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Exploring the 5Rs Holistic Model for Zero Food Waste in Saudi Arabian Food Service Outlets

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Abstract: *Background:* The proportion of food waste in the Kingdom of Saudi Arabia, particularly in food service outlets, sends an important and urgent call for a holistic model to either prevent or at least properly manage this high level of food waste. This study draws on the European Union Waste Hierarchy Framework and the United States Environmental Protection Agency Food Recovery Framework to develop a holistic model to manage the high rate of food waste in Saudi food service outlets. *Methods:* This study adopted the Standards for Reporting Qualitative Research using one-to-one interviews with food service experts to explore the current and appropriate practices for food waste prevention. The in-depth interviews discussed the implementation of the 5Rs hierarchy, which includes reducing food surplus and waste at the source, redistributing food surplus to needy people, reusing food surplus/waste, recycling food waste, and recovering food waste benefits, i.e., bioenergy production. *Results:* The successful implementation of the 5Rs hierarchy depends on effective collaboration between the key stakeholders, i.e., policy makers, food industry administrators, non-governmental organizations, and customers. The effective management of the food supply chain is also vital to avoid food surplus and prevent waste in food service outlets. Additionally, sustainable production by staff and responsible consumption by consumers contribute effectively to the implementation of the 5Rs model, which contributes to the achievement of zero food waste and, ultimately, to sustainable development. *Conclusions:* This study provided a novel hierarchy model, which has five tiers, aiming to avoid food waste. The successful implementation of this model will lead to several significant positive impacts on the economy, community, and environment.

Keywords: food waste; 5Rs model; waste prevention; zero waste; waste hierarchy; sustainable production; responsible consumption



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1. Introduction

Since the initiation of the United Nations Sustainable Development Goals [1], significant global attention has increasingly been paid to food loss and waste by policy makers, industry leaders, and scholars [2,3]. Food loss and waste have been connected to multiple concerns, e.g., climate change, biodiversity loss, water loss, and soil degradation [4,5]. In the situation of the Kingdom of Saudi Arabia (KSA), the country has multiple challenges, e.g., high temperatures, a harsh environment with limited rainfall, scarcity of arable land, and restricted water supplies [6]. Such features pose significant obstacles to the development of agriculture in KSA. Moreover, urbanization and a growing living level among Saudis have also influenced the demand for food [7]. Consequently, imports play a major role in meeting the food needs of communities in KSA, with approximately 80% of the food being imported [6]. Shockingly, despite the role of the KSA leadership in addressing this concern, more than 30% of such food goes to waste [8]. This highlights the urgency to understand

the underlying causes of this persistent food waste and evaluate the effectiveness of the approaches undertaken by such outlets to reduce food loss and waste [9].

KSA is classified among the countries with the highest proportions of food waste worldwide. Shockingly, food waste equals all other types of waste in the country at a minimum of 50% of the total waste generated [10]. According to the latest survey undertaken by the Saudi Grains Organization [8], more than a third of the food produced in KSA is either lost or wasted, which is slightly higher than the global average (31%), as confirmed by a study conducted by the Food and Agriculture Organization [11]. On an individual level, the average volume of food waste per person in KSA is 250 kg, which is more than double the global average of 115 kg. Additionally, KSA has a higher average grain consumption per capita of 158 kg in comparison to the international mean of 145 kg [11]. It is noteworthy that food waste rises meaningfully on special occasions, e.g., Ramadan and feast days [6,9,12].

Several studies, e.g., refs. [13,14], indicated that food security and the global economy are gravely threatened by food loss and waste. About 1.3 billion tons of food is either lost or wasted annually [15,16]. This alarming statistic is juxtaposed against the fact that there are approximately 828 million people suffering from hunger worldwide. From an economic standpoint, food loss and waste cost countries USD 750 billion every year [15]. It costs the Saudi government around SR 41.00 billion annually (approximately USD 11 billion) [8]. The amount of food lost or wasted is sufficient to feed 1.26 million hungry people [17]. Food waste is a threat to environmental sustainability since it is dumped in landfills without being processed and has an overall carbon footprint of 3.3 billion tons of CO₂ [8]. Food loss and waste account for 10% of the world's greenhouse gas emissions [18]. Considering these alarming facts, the Crown Prince of KSA launched the Saudi Green Initiative (SGI) in 2021 to promote climate action in KSA. The SGI aims to reduce carbon emissions, achieve net-zero emissions by 2060, and protect land and marine ecosystems [19]. In line with this environmental project and the Saudi Vision 2030, the reduction in food waste became an important matter for sustainable development.

A review of the growing body of literature on the motives of food waste in KSA [6,9,12,13,20] has reported a number of factors that influence consumer behavior towards food waste. These factors include a lack of consumer awareness [6,12]; food consumption culture [12]; social media [21]; economic prosperity [6]; impulsive food buying [9,22,23]; promotions and food offers [6]; social influence and personal attitude towards food waste [12]; religiosity [9,12]; and demographic variables [24]. Other factors that affect food waste in KSA include the absence of strategic and legal frameworks, including incentives for organizations to manage food waste [6,9]. There are also factors specific to food service outlets, such as the management of the food cycle inside these outlets and staff skills [9]. Regardless of the causes of food waste, considering the waste incurred by all parties engaged in this process (consumers, producers, and operators), food waste has significant environmental, social, and economic impacts [25,26].

