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From plate to waste: a cross-sectional study of food waste trends in Al Ahsa, Saudi Arabia

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Background: Food waste is a global concern that needs special attention and urgent actions to reduce the amount of wasted food. This study aims to investigate the trend of food waste in Al Ahsa.

Methods: This is a cross-sectional study designed to analyze the factors associated with the generation of wasted food within Al Ahsa community.

Results: The results showed that out of 257 participants, 82.9% were of Saudi nationality, 83.3% were females, 69.6% below 34 years and the family sizes mean was around 6. The majority of study participants were unemployed (62.3%), the employed ones were in healthcare field (56.4%). No significant gender differences was found in terms of other food waste-related variables. No significant association was found with age and occupation. Non-Saudi participants significantly report a lower frequency of wasting food and a higher rate of attitudes toward food waste sorting with $p = 0.02$ and $p = 0.02$, respectively. Working participants showed significant differences in terms of attitudes toward food waste sorting ($p = 0.002$), attitudes toward reducing food waste ($p = 0.042$), and the amount of food wasted per day ($p = 0.010$) when compared to those who are not working. Doctorate level of education exhibited significant ($p = 0.002$) attitudes toward food waste sorting and those who are in the commerce field of education had higher mean scores (M = 2.81, SD = 0.84) to reduce food waste. The cause of food waste was related to expiry date (61.1%). The common cause of wasting food when eating out or ordering online, was related to participants' preference for trying a variety of dishes (40.1%). The participants adherent to home-cooked food during pandemic (mean 3.85, SD 1.40). Males reported a slightly higher impact of COVID-19 on their dietary habits when compared to females ($p = 0.04$). The majority of participants agreed that sharing food with neighbors decreases food waste (Mean = 3.96, SD = 1.32). Moreover, they do not throw food due to religious and cultural beliefs (Mean = 3.36, SD = 1.60).

Conclusion: Creating educational campaigns, promoting sustainable waste management and integrating technology to reduce food waste are recommended to achieve Saudi vision 2030.

KEYWORDS

food waste, sustainable development, COVID-19, food security, Saudi Arabia

1 Introduction

On July 10th 2023, the United Nations (UN) announced that the current world population had exceeded 8 billion [United Nations (UN), 2023]. The rapid global population growth as well as the scarcity of natural resources have increased food waste prominent problem, rendering sustainable food consumption (SCF) an urgent matter. According to World Food Program (WFP), as many as 828 million people were affected by hunger in 2023, and extreme weather, rising costs, and conflict continue to worsen the global food crisis [World Food Program (WFP), 2023]. On the other hand, the United Nations Environment Program's declared that the global amount of yearly wasted food from household, food chain supplies and retails sectors sources is 1.3 billion tons which is sufficient to make 1.24 billion people food secure [United Nations Environment Programme's (UNEP), 2021]. Most importantly, most of the world's food waste comes from households. Out of the total food wasted in 2022, households were responsible 60%; while, the food service and retail sectors' portion accounted for 40% [United Nations Environment Programme's (UNEP), 2024]. Wasted food is not just a food security and social threat, but also it harms the environment by increasing the amount of greenhouse gases emitted, exacerbating energy consumption as well and depletion of biodiversity (Zhang et al., 2021). Evidence has shown that the food waste issue needs global special attention and urgent actions to reduce the amount of wasted food to achieve the UN Sustainable Development Goal (SDG) 12 "Ensure sustainable consumption and production patterns" by 2030 through well designed waste management actions. Waste management is essential for every country since it has direct potential effect on the environment and population health. Therefore, an efficient and effective municipalities waste management is crucial (Barma et al., 2022). Accordingly, Olapiriyakul et al. (2019) declared that inadequate or poor waste management systems have negative impact not only on the societies but also on the economy of countries.

Since 1980, researchers started to investigate the issue of food waste and by the end of 2005, this context became widely tackled around the world (Schneider, 2013). Recently, the studies on food loss have focused on 5 main objectives; the policies and implemented interventions to reduce food waste (Lipinski, 2013; Shen et al., 2023), the volume of household wasted food (Van der Werf et al., 2018; Withanage et al., 2021), the assessment of the adverse effect of food waste (Withanage et al., 2021; Sarker et al., 2022), the analysis of factors associated with household food wasting behaviors (Zhu et al., 2022; Li et al., 2021) as well as developing techniques for food waste management (Haas et al., 2022; Hanson and Ahmadi, 2022). Moreover, waste management can be achieved at the municipal level. According to Abbasi et al., the waste flow rates are tracked at each point of waste management facilities during seasonal fluctuations, religious celebrations, and emergency health conditions, such as those experienced during the COVID-19 pandemic (Abbasi et al., 2024). Shen et al. summarized the European Union's practical experience toward the anti-food waste approach and showed that the key driver to solve this issue is enhancing cooperation between food chain suppliers and consumers since the greater amount of food waste are generated at the end consumption level (Shen et al., 2023). Accordingly, a recent study estimated the average food waste in South Korea by 0.26–0.11 kg/person/day. Moreover, it was shown that the amount of generated food waste was greatly affected by seasons as well

