

Article

Battling Food Losses and Waste in Saudi Arabia: Mobilizing Regional Efforts and Blending Indigenous Knowledge to Address Global Food Security Challenges

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Abstract: Food Loss and Waste (FLW) that entail substantial economic, environmental, and social cost is of great concern for a country fulfilling > 80% of food demands through the import of agricultural commodities. The current study mainly aimed at bringing together a wide range of perspectives on FLW by multi-stakeholder engagement in order to enhance cooperation and network building with respect to sharing knowledge and experiences on FLW prevention activities along the entire food supply chain for a country located at the geographic frontier facing stubborn challenges of desertification, water scarcity, and harsh climatic conditions. These challenges are not only being addressed at the national level but have also been made the focus of multilateral activities in 2020 as part of the Saudi G20 Presidency. The Ministry of Environment, Water and Agriculture under the umbrella of the G20 Meeting of Agricultural Chief Scientists (MACS) hosted a regional workshop on FLW in collaboration with the Thünen Institute, Germany, to raise awareness among Gulf Cooperation Council (GCC) countries. The present paper provides insights into the current status of FLW by revealing that, overall, 33.1% of the total available food in the Kingdom is lost and wasted during the entire food supply chain. Overall, the GCC countries witnessed higher percentages of food waste compared with food losses. Environmental conditions prevailing in the region necessitate the development of adequate and appropriate cold chain storage facilities for balanced distribution through cold storage transportation facilities along the food supply chain to minimize food losses. However, campaigns and activities to raise awareness with a view of changing attitudes towards reducing FLW by the adoption of good practices, promoting the concept of circular economy practices, and the establishment of food banks for surplus food redistribution are important to mitigate FLW in the Kingdom.

Keywords: FLW; baseline measurement; food security; food recycling; food processing; circular economy; food redistribution



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1. Introduction

Modern agriculture is the story of humankind's key developments that progressed through "hunter-gatherer societies", to the early masters of agriculture, to the industrialization of agriculture to address global challenges of food security and sustainability, which are arising because of a growing human population and changing dietary habits. Providing adequate, nutritious food for such a large population under challenging circumstances of depleting natural resources highlights the importance of the issue of Food Loss and Waste (FLW), a "global problem of enormous economic, environmental and societal significance" [1]. This issue necessitates the global efforts on reducing losses and waste

from the edible food mass during different stages of food supply chain (Figure 1), and the classifications of the food supply chain dealing with food loss and waste varies from country to country [2,3]. Overall, there is a pressing need to develop consensus about these main steps for the standardization of FLW quantification methods. However, FLW ramifications are part of several United Nations Sustainable Development Goals (SDGs), both directly and indirectly. Reducing Food Loss and Waste has long been considered a key topic on the G20 agenda. The latest G20 Leaders' Riyadh Declaration, keeping in mind the severity of the FLW issue, endorses the SDG commitment 12.3 by acknowledging the "goal of voluntarily establishing intermediate country-specific targets to strengthen efforts towards halving global per capita food loss and waste by 2030" [4]. These efforts at such an apex level would help to develop collaboration, knowledge sharing, expertise, and capabilities to expedite and promote coordination between the value chain players responsible for inter-related food issues, such as marketing, storage, handling, processing, quality, and safety in order to protect global food security and nutrition by reducing food loss and waste.

The cultural characteristics such as the joint celebration of large festivals, which lead to above-average amounts of surplus food that is wasted, and the prevailing environmental conditions of the region such as very hot weather contribute to enormous amounts of food losses. The present paper aims to provide an overview on the state of food sustainability and security in the Kingdom of Saudi Arabia as well as present food loss and waste generation on the basis of the first comprehensive national FLW estimation. In a next step, it provides selected policies in the Kingdom tackling the challenge with its economic, environmental, and social impacts. Then, local strategies, regional efforts, and global practices are introduced that could be adopted to overcome food loss and waste in the Kingdom of Saudi Arabia and to become a role model in the region to contribute to food security and nutrition under challenging environmental conditions.

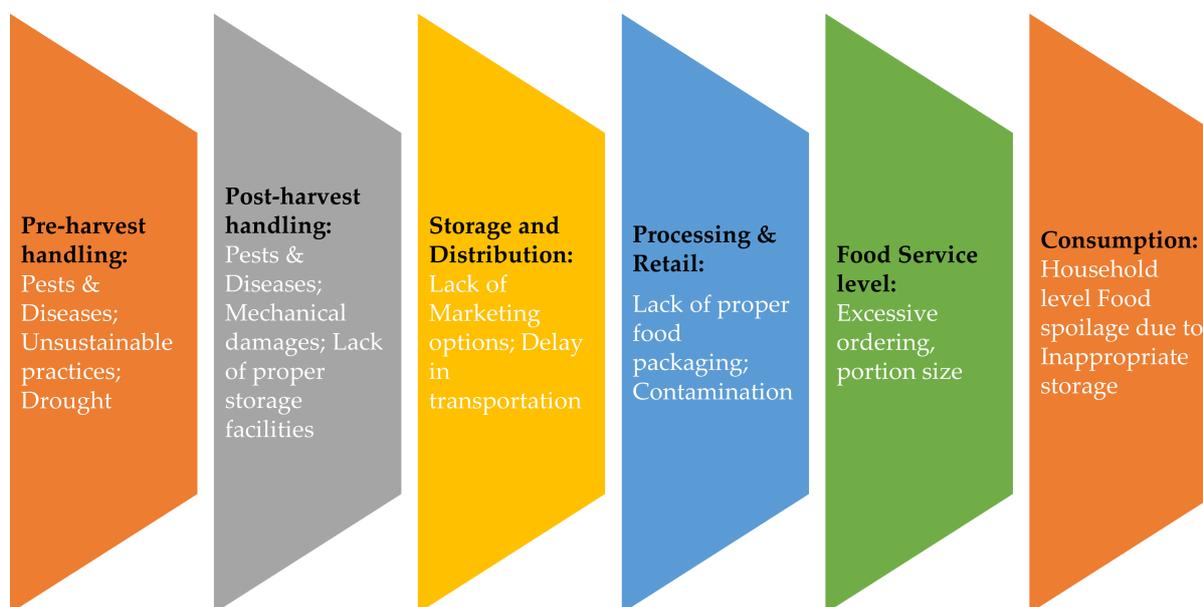


Figure 1. Food loss and waste at different stages of the food supply chain.

2. Materials and Methods: Fulfilling G20 Presidency as Leader in Tackling FLW

Against the background of the aforementioned challenges which the Kingdom of Saudi Arabia is facing in relation to food sustainability and security as well as food loss and waste, the hosting of the G20 presidency in 2020 was a very good opportunity to enhance further steps within G20 community and beyond. In this section, we will present a brief about the temporary leading role of the Kingdom as being the Incumbent G20 Presidency to raise awareness towards FLW among those important stakeholders.