Adopting a food waste hierarchy enhances the effective management of food loss and waste [27]. The food waste hierarchy refers to a prioritized approach to manage and reduce food waste [25]. It has a set of steps or levels to guide actions and decisions aimed at minimizing and mitigating the environmental, economic, and social impacts of food waste [28]. The hierarchy typically consists of a sequence of actions, starting with the most preferred and environmentally friendly options, down to the least desirable options [29]. There are some international models that were developed to manage waste, particularly food waste. First, the European Union Waste Hierarchy Framework was undertaken as an integrated model for managing waste [30]. This hierarchy was adapted to the food waste context and recognized as a holistic approach not only to manage food waste but also to prevent it [25,30]. The hierarchy has five steps, which starts by reducing food waste at the source, reusing through feeding hungry people, recycling through feeding animals or composting, recovering energy through bioenergy, and finally, disposing through landfills [25]. Second, the Food Recovery Hierarchy developed by the US

Environmental Protection Agency (EPA) [31] has six tiers to manage food waste effectively. Similar to the EU framework, the USEPA framework starts with source reduction, followed by feeding hungry people, and then feeding animals. It then moves to the fourth tier, which includes industrial uses, followed by composting, and finally, landfills [31]. Third, the 5Rs model was suggested by Dunga et al. [32] for food waste management to produce bioenergy. This model has five stages, starting with reduction at the source, followed by reusing, recycling, recovery, and finally, refinery. These five stages aim to manage food waste by focusing on bioenergy production. Regardless of the type and the number of model levels, the primary step of any food waste pyramid is prevention, which entails putting the highest effort into ensuring that edible food remains edible [33]. The next level symbolizes reusing food for human consumption, i.e., to feed needy people. The only portion of excess food that can be directly reused for human consumption is surplus food, and it is commonly included in prevention strategies or research studies [33,34]. As food deteriorates easily, there are strict safety and hygiene regulations associated with reusing surplus food, which can restrict the amount that can be reused and consequently influence the rate of food waste [35]. Descending the hierarchy, the terms “recovery” and “recycling” are often used interchangeably, despite the fact that they are two distinct categories [29]. For example, the redistribution of food is sometimes labeled as recovery [33], whereas using food waste as animal feed has been categorized as “recycling” [34].

This study investigates the perspectives of food service managers and specialists about the prevention and management of food waste in the food service outlets in KSA. The current paper draws on the EU Food Waste Hierarchy Framework and the US EPA Food Hierarchy Framework as well as existing research to investigate the current and proper practices that should be undertaken to achieve zero food waste. It explores the potential of the newly developed 5Rs framework (reduce, redistribute, reuse, recycle, and recover) as a holistic model to achieve zero food waste. Considering the national and global concern about food waste and its environmental, economic, and social impacts, it is important to re-evaluate the current strategies of waste prevention and management in KSA. A fresh study conducted by Sobaih [9] reveals a scarcity of research that effectively addresses food waste prevention or effective food waste management. Remarkably, there are no published studies, to date, that undertake a comprehensive approach to tackle food waste from the perspectives of various stakeholders in the KSA context [9]. Despite the growing number of research studies on food waste in the Saudi context, none of these studies have delivered an intensive model for dealing with food waste in the food service outlets, despite their significant contributions to waste in KSA [12]. Hence, this research is considered as the first study that adopts the 5Rs model as a holistic model for zero food waste in KSA. It is evident that food waste is a significant concern and a key challenge for Saudi Vision 2030 [9]. Additionally, the problem of food waste has not been resolved or even reduced despite numerous initiatives and approaches that have been adopted by the government [6,9].

This study aims to explore the challenges of implementing the 5Rs hierarchy model for food waste management in the food service outlets in KSA. By utilizing a qualitative research methodology, this study provides insights into managing food waste in the food service outlets in KSA, contributing to zero food waste and ultimately achieving food security. This study addresses the following questions: (1) What are the current practices of food waste prevention and management applied in the food service outlets? (2) What approaches can be implemented for effective food waste prevention and management? (3) How can food waste in food service outlets adopt the 5Rs hierarchy framework? (4) What are the challenges and barriers of implementing the 5Rs hierarchy framework in KSA? The next section of this study presents the research techniques employed for data collection and analysis, followed by the key findings in Section 3. Section 4 discusses these findings. Finally, Section 5 concludes the paper and addresses its limits.

2. Results

2.1. *The Concepts of Food Surplus and Waste*

The participants in the interviews were asked about the concepts of food surplus and food waste and whether the managers of food service outlets recognize the differences between these two terms. They argued that most managers of food service outlets do not really understand the key differences between food surplus and waste. They recognized food surplus as the same as food waste. However, food surplus refers to the existence or provision of more food than needed, while food waste relates to any edible food for human consumption that is not consumed. The interviewees argued that offering large portions of food to customers at food service outlets is the norm and part of the Saudi culture. However, it is important that managers do not recognize this food surplus as a step towards food waste. Considering that food surplus can lead to food waste if not properly managed, it is important for it to be considered as food waste. Hence, in order to undertake waste prevention, it is essential to prevent food surplus or bring it to the lowest minimum level. Conversely, most food service managers and professionals are concerned with food waste management, and not prevention. Food waste prevention should contain any practices that avoid waste generation, whereas waste management refers to managing food waste once it generated. The management of food waste is a reaction to the ineffective management of the food chain and/or consumer behavior. Nevertheless, the prevention of food waste consists of proactive practices undertaken by managers in the food chain with consumers' engagement to decrease food surplus and prevent food waste.

The interviewees reported that food waste varies significantly across different types of food service outlets due to various factors such as the sizes of the outlets, restaurant type, menu offerings, customer behaviors and preferences, operational efficiency, and waste management practices. Certainly, the restaurant type such as full-service restaurants, fast food chains, cafeterias, and food trucks have different operational models and customer dynamics, which can influence food waste. Furthermore, restaurants with extensive menu items often face challenges in managing ingredients and predicting customer demand accurately. Items with a short shelf life or seasonal ingredients can further increase waste. Conversely, the food service outlets with limited, specialized menus may have better control over their inventory and waste. Additionally, the interviewees commented that operational efficiency in the food service outlets could affect food waste significantly. Efficient inventory management, proper staff training to manage ingredients effectively, and timely stock rotation can reduce food loss and waste. At the end, the interviewees confirmed that the waste management practices followed by different food service outlets vary widely. Some outlets may have well-implemented food waste prevention, reusing, and recycling programs, while others may lack such practices. Larger outlets may have dedicated staff and systems for controlling and managing food waste, whereas smaller ones might face challenges in implementing comprehensive waste management strategies due to limited resources. Understanding these variations is crucial for identifying waste reduction opportunities and implementing effective strategies to minimize food surplus and waste.

