



Contents lists available at ScienceDirect

Saudi Journal of Biological Sciences

journal homepage: www.sciencedirect.com

Review

Understanding and addressing waste of food in the Kingdom of Saudi Arabia

Mirza Barjees Baig^{a,*}, Irena Gorski^b, Roni A. Neff^c^a Department of Agricultural Extension and Rural Society, College of Food and Agriculture Sciences, King Saud University, P.O. Box 2460, Riyadh 11451, Saudi Arabia^b Department of Environmental Health & Engineering, Johns Hopkins Bloomberg School of Public Health, 615 N. Wolfe St, W7010 Baltimore, MD 21205, USA^c Department of Environmental Health & Engineering, Center for a Livable Future, Johns Hopkins Bloomberg School of Public Health, 615 N. Wolfe St, W7010 Baltimore, MD 21205, USA

ARTICLE INFO

Article history:

Received 20 June 2018

Revised 23 August 2018

Accepted 31 August 2018

Available online 1 September 2018

Keywords:

Food waste

Saudi Arabia

Drivers

Recent estimates

Control measures

Agricultural extension

Consumer behavior

ABSTRACT

Introduction: Multiple estimates suggest the Kingdom of Saudi Arabia (KSA) may have one of the highest rates of wasted food globally. The KSA has limited arable lands and scarce water and thus relies on extensive imports and food subsidies to meet food demand. Accordingly, waste and loss of food are a significant concern for food security.

Materials and methods: A narrative literature review was performed to identify the available information relevant to characterizing the context, magnitude of food wasted in the KSA, key contributing factors, and existing interventions and recommendations.

Results: Estimates of annual per capita waste of food ranged from 165 kg to 511 kg. Given the country's relatively limited agricultural production, the consumer and retail levels are primary targets for intervention. Key contributors to waste include culture, food valuation, policy and industry factors, and awareness and concern. The country is at an early stage of developing responses. We build upon existing approaches and recommendations, with particular emphasis on the potential role of agricultural extension staff in addressing the issue, and highlight research needs.

Conclusions: Given the potentially exceptional levels of wasted food in the KSA and the extensive evidence gaps, there is a great need for further research and action. Our review and synthesis presents numerous opportunities to advance innovative waste reduction approaches in the country, with particular relevance for other parts of the Middle East and other areas early in their efforts to address waste of food.

© 2018 Production and hosting by Elsevier B.V. on behalf of King Saud University. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Contents

1. Introduction	1634
1.1. Saudi Arabia's food & agriculture system	1634
1.2. Economic and environmental impacts of wasted food	1635
2. Materials and methods	1635
2.1. Literature review	1635
2.2. Analysis	1636
2.3. Definitions	1636
3. Results	1636

* Corresponding author.

E-mail addresses: mbbaig@ksu.edu.sa (M.B. Baig), Igorski1@jhu.edu (I. Gorski), Rneff1@jhu.edu (R.A. Neff).

Peer review under responsibility of King Saud University.

<https://doi.org/10.1016/j.sjbs.2018.08.030>

1319-562X/© 2018 Production and hosting by Elsevier B.V. on behalf of King Saud University.

This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

3.1.	How much food is wasted in the KSA?	1636
3.1.1.	United Nations Food & Agriculture Organization (FAO).....	1636
3.1.2.	Barilla	1636
3.1.3.	COMCEC	1637
3.1.4.	Solid waste analyses.....	1637
3.1.5.	Media reports	1637
3.1.6.	Most commonly wasted foods.....	1637
3.2.	What factors shape the KSA's food wastage?	1638
3.2.1.	Culture.....	1638
3.2.2.	Food valuation	1638
3.2.3.	Awareness and concern	1639
3.2.4.	Policy and industry factors	1639
3.3.	Existing efforts and recommendations.....	1639
3.3.1.	Overarching initiatives.....	1639
3.3.2.	Source reduction.....	1640
3.3.3.	Food recovery	1640
3.3.4.	Food recycling.....	1641
3.4.	Existing recommendations to address wasted food in the KSA.....	1641
4.	Discussion.....	1641
4.1.	Amounts and determinants of wasted food.....	1641
4.2.	Six additional opportunities.....	1641
4.2.1.	Elevating the role of agricultural extension staff.....	1641
4.2.2.	Extension-run education campaign.....	1644
4.2.3.	Use waste tracking and analytics tools.....	1645
4.2.4.	Extend the food donation system.....	1645
4.2.5.	Develop animal feed applications.....	1645
4.2.6.	Build waste to energy generation facilities.....	1645
4.2.7.	Composting.....	1646
4.3.	Strengths and limitations.....	1646
5.	Conclusions.....	1646
	Acknowledgements.....	1646
	References.....	1646

1. Introduction

The Kingdom of Saudi Arabia (KSA) imports 80% of its food supply (Lovelle, 2015), and food dependence may rise with declining water resources, decreasing domestic crop production, rapidly expanding population and worsening climate change (Baig et al., 2017). As we will describe, multiple estimates suggest the KSA may have one of the highest rates of wasted food per capita globally, although improved evidence is greatly needed. United Nations (UN) Sustainable Development Goal 12.3 seeks to “halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses” by 2030 (United Nations, 2016). Meeting this goal requires diverse strategies tailored to national contexts. Focusing on countries with high waste levels can provide high payoffs.

1.1. Saudi Arabia's food & agriculture system

The KSA is among the few countries the UN classifies as both a “developing” and a “high income” country (United Nations, 2017). In developing countries, waste of food typically occurs primarily early in the food chain, including due to difficulty preserving and transporting food before spoilage. In higher income countries, a greater portion occurs in the consumer and retail end of the food chain. The latter is likely true in the KSA, due both to the country's distinctive food chain centered on distribution and consumption rather than production, and its income level.

The KSA (Fig. 1) is among the driest countries in the Arabian Peninsula, with scarce water, high temperatures, low rainfall and therefore restricted agricultural growth. Such conditions have already caused conflicts in the region (International Food Policy Research Institute, 2016). Moreover, despite having the largest

land mass among Middle Eastern countries, it has the lowest arable land per capita worldwide, at 0.114 ha/capita. Agricultural lands cover only 1,736,472 km² (World Bank, 2017a). Population growth further pressures the country's food supply, with numbers surpassing 32 million in 2016 and predicted to increase 43% to over 46 million by 2050 (World Bank, 2017a, 2017b). The population is heavily urbanized.

Agriculture was practiced on a small scale prior to 1970, but in the 1980s, the country began modernizing its system, including by providing farmer support (free loans and land) and irrigation (Baig and Straquadine, 2014). The Kingdom achieved self-sufficiency for several commodities and became the 6th largest global wheat exporter in 1992 (USDA Foreign Agricultural Service, 2014a, 2014b).

Such production led to problems including damage to limited groundwater resources (Al-Shayaa et al., 2012). Accordingly, in the 2000s the KSA shifted its strategy toward sustainable agriculture, including increased emphasis on crops requiring less water and introducing irrigation techniques like drip irrigation (Saudi Arabia Ministry of Economy and Planning, 2015). In 2008, the government launched a policy to stop producing wheat by 2016 (Muhammad, 2014; Tanyeri-Abur and Hag Elamin, 2011). Such shifts reduced the country's food self-sufficiency, making it essential to explore alternate food supply approaches.

Today, the KSA is the largest food and agricultural product importer among Gulf Cooperation Council (GCC) countries, with 80% of food requirements imported as of 2013 (USDA Foreign Agricultural Service, 2014a, 2014b; Lovelle, 2015). Food import costs amounted to SR75 billion (20 billion USD) in 2010 (Chatham House, 2013). Import dependency is expected to remain high, particularly for commodities such as cereal grains, since there is no comparative advantage to domestic production (Woertz, 2010; Pradhan, 2010; Lampietti et al., 2011).



Fig. 1. Saudi Arabia Map. Source: Wikimedia commons.

With increased imports and decreased cultivation of high water requirement crops, the portfolio of the country's agricultural extension service has been greatly reduced (Baig et al., 2017). Agricultural extension services generally provide adult education to advance agriculture, though they assume diverse forms across countries. In the KSA, the focus has been on disseminating research-based information to farmers on topics including enhancing crop yields, conserving land and water, and other sustainable agriculture principles and practices (Baig et al., 2017; Al-Zahrani and Baig, 2014; Baig and Straquadine, 2014; Fiaz et al., 2016; Al-Shayaa et al., 2012). One possible new role, aligned with the goal of meeting the country's food security needs, is to bring staff expertise in community/adult education to address the country's waste of food.

1.2. Economic and environmental impacts of wasted food

The Saudi Ministry of Environment Water & Agriculture estimates food wastage costs the country \$13 billion annually, which may rise to \$17.5 billion by 2020 (Whitman, 2016). Additionally, food that is wasted must be replaced, leading to unnecessary imports and reliance on other countries. The cost is exacerbated as world food prices increase and oil revenues decrease (UN FAO, 2016).

Beyond economic losses, wasting food means unnecessary use of resources to produce, process, distribute and prepare food, including water, land, energy, labor, and capital; and unnecessary contamination of water, air and soil. The UN has estimated that if wasted food was a country, it would be the third largest greenhouse gas emitter

and top user of blue water for agriculture (UN FAO, 2013). Generally speaking, the greatest environmental impacts from food come at the production stage, meaning other countries bear much of the environmental burden for food wasted in the KSA. Nonetheless, given the KSA's reliance on affordable food from these importing countries and the food supply's many global interdependencies, those losses still affect it. Moreover, for the portion of food produced domestically, unnecessary losses of limited agricultural resources are concerning. Most wasted food is landfilled in the KSA, contributing significant amounts of methane, a powerful greenhouse gas, from decomposition (Anjum et al., 2016). Landfills that are not adequately engineered or maintained contribute significant environmental harm, with emissions of leachate, waste sludge, methane, and odors. Many Saudi cities are building or planning new sanitary landfills to avoid these emissions.

As the KSA develops plans and policies for addressing waste of food, it is essential to gather what is currently known – and not known – about the issue domestically, and to identify promising future directions relevant to the KSA's context and resources. This paper describes causes, impacts, existing activities, further proposed interventions and research needs.

2. Materials and methods

2.1. Literature review

A narrative literature review (Green et al., 2006) was performed to curate available content on waste of food in the KSA from

peer-reviewed and governmental literature, plus credible grey literature and media. In summer 2017, we searched Google Scholar for all combinations of terms from lists A & B: (A) “food waste,” “wasted food,” “organic waste,” “plate waste,” “food recovery,” “food loss,” “food recycling,” “composting,” “anaerobic digestion”; and (B) “Saudi Arabia,” “Middle East,” “Near East,” “Arabian Peninsula,” “Gulf Cooperation Council,” “Kingdom of Saudi Arabia,” “KSA,” “Ramadan,” “Hajj” and “Muslim”. There are no relevant journals in Arabic indexed in ISI or Web of Knowledge, but this strategy yielded over 500 English language results, which were narrowed to 19 peer reviewed articles and 9 Gy literature reports after removing items with low relevance, duplicate content, and publication prior to 2010. We included sources focused on the KSA, the Middle East (also called the Near East), the Arabian Peninsula, and the GCC. The search terms “Muslim,” “Ramadan,” and “Hajj” were included to capture content on food waste patterns and interventions specific to culture and celebrations.