as the type of housing (Adelodun et al., 2021). Interestingly, Everitt and his colleagues proved that 2.81 kg/household/week of food waste are generated in all of Canada, London, and Ontario, knowing that around 52% of which are avoidable waste. In the mentioned study, the volume of food thrown away was mainly affected by household size, number of children, socio-economic characteristics as well and the availability and accessibility to retail food stores (Everitt et al., 2022). On the other hand, food waste has an adverse impact on the economy of society, by affecting its environment through emission of pollutants and greenhouse gases and by depleting its natural resources and biodiversity. Accordingly, Moult et al., conducted research in United Kingdom to study the relationship between the amount of greenhouse gases emitted and type of food wasted, they proved the correlation between the energy density of food and the net greenhouses gas emission (Moult et al., 2018). In China, food waste resulted in water footprint and carbon footprint by 6.108 billion m^3 and 9.7517 million tons of CO_2, respectively. When it comes to low-income countries (LIC), Bangladesh is among those countries generating high amount of wasted food which need urgent actions to allow such developing countries to move toward a sustainable future (Sarker et al., 2022). In terms of individual behaviors toward reducing food waste, a study conducted in Pakistan has shown a significant association between sustainable food consumption practices with participant's gender, level of education, income, and housing type (Shahbaz et al., 2022). Schanes et al., found that households often face conflicting behaviors toward reducing food waste at the individual level due to variation between their preferences for freshness, taste, and safety of food (Schanes et al., 2018). Interestingly, a study conducted in Japan revealed that individuals with agricultural feedback have low rates of wasting food (Nakamura et al., 2022).

Currently, in Saudi Arabia food waste is the key factor affecting its food security (Baig et al., 2022). According to the recent report issued by the Ministry of Environment, Water and Agriculture (MEWA), Saudi Arabia ranked in the first place in the world in terms of wasted food (Gazette, 2018). The Saudi Grains Organization (SAGO) announced that about 33% of food is thrown away with an estimated cost of around 40 billion SAR/year (Baseline, 2019). The world's average food waste *per capita* is around 115 kg, whereas Saudi Arabia exceeded it to attain 250 kg *per capita* annually. Studies have shown that a greater portion of food is wasted during gathering parties, buffets in hotels, restaurants, and even at the household level (Abdullah et al., 2022). Baig et al. revealed that a lack of awareness of the importance of reducing food waste, and individual's tendency to show off luxurious food for guests are the key drivers for the increased amount of food waste in Saudi Arabia (Baig et al., 2022). On the other hand, Saudi Arabia showed a high consumption of grains where the average citizen consumes 158 kg/year which exceeded the global average (145 kg *per capita*). Knowing that Saudi Arabia mainly relies on exports to ensure its food security despite its incapability to produce agricultural growth due to low rates of rainfall, hot temperatures, limited water resources, and lack of fertile soil (Baig et al., 2017). Poor food recycling and reuse worsen the situation, where individuals take action to decide whether the food is edible or not. However, food waste is sometimes avoidable. Accordingly, rice husk is an example of avoidable waste, since it has high cellulose, ash, and silica contents so could be used in agricultural fields as a supplement (Phonphuak and Chindaprasirt, 2015). Moreover, inedible fruits and vegetables peels,

and bones are among the avoidable food waste that have important use in feeding animals and making composting (Evans, 2014). Interestingly, the behavior of wasting food by people is not isolated but it is the result of the interaction between different activities starting from food production till the end of consumption (Pearson and Perera, 2018) and at present, Saudi Arabia needs clear laws and urgent actions that could stop or limit food waste. Despite this local context, food waste is a global issue rendering food waste reduction one of the global Sustainable Development Goal (SDG) targets, where Target 12.3 of the SDGs aims to halve the global food waste *per capita* at the retail and consumer levels and to reduce food losses along the production and supply chains, including post-harvest losses, by 2030 [United Nations (UN), 2021]. Therefore, the aim of this study is to investigate the antecedent factors, trends, and characteristics of food waste in Al Ahsa governate, to assess the participants' attitudes toward reducing food waste as well as to explore the potential impact of COVID-19 exposure on dietary habits and food waste.

2 Materials and methods

2.1 Study design

This research employed a cross-sectional survey to investigate the factors associated with the generation of wasted food within Al Ahsa community in addition to the participants' attitudes toward reducing food waste. The study also explored the potential impact of COVID-19 exposure on dietary habits and food waste.

2.2 Study population and setting

This study was conducted in Al Ahsa governate, Eastern Province of Saudi Arabia during December 2023. The study included resident population of Al Ahsa governate from different nationalities. However, the excluded population involves those who are below 18 years old and not living in the Al Ahsa governate.

2.3 Sample size calculation and sampling technique

A convenient sampling technique, non-probability sampling technique that involves selecting participants based on their availability and accessibility. While convenient sampling offers accessibility, it is essential to acknowledge its limitations, such as potential selection bias. Results may not be fully representative of the entire population. Therefore, findings should be interpreted with consideration of these limitations. A sample size calculation was performed to ensure adequate statistical power. The goal is to achieve a representative sample that reflects the diversity of Al Ahsa's population. Using power analysis statistical packages G*Power for sample size calculation for multiple regression, considering medium effect size ($f^2 = 0.15$) and a significance level (*p*-value) $p < 05$, with a power of 80%, the estimated sample size will be 121 people. Because we are surveying a population, we will oversize the collected samples to make sure that we have covered the objective of this study.

2.4 Ethical considerations

Participants were provided with clear information about the study's purpose. Participants' consent to participate in this study was implied by their response, since the participants were informed that "by pressing next, they consent to participate in this study." Participants' identities are kept confidential and anonymized during analysis to ensure privacy. Participation in the study is entirely voluntary, and participants have the right to withdraw at any stage without consequence.

2.5 Institutional committee approval

The research was performed in accordance with relevant guidelines/regulations. The Institutional review board (IRB) of research center at Almoosa Health Group with the log No:ARC-23.12.13 approved this study.

