safety of its food supply, with efforts focused on monitoring the food supply chain and implementing quality control measures. However, the country still faces several challenges, including poor infrastructure and limited resources, which makes it difficult to enforce regulations consistently (WHO, 2017c).

Jordan commits to food safety through a multi-faceted approach involving regulation, training, coordination, and surveillance. However, challenges remain as the food control system is fragmented among several governmental institutions despite the existence of regulatory bodies such as the Jordan Food and Drug Administration (JFDA). These include the Directorates of Plant Health and Animal Resources, the Ministry of Agriculture, the Jordan Atomic Energy Commission, the Ministry of Health, municipalities, the Ministry of Environment, the Aqaba Special Economic Zone Authority, and the Jordan Standard and Metrology Organization. Jordan has implemented a foodborne surveillance system across all regions and invested in training for food inspectors who conduct risk-based inspections in line with established guidelines, but the number of food inspectors remains limited. Continued efforts are needed to address these challenges and enhance overall food safety (Chanegriha, M. 2018).

Lebanon is currently struggling with widespread pollution, a weakened infrastructure, political and civil unrest, and the most significant and debilitating economic crisis in its history. The Food Safety Lebanese Commission (FSLC), whose primary role is to draft legislative instruments for implementing FSL provisions, was created in 2015 when the Lebanese parliament passed the new food law. But to date, this commission is inactive due to conflicts in ministerial roles and disagreements within the cabinet on developing an independent body (WHO, 2017d).

Recently, a joint initiative launched by the EU, FAO, and the French Research Centre for Agricultural Development further underlined the lack of coordination among public (and non-public) actors, resulting from the myriads of economic and political challenges, that enables some food producers, distributors, and importers to act with impunity, taking advantage of the situation to supply non-safe foods (FAO, European Union and CIRAD, 2022).

Consequently, food safety and security issues in Lebanon have increased, with various cases of spoiled and expired food, fraud, and outbreaks receiving heightened national attention (Kharroubi *et al.*, 2020). Food inspectors have low professional standing, insufficient logistical support for inspections, and multiple responsibilities beyond food inspection (Idriss and El-Habbab, 2014), and in some instances, they are perceived by the food sector as being oblivious to their core responsibilities (Faour-Klingbeil, Kuri and Todd, 2020).

In a similar vein, Iraq has a long history of political instability, socioeconomic crises, and religious tensions which have resulted in shortages of skilled workers, poor availability of resources, significant healthcare challenges, and a lack of enforcement of law (Qamar *et al.*, 2022; Ali, Azmi and Shahid, 2022). These factors have been compounded by the lack of government control over certain regions, making it difficult to enforce the law. The aftermath of the regime change in April 2003 has put Iraq into a state of sustained uncertainty, exacerbating food safety issues.

A needs assessment conducted between 2003 and 2004 reported the absence of robust food control and surveillance mechanisms, particularly within vital government institutions such as hospitals (Ali, Azmi, and Shahid, 2022) in Iraq. These shortcomings endured over time, prompting the WHO to issue recommendations to the Iraqi authorities in 2019, which underscored the imperative of enhancing intersectoral coordination, improving the implementation of food safety policies, strengthening emergency preparedness and response capabilities, enhancing surveillance and response to FBD, and improving food safety monitoring and inspection procedures (WHO EMRO, n.d.). Additionally, earlier data revealed the lack of an effective system to trace the origin of food items from animals and plants and insufficient testing and inspection procedures due to inadequate laboratory facilities. This deficiency hindered timely evaluation and corrective actions, further elevating food safety risks, given Iraq's heavy reliance on food imports (ElAddad, 2011; Hasan and Gheni, 2011).

The Syrian Arab Republic has embarked on updating its food standards and regulations by introducing a new food law in 2008 that aligns with national specifications and international agreements, notably the Codex Alimentarius. Despite this progressive step, the current presence of overlapping and numerous regulatory agencies, coupled with a shortage of qualified food inspectors and inadequate communication about food safety as a public health concern among key stakeholders, impedes the practical operability of the food control system (Faour-Klingbeil, Al-Busaidi and Todd, 2022). Furthermore, the Syrian Arab Republic's capacity for disease control has been hampered by governance fragmentation and ongoing conflicts, which pose a significant threat to public health not only within the Syrian Arab Republic but also in the surrounding regions (Ismail, 2016).

Likewise, significant deficiencies were identified in establishing a comprehensive regulatory framework for food safety in Occupied Palestinian Territory. The existing regulatory system for food safety is fragmented and does not adhere to international standards. Multiple official organizations are responsible for monitoring food safety, but there is inadequate coordination among them. Moreover, the scarcity of inspectors and the inability of local authorities to control the borders due to the ongoing Israeli military occupation have contributed to an increase in non-compliance,

fraudulent activities, and the smuggling of food products, exacerbating risks to food safety. Similarly, local authorities are unable to implement sufficient measures to manage the quality of water used in agricultural fields (FAO NERC, 2024).

4.5.3 Holistic approach in the food control system

According to FAO, the defining feature of a holistic food supply chain approach is "*recognition that the responsibility for the supply of food that is safe, healthy and nutritious is shared along the entire food chain*" by all involved in the production, processing, trade, transport, and consumption of food. The food chain consists of all stages of, and operations involved in, the creation and consumption of food products; and includes operators of the production of animal feed the supply of raw materials and food ingredients. Primary production refers the direct production of foodstuffs and includes harvesting, slaughter, milking, and fishing. This stage of production should be closely managed to ensure its outputs are safe and suitable for its intended use (Uyttendaele *et al.*, 2015).

In principle, food safety should be regulated through both public and private sector engagement. Public authorities enforce food control regulations to ensure food safety and quality. The private sector manages production, manufacturing, and distribution processes to meet the safety and quality needs of consumers, while also maintaining or enhancing its competitive position. These complementary control systems form a key part of holistic food systems safety management, operating on the following two principles:

1. The precautionary principle, which posits that decisions on the handling of food, feed, animals, and plants, and requirements-setting around this, should be taken with caution while respecting the best scientific knowledge.
2. The preventive principle, which posits that potential risks in the food chain should be addressed at their source, preferably through system analyses and control of critical points (e.g. HACCP and GAP).

The Hazard Analysis Critical Control Point System (HACCP) is a preventative systematic approach of proactive intervention and is a legal requirement in many NENA countries. Good hygiene practice (GHP) and good manufacturing practice (GMP) are prerequisites for the production of safe food. The HACCP approach applies science to identify hazards, assesses hazards based on risks, and determines hazard control critical control points (CCPs) (as per the CAC/RCP 1-1969, amended 2022).

Good agricultural practices (GAP) are those that address economic viability, environmental sustainability, social acceptability, and food safety and quality for on-farm processes and result in safe and quality food. Adoption of GAPs from production to consumption helps improve the safety and quality of food and agricultural products. In addition, it allows producers and consumers to benefit from global markets (improving market access) and improve their livelihoods and the national economy. GAPs help promote sustainable agriculture and contribute to meeting national and international environmental and social development objectives (Mushobozi, 2010; Poisot, 2005).

The GLOBALG.A.P was launched in 1997 as a leading farm assurance program for certification of compliance with GAP, while the Food Safety Management System (ISO 22000) is a voluntary standard that assists food manufacturers in the appropriate use of HACCP principles (GLOBALG.A.P., 2024; ISO 22000 FSMS Standard).

According to a recent survey conducted by the International Organization for Standardization (ISO), the number of food establishments in the region that have valid certificates of food safety management systems according to the international standard ISO 22000:2008 is indicated in Table 14 (ISO, 2022).

Table 14. Food establishments with valid ISO 22000:2018 certificates in NENA

Country	No. of certified ISO 22000:2018 food establishments*
Algeria	12
Bahrain	49
Egypt	574
Iraq	35
Jordan	202
Kuwait	112
Lebanon	136
Libya	13
Mauritania	1
Morocco	71
Oman	63
Palestine	32
Qatar	148
Saudi Arabia	299
Sudan	21
Syrian Arab Republic	14
Tunisia	123
United Arab Emirates	464
Yemen	11

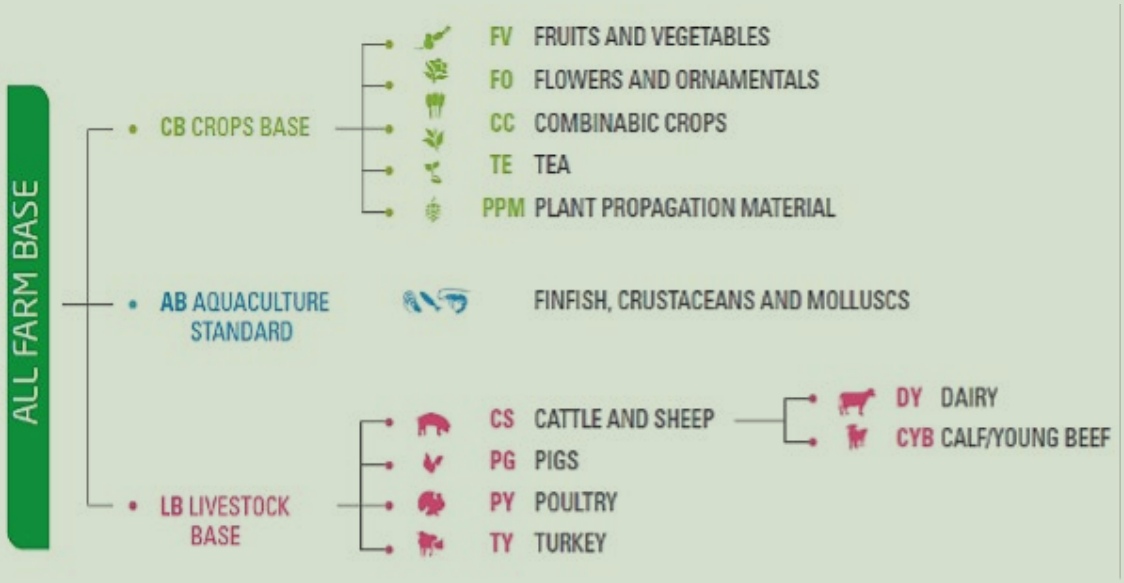
Source: Adopted from ISO (International Organisation for Standardization). Table developed by Moustapha. 2022. Survey of Management System Standard Certifications, 2022. [Cited 1 May 2024]. https://www.iso.org/the-iso-survey.html.

* ISO 22000:2018 Food Safety Management System - Requirements for any organization in the food chain

GLOBALG.A.P. as a voluntary international scheme comprises a global verification framework in the form of guidelines to be applied by all farms as well as those specific to crops (including fresh fruits and vegetables), livestock, and aquaculture systems as outlined in Figure (15).

In 2017, the total GLOBALG.A.P.-certified agricultural land for fruits and vegetables in Egypt and Morocco was 73 425 and 43 652 hectares, respectively (World Bank, 2018c).

Figure 15. Global G.A.P. standard structure and scope



Source: UN ESCWA. 2019a. Adopting Good Agriculture Practices (GAPs) for Enhanced Food Safety in the Arab Region. E/ESCWA/SDPD/2018/TP.6. Beirut, Lebanon, ESCWA. http://www.unescwa.org/sites/default/files/pubs/pdf/good-agriculture-practices-enhanced-food-safety-arab-region-english.pdf

The process of implementing a comprehensive reform from production to consumption, within a risk analysis framework, is complex and multifaceted. It requires addressing food safety gaps and ensuring consistent adherence to regulations across the entire supply chain, including domestic, import, and export control functions (Codex Alimentarius Commission, 2007; FAO/WHO, 2006).