Given the limited peer-reviewed, governmental and gray literature, we also reviewed news media for updated information about activities and to identify information for which we could seek more credible sources. In some cases we could not find further sources but believed the information warranted inclusion; these are identified as such in the text. We searched Arabic language newspapers and magazines online using the terms, “food waste in Saudi Arabia (Arabic);” “food waste in GCC (Arabic);” “food waste in MENA [Middle East and North Africa] Arabic;” “Food waste in Near East countries (Arabic).” Ten articles were translated to English using the newspapers’ translation functions, or when unavailable, Google translate. We additionally searched prominent English language news sources including Arab News, Saudi Gazette, and EcoMENA using the search terms from list A above, yielding 11 relevant results.

A key information source regarding consumer and food service perceptions was the KSA results from a 2017 multi-country survey on wasted food, commissioned by the Standing Committee for Economic and Commercial Cooperation of the Organization of Islamic Cooperation (COMCEC). The survey provides by far the most extensive and detailed evidence available. We note four key limitations: (1) The survey scaled results to the national level from 111 households and 94 food service establishments, all in the capital city of Riyadh. (2) As a survey, it uses self-report to draw conclusions regarding a behavior that international studies have suggested is commonly performed with little self-awareness (Neff et al., 2015; Quested et al., 2013). Indeed, a UK analysis suggested that using a survey to quantify the amount of food wasted resulted in under-reporting by 40% (Quested et al., 2011), although the Saudi context could differ. (3) The COMCEC report did not supply question text. (4) It did not describe how respondents were identified and sampled other than noting that consumer selection was random from among those aged 24–60 and that food services were first organized into type of venue and then randomly sampled. The demographic data provided did suggest diversity was obtained, but the numbers were not compared with a national sample.

2.2. Analysis

We summarized findings from the above review, with reference to the questions:

- (1) How much food is wasted in the KSA?
- (2) What are possible contributors to this waste?
- (3) What actions are currently taken and recommended to address waste of food in the country?

The discussion section then builds upon the existing recommendations, based on findings from the literature review and our own expertise in wasted food and agricultural extension.

2.3. Definitions

We define wasted food as food that is or was edible or that could have been used in other applications, but that was landfilled or incinerated. We do not consider food, food scraps or inedible portions as wasted if they are donated, recovered for animal feed or industrial uses, or recycled through composting or anaerobic digestion. We generally use the term, “wasted food” rather than “food waste,” to emphasize that the product is food rather than waste, and to avoid implying that food recovery involves giving people waste to eat. We define food loss as edible food, postharvest, discarded before reaching retail. Given the Saudi context of relatively little agricultural production, this article focuses on waste rather than loss.

3. Results

3.1. How much food is wasted in the KSA?

Quantifying food loss and waste enables setting baselines to measure change over time, determining optimal intervention points, and building motivation for action. Given the great differences in results that may be obtained based on what specifically is measured, the international Food Loss and Waste Accounting and Reporting Standard, published in 2016 provides a globally standardized approach (World Resources Institute, 2016). The Standard requires establishing the scope of measurement, specifically time frame, material type (edible and/or inedible parts), destinations included (e.g., landfills), and the inventory boundaries (e.g., food category, where in the food chain or lifecycle the discarding occurs, geography, and organizational units such as country, company, or household) and characterizing uncertainty.

Though no scientific estimates have been made on the waste of food from various sources and groups to date (Baig et al., 2019), we identified ten estimates of food wasted in the KSA (Table 1), each quantifying different dimensions, based on different data, and most with little or no publicly available documentation. Most defined the time frame and provided some information about inventory boundaries, but virtually none indicated the material type or waste destinations that had been included in the calculation. Only a few mentioned uncertainty. All reports on the subject recognized the limitations of their estimates and strongly called for better data collection.

3.1.1. United Nations Food & Agriculture Organization (FAO)

The FAO estimates that the North Africa, West & Central Asia region generates 210 kg of food loss and waste annually per capita (UN FAO, 2011) with 68% during production, handling, processing, and distribution and the rest during consumption, mostly in urban centers. These estimates are based on literature review, information from local FAO offices and universities, and where needed, assumptions and estimates based on comparable regions, commodity groups, and food supply chain stages (Gustavsson et al., 2013). The applicability to the KSA is limited by cultural, economic and other differences with the other included countries.

3.1.2. Barilla

The Barilla Food Sustainability Index ranks the 20 largest economies plus Nigeria, Ethiopia, Colombia, the United Arab Emirates (UAE), and Israel on multiple dimensions. This analysis placed the KSA as the #1 per capita food waster, at 427 kg per person per year, more than double the amount estimated by the FAO (Barilla Ctr for Food & Nutrition and Economist Intelligence Unit, 2016). Supplementary materials indicated, however, that the Saudi estimate was based on information provided by Khaled Al-Khan of

Table 1
Overview of identified estimates of amounts of wasted food in Saudi Arabia. National kg/capita/year estimates are highlighted in bold/underline.

Source	Estimate	Data Source for Estimate
UN FAO	210 kg/cap/year (food loss and waste, North Africa, West & Central Asia)	Literature search, info from local FAO offices/universities; assumptions, estimates based on comparable places/commodities/supply chain stages
COMCEC	119 kg/cap/yr (household) 733 kg/establishment/year (food service)	Self-report survey of 111 consumers, 94 food service establishments in Riyadh
Saudi General Authority for Statistics	14,220,000 metric tons household solid waste/year [equivalent to 458.5 kg/cap/year household solid waste. If this is 36% food, then waste of food = 165.1 kg/cap/year]	
Tolba and Saab (2008)	1.5 kg/cap/day solid waste [equivalent to 547.5 kg/cap/year solid waste. If this is 36% food, then waste of food = 197.1 kg/cap/year]	Solid waste analysis in cities such as Riyadh, Doha and Abu Dhabi
Khan & Kaneesamkandi (2013)	5.5 million tons/year	Solid waste experts est based on idea that KSA solid waste may be 36% food
Undersecretary of Saudi Arabia Ministry for Municipal and Rural Affairs	28% of Saudi waste is food 1.2–1.4 kg food waste/person/day 511 kg/capita /year	Solid waste data?
Saudi Ministry of Agriculture, unverified	250 kg/cap/year	NA
Eta'am (Food Bank) Director, 2016	1/3 cooked food	NA
Barilla	427 kg/cap/yr	Estimate from Eta'am (food bank) director
Fadal Al-Buainain (Al-Fawaz, 2015)	Over 50% of food wasted Over 70% of food from public events wasted	NA

Saudi Food Bank Eta'am; his data source is unclear (Barilla Ctr for Food & Nutrition and Economist Intelligence Unit, 2016).

3.1.3. COMCEC

COMCEC aggregated estimates from survey responses in context of the Saudi population and food service industry, estimating household waste of food at 119 kg/capita/year, and food service food waste at 733 kg/year, presumably a by-establishment estimate (UDA Consulting, 2017). Limitations are noted in 2.1.

3.1.4. Solid waste analyses

Further suggestion that Saudi waste levels may be exceptionally high comes from solid waste analyses. The Saudi General Authority for Statistics estimates the total household waste at 14,220,000 metric tons in 2015. Based on the population of 31,016,000, annual household waste per capita would be 458.5 kg (Saudi Arabia General Authority for Statistics, 2017). If this is 36% food, then waste of food would be equivalent to about 165 kg/capita per year.

A 2008 report estimates over 1.5 kg per capita per day solid waste in Arab cities such as Riyadh, Doha and Abu Dhabi, among the highest globally (Tolba and Saab, 2008). One expert estimate suggests solid waste in the KSA may contain approximately 36% food, roughly 5.5 million tons per year (Khan and Kaneesamkandi, 2013). A workshop paper by Yousef Al-Saif, Undersecretary of Saudi Arabia Ministry for Municipal and Rural Affairs (described in Arab News, 2016), alternately estimated 28% of Saudi waste was food, and accordingly that the average Saudi may waste 1.2–1.4 kg of food per day, or 511 kg a year (Arab News, 2016). It is not clear if this food waste estimate is derived from the General Authority for Statistics household waste estimate or another source. A report in a local publication stated that the KSA's growing population could increase the country's solid waste from 14 million tons in 2017 to 17.5 million tons in 2020, with collection costs likely to be SR360 million (96 million USD) annually (Arab News, 2016; Whitman 2016).

3.1.5. Media reports

We identified several estimates provided in the news media, sometimes repeated in multiple places, for which no official source could be identified, and for which no information was available about calculation approach. Most commonly, reports described a Saudi Ministry of Environment Water & Agriculture estimate that the country wastes 250 kg/capita year, costing SR49.833 billion annually (US\$13.3 billion) (Middle East Monitor, 2016). One article indicated that that estimate was equivalent to 30% of local food production combined with imported food (Middle East Monitor, 2016). We speculate that the number might simply reflect applying the FAO global estimate that 30% of food is wasted (UN FAO, 2011) to the Saudi food supply. One source dating to 2004 also provided this 250 kg figure (Ahmed, 2004). Other estimates provided by Eta'am (food bank) are that 1/3 of cooked food is wasted nationally (Bishara, 2015) and 4 million meals are discarded daily in the Eastern Province (Al-Fawaz, 2015). Lastly, Arab News reported unidentified studies finding the country wastes over 13 million metric tons of food annually, and cited economist Fadal Al-Buainain's estimate that Saudis waste over 50% of food, and that waste from public events is over 70% (Al-Fawaz, 2015).

In sum, evidence suggests food wastage may be exceptionally high in the KSA, but estimates are diverse and inconsistent, and there remains a need for solid and country-specific data to enable estimating waste magnitude and types.

3.1.6. Most commonly wasted foods

We also sought to understand which foods are most wasted, because different types of foods could lead to different priority strategies. Data were limited. The FAO provided regional estimates by food product, suggesting that in North Africa, West and Central Asia, wasted food is comprised of 45% fruits and vegetables, 28% fish and seafood, 26% roots and tubers, 18% dairy products, 14–19% grains, 16% oilseeds and pulses, and 13% meats (UN FAO, 2015a).

Saudi household respondents in the COMCEC survey most frequently identified the top wasted foods by weight as fruits and vegetables followed by bread/cereals and meat/eggs/legumes. But for a different question, 60% indicated the category most over-purchased and disposed was meat/fish/chicken, while only 25% highlighted fruits and vegetables. COMCEC respondents in the food service industry most frequently selected bakery items as top-disposed (53%) followed by vegetables (25%), fruits (24%) and meat/chicken/fish (22%).

In self-reported survey data from a June 2017 omnibus panel survey by marketing firm YouGov, respondents reported most frequently discarding leftovers from home and restaurants (48%), fruits and vegetables (33%), dairy (33%), and canned foods (33%)

(Gleeson, 2017). That survey included respondents from the KSA (n = 580), United Arab Emirates (n = 559), and Egypt (n = 705).

Overall, questions and categories in the different data sources do not align well, but they do jointly support the idea that fruits and vegetables may be wasted at particularly high rates, which is common internationally given their perishability.

3.2. What factors shape the KSA's food wastage?

We review evidence for four of the drivers that shape the KSA's consumer, retail, and food service food wastage: culture; food valuation; policy and industry factors; and awareness and concern.

3.2.1. Culture

Food wastage patterns are shaped by cultural approaches to the special events; and everyday shopping, cooking, and eating. Saudis place high value on generous hospitality; providing ample food is a gesture of welcome. Even families with little food to spare commonly share sufficient food for a surplus with guests. This practice contributes to wastage, especially during Eid festivals, weddings, and parties, where it is common to present lavish banquets with copious fresh food (UN FAO, 2014; Baig et al., 2019).