2.2. *The Current Practices of Food Waste Prevention and Management Applied in the Food Service Outlets*

The interviewees were asked about the current practices undertaken by the food service outlets in KSA to prevent food surplus and deal with food waste. There was a consensus among the interviewees about the importance of food waste reduction at the source. Nevertheless, they confirmed that proper food handling techniques to reduce food surplus and prevent food waste are marginally practiced in the food service outlets in KSA. In most food service outlets, there are no established regulations nor operational guidelines for reducing food surplus or handling food waste properly. The interviewees commented on the environmental, social, and economic consequences and ethical considerations of food waste. They argued that many managers of the food service outlets do not really

recognize the negative consequences of food waste, nor do they consider it as a significant problem that affects the environment, economy, or society. In other words, the interviewees argued that managers engaged in food waste do not feel shamefaced for their current practices of improper food waste handling. The most important issue for managers is to run their businesses and maximize their profits.

The current practices of the food service outlets lead to food surplus. Food surplus can be generated in the food chain if it is not handled appropriately. This comprises oversupply and improper item storage, issuing, preparation, and service. For instance, food surplus can be generated by ineffective food storage, and implementing inappropriate issuing technique such as last in, first out (LIFO). Poor kitchen and service staff skills could also contribute to food waste, such as food cutting skills. It was argued that poor culinary skills lead to food surplus and food waste.

The interviewees commented on the current practices that contribute to food surplus, and hence, its waste. These practices include using buffet services, especially for special events such as weddings and other ceremonies, a variety of food promotions, and offering oversized food items with free side items and uneaten food garnishes. These factors motivate consumers' behaviors towards ordering more food than they need, leading to food waste. They added that there is a lack of support for handling food surplus. They also commented on the lack of infrastructure for handling food surplus and dealing with food surplus/waste. Consequently, there was a consensus among the interviewees that the current practices do not support the food waste management hierarchy, which includes reusing, recycling, and recovery. Such practices of the food hierarchy are limited or not applicable at all in most outlets.

The interviewees argued that most managers of food service outlets mix food waste with other types of solid waste and disposed them in landfills. There is no clear plan to implement more sustainable practices of food waste management, whereas some of the interviewed specialists stated that some outlets have started to redistribute food surplus to needy people through a partnership with a local food organization such as the Saudi Food Bank (SFB), or with community organizations such as It'aam" and Kafa'. However, only few food service outlets donate their surplus food to charity programs that feed hungry and needy individuals.

The food waste specialists criticized the current practices of the food service outlets in KSA. They commented that the present practices of food waste management in the food service outlets in KSA are not appropriate. They added that the managers of these food service outlets do not adopt the food waste hierarchy nor recognize its significant impacts. Thus, they just redistribute the surplus or excess food, while they neglect the other aspects such as reusing, recycling, and recovering food waste. There was a consensus among all of the interviewed experts that food waste management has to be circular, which starts with prevention at the source, and then reusing, recycling, and recovery.

2.3. Appropriate Practices for Effective Food Waste Prevention and/or Management

The interviewees confirmed that food service outlets should adopt the proposed 5Rs hierarchy to handle any food surplus and achieve zero food waste. This begins with reducing the food surplus as much as they can in the food chain. This could be achieved by serving proper portions of food items and avoiding providing any food garnishes that cannot be eaten. In buffet services, it is important that consumers are encouraged to take only what they want and obtain refills if needed. Additionally, food service outlets should offer side items that meet customer needs and refill them when needed. Another important aspect to reduce food surplus and prevent food waste is to follow the proper management of the food chain to prevent any waste during the chain until it is served to consumers. Trained and qualified workers are required to ensure the implementation of such proper system.

The second stage of handling food surplus that exceeds consumers demand is to redistribute food to needy people through certain organizations, such as It'aam or Kafa'.

Hence, food service outlets have to collaborate with the SFB or other non-governmental organizations. The third option is to reuse any food that is left and cannot be consumed by humans to feed animals and pets. The surplus/waste of a kitchen can also be used in other food preparation practices; for example, stale bread can be used as crumbs for breeding food, vegetable trimmings can be used in soups and stocks, bones can be used in stocks, etc. However, this requires more attention from the kitchen and service staff to create zero food waste. The fourth stage is recycling food waste through feeding animals and composting. This compost can be used for gardening and agricultural purposes. The fifth stage is to extract any benefits from the food waste such as energy. This recovery includes rendering, biodiesel, and anaerobic digestion. Examples of rendering include the use of liquid fats and solid meat products as materials, which converts them into cosmetics. Examples of biodiesel include collecting and converting fats, oils, and grease into environmentally friendly biodiesel fuel. Examples of anaerobic digestion include adding fats, oils, and grease to anaerobic digesters to generate renewable energy, e.g., biogas. Food service outlets' owners/managers could gain many benefits through applying appropriate practices of the 5Rs model, such as reducing the food cost, because the surplus/waste of the kitchen could be used in other food preparation practices. Consequently, they can minimize their restaurant waste and increase their profits. Furthermore, food service outlets that adopt proper practices can create other positive consequences on the environment and society.

2.4. Challenges and Barriers for Implementing the 5Rs Food Waste Hierarchy Framework

The interviewees argued that there are several challenges that hinder the effective implementation of the 5Rs framework, especially the reduction in food surplus and the prevention of waste at the source. First, the managers of food service outlets miss the motive of their engagement in food waste prevention or management. Some owners and/or managers of food service outlets do not understand why they should prevent food waste and do not know the benefits for their outlets. Managers are not motivated to control their food waste and do not realize the economic value of food waste management. Hence, this low motivation among managers becomes a key barrier for the effective implementation of the 5Rs framework. Second, consumers' attitudes and behaviors towards food surplus and waste are due to many variables, especially cultural and social norms that encourage these behaviors. Third, there is a lack of consumers' awareness and engagement in the prevention and management of food waste. Fourth, there is a lack of regulation or legislation that encourages or enforces outlets to engage in food waste management. Fifth, there is insufficient management of the food chain in the food service outlets. Sixth, there is a shortage of staff engagement in food waste management, including limited awareness about the importance of food conservation; however, they must develop their skills to be a part of the program.

There are other challenges in redistributing food surplus and reusing food waste. First, the food safety of food surplus during the process of packaging and redistribution is a key challenge that requires proper handling techniques. Second, there is a lack of awareness among food service outlets regarding how they can engage in this action and what they should do. Third, there are financial concerns raised by the interviewees for handling food waste, which could hinder the implementation of this process. Food waste redistribution requires infrastructure such as smart packaging. Fourth, there are other challenges related to the logistics and lack of experience among non-governmental organizations to redistribute or reuse extra food. Fifth, staff qualification could be a challenge for food redistribution and/or reuse if they are not trained on how to handle food waste in the food chain.