Several countries, including Egypt, Jordan, Lebanon, Tunisia, and Morocco, have shown examples of the stronger focus and prioritization placed on enhancing public capacities, resources, and controls over economically significant food sectors in trade. These efforts are often supported by international funds and projects that aim to promote food trade and compliance with external markets. Unfortunately, the use of resources to upgrade local market infrastructure and capacities remains less developed.

The trade-driven approach of aligning with international food safety standards appears to have resulted in skewed prioritization and discriminatory oversight and marginalization of food safety in local food and rural markets, and a neglect towards government policies in this sector.

At the same time, this approach overlooks the significance of incorporating Codex Principles and Guidelines for National Food Control Systems CAC/GL 82-2013 (FAO, 2017) and fails to holistically address the needs of trade in both international and local markets. As such, various activities along the food chain evade sufficient monitoring and controls and swift corrections at the source of hazards. This stands in contrast to a more compliant system where alerts are flagged during official authority audits, such as those conducted by the Directorate-General for Health and Food Safety of the European Commission on exporting countries (Table 15).

Limited information currently exists on pluralistic governance and discriminatory oversight in specific countries. The prevailing approach leans toward addressing isolated concerns in the food chain to meet trade requirements rather than embracing a holistic perspective. Nevertheless, there are growing concerns surrounding the importance of this issue.

Lebanon serves as a case in point, where notable improvements in infrastructure and the management of post-harvest handling facilities and technologies have been observed. These improvements include proper sanitation, temperature control, quality and safety awareness, and adherence to quality requirements and market regulations, with a primary focus on meeting export market standards. However, issues still exist in the handling of fresh produce destined for the domestic market, including the high use of pesticides and a lack of adequate food testing for fresh produce that does not meet international standards. Compliance with food safety rules also varies, with fresh produce destined for international markets undergoing more thorough post-harvest washing than produce destined for local markets (Faour-Klingbeil, 2017; Faour-Klingbeil and Todd, 2019). There is a perception that fresh products must abide by regulations only when they are destined for international markets, and local wholesale markets often become a "dumpster of products" determined unfit for export (Zurayk and Ghyda, 2009).

Similar situations can be observed in Morocco and Egypt, where products intended for export are subject to stricter control of pesticide residues compared to those distributed in the domestic market (Kasraoui, 2019; EC-DG Sante, 2024b). Also in Oman, fish products intended for export to international markets adhere to strict food safety and quality standards and are typically transported under controlled temperature conditions, in contrast to those distributed locally (Al-Busaidi, Jukes, and Bose, 2016).

In Tunisia and Egypt as well, the GAP certification scheme and ISO 22000:2018 standard are mandatory for all exporters to the EU (Table 14, Figure 15). However, in other countries in the region, similar standards are not applied to control the safety of their local and imported foods.

Along the same lines, the International Food Policy Research Institute (IFPRI) highlighted a significant disparity in food quality and access among different socioeconomic groups in Egypt. Affluent consumers have the privilege of purchasing high-quality, internationally compliant food from supermarket chains that offer imported beef and fish from reputable suppliers, and locally grown produce adhering to international food safety standards. On the other hand, the majority of Egyptian consumers lack the financial means to indulge in such premium food commodities and often resort to consuming foods of lower quality and safety standards available from street vendors or small local stores (Robertson, 2016).

The disparity in cold chain capacity and utilization between food products intended for export and those intended for domestic markets is evident. This contrast becomes apparent when considering the significant presence of smallholding farmers in the NENA region who primarily distribute their produce through traditional food supply chains. Cold chains in these distribution networks are often either disrupted or non-existent (Yahia and Smolak, 2015).

Within this context, the adoption of the HACCP concept is predominantly voluntary within the private sector in some countries in the region, particularly among entities with sufficient resources to expand their domestic market share and enhance their position in export markets. In contrast, traditional and local markets, largely dominated by small and medium-sized enterprises, have not received formal training in food safety, and lag in technical capabilities, financial resources, and support for food hygiene and safety, in stark contrast to the extensive support enjoyed by larger industries and exporters. To add to this, officials and inspectors in these markets often lack knowledge and training, and weak controls persist particularly in the cold chain (Boulfoul and Brabez, 2022; Whitworth, 2023).

Overall, risk-based and proactive food safety systems have not been fully integrated into the national control frameworks of most countries, with some exceptions like Dubai of the United Arab Emirates and, more recently, Egypt, Saudi Arabia, and Tunisia.

Egypt has implemented a contemporary strategy of risk-based food importing, aiming to facilitate food trade into the country and to guarantee consumers consistent access to safe and healthy food. Jordan implemented a three-tier risk-based system for imported food products based on the product's health risk ranking which determines the inspection, sample/test rate, and further procedures. The Abu Dhabi Agriculture and Food Safety Authority (ADAFSA) has recently introduced the '*Zadna*' rating scheme to covering 6900 food establishments, including restaurants, cafes, bakeries, and catering establishments. The initiative aims to enhance transparency and compliance with food safety and was launched as an electronic platform that allows Abu Dhabi residents, tourists, and visitors to review the compliance of food establishments to health and safety regulations and improve their dining experience (WAM, 2023).

In a nutshell, the complexity of food safety and the impact of food fraud on vulnerable segments of society necessitate addressing deficiencies in food control systems. Engaging stakeholders is crucial for allocating support and resources throughout the entire food chain, and governments should take primary responsibility for inclusive governance.

Within this context, and since 2019, FAO and WHO have worked together to jointly develop a comprehensive Food Control System Assessment Tool (FCSAT) incorporating the Codex Principles and Guidelines for National Food Control Systems CAC/GL 82-2013 (FAO, 2017) to assist countries in assessing the effectiveness of their national food control systems. A thorough assessment of food control systems can facilitate the identification of their strengths and weaknesses so that strategic plans can be developed to make food safer, improve public health, and be more competitive in the food market.

In 2018, the Sudan took the lead in the region by requesting FAO to assess their national food control system (using an early version of the tool). Abu Dhabi also used the assessment tool through ADAFSA in 2020, as did Morocco and Tunisia in 2018 and 2019, respectively. These countries used the tool in strategic planning workshops where continuous improvement processes were discussed.

FAO provided technical support to the governments of Egypt, represented by NFSA (2024) and the United Arab Emirates (2025) in conducting facilitated assessments of their National Food Control Systems using the FAO/WHO FCSAT.

Table 15. Findings of the EU audits on the food safety control systems in NENA countries for foods exported to the EU market (2005-2024)

Audit area	Country	Year-audit No.	Audit scope	Common key recommendations
Fishery products and live bivalve molluscs	Algeria	2010-8535	Fishery products and live bivalve molluscs	Enhance officials' capacities to conduct official controls. Monitor the levels of chemical contaminants, particularly heavy metals (Cadmium, Lead, and Mercury), dioxins, biotoxins, and polychlorinated biphenyls (PCBs). Random testing for histamines to be conducted in fishery products deriving from species of fish associated with high levels of histidine, and identifying families of poisonous fish species, including ciguatoxin. Adopt standards and regular inspections of fishing vessels (including freezer vessels). Regular inspections of landing sites, auctions, and fish markets. Issue/update the standards that define the temperature limits for fresh/chilled and frozen products. Ensure that the health control plans drawn up by the FBOs are validated according to HACCP principles and criteria, following EU requirements. Verification of FBO compliance with hygiene requirements. Laboratories involved in the official controls of fishery products apply internationally recognized principles governing quality assurance techniques and are accredited under official quality management according to ISO/IEC 17025 international standard. Identify and assess the establishments for EU listing for compliance with all the relevant EU requirements. Develop and implement appropriate controls on traceability. Ensure that the geographical distribution of the sampling points and sampling frequency complies with requirements. Ensure that the procedure to manage RASFF notifications is in place.
	Egypt	2021-7328	Fishery products	
	Mauritania	2019-6617	Live bivalve molluscs	
		2019-6691	Fishery products	
	Morocco	2022-7456	Fishery products	
		2021-7256	Bivalve molluscs	
		2017-6168	Fishery products	
	Oman	2006-8232	Fishery products	
	Saudi Arabia	2023-7851	Fishery products	
	Tunisia	2019-6694	Fishery products	
		2022-7516	Live bivalve molluscs	
	Yemen	2006-8160	Fishery products	

Continue ▶

Audit area	Country	Year-audit No.	Audit scope	Common key recommendations
Other foods of animal origin	United Arab Emirates	2022-7516	Animal health - camel milk products - export to the EU	Adopt the necessary legislation regarding animal health and the adoption of specific and detailed rules for disease control. Ensure that laboratories involved in controls apply the principles of internationally recognized quality assurance techniques, such as ISO/IEC 17025, and use internationally recognized standards for standardizing test methodologies to ensure the reliability of analytical results. Improve disease notification and control systems. Set up a traceability system to guarantee the origin of animals used to produce camel milk for export. Reinforce import conditions and controls.
	Morocco	2017-6227	Poultry Meat and Derived Products	Provide guarantees of the conformity of establishments to EU requirements. Ensure that all slaughterhouses comply with the requirements. Ensure that EU animal welfare requirements are met.
Chemical contaminants	Egypt	2022-7391	Chemical contaminants (aflatoxins)	Promote good agricultural practice to prevent aflatoxins contamination. Ensure that practices implemented by laboratories are in line with all relevant EU requirements (sampling methodology and reported measurement uncertainty and recovery data). Ensure that EU RASFF notifications are subject to adequate investigations.
Microbiological contamination in Non-animal Origin Food (FNAO)	Egypt	2019-6697	Microbiological contamination in food of non-animal origin	Require farms to obtain GAP certification (GLOBALG.A.P.). Microbiological food safety at primary production to be addressed for the most commonly produced/exported commodities through inspection and certification systems. Ensure official controls for FBOs producing high-risk foods include effective control of measures to reduce the risks associated with *Listeria monocytogenes*. Ensure that methods for the detection of STEC and foodborne viruses in food of non-animal origin are accredited.
	Morocco	2023-7762	Microbiological contamination in food of non-animal origin intended for export to the EU	

Source: Created by Moustapha.

4.5.4 Surveillance and monitoring systems

4.5.4.1 Surveillance systems and response functions

Surveillance plays a key role in the development and implementation of strategies and interventions to limit the emergence and spread of FBDs, zoonoses, and AMR. The NENA region exhibits varying levels of capability in public health surveillance and emergency response systems. While countries like Jordan, Kuwait, Oman, Saudi Arabia, and the United Arab Emirates have well-established mechanisms for reporting FBDs, others possess less efficient surveillance systems or lack comprehensive pathogen characterization, a critical component of robust epidemiological studies (Kharroubi *et al.*, 2020; Shalaby, 2024; Todd, 2016).

Additionally, PulseNet Middle East as an FBD Surveillance Network was established in 2006 to streamline surveillance and facilitate rapid responses to food safety crises, and includes countries such as Bahrain, Egypt, Jordan, Kuwait, Lebanon, Libya, Oman, Occupied Palestinian Territory, Qatar, and Saudi Arabia (PulseNet International, 2019). Despite these efforts, the reporting of FBDs in the region remains limited due to the absence of rigorous reporting and monitoring systems or inadequate capacity to accurately quantify the prevalence of foodborne pathogens and associated diseases (Al-Kandari and Jukes, 2009; Al-Rifai *et al.*, 2019; Kamleh, Jurdi and Annous, 2012). Moreover, many countries face constraints in their ability to respond effectively at the local level due to resource shortages and a shortage of qualified personnel.