During the Ramadan and Hajj seasons, one study found that around 600 metric tons of waste is generated daily in the KSA, with food comprising a large portion (Khan and Kaneesamkandi 2013). A Jeddah news report indicates that waste of food rises during Ramadan from 4000 tons per day to 5300 (MBC, 2015). While celebrations are impactful for waste in many places, the spike is likely especially high in the KSA because it draws Muslim pilgrims globally, and due to difficulty preserving or carrying food (Pirani and Arafat, 2016).

Food shopping in the KSA is commonly performed by men, while women commonly prepare food (UDA Consulting, 2017), thus communication between partners is required to align purchasing with planned meals. In the COMCEC survey, 79% reported always or often checking home food stocks before shopping. Half said they always or often create shopping lists, however only 1/3 routinely stick to them. Among respondents, 97% said they would likely discard less food if they knew more about effective food shopping. The survey did not ask about another cultural factor known to affect retail waste internationally: willingness to purchase misshapen or disfigured produce. Home cooking is a norm in the KSA, with about half the COMCEC respondents saying they rarely or never eat restaurant food. Ninety percent agreed that cooking too much food causes much waste.

Several food consumption practices may contribute to increased waste. First, most COMCEC consumer respondents said they prefer to eat fresh food, considering it to be hygienic. Similar to several international studies, the most frequently given causes of food discards were food poisoning (34%) and health (31%) (Neff et al., 2015). Additionally, 8% prefer fresh cooked food each day and 7% said they dislike older food. In a 2016 survey by YouGov, 78% of Saudi respondents reported discarding food each week to make room for new groceries due to the belief that their older food is no longer healthy (YouGov, 2016a). Both consumer and restaurant respondents highlighted children's food consumption practices as a top contributor to waste. One article describes a phenomenon of young residents discarding partially eaten packets of chips, chocolates, burgers, sandwiches and soft drink bottles (Pollution Solutions, 2012).

The COMCEC survey provided mixed information regarding restaurant leftovers. Nearly 40% of food service respondents indicated that among customers, 70% take leftovers – far higher than in other surveyed countries. That said, about the same percentage of food service respondents reported that less than 15% of customers take leftovers. Further, 76% of consumers reported being

embarrassed to take leftovers. An additional frequently-mentioned factor contributing to waste (and obesity) is portion size, which has expanded at restaurants over time. Sixty percent of COMCEC consumers did say they always or often cleaned their plates at home, thus not leaving excess food as waste (though undesired consumption itself is a form of waste).

3.2.2. Food valuation

A population's valuation of food, affected by food costs, income and cultural factors, can shape the care with which waste is prevented. As we will describe, the complex reality is that some factors in the KSA mitigate toward lower valuation of food, while others point the country toward higher valuation.

By conventional definitions, the KSA is food-secure. At least until recent reforms, most residents have had sufficient food to enable activities of daily living, and the country has a strong fiscal balance and large oil reserves, creating the wherewithal to import sufficient food to feed the population (Breisinger et al., 2010; Alpen Capital, 2017). The KSA occupies a prestigious economic position, especially since it is the world's largest oil producer and exporter (Boughanmi et al., 2014; UN Development Programme, 2012). Even when food prices rise, Saudis have historically been shielded because the government has provided mechanisms including price caps and subsidies, to enable relatively low prices (Aljamal and Bagnied, 2012).

Affluence and policies that help keep food relatively affordable could contribute to high waste levels by encouraging purchase and preparation of more food than will realistically be consumed (UN FAO, 2014), as described in Section 3.2.1.

At the same time, some factors lead to higher valuation of food. Food costs account for about 27% of income on average in the KSA (USDA Foreign Agricultural Service, 2014a, 2014b). In December 2015, the country slashed subsidies on fuel, seeking to narrow its budget deficit brought on by sagging global oil prices. Given the intersections between oil prices and both food prices and incomes, (Neff et al., 2011) this policy may further reduce food affordability. Further austerity measures were implemented in 2016, including wage cuts. The government has also since expanded its economic reforms, lifting subsidies for consumables such as dairy products and certain services (Zareen, 2017). The unprecedented price increases for fresh grocery items combined with decreased disposable income may further increase the extent to which Saudis experience food costs as high (Food Export Association of the Midwest USA, 2017).

Another driver of increased valuation of food is Islamic teachings, which have great influence on KSA society. For example, Islam teaches that it is important to project solidarity towards millions of people around the world who face hardships in having a single meal each day during Ramadan. It further advocates avoiding waste of food in verses from the Holy Quran such as, "Allah says: 'O children of Adam! Beautify yourselves for every act of worship, and eat and drink (freely), but do not waste: verily, he does not love the wasteful!'" (7:31). Fasting is also important; it is recommended that Muslims maintain regular voluntary fasting in addition to mandatory fasting during Ramadan. Such fasts can focus attention on food's value. A survey in Cairo found that religious beliefs were an important contributor to environmental awareness (Abdelradi, 2018).

A third driver is poverty. Despite the country's affluence, food insecurity and poverty do exist, and inequality has grown (AlOmar et al., 2018; Breisinger et al., 2012). Although overall the FAO reported in 2014 that <5% of KSA residents are undernourished, a 2010 study found children especially in the Southwestern region with underweight (19.7%), wasting (16.7%), and stunting (13.2%) (El-Mouzan et al., 2010; UN FAO, 2015b). While poverty can lead to valuing food and moderated purchasing, it has been

shown elsewhere that consumer food waste still happens, for example due to unavailable cold storage, ingrained habits and attitudes, and a desire to suggest that resources are not strained (Porpino et al., 2015). Beyond a COMCEC finding that rural residents often lacked cold storage to preserve food properly, we did not identify studies or reports addressing this possibility for the KSA.

3.2.3. Awareness and concern

In the COMCEC survey, Saudis reported awareness and concern about food waste, with 58% saying they were concerned about throwing food away and 97% of food service interviewees saying they try to keep food discards to a minimum (UDA Consulting, 2017). To our knowledge, however, no assessment was performed to understand the relative salience of these concerns compared to other issues.

Respondent knowledge was mixed regarding impacts; for example, 71% of COMCEC food service employees were unsure if food waste is a problem given that it is natural and biodegradable. Consumers also indicated relatively low knowledge of how wasted food affects the environment, and said that if they knew more about this, they would reduce their waste more. Such perceptions are common internationally as well, and have been linked with a broader knowledge gap regarding food production environmental impacts (Tobler et al., 2011). Respondents also said they would like more information about ways to prevent waste including tips for shopping and for food service staff, trainings.

3.2.4. Policy and industry factors

While consumers create a high portion of waste in the KSA, often their behaviors are shaped by policy and industry factors outside their control, such as marketing and restaurant practices. Food promotions can contribute to waste by encouraging consumers to purchase food they do not need and are unlikely to consume prior to spoilage. In the COMCEC (2017) survey, consumers commonly described efforts to manage their purchases, and 36% said they rarely or never increased their purchases in response to promotions. However, 40% said they always or often did. When asked to identify top contributors to food waste (with the option to select multiple), 86% of household respondents highlighted store promotions and offers, while 36% chose over-purchasing.

Restaurant practices are another contributing factor. COMCEC respondents highlighted buffets, portion sizes, and restaurant attitudes toward leftovers as concerns, and 86% of consumers felt large portions were a key reason leftovers were created.

In the COMCEC survey, 40% of Saudi respondents viewed food expiration dates as the top reason for food discards. Internationally, food date labels have been a priority target for food waste interventions; a UK study suggested that 20% of food waste could be attributed to label misunderstanding (WRAP, 2011), while a US analysis suggested that standardizing date labels was the most cost-effective of 27 interventions (ReFED, 2016). COMCEC reviewed governmental policies, finding that Saudi Arabian date label language refers to “use by” and “best before,” and also requires labels on imported food to be in Arabic (UDA Consulting, 2017). Respondents in the 2017 YouGov survey reported frequently discarding food at the “best before” date rather than the “expiry” or “use by date.” Specifically, respondents indicated early discards of fresh meat (72%), fruit and vegetables (68%), baby foods (68%), frozen foods (63%), dairy (66%), canned foods (55%), and grains (54%) as reported by Gleeson, 2017. It is not known how they interpreted the date label meanings.

Beyond the labels on the outside, food packaging can also contribute to waste, for example, if package sizes are too large for consumers to finish the product before it decays, or if packaging is insufficient to protect an item. Most consumer and food service

respondents in the COMCEC survey perceived food packaging to be a greater concern than food waste, although evidence suggests that due to packaging greenhouse gas emissions are commonly minimal compared to those of food it protects (Heller, 2017).

While many other specific practices within retail and food service industries have been identified internationally as shaping waste, no additional Saudi-specific information was identified. But high percentages of COMCEC food service respondents said they wanted information and training on factors including food storage and menu planning, and some 94% saw using food waste usefully as important in their work.

3.3. Existing efforts and recommendations

The above-described Barilla analysis ranked the KSA 2nd-lowest among nations for its policy responses to wasted food (Barilla Center for Food & Nutrition and Economist Intelligence Unit, 2016). Until recently, the country had virtually no relevant activities, but many are currently developing. We describe overarching initiatives and actions, organized around the Food Recovery Hierarchy (Fig. 2), a model ranking approaches from most beneficial to least (United States Environmental Protection Agency, 2016). We did not identify reports of activities at the lower end of the hierarchy, including animal feed, industrial uses, composting or anaerobic digestion – though this was not our primary focus. We also summarize existing recommendations for addressing waste of food in the country (see Fig. 3).

3.3.1. Overarching initiatives

The KSA's King Abdullah ordered that wasted food be examined as a matter of urgency for the country (The Saudi Arabia General Authority for Meteorology and Environmental Protection, 2017). Arab News also reported that the Royal Court ordered formation of committees to determine how to address wasted food (Arab News, 2016). In response, the Ministry of Environment Water & Agriculture arranged an expert panel including representatives from other Ministries, to assess food waste causes and impacts, and identify solutions (Alshuwaikhat and Mohammed, 2017). We have not identified a report from this panel.

In the private sector, the Savola Group, a major food business in the region, is coordinating with the UN Environment Program and

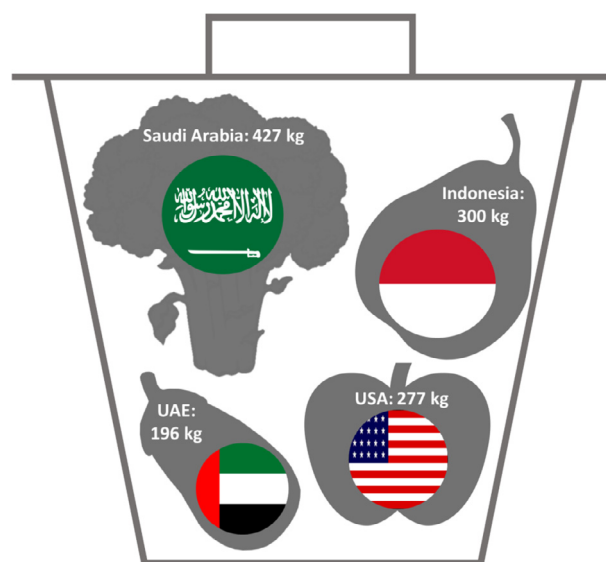


Fig. 2. Four Countries Wasting Greatest Amount of Food, as Assessed by Barilla Center for Food & Nutrition (per person per year). Figure source: authors.