2.6 Data collection plan

The Data of the sampling will be collected by the survey which including the following sections:

- Demographic characteristics
- Causes of food waste in households
- Causes of food waste when eating out/ordering online
- Effect of the COVID-19 pandemic on participants' dietary habits
- Effect of the COVID-19 pandemic on generated food waste
- The amount of food wasted per day
- Separation of kitchen food waste
- Participants' attitudes toward food waste sorting from general
- Household garbage
- Participants' attitude toward reducing food waste

Survey form was administered electronically using online Google Forms. Recruitment of participants includes the following: social media and another multi-platform approaches to reach a diverse audience. The researchers ensured that the online survey was easily accessible and mobile-friendly to accommodate participants using various devices. After data collection and data entry are completed, Microsoft Excel was transferred for statistical analysis.

2.6.1 Variables and measurements

Section 1: Demographic characteristics.
- Nationality.
- Gender.
- Age group.
- Level of education.
- Occupation.
- Field of study.
- Household size.
- Employment.
- Household income.

Section 2: Causes of food waste in households.
- Seven questions about the frequency and the reasons for food waste in households.

Section 3: Causes of food waste when eating out/ordering online.
- Eight questions about the frequency and the reasons for food waste when eating out/ordering online.

Section 4: Effect of the COVID-19 pandemic on participants dietary habits.
- The extent to which you agree or disagree with each of the 1 statements.

Section 5: Effect of COVID-19 pandemic on generated food waste.
- Two statement on a scale of 1–6 scale from significantly decreased to Significantly increased.

Section 6: The amount of food wasted per day.
- Three questions on a scale from 1 to 6 starting with 0–1 cup up to more than 5 cups.

Section 7: Separation of kitchen food waste.
- Three statements to Select the appropriate one.

Section 8: Participants' attitudes toward food waste sorting from general household garbage.
- The extent to which you agree or disagree with 7 statements.

Section 9: participants' attitude toward reducing food waste and household garbage.
- The extent to which you agree or disagree with the 7 statements.

2.6.2 Data management and statistical analysis plan

The comprehensive data management process involved rigorous procedures for data cleaning, meticulously addressing missing values, outliers, and inconsistencies to ensure the utmost reliability of the dataset. Composite variables were judiciously crafted, and specific variables, especially those associated with small group sizes, underwent recoding to bolster statistical robustness. Frequencies were judiciously employed for categorical data, while mean and standard deviation (SD) calculations were applied to continuous variables, furnishing a nuanced comprehension of the participants' characteristics and behaviors. Moreover, the application of multiple response analysis facilitated an in-depth exploration of the causes of food waste, unraveling the diverse perspectives of participants on this critical issue. This meticulous data management strategy significantly augments the validity and interpretability of subsequent analyses, thereby contributing substantially to the overall rigor of the study. The data analysis, employing a comprehensive array of statistical tools such as descriptive statistics, t-tests, ANOVA, and correlation analyses, unveils a spectrum of insights into diverse demographic characteristics, frequencies, and underlying causes of food waste. It also sheds light on the nuanced impacts of the COVID-19 pandemic on dietary habits, patterns of daily food wastage, kitchen waste disposal practices, and participants' attitudes toward food waste sorting and reduction. Furthermore, correlations between demographics, food waste, and attitudes were systematically explored. In addition, graphs, including histograms, were utilized to visually represent data distributions and patterns, enhancing the clarity and interpretability of the findings. This multifaceted data analysis approach, complemented by graphical representation, enriches the depth of understanding in the study, providing a robust foundation for meaningful conclusions.

3 Results

3.1 Demographic characteristics of study participants

Table 1 illustrates the demographic characteristics of the surveyed participants (N: 257), revealing a predominant Saudi nationality (82.9%), a higher representation of females (83.3%), a significant proportion not currently employed (62.3%), and diverse fields of study, with Healthcare being the most prevalent (56.4%). Additionally, notable occupational categories include teachers (13.2%), healthcare providers (12.8%), and those in managerial positions (8.9%). A considerable portion of participants preferred not to disclose their income (39.7%), while among those who did, a noteworthy percentage earned 10,000 SAR or more (35.8%). The descriptive statistics also revealed a diverse age distribution among participants (mean = 28.94, SD = 10.54) and variable family sizes (mean = 5.51, SD = 2.71).

3.2 Causes of food waste in households

Regarding the frequency of throwing away food at home, the results demonstrated a range of responses from 1.00 to 5.00, with a mean of 2.81 and a SD of 1.05, indicating moderate variability in participants' disposal frequency and providing insights into their food waste habits. The causes of food waste in households, arranged in descending order based on the percentage of cases, are as follows: the food item is close to or has already passed the expiration date label (61.1%), the food item is spoiled (41.2%), I do not like to eat stale food (30.0%), the food item is cooked in excessive amounts (28.8%), I already bought a new one (5.8%), and the food item is not tasty (5.4%; Figure 1).

3.3 Causes of food waste when eating out/ordering online

Data in Figure 2, shows the frequency of wasting food when eating out or ordering online (mean = 1.90, SD = 0.89) indicates a limited tendency. The primary causes identified include a preference for trying a variety of dishes (40.1% of cases), difficulty estimating the appropriate food quantity (32.9%), challenges associated with large serving sizes (28.1%), dissatisfaction with taste (15.0%), reluctance to share meals (3.6%), embarrassment in ordering a small quantity (4.8%), and a disinclination to take away leftovers (18.6%).

3.4 Effect of the COVID-19 pandemic on participants dietary habits

On the other hand, a moderate impact of the pandemic on their dietary habits overall (Mean = 2.87, SD = 1.42). Moreover, participants tended to consume more home-cooked food during the pandemic for safety reasons, indicating a higher mean score of 3.85 with a SD of

TABLE 1 Demographic characteristics of study participants.