Nevertheless, some countries in the region (including Bahrain, Iraq, Jordan, Lebanon, Libya, Morocco, Oman, Occupied Palestinian Territory, Saudi Arabia, and the United Arab Emirates) have formulated policies related to action on combating or preventing the AMR. The alarming misuse and overuse of antimicrobials in non-therapeutic contexts, particularly in animal production, further stresses the significant need to monitor and control its spread.

WHO EMRO reported that no countries in the Eastern Mediterranean Region, which includes nations from in NENA region, had ongoing surveillance of AMR in food-producing animals and food (WHO EMRO, n.d.). This could be related to limited communication and coordination within the health sector, weak health infrastructures, and diagnostic obstacles, all of which continue to hinder surveillance capabilities (FAO, WHO, WOAH, and UNEP, 2022; WHO, 2023b; WHO, 2023c; FAO NERC, 2024; Katoue *et al.*, 2022). Therefore, there is an urgent need for improved surveillance efforts geared toward acquiring a deeper understanding of how AMR transmits via food chains to humans and the resulting implications for human populations (FAO NERC, 2024; Habib and Mohamed, 2022).

In Egypt, bacterial resistance, particularly methicillin-resistant *Staphylococcus aureus*, poses a threat to both animals and humans, a case that underscores the importance of implementation of the One Health Concept in Egypt's agricultural sector, given its association with the majority of zoonotic meat-transmitted parasites in the Arab World (AL-Eitan, Sendyani and Alnemri, 2023). Nevertheless, there is ongoing work on strengthening the intersectoral coalition, where a national action plan to combat AMR has been developed and is to be ratified.

The absence of a national strategy for zoonoses and a cohesive One Health framework is notable in many NENA countries. Institutional and cultural barriers, limited data and resource sharing, and the lack of an efficient national capability for rapid and effective investigation of zoonotic infections have

hindered the adoption of a One Health approach (Awaidy and Al Hashami, 2020). The CAs should also focus on enhancing communication, coordination, and cooperation among stakeholders in the fields of animal production, animal health, and public health (WHO EMRO, 2023). Integration between the human and veterinary sectors for the detection and diagnosis of zoonoses is also an area of weakness that needs to be addressed.

Jordan and Occupied Palestinian Territory need to enhance the sharing of epidemiological and laboratory surveillance data to improve diagnostic capabilities for detecting zoonotic infections (WHO EMRO, 2023; Al-Eitan, Sendyani, and Alnemri, 2023). Meanwhile, Bahrain is required to prioritize collaboration between its public health and animal health sectors to establish a joint priority list of zoonotic diseases, enhancing diagnostic laboratory capacity, and improving communication and data sharing among relevant agencies. Separately, Kuwait grapples with difficulties in linking its public health and animal health surveillance systems, which hinders swift responses to zoonotic disease outbreaks. Similarly, Oman faces significant challenges in establishing strong collaboration and coordination mechanisms to sustainably prevent, control, and eliminate zoonoses.

To address the increased risk of animal diseases and zoonotic infections, Morocco has embarked on improving the capabilities of veterinary laboratories in identifying a wider range of veterinary diseases and toxins through training and upskilling (Krickl, 2016). However, challenges in harmonizing standards, organizational functioning, accountability, transparency, and risk communication remain (Chammem *et al.*, 2018).

Qatar stands out as one of the few Arab countries that effectively applied the One Health concept during the MERS outbreak in 2012. Prompt action was taken by reactivating the Qatar National Outbreak Control Taskforce and collaborating with experts from organizations such as the CDC and the WHO.

The animal health sector also played a crucial role by developing a comprehensive roadmap towards understanding zoonotic diseases, addressing their epidemiology, and developing surveillance and managing outbreaks. Rapid disease diagnosis was prioritized, allowing for the timely management of infections and the implementation of appropriate measures to reduce the spread of disease (Al-Eitan, Sendyani, and Alnemri, 2023). While Oman and many countries in the region continue to face obstacles in adopting a One Health approach, Qatar's initiative demonstrates the importance and feasibility of addressing zoonotic risks and ensuring food safety through comprehensive surveillance and control programs.

To enhance prevention and control measures in Dubai, a collaborative effort between the municipality and the Dubai Health Authority has led to the establishment of an FBD investigation and surveillance system. This initiative was undertaken with guidance from WHO and the US CDC. Furthermore, the United Arab Emirates has embraced an integrated approach centred around HACCP and risk analysis and has developed a national food safety committee comprising representatives from different ministries and agencies, leading to substantial modernization of its food safety risk management systems for both locally produced and imported foods.

In general, the scarcity of quantitative risk assessment endeavours in the region and data remains a major obstacle to transitioning to risk-based preventive systems and risk management. The fundamental principles of risk analysis cannot function optimally without the generation, compilation, analysis, and sharing of local data (FAO/WHO, 2006).

For instance, the magnitude of FBD such as *Salmonellosis spp.* in the food chain is poorly understood in the region and not much work has been done at the molecular characterization level to address the source attribution of the pathogen.

Moreover, additional concerns pertain to the lack of comprehensive surveillance programs. With campylobacteriosis a significant concern in the region, comprehensive surveillance programs dedicated to *Campylobacter spp.* are lacking across the countries. Currently, nationally representative data regarding the prevalence of *Campylobacter spp.* in chicken meat are not available, particularly within the Gulf countries, although a substantial proportion of diarrheal cases (2 to 28 percent) in those countries are attributed to Campylobacter infection (Habib and Mohamed, 2022).

4.5.4.2 Monitoring programs and response functions

Risk assessment is a scientific process consisting of hazard identification, hazard characterization, exposure assessment, and risk characterization. The development of an effective method of data collection across the food chain by conducting national monitoring programs for food hazards is fundamental to assessing compliance with existing regulations for maximum limits and ensuring the safety and quality of food products placed on the market.

National monitoring programs are an essential step, providing realistic and comprehensive estimations of control system performance, identifying safety concerns associated with the highest levels of risk, and assessing the intake of hazardous substances of significance as related to consumption patterns (short- and long-term dietary exposure assessment). Monitoring programs can be used to target priority risks and to adjust inspection areas and frequencies; however, significant challenges persist in many countries when it comes to monitoring food hazards (FAO, 2022a).

Several studies on food hazards identification have been published in peer-reviewed journals, surveying food supply chains, and detecting and assessing potential risks to consumers (section 4.3.1). However, official reports and statistics regarding the levels of food contamination and the assessment of the risk of food contamination for different population groups are scarce in the region.

Countries intending to export food to the EU must demonstrate that their food control regulations and procedures, including residue surveillance programs, are equivalent to those outlined in the EU regulations. Accordingly, exporting countries in the region are required to implement national residue-control programs in foodstuffs destined to be exported, and must be able to demonstrate the results of these monitoring programs.

Among the few published reports in the region, Saudi Arabia in 2018 issued the results of a coordinated pesticide residue monitoring program between three CAs. This program targeted the analysis of 3 421 collected food samples. Results showed that 91 percent of the food samples tested were compliant with the statutory standards, 61 percent had no traces of pesticide residues, and 9 percent were found to exceed the legal MRLs.

Furthermore, in 2022, Qatar proactively addressed food safety concerns by launching a comprehensive surveillance and control program as part of their One Health initiative. It was initiated by the Ministry of Public Health in collaboration with the Ministry of Municipality and covers all stages of the food chain.

The program focused on developing strategies to address biological and chemical hazards on local farms and state abattoirs, aligning with international best practice. Its activities include surveys, data collection, workshops, and training programs aimed at enhancing biosecurity measures and monitoring critical control points in slaughterhouses. Furthermore, the program fostered research collaborations with universities and academic centres to fill data gaps and devise effective measures to control pathogenic pollutants in food products (Qatar Tribune, 2022).

Challenges in implementing these monitoring programs may stem from insufficient funding, a lack of scientific expertise needed for data analysis and interpretation, inadequate training, and limited access to necessary equipment and reagents (Benaboud *et al.*, 2021; FAO, European Union and CIRAD, 2022; Jallow *et al.*, 2017c; Mohammadzadeh *et al.*, 2022; Nasreddine *et al.*, 2016; Osaili *et al.*, 2022).

4.5.4.3 Laboratory infrastructure and analytical resources

According to the International Laboratory Accreditation Cooperation (ILAC), several regional and national accreditation bodies (ABs) are signatories to the Mutual Recognition Arrangement (MRA) of the ILAC as accredited providers of facilities for testing and inspection bodies.

The availability of food-testing services in the NENA region are diverse (Table 16), and most laboratories are government-owned. Some of these laboratories are sufficiently equipped and accredited according to ISO/IEC 17025 international standard, however, unaccredited laboratories in most NENA countries are still designated by official food control authorities to provide testing services. The exact number of accredited food testing laboratories in the NENA region isn't readily available from a single source.

Several official laboratories in the region have made significant contributions to food safety and quality through their technical competencies, broad scope of testing services, implementation of internationally recognized quality management systems, and use of advanced technologies. Among these, the Central Laboratory of Residue Analysis of Pesticides and Heavy Metals in Food (QCAP Lab) in Egypt has been recognized as a Reference Laboratory by the African Union (AU) since 2019 for its expertise in analyzing pesticide residues and heavy metals in food. The Animal Health Research Institute (AHRI) in Egypt serves as a designated Reference Laboratory for scientific and technical matters related to foodborne diseases and zoonoses. The Dubai Central Laboratory (DCL) has also established a strong presence at both regional and international levels.

However, few qualified accredited laboratories have been found to cover the required scope of chemical residue and contaminants testing. There is a notable shortage in the number of accredited laboratory facilities capable of performing a wide range of chemical and biological tests. Competencies and capacities vary when it comes to testing for pesticide residues, heavy metals, mycotoxins, dioxins, food additives, antibiotics, marine biotoxins, food viruses, and food processing hazards at low concentrations to meet statutory limits. This is compounded by a lack of trained personnel to conduct such laboratory measurements (Al-Riyami *et al.*, 2018). There is also a deficiency in test laboratories in key geographical areas, and in industrial zones, areas with large clusters of food factories/establishments, and at national borders and customs checkpoints.

Table 16. National/regional accreditation bodies and number of accredited food testing laboratories in NENA

Country	National AB	Membership #	No. of official accredited food test labs *
Algeria	Algerian Accreditation Body **(ALGERAC)**	ILAC, AFRAC	>5
Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, UAE, Yemen	GCC Accreditation Center **(GAC)**	ILAC, ARAC	>30
Egypt	Egyptian Accreditation Council **(EGAC)**	ILAC, ARAC, AFRAC	>40
Iraq	Iraq National Accreditation Center **(IRNAC)**	ILAC Associate, ARAC	Data not attainable
Jordan	Joran Accreditation and Standardization Systems – Accreditation Unit **(JAS)**	ILAC, ARAC	>10
Kuwait	Kuwait Accreditation System (KAS) - Public Authority for Industry (PAI) **(KAS-PAI)**	ILAC Associate, ARAC	>5
Lebanon	Industrial Research Institute **(IRI)**	ILAC Stakeholder	>5
Libya	Libyan Accreditation Unit **(LIBAC)**	ARAC	Data not attainable
Mauritania	Direction de la Normalisation et de la Promotion de la Qualité **(DNPQ)**	ARAC	Data not attainable
Morocco	Moroccan Accreditation Service **(SEMAC)**	ILAC, AFRAC	>15; incl. 8 ONSAA branch Labs
Oman	Accreditation Unit Directorate General for Standards and Metrology Ministry of Commerce and Industry	ARAC	3; incl. Oman's central laboratories
Palestine	Palestinian Accreditation Laboratory Committee **(PALAC)**	ARAC	Data not attainable
Saudi Arabia	Saudi Accreditation Center **(SAAC)**	ILAC, ARAC	>20; incl. 4 SFDA central labs
Sudan	Sudanese Accreditation Council **(SDAC)**	ILAC, AFRAC	2
The Syrian Arab Republic	-	-	Data not attainable
Tunisia	Tunisian Accreditation Council **(TUNAC)**	ILAC, AFRAC	>20
United Arab Emirates	Emirates International Accreditation Center **(EIAC)**	ILAC, ARAC	>20; incl. Central Testing Lab (CTL), Dubai Central Laboratory (DCL), and ADAFSA Labs
	Emirates National Accreditation System **(ENAS)**	ILAC, ARAC	
Yemen	Yemeni Accreditation Unit YAU Yemen Standardization, Metrology and Quality Control Organization **(YSMO)**	ARAC	Data not attainable

Source: Created by Moustapha.