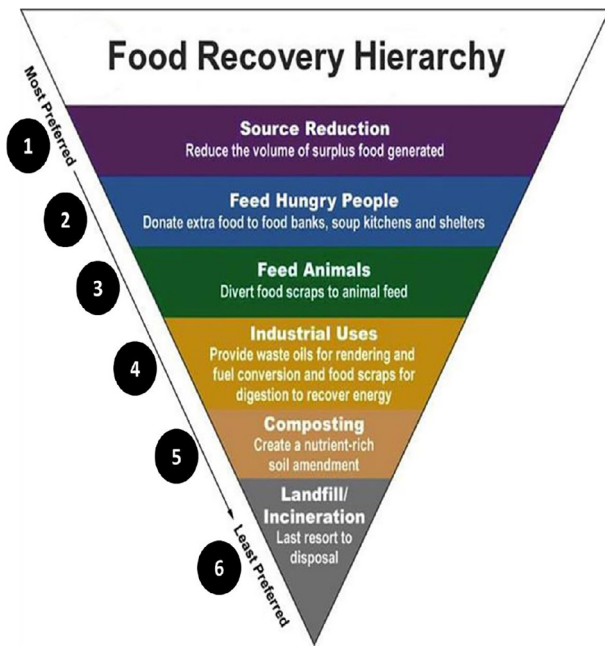


Fig. 3. Food Recovery Hierarchy. (US EPA 2016)

the UK's WRAP to develop the Negaderha program, which appears to be the highly well-developed overarching intervention, though it only began in March 2017. As described in the media, the extensive activity list includes measuring food loss and waste through the supply chain to better characterize drivers, actors and volumes of waste, developing an action plan, providing 1 million containers for food leftovers, developing a business manual on food waste reduction, developing a consumer awareness campaign based on effective campaigns globally, and developing a framework for food waste tracking and measuring progress toward goals (Negaderha, 2017; Saudi Gazette, 2017; Fareed, 2017; Balkhi, 2018). Another news article describes that through the WRAP partnership, they will obtain access to tools, advice, strategic guidelines and business models, enabling them to build upon existing international knowledge (Saudi Gazette, 2017).

In April 2017, the Saudi Food Bank, Eta'am, hosted an international conference in Riyadh with the theme, "Food Preservation is the Solution." The event, under the patronage of His Royal Highness Prince Faisal bin Bandar bin Abdulaziz, was attended by dignitaries and experts and included a focus on linking nutrition, food safety and food waste (Saudi Ministry of Health, 2017).

The FAO is working to build capacity for reducing food losses throughout the Middle East. Their plan focuses primarily on food losses early in the supply chain and provides little detail on actions at the consumer level. The report did indicate that for countries importing much of their food, strategies to reduce wasted food should be targeted at consumers and other actors later in the food supply chain, so future FAO activities may address this need (UN FAO, 2014). In 2017, the FAO program included training for 2000 stakeholders (United Nations Food & Agriculture Organization, 2017).

The KSA's Vision for 2030, published in 2016, describes a human and moral obligation to preserve the environment and natural resources. While it does not dig deep into wasted food, the plan does include investments in efficient waste management and a program to provide appropriately-timed information for agricultural markets to reduce waste. It also addresses food supply concerns with a plan to create a food reserve program incorporating an early warning system and timely information for agricultural markets to reduce waste (Government of Saudi Arabia, 2016).

3.3.2. Source reduction

Source reduction, also known as prevention, aims both to avoid unnecessary discards and to reduce surplus food. The food recovery hierarchy places it as the highest priority, with the greatest ability to conserve resources and money. ReFED's ranking of 27 wasted food interventions for the US found that source reduction activities were the most cost-effective (ReFED, 2016). A distinction may be made between "strong" prevention, focused on reducing surplus at the source, and "weak" prevention, focused on improving efficiency (Mourad, 2016). The greatest resource saving benefit may come from the former, though in most countries the emphasis has been on the latter.

Given the extent of food believed to be wasted at the consumer level, several efforts are prioritizing public communications to encourage consumers to reduce their own waste. For example, through its Extension Education Programs, Eta'am, is raising awareness about saving food and encouraging mindfulness and gratitude about food practices. As described in a news article, innovative Eta'am interventions include a new magazine, animated short films for children, teacher communications, messaging for tourists (including brochures in hotels during Ramadan), and messaging on social media using the hashtag, "continuing it as grace" (Alhamdan, 2016). Eta'am is collaborating with Savola and UNEP on the above-mentioned campaign, including education with households and hotels. They are also working with the Dow Saudi Arabia Company to develop a pilot school education program linking reduced wastage, preserving food, and healthy eating (Dow, 2017).

There are also more applied prevention efforts; for example, a Saudi man developed a model plate with a central bump, said to reduce rice waste by 1/3. A January 2017 news article indicated the plate was used in 40 restaurants and was being sold across the Gulf (Al-Jaber, 2017).

Lastly, while we have not identified Saudi laws or policies targeted at reducing food wastage at the source, local media reported that the Shura Council [the KSA's formal advisory body] sought laws addressing and penalizing food waste. One report said they had discussed legislation to fine companies wasting food 38% of the bill per serving (Al Arabiya, 2017).

3.3.3. Food recovery

Overall, evidence suggests the infrastructure for food donation in the KSA is early in its development. Among COMCEC food service respondents, 97% felt it would be beneficial for local authorities to organize collection of discards from catering and hospitality places.

While active in informal education, Eta'am's primary focus is as a food bank. It has a database of over 3000 volunteers who perform activities including collecting food from restaurants, hotels, schools, institutions, and wedding halls, packaging and storing it in refrigerated facilities, and distributing it to hungry people. In 2013, they successfully collected approximately 231,764 meals (Al-Khan 2014; Toumi 2014a).

Jeddah has been proactive in food recovery. As described in a news article, they placed 900 containers for food leftovers throughout the city and required restaurants and ceremony services to contract with charities to redistribute leftovers to the hungry (Saudi Gazette, 2015). The city signed contracts with several companies to deliver the food to hungry people while maintaining food safety. The Arab Gazette reported that 60% of municipal waste in Jeddah is food leftovers, contributing to the motivation for action (Al-Bugamy, 2015). (The source of this unusually high statistic is not known).

Interventions are happening at the individual level as well. For example, one wealthy Saudi man in the city, Hail, placed a refrigerator in front of his house and encouraged food donations so those

who are hungry can obtain food without the discomfort of asking for it (Toumi, 2014b).

3.3.4. Food recycling

As we will describe, there is considerable opportunity for recycling wasted food in the KSA, including feeding it to animals, generating energy and creating compost. That said, we did not identify published descriptions of current recycling activities.

3.4. Existing recommendations to address wasted food in the KSA

We identified three reports providing recommendations to guide future food waste interventions with content specific to the KSA: the “Regional Strategic Framework for Reducing Food Losses in the Near East and North Africa (UN FAO, 2015a); “Reducing Food Waste in OIC Countries” (UDA Consulting, 2017); and The Saudi Arabia Vision 2030 (Government of Saudi Arabia). Several reports also provide generic recommendations for countries developing responses to wasted food; we selected “Strategies to Achieve Economic and Environmental Gains by Reducing Food Waste (WRAP, 2015) as a strong example. Table 2 summarizes all recommendations made in these reports, which jointly include:

- (1) Developing overarching interventions and approaches (including identifying a national authority to coordinate and implement activities);
- (2) Collecting data and performing research (including improving measurement and evaluation);
- (3) Building awareness (including developing an awareness campaign);
- (4) Supporting food recovery and recycling (including expanding food banks and incentives for donation);
- (5) Developing policies to enable or support food waste reduction, recovery and recycling (including standardizing date limits and investing in capacity-building);
- (6) Shifting practices of businesses and consumers (including requiring waste prevention and waste management in procurement strategies and contracts); and
- (7) Working across the food system (including developing collaborations and reaching smaller businesses).

4. Discussion

4.1. Amounts and determinants of wasted food

This review finds considerable need for additional rigorous and consistently-framed research to understand the magnitude, distribution, and causes of wasted food in the KSA, and to identify, track and evaluate interventions and progress over time. Estimates of annual per capital waste of food ranged from 165 kg to 511 kg. Our review summarized evidence identifying contributors to the country’s food wastage, including culture, food affordability, awareness and concern, and policy and industry factors. Additionally, there is minimal infrastructure for food recovery and recycling as yet.

Notably, none of these factors are unique to the country, and none of the evidence points to clear reasons why the country’s waste levels would exceed those of other high-income countries as has been estimated in previous analyses. We suggest the possibility for further exploration, that a leading factor might be the intersection of tradition and wealth. As in many traditional and lower income countries, Saudis place high value on hospitality and providing food abundance. As the country’s income has rapidly risen, these values remain but food affordability has expanded, enabling the population to engage in widespread provision of great abundance and surplus. This theory aligns with evidence of high and rising obesity levels in the country (Musaiger, 2011; Memish et al., 2014). Evi-

dence from other countries suggests that when abundant food is presented, people are more likely both to consume more and to waste more (Wansink and van Ittersum, 2013; Wansink et al., 2014).

4.2. Six additional opportunities

We endorse the excellent recommendations outlined in Section 3.4 and Table 2. The following discussion builds on them and on the existing activities described in Section 4, to highlight three further opportunities for the KSA to reduce waste of food, with a focus on use of agricultural extension staff. Table 3 presents a distribution of responsibilities for implementing both existing recommendations and our additions (in bold) across: (1) extension agents; (2) other public sector entities (including the Shura Council, Ministry of Agriculture, and other national and local government agencies); (3) the private sector (including restaurants, grocery chains, hotels); (4) the nongovernmental sector; (5) consumers; and (6) researchers. Responsible actors may benefit from coordinating roles and efforts, and from tools and information to increase effectiveness.

4.2.1. Elevating the role of agricultural extension staff

Multiple education campaigns have begun in the KSA around wasted food, and education is a priority recommendation in the documents reviewed. We highlight the opportunity to develop an education campaign (or campaign component) utilizing agricultural extension staff expertise. In some countries, such as the US, the mission of agricultural extension has expanded to consumer education, and some use a land-grant system to link extension staff with universities, in order to mutually strengthen expertise and information (US Department of Agriculture, & National Institute of Food and Agriculture, 2017). The Saudi program run by the Ministry of Environment Water & Agriculture currently focuses primarily on farming.

As the KSA’s agricultural area and crop production have reduced (to conserve water resources), the role of agricultural extension agents has been shifted to greenhouse vegetables and fruits, making their role quite limited. Extension staff (employees of the government) will retain their jobs, so it is in the Kingdom’s interest to deploy them in ways that keep them functional and productive. We have previously advised a shift in role to promoting the sustainable agriculture tools needed for a resource-scarce future (Baig et al., 2017), but given the relatively low agricultural production, additional opportunity remains to redefine job descriptions to make best use of extension staff talents to meet the country’s food security needs. Relevant existing skills include expertise in adult education, translating research, and using networks to reach key audiences. Further training will be necessary to build expertise relevant to preventing waste of food and to adapt their education skills for reaching adults and youth in their consumer roles, as well as food service and retail staff. The three universities that work closely with agricultural extension in the KSA, King Saud University, King Faisal University, and Qassim University, offer degree and non-degree programs to train the country’s agricultural professionals (UN FAO Office of Evaluation, 2016). They could provide the needed staff training to enable this work.

We envision extension staff:

- Running an education campaign for consumers, with focus on adults involved in shopping and cooking, students at schools, colleges and universities;
- Running campaigns or other efforts targeted to and in partnership with food service and retail industries;
- Disseminating waste tracking and analytics approaches;
- Participating in efforts to advance food donation.

Table 2
Policy Recommendations for Addressing Waste of Food (overarching strategies and those relevant for retail, restaurants, and consumers).