The issue of food loss and waste has been addressed within the Meeting of Agricultural Chief Scientists of G20 (MACS-G20) since 2015. MACS-G20 was established in 2011 by the Agricultural Ministers of the G20 as a board at the science–policy interface. This board consists of respective decision makers and advisors from the G20 (MACS-G20 members) and from several international organizations (MACS-G20 guests). It meets annually in order to discuss transnational or global challenges and tasks in terms of food and agriculture, which cannot be solved by a single country (e.g., climate change, FLW, transboundary plant and animal diseases, biodiversity, agri-tech innovations, sustainable agriculture development in drylands, solutions concerning the Water, Energy, Food Nexus, etc.). Objectives of these efforts are to inform each other about agricultural research systems and accordingly funding structures in G20 states, bring together national resources and capabilities and launch joint initiatives and formats to work on problems of global relevance.

In 2015, Turkey hosted the G20 presidency, which is passed on to another member every year and raised the FLW issue to the agenda of MACS. As a result, a Collaboration Initiative Food Loss and Waste was put in place in which Germany voluntarily took over the coordination. The aim of the initiative is to increase the global impact of FLW prevention activities by a multilateral approach by sharing knowledge and experiences throughout the broad range of the topic. The MACS-G20 communiqué 2015 pointed out some tasks for the new initiative:

“MACS emphasized the importance of science and technology, pre- and post-harvest and throughout the food value chain, to reduce FLW including the control of plant and animal diseases, enhanced storage technologies, innovative packaging solutions, prolonged shelf life, creation of value added byproducts, and improved management practices”.

To support FAO, IFPRI, and other relevant international organizations in their efforts to develop a platform related to FLW, MACS agreed to share information and experiences relating to agricultural science and technology, in measuring and reducing FLW. MACS emphasized the value of having a common definitional and measurement framework as noted by Agriculture Ministers.

MACS agreed that a subset of members, led by Germany and in consultation with FAO and IFPRI, would conduct a preliminary mapping of their existing science and technology activities related to FLW, so as to contribute to enhanced information sharing and global coordination ... ” [5].

It was agreed that there should be concerted actions implemented to facilitate knowledge exchange not only on the level of G20 members and guests, but also available for other countries and stakeholders. The latter part of the communiqué was addressed by two activities shared by the Food and Agriculture Organization (FAO) and Germany. The FAO, as a MACS-G20 guest, launched a specialized website within their online presence, which summarized all previous food loss and waste related documents, statements, events, and education material released by the FAO. Germany was responsible for elaborating and implementing an online global food loss and waste expert and project database (www.global-flw-research.org, accessed on 16 July 2021) in order to cover the gap of identifying FLW experts in an easy way. The aim of the database is to search and find experts for specific FLW-related topics without an intensive scientific literature research, which is a barrier for stakeholders such as companies, private persons, or governmental staff members.

Both online tools were launched in the course of 2016 and are further hosted and sourced by the FAO and Germany. In parallel, the above-mentioned Collaboration Initiative Food Loss and Waste was equipped with a coordinator who is available to interested parties with expertise, develops ideas for cooperation or supports their implementation, and actively promotes exchange within the G20 group and beyond. In contrast to the general focus of the MACS-G20 on agriculture, the pressing issue of Food Loss and Waste is not restricted to the agricultural level but operates along the entire food supply chain as it has already formulated within the communiqué released in Izmir, Turkey in 2015 [5].

Since 2015, the FLW issue has been a part of the annual MACS-G20 communiqué as well as the Agricultural Ministers' Declaration.

Although in some countries, the agriculture and water responsibility is united within one ministry, in other countries, shared responsibilities address those topics. Thus, in 2020, under the Saudi G20 presidency, the Ministers' Declaration was enlarged from agriculture to agriculture and water ministers in order to highlight the need of joint forces against urgent issues such as food loss and waste. In order to further enhance cooperation among different policy areas, Saudi Arabia organized other inter-disciplinary activities such as the Working Group on Climate Change meeting or the International Workshop on the Water, Energy, Food Nexus.

FLW contributes to the release of human-made greenhouse gas emissions along the entire food supply chain to a huge extent. The estimated global carbon footprint is 3.3 Gt carbon dioxide equivalents excluding emissions from land use change [6]. This figure is equal to 7% of the total global GHG emissions. In order to enhance the acknowledgement of the important contribution of FLW reduction towards climate change mitigation, within the working group meeting the establishment of national baselines and the consideration of FLW reduction activities as part of reported National Determined Contributions (NDCs) and other reporting towards climate change goals were addressed on initiative of the Kingdom of Saudi Arabia.

The International Workshop on the Water, Energy, Food Nexus aimed to (1) share valuable knowledge through international collaboration with relevant international organizations and interested G20 members in the balancing of water, energy, and land use for food production in challenging environmental conditions; (2) enhance collaboration towards capacity development for the implementation of WEF Nexus solutions; (3) exchange views and good practices for the effective and efficient utilization of global resources at the local, regional, and international levels; (4) support the development of evidence-based policies by providing tools and measures to the policy makers for responsible use of water and energy resources for achieving global food security; and (5) continue to build momentum and awareness of WEF Nexus challenges and potential solutions conditions. Due to the COVID-19 pandemic, the workshop was held on a virtual basis. Four contributors presented their results on FLW from research and practice including [7]:

- Germany: Sustainability assessment methodology to evaluate FLW prevention measures for monitoring purposes and as information basis for decision makers.
- UK: Innovative public-private partnerships to achieve 27% reduction in food waste. The strategies developed in the UK, delivered through wide-ranging partnerships supported by Governments and industry are effective—but more citizens and businesses must be reached and motivated to act.
- Italy: Value from food chains and waste reduction: Complementary approaches for global sustainable food systems and bio-based economy.
- USA: Food waste and the Water-Energy-Food Nexus: Water and energy footprints of produced and landfilled food waste: A Florida case study.

Food loss and waste contribute to a considerable portion of the global food supply. A Water, Energy, Food (WEF) Nexus approach can be a framework for quantifying impacts of wasted food to energy and water sectors, leading to better management decisions. Human decision making in terms of consumer choices leads to food waste and is at the root of the WEF waste nexus. Water and energy are both consumed in the production of wasted food. Water and energy are also consumed and energy may be produced in food waste management. The remediation of pollution is associated with both producing and managing wasted food. When less food is wasted, more food will be available without the need for increased agricultural production, and there is less food waste and food waste contamination to be managed. The awareness campaigns/measures should be carried out along the entire agri-food chain in line with this holistic approach—from farm to fork—and a balance between providing incentives and support for regulation and enforcement is needed. National guidelines, educational measures, and dissemination initiatives for

consumer awareness are important to reduce waste and support transition through correct lifestyle and the adoption of healthy diets. Furthermore, sustainable development considers not only waste reduction but also (implementation) costs, relevant ecological indicators, and social effects.