In addition, there are challenges related to the recycling stage. First, there is an absence of a national program for food waste recycling. Second, there is an absence of organizations specialized in recycling food waste. Third, there is a lack of infrastructure for recycling food waste at the outlets or even outside of the outlets. Fourth, there is an absence of legislation or regulations that organize food waste recycling. Fifth, consumers are not encouraged to recycle their food waste and find it easier to dispose it in landfills. Sixth, there are more

financial concerns related to food recycling than benefits gained by the consumers of the outlets, as perceived by some managers.

Finally, there are challenges related to recovery of benefits and energy from food waste. First, there is an absence of knowledge among policy makers on how to recover energy from food waste. Second, there is an absence of organizations related to the recovery of benefits and energy from food waste. Third, there is a lack of infrastructure for food waste recovery. Fourth, there is an absence of legislation or regulations that organize food waste recovery. Fifth, there is an absence of motivation for engaging in the recovery of food waste.

2.5. Requirements for the Implementation of the 5Rs Food Waste Hierarchy Framework

In order to meet the challenges above and adopt the 5Rs in the food service outlets in KSA, there are some requirements for effective implementation. To decrease food surplus and prevent food waste at the source, it is important that consumers engage in this action, because consumers' behaviors are the main drivers for food waste. Hence, the interviewees suggested that awareness campaigns are urgently needed to raise the awareness of customers about the value of food conservation and the negative consequences of wasting food on the economy and environment. This awareness campaign has to be part of a strategic framework that aims to prevent food waste in KSA. Additionally, a legal framework on food waste management is needed to support this strategic framework and drive both consumers' and organizations' behaviors towards conserving food and preventing food waste. Engaging staff and developing their skills are also important to save food and prevent food waste at the source, which has to be part of the operation manual for effective food management at the food service outlets in KSA. This also includes effective inventory management that can track and analyze data related to food waste.

There are other requirements to implement extra food redistribution and/or reuse effectively. A legal framework is needed to organize this issue and encourage outlets to be engaged in either food redistribution or reuse. Partnership should also be established between specialized organizations, e.g., SFB, It'aam, and Kafa', and food service outlets to redistribute food to needy people or reuse it for animal feed. They have to follow smart packaging and labeling practices to tackle food safety concerns. Food sharing platforms could be established to facilitate communication between various organizations. Staff should be effectively trained to handle food safely. Staff skills and innovation are required to reuse extra food for other purposes, as highlighted earlier, e.g., stale bread can be used as crumbs for breeding food, and vegetable trimmings can be used in soups and stocks.

Food waste recycling requires a national recycling program. This national program should benefit the organizations and the country and help in the proper handling of food waste. There should be identified organizations or bodies that manage this program. This national program should be supported with governmental regulations for food waste recycling. The program should set incentives, e.g., tax reduction, for organizations and managers engaged in this program. Food waste can be recycled into compost or fertilizer for agricultural usage. This program should organize a partnership between SFB in collaboration with a specialized organic waste management company and food service outlets to convert collected food waste that is unsuitable for consumption into compost.

The last option for handling food waste is to recover any benefits or energy from the food waste, as discussed earlier. However, this requires a legal framework with a national program to encourage the engagement of food service outlets in this program. Effective collaboration between various stakeholders, e.g., the government, food service outlets, and food handling organizations, is highly required for the effective implementation of this issue. The roles of related universities and research centers are also important in addressing this point, since they could help in developing proper guidelines for bioenergy production from food waste generated by the food service outlets in KSA. A summary of all findings is shown in Table 1, and the 5Rs model is presented in Figure 1.

Table 1. Exploring the role of the 5Rs holistic model for zero food waste in food service outlets.

5Rs	Concept	Current Practices	Best Practices	Barriers	Requirements
Reducing	This aims to prevent food waste and minimize the opportunity to generate food surplus at the source (i.e., inside a food service outlet)	<ul style="list-style-type: none"> • Oversized food portions with uneaten garnishes • Offering extra/free side items • Using buffet services for special events and weddings with a variety of food items and limited control • Variety of food promotions and offers, especially for packages • In some cases, improper storage and food issuing procedures • Poor staff skills during preparation and servicing of food 	<ul style="list-style-type: none"> • Serve proper food sizes and avoid the use of garnishes that are not eaten • For buffets, raise consumers' awareness to take only what they will actually eat and obtain refills when needed • Encourage consumers to reduce food surplus and order extra items when needed • When offering side items, provide appropriate sizes and refill when needed • Ensure appropriate storage and issuing practices • Train and develop kitchen and service staff skills to control food waste • Reassess food preparation and service to prevent waste 	<ul style="list-style-type: none"> • Cultural and social norms • Lack of consumers' awareness and engagement • Improper management of food chain • Absence of clear regulatory framework • Inefficient inventory management • Poor staff engagement 	<ul style="list-style-type: none"> • Public awareness campaigns • Setting a clear strategic framework • Develop an appropriate legal framework • Smart packaging and labeling • Train and develop staff's cutting, cooking, serving, and packaging skills • Staff engagement • Inventory management supplemented with technology tools or software that can track and analyze data related to food waste
Redistribution	This refers to the practice of redirecting food surplus valid for consumption from food service outlets to other organizations to feed hungry and needy persons	<ul style="list-style-type: none"> • There are some food service outlets that have a partnership with a local food organization such as Saudi Food Bank, or community organizations such as It'aam" and Kafa'a, to donate the food surplus that is valid for consumption to charity programs that feed hungry and needy individuals 	<ul style="list-style-type: none"> • Identify local organizations that specialize in food redistribution or food rescue initiatives. This can include established charities, food banks, or non-profit organizations • Reach out and establish partnerships • Ensure food safety and quality handling techniques • Collection of unspoiled, healthy food by specialized organizations and donate it to needy people 	<ul style="list-style-type: none"> • Food safety and handling techniques • Lack of awareness among organizations and consumers • Logistic and distribution challenges • Legal and liability concerns • Financial concerns 	<ul style="list-style-type: none"> • Legal considerations • Donation partnerships • Public awareness campaigns • Smart packaging and labeling • Staff and customer engagement • Food sharing platforms such as mobile applications • Food safety regulations • Required substantial group of extensively trained volunteers

Table 1. Cont.