	COMCEC (UDA Consulting, 2017)	Saudi Arabia Vision 2030 (Government of Saudi Arabia, 2016)	WRAP Strategies to achieve economic & environmental gains by reducing food waste (WRAP, 2015)	FAO Regional Strategic Framework – MENA* (UN FAO, 2015a)
Develop Overarching Interventions & Approaches				
Establish or identify national authority to implement and coordinate food waste activities				
Develop roadmap and detailed plans				
Support stakeholder voluntary agreements				
Focus on perishables				
Network/share internationally and regionally				
Identify, pilot, adapt, finance low-cost and impactful interventions & technologies				
Collect Data, Perform Research				
Improve measurement & reporting of waste (quantity, what foods, where in food chain, determinants); actual rather than estimated data				
Monitor & evaluate progress and intervention impacts, make data available				
Identify gaps in data and evidence				
Address knowledge gaps, support research and technology development				
Use data to identify and prioritize interventions				
Perform research jointly with international entities				
Understand opportunities, including influencers & mechanisms contributing to waste levels				
Build Awareness				
Develop awareness campaign including education in key areas: mosques, schools/universities, farmers, etc; Disseminate targeted materials through those working with key stakeholder groups				
Provide education on strategies for food purchasing, cooking, leftover use				
Link advice about food waste and healthy eating				
Educate about economic and environmental impacts				
Address cultural drivers like stigma of taking food from restaurant				
Educate business & consumers about food storage/handling and safety				
Provide practical support, training to businesses				
Use extension services (mentioned briefly)				
Support Food Recovery and Recycling				
Expand food banks				
Explore incentives for food donation				
Develop food safety regulations to enable redistributing surplus				
Provide incentives to advance development of food waste recycling infrastructure, technology, strategies; integrate with prevention				
Increase the efficiency of waste management				
Integrate renewable energy resources				
Develop regulations on what can safely be used as animal feed				
Develop Policies that Enable/Support Food Waste Reduction, Recovery, Recycling				
Standardize, educate about food date labels				
Explore waste bans or limits (e.g., limit discards of unsold food, prevent excess food at events)				
Seek alternatives to state-subsidized food programs				
Invest in capacity-building				
Improve regulation and oversight of food imports to minimize poor handling and effects on food quality and safety				
Identify policies and regulations that can contribute to reducing food waste and integrate into food security strategies				
Identify/address policy gaps				
Shift Practices for Food Service, Retail, Consumers				
Improve specifications for equipment and building design				
Require waste prevention and waste management in procurement strategies and contracts				
Develop/promote procedures and technologies for end users in different sectors				
Attract investors (public investment in infrastructure, services; enabling business environment)				
Address excessive food at communal events				
Improve or limit use of restaurant buffets				
Use extension services (mentioned briefly)				
Work Across Food System				
Support packaging industry efforts to extend food shelf life; Support appropriate amounts of packaging, related consumer education				
Support sustainable food system				
Support integrated supply chains, connect farmers to markets, policy support				
Support improved cold storage				
Develop food reserve program incorporating early warning system				
Provide appropriately timed information to agricultural markets to reduce waste				
Develop and incentivize collaborations, info-sharing between government and diverse food system actors; and among all stakeholders; and obtain input on plans/decisions				
Reach smaller businesses				

Note –In some cases recommendation descriptors come directly from these plans.

Table 3

Roles for addressing wasted food in Saudi Arabia. (Our additions to existing recommendations are in bold italics)

	Extension Agents	Public Sector	Private Sector	Non-profit Sector	Consumers	Researchers
Develop	Overarching Interventions & Approaches	<p>* Transition extension's role into tackling food waste – including through new training for agents</p> <p>* Host collaborative workshops/conferences to synchronize efforts between the Ministry of Agriculture, Inter-ministerial coordination, food banks, educational and religious institutions, international organizations, and others</p> <p>* Promote collaborations and stakeholder engagement</p> <p>* Help guide planning</p>	<p>* Establish national authority to implement, coordinate activities</p> <p>* Create evidence-based roadmap action plan</p> <p>* Develop policies/regulations</p> <p>* Network/share internationally</p> <p>* Strengthen collaboration and networking between actors in country and regional partners</p> <p>* Work with FAO Global SAVE FOOD Initiative, Regional Initiative on “Building Resilience for Food Security and Nutrition in NENA”</p>	<p>* Develop stakeholder voluntary agreements</p> <p>* Identify, pilot, adapt, finance low-cost and impactful interventions, technologies</p> <p>* Help guide planning</p>	<p>* Develop stakeholder voluntary agreements</p> <p>* Help guide planning</p>	<p>* Help guide planning</p>
* Monitor, evaluate impacts						
* Identify potentially impactful strategies						
Collect Data, Perform Research	<p>* Work with researchers to collect data, provide training to farmers, business and others in how to collect</p> <p>* Establish relationships needed for data collection</p>	<p>* Collect surveillance data</p> <p>* Develop reporting scheme</p> <p>* Monitor & evaluate progress</p> <p>* Make data available</p> <p>* Coordinate data collection w international entities</p> <p>* Fund research</p>	<p>* Support research, technology development</p> <p>* Share data</p> <p>* Help guide data collection plans</p>	<p>* Share data</p> <p>* Help guide data collection plans</p>	<p>* Share data</p>	<p>* Qualitative, quantitative research on waste of food, determinants, potentially impactful interventions</p> <p>* Evaluate impacts of policies & interventions</p>
Awareness raising, Education	<p>* Develop, lead awareness campaigns: populations, farmers, business</p> <p>* Share info about food storage, preservation, and inventory management with farmers, businesses</p> <p>* Host trainings, webinars, other education</p> <p>* Develop educational materials</p> <p>* Mobilize other actors</p> <p>* Translate evidence about “what works”</p>	<p>* Lead public awareness campaigns</p>	<p>* Lead public awareness campaigns</p> <p>* Track own discards to identify patterns</p> <p>* Provide guidance to employees</p>	<p>* Lead public awareness campaigns</p> <p>* Track own discards to identify patterns</p> <p>* Provide guidance to employees</p>	<p>* Track discards to identify patterns</p> <p>* Learn about issue of wasted food and ways to reduce</p>	<p>* Assess and track awareness, attitudes, knowledge, behavior among consumers, businesses, others</p> <p>* Evaluate campaign impacts</p>
Support Food Recovery	<p>* Help Food Banks in their mission by aiding in food pick-up, food preservation, etc.</p>	<p>* Build infrastructure for large scale food recovery</p> <p>* Provide incentives and laws to promote recovery</p> <p>* Develop food safety regulations to enable distributing surplus</p> <p>* Financially support food recovery organizations and the staff and infrastructure needed to operate them</p>	<p>* Create new entrepreneurial ventures to develop systems for food recovery, creating value-added products such as soups</p> <p>* Assure quality of donated food</p> <p>* Provide financial support to food donation organizations</p>	<p>* Scale up food recovery network of food banks and food pantries</p> <p>* Work to assure quality of donated food</p> <p>* Work to assure food reaches those who need it</p> <p>* Improve logistics systems for collecting, transporting, distributing food</p> <p>* Creating value-added products such as soups</p>	<p>* Donate food</p> <p>* Provide financial support to food donation organizations</p>	<p>* Develop new interventions and improvements on existing ones</p> <p>* Perform analytical research and knowledge generation on strategies</p>

(continued on next page)

Table 3 (continued)

	Extension Agents	Public Sector	Private Sector	Non-profit Sector	Consumers	Researchers
Support Food Recycling	<ul style="list-style-type: none"> * Build collaborations to help integrate recycling with prevention, recovery * Educate businesses, consumers about what can/can't be put in compost 	<ul style="list-style-type: none"> * Provide incentives to advance development of food waste recycling infrastructure, technology, strategies * Increase efficiency of waste management * Integrate renewable energy resources * Develop regulations on what can safely be used as animal feed 	<ul style="list-style-type: none"> * New entrepreneurial ventures to develop systems, logistics, infrastructure for food recycling * Invest * Recycle food scraps and waste * Develop end-uses for recycled materials incl animal feeds, energy, industrial products 	<ul style="list-style-type: none"> * Recycle food scraps and waste 	<ul style="list-style-type: none"> * Recycle food scraps and waste 	<ul style="list-style-type: none"> * Develop new interventions and improvements on existing ones * Perform analytical research and knowledge generation on strategies
Shift practices for food service, retail, other supply chain actors, consumers	<ul style="list-style-type: none"> * Share information about available incentives to support new practices * Identify and share information about money that can be saved through waste prevention measures * Use knowledge of behavior change approaches to advance changes with other segments of society * Serve as conduit for 2-way communication about needs from other stakeholders to decision-makers 	<ul style="list-style-type: none"> * Require waste prevention and waste management in procurement strategies and contracts * Provide incentives and develop policies to support shifts in practice * Attract investors * Improve specifications for equipment and building design 	<ul style="list-style-type: none"> * Minimize waste through improved practices in food storage, packing, handling, transportation, processing, distribution, inventory management and sales * Create alternatives to buffets * Avoid excessive food at communal events * Decrease portion sizes at restaurants * Develop new technology to enable changed practice * Address portion size 	<ul style="list-style-type: none"> * Provide certification/ recognition for businesses working to reduce food waste * Develop incentives for other actors to address wasted food through interventions high on the food recovery hierarchy 	<ul style="list-style-type: none"> * Reduce over-purchasing and over-preparing * Eat leftovers * Only store non-perishable food for unexpected guests * Compost inedible food scraps if nearby infrastructure available * Retailer, restaurant changes to support consumer efforts * Track discards to identify patterns * Learn about issue of wasted food and ways to reduce 	<ul style="list-style-type: none"> * Evaluate practice changes, interventions including monitoring for unintended consequences
Awareness raising, Education	<ul style="list-style-type: none"> * Develop, lead awareness campaigns for different population segments, farmers, business * Share info about successful food storage, preservation, inventory management with farmers, businesses * Host trainings, webinars, other education * Develop educational materials * Mobilize other actors * Translate evidence about "what works" 	<ul style="list-style-type: none"> * Lead public awareness campaigns 	<ul style="list-style-type: none"> * Lead public awareness campaigns * Track own discards to identify patterns * Provide guidance to employees 	<ul style="list-style-type: none"> * Lead public awareness campaigns * Track own discards to identify patterns * Provide guidance to employees 	<ul style="list-style-type: none"> * Track discards to identify patterns * Learn about issue of wasted food and ways to reduce 	<ul style="list-style-type: none"> * Assess and track awareness, attitudes, knowledge, behavior among consumers, businesses, others * Evaluate campaign impacts
Work Across Food System	<ul style="list-style-type: none"> * Support sustainable food system generally * Develop collaborations, info-sharing between government & diverse food system actors * Help support integrated supply chains, connect farmers to markets * Reach smaller businesses * Provide appropriately timed information to agricultural markets 	<ul style="list-style-type: none"> * Develop/strengthen collaborations, info-sharing between government & diverse food system actors * Develop food reserve program * Provide appropriately timed information to agricultural markets 	<ul style="list-style-type: none"> * Develop collaborations, info-sharing between government & diverse food system actors * Reach smaller businesses 	<ul style="list-style-type: none"> * Develop collaborations, info-sharing between government & diverse food system actors 		<ul style="list-style-type: none"> * Research, evaluate new cross-supply chain approaches to reducing food waste

4.2.2. Extension-run education campaign

Beyond items mentioned in Table 2, well-designed messaging could contribute to shifts in social norms regarding the extent of surplus needed in portion sizes and hospitality, and regarding leftovers. The campaign also can highlight enjoyment and savings in time and money from eating leftovers, and the benefits of freezing food to preserve them. Additionally, they can help break down stigma from eating leftovers. Such themes can be blended with

health and nutritional messages. Message design and focus testing are essential to shape consumer messages that resonate locally and go beyond awareness to provide information needed in making change (e.g., tips on shopping, meal planning and preparing leftovers) and to build motivation.