An important political statement was achieved by the Saudi G20 presidency by including FLW issue on the highest G20 declaration, which is the Leaders' Declaration. In that document, the focus is laid on establishing voluntary, intermediate, country-specific FLW reduction targets in order to strengthen efforts towards a 50% reduction per capita according to Sustainable Development Goal 12.3 [2].

The FLW issue was also set as one priority within the G20 Agriculture deputies' meeting where the cross-cutting characteristic of FLW and the interrelation to other Sustainable Development Goals than SDG 12.3 were highlighted.

One annual task of the aforementioned Collaboration Initiative is to organize a regional FLW workshop. In order to take the G20 responsibility more into account, the workshops are annually organized with the cooperation of the Thünen Institute, Germany, which hosts the Initiative coordinator with the corresponding G20 presidency. The workshop series started with the kick-off workshop in Berlin, Germany, in 2017. It was followed by a regional FLW workshop, which was organized for Latin America and the Caribbean countries (LAC) in November 2018 in Buenos Aires, Argentina. In 2019, the target region included Southeast and East Asian countries, while the workshop took place in Tokyo, Japan. In 2020, the target region was the Gulf Cooperation Council (GCC) countries and Yemen. Despite the COVID-19 pandemic, a half-day hybrid workshop was organized on 15 October 2020. In total, 65 participants from Saudi Arabia, the United Arab Emirates, Oman, Lebanon, Egypt, Bahrain, and Germany as well as from the United Nations Environment Programme (UNEP) represented the scientific community, companies, interest groups, as well as authorities. The aim of the GCC Countries workshop was to provide an impetus for the establishment of regional networks and cooperation along the food value chain to facilitate further monitoring of Food Loss and Waste and the implementation of prevention measures in GCC countries. Particular emphasis was placed on the link between food security and food waste, business models for prevention, the contribution of households to the topic, and the role of an unbroken cold chain as well as reliable infrastructure. Participants also reported on the impact of the COVID-19 pandemic on the food supply chain in their countries and the measures taken to secure the supply and avoid unused surpluses. Special emphasis was placed on the cultural characteristics of the region, such as the joint celebration of large festivals, which lead to above-average amounts of surplus food. In addition to technical solutions to the special challenges posed by the region's climate, the conference therefore called for awareness-raising measures targeting all stakeholders.

3. Results and Discussion

3.1. Status of Food System in the Kingdom of Saudi Arabia

Despite significant technological advancement over the last two decades, recent reports are signalling that the prevalence and number of people with insufficient food consumption as of today in the world jumped to 0.9 billion [8], due to unprecedented economic shutdowns resulting from the COVID-19 pandemic, e.g., broken import chains, a slow-down of loading and unloading at harbor/storage facilities due to reduced number of workers, partially full shelves in supermarkets due to missing goods. This extraordinary situation demands renewed focus to address global food security and nutrition by improving resilience and sustainability to our food system in order to meet specially the ZERO HUNGER Sustainable Development Goal (SDG 2) set by the United Nations for 2030. The status on the prevalence of insufficient food consumption in GCC nations, particularly in the Kingdom of Saudi Arabia, is categorized under the countries with a very low (0–5%) number of people with insufficient food consumption [8]. Furthermore, the Suite of Food Security Indicators developed by the Food and Agriculture Organization of the United Nations (FAO) also showed less than 5% average three years (2018–2020)

prevalence of undernourishment compared with the global 8.9% average prevalence of undernourishment [9]. The Kingdom of Saudi Arabia in this regard has already designed an ambitious strategic National Transformation Program that was launched in 2016 to achieve the ambitious goals of the Kingdom's "Vision 2030" that involves 24 government agencies. The government has launched several initiatives over this period of time with the objectives to Ensure Development and Food Security, Ensure Sustainable Access to Water Resources, Provide Environmental Protection from Natural Hazards, and Protect and Rehabilitate Natural Landscapes to develop sustainable food production systems that ensure food security and nutrition through regulations and awareness programs promoting Good Agricultural Practices (Saudi G.A.P). In this regard, it is important to mention here the launch of the Sustainable Agricultural Rural Development Program (2018–2025) that mainly aimed to target eight sectors including (1) smallholdings and traditional agriculture; (2) production, processing, and marketing of Arabic coffee; (3) beekeeping and honey production; (4) rose cultivation and marketing; (5) fruit production and marketing; (6) small-scale fisheries and fish farming; (7) smallholder livestock production; and (8) rain-fed crops.

The Kingdom of Saudi Arabia is facing stubborn challenges of desertification, hot dry climate, water scarcity, poor soil fertility, and labor shortages. All these challenges are putting the Kingdom at food security risk. Currently, one-fifth of all food requirements are met through the domestic production of grains (1,440,065 tonnes), vegetables (2,022,817 tonnes), fruits excluding dates (770,015 tonnes), and fodder (9,132,687 tonnes) [10]. Therefore, rest of the food requirements of Saudi Arabia are met through import of agricultural commodities (>80%) from foreign countries. Under such circumstances, food security and nutrition has become the main challenge that demands the optimization of food import bill by developing the infrastructure to promote domestic agricultural production. As a result of holistic, systems-based approaches and coordinated actions to drive the scientific and technological innovations into the policy making, the Kingdom of Saudi Arabia, according to the latest Global Food Security Index model, was ranked 38th with an overall score of 69.5 calculated on the basis of Affordability (Category Rank 42), Availability (Category Rank 8), Quality and Safety (Category Rank 40), and Natural Resources and Resilience (109). Despite severe environmental factors, the Kingdom is categorized with the GOOD PROGRESS COUNTRIES due to multiple transformative steps to revamp its agriculture sector (Figure 2).