5Rs	Concept	Current Practices	Best Practices	Barriers	Requirements
Re-use	This includes finding alternative purposes for leftover or surplus food that would have otherwise gone to waste	<ul style="list-style-type: none"> There is no centralized nationwide program in place for repurposing unconsumed food that is not suitable for donation to those in need 	<ul style="list-style-type: none"> Animal feed production: some food waste can be safely processed and used as animal and pet feed Reuse waste in other food preparation practices; for example, stale bread can be crumbs for breeding food, vegetable trimmings can be used in soups and stocks, bones can be used in stocks, etc. 	<ul style="list-style-type: none"> Absence of national program on food reuse Lack of infrastructure and logistics Food safety concerns Staff skills 	<ul style="list-style-type: none"> Legal framework Donation partnerships Food waste management companies Food delivery applications Developing staff skills
Recycling	When food waste is unavoidable or unsuitable for human consumption, recycling can be considered; recycling typically involves the conversion of food waste into product	<ul style="list-style-type: none"> Recycling programs have been relatively limited A small proportion of organizations in Saudi Arabia are engaged in producing compost from leftover food The recently initiated “enviromate” program by the Ministry of Environment, Water, and Agriculture aims to distribute composting bins to households 	<ul style="list-style-type: none"> Composting: if the surplus food cannot be consumed or donated, consider composting it; this allows the food waste to be converted into nutrient-rich compost that can be used for gardening or agricultural purposes In regions characterized by dry climates and limited fertile land, composting could potentially assist farmers in achieving successful plant growth 	<ul style="list-style-type: none"> Lack of knowledge about composting procedures, which are essential for maximizing agricultural productivity Lack of infrastructure Cultural and societal norms Cost and resources Absence of legal and regulation frameworks 	<ul style="list-style-type: none"> Compost equipment and bin Food waste management companies Staff training and engagement A collaboration between food banks in Saudi Arabia with a specialized organic waste management company to convert the food they collect, which is unsuitable for consumption, into compost Legal framework to support recycling Promoting economic value of recycling

Table 1. Cont.

5Rs	Concept	Current Practices	Best Practices	Barriers	Requirements
Recovery	The process of utilizing food waste to extract benefits through various innovative techniques by industrial use	<ul style="list-style-type: none"> The Saudi government is committed to exploring alternative sources of energy while also conserving its current energy sources, which means that they are willing to consider other options apart from their current sources; additionally, they see potential in using waste as a means to generate energy 	<ul style="list-style-type: none"> Rendering: liquid fats and solid meat products can be used as raw materials in the rendering industry, which converts them into cosmetics Biodiesel: fats, oils, and grease could be converted into environmentally friendly biodiesel fuel Anaerobic digestion: fats, oils, and grease can be added to anaerobic digesters to produce renewable energy, e.g., biogas 	<ul style="list-style-type: none"> Lack of awareness and understanding Infrastructure limitations Cost considerations Regulatory and policy framework Logistic challenges 	<ul style="list-style-type: none"> Food waste management companies Legal framework Collaboration with other stakeholders Developing technical skills for successful food waste management Promoting economic value of recycling