Given the overwhelmingly Muslim population, and given the message alignment with Muslim teachings, religious leaders are viewed as the great opinion makers in the society and they can

be engaged to help deliver messages in their Friday sermons (the biggest weekly congregation of Muslims at noontime to offer prayers). Campaign measures to minimize food waste may also especially target the 75% of the population that is youth and women (World Bank, 2017b). Women are often responsible for food management and cooking in households. TV programs, particularly morning shows are widely watched by this audience and could be a particularly effective strategy for reaching them to bring the desired change in their behaviors (Baig et al., 2019). A 2016 YouGov survey of over 4000 Saudi residents found that they used social media for about five hours daily on average, with users under age 35 spending 2–6 h per day and those 36–55 spending ½ to 2 h (YouGov, 2016b). Further, 44% identified social media as the “most helpful” way to learn about brands and products. Extension messages could be released via social media, and food waste-relevant cell phone apps could be adapted to Arabic. An important population not mentioned in Table 2 recommendations is the approximately 10 million immigrant workers in the country. Messages should be broadcasted in several different languages and should be developed with distinctive targeting for the larger groups.

With their expertise in adult education, extension professionals are also ideal for educating food chain businesses about waste reduction. Such education will help respond to the need identified for trainings about menu planning, other ways to prevent waste, and education about the importance of doing so (Baig et al., 2019).

4.2.3. Use waste tracking and analytics tools

Waste tracking and analytics programs work on the principle that what is not measured is not managed. This approach focuses on logging discards and potential contributing factors, and aggregating findings to identify patterns and gain insight into the particular practice changes that may be most impactful for the facility in question. The act of tracking itself can draw attention to habitual or unquestioned practices. Further, by treating waste as a puzzle rather than a failing, it can contribute to a climate of openly exploring prevention opportunities rather than one of shame and denial about wastage. Tools range from simple paper logs, to scales and spreadsheets, to apps, to sophisticated tracking and analytic software and consultants hired for analysis. Waste tracking approaches are valuable across the food chain including in farming, food storage, processing and distribution, retail and restaurant, and households. ReFED estimated that waste tracking had a return on investment over three times that of the next best intervention studied (ReFED, 2016).

Staff at the National Agricultural Extension Service in Saudi Arabia could play an important role in disseminating this approach by providing training and guidance (Baig et al., 2019). The approach aligns with the extension mission of disseminating new approaches to improve farm (and other business) profitability and functioning. Additionally, as a data driven tool, waste tracking shares similarities with other tools extension staff have been accustomed to sharing with farmers.

4.2.4. Extend the food donation system

COMCEC and others have recommended expanding the food bank system and exploring incentives for food donation, and we concur. In addition, we highlight the need to develop system logistics for obtaining and distributing donations. We are not aware of estimates of the extent of food donation programs in the KSA, but the lack of online information suggests the possibility the system may be small, mostly relatively new, and potentially not supported by the innovations in logistics developed internationally.

Beyond building up infrastructure, we highlight four additional challenges which can be addressed by extension agents and others. (1) *Developing markets for value-added processing* into products

such as soups or stews, which can then be donated, for still-good food going to waste because it is “ugly” including due to being misshapen, bruised, or partly decayed (2) *Increasing consumers acceptance of donations*, including addressing stigma and communicating about availability. The KSA may benefit from developing innovative ways to provide food to people outside the pantry setting, unique to its cultural context. (3) *Ensuring a steady food inflow*, including by encouraging and supporting businesses and individuals to donate. Without tax incentives in the KSA, other incentives may appeal, including public recognition, certification stickers to let others know about a business’ donations, providing packaging materials and cooling facilities, or supporting worker time to pack food. (4) *Ensuring the food is high quality* and supports recipient dignity, as well as supporting the country’s need to advance a healthy population. (Relatively unhealthy and lower quality foods may be diverted to food recycling uses such as animal feed and industrial uses).

Additionally, as this sector is developing, there is an opportunity to consider whether its primary financial support should be charitable, or whether it could evolve as a government or hybrid function. Governmental support could help ensure the system’s stability, disseminate best practices, and facilitate extending the geographic reach into prioritized areas.

4.2.5. Develop animal feed applications

Food scraps have been fed to animals through the ages, and in the suburbs of the KSA, surplus food is still often fed to chickens, sheep, and goats. However, most food animals are raised by large industries in the KSA, which use commercial feed. Corn composes about 60% of poultry feed formulations and is also a major feed grain used by domestic dairy farms (USDA Foreign Agricultural Service, 2014a, 2014b). To help reduce animal product production costs and reduce use of limited water supplies, the Saudi government has provided import subsidies for feed corn and other feed ingredients (Agriculture and Agri-Food Canada, 2017). Fodder crops such as alfalfa, maize and sorghum have high water needs and keeping in view the diminishing water resources, the Saudi farmers have been asked not to grow these crops on mass-scale to conserve water (Baig et al., 2017).

Food surpluses and scraps may be recycled into animal feed, thus reducing costs, environmental impacts, and imports of feed, and keeping food from landfills (Salemdeeb et al., 2017). In many cases, particularly if animal products are included, heat treatment is needed to prevent disease outbreaks such as foot and mouth disease, and thus equipment is required. Scraps can be aggregated for heat treatment and then distributed to smaller producers that are unlikely to purchase their own heat treatment equipment. Agricultural extension service staff members have a valuable role to play in characterizing and disseminating best practices for food product collection and treatment (Makkar and Ankers, 2014).

4.2.6. Build waste to energy generation facilities

Anaerobic digestion entails using anaerobic bacteria to ferment wasted food into biogas, especially methane to use for fuel, and bio-fertilizer, the leftover sludge to use as fertilizer. With oil reserves decreasing in the KSA, the country is looking to other energy sources, and there are increasing investments in waste to energy technologies (Khan and Kaneesamkandi, 2013) and as we describe, considerable opportunity. Nonetheless, practical implementation remains negligible thus far.

A 2013 study evaluated waste generation in the KSA, to identify available feedstock for energy recovery. It found that since organic matter comprises the majority of the waste, anaerobic digestion would be the most feasible energy recovery strategy (Khan and Kaneesamkandi, 2013). That study also noted that since the KSA is a tropical country, thermophilic (high temperature) anaerobic

digestion would work well. Further, they calculate that biogas plants could generate a gross benefit from direct saving and revenue of more than SR4.7 billion (USD1.25 billion) annually.

One study in Riyadh examined the potential environmental benefit from converting wasted food into biogas. The authors calculated that based on the city's estimated food waste, the annual usable biogas that could be generated there is nearly 38 tons, enough to generate over 86,000 kWh of energy (Alruqaie and Alharbi, 2012). Another study evaluated several waste-to-energy conversion technologies and concluded the biomethanation technology was most suitable for the KSA due to the significant volume of food waste for feedstock (which they determined to be 37% of the waste stream), higher efficiency than other technologies, and the lowest annual capital and operational cost (Ouda et al., 2016). One other study assessed the amount of biodiesel potentially produced from fat in municipal waste in the city of Makkah, the KSA. With their assumption that food waste composes up to 51% of the waste stream, they calculate that 62,500 tons of biodiesel could be produced, with an electricity potential of 852 million kWh (Shahzad et al., 2017). They further calculate it could be possible to add a net revenue of SR611–1274 million (USD163–340 million) annually to the Saudi economy, from 2014 to 2050, based on net savings from landfill waste diversion, carbon credits, fuel savings, and electricity generation.

We recommend increased implementation, including investment in infrastructure and logistics development. Agricultural extension could play a role in the latter.

4.2.7. Composting

Composting is a process of breaking down organic matter to produce a rich soil amendment providing beneficial microbes and drought resilience. Composting is placed toward the bottom of the food recovery hierarchy because, while the end product is beneficial, producing it requires inputs of water, labor, energy, and other resources to package, process, transport, sell, chill, heat and prepare food that will be used only in its decomposed form. Composting interventions can happen at diverse scales, from backyard bins to a single business to a large facility serving a municipality. The KSA has multiple facilities for composting organic matter including food waste, generally using traditional compost piles and trenches. According to one report, it does not meet international standards for compost quality (Waqas et al., 2017). Additionally, given the relatively low amount of agricultural production, the market for compost is small (Anjum et al., 2016) although important given how compost increases water holding capacity of soils.

A 2017 study tested a continuous thermophilic composting method in the KSA and found that with the naturally high temperatures in the country, high quality compost could be produced quickly (30–45 days). The projected net savings would be about SR265 million (USD70.7 million) per year for converting eight million tons of wasted food into compost and selling it instead of paying for landfill disposal (Waqas et al., 2017).

4.3. Strengths and limitations

This analysis represents the first broad overview of wasted food in the KSA, bringing together a great diversity of information sources and ideas. It takes a critical lens to the data, including highlighting places where evidence is questionable and where further research is needed.

The chief limitation of this analysis is the sparsity of information on which to base it, including gaps in research and information about current activities to address waste of food. Much of the data about policies and practices in the KSA are not publicly available. There could be additional articles we were unable to identify, which might have been found with a multi-database

search strategy or additional Arabic language research. Additionally, much of the information about consumers comes from a single survey with limitations described in Section 2.1.

5. Conclusions

To meet the food needs of its citizens, the Kingdom of Saudi Arabia relies upon and is likely to become more dependent on international markets, while still making abundant food and water resources available to its citizens at highly subsidized rates. Dependency upon food imports is expected to continue to rise as a result of the rapidly growing population, improving living conditions, sustained economic/industrial development and depleting natural resources. As agricultural production declines, an opportunity arises to redirect a portion of agricultural extension work to advance the country's food security in a new way, by working to reduce waste of food.

Food waste is a multi-dimensional and complex issue and there is not a single solution that could combat the issue in the Kingdom of Saudi Arabia. In response, today the Kingdom is working hard with the help of FAO to frame laws and design strategies to reduce the waste volumes. The problem has diverse antecedents embedded in ingrained behaviors of multiple stakeholders and populations. This narrative literature review summarizes the state of evidence and builds on existing strategies to advance more sustainable consumption patterns and a circular economy. It highlights innovations including the benefits of using an extension staff education campaign, waste tracking and analytics, and further development of food donation. Among all the workable solutions, application of the appropriate extension education strategies to change the behaviors of the consumers could be the most promising one and the extension staff can be the glue, motivating all the segments of the society contributing waste of food in the KSA.

Acknowledgements

The authors would like to thank Prof. Dr. Abdulrasoul M. Alomran and Prof. Dr. Safar Al-Kahtani at the King Saud University; Dr. Mai Mahmoud of IFPRI, and Jim Yager, Amelie Hecht and Emma Cogan of the Johns Hopkins Center for a Livable Future (CLF) for their review of the initial drafts and adding valuable input.

The authors are thankful to the Deanship of Scientific Research, King Saud University and the Agricultural Research Center, College of Food and Agriculture Science, King Saud University, for their valuable support and cooperation.