International Laboratory Accreditation Cooperation (ILAC), Regional Arab Accreditation Cooperation (ARAC), African Accreditation Cooperation (AFRAC).

* Tentative.

The designated laboratories involved in the formal control of fishery products need to be accredited according to ISO/IEC 17025 with regards to testing for heavy metals (Cadmium, Lead, and Mercury), dioxins, marine toxins, polychlorinated biphenyls (PCBs), histamine (as outlined in section 4.5.3, and Table 15). This issue has been highlighted in several EU audit reports on Tunisia, Oman, Algeria, Morocco, and Mauritania. The audits raised questions about the competency of test laboratories and the application of non-validated analytical methods for testing (Table 15).

Public health authorities often struggle with inadequate laboratory resources, despite some research institutions possessing modern equipment and specialized technical expertise (Todd, 2016). These deficiencies in laboratory capacity directly impact the feasibility of implementing monitoring plans and field investigations, leading to underreporting and a scarcity of official data on causative agents. As a result, incidents go unreported and are perceived as commonplace (Todd, 2017; Moumni Abdou *et al.*, 2019). Consequently, the burden of FBDs is generally underestimated, and the actual incidence rate is inadequately reflected in national food safety strategies. These factors hinder the rapid identification and tracking of causative agents (AL-Eitan, Sendyani, and Alnemri, 2023; Davedow *et al.*, 2022).

There have been initiatives to enhance analytical capabilities in the detection of chemical hazards, including antimicrobial and pesticide residues (Sasanya and Karar, 2021). The United Arab Emirates has invested in upgrading its laboratory food analysis techniques, introducing new methods and equipment for the rapid testing of food pathogens, and implementing software programs to manage and communicate the results (Faour-Klingbeil, Al-Busaidi, and Todd, 2022). Furthermore, efforts have been taken to enhance testing capacities through training initiatives focussing on advanced techniques such as Pulsed-Field Gel Electrophoresis (PFGE) and Whole Genome Sequencing (WGS) (Oman Ministry of Health, 2019; PulseNet International, 2019).

According to the International Health Regulations (IHR)[4] core capacity index, Kuwait, Oman, Qatar, and the United Arab Emirates achieved the highest scores in core capacity laboratories, which reflects compliance with the obligations, procedures, and requirements for the detection of priority diseases for public health through accurate and timely diagnosis. Other laboratories in the region urgently need to enhance and sustain their capacities for appropriate confirmation of diseases for public health events (WHO, 2018b; WHO, 2017e; WHO, 2017d; WHO, 2017c; WHO, 2017b; WHO, 2017a).

The establishment of the NENA Food Laboratory Database is necessary for building a network of accredited laboratories, which will improve the reliability, comparability, and harmonization of test results generated by the official laboratories across the NENA region.

4.5.4.4 Communication flows and information sharing with stakeholders

Strategic partnerships and the exchange of information play a crucial role in the efficient detection of food safety threats and outbreaks. Effective information sharing, as an integral part of risk communication, requires transparency and collaboration among all stakeholders to address and rapidly respond to food outbreaks and food-related incidents.

[4] The International Health Regulations (IHR) are an international legal instrument that covers measures for preventing the transnational spread of infectious diseases.

Collaborative exchanges of information between national food safety authorities, the private sector, and consumer organizations are not common. This deficiency hampers the ability of CAs and stakeholders to effectively identify emerging risks, monitor the incidence of FBDs, and implement evidence-based policies to protect public health. Moreover, food safety CAs and local authorities face significant limitations in fulfilling their mandates related to risk assessment and the adoption of science-based approaches due to their inability to share critical data effectively through the entire food supply chain (ERF, 2020).

The institutional framework for producing and disseminating official statistics and information related to food emerging risks, food safety, incidence of FBD, regulatory actions, and guidance for industries and consumers remains generally weak in many countries.

Recent discussions at a UN ESCWA meeting underscored the vital need for robust data and information exchange systems in many regional countries (UN ESCWA, 2023). According to a significant majority of forum participants, governments and policymakers should be the key players driving any transition toward more resilient agrifood systems. However, several barriers hinder effective stakeholder collaboration, with forum polls suggesting power imbalances and competing interests being the key barrier (62 percent), followed by a lack of trust (32 percent). These figures are outcomes of polls conducted during the forum and remain unpublished.

Consequently, a notable scarcity of official risk assessment data exists in the region, mirroring the limited availability of diverse socioeconomic statistics.

Almost all countries in the NENA region are members of several global food safety warning and alert networks that promote the rapid exchange of information during food safety related events, control outbreaks, and help countries strengthen their capacity to manage food safety emergencies. NENA countries are members of the FAO/WHO International Food Safety Authorities Network (INFOSAN) and Global Outbreak Alert and Response Network (GOARN), and the GCC Rapid Alert System for Food (G-RASF) was developed to enhance regional communication and connection across the national authorities of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates (FAO/WHO INFOSAN. n.d.; Savelli *et al.*, 2021) (Table 17, Figure 16).

Nevertheless, the absence of independent statistical offices and the monopolization of data collection by the state hinder the involvement of non-governmental actors in data collection processes. Political motivations often influence the methodology employed for data collection, leading to a lack of disaggregated data below the regional level and the concealment of regional disparities. Furthermore, statistical offices face challenges in attracting highly qualified human resources, resulting in a varying quality of traditional statistical products. Consequently, the integration of the One Health Approach is lagging behind current pressing needs amidst the rising challenges in food safety (WHO EMRO, n.d.).

One of the challenges in participating in and addressing food safety events in INFOSAN is the scarcity of resources and infrastructure (Savelli & Mateus, 2023).

Of the laboratories surveyed within the PulseNet Middle East countries (Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Occupied Palestinian Territory, Qatar, and the United Arab Emirates), only half of the responding laboratories make their sequencing data publicly available. Data is often unavailable to the public due to legal and policy restrictions, lack of time and personnel, and concerns about personal data and privacy protection.

In contrast, the majority of available sequences are contributed by the United States of America and the EU, while Bahrain, Jordan, Lebanon, the United Arab Emirates, Libya, Morocco, Oman, and Qatar have null data representation (Davedow *et al.*, 2022).

In addition, some NENA countries face significant challenges with various animal and aquatic diseases. However, the actual occurrence and potential threats posed by these diseases often go underreported in immediate notifications to the WOAH/OIE, primarily due to the reluctance of countries in the region to notify endemic diseases out of concerns about trade implications (WOAH/OIE, 2019).

Frequently, healthcare authorities in the EMRO, which includes many of the NENA countries, acknowledge the presence of human cases, which creates challenges for these agencies in determining the spread of the disease and its progression, and in determining effective control measures across various contexts (WHO EMRO, n.d.).

Table 17. NENA countries in global warning and alerting platforms

Country	Membership #		
	INFOSAN	GOARN	G-RASF
Algeria	✓	Institut Pasteur (IP), Algeria	
Bahrain	✓	-	✓
Egypt	✓	CDC Egypt Country Office, NAMRU-3. Naval Medical Research Unit, NAMRU-3. WHO Regional Office for the Eastern Mediterranean (EMRO).	
Iraq	✓	-	
Jordan	✓	Eastern Mediterranean Public Health Network (EMPHNET). Jordan Center for Disease Control. Jordan Food and Drug Administration.	
Kuwait	✓	-	✓
Lebanon	✓	American University of Beirut Medical Center. Ministry of Public Health. Faculty of Public Health - Lebanese University.	
Libya	✓		
Mauritania	✓	Le Centre National des Opérations d'Urgence en Santé Publique (CNOUSP), Mauritania.	
Morocco	✓	Directory of Epidemiology and Control Diseases (DELM) / MOH Morocco. Institut Pasteur (IP), Morocco.	
Oman	✓	Directorate General for Disease Surveillance and Control, Ministry of Health Oman.	✓
Palestine	✓	-	
Qatar	✓		✓
Saudi Arabia	✓	King Abdulaziz Medical City, National Guard Health Affairs.	✓
Sudan	✓	Ministry of Health Sudan, National Public Health Laboratory (NPHL).	

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Country	Membership #		
	INFOSAN	GOARN	G-RASF
The Syrian Arab Republic	✓	-	
Tunisia	✓	Institut Pasteur (IP), Tunis.	
United Arab Emirates	✓	Abu Dhabi Public Health Center (ADPHC). Ministry of Health and Prevention United Arab Emirates, Emergency - Crisis - Disaster Operations Center.	✓
Yemen	✓	-	

Source: Created by Moustapha.

International Food Safety Authorities Network (INFOSAN), Global Outbreak Alert and Response Network (GOARN), GCC Rapid Alert System for Food (G-RASF).

The lack of transparency in promptly notifying the WHO, INFOSAN, or other international organizations responsible for investigating and effectively responding to emerging zoonotic infections, food safety outbreaks, and public health events in the interest of global health security, has been repeatedly raised.

Enhancing early warning capabilities and capacities for food safety in the region requires continuous and effective coordination and communication among multiple sectors and stakeholders across all steps of the early warning process, from the identification of an initial early warning signal to the subsequent actions and responses.

Figure 16. INFOSAN as a network of networks

Source: Adopted from FAO/WHO INFOSAN.

Regional Rapid Alert Networks can serve to strengthen INFOSAN as an important source of food safety intelligence. Complementarity of such systems is encouraged to avoid the creation of duplication and parallel communication tracks, especially during food safety emergencies. In November 2024, the inaugural INFOSAN regional meeting for the WHO East Mediterranean and

FAO Near East and North Africa regions was convened to enhance intra-regional collaboration for improved preparedness and effective management of food safety incidents. A key recommendation from this meeting was the development of a regional FAO/WHO INFOSAN strategy, detailing priority actions for 2025-2030. This strategy aims to align with the global targets set by the WHO Global Strategy for Food Safety 2022-2030 and the FAO Food Safety Priorities 2022-2031 (EMRO, n.d.).

4.5.5 Inclusive strategies and multisectoral partnerships under the One Health approach

In principle, the extent of pressures exerted on the food chain is inextricably linked to the broader environment and geopolitical factors. This relationship emphasizes the necessity for a holistic approach to mitigating their adverse effects by adopting comprehensive strategies for environmental preservation, sustainable agricultural practices, and institutional reforms. Only through concerted multi-sectoral efforts can the vicious cycle be broken and solutions to food safety issues evolve and be sustained.