Variable		N	%
Nationality	Saudi	213	82.9
	Non-Saudi	44	17.1
Gender	Male	43	16.7
	Female	214	83.3
Age	18–33	179	69.6
	34–53	70	27.3
	54–73	8	3.1
Education	Less than primary school	2	0.8
	Primary school	1	0.4
	Middle school	4	1.6
	High school	19	7.4
	Undergraduate	114	44.4
	Bachelor's or equivalent	87	33.9
	Master's or equivalent	16	6.2
	Doctorate or equivalent	14	5.4
Field of the Study	Healthcare	145	56.4
	Education	56	21.8
	Commerce	11	4.3
	N/A	11	4.3
	Other	21	8.2
Household	0–3	52	20.2
	4–7	151	58.8
	8–11	46	17.9
	>11	4	1.6
	NA	4	1.6
Employment	Not Working	160	62.3
	Working	97	37.7
Occupation	Worker	1	0.4
	Teacher	34	13.2
	Technician	11	4.3
	Healthcare Provider	33	12.8
	Engineer	5	1.9
	Managerial position	23	8.9
	N/A	93	36.2
	Other	5	1.9
	Students	50	19.5
Income	5000 SAR or Less	30	11.7
	5000–6999 SAR	16	6.2
	7000–9999 SAR	17	6.6
	10000 SAR or More	92	35.8
	Prefer not to Answer	102	39.7

1.40. Conversely, the consumption of delivered food increased to a lesser extent during the lockdown, as reflected in a mean score of 2.05 with a SD of 1.26 (Table 2), when it comes to the effect of the COVID-19 pandemic on dietary habits it was shown that the effect as

perceived by the respondents for mean of 2.87 and SD of 1.42 suggesting a moderate impact.

3.5 The amount of food wasted per day

Table 3 represents data on daily food wastage, revealing that respondents exhibited varying levels of waste in different categories. Cooking waste (Mean = 1.98, SD = 1.24) showed the highest level of waste, followed by untouched cooked food (Mean = 1.85, SD = 1.21) and leftovers from cooked or delivered dishes (Mean = 1.81, SD = 1.12).

3.6 Separation of kitchen food waste

Participants' practices in separating and disposing of kitchen food waste are shown in Table 4. About 39.1% of the respondents reported disposing of kitchen food waste without separation, followed by 37.2% indicated that they separate kitchen food waste before disposal, while 23.7% reported separating it and then reusing or recycling it. This suggests that a significant portion of participants do not engage in the separation of kitchen food waste, emphasizing an opportunity for promoting more sustainable waste management practices.
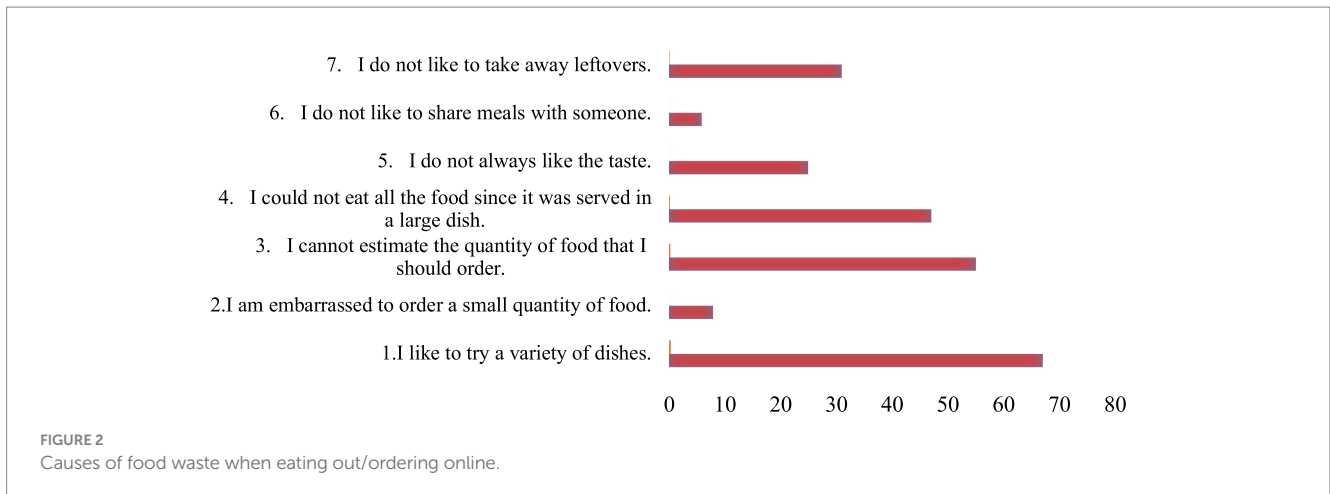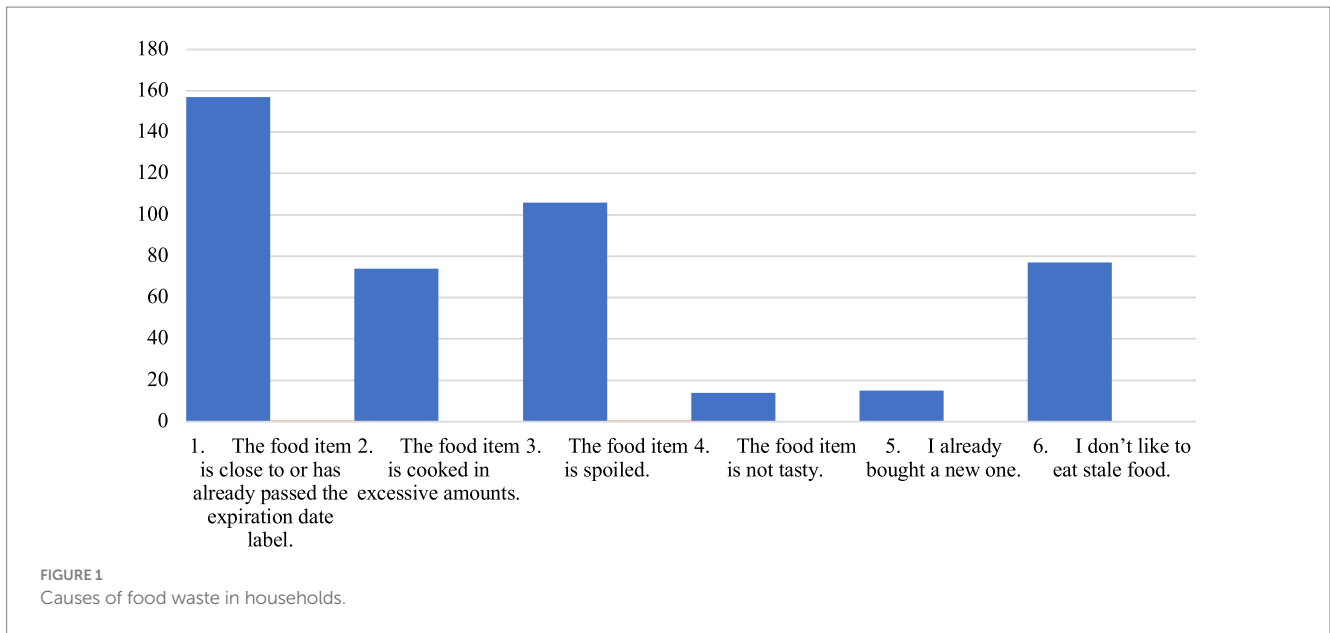
3.7 Participants' attitudes toward food waste sorting from general household garbage