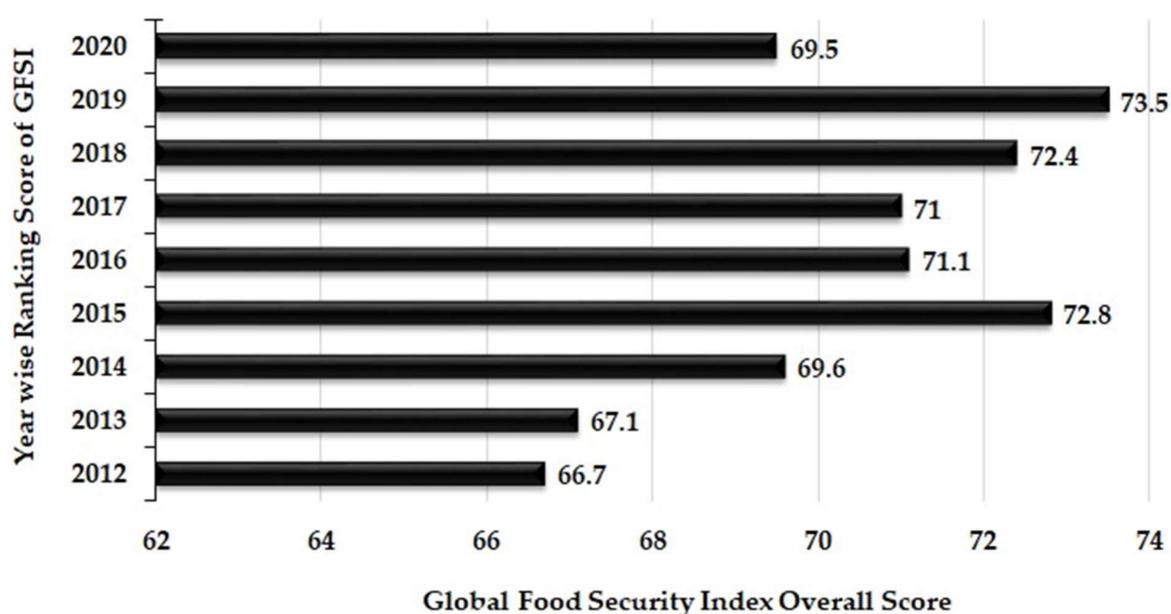


Figure 2. Year-wise trends in the Global Food Security Index of the Kingdom of Saudi Arabia [11]. The GFSI is a dynamic benchmarking model (quantitative and qualitative), ninth edition, compiled from unique indicators (59) that measure the four drivers of food security across 113 countries.

The Economist Intelligence Unit (EIU) along with the Barilla Center for Food and Nutrition (BCFN) have gauged the sustainability of the global food system. Food loss and waste in their quantitative and qualitative benchmarking model is considered an important pillar to calculate the Food Sustainability Index (FSI). According to the 2018 FSI, globally, France (FSI score = 76.10), the Netherlands (FSI score = 75.60), Canada (FSI score = 75.30), Finland (FSI score = 74.10), and Japan (FSI score = 73.80) are the top scored countries out of 67 countries due to their effective implementation of government policies regarding global challenges that are the pillars of this index such as Food loss and Waste, Sustainable agriculture, and Nutritional challenges (Figure 3). The Middle East and North Africa (MENA) region stands at the bottom due to the lowest FSI score. In this index, only two GCC nations including the Kingdom of Saudi Arabia and the United Arab Emirates were included in this 2018 edition with 56.20 and 52.30 overall GSI scores, respectively [12]. The fourth iteration of Food Sustainability Index (FSI) developed by EIU and BCFN launched during July 2021 provided an exciting opportunity for G20 countries to lead the way towards sustainable food systems [13]. The index proposed three action points (1) prioritize policy to make access to sustainable and healthy diets; (2) reviewing the Food-based dietary guidelines for cultural acceptability, and sustainability, and ultimate investment on amplification plans; (3) incentivizing industry actions towards food components essential for sustainable and health diet.

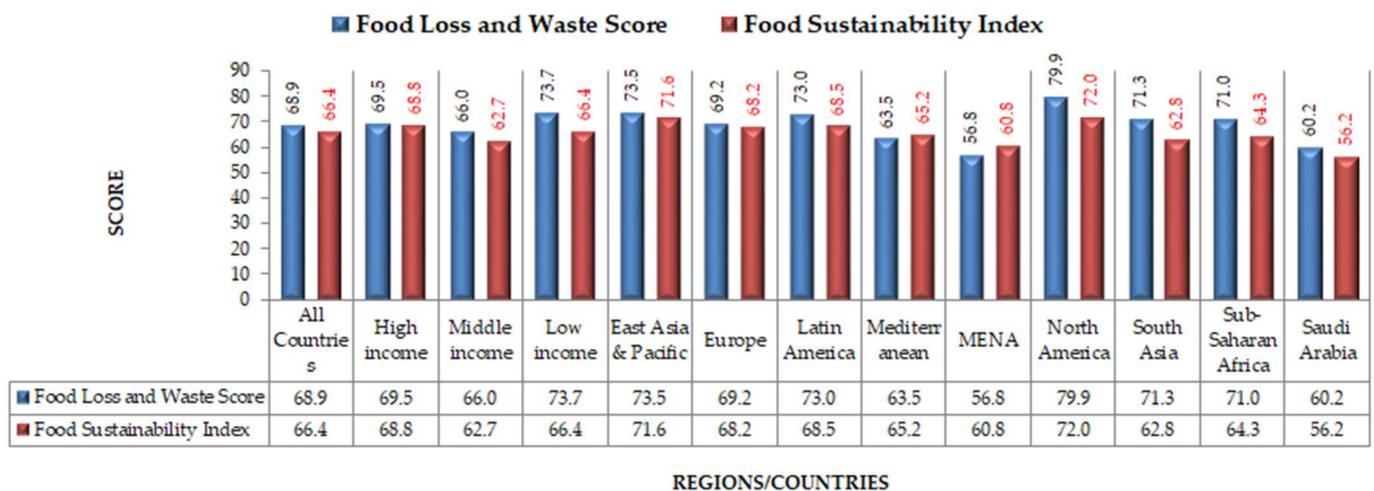


Figure 3. Regional trends in the Food Sustainability Index (FSI) released during 2018, and the score of its important pillar Food Loss and Waste in comparison with the Kingdom of Saudi Arabia. The scale is from 0–100, a higher score represents a sustainable food and nutrition system. The country/region with higher score is designated as the country which is on the right track towards Food Sustainability [12].

3.2. Extent of Food Loss and Waste in the Kingdom of Saudi Arabia

In order to tackle food sustainability challenges, the Kingdom of Saudi Arabia has launched several initiatives under the National Transformation Program 2020 and Vision 2030 to ensure sustainability to our food system and preserving natural resources. In this regard, the Saudi Grains Organization (SAGO) under the umbrella of Ministry of Environment, Water and Agriculture (MEWA), has launched a national program to reduce Food Loss and Waste based on the evidence of the magnitude of FLW. The aim of the program is to define the baseline for FLW for edible food in addition to gain global experience waste prevention and capability building about the best waste management and recycling practices. The FAO methodology [A {Production} + B {Import quantity} + C {Stock variation} – D {Export quantity} = E {Domestic supply quantity} – (F {Feed quantity} + G {Seed quantity} + H {Processing quantity} + I {Waste}) = J {Food} = K {Fresh Food} + L {Processed Food}] [14] was used to measure the Saudi FLW baseline of 19 food commodities

compiled under eight groups collected from the 35 cities of the Kingdom of Saudi Arabia. The first edition of this initiative revealed that, overall, 33.1% of the total edible food in the Kingdom is lost (*quantities of food lost along the food supply chain (on farms, factories, transportation, etc.) that do not reach end consumer*) and wasted (*This explains what is wasted from food prepared for consumption after the stages of production and distribution in restaurants, hotels, houses*) during the entire food supply chain that translates into 4.07 million tons of edible food per year [2]. The baseline of different agricultural commodities defined by the SAGO with respect to domestic production is provided in Table 1. FLW calculated from the food loss to waste ratio revealed a 14.2% (1.741 million tons) share of food loss and 18.9% (2.325 million tons) food waste. Furthermore, the Saudi FLW baseline reported a 79 kg/capita/year food loss size and a 105 kg/capita/year food waste size that collectively led to 184 kg/capita/year total FLW; this translates to a value of 12,980 million Saudi Riyals/annum [2]. Furthermore, it is important to mention here that the total per capita FLW includes all 19 food products that are included while recording the FLW baseline of the Kingdom of Saudi Arabia.