There has been some progress in recognizing the importance of collaboration, for instance, several NENA countries such as Qatar, the United Arab Emirates, Tunisia, and Bahrain, have initiated measures within the framework of the One Health approach to address challenges to food safety while safeguarding food safety and ensuring sustainable agricultural practices. Nevertheless, the coordination remains weak, insufficient, and often informal (WHO, 2017a, 2017b, 2017c, 2017d, 2017e).

Promoting multisectoral collaboration in the region is generally deterred by siloed thinking, resistance to adopting multisectoral perspectives, limited understanding of its importance, and a lack of awareness about the broader determinants of health (El-Jardali, Fadlallah, and Daher, 2021).

This is evident in the prevailing approach of most governments, who operate in isolated sectors whilst addressing the impacts of climate change on water scarcity and water quality through various interventions and policies. Some of these measures include enhanced wastewater treatment to augment freshwater supplies and recycling to reduce pollution.

Governments are also strengthening water-related regulations and laws to promote responsible water management. For instance, Egypt and Tunisia have updated their water and irrigation laws to improve water governance and combat industrial waste and other forms of pollution. However, the emphasis within the political, economic, and managerial spheres remains predominantly on the quantity of available water, with limited attention directed towards the critical aspect of water quality in numerous NENA countries (FAO, 2022e; World Bank, 2018b; FAO NERC, 2014; Qureshi, 2020; FANACK, 2017).

Inadequate sanitation infrastructure, particularly in rural areas, and inadequate maintenance of existing facilities are prevalent issues in the region. This results in discharged effluents that are generally unsuitable for reuse in agriculture. Furthermore, the lack of reliable and transparent data on water quality poses a challenge to the assessment of the viability of reclaimed water for irrigation (GIZ, 2016; FAO, 2022e).

The institutional fragmentation in water governance, subpar policies, limited participation of the health sector and non-state and informal actors in decision-making processes and overlapping

responsibilities, collectively hinder the application of effective solutions and policies in the region (Haddaoui and Mateo-Sagasta, 2021). This reality stands in direct contrast with the tenets of the One Health approach and raises legitimate doubts about the maturity of systems and the ability of many countries to embrace the risk analysis paradigm and the One Health approach of managing food safety risks.

It takes an in-depth examination of the water, agriculture, political, and health policies of each country to identify food safety issues and devise solutions at the grassroots level. To then be able to adapt solutions in priority areas, it is necessary to gain insight into the practical implementation of these policies, to gauge the commitment of all stakeholders up to decision-makers in advancing shared values and vision, and to foster accountability, transparency, and partnerships among entities in the public and private sector. Finally, it is important to evaluate the extent to which the current measures embedded within these policies account for the risks associated with water, soil, and air contamination within the food chain.

4.5.6 Adoption or adaptation of sanitary and phytosanitary (SPS) measures

Over the last decade, many countries, like the GCC states, Egypt, Jordan, Morocco, and Tunisia, have made efforts to adopt international standards, principally using the Codex Alimentarius Commission (CAC) as the basis for setting their national food standards, guidelines, and code of practice by their national standardization bodies (Table 18).

Under the WTO SPS Agreement, SPS measures encompass all laws, decrees, regulations, requirements, and procedures that are directly related to food safety. These measures also include mandatory standards addressing chemical and microbial contaminants, pesticide or veterinary drug residues in food, as well as certification and labelling requirements specifically related to food safety, such as those for food allergens. The SPS Agreement explicitly cites Codex Alimentarius standards as benchmarks for food safety and encourages harmonization with Codex standards.

Table 18. National standardization bodies and their membership in regional and international standardization communities

Country	Standardization body	Year established	Membership				
			ISO#	GSO#	SMIIC#	AIDMO#	ARSO#
Algeria	Institut Algérien de Normalization (IANOR)	1998	✓		✓	✓	✓
Bahrain	Bahrain Standards and Metrology Directorate (BSMD)	1988	✓	✓		✓	
Egypt	Egyptian Organization for Standardization & Quality (EOS)	1957	✓		✓	✓	✓
Iraq	Central Organization for Standardization and Quality Control (COSQC)	1979	✓		✓	✓	
Jordan	Jordan Standards and Metrology Organization (JSMO)	1972	✓		✓	✓	

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Country	Standardization body	Year established	Membership				
			ISO#	GSO#	SMIIC#	AIDMO#	ARSO#
Kuwait	Public Authority for Industry (PAI)	1967	✓	✓	✓	✓	
Lebanon	The Lebanese Standards Institution (LIBNOR)	1962	✓		✓	✓	
Libya	Libyan National Centre for Standardization and Metrology (LNCSM)	1991	✓		✓	✓	✓
Mauritania	Direction de la Normalisation et de la Promotion de la Qualité - Mauritanie (DNPQ)		✓		✓	✓	
Morocco	Institut Marocain de Normalisation (IMANOR)	2006	✓		✓	✓	✓
Oman	The Directorate General for Standards and Metrology (DGSM)	1976	✓	✓		✓	
Palestine	Palestine Standards Institution (PSI)	1996	✓		✓	✓	
Qatar	Qatar General Organization for Standardization (QS)	2002	✓	✓	✓	✓	
Saudi Arabia	Saudi Standards, Metrology and Quality Organization (SASO)	1972	✓	✓	✓	✓	
Sudan	Sudanese Standards and Metrology Organization (SSMO)	1993	✓		✓	✓	✓
Syrian Arab Republic	Syrian Arab Organization for Standardization and Metrology (SASMO)	1969	✓			✓	
Tunisia	Institut National de la Normalisation et de la Propriete Industrielle (INNORPI)	1982	✓		✓	✓	✓
United Arab Emirates	Ministry of Industry and Advanced Technology (MOIAT)	2020	✓	✓	✓	✓	
Yemen	Yemen Standardization Metrology & Quality Control Organization (YSMO)	2000	✓	✓	✓	✓	

Source: Created by Moustapha.

International Organization for Standardization (ISO), Standards and Metrology Institute for Islamic Countries (SMIIC), Gulf Standardization Organization (GSO), Arab Industrial Development and Mining Organization (AIDMO), African Organization for Standardisation (ARSO)

In almost all NENA countries, national Codex committees have been set up within their standardization bodies. However, due to limited resources and insufficient technical capacity, these committees face challenges in fully participating in the meetings of Codex technical committees (FAO, 2020a). As a result, the food standards, and regulations in several countries in the region do not completely align with the Codex Alimentarius and the provisions of the WTO SPS and TBT agreements.

Table 19. Information on membership of NENA countries in the Codex and WTO

Country	Membership		
	Codex Alimentarius	Codex region #	WTO
Algeria	Since 1970	CCNE	In accession process (1987)
Bahrain	Since 1981	CCNE	1995
Egypt	Since 1972	CCNE, Observer in CCAFRICA	1995
Iraq	Since 1969	CCNE	In accession process (2004)
Jordan	Since 1966	CCNE	2000
Kuwait	Since 1964	CCNE	1995
Lebanon	Since 1970	CCNE	In accession process (1999)
Libya	Since 1972	CCNE	In accession process (2004)
Mauritania	Since 1996	CCAFRICA	1995
Morocco	Since 1968	CCAFRICA	1995
Oman	Since 1972	CCNE	2000
Palestine	-	-	-
Qatar	Since 1971	CCNE	1996
Saudi Arabia	Since 1968	CCNE	2005
Sudan	Since 1968	CCNE	In accession process (1994)
The Syrian Arab Republic	Since 1968	CCNE	In accession process (2010)
Tunisia	Since 1965	CCNE	1995
United Arab Emirates	Since 1972	CCNE	1996
Yemen	Since 1988	CCNE	2014

Source: Created by Moustapha.

FAO/WHO Coordinating Committee for Near East (CCNE), FAO/WHO Coordinating Committee for Africa (CCAFRICA).

FAO, in collaboration with several countries in the region, has organized several training workshops to support their national Codex systems and to raise awareness of the Codex program. The workshops provide training on Codex program organizational structure, work procedures, and the role of Codex Contact Point. FAO also supports the effective participation of different sectors in the Codex activities at both the national and international levels (FAO 2015-2023).

The Arab Codex Initiative is an ongoing program in the NENA region that endeavours to enhance Codex competencies and to facilitate effective preparation and contribution to Codex Technical Committees and the Executive Committee (GFORSS, 2023). Its goals include promoting effective participation of the region's delegations in international food standard-setting activities and maximizing the reliance of Arab countries on Codex standards for the establishment of national food regulatory requirements. According to the Arab Codex Initiative outputs, government representatives lack technical skills and accessibility to information, hence academic experts are often called upon to participate in national committees.

Moreover, the Arab Codex Initiative highlighted the need for a mechanism to assist countries in adapting or adopting the Codex standard in national legislation, as well as for training and capacity building, to ensure best practice and adherence to rules with regard to representing countries in Codex meetings.

Sixteen countries in the NENA region are members of the FAO/WHO Coordinating Committee for the Near East (CCNE), while Mauritania and Morocco are members of the FAO/WHO Coordinating Committee for Africa (CCAFRICA) (Table 19). Only a few regional Codex standards were developed (Table 20).

Table 20. Regional food standards issued by NENA countries

Reference	Title	Committee	Last modified
CXC 71R-2013	Regional Code of Practice for Street-vended Foods (Near East)	CCNE	2013
CXG 58R-2005	Regional Guidelines for Codex Contact Points and National Codex Committees (Near East)	CCNE	2005
CXS 257R-2007	Regional Standard for Canned Humus with Tehena (Near East)	CCNE	2007
CXS 258R-2007	Regional Standard for Canned Foul Medames (Near East)	CCNE	2007
CXS 259R-2007	Regional Standard for Tehena (Near East)	CCNE	2007
CXS 308R-2011	Regional Standard for Harissa (Red Hot Pepper Paste) (Near East)	CCNE	2011
CXS 309R-2011	Regional Standard for Halwa Tehenia (Near East)	CCNE	2011
CXS 314R-2013	Regional Standard for Date Paste (Near East)	CCNE	2013
CXS 332R-2018	Regional Standard for Doogh (Near East)	CCNE	2018
CXS 341R-2020	Regional Standard for Mixed Zaatar (Near East)	CCNE	2020
CXG 22R-1997	Regional Guidelines for the Design of Control Measures for Street-Vended Foods (Africa)	CCAFRICA	1999
CXG 43R-2003	Regional Guidelines for Codex Contact Points and National Codex Committees (Africa)	CCAFRICA	2003
CXG 98-2022	Guidelines for Developing Harmonized Food Safety Legislation for the CCAFRICA Region	CCAFRICA	2022

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CXS 325R-2017	Regional Standard for Unrefined Shea Butter (Africa)	CCAFRICA	2022
CXS 334R-2020	Regional Standard for Fermented Cooked Cassava-based Products (Africa)	CCAFRICA	2022
CXS 335R-2020	Regional Standard for Fresh Leaves of *Gnetum spp.* (Africa)	CCAFRICA	2022
CXS 350R-2022	Regional Standard for Dried Meat (Africa)	CCAFRICA	2022

Source: Created by Moustapha.

In addition, except for Bahrain and The Syrian Arab Republic, most NENA countries are members of the Standards and Metrology Institute for Islamic Countries (SMIIC). SMIIC members issued about 17 regional standards with a focus on "Halal Food," including requirements, inspection, certification, testing, trading, and the requirements of halal accreditation bodies. Moreover, SMIIC issued a regional standard for the specifications and testing methods for dates.