Presents participants' attitudes toward sorting food waste from general household garbage, with mean scores reflecting their sentiments. The highest mean score is observed for religious and cultural beliefs (Mean = 3.36, SD = 1.60), Following this, participants expressed moderate agreement about they do not have an idea about what to do after sorting (Mean = 2.58, SD = 1.53) and that the local authorities apply a penalty (Mean = 2.30, SD = 1.46). The lowest mean scores were reported for their thinking that this is the role of local authorities" (Mean = 1.95, SD = 1.24) and sorting because they feel embarrassed (Mean = 2.09, SD = 1.38, suggesting lower agreement with these reasons for sorting; Table 5).

3.8 Participants' attitude toward reducing food waste

Participants' attitudes toward reducing food waste are represented in Table 6, where the highest mean score is associated with sharing food with neighbors (Mean = 3.96, SD = 1.32), suggesting a strong endorsement of the idea that communal sharing can be an effective strategy for waste reduction; followed by the availability of food items in different sizes (Mean = 3.68, SD = 1.44) and "COVID-19 affect food waste" (Mean = 3.26, SD = 1.26). On the other hand, the lowest mean scores were observed for cooking at home generates more food waste (Mean = 2.77, SD = 1.35) and offers while shopping for food (Mean = 2.77, SD = 1.49), indicating less agreement with these perspectives on reducing food waste.

The Correlation between demographics, food waste, and attitude toward food waste were studied. The family size shows a positive

FIGURE 1
Causes of food waste in households.

FIGURE 2
Causes of food waste when eating out/ordering online.

correlation with their attitude toward reducing food waste ($r = 0.130$, $p > 0.05$). The frequency of throwing away food when you eat out/order online is positively correlated with the respondents' attitude toward reducing food waste ($r = 0.180$, $p > 0.05$) and their attitudes toward food waste sorting from general households ($r = 0.152$, $p > 0.05$). In addition, a significant positive correlation between the respondents' attitudes toward reducing food waste and cooking waste/day ($r = 0.179$, $p > 0.05$), leftovers of plates from cooked/delivered dishes/day ($r = 0.199$, $p > 0.05$), and untouched cooked food/day ($r = 0.207$, $p > 0.05$). Finally, attitude toward reducing food waste is highly correlated with their attitudes toward food waste sorting from general households ($r = 0.406$, $p > 0.05$). Importantly, t-test results between Saudi and non-Saudi participants reveal significant differences in frequently wasted food when you eat out/order online ($t = 2.38$, $p = 0.02$) and attitudes toward food waste sorting from general household garbage ($t = -2.70$, $p = 0.01$). Specifically, non-Saudi participants report a lower frequency of wasting food when eating out/ordering online compared to their Saudi counterparts and a higher rate of attitudes toward food waste sorting from general households. On the other hand, a significant gender difference in the

perceived effect of the COVID-19 pandemic on participants' dietary habits ($t = -2.01$, $p = 0.04$), where males (Mean = 2.48, SD = 0.91) reported a slightly higher impact compared to females (Mean = 2.42, SD = 0.88). However, no significant gender differences were found in other food waste-related variables, including the frequency of food waste, the amount of food wasted per day, attitudes toward food waste sorting, and attitudes toward reducing food waste. The ANOVA results revealed that the daily amount of food wasted per day exhibited significant variations among groups with different income levels ($F = 3.046$, $p = 0.018$). Specifically, participants earning between 5,000 and 6,999 SAR demonstrated the highest mean amount of daily food waste (Mean = 2.5208, SD = 1.42) compared to other income categories. This finding suggests a noteworthy association between income and the extent of daily food waste. A t-test indicated that there was a difference between participants who work and those who do not work with attitudes toward food waste sorting from general households ($t = -3.16$, $p = 0.002$) with higher mean for participants who are working (M = 2.64, SD = 0.83), attitudes toward reducing food waste ($t = -2.04$, $p = 0.042$) with higher mean for participants who are working (M = 3.63, SD = 0.77), and the amount of food wasted per day

TABLE 2 Effect of the COVID-19 pandemic on participants dietary habits.