Roni Neff and Irena Gorski's time was supported by the CLF with a gift from the Grace Communications Foundation. Neither funder had a role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

References

- Abdelradi, F., 2018. Food waste behaviour at the household level: A conceptual framework. *Waste Manag.* 71, 485–493. <https://doi.org/10.1016/j.wasman.2017.10.001>. Epub 2017 Oct 14.
- Agriculture and Agri-Food Canada, 2017. Market Overview: Saudi Arabia. Available at: <http://www.agr.gc.ca/eng/industry-markets-and-trade/international-agri-food-market-intelligence/middle-east-and-africa/market-intelligence/market-overview-saudi-arabia/?id=1490121465390>.
- Ahmed, F.H., 2004. Waste management in Saudi Arabia. *First Arab Environ. J.* 78 [Translated].
- Al Arabiya, 2017. Saudi Shoura discusses law addressing food waste issue. Published in the English Magazine Al Arabiya on Jan 14, 2017. Available at: .
- Al-Bugamy, Mohamed, 2015. 900 food waste containers in Jeddah. Available at: <http://saudigazette.com.sa/saudi-arabia/900-food-waste-containers-in-jeddah/>
- Al-Fawaz, Nadia, 2015. Need to reduce food waste: Experts. An article published in the Daily Arab News on March 23, 2015. Available at: <http://www.arabnews.com/saudi-arabia/news/722026>.

- Alhamdan, Shahd, 2016. Eta'am's Ramadan drives in full swing. An article published in the Daily Saudi Gazette on June 07, 2016. Available at: <http://www.saudigazette.com.sa/article/156647>.
- Al-Jaber, Mariam, 2017. Saudi man develops plate to reduce rice wastage by a third. (2017, January 29). An article appeared in the Daily Al-Arabiya. Available at: <http://english.alarabiya.net/en/variety/2017/01/29/Saudi-man-develops-plate-to-reduce-rice-wastage-by-a-third.html>.
- Aljamal, A., Bagnied, M., 2012. Food consumption and waste in Kuwait: the prospects for demand-side approach to food security. *Int. Rev. Business Res. Papers* 8 (6), 15–26.
- Al-Khan, Khaled Abdulwahed, 2014. Saudis throw away 440 tons of rice annually. Al-Khan, Director Eta'am made the statement that surplus quantities of food in 2013 reached 231,764 meals and published in the Daily Arab News on July 04, 2014. Available at: <http://saudigazette.com.sa/article/89553/Saudis-throw-away-440-tons-of-rice-annually>.
- AlOmar, R.S., Parslow, R.C., Law, G.R., 2018. Development of two socioeconomic indices for Saudi Arabia. *BMC Public Health* 18, 791. <https://doi.org/10.1186/s12889-018-5723-z>.
- Alruqaie, I.M., Alharbi, B.H., 2012. Environmental advantage assessment of recycling food waste in Riyadh, Saudi Arabia. *Res. J. Environ. Sci.* 6 (6), 230.
- Al-Shayaa, M.S., Baig, M.B., Straquadine, G.S., 2012. Agricultural extension in the Kingdom of Saudi Arabia: difficult present and demanding future Available at: *J. Animal Plant Sci.* 22 (1), 239–246 <http://www.thejaps.org.pk/docs/vv-22-1/12.pdf>.
- Alshuwaikhat, H.M., Mohammed, I., 2017. Sustainability matters in national development visions—evidence from Saudi Arabia's Vision for 2030. *Sustainability* 9 (3), 408. <https://doi.org/10.3390/su9030408>.
- Al-Zahrani, K., Baig, M., 2014. Food Waste in the Kingdom of Saudi Arabia: need for extension education programs to increase public awareness. In: *Proceedings of International Academic Conferences, Vienna, 2014 (No. 0200895 ed.)*. International Institute of Social and Economic Sciences, p. 55.
- Alpen Capital, 2017. GCC Food Industry Report. Available at: http://www.alpencapital.com/gcc-food-industry-report_february-22-2017.pdf.
- Anjum, M., Miandad, M., Waqas, M., Ahmad, I., Alafif, Z.O.A., Aburiazza, A.S., Barakat, M.A., Akhtar, T., 2016. Solid waste management in Saudi Arabia: a review. *J. Appl. Agric. Biotechnol.* 1(1) 13–26. Available at: https://www.researchgate.net/publication/303348044_Solid_waste_management_in_Saudi_Arabia_A_review [accessed Aug 29 2018].
- Al-Fadli, Abdul Rahman, 2016. Food-saving panels soon. Statement issued and published in the Daily Arab News on Jan 23, 2016 regarding the orders of Royal Courts on the formation of committees to reduce food waste to conserve natural resources including water. Available at: <http://www.arabnews.com/saudi-arabia/news/869191>.
- Baig, M.B., Straquadine, G.S., 2014. Sustainable agriculture and rural development in the Kingdom of Saudi Arabia: implications for agricultural extension and education. In: Behnassi, M., Syomiti, M., Gopichandran, R., Shelat, K. (Eds.), *Vulnerability of Agriculture, Water and Fisheries to Climate Change*. Springer, Netherlands, pp. 101–116.
- Baig, M.B., Straquadine, G.S., Aldosari, F.O., 2017. Revisiting extension systems in Saudi Arabia: emerging reasons and realities. *J. Exp. Biol. Agric. Sci* 5 (Spl-1-SAFSAW), S160–S164. [https://doi.org/10.18006/2017.5\(Spl-1-SAFSAW\).S160.S164](https://doi.org/10.18006/2017.5(Spl-1-SAFSAW).S160.S164).
- Baig, M.B., Al-Zahrani, K.H., Schneider, F., Straquadine, G.S., Mourad, M., 2019. Food waste posing a serious threat to sustainability in the Kingdom of Saudi Arabia – a systematic review. *Saudi J. Biol. Sci.* 26, 1743–1752. <https://doi.org/10.1016/j.sjbs.2018.06.004>.
- Balkhi, Khadeeja, 2018. Ideas to chew on: how to end food waste in Saudi Arabia. Article published in *The National* on February 18, 2018. Available at: <https://www.thenational.ae/business/ideas-to-chew-on-how-to-end-food-waste-in-saudi-arabia-1.705509>.
- Barilla Ctr for Food & Nutrition, Economist Intelligence Unit, 2016. *Fixing Food: Towards a More Sustainable Food System*.
- Boughanmi, H., Kodithuwakku, S., Weerahewa, J., 2014. Food and Agricultural Trade in the GCC: An Opportunity for South Asia?
- Breisinger, C., Van Rheenen, T., Ringler, C., Pratt, A.N., Minot, N., Aragon, C., et al., 2010. Food security and economic development in the Middle East and North Africa. *IFPRI Discussion Paper* 00985.
- Breisinger, C., Ecker, O., Al-Riffai, P., Yu, B., 2012. Beyond the Arab awakening: policies and investments for poverty reduction and food security. *Food policy reports* 25, International Food Policy Research Institute (IFPRI). USA. Available at: <https://pdfs.semanticscholar.org/eca6/af30ba46db982d667db7e3e1f364529dca6.pdf>.
- Bishara, Y., 2015. This is the percentage of wasted Saudi food in waste [translated from Arabic]. *Sayidaty*. October 30. <http://www.sayidaty.net/node/355966/> Last accessed: September 4, 2018.
- Chatham House, 2013. *Global Food Insecurity and Implications for Saudi Arabia*. Energy, Environment and Resources Summary, pp. 1–10. London. Available at: <https://www.chathamhouse.org/sites/default/files/public/Research/Energy,%20Environment%20and%20Development/290413summary.pdf>.
- Al-Fozan, Abdullah, 2017. Dow KSA, Eta'am promote 'healthy eating' and food waste reduction 2017. Available at: <http://saudigazette.com.sa/article/519029/BUSINESS/Dow-KSA-Etaam-promote-healthy-eating-and-food-waste-reduction>.
- El Mouzan, M.I., Foster, P.J., Al Herbish, A.S., Al Salloum, A.A., Al Omer, A.A., Qurachi, M.M., Kecojovic, T., Mouzan, A. et al. 2010. Prevalence of overweight and obesity in Saudi children and adolescents Available at: *Ann. Saudi Med.* 30 (3), 203–208 <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2886870/>. <https://doi.org/10.4103/0256-4947.62833>.
- Fareed, Saleh, 2017. Savola and UNEP launch drive to reduce food waste in the Kingdom. An article published in the Daily Saudi Gazette on March 16, 2017. Available at: <http://saudigazette.com.sa/article/174890/Savola-and-UNEP-launch-drive-to-reduce-food-waste-in-the-Kingdom>.
- Fiaz, S., Noor, M.A., Aldosri, F.O., 2016. Achieving food security in the Kingdom of Saudi Arabia through innovation: potential role of agricultural extension. *Journal of the Saudi Society of Agricultural Sciences*.
- Food Export Association of the Midwest USA, 2017. Saudi Arabia Country Profile. Available at: <https://www.foodexport.org/get-started/country-market-profiles/middle-east/saudi-arabia-country-profile>.
- Government of Saudi Arabia, 2016. Saudi Arabia's Vision for 2030. Available at: vision2030.gov.sa/download/file/fid/417.
- Green, B., Johnson, C., Adams, A., 2006. Writing narrative literature reviews for journals: secrets of the trade. *J. Chiropractic Med.* 3 (5).
- Gleeson, B., 2017. Infographic: Issues Related to Food Wastage. Available at: <https://mena.yougov.com/en/news/2017/06/08/infographic-issues-related-food-wastage/>.
- Gustavsson, J., Cederberg, C., Sonesson, U., Emanuelsson, A., 2013. The methodology of the FAO study: "Global Food Losses and Food Waste – extent, causes and prevention" – FAO, 2011: SIK. The Swedish Inst. Food Biotechnol.
- Heller, M.C., 2017. *Food Product Environmental Footprint Literature Summary: Packaging and Wasted Food*. Center for Sustainable Systems, University of Michigan for the State of Oregon Department of Environmental Quality. Available at: <https://www.oregon.gov/deq/FilterDocs/PEF-Packaging-FullReport.pdf>.
- International Food Policy Research Institute, 2016. Middle East and North Africa. Available at: <http://www.ifpri.org/topic/middle-east-and-north-africa>.
- Khan, M.S.M., Kaneesamkandi, Z., 2013. Biodegradable waste to biogas: renewable energy option for the Kingdom of Saudi Arabia Available at: *Int. J. Innovation Appl. Stud.* 4 (1), 101–113 <http://www.ijias.issr-journals.org/abstract.php?article=IJIAS-13-142-18>.
- Lampietti, J., Michaels, S., Magnan, N., McCalla, A., Saade, M., Khouri, N., 2011. A strategic framework for improving food security in Arab countries. *Food Sec.* 3 (S1), 7–22. <https://doi.org/10.1007/s12571-010-0102-3>.
- Lovelle, M., 2015. Food and water security in the Kingdom of Saudi Arabia. Published by Future Directions International Pty Ltd. Australia. www.futuredirections.org.au/publication/food-and-water-security-in-the-kingdom-of-saudi-arabia/.
- Makkar, H., Ankers, P., 2014. Towards sustainable animal diets: a survey-based study. *Animal Feed Sci. Technol.* 198, 309–322.
- MBC, 2015. Jeddah: 5300 tons of food waste per day in Ramadan (Translated from Arabic Article). (July 08, 2015). MBC.net. Available at: <http://www.mbc.net/ar/programs/mbc-news/articles/5300.html>.
- Memish, Z.A., El Bcheraoui, C., Tuffaha, M., Robinson, M., Daoud, F., Jaber, S., Mikhitarian, S., Al Saeedi, M., AlMazroa, M.A., Mokdad, A.H., Al Rabeeah, A.A., 2014. Obesity and associated factors— Kingdom of Saudi Arabia, 2013 Available at: *Prev. Chronic Dis.* 11 (140236) <https://www.ncbi.nlm.nih.gov/pubmed/25299980>. <https://doi.org/10.5888/pcd11.140236>.
- Middle East Monitor, 2016. Official data: Saudi wastes \$13.3bn of food each year. January 25. <https://www.middleeastmonitor.com/20160125-official-data-saudi-wastes-13-3bn-of-food-each-year/>. Accessed Sep 4, 2018.
- Mourad, M., 2016. Recycling, recovering and preventing "food waste": Competing solutions for food systems sustainability in the United States and France. *J. Clean. Prod.* 126, 461–477. <https://doi.org/10.1016/j.jclepro.2016.03.084>.
- Muhammad, Fatima, 2014. Saudi Arabia to stop wheat production by 2016. Article published on December 11, 2014. Saudi Gazette. Available at: <http://english.alarabiya.net/en/business/economy/2014/12/11/KSA-to-stop-wheat-production-by-2016.html>.
- Musaiger, A., 2011. Overweight and obesity in eastern mediterranean region: prevalence and possible causes. *J. Obesity* 17. <https://doi.org/10.1155/2011/407237>.
- Neff, R.A., Parker, C.L., Kirschenmann, F.L., Tinch, J., Lawrence, R.S., 2011. Peak oil, food systems, and public health. *Am. J. Public Health* 101 (9), 1587–1597.
- Neff, R.A., Spiker, M.L., Truant, P.L., 2015. Wasted Food: U.S. Consumers' reported awareness, attitudes, and behaviors. *PLOS ONE* 10 (6), e0127881. <https://doi.org/10.1371/journal.pone.0127881>.
- Ouda, O.K.M., Raza, S.A., Nizami, A.S., Rehan, M., Al-Waked, R., Korres, N.E., 2016. Waste to energy potential: a case study of Saudi Arabia. *Renew. Sustain. Energy Rev.* 61, 328–340.
- Pirani, S.I., Arafat, H.A., 2016. Interplay of food security, agriculture and tourism within GCC countries. *Global Food Sec.* 9, 1–9.
- Pollution Solutions, 2012. Food is the largest waste in Saudi Arabia. Available at: <https://www.pollutionsolutions-online.com/news/waste-management/21/breakingnews/food-is-the-largest-waste-in-saudi-arabia/22804>. Accessed Dec 18 2017.
- Porpino, G., Parente, J., Wansink, B., 2015. Food waste paradox: antecedents of food disposal in low income households. *Int. J. Consumer Stud.* 39 (6), 619–629.
- Pradhan, S., 2010. Gulf-South Asia Economics Relations; Realities and Prospects. In: Evenett, S.J., (Ed.), *Will Stabilisation Limit Protectionism? The 4th GTA Report*. Centre for Economic Policy research. Available at: <http://www.globaltradealert.org/sites/default/files/GTA4.pdf> [Accessed 10 January 2014].
- Qusted, T.E., Parry, A.D., Easteal, S., Swannell, R., 2011. Food and drink waste from households in the UK. *Nutr. Bull.* 36 (4).