4.5.6.1 Trade and economic integration within the NENA region

The NENA region encompasses 19 nations (as of 2024), all of which are members of the League of Arab States (LAS). The regional Pan-Arab Free Trade Agreement (PAFTA) (also referred to as the Greater Arab Free Trade Agreement [GAFTA]) was ratified in 1997 with the aim of (1) reducing trade barriers and increasing intra-regional trade, (2) exploiting comparative advantages and economies of scale among the countries, which leads to higher productivity, and (3) promoting increased competition within domestic markets aims at enhancing product variety and quality and lowering prices for consumers.

The PAFTA currently encompasses approximately 95 percent of the trade among its member countries and 96 percent of its members' trade with the outside world. The PAFTA primarily focuses on rules of origin, customs procedures for import and export, and tariffs, and is the most recent comprehensive trade agreement, which includes provisions related to the WTO SPS and WTO TBTagreements.

In parallel, the number of bilateral and multilateral free trade agreements in the region has increased. Morocco, Egypt, Jordan, and Tunisia concluded the Agadir Agreement in 2004. Egypt, Libya, Mauritius, the Sudan, and Tunisia are member states of the Common Market for Eastern and Southern Africa (COMESA), and recently, Egypt, Saudi Arabia, and the UAE have confirmed they are joining the BRICS. Implementation of these agreements remains rather challenging in terms of compliance with the food safety measures and controls imposed by the trade partners.

Trade liberalization in the NENA region can stimulate further momentum through various levels, including bilateral, regional, and multilateral agreements. This will in turn enhance economic cooperation and foster greater integration among the countries in the region.

So far, only 12 NENA countries are full members of the multilateral trading system of the WTO (Table 19). Lebanon, Tunisia, Egypt, and Morocco are parts of multilateral and bilateral trade agreements, e.g. EuroMed treaties and, the European Free Trade Association (EFTA), which facilitates support from USAID and EU-funded projects aimed at enhancing their SPS measures and initiating legislative reforms to ensure the effective implementation and operationalization of new food safety laws (USDA, 2022).

Another significant initiative was the signing of a Memorandum of Understanding (MOU) between the German Institute for Risk Assessment (BfR) and the Moroccan Food Safety Authority (ONSSA), with a view to enhancing cooperation between the two authorities. Morocco, as a key trading partner for Germany in North Africa, is at the centre of this collaboration (BfR, 2021). The BfR particularly values the effective harmonization and standardization of international risk assessments for food products, especially in relation to plant protection products (e.g. pesticides), and risk communication during foodborne disease outbreaks. Collaboration has led to the development of novel molecular-based methods for quantitative detection of *Campylobacter spp.* across food chains (BfR, 2021; BfR, 2022).

The SAFE initiative links into the regional standard harmonization efforts coordinated by the LAS, AIDMO, UNIDO, and the Arab Organization for Agricultural Development (AOAD). At the regional level, the SAFE Initiative was expected to strengthen AIDMO's and AOAD's technical and regional coordination capacities for the planning, implementation, and management of a harmonized regional food control system using best practices and by following regionally harmonized policies and protocols. UNIDO also funded participants in the meetings of the Arab Task Force and its Expert Working Groups by selecting stakeholders in the private sector, consumers, and academics. UNIDO's support was chiefly related to issues that need to be addressed in an SPS annex to the PAFTA agreement for facilitating the trade of food products that are safe for human consumption across borders. The five priority areas were addressed by the ATF based on the needs of the region and include the risk assessment system, inspection and certification systems, the Arab Rapid Alert System for Food and Feed (ARASFF), country needs assessments, and Codex Alimentarius Coordination.

In Egypt, efforts continue to support the NFSA in assuming its role in setting technical regulations. USDA supports NFSA through the 'Transforming the Assessment and Inspection of Food Businesses' (TAIB) project in Egypt and by expanding the domestic and international trade of Egyptian food products. Between 2018 and 2025, the TAIB project aligned food safety and quality regulations, improved inspection, and rapid response planning, and raised consumer and industry awareness to expand the domestic and international trade of Egyptian food products.

TAIB is working in close collaboration with the NFSA and other key stakeholders to ensure a successful transition to a modern food safety system. Through its efforts, the project is harmonizing Egyptian food law and alignment with international standards, supporting the implementation of robust inspection systems, strengthening NFSA's workforce, promoting the usage of science-based risk assessments following the SPS Agreement, and facilitating trade (USDA TAIB).

USAID provides another support line to Egypt through its Trade Reform and Development in Egypt (TRADE) project, which seeks to increase exports from and foreign direct investment in Egypt. It aims to improve trade and investment policy whilst reducing trade barriers, with the goal of boosting exports and driving economic growth.

Through technical advisory services, demand-driven technical assistance, and food safety training, the project helps enterprises access new markets and comply with international requirements. USTRADE also provides training to Egypt's NFSA and aids in the development of food safety policy

recommendations to support Egypt's compliance with international trade agreements (US Trade).

Thus far, there have been limited efforts to fully empower the role of risk assessment agencies such as NFSA, SFDA, and JFDA. The coordination and engagement of scientific communities, whose expertise within the local context can complement external expertise and provide scientific guidance, are instrumental and not harnessed yet. During the recent meeting of the GFORSS's Second Arab Codex Colloquium (2023), representatives from various countries reached a consensus on the crucial importance of harnessing multisectoral collaboration, including academia. They emphasized the pressing need for targeted scientific research programs and data generation to gain insights into food safety risks and develop appropriate strategies for risk mitigation.

Such programs are of paramount importance in the context of SPS measures, as they not only facilitate international trade but also foster cooperation and knowledge exchange between countries.

In May 2023, the FAO-RNE hosted a Regional Workshop in Amman, Jordan, titled "Enhancing Food Trade in the Near East and North Africa: Food Safety and Trade Facilitation". Representatives from 13 countries shared case studies and best practices on trade-related food safety to boost intra-regional trade. The workshop highlighted the need for harmonized food quality and safety standards and proposed establishing a Regional Cooperation Platform for NENA member states. This platform aims to facilitate dialogue, information sharing, and coordination on food safety and quality standards, enhance inspection and certification processes, improve finance and investment in technology transfer, build inspector capacity, and strengthen public-private partnerships for targeted investment plans.

4.5.2 Drivers-related responses

4.5.2.1 Integrated water management and effective water reuse policies

Integrated water resources management and effective water reuse policies are essential for sustainable resource use in the NENA region. The growing issue of water scarcity has compelled many agricultural systems to recycle or reuse contaminated water sources, thereby raising the risk of waterborne illnesses. Implementing treatment processes such as sludge separation, oxidation, and chlorination can help reduce contaminants in recycled water, mitigating these risks (FAO, 2024d).

Although Arab countries have made strides in water resource management, these efforts are insufficient given the scale of the challenge. To address food and water security, FAO RNE and its partners have launched initiatives like the Water Scarcity Initiative (WSI) and a "Partnership Pledge" to support collaborative strategies such as the Arab Strategy for Water Security (2010-2030) and the Strategy for Sustainable Arab Agricultural Development (2005-2025). Part of these initiatives is to maximize the use of safe treated wastewater and other non-conventional water sources in agriculture and industry, reducing pressure on freshwater resources. Countries like Oman, Saudi Arabia, Jordan, Egypt, and Occupied Palestinian Territory have implemented regulations and setting safe levels of water-borne parameters, focusing on ensuring the safety and quality of the water used in agriculture (FAO NERC, 2024; Qureshi, 2020; FAO, 2022g; Qadir et al., 2010; WHO, 2022).

4.5.2.2 Adaptive measures and early warning systems for food safety

Early warning and foresight systems are playing a vital role in identifying and addressing emerging food safety issues before they escalate into widespread food outbreak and crises. These systems utilize a combination of big data collection, analysis, and predictive modelling to provide timely alerts and forecast outbreaks of foodborne illnesses or contamination events by monitoring indicators such as weather patterns, crop health, and market trends. Early warning and foresight require leveraging advanced technologies like artificial intelligence (AI) and machine learning to analyse the collected data and predict potential food safety issues (FAO, 2023f; FAO, 2022c; FAO, 2022g; FAO, 2015a).

Enhancing these systems requires robust infrastructure for big data collection and continuous coordination among multiple sectors and stakeholders. By providing reliable data and forecasts, early warning systems support informed decision-making at various levels, enabling quick action to mitigate risks and improve control measures. Implementing such systems can significantly reduce the risk of food safety incidents and ensure a safer food supply chain (FAO, 2023f; FAO, 2015a). The FAO has released a technical background report on early warning tools and systems for emerging food safety issues. This report aims to support the adoption of effective measures to mitigate potential risks from various hazards (FAO, 2023f).

Global early warning systems for food safety encompass open access tools and methods for monitoring hazards and enhancing controls. Examples include MedISys-FF, which combats food fraud, and the SGS DIGICOMPLY digital platform, which continuously scans and monitors big data such as regulations, food safety, supply chain information, and consumer perceptions. Additionally, food safety management software - covering traceability, regulatory compliance, audit trails, incident reporting, and corrective actions - can serve as comprehensive solutions for establishing early warning systems (FAO, 2023f).

Several countries in NENA region have implemented early warning applications and systems at the food establishment level to better understand and forecast supply chain risks. UAE, Bahrain, and Egypt have modernized their Customs administration by integrating advanced algorithm-based AI and machine learning technologies to optimize risk-based food control, streamline procedures, and facilitate cross-border food trade. Additionally, the Gulf Cooperation Council Rapid Alert System for Food and Feed (G-RASFF) was exploited to enable rapid communication among GCC members regarding risks to consumer health from food and food contact materials (FAO, 2023f).

However, key barriers to uptake of these tools still exit. This includes lack of coordination between agencies, insufficient financial, human, and material resources, and challenges related to data accessibility, quality, and integration. Technical obstacles encompass a lack of applied technologies, limited internet access, and inadequate monitoring of foodborne hazards. Effective management of food safety risks at both national and international levels requires collaboration among researchers, authorities, and policymakers (FAO, 2023f; FAO, 2022c; FAO, 2015a).

4.5.2.3 Sustainable urban agriculture practices for safer and more resilient agrifood systems

Agrifood systems should be viewed as integrated entities encompassing both rural and urban areas. Integrating urban and peri-urban agriculture into city planning and zoning regulations is crucial. FAO is spotlighted its urban agrifood systems initiatives across NENA region, advocating for transformative approaches to urban sustainability and food security. Urban populations in the NENA region projected to rise to 73 percent by 2050, reaching over 450 million people (FAO, 2022e; FAO. 2022g; FAO NERC, 2024). The shift to urban living and industrialized economies has increased the release of pollutants into water, air, and soil. These pollutants encompass pesticides, heavy metals, toxic industrial chemicals, and hazardous wastes (CoSAI, 2022; FAO, 2019d; Miller et al. 2016).

The FAO addresses the urgent need for cities to adopt sustainable urban agrifood frameworks and best practices, enhancing food safety within urban areas, local food markets, and food distribution systems (FAO NERC, 2024; FAO, 2019d; Maurizio Aragrande et al).

By providing technical support and guidance, the FAO helps local governments implement effective food safety regulations and practices, modernize food supply chains, improve infrastructure, and promote advanced technologies for monitoring and controlling food safety risks in order to ensure that urban populations have access to safe and nutritious food, thereby strengthening overall food security. Egypt, Bahrain, Tunisia, Kuwait, and Jordan have launched initiatives to integrate urban agriculture into city planning and bolstering food safety through modernized food supply chains and infrastructure improvements (FAO/WUF, 2024).