Variable	N	Min	Max	Mean	SD
1. The pandemic has affected my dietary habits.	257	1.00	5.00	2.87	1.42
2. During the pandemic, I consumed more home-cooked food than before because it is safer	257	1.00	5.00	3.85	1.40
3. During the pandemic, I consumed more delivered food than before because the lockdown made home cooking harder	257	1.00	5.00	2.05	1.26

TABLE 3 The amount of food wasted per day.

Variable	N	Min	Max	Mean	SD
1. Cooking waste	257	1.00	6.00	1.98	1.24
2. Leftovers of plates from cooked/delivered dishes	257	1.00	6.00	1.81	1.12
3. Untouched cooked food	257	1.00	6.00	1.85	1.21

TABLE 4 Separation of kitchen food waste.

Variable	N	%
1. Dispose of kitchen food waste without separation.	84	39.1
2. I separate kitchen food waste and then dispose of it.	80	37.2
3. I separate kitchen food waste and then reuse or recycle it.	51	23.7

($t = -2.95$., $p = 0.010$) with higher mean for participants who are working (M = 2.11, SD = 1.23). Moreover, ANOVA indicated that a Doctorate level of education or equivalent has a significant difference from other levels of education regarding attitudes toward food waste sorting from general households ($F = 3.84$, $p = 0.002$). Participants with a Doctorate level of education exhibited a higher mean (M = 2.90, SD = 0.72) compared to other education levels. The ANOVA results reveal noteworthy distinctions in attitudes toward food waste sorting from general households based on the field of study ($F = 3.14$, $p = 0.009$). Participants with a background in commerce exhibited higher mean scores (M = 2.81, SD = 0.84). Additionally, the amount of food wasted per day showed a significant difference among participants with different fields of study ($F = 2.39$, $p = 0.038$). Specifically, those in the field of education reported a higher mean in daily food waste (M = 2.17, SD = 1.39).

4 Discussion

Food waste is a global concern that needs special attention and urgent actions to reduce the amount of wasted food to achieve the United Nations Sustainable Development Goals by 2030. This study aimed to investigate the antecedent factors, trends, and characteristics of food waste in Al Ahsa as well as to explore the potential impact of COVID-19 exposure on dietary habits and food waste.

4.1 Trends and causes of food waste

The results showed that the majority of participants were from Saudi nationality (82.9%), females (83.3%), most of them were young with an age mean of 30 years, and the family size mean was around 6.

The majority of study participants were not employed (62.3%). The employed ones belong mainly to the healthcare field (56.4%). Additionally, notable occupational categories include teachers (13.2%), a noteworthy percentage earning 10,000 SAR or more (35.8%). On the other hand, the study has shown that the participants tended to throw away food at home 2–3 times per week, indicating moderate variability in participants' disposal frequency and providing insights into their food waste habits. The causes of food waste in households were mainly related to expiry date, since 61.1% of the study participant declared that they throw away food when it is close to or has already passed the expiration date label or if the food item is spoiled (41.2%), few of them thrown away food if it is not tasty (5.4%).When it comes to food waste generated when eating out or ordering online, it was found that the participants rarely throw food, and in case of wasting food the most common causes were related to participants' preference for trying a variety of dishes (40.1% of cases) or difficulty of estimating the appropriate food quantity (32.9%). In the present study it was found that, nowadays, the participants' dietary habit was not significantly affected by COVID-19 pandemic which coincide with other studies showing that, after the normalization of COVID-19, the food waste generated by dining out is likely to increase significantly (21–16). However, during the pandemic the participants agreed that they were more adherent to home-cooked food for safety reasons and not consuming delivered food (mean 3.85, SD 1.40), these findings were in accordance with Parker and his colleagues who showed that eating food from restaurants declined and, for some, home-based cooking increased [United Nations (UN), 2021]. Moreover, it has shown that the COVID-19 pandemic mildly decreased food waste generated at the household level since with the implementation of stay-at-home orders and lockdown measures, many people have had to change their dietary and lifestyle habits which made food more valuable (Shimpo et al., 2021). The quantity of food wasted per day is a good measurement of food waste trends. Therefore, it was shown that the study participants generated around 250-500 g/day of food waste from cooking waste, leftover dishes, and untouched food, respectively. When study participants were asked about their adherence to separating food waste from general household garbage, it was found that only one-quarter of them reported separating food items and then reusing or recycling them. However, 39.1 and 37.2% reported that they disposed of kitchen food waste without separation or separate kitchen food waste before disposal, respectively. The participants' attitude

TABLE 5 Participants' attitudes toward food waste sorting from general household garbage.

Variable	N	Min	Max	Mean	SD
Attitudes Toward Food Waste Sorting from General Household Garbage Total	257	1.00	5.00	2.42	0.88
1. I sort food waste because I feel embarrassed if I am seen wasting food.	257	1	5	2.09	1.38
2. I sort food waste due to religious and cultural beliefs.	257	1	5	3.36	1.60
3. I do not sort food waste because I think this is the role of local authorities.	257	1	5	1.95	1.24
4. I do not sort food waste because I have no idea what to do after sorting.	257	1	5	2.58	1.53
5. I will only sort food waste if local authorities apply a penalty for not doing that.	257	1	5	2.30	1.46
6. I have no idea how to sort food waste.	257	1	5	2.46	1.47
7. I do not sort food waste because it is time consuming	257	1	5	2.26	1.37

TABLE 6 Participants' attitude toward reducing food waste.