Table 1. Magnitude of food loss and waste in terms of volume, value, and per capita per year of 19 different foods in the Kingdom of Saudi Arabia according to the Kingdom of Saudi Arabia FLW baseline [2].

| Food Products | Volume of FLW (Tonnes) | Overall FLW Share (%) | Loss Share (%) | Waste Share (%) | Value of FLW (Million USD/Year) | Value of FLW (Million SR/Year) | Total FLW/Capita (kg/Capita/Year) |
|-------------------------|------------------------|-----------------------|----------------|-----------------|---------------------------------|--------------------------------|-----------------------------------|
| Poultry | 444,000 | 29.00 | 13.00 | 16.00 | 746 | 2799 | 13 |
| Unclassified Fruits | 608,000 | 40.00 | 22.50 | 17.50 | 602 | 2257 | 18 |
| Rice | 557,000 | 34.00 | 3.00 | 31.00 | 449 | 1682 | 17 |
| Unclassified Vegetables | 335,000 | 44.00 | 27.50 | 16.50 | 334 | 1252 | 10 |
| Wheat Flour Bread | 917,000 | 30.00 | 5.00 | 25.00 | 243 | 913 | 28 |
| Unclassified Meat | 41,000 | 43.00 | 24.00 | 19.00 | 165 | 619 | 1.2 |
| Dates | 137,000 | 21.50 | 16.00 | 5.50 | 157 | 588 | 5 |
| Fish | 69,000 | 33.00 | 18.50 | 14.50 | 132 | 494 | 2.4 |
| Watermelon | 153,000 | 41.00 | 32.00 | 9.00 | 68 | 254 | 5 |
| Carrot | 27,000 | 31.00 | 16.00 | 15.00 | 13 | 47 | 0.8 |
| Orange | 69,000 | 28.00 | 14.50 | 13.50 | 48 | 181 | 3 |
| Onion | 110,000 | 26.00 | 8.50 | 17.50 | 45 | 167 | 3.5 |
| Sheep | 22,000 | 15.00 | 7.00 | 8.00 | 107 | 401 | 0.7 |
| Tomato | 234,000 | 40.00 | 23.00 | 17.00 | 114 | 428 | 8 |
| Potatoes | 201,000 | 42.00 | 28.00 | 14.00 | 99 | 372 | 6 |
| Cucumber | 82,000 | 43.00 | 26.00 | 17.00 | 69 | 260 | 2 |
| Camel | 13,000 | 34.00 | 14.50 | 19.50 | 40 | 150 | 0.4 |
| Zucchini | 38,000 | 41.00 | 26.00 | 15.00 | 20 | 74 | 1.1 |
| Mango | 12,000 | 26.00 | 17.00 | 9.00 | 11 | 42 | 0.4 |

The food losses (post-harvest to distribution) disclosed in the KSA baseline are comparable to other regions of the world calculated by Food Loss Index for Central Asia and Southern Asia (20.70%); North America and Europe (15.70%); Sub-Saharan Africa (14.00%); Latin America and the Caribbean (11.60%); Western Asia and North Africa (10.80%); Oceania, excluding Australia and New Zealand (8.90%); Eastern Asia and South Eastern Asia (7.80%); Australia and New Zealand (5.80%); and the world (13.80%) [15]. The baseline developed in the Kingdom, similar to other countries, is critically important to achieve the ambitious target laid out in SDG 12.3, i.e., halving the per capita global food waste at the retail and consumer levels and reducing food loss along production and supply chains, including post-harvest loss, by 2030. In this regard, establishing the intermediate targets to

achieving SDG commitment 12.3 taking into account each country's specific circumstances will be the way forward to tackle FLW.

3.3. Stage-Specific Policies to Overcome Food Losses along the Entire Food Supply Chain

The Ministry of Environment, Water and Agriculture in the Kingdom is striving to minimize food losses whether at the production, harvesting, post-harvesting, or retail level, as shown in Figure 4. In this regard, agricultural pests and diseases, especially transboundary pests, are posing a great threat by reducing production due to the lack of natural enemies in the invaded region.

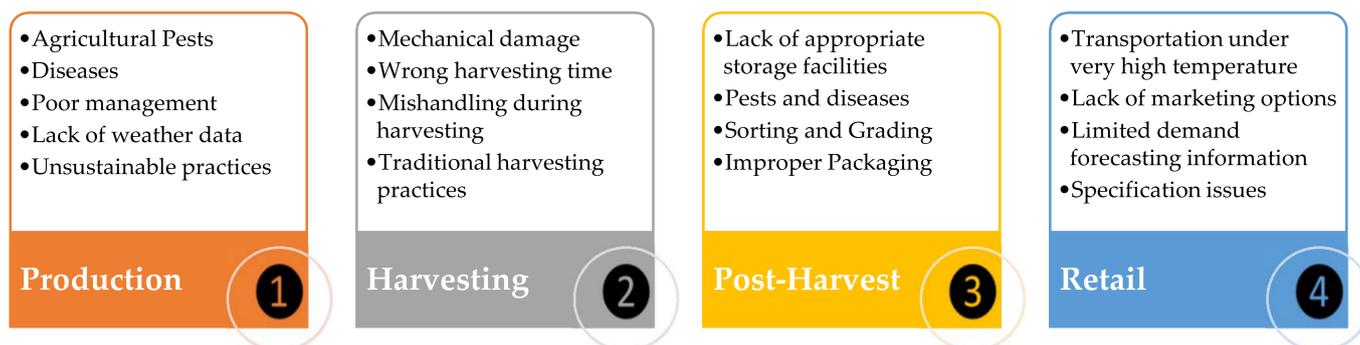


Figure 4. Stage-specific drivers of food losses in the Kingdom of Saudi Arabia.

Red palm weevil, a trunk pest that destroyed the oldest domesticated fruit tree, the date palm, which serves as a critically important staple food, is a classic example of this threat [16–19]. The unique nutritional characteristics has unrivaled cultural importance in arid regions especially Middle East and North Africa (MENA). The Kingdom of Saudi Arabia ranks among the top date palm producing countries, with approximately 31,234,155 date palm trees, which cover 117,881 ha of land, and are producing over 1.54 million tonnes of dates annually [20]. According to our estimates, approximately 1% of date palms are infested every year in the Kingdom of Saudi Arabia. Among the infested date palms, 10% of infested date palms are removed due to pest infestations. The rest of the 90% infested along with 10% removed palms lead to tremendous reduction in dates production. This reduction and loss worth USD 15.2 million per year.