Fostering public-private partnerships is essential to support infrastructure projects, urban markets, and sustainable job creation for SMEs and new urban dwellers. These efforts are key to managing the challenges of rapid urbanization and climate change sustainably (FAO NERC, 2024).

4.5.2.4 Economic reforms to support food safety

Economic reforms and inclusive investment are essential for creating an environment that supports sustainable agrifood systems, prioritizes food safety across the entire supply chain, and promotes a culture of compliance with food safety and quality standards. Developing and implementing policies that promote food safety and quality is vital to address the unique challenges faced commonly by NENA countries, such as limited resources, inadequate food safety infrastructure, and the need for modernization of food control systems.

Educating stakeholders, including farmers, food processors, and consumers, on the importance of adhering to food safety measures is vital for fostering a culture of compliance. Capacity-building programs and workshops are necessary to enhance the knowledge, awareness, and skills of FBOs, enabling them to implement best practices and maintain high standards of food safety. Moreover, advocating for the integration of advanced technologies, such as AI and machine learning, and innovation to optimize food safety monitoring, control, and timely detection of food safety risks is paramount for swift action to mitigate potential food hazards.

Through technical support, education, the integration of advanced technologies, and Public-Private Partnerships, NENA countries require ongoing support and commitment to build a resilient and sustainable agrifood system that prioritizes the safety, health, and well-being of their populations

(FAO NERC, 2024). A recent FAO publication in the NENA region has highlighted various agricultural and food safety related subsidies that contribute to the development of more resilient and sustainable agrifood systems in Egypt, Morocco, Saudi Arabia, Tunisia, and the UAE (FAO, 2024c).

4.5.2.5 Anti-corruption policies

Consumers place significant trust in the entire food supply chain, from producers to traders, and in governments to establish and enforce safety standards that protect public health. However, corruption can undermine these safety measures, compromising the government's ability to ensure food safety. Governments need to implement and strictly enforce robust food safety regulations, harmonizing them with international standards, especially in the context of international trade.

Corruption significantly undermines the effectiveness of national food safety measures and control systems, highlighting the necessity of incorporating robust anti-corruption safeguards to protect public health and ensure the integrity of local and international food trade. The design, adoption, implementation, and enforcement of these measures are particularly vulnerable to corruption, which can have severe public health implications if these systems fail (UNODC, 2023).

The food industry's susceptibility to corruption is exacerbated by the often-overlapping responsibilities of various agencies or ministries tasked with food safety and control. Protecting the food industry from the effects of corruption is crucial for safeguarding global public health and the growth of national economies. Corruption at one stage of the food supply chain can impact the entire system. While the majority of stakeholders act with integrity, the profit-driven and competitive nature of the industry can lead some to engage in corrupt practices to maximize profits and reduce competition (UNODC, 2023; Roberts, et al., 2022).

Possible corruption cases may result from companies trying to bypass costly food safety measures, and corrupt actors might influence government decisions through bribery or coercion. Public officials responsible for enforcing SPS measures often face challenges such as limited scientific data, inadequate training on anti-corruption measures and food safety regulations, and insufficient understanding of food production processes, increasing the risk of corruption. The lack of specialized training and expertise among officers responsible for managing food safety measures and controls can hinder their ability to detect and investigate irregularities or failures effectively (UNODC, 2023).

Coordination with food regulatory authorities is vital to establish and enforce robust food safety regulations to prevent corruption in food production and distribution. Several countries in the region, including Saudi Arabia, Lebanon, and Jordan, have enacted various anti-corruption laws and established anti-corruption commissions to ensure the enforcement of integrity and accountability policies. These measures aim to strengthen mechanisms for preventing, detecting, punishing, and eradicating corruption and related offenses in both the public and private sectors. Since 2003, African countries in the NENA region, as Member States of the African Union, have signed the "African Union Convention on Preventing and Combating Corruption" to establish relevant anti-corruption measures, coordinate actions, and harmonize policies and legislation. Commercial fraud laws in NENA countries aim to address issues like mislabelling, adulteration, and counterfeit products including food. These laws are designed to protect consumers and ensure fair competition in the market. However, these measures need further strengthening and harmonization across NENA countries to create a more transparent, accountable, and safe food system. Enforcement can still be challenging due to overlapping responsibilities among various agencies and limited resources.

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5. CONCLUSIONS

There is a substantial disparity between food challenges in the GCC states and other countries in the region. GCC states have taken remarkable strides in reforming food laws and strengthening inter-agency coordination for legislative implementation, embracing modernity, and promoting stability, leadership, and shared values. Conversely, in many other countries, such as Lebanon, the Syrian Arab Republic, Iraq, Yemen, Sudan, Algeria, Libya, Egypt, and Occupied Palestinian Territory, decades of conflicts and civil wars, recurrent anti-government protests, and the destabilization of social, political, and economic systems have eroded the concept of the rule of law and fostered pervasive corruption, a lack of accountability and transparency, and fraud. This renders the challenge of maintaining a safe and resilient food supply chain that is compliant with regulations and fit for purpose in a globalized world especially difficult.

Hence, while achieving robust national food control systems based on an integrated approach may be feasible in some countries, it is realistically unachievable without restoring stability and ending conflicts. This is essential to the development of institutions that foster the rule of law, transparency, and accountability across the food supply chain, and towards achieving sustainable development through inclusive governance.

Experience has shown that well-funded strategic initiatives in, and international support for, capacity-building of the region's public sector, such as food inspector training, risk assessor workshops, and laboratory training, brings substantial benefits to communities. However, they often serve as temporary solutions to persistent problems, and their effects are short-lived. In conjunction with these key international collaborations, sustainable solutions hinge on the fundamental transformation of education systems. Recognizing the pivotal role of innovation in research to advancing food safety programs and science is essential for developing competent personnel and informing policymaking.

In general, the adoption of the risk analysis concept and the integration of a One Health approach in food safety governance is relatively nascent in the region, undermined by the absence of effective intersectoral collaboration, weak institutional frameworks, lack of robust regulatory bodies, a shortage of skilled personnel and resources, and limited conformity assessment capacities. In this context, prioritizing regional food safety issues is intrinsically linked to the political and economic aspects of each country.

Consequently, these issues must be identified, with the engagement of representatives and stakeholders from the respective countries to allow for an in-depth understanding of the intricacy of food safety governance within the One Health approach, and to formulate relevant sustainable and strategic interventions.

A participatory regional analytical approach within a framework of international support offers one example of a viable approach for assessing the level of coordination and communication based on theory of change (ToC) analysis, to foster effective partnerships. The proposed initiative involves several key components:

First, the evaluation of the country's enabling environment involves assessing numerous factors related to institutional mandates, regulations, resources, and capacity. This assessment aims to understand how well the country's systems support sustainable development and other goals. One approach is to facilitate this evaluation in selected countries in the region by using the FAO/WHO Food Control System Assessment Tool (FCSAT), which comprises a set of assessment criteria under 25 system competencies across 4 dimensions.

Second, conducting a food value chain and stakeholder analysis to map the stakeholders engaged in various stages of the value chain, such as the government, nonprofit organizations, private industry, academia, research centres, and community groups. These stakeholders play critical roles in the coordinated production and value-adding activities necessary for creating food products. This involves:

A- Understanding the inclusive food value chains and stakeholders/actors:

- Identify the food Competent Authority(-ies) (CAs), mandates, and the available resources for food control and enforcement, as well as the coordination between CAs and local government for domestic food and other entities that are responsible for food imports, export, and border control.
- Evaluate the linkages between domestic food control systems – including FBOs and consumers.
- Review food handlers' and traders' knowledge of good practices in line with governing technical regulations and employed product standards.

B- Defining mandate roles and responsibilities:

- Determine national inspection program priorities to serve as a verification measure to identify/adjust where controls are required to correct the situation.
- Assess the risk-based food control framework that characterizes, prioritizes, and integrate hazards associated with food type and production/import volume.
- Setting corresponding import risk management measures (e.g. certification, visual inspection, sampling, and analysis).
- Legal actions and criteria for a traceability system throughout the food supply chain are traced back to the farmer, the packing house, and even to the plot (primary production).
- National surveillance and monitoring programs to investigate the levels of contaminants and residues in traded foodstuffs.

C- Identify priority action areas and potential sources of funding, expertise, capacities, and other resources for the following examples:

- Capacity-building programs to train food inspectors, develop inspection manuals, apply standard operating procedures (SOPs), and apply risk-based controls.
- Support NENA countries in adopting sustainable food system concepts in two key areas: food systems and healthy diets.
- Deficient logistics in terms of cold store chains, refrigerated transport systems, and air cargo space, combined with a shortage of knowledge of the post-harvest handling of perishable products from the farm to factory to ports, and consequently high postharvest losses.
- Compliance with the legal acts and the criteria for the traceability system of food supply chains (for both import and export agrifood crops) for effective traced back to the farmer, the packing house, and even to the plot.
- Low capital-to-labour ratios and the need to enhance the use of control technologies.
- Databases and platforms for regional food control measures, customs regulations, border control processes, and food export contaminant levels.
- Investment in research and awareness of exporting countries' requirements, where there is a low level of innovation within the sector and, therefore, a lack of new product compliance.
- Consumer risk assessment studies for both short- (peak) and long-term intakes for food hazards to enhance public awareness and protect their health from adverse effects.
- Building up a database on national and regional food consumption, and collecting dietary surveys, in conjunction with the residue levels found.
- Enhancing efforts to combat and prevent Illicit trade in food and food fraud by highlighting the challenges posed by smuggling, counterfeiting, and other fraudulent practices that undermine the global food system and put public health at risk.
- Tackling innovation in food production: Embracing technology and innovation, using biotechnology in crop development, and exploring sustainable alternatives in food production.
- The development of new food safety and quality standards under Codex principles, including guidelines for controlling certain bacteria in food products, the safe use and reuse of water in food production, principles for the use of remote audits and inspections in regulatory frameworks, responses to emerging global food safety challenges, and addressing issues such as antimicrobial resistance (AMR) in food production.
- Artificial Intelligence (AI) & robotics in food regulation, and their application in product development, supply chain traceability, market trends, consumer preferences, inspection of food establishments. AI-enhanced surveillance systems in food safety programs and the aggregation and analysis of data from various sensors across food production can help ensure food safety, labelling accuracy, traceability, and enforcement actions.
- Research studies in the field of microbiota-friendly diets and tackling the enhancement of gut health will substantially reflect various conditions, including inflammatory bowel disease, type 1 diabetes, obesity, and heart disease.

Third, effective actions by policymakers to create a healthy food environment and develop coherence in national policies and investment plans, including trade, food, and agricultural policies, to promote healthy diets and protect public health.

Fourth, network mapping interconnections with the participation of stakeholders from various sectors will be instrumental in navigating complex political and societal issues. This step aims to uncover barriers and opportunities to enhance multisectoral collaboration by facilitating mutual understanding, alignment, and effective engagement among diverse stakeholders.

To this end, effective communication can be achieved by simulating practical scenarios – for example, the simulation of a real-life food safety crisis – that identify specific problems and flaws, and engaging stakeholders in the public and private sectors to enhance their preparedness for, improve their response to, potential food safety incidents. The initiatives mentioned above not only promote open dialogue and discussion but also contribute to building trust among all parties involved. Additionally, they foster a culture of partnerships and shared responsibilities, which transcends the prevalent silo thinking that often characterizes the region's approach to the implementation of regulations and policies.