- Quested, T.E., Marsh, E., Stunell, D., Parry, A.D., 2013. Spaghetti soup: the complex world of food waste behaviours. *Resour., Conserv. Recycl.* 79, 43–51. <https://doi.org/10.1016/j.resconrec.2013.04.011>.
- ReFED, 2016. A roadmap to reduce US food waste by 20 percent https://www.refed.com/downloads/ReFED_Report_2016.pdf.
- Salemdeeb, R., Ermgassen, E., Kim, M., Balmford, A., Al-Tabbaa, A., 2017. Environmental and health impacts of using food waste as animal feed: a comparative analysis of food waste management options. *J. Cleaner Prod.* 140, 871–880.
- Saudi Arabia General Authority for Statistics, 2017. Waste production rate per individual (2010–2015). Environmental Indicators. Available at: https://www.stats.gov.sa/sites/default/files/per_capita_daily_waste_generation_in_saudi_arabia_during_the_period_2010-2016_en.pdf.
- Saudi Arabia Ministry of Economy and Planning, 2015. The Tenth Development Plan <https://www.stats.gov.sa/en/page/72>.
- Saudi Gazette, 2015. 900 food waste containers in Jeddah. An article published in the Daily Saudi Gazette on December 02, 2015. Available at: <http://saudigazette.com.sa/saudi-arabia/900-food-waste-containers-in-jeddah/>.
- Saudi gazette, 2017. Savola and UNEP launch drive to reduce food waste in the Kingdom. March 16. <https://www.gulfbase.com/news/savola-and-unep-launch-drive-to-reduce-food-waste-in-the-kingdom/295487> Accessed September 4, 2018.
- Saudi Ministry of Health, 2017. Food Waste Tops Menu at Riyadh Conference https://www.zawya.com/mena/en/story/Food_Waste_Tops_Menu_at_Riyadh_Conference-ZAWYA20170411075212/.
- Shahzad, K., Nizami, A.S., Sagir, M., Rehan, M., Maier, S., Khan, M.Z., et al., 2017. Biodesign production potential from fat fraction of municipal waste in Makkah. *PLOS ONE* 12 (2).
- Tanyeri-Abur, A., Hag Elamin, N., 2011. International investments in agriculture in Arab countries: an overview and implications for policy. *Food Sec* 3 (S1), 115–127. <https://doi.org/10.1007/s12571-010-0097-9>.
- The Saudi Arabia General Authority for Meteorology and Environmental Protection, 2017. The State of the Environment 2017: Responsibilities and achievements.
- Tobler, C., Visschers, V.H.M., Siegrist, M., 2011. Eating green. Consumers' willingness to adopt ecological food consumption behaviors. *Appetite* 57, 674–682. <https://doi.org/10.1016/j.appet.2011.08.010>.
- Tolba, M.K., Saab, N.W., 2008. Arab Environment: Future Challenges. In: Arab Forum for Environment and Development (Ed.).
- Toumi, Habib, 2014a. Alarming wastage of food in Gulf countries. An article published in the Gulf News on July 11, 2014. Available at: <http://gulfnews.com/news/gulf/saudi-arabia/alarming-wastage-of-food-in-gulf-countries-1.1358576>.
- Toumi, Habib, 2014b. Man installs 'charity fridge' outside his house. Published in the Gulf News – Saudi Arabia on May 06, 2014. Available at: <https://gulfnews.com/news/gulf/saudi-arabia/man-installs-charity-fridge-outside-hishouse-1.1328931>.
- UDA Consulting, 2017. Reducing Food Waste in the OIC Countries. Ankara, Turkey: Committee for Economic and Commercial Cooperation of the Organization of Islamic Cooperation (COMCEC) Coordination Office.
- UN Development Programme, 2012. About Saudi Arabia. Available at: http://www.sa.undp.org/content/saudi_arabia/en/home/countryinfo.html. Accessed Dec 18, 2017.
- UN FAO, 2011. Global food losses and food waste: Extent, causes and prevention. Rome <http://www.fao.org/docrep/014/mb060e/mb060e00.pdf>.
- UN FAO, 2013. Food Waste Footprint: Impact on Natural Resources <http://www.fao.org/docrep/018/i3347e/i3347e.pdf>.
- UN FAO, 2014. Reducing Food Losses and Waste in the Near East & North Africa Region <http://www.fao.org/docrep/meeting/030/mj427E.pdf>.
- UN FAO, 2015a. Regional Strategic Framework Reducing Food Losses and Waste in the Near East & North Africa Region <http://www.fao.org/3/a-i4545e.pdf>.
- UN FAO, 2015b. Statistical Handbook <http://www.fao.org/3/a-i4691e.pdf>.
- UN FAO, 2016. Building Resilience to Enhance Food Security and Nutrition in the Near East and North Africa.
- UN FAO Office of Evaluation, 2016. Evaluation of FAO's technical cooperation assistance in the Kingdom of Saudi Arabia. Rome <http://www.fao.org/3/a-br270e.pdf%20>.
- United Nations, 2016. Sustainable Development Goal 12. <https://sustainabledevelopment.un.org/sdg12>. Accessed Dec 18, 2017.
- United Nations, 2017. World Economic Situation and Prospects 2017 Statistical Annex http://www.un.org/en/development/desa/policy/wesp/wesp_current/2014wesp_country_classification.pdf.
- United Nations Food & Agriculture Organization, 2017. FAO Facilitates Training for 2,000 Stakeholders on Capacity Building for Food Loss Reduction in the Near East. <http://www.fao.org/neareast/news/view/en/c/1025761/>. Accessed Dec 18, 2017.
- United States Environmental Protection Agency, 2016. Food Recovery Hierarchy. <https://www.epa.gov/sustainable-management-food/food-recovery-hierarchy>. Accessed May 10, 2017.
- USDA Foreign Agricultural Service, 2014. Global Agricultural Information Network: Report Number SA1417.
- USDA Foreign Agricultural Service, 2014. Global Agricultural Information Network: Report Number SA1417.
- Wansink, B., van Ittersum, K., 2013. Portion size me: plate-size induced consumption norms and win-win solutions for reducing food intake and waste. *J. Exp. Psychol. Appl.* 19 (4), 320–332. <https://doi.org/10.1037/a0035053>.
- Wansink, B., van Ittersum, K., Payne, C.R., 2014. Larger bowl size increases the amount of cereal children request, consume, and waste. *J. Pediatr.* 164 (2), 323–326. <https://doi.org/10.1016/j.jpeds.2013.09.036>.
- Waqas, M., Almelbi, T., Nizami, A.S., 2017. Resource recovery of food waste through continuous thermophilic in-vessel composting. *Environ. Sci. Pollut. Res.*, 1–11.
- Whitman, Elizabeth, 2016a. Oil-Rich Saudi Arabia Wastes Astounding \$35 Million In Food Every Day. Published in the International Business Times on Jan 27, 2016. Available at: <http://www.ibtimes.com/oil-rich-saudi-arabia-wastes-astounding-35-million-food-every-day-2282137>.
- Woertz, E., 2010. The Gulf food import dependence and trade restrictions of agro exporters in 2008. In: Evenett, S.J., (Ed.), Will Stabilisation Limit Protectionism? The 4th GTA Report: A Focus on the Gulf Region. Available at: <http://www.globaltradelert.org/sites/default/files/GTA4.pdf>. Accessed 10 January 2014.
- World Bank, 2017a. Arable Land (hectares per person) – Saudi Arabia. <http://data.worldbank.org/indicator/AG.LND.ARBL.HA.PC?end=2014&locations=SA&start=1961&view=chart>. Accessed Dec 18, 2017.
- World Bank, 2017b. Population Dynamics by Country and Group 2017. <http://datatopics.worldbank.org/health/population>. Accessed Dec 18, 2017.
- World Resources Institute, 2016. Food Loss and Waste Accounting and Reporting Standard. Washington, DC.
- WRAP, 2011. Consumer insight: date labels and storage guidance. London.
- WRAP, 2015. Strategies to Achieve Economic and Environmental Gains by Reducing Food Waste.
- YouGov, 2016a. Consumer Behaviour this Ramadan. Available at: <https://mena.yougov.com/en/news/2016/06/06/infographic-consumer-behaviour-ramadan/> Accessed Dec 18, 2017.
- YouGov, 2016b. Residents in Saudi Arabia spend almost a quarter of their day on social media. <https://mena.yougov.com/en/news/2016/07/04/saudi-residents-spend-quarter-day-socialmedia/>. Accessed Dec 18, 2017.
- Zareen, Nadeshda, 2017. Saudi food prices set to rise on higher costs, import duties. Article published in Argaam on 31 March, 2017. Available at: <https://www.argaam.com/en/article/articledetail/id/477316>.