3.3.1. Pests and Diseases Management Program to Reduce Food Losses

Overall, in the Kingdom of Saudi Arabia, there are 262,000 agricultural farms and approximately 910,000 workers that are involved in this sector. Most of the land holdings belong to the small farmers that could not afford the protection cost for their farms. In order to address the cost issue for the control of pests and diseases, MEWA launched in August 2019 a farmer's pests and diseases reporting mobile application for possible eradication of pests and diseases following an effective Integrated Pests and Disease Management strategy (Figure 5). The farmers share the pictures of damaged plants through this application for possible control through concerned staff at MEWA in order to secure their crops in the Kingdom of Saudi Arabia. The mobile application was widely adopted by the farmers, and within one month of its launch, more than 3700 queries/day were reported. Such kinds of applications are very much helpful, especially during the currently prevailing COVID-19 situation.

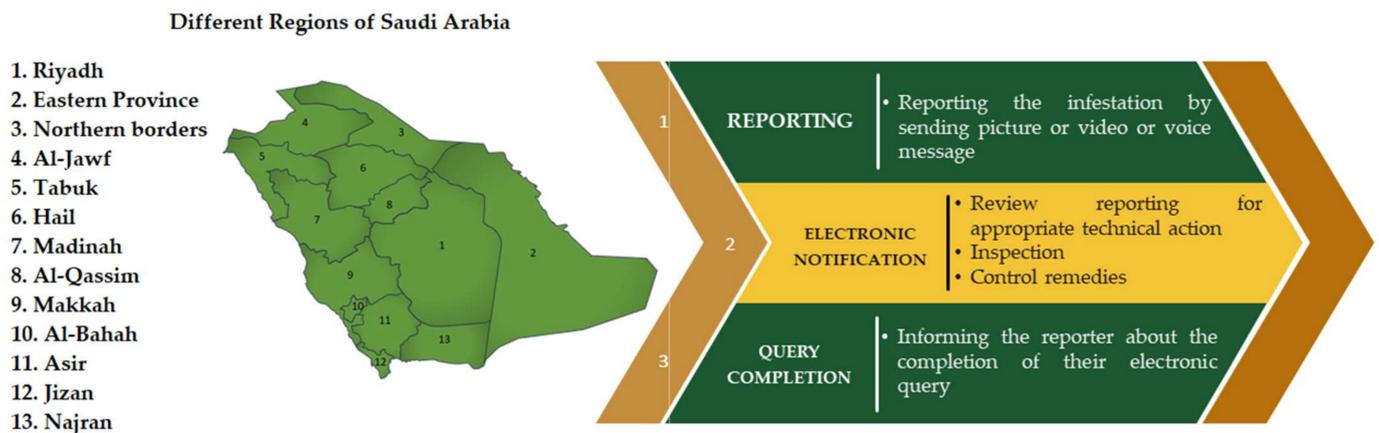


Figure 5. Pests and diseases reporting and management mobile application to curtail crop food losses.

3.3.2. Cold Chain Strategy to Reduce Food Losses

The environmental conditions prevailing in the Kingdom of Saudi Arabia are hot and the country is stretched to large area of land that is approximately 2.15 million km², which is approximately 65% of the total area of the Arabian Peninsula. There is the risk of locally produced food to be lost in the supply chain during transportation under harsh climatic conditions [3]. In addition, the increasing demands of food are currently being met mainly through the import of food (~80%), especially for fresh perishable produce, and these necessitate the development of adequate and appropriate cold chain storage facilities for balanced distribution through cold storage transportation facilities along the food supply chain to minimize food losses. According to the latest report published by Ken Research for the period of 2013–2018 revealed that there is positive increase of 9.7% in the Compound annual growth rate (CAGR) of the cold chain market in the Kingdom of Saudi Arabia [21]. In the future, it seems to be increased up to 11.2% CAGR (2018–2023) in Saudi Arabia cold chain market due to the improvement in the infrastructure facilities, and government initiatives mainly aimed to improve operational efficiency in cold chain market. However, the high cost for smart monitoring, energy, storage, transportation, and distribution are the main challenges to this sector. These challenges are overcome through financing to the agricultural farmers through loan scheme under the initiative of “Expansion across the Agriculture Supply Chain” announced by the Saudi Agricultural Development Fund (AFD) for the period of 2021 to 2025. In short, these initiatives are important to safeguard our produce to gain maximum returns.

3.4. Food Waste Drivers and Strategies to Overcome Food Waste along the Food Supply Chain

Food waste drivers across the entire food value chain especially wholesale, and consumer levels are myriad with cross-disciplinary nature. Overall, there is a general consensus that developed countries are facing high levels of food waste compared with underdeveloped and developing countries [22]. The driving force behind food waste include (1) public demands for high quality food; (2) serving sizes; (3) packaging properties; (4) consumer behavior; (5) technical malfunctions; (6) demand market uncertainty; (7) sociocultural standards and norms; and (8) market standards [22]. There is a scarcity of knowledge on the ways to tackle wasted food, which necessitates the promotion of sector-specific, knowledge-based solutions, which ultimately help to tackle global food security and nutrition challenges. Here in the Kingdom, food waste drivers could be divided into four main categories during the food supply chain, as shown in Figure 6.



Figure 6. Drivers of food waste in the Kingdom of Saudi Arabia.

3.4.1. Food Processing Approaches to Reduce Food Waste

Food waste in the form of exceptional wastage of non-consumed valuable nutrients and natural resources, which realistically could be made available through redistribution and recycling, is a global challenge [23]. According to an estimate revealed by Tarik Ismail, executive director of the Savola Group, 1.65 million tonnes of food from the domestic kitchens in the Kingdom of Saudi Arabia are disposed of to the landfills annually [24]. However, the food disposal through traditional landfilling is generating disposal problems and polluting the environment [25,26]. Food waste mitigation at various levels of the food supply chain could be made through a balanced approach involving technology, capacity building through training, and marketing tactics.

Food spoilage is an ongoing phenomenon in which microbial infection spoiled the food before consumption. In order to tackle food spoilage, a great number of already established, simple food processing technologies followed by appropriate packaging [27] are available not only to extend the shelf-life but also to enhance the safety and quality of the food [28].

3.4.2. Food Recycling Potential Opportunities for Wasted Food

Food recycling is another potential opportunity for the Kingdom of Saudi Arabia under the compliance criterion of the Saudi Food and Drug Authority (SFDA) about feed materials, additives, premixture, and compound feed to recycle the unavoidable food waste and to produce value-added products [26,29]. Animal feeding is the widely adopted food waste recycling technique due to eco-friendly utilization of the waste [30]. Here in the Kingdom, there is a tremendous potential due to the bulk (917,000 tonnes) of the FLW from flour and bread products according to the Saudi FLW baseline that could be valorized for animal feed in KSA [2]. However, the emerging issue of food safety and the carbon footprint in the waste hierarchy [31] necessitates the incorporation of alternate waste utilization approaches such as valorization [32] and integrated processing to produce value-added biochemical, biofuels, biomaterial, power, and heat [33]. These are ideal candidates to maximize the value of wasted food through advanced valorization [33]. In the past, a lot of efforts on pilot scales (compiled in Table 2) have been made to recycle wasted food from different origins including fruits, vegetables, etc. However, the public–private partnership might be the way forward to market these solutions on a commercial scale here in the Kingdom of Saudi Arabia.