Glossary of terms

Term	Definition and description
Agrifood System	Covers the journey of food (for example, cereals, vegetables, fish, fruits, and livestock) from farm to table – including when it is grown, harvested, processed, packaged, transported, distributed, traded, bought, prepared, eaten, and disposed of. It also encompasses non-food products (for example forestry, animal rearing, use of feedstock, biomass to produce biofuels, and fibres) that also constitute livelihoods and all the people as well as the activities, investments, and choices that play a part in making these products.
Antimicrobial Resistance (AMR)	The ability of a microorganism (such as bacteria, viruses, fungi, and parasites) to stop an antimicrobial (such as antibiotics) from working against it.
Certification	The procedure by which a third party gives written assurance that a product, process, or service conforms to specified requirements (as in the ISO/IEC Guide 2:2004).
Climate Change	A change of climate attributed directly or indirectly to human activity that alters the composition of the global atmosphere, in addition to natural climate variability observed over comparable periods.
Carbon Footprint	The carbon footprint of a food product is the total amount of GHG emitted throughout its lifecycle, expressed in kilograms of CO_2-equivalents. Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are GHGs that contribute to global warming and climate change. They are emitted at all stages of the food life cycle.
Codex Alimentarius	Latin for 'food code' It is a code of food standards for all nations, developed by an international commission established in 1962 when the FAO and the WHO recognized the need for international standards to guide the world's growing food industry and to protect the health of consumers. The standards contain requirements for food aimed at "ensuring the consumer a sound, wholesome food product free from adulteration and correctly labelled and presented".
Competent Authority	Government agency or institution responsible for food control, covering food safety and quality as defined in legislation (enforcing the legislation).
Conformity Assessment Procedure	Any procedure used, directly or indirectly, to determine that relevant requirements in technical regulations or standards are fulfilled (as in the WTO/TBT agreement).
Event-based Surveillance	The organized collection, monitoring, assessment, and interpretation of unstructured information about health events that may represent a risk to public health.
Farm-to-Fork	Includes all steps involved in the production, storage, handling, distribution, and preparation of food products.
Food Business Operator (FBO)	The owner of the business or the person in control of the food business, including farmers, food producers, processors, distributors, food service providers, retailers, and wholesalers, as well as suppliers of equipment, technology, and ingredients.

Term	Definition and description
Food Control	A mandatory regulatory activity of enforcement by national or local authorities to provide consumer protection and to ensure that all foods during production, handling, storage, processing, and distribution are safe, wholesome, and fit for human consumption; conform to quality and safety requirements; and are honestly and accurately labelled as prescribed by law.
Food Control System	A system to ensure compliance with regulatory requirements either on food safety or essential food quality characteristics.
Food Fraud Vulnerability	The susceptibility or exposure to a food fraud risk is regarded as a gap or deficiency that could place consumer health at risk if not addressed.
Food Inspection	The examination by an agency empowered to perform regulatory and/or enforcement functions of food products or systems for the control of raw materials, processing, and distribution. This includes in-process and finished product testing to verify conformity with regulatory requirements.
Food Loss and Food Waste	Food loss is the decrease in the quantity or quality of food resulting from the decisions and actions of food suppliers in the chain, excluding retail, food service providers, and consumers. Food waste is the decrease in the quantity or quality of food resulting from the decisions and actions of retailers, food services, and consumers.
Food Policy	All policies that influence agrifood systems and what people eat.
Food Safety	Assurance that food will not cause harm to the consumer when it is produced, prepared, and/or eaten according to its intended use.
Food Safety Culture	Food safety attitudes, values, and beliefs shared by a group of people. It is the product of employee attitudes, beliefs, and behaviours that determine the commitment to and robustness of an organization's food safety management.
Food Supply Chain	Encompasses the entire range of actors and their interlinked activities adding social, cultural, and economic value involved in the production, aggregation, processing, distribution, labelling, marketing, consumption, and disposal of food products. These actors work across the supply-side of a food system.
Food Surveillance / Monitoring	The continuous monitoring of the food supply to ensure consumers are not exposed to components in foods which pose a health risk, such as chemical contaminants and residues or microbiological hazards
Food System Governance	Refers to the institutions, formal and informal rules, regulations, market interventions, coordinated distribution systems, and collective actions through which public and private actors articulate their interests and make and implement decisions. It also refers to the process by which societies negotiate, implement, and evaluate collective priorities while building a shared understanding of synergies and trade-offs among diverse sectors, jurisdictions, and stakeholders.
Foodborne Disease Outbreak	An incident in which two or more people develop a similar illness after ingesting the same contaminated food or drink.
Foodborne Disease Surveillance	The systematic collection, analysis, interpretation, and dissemination of human health data on an ongoing basis, to gain knowledge of the pattern of disease occurrence and potential in a community, to control and prevent disease in the community.
Foodborne Diseases (FBDs)	A wide spectrum of illnesses resulting from ingestion of foodstuffs contaminated with microorganisms or chemicals.
Good Agricultural Practices (GAP)	Practices of primary food producers (such as farmers and fishermen) that are necessary to produce safe and wholesome agricultural food products that conform to food laws and regulations.

Term	Definition and description
Good Manufacturing Practices (GMP)	Conformance with codes of practice, industry standards, regulations, and laws concerning the production, processing, handling, labelling, and sale of foods decreed by industry, local, state, national, and international bodies to protect the public from illness, product adulteration, and fraud.
HACCP System (hazard analysis and critical control point)	A scientific and systematic way of enhancing the safety of foods from primary production to final consumption through the identification and evaluation of specific hazards and measures. HACCP is a tool to assess hazards and establish control systems that focus on prevention rather than relying mainly on end-product testing.
Hazard	The inherent property of a biological, chemical, or physical substance, agent, or situation having the potential to cause undesirable consequences (e.g. properties that can cause adverse effects or damage to health, the environment, or property). It includes both active ingredients and formulations, and undesirable consequences.
Hazard Analysis	The process of collecting and interpreting information on hazards and conditions leading to their presence to decide which are significant for food safety and therefore should be addressed in the HACCP plan.
Healthy Diet	A balanced, diverse, and appropriate selection of foods eaten over a period of time. A healthy diet protects against malnutrition in all its forms, including diet-related non-communicable diseases (NCDs), and meets macronutrient (proteins, fats, and carbohydrates, including dietary fibre) and essential micronutrient (vitamins, minerals, and trace elements) needs specific to a person's gender, age, physical activity level, and physiological state.
Legislation (Primary and Secondary)	Primary legislation is laws enacted by parliament, known as statutes or Acts of Parliament. In general, statutes contain major policy and legal provisions and often contain enabling powers for ministers to make secondary legislation.
Microplastics	Microplastics (>5 mm) is a term coined in 2004 to describe plastics from a variety of sources that are weathered and broken down into smaller pieces (1µm to 5 mm) in the environment through processes such as photodegradation, physical abrasion, hydrolysis, and biodegradation.
Metrology	The science of measurements.
Noncommunicable Diseases (NCDs)	A medical condition or disease that is not caused by infectious agents (non-infectious or non-transmissible). NCDs can refer to chronic diseases that last for prolonged periods and progress slowly.
Nuclear and Radiation Accidents	Radiation events that have led to significant consequences for people, the environment, or facilities, as defined by the International Atomic Energy Agency (IAEA).
One Health	Collaborative, multidisciplinary work at the local, national, and global levels to attain optimal health for humans, animals, and the environment.
Perishable Food Products	Any food that may spoil or otherwise become unfit for human consumption because of its nature, type, or physical condition.

Term	Definition and description
Pesticide	Any substance, or mixture of substances, or micro-organisms including viruses, intended for repelling, destroying, or controlling any pest, including vectors of human or animal disease, nuisance pests, unwanted species of plants or animals causing harm during or otherwise interfering with the production, processing, storage, transport, or marketing of food, agricultural commodities, wood, and wood products or animal feeding stuffs, or which may be administered to animals for the control of insects, arachnids or other pests in or on their bodies. The term includes substances intended for use as insect or plant growth regulators; defoliants; desiccants; agents for setting, thinning, or preventing the premature fall of fruit; and substances applied to crops either before or after harvest to protect the commodity from deterioration during storage and transport. The term also includes pesticide synergists, where they are integral to the satisfactory performance of the pesticide. The term 'technical pesticide' refers to technical materials and technical concentrates. The term 'formulated pesticide' refers to any formulation containing a pesticide.
Primary Production	Early steps in the food chain up to and including, for example, harvesting, slaughter, milking, and fishing.
Produce	A constructive term for a group of farm-produced crops and goods, it often implies that the products are fresh and generally in the same state as where they were harvested. In supermarkets, the term is also used to refer to the section where fruit and vegetables are kept. Produce is the main product sold by greengrocers, farmers' markets, and fruit markets.
Response	Any public health action (e.g. event monitoring, providing information to the public, field investigations, and control or mitigation measures) triggered by the detection of a public health risk.
Risk	A function of the probability of an adverse health effect and the severity of that effect, following exposure to a hazard(s) in food.
Risk Analysis	A process consisting of 3 components: risk assessment, risk management, and risk communication.
Risk Assessment	A scientifically based process consisting of the following steps: hazard identification, hazard characterization, exposure assessment, and risk characterization.
Risk Characterization	The qualitative and/or quantitative estimation, including attendant uncertainties, of the probability of occurrence and severity of known or potential adverse health effects in a given population based on hazard identification, hazard characterization, and exposure assessment.
Risk Communication	The interactive exchange of information and opinions concerning risks and risk-related factors among risk assessors, risk managers, consumers, and other stakeholders.
Risk Management	The process of weighing policy alternatives in consultation with all stakeholders, considering the results of risk assessment and other factors relevant to the health protection of consumers and for the promotion of fair-trade practices and, if needed, selecting appropriate prevention and control options, including regulatory measures.
Risk-based Inspection	Structured activities to identify risk factors and to assess the effectiveness of current control practices in preventing food safety challenges as well as to determine compliance with regulations and standards.
Stakeholder	An individual, group, industry, association, organization, etc. with an economic or professional interest/responsibility in an area, or one that is (involuntarily), affected by, or perceived to be affected by, a decision, activity, or outcome of the action in the same area.

Term	Definition and description
Standardization	The activity of establishing provisions for common and repeated use, aimed at the achievement of the optimum degree of order in each context (as in the ISO/IEC Guide 2:2004).
Staple Food	A food that is eaten regularly and, in such quantities, as to constitute the dominant part of the diet supplying a major proportion of energy and nutrient needs.
Sustainable Development Goals (SDGs)	A set of 17 interlinked, integrated, and indivisible development goals adopted by UN Member States in September 2015. They set out a vision of economic, social, and environmental development until 2030 with a specific focus on equity and leaving no one behind.
Technical Regulation	Documents laying down product characteristics or their related processes and production methods, including their applicable administrative provisions, with which compliance is mandatory. They may also include or deal exclusively with terminology, symbols, packaging, marking, or labelling requirements as they apply to a product, process, or production method (as in the WTO/TBT agreement).
Theory of Change (ToC)	Is an analysis used to assess how realistic the pathways between outputs and outcomes and between outcomes and impact are, including the identification of major external factors.
Traditional Food Market	The term traditional food market includes wet markets, informal markets and farmers' markets that sell foods of animal origin/non-animal origin/dried goods, and where live animals are sometimes housed and slaughtered on site.
Undernourishment	Specifically refers to the condition in which an individual's habitual food consumption is insufficient to provide the dietary energy levels (enough calories) required to maintain a normal, active, and healthy life. It is a leading indicator of food insecurity and is often used to measure the prevalence of hunger (SDG 2).
Zoonoses	Any disease or infection that is naturally transmissible from animals to humans or vice versa.

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