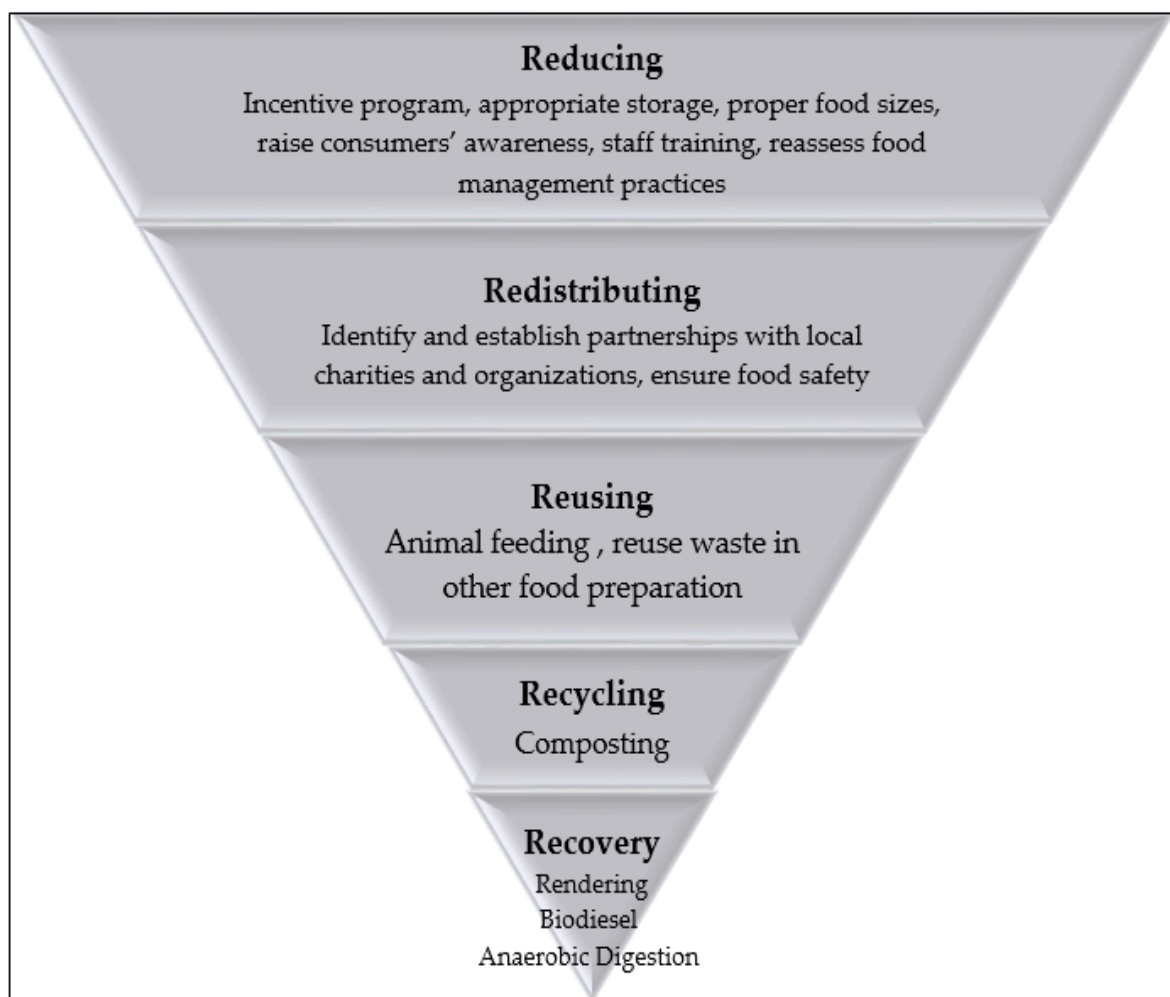


Figure 1. The 5Rs holistic model for zero food waste in food service outlets. (Developed by the authors based on the findings).

3. Discussion

One of the key issues in understanding food waste in food service outlets is realizing the key differences between food surplus and waste [25]. The results showed that most managers of the food service outlets do not really distinguish the differences between them and deal with food surplus as waste. This finding is in agreement with the findings of Teigiserova et al. [29]. However, it is important that food service professionals recognize that food surplus is not waste and understand the major differences between food surplus and food waste [25]. This research confirms the work of Papargyropoulou et al. [25], which states that the key step to prevent food waste is to minimize food surplus in the food chain, especially when offering more food to consumers than needed.

The results revealed that the current practices of the managers of food service outlets confirm the absence of the 5Rs hierarchy and the EU waste hierarchy framework [30]. Food surplus is the norm of the food waste outlets in KSA, which leads to high amounts of food waste that are inappropriately handled by managers and their teams. Consumers, managers, and policy makers are the key responsible stakeholders for these high volumes of food surplus and waste. Consumers' behaviors of buying more food than they need and not managing unconsumed food appropriately lead to a high proportion of food waste. Supporting the notion of Sobaih [9,22], this excessive food buying is primarily due to cultural and social norms expressing the Arabic hospitality of serving large food portions to their families and guests. This finding is in agreement with previous studies [12,22]. Managers, on the other hand, provide large food portions with free side items to attract

their customers to their outlets in a competitive environment. Managers, however, do not recognize the significance of adopting a food waste hierarchy, and they often do not handle food waste properly. This finding is supported by the study by Tsalis et al. [2]. Managers often dispose food waste in landfills instead of following a waste hierarchy framework. In addition, they do not manage food properly in the food chain, leading to food waste at some stages of the chain. They do not feel motivated to engage in food waste management, especially with the absence of a legal framework that encourages them to manage their food waste properly. Policy makers did not play their important role of developing and implementing a plan for food waste in the country based on the waste hierarchy framework. Policy makers also did not develop a legislative framework that supports the waste hierarchy and they are missing a strategy for food waste management. This outcome is in agreement with the study by Sobaih [22]. Nevertheless, collaboration between these key stakeholders will ensure the effective implementation of the 5Rs and the prevention of food waste in KSA.

The results confirm the significance of the 5Rs model in managing food surplus and waste, albeit the roles of the key stakeholders are vital for the effective implementation of this hierarchy. The managers of food service outlets should develop an operation manual to facilitate the effective implementation of food management in the food chain, especially during the preparation and servicing of food. For example, they should offer proper item sizes to consumers and avoid providing free side items with large portions. They should also encourage consumers to reduce surplus by providing their needs and provide refills when needed. Managers should also ensure that their staff are engaged in food waste management and have the required skills to carry this out [9]. In addition, without consumers' engagement, food waste hierarchy management cannot be implemented effectively, as consumers' behaviors are critical in this process. This finding is supported by the work by Aschemann-Witzel et al. [36], who confirmed the roles of consumers in food waste management. Policy makers should develop a national program as part of the strategic framework to implement the food waste hierarchy. This program should integrate non-governmental organizations, which have the knowledge and experience to collaborate in handling food waste safely. These organizations can help food service outlets to implement the food waste hierarchy. They could assist in managing food waste through redistributing food to needy individuals and families, reusing it for animal feed, recycling it through composting, and recovering benefits and energy through rendering, biodiesel, and anaerobic digestion. This program should motivate food service outlets and their managers to engage in food waste management. Incentives should be granted to outlets and managers that adopt the 5Rs model and prevent food waste or manage it properly. This could include a certificate given to the outlets with a reduction in paid tax for instance.

The current study provided a holistic model for reaching zero food waste in food service outlets. The order made in this study, the 5Rs holistic model, was tested in food service outlets in Saudi Arabia, and zero food waste was the outcome without reaching tier number 4, or even tier number 3 in some cases. A comparison between this research model, "the 5Rs", and earlier models is presented in Table 2.

Table 2. The key advantages and differences between the 5Rs holistic model and other frameworks.