Table 2. Recycling strategies to tackle the wastes of fruits and vegetables.

| Name | Waste Entity | Possible Outputs | Reference |
|-----------------------|--|--|------------|
| Fruits | | | |
| Apples | Peels, Pomace, and seeds, etc. | Food products, fuel, pectin extraction, animal feed, Phenolic compounds, antioxidants, dietary fibers | [34–36] |
| Banana | Peel/Skin | Laccase, α -amylase | [29,37,38] |
| Berries | Seeds, Pomace | Oil, phenolic compounds, antioxidants, fatty acids, tocopherols, phytosterols, dietary fibers, enriched cookies | [39–41] |
| Citrus fruits | Waste materials, rag, pulp, peels, seeds, etc. | Food processing, increase dietary fibers contents of sausages, bioactive compounds, flavonoids, polyphenols, dietary fibers, phenolic compounds, carotenoids, promising alternative as a fat replacer in ice cream production, essential oils, pectins | [42–46] |
| Grapes | Unripe grapes, Pomace, grape agro-waste | Bioactive phytochemicals, phenolic compounds | [47,48] |
| Kiwifruit | Pomace | Dietary fibers | [49] |
| Mangoes | Peel and seeds | Bioactive compounds | [50,51] |
| Melons | Barks, peels, and seeds | Antioxidants, bioactive compounds, food processing | [52] |
| Olives | Pomace | Natural phenolic antioxidants, bioactive compounds | [53,54] |
| Pear | Pomace | Dietary fibers | [49] |
| Pineapple | Core, crown, and peel parts of pineapples | Antioxidants, bioactive compounds, glycosides, polyphenols | [55,56] |
| Vegetables | | | |
| Carrot | Pomace | α - and β -carotene | [57] |
| Onion | Brown skin and top–bottom, husk | Dietary fibers, bioactive compounds, phenolic compounds, flavonoids, fuel pellets | [58–60] |
| Tomato | Peel, pomace, and tomato waste | Bioactive compounds, natural additives, lycopene, beta-carotene, glutamic acid or aspartic acid, food products enrichment, ellagic and chlorogenic acids | [61–63] |
| Potato | Potato waste and peel | Bioactive compounds, antioxidants, glycoalkaloids and polyphenols, natural food additive | [64–66] |
| Mixture of vegetables | Vegetable wastes of potato, pumpkin, brinjal, cauliflower, and cabbage | Biobutanol, protease production, biomethane production | [67–69] |

3.5. Guidelines to Tackle Food Loss and Waste

Population growth, changing dietary habits, and the scarcity of depleting natural resources add to the urgency of food loss and waste reduction and further exacerbate the pressures on the global food value chain. Mitigating food loss and waste would also reduce the needed land, water use, and GHG emissions to produce that food, thereby reducing ecological pressures to ensure future food security. Despite momentum, the food loss and waste situation has not witnessed major improvements, and experts do not expect this trend to curb unless further actions both upstream and downstream are taken. The following recommendations are prepared by the authors on their self-assessment in addition to the recommendations shared by the distinguished participants of the Regional Food Loss and Waste Workshop organized by the Ministry of Environment, Water and Agriculture in partnership with Thünen Institute, Germany, as co-host on 15 October 2020 to highlight the issue of FLW among GCC countries.

3.5.1. Enabling Policy Reforms for Quantifying FLW Baseline, Setting Intermediate FLW Targets, and Stopping Unfair Trading Practices

The data on global FLW suffers from notable shortcomings in terms of availability and accuracy. There is a need for quantifying FLW by individual drivers across the supply chain. There is also a need for a better assessment of the economic, social, and environmental impacts of FLW at the national, regional, and global levels. Available estimates are not consistent across countries and often incomplete, limiting the effectiveness of policy making and planning and the ability to monitor progress. Existing policies,

regulations, and standards sometimes have a negative impact on FLW. For instance, in medium and high-income countries, subsidized agricultural production may generate a surplus of certain products depending on market changes, resulting in the loss and waste of large quantities of products. In addition, the rigorous standards for food safety and quality in developed countries, especially in the late stages of the food supply chain, exacerbate FLW. For instance, food retailers apply certain appearance quality criteria that leads to the elimination of foods fit for human consumption. Keeping in mind the current scenarios, it is the need of the hour to develop or amend legislative instruments to support the reduction of FLW, promote the prevention of FLW, penalize the generation of FLW, and set clear targets in line with SDG 12.3, establishing a roadmap to achieve the desired objectives. Furthermore, sharing policy experiences among regional countries could help us to amicably cope FLW and ensure global food security and nutrition.

The markets occupied by a few giant retailers directly interacting with the suppliers of the perishable products pose a risk to find alternative outlets. These Unfair Trading Practices (UTP) are putting the food supply chain at risk. The legislative instrument must address UTPs and introduce online electronic trading platforms to protect the produce's rights and safeguard the products from being lost and wasted due to UTPs. Furthermore, establishing an independent authority to investigate UTPs could greatly help to enforce good trading practices.

3.5.2. Mobilizing Regional and Global Efforts through Collaborative Initiatives

The GCC countries are facing dual challenges of water stress and severe drought frequency. Therefore, most of their food requirements are met through the import of agricultural commodities. The issue of FLW that is of enormous economic, environmental, and societal significance pays little attention in this region. Only two nations, the Kingdom of Saudi Arabia (184 kg/capita/year FLW) and the United Arab Emirates (annually 197 kg per person food waste) [70], have developed their FLW baseline. There is a need in this region to establish FLW baseline for each country in order to truly understand and quantify the magnitude of the problem. In addition, qualitative approaches and other methodologies such as questionnaires, diaries, or interviews which include the stakeholders under survey in this regard are important to identify the reasons of these FLW volumes. These analyses necessitate the importance of highlighting the methodology of waste composition analyses used to examine the share of different waste fractions (e.g., food waste, paper waste, specific products, etc.) within a waste stream. The collaboration among the GCC countries in this regard could help GCC countries to deploy corrective actions and measures to prevent FLW that is critically important to protect their food security and nutrition.