Variable	N	Min	Max	Mean	SD
Attitude Toward Reducing Food Waste Total	257	1.00	5.00	3.21	0.89
1. Offers on food items generate food waste since I buy more than I need.	257	1.00	5.00	2.77	1.49
2. The availability of food items in different sizes can reduce food waste.	257	1.00	5.00	3.68	1.44
3. Sharing food with neighbors and others can reduce food waste.	257	1.00	5.00	3.96	1.32
4. A vegetarian diet may result in more food waste than other diet types.	257	1.00	5.00	2.79	1.21
5. COVID-19 has made food more valuable and decreased food waste.	257	1.00	5.00	3.26	1.26
6. Cooking at home generates more food waste than eating out.	257	1.00	5.00	2.77	1.35
7. Ordering food when feeling extremely hungry can increase food waste	257	1.00	5.00	3.28	1.37

toward food waste sorting from general household garbage was studied, and it was shown that the majority of study participants do not throw food due to religious and cultural beliefs (Mean = 3.36, SD = 1.60), a moderate agreement that they have no idea about what to do after sorting (Mean = 2.58, SD = 1.53), and they will adhere to sort food waste if the local authorities apply a penalty (Mean = 2.30, SD = 1.46). On the other, the participants' attitude toward reducing food waste revealed that the majority of them agreed that sharing food with neighbors decreases food waste (Mean = 3.96, SD = 1.32). Moreover, they agreed that the availability of food items in different sizes decreases wasting food (Mean = 3.68, SD = 1.44) and COVID-19 pandemic made food more valuable (Mean = 3.26, SD = 1.26). However, they declared that offers while shopping for food do not affect in increasing food waste (Mean = 2.77, SD = 1.49).

4.2 Association between antecedent factors, COVID-19, and attitude toward reducing food waste

In this study, non-Saudi participants significantly report a lower frequency of wasting food when eating out/ordering online compared to their Saudi counterparts and a higher rate of attitudes toward food waste sorting from general households ($p = 0.01$), these findings where in accordance with other studies showing that Saudi citizens showed the behavior of cooking frequently and profligately which results in increased amount of wasted food (Baig et al., 2022), in addition the non-Saudi nationalities tend more to save food, re-use and recycle it that reflects a holistic way of thinking about the economy as an entire system and strategies that ensure their food security as well as saving money,

since personal saving as a migrant is an important indicator of future prosperity when they retire or return to home country. Moreover, a significant gender difference in the perceived effect of the COVID-19 pandemic on participants' dietary habits ($p = 0.04$), where males reported a slightly higher impact compared to females (Mean = 2.42, SD = 0.88). These findings indicate that gender may play a nuanced role in the context of the pandemic's influence on dietary habits among participants which is in accordance with Ben Hassen et al., 2022 who showed that the COVID-19 pandemic-related measures have resulted in many lifestyle modifications, including changes in diet and food buying patterns among adults (32). Moreover, Parker et al., 2023 declared that in their study males reported more changes in dietary composition. However, no significant gender differences were found in other food waste-related variables, including the frequency of food waste, the amount of food wasted per day, attitudes toward food waste sorting, and attitudes toward reducing food waste. These findings were in accordance with Bretter et al. (2022) and Principato et al. (2015) who found no gender differences in food waste generation. When it comes to age group, this study showed that age was negatively correlated to the effect of the COVID-19 pandemic on participants' dietary habits ($r = -0.129, p < 0.05$), indicating that younger participants think that the COVID-19 pandemic affected their dietary habits, this finding was in correlation with a study conducted by Rodgers et al. (2021) who found that age was one of the demographic characteristics that influence the eating lifestyle during the pandemic. In this study, the family size shows a positive correlation with the participants' attitude toward reducing food waste ($r = 0.130, p > 0.05$) indicating that larger family sizes are associated with a greater attitude toward reducing food waste. This finding was in accordance with previous studies showing that the amount of food waste generated *per capita* decreases with increasing