	The European Union Waste Hierarchy Framework	The US EPA Food Recovery Framework	Food Waste to Bioenergy via Anaerobic Processes	The 5Rs Zero Food Waste Model
Concept	The European Union Waste Hierarchy Framework is a five-step waste hierarchy model, established in the Waste Framework Directive. It gives a general framework for handling waste and establishes an order of preference for managing and disposing waste.	The US EPA food recovery framework prioritizes actions that organizations could consider to prevent and divert wasted food. Each tier requires a different strategy to handle the waste. The top level of the tiers is the best to prevent and divert wasted food since they generate the top benefits for the environment, society, and the economy.	The study presented a model called “5Rs” as a way forward for food waste (FW) management via bioenergy production. The focus of the model is to manage waste and produce bioenergy instead of disposing food into landfills without handling this waste.	The Five Rs is a holistic model that not only aims to reduce waste but also to achieve zero food waste in food service organizations. The Five Rs model has five tiers, where each tier requires a different strategy to prevent waste, starting at tier 1, and waste is managed properly at the next tiers, leading to no food waste going to landfills. The top tiers are the best options to prevent food waste, starting by reducing surplus food, and then redistributing the surplus and reusing it for other purposes, such as feeding animals, without adding any other materials. Tiers 4 and 5 are the least favorable options, albeit they are efficient for the environment, society, and economy.
Tier No. 1	Prevention This tier aims to reduce waste at the source	Source reduction This tier aims to reduce the volume of food surplus generated	Reduce The tier aims to reduce the cost of FW by not producing it in the first place and to prevent producing FW by avoiding over-preparation	Reducing This first tier aims to prevent food waste and minimize the opportunity to generate food surplus at the source (in food service organizations or households) in the food chain
Tier No. 2	Preparing for reuse This tier aims to reuse the waste for other purposes	Feed hungry people This tier aims to donate extra food to food banks, soup kitchens, and shelters	Reuse This tier aims to store leftover food in the refrigerator for reuse or to donate (i.e., redistribute) unused food to local charities or hostels for the homeless	Redistributing The second tier is only implemented if there is food surplus from tier 1. This tier refers to the practice of redirecting surplus food that is valid for consumption to food banks and specialized organizations to feed hungry and needy persons.
Tier No. 3	Recycling This tier aims to recycle the waste	Feed animals This tier aims to divert food scraps to be used as animal feed	Recycle This tier uses FW as a feedstock of commercial feed for animals; additionally, FW can be converted to produce bio-fertilizer and biogas	Reusing This third tier includes finding alternative purposes for leftover or surplus food that would have otherwise gone to waste, such as reusing kitchen scraps in other food preparation practices or using the surplus for animal feed

Table 2. Cont.

	The European Union Waste Hierarchy Framework	The US EPA Food Recovery Framework	Food Waste to Bioenergy via Anaerobic Processes	The 5Rs Zero Food Waste Model
Tier No. 4	Recovery This tier aims to recover energy from the waste	Industrial uses This tier aims to provide waste oils for rendering and fuel conversion and food scraps for digestion to recover energy	Recovery In this tier, FW recovery is a series of activities where discarded FW are collected, sorted, processed, and converted into other higher-value and marketable products	Recycling The fourth tier starts when food waste is unavoidable or unsuitable for human consumption, so recycling can be considered; recycling typically involves the conversion of food waste into products, such as compost, which could be used for agricultural purposes
Tier No. 5	Disposal This tier is the last option, which is to send the waste to a landfill	Composting This tier aims to create a nutrient-rich soil amendment	Refinery In the last tier, multiple final products could be produced from FW refinery; bioenergy yields the highest benefit to the economy and environment	Recovery The fifth tier includes the process of utilizing food waste to extract benefits through various innovative techniques such as biodiesel and anaerobic digestion
Tier 6	-	Landfill/incineration This tier is the last resort, which is disposal	-	-
Key advantage and/or concern	The major advantage of this framework is that it helps reduce waste in general, but it does not give more alternatives for handling food surplus, such as donating it to needy people or using it to feed animals; however, it considers “Preparing for reuse” as the second tier, which is mainly for industrial reuse	This model is more integrated for managing food waste at organizations than the EU framework. However, the model has two main concerns: First, it prioritizes industrial uses before composting, which is costly and has more effects on the environment and economy. Second, despite the option of landfill being the last resort, it is still an option despite its negative consequences on the environment and society. The food waste should be totally handled and zero waste goes to landfill.	This model is similar to the US EPA model, but it focuses mainly on the production of bioenergy from food instead of wasting this “food waste” resource	This model considers the advantages of the three models and provides five hierarchy tiers that ensure no waste goes to landfill, albeit it is more suitable for food service organizations than the earlier models. The five tiers or stages are critically developed to ensure more positive consequences for the environment, economy, and society. The first option aims to prevent surplus food; the next two tiers aim to best handle surplus/waste with no negative effects or consequences on the environment, society, and the economy; and the last two tiers are ordered to consider the cost of handling the waste and the consequences. Hence, the model prioritizes recycling before recovery.

4. Methods

4.1. Research Approach

This study presents the findings of one part of a broader study on the management of food waste in KSA. The current study undertook a qualitative research strategy to collect and analyze the data. More particularly, this study adopted the Standards for Reporting Qualitative Research (SRQR) [37]. The qualitative methodology allows for the collection of in-depth information and probing of the responses of the interviewees [38]. Therefore, the focus of this approach is on the perceptions and experiences of the participants [37]. Knowledge is constructed based on the experiences and opinions of the research participants [38]. The participants have more opportunities to explain their opinions, justify their answers, and give examples for their views [39]. The data were collected through one-to-one interviews with food service experts. The main motive for undertaking this approach was to collect in-depth information from the experts, which could only be collected through a qualitative research design. These data cannot be collected through questionnaires or other methods. Moreover, a qualitative approach was found to be more applicable than a quantitative approach to fulfill the purpose of this study and answer its questions. This research approach did not aim to collect quantitative data or statistics on food waste. However, it focused on the perceptions and experiences of experts in relation to food waste management in the food service outlets. The issues discussed with the interviewees were drawn from the study's aim and its questions. There were five issues discussed with the interviewees as follows:

1. The concepts of food surplus and waste and the differences between them.
2. The current practices of food waste prevention and/or management applied in the food service outlets.
3. The appropriate practices for effective food waste prevention and/or management in the food service outlets.
4. The requirements for the implementation of the 5Rs food waste hierarchy (Figure 2) in the food service outlets.
5. The challenges and barriers for implementing the 5Rs food waste hierarchy in food service outlets.

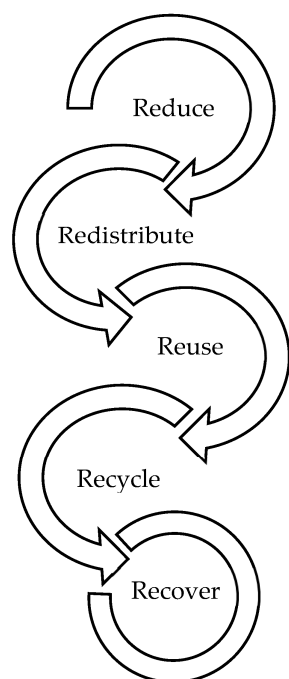


Figure 2. The proposed 5Rs holistic model for zero food waste in food service outlets. (Developed by the authors).