3.5.3. Promoting and Developing Circular Economy Practices for Waste Utilization

The traditional landfill management strategy to deal with FLW seems to be adversely affecting the environment. Furthermore, the large extent of lost and wasted food during the entire food supply chain not only negatively impacts the socioeconomic conditions of the society but also seems to be wasteful in its model of value creation [71]. In order to transform currently prevailing resource-exhausting policy to resource conserving economy, concrete efforts are needed to tackle FLW. The concept of the circular economy, which mainly aims to maximize resource efficiency and reduce the environmental impacts by waste management hierarchy, is pertinent in this context to recover nutrients and energy from wastes. The composting of FLW for agricultural purposes is an exciting economical, eco-friendly opportunity for the efficient recirculation of food waste. The previous investigation revealed large variation among locally produced composts. They suggested the need for quality assurance proper regulations regarding composting in the Kingdom of Saudi Arabia [72]. Recently, King Abdullah University of Science and Technology invested USD 780,000 from their Innovation Fund and signed a contract with Edama Organic solutions for constructing commercial-scale composting facility in their Thuwal campus. The composting facility aimed to recycle > 80% of the university's waste (5500 tonnes per year) [73].

The replication of such kind of facilities could contribute to provide sustainability to the local production systems and amicably achieve the FLW intermediate targets.

3.5.4. Changing Behavior to Reduce Hospitality Waste

In GCC countries, a massive amount of food is wasted in the hospitality and food service sector, especially in restaurants and hotels. Hospitality sector food waste seems to be the main food waste driver in the GCC food system. This will require campaigns and activities to raise awareness with a view of changing attitudes towards reducing FLW by the adoption of good practices or incentives to reduce FLW in order to reach maximum productivity. In this regard, Food Waste Apps over a period of time have proven to upgrade the sustainability of the user and have saved millions of meals. The WINNOWER SOLUTIONS (<https://www.winnowsolutions.com/>, accessed on 1 June 2021) is an example to convert it into an economic opportunity in the hospitality sector, especially in the GCC region, to reduce their food waste through the incorporation of artificial intelligence that seems to make food systems more efficient by smart recommendations about (1) food spoilage; (2) overproduction optimization; (3) preparation errors; and (4) plate waste left on customer plates [74]. Globally, Too Good To Go, Karma, No Waste, Olio, FoodCloud, and Refill are widely used Food Waste Apps that have been shown to save millions of meals in different parts of the world.

3.5.5. Awareness Campaigns to Reduce Household Food Waste

Household waste, especially in the Kingdom of Saudi Arabia, is among the top five social issues surveyed by the Savola back in 2013 [75]. According to their estimate, approximately 20% (25 Saudi Riyals) of the food in a household is wasted daily in the Kingdom of Saudi Arabia. The Negaderha Program (<https://negaderha.savolaworld.com/en/>, accessed on 3 June 2021) launched by the SAVOLA WORLD as Food Waste Prevention Program in partnership with the Saudi Grains Organization (SAGO), the United Nations Environment Programme (UNEP), the Waste and Resources Action Programme (WRAP), and Eta'am. Such kinds of awareness-raising information campaigns on the best waste management practices about food leftovers recipes, food storage innovative solutions, and tips and hints about grocery shopping are of great importance to reduce household waste not only at domestic level but also at regional level.

3.5.6. Promoting the Concept of Food Banks for Surplus Food Redistribution

Since the establishment of the first food bank (St. Mary's Food Bank) in 1967, thousands of food banks have been established around the world to distribute food among needy people by operating under various models including the warehouse model (providing food to the intermediaries for distribution) and the frontline model (directly distributing food to the hungry) [76]. In the Kingdom, food banks are coordinated under the Specialized Council for Food Preservation approved by the Ministry of Human Resources and Social Development, working along with strategic partners including the Ministry of Municipal and Rural Affairs, the Ministry of Environment, Water and Agriculture, the Saudi Grains organization, the Ministry of Education, the Ministry of Commerce and Investment, the Public Investment Fund, and recycling companies. They are providing food assistance to the needy people in the society. In the Kingdom of Saudi Arabia, there are approximately 40 food banks (collected 12,000 tonnes excess food) that are operating under the frontline model by providing door to door excessive food collection, handling, and multiple distribution services including instant distribution, cooling, next day distribution, and cooling, next day heating, and distribution. The Kingdom is aiming to utilize 75% (3 million tonnes) of the wasted food along the entire food supply chain by the end of 2024 through strategic partnerships with all domestic players [77]. As of 30 November 2020, 100,464 food baskets were successfully distributed among 82,653 beneficiary families in the Kingdom through Eta'am (<https://saudifoodbank.com/>, accessed on 7 June 2021). During COVID-19, food banks distributed approximately 4 million meals in support of

Needy People, Communities, and COVID-19 shelters. In the UAE, there are currently 80 (Dubai), 10 (Ajman), and 10 (Ras al Khaimah) Food Bank refrigerators (144) collecting 13,488 tonnes of food from hotels, restaurants, and supermarkets and redistributing it among less fortunate members of the community, including laborers, underprivileged families, and vulnerable citizens in the UAE after efficient storing and packing with the highest standards of food hygiene and safety under the supervision and approval of Dubai Municipality. These food banks are run through the non-profit charitable organization “UAE Food Bank” launched under the umbrella of Mohammed bin Rashid Al Maktoum Global Initiatives (MBRGI) (<https://www.dm.gov.ae/foodbank/>, accessed on 7 June 2021). According to the latest June 2021 media reports, overall, 27,362 tonnes of food has been distributed among beneficiaries since its inception. In addition, these food banks have conducted 127 educational and awareness campaigns for reducing food waste. The promotion of food banks in this region will help to rescue massive volumes of wasted food as an important element of food waste management strategy.

3.5.7. Research and Innovations

The nature of challenges to FLW within the entire food supply chain are highly diverse and context specific. These challenges creating opportunities and attractive avenues for science and technology to provide tailor-made innovative solutions. In this regard, research and development in all the disciplines dealing with production, post-harvest, packaging, distribution, marketing, and consumption could play a key role to develop cost-effective innovative solutions to tackle FLW challenges. Furthermore, future research must also focus on dire need to quantify food waste generated from Halal Food (food that complies with Islamic dietary laws) and Halal kitchen flight catering production process, and, ultimately, reduction measures in terms of innovations in the Halal Food Processing in order to minimize food losses [78] and the utilization of Halal food waste to produce value-added products [79]. The allocation of budgets from public sector for research and development would be a vital step to curb FLW.

4. Conclusions

The scale of FLW in the entire food supply chain from farm to fork is of enormous economic, environmental, and societal significance. Currently, there is a scarcity of knowledge on the Halal food waste quantification and reduction measures along with a lack of consensus on the classifications of the food supply chain dealing with food loss and waste that varies from country to country. In this regard, there is a pressing need to develop consensus about the main steps for the standardization of FLW quantification methods. The measurement of FLW by each country to define the baseline and to set intermediate targets to reduce food loss and food waste is critical to underpin the actions to overcome this global issue. The future efforts must focus on the SDG 12.3 roadmap to establish intermediate goals by each country to reduce FLW. The regional collaboration about stage-specific food loss and food waste management strategies, awareness campaigns to reduce hospitality waste, Food Waste Apps, food redistribution, and waste utilization by circular economy practices, along with enabling policy reforms to set country-specific, intermediate targets and stopping unfair trading practices are of great significance to secure global food security and preserve the depleting natural resources.

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