household sizes (Jrissen et al., 2015; Schanes et al., 2018). Although, the majority of participants in this study preferred not to declare their income, participants earning between 5000 and 6999 SAR demonstrated the highest mean amount of daily food waste (Mean = 2.5208, SD = 1.42). This finding suggests a noteworthy association between income and the extent of daily food waste, which is in coincidence with Tonini et al. (2023) who showed that income was found to be a predicting factor for food waste generation. Moreover, a t-test indicated that there was a difference between participants who work and those who do not work with attitudes toward food waste sorting from general households ($t = -3.16$, $p = 0.002$), attitudes toward reducing food waste ($t = -2.04$, $p = 0.042$), and the amount of food wasted per day ($t = -2.95$., $p = 0.010$) with higher mean for participants who are working (M = 2.64, SD = 0.83), (M = 3.63, SD = 0.77) and (M = 2.11, SD = 1.23), respectively, these findings are in accordance with Parizeau et al. (2015), who proved that the fewer time and/or money, the lower likelihood of food waste generation. However, some studies showed that employed people tend to produce more food waste, since food preparation practices for working people, such as emphasizing daily fresh ingredients versus batch cooking, also impact waste levels (Schanes et al., 2018). When it comes to the level of education, a doctorate level of education or equivalent has a significant difference from other levels of education regarding attitudes toward food waste sorting from general households ($F = 3.84$, $p = 0.002$). This suggests that individuals with advanced educational qualifications may have distinct attitudes toward food waste sorting, emphasizing the potential influence of higher education on perspectives related to household waste management. Accordingly, studies have found that the higher the education level, the less food waste is produced. These findings were in accordance with other studies showing that people with higher education levels have better discernment abilities and are less likely to be influenced by impulse purchases (Liu et al., 2023; Wu et al., 2019). However, these findings were in contradiction with some studies with the opposite view showing a positive correlation between their level of education and the amount of food waste they produce (Schneider, 2008), since they believe that highly educated people have more chance to be persons with full-time employment with less time to/or do not want to plan and use their food stock (Schneider, 2008; Wassermann and Schneider, 2005). Although, occupation or job role showed no significant association with food waste generation in terms of the frequency of food waste, the amount of food wasted per day, attitudes toward food waste sorting, and attitudes toward reducing food waste, the field of education was an important predicting factor of wasting food since participants with a background in commerce exhibited higher mean scores (M = 2.81, SD = 0.84), suggesting a potential correlation between their academic focus and attitudes toward household waste management (Tavill, 2020). Additionally, the amount of food wasted per day showed a significant difference among participants with different fields of study ($F = 2.39$, $p = 0.038$). Specifically, those in the field of education reported a higher mean in daily food waste (M = 2.17, SD = 1.39). This implies that academic disciplines may play a role in shaping individuals' behaviors and attitudes toward food waste, emphasizing the need for targeted interventions and awareness campaigns within specific educational domains. Accordingly, an Australian study proved that of household food waste was significantly affected by leftover reuse skills, dining-out and ordering food online behaviors, methods of food storage and preservation, thus Ananda et al., 2021 emphasis the importance of daily control on household daily food practices to reduce food loss. Most importantly, the contradiction with previous studies if any do not arise from differences in methodology or design of the studies, but it can be attributed to country-specific or cultural factors affecting the attitude toward reducing food waste, since culture influences food waste through dietary habits, food preparation practices, and social norms. Different traditions and food preferences can lead to varying levels of waste, with cultures favoring large feasts or multiple-course meals often generating more waste. Additionally, cultural attitudes toward food, including the value placed on leftovers and the stigma associated with wasting food, shape behaviors around consumption and disposal. These cultural factors collectively determine how much food is wasted in different societies. Accordingly to Obuobi and his colleagues, declared that personal norm influences food waste reduction intention positively (Obuobi et al., 2024).

5 Conclusion

This research study took Al Ahsa governate as a case study to illustrate the current situation and trends of food waste, to compare and analyze different antecedent factors and COVID-19 exposure that affect the generation of food waste and to propose recommendations for preventing and reducing food waste among Al Ahsa community and promoting sustainable development in A Ahsa. This research found that: (1) COVID-19 pandemic had positive impact on the dietary habits of participants in terms of decreasing household food waste; (2) the total amount of food waste in Al Ahsa is high; (3) the amount of wasted food was significantly associated with nationality, where Saudi participants tends more to waste food. Second, with the level of education, where highly educated participants showed attitude toward reducing food waste. Finally, the field of education where certain professional settings might promote better food waste practices due to awareness or institutional policies. For example, those in commerce may have better access to information and practices around food waste management.

6 Limitation

The study's reliance on self-reported data through an online survey may introduces possible biases, such as social desirability and recall bias, which may lead participants to overestimate or underestimate their food waste habits. Additionally, the cross-sectional design captures behaviors and attitudes at a single time, limiting the study's ability to account for changes over time or seasonal variations in food consumption and waste.

7 Future study areas

This research could shed light on various aspects of food waste at the household level and. The future perspective for this study involves multiple dimensions areas in terms of commercial sectors and population cultural behavior in Al Ahsa. Future research could explore how these cultural factors influence food waste behaviors and how they can be shifted through education and awareness campaigns. Studies could develop behavioral interventions that aimed at reducing waste at the consumer level, such as portion control, meal planning, and more conscious consumption. Moreover, artificial intelligence and

innovative technologies that could play a potential role in reducing wasting food, should be emphasized.

8 Recommendations

Based on these results, this research proposes some recommendations:

- Suggest a strong endorsement of the idea that communal sharing can be an effective strategy for waste reduction.
- Create educational campaigns to address those with lower education levels and non-working individuals, while income-based initiatives could focus on participants with incomes between 5000 and 6999 SAR who demonstrated higher daily food waste.
- Implement Gender-specific strategies, considering the impact of the COVID-19 pandemic on dietary habits.
- Enhance food quantity estimation, leveraging cultural and religious values, promoting sustainable waste management, encouraging food sharing, and integrating waste reduction topics into academic curricula.
- Monitor regularly, policy advocacy, collaboration with local authorities, and longitudinal studies are recommended for effective and sustainable outcomes.
- Integrate technology to reduce food waste by creating networks between Al Ahsa community and local authorities.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

No human images or any indefinable character for study Participants. Participants' consent to Participants in this study was implied by their response, since the Participants were informed that "by pressing next, they consent to Participants in this study." Participants' identities are kept confidential and anonymized during analysis to ensure privacy.

Author contributions

AlA: Conceptualization, Investigation, Supervision, Visualization, Writing – original draft, Writing – review & editing. SH: Data curation, Investigation, Methodology, Visualization, Writing – review & editing. AmA: Data curation, Formal analysis, Methodology, Software, Writing – review & editing. MoA: Data curation, Formal analysis, Methodology, Software, Validation, Writing – original draft. SA-T: Data curation, Investigation, Methodology, Writing – original draft. MaA: Resources, Writing – review & editing. AhA: Resources, Visualization, Writing – review & editing.

Funding

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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