Following the SRQR, the purpose of this study was clarified to all interviewees before conducting the interviews. They were all notified that their participation in the study relied on their consent of participation. They were notified that they could quit the study at any time. All ethical considerations were adopted during data collection and processing to protect the participants' identities and privacy. All interviews were undertaken by the principal researcher with support from the co-researcher and a specialized company for data collection. The role of the company was only to facilitate communication with the participants, and it did not carry out any scientific intervention. The participants were informed that the results could help food service outlets control the ongoing food waste problem and encourage responsible consumption and the sustainable production and consumption of food. Interviewees who reported their consent participated in the study. The interviews were recorded after receiving consent from the interviewees. This recording was made to ensure that the collected data were complete and hence transcribed straight after the meeting to ensure there was no missing information. Additionally, the researchers contacted the interviewees to probe their comments if they were unclear. The data for this phase of the study were collected from March 2023 to June 2023, i.e., over three months.

4.2. The Interviewees

The interviewees in this study were divided into two groups. The first group comprised the managers of food service outlets. Experienced managers with over 15 years of experience in a managerial position related to food management were selected for interviews. The researchers made sure that the participating managers had enough experience to share in this study. The second group comprised experts in food waste management from food conservation, waste management, or other related organizations and academia. The main purpose of the interviews was to answer the research questions. The interviews were conducted to investigate the potential of adopting the food waste hierarchy, particularly the 5Rs, in the food service outlets in KSA. All the interviewees were identified via personal linkage and snowballing techniques, as some experts recommended other experts to participate in the study. All interviewees of the current study were from the Eastern Province of the KSA.

Regarding how the number of interviewees was decided for each group of interviewees, this research followed the guidelines of Oppenheim [40], who confirmed that the quality of collected information is the key determinant for deciding on the number of participants. This means that the numbers were confirmed after data saturation was accomplished [40]. Based upon this evidence, the total number of participants after the saturation of the data was achieved was 64 experts, including 34 managers of the food service outlets and 30 food waste specialists.

4.3. Data Analysis

The data were analyzed manually by adopting the qualitative contents analysis technique. The data were grouped into meaningful classifications and then presented under five themes: Theme 1: the concepts of food surplus and waste; Theme 2: current practices of food waste prevention and/or management applied in the food service outlets; Theme 3: appropriate practices for effective food waste prevention and/or management in food service outlets; Theme 4: requirements for the implementation of the 5Rs food waste hierarchy framework in food service outlets; and Theme 5: challenges and barriers of implementing the 5Rs food waste hierarchy framework in the food service outlets in KSA.

5. Conclusions and Implications

Although many initiatives and efforts were undertaken by the Saudi government to reduce the level of food waste, there are no results to date about the impacts of these initiatives. Hence, the main objective of this study was to explore the potential of the 5Rs holistic model as a hierarchy framework (reduce, redistribute, reuse, recycle, and recover) to achieve zero food waste in the food service outlets in KSA. Furthermore, this study

addresses the challenges of implementing the 5Rs hierarchy framework for food waste management in the food service outlets in KSA. This study compared the proposed model with other models and highlighted the current practices of the food service outlets with the best practices that should be followed to minimize food waste to zero. Furthermore, this study illustrated the potential advantages of adopting the 5RS holistic model as a hierarchy framework. Additionally, this study answered four research questions regarding the current practices and best practices as well the challenges of implementing the 5Rs for food waste management in food service outlets. The results confirmed that the current practices of food service outlets do not implement the food waste hierarchy despite its significant impact on the environment and economy. However, the results showed that some managers do not realize the positive consequences of managing food waste nor the negative consequences of the current practices of most food service outlets. They do not feel motivated to engage in food waste management, especially with the absence of an incentive program and regulation for food waste management. Additionally, the absence of the role of key stakeholders (policy makers, industry administrators, and consumers) is a key challenge of the effective implementation of the 5RS model and the food waste hierarchy management. Hence, collaboration between these stakeholders is crucial for the proper management of food surplus and waste. This collaboration should be initiated by policy makers by developing a strategic framework drawn on the 5Rs holistic model for zero food waste.

This study sends an important message and recommendation for all stakeholders regarding the importance of food waste reduction to the lowest level. To address the issue at hand, the primary objective for government officials in KSA is to initiate a media initiative aimed at educating the public about the importance of food conservation. This campaign should encompass diverse perspectives, including economic, social, and religious dimensions. Additionally, it is crucial to collectively work towards raising awareness and implementing educational programs specifically targeting food waste. In parallel with such awareness campaign, the policy makers in KSA should introduce incentives and rewards programs for restaurants that effectively manage their food waste. This can include recognition and certification programs, tax benefits, or government grants for implementing food waste reduction strategies. Furthermore, the policy makers in KSA should motivate and obligate restaurant managers/owners to collaborate with local food banks or charitable organizations to donate surplus food instead of wasting it. Offering logistical support or simplifying donation procedures can make this process more attractive for managers. Furthermore, the KSA government should provide restaurant managers with tools and technologies to track, monitor, and tackle their food waste. This can include software or apps that help to quantify and analyze the amount of waste generated, making it easier for managers to identify areas that need improvement. Restaurant owners/managers should have an effective food waste management plan, including methods for handling food surplus and waste. Hence, a regular audit is required to follow up on the achievement of the plan. Employees' training on proper practices of food handling should be part of this plan. Additionally, there is an urgent need for collaboration between restaurant managers and local organizations for the proper implementation of the 5Rs model, including reusing, recycling, and recovering.

6. Opportunities of Future Research

This study was limited to the food service outlets in KSA. Therefore, future studies might address this limitation. There is a need for an increased understanding of food waste handling in other sectors. Hence, conducting further research in these areas can provide valuable insights and guidance for designing effective food waste management strategies in KSA. This ultimately contributes to the country's broader sustainability goals and the global fight against food waste. Another venue for an upcoming study could be testing the effectiveness of the 5Rs model on household levels or in other food production sectors. Furthermore, future research may address the roles of new technologies in applying the current

model. Research could focus on the development and implementation of new technologies, such as artificial intelligence, to better apply the food waste management model.

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