frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 15 October 2025
DOI 10.3389/fsufs.2025.1685008

Check for updates

OPEN ACCESS

EDITED BY
Oscar Abel Sánchez-Velázquez,
University of Leeds, United Kingdom

REVIEWED BY
Subhasree Ray,
TVS Motor Company, India
Abusailan Akmad,
Sultan Kudarat State University, Philippines

*CORRESPONDENCE
Ahlam Saleh Alhajri
✉ aalhajri@kfu.edu.sa

RECEIVED 13 August 2025
ACCEPTED 23 September 2025
PUBLISHED 15 October 2025

CITATION
Alhajri AS (2025) Locusts as a sustainable protein source: perceptions and nutritional awareness among Saudi citizens. *Front. Sustain. Food Syst.* 9:1685008. doi: 10.3389/fsufs.2025.1685008

COPYRIGHT
© 2025 Alhajri. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.

Locusts as a sustainable protein source: perceptions and nutritional awareness among Saudi citizens

Ahlam Saleh Alhajri*

Department of Food and Nutrition Sciences, College of Agricultural and Food Sciences, King Faisal University, Al-Ahsa, Saudi Arabia

Background: Locusts are traditionally consumed in Saudi Arabia and recognized globally for their high nutritional value and environmental sustainability. However, their acceptance as a mainstream protein source remains limited due to psychological and cultural barriers.
Aim: This study aimed to assess locust consumption patterns, nutritional awareness, and public acceptance among Saudi citizens, with implications for sustainable nutrition and food security.
Methods: A cross-sectional survey was conducted with 564 participants using a structured questionnaire. Data were analyzed using descriptive statistics, ANOVA, and Pearson correlation.
Results: Only 24.1% had ever consumed locusts. Nutritional awareness was high, with 72.3% identifying locusts as protein rich. Half (50.0%) considered them a sustainable protein alternative. Willingness to try processed locust products was 37.2%. ANOVA revealed no significant demographic differences ($p > 0.05$), and the correlation between sustainability perception and willingness was weak ($r = -0.0246$).
Conclusion: Although awareness is growing, public acceptance remains modest, highlighting the need for education and culturally appropriate interventions to promote edible insect consumption.

KEYWORDS

locust consumption, edible insects, nutritional awareness, sustainable protein, food security

Introduction

Locusts have long been recognized as both a formidable agricultural pest and, in some cultures, a traditional food source (Egonyu et al., 2021; Siddiqui et al., 2023). The FAO landmark report *"Edible Insects: Future Prospects for Food and Feed Security"* (FAO, 2013) underscores that insects can play a major role in addressing protein demand while reducing environmental impacts. This global perspective supports the Saudi case for exploring locusts as a sustainable dietary component. In Saudi Arabia, locusts are not only a recurring environmental challenge but also part of the culinary heritage, consumed in various regions for generations (Hansch, 2021). The dual identity of locusts as both a threat to food security and a potential contributor to sustainable nutrition places them at the center of contemporary debates on alternative protein sources and environmental sustainability.

Desert locust swarms, capable of consuming vast amounts of vegetation and devastating crops, have repeatedly threatened the Arabian Peninsula, including Saudi Arabia (Arshad

et al., 2022; Riaz and Hakeem, 2023). A single swarm can consume as much food in a day as 35,000 people, underscoring the scale of their impact on local agriculture and food systems (Sultana et al., 2021; Babar, 2023). Despite the government's advanced monitoring and control programs, climate change and shifting ecological conditions continue to make locust outbreaks a persistent risk (Peng et al., 2020; Food and Agriculture Organization of the United Nations (FAO), 2024). However, this challenge also presents an opportunity: the abundant locust populations could be harnessed as a sustainable, locally available protein source (Makkar et al., 2022; Akande et al., 2022; Lisboa et al., 2024).

Globally, the search for alternative proteins has intensified in response to concerns about the environmental impact of conventional livestock production, rising food insecurity, and the need for more sustainable diets (Nadathur et al., 2016; Michalk et al., 2018; Gil et al., 2024). Edible insects, including locusts, have gained attention for their high protein content, favourable amino acid profiles, and efficient feed conversion rates (Egonyu et al., 2021). Locusts, in particular, are rich in protein, essential fatty acids, vitamins, and minerals, making them a nutritionally valuable food source (Salama, 2020; Ahmed and İnal, 2024). Their cultivation and harvest have a lower environmental footprint compared to traditional livestock, requiring less land, water, and feed, and producing fewer greenhouse gas emissions (Van Huis and Oonincx, 2017; Jafir et al., 2024).

In Saudi Arabia, locust consumption is rooted in tradition (Hansch, 2021; Moments, 2024), but its prevalence and acceptance in modern society remain unclear. As global trends shift toward sustainable nutrition, understanding local attitudes toward edible insects is critical. Factors such as cultural norms, religious beliefs, psychological perceptions, and nutritional awareness, all play significant roles in shaping food choices. While some may view locusts as a delicacy or a nostalgic food, others may harbour reservations due to changing tastes, urbanization, or concerns about food safety and hygiene.

To better contextualize locust consumption within established behavioral science, this study draws on several theoretical frameworks. Food choice research highlights that dietary decisions are shaped not only by nutritional knowledge but also by cultural identity, sensory expectations, and social norms (Furst et al., 1996; Shepherd, 1999). Psychological resistance can be further explained by the Food Neophobia Scale, which measures reluctance to try novel or unfamiliar foods (Pliner and Hobden, 1992). Moreover, the Theory of Planned Behavior (Ajzen, 1991) provides a valuable lens: attitudes toward insects (e.g., disgust), subjective norms (family, religion, and peer influence), and perceived behavioral control (availability and safety concerns) all interact to determine intention. Finally, sustainability transitions frameworks (Geels, 2002) emphasize that individual adoption of alternative proteins must be viewed within wider systemic shifts in food production and consumption. Positioning the study within these theoretical perspectives enables a more robust interpretation of the cultural and psychological barriers that emerged in the data.

The nutritional potential of locusts is particularly relevant in the context of food security. With the Kingdom's growing population and increasing pressure on natural resources, diversifying protein sources is a strategic priority. Locusts offer a resilient, adaptable, and locally sourced alternative that could help reduce dependence on imported meat and bolster national food security. Yet, public awareness of their nutritional value and willingness to embrace them as a regular dietary component remain underexplored.

Therefore, this study seeks to address these knowledge gaps through a comprehensive survey-based approach. The research aims to:

1. Identify the consumption rate of locusts in Saudi society and the factors influencing consumption patterns.
2. Analyze the level of awareness regarding the nutritional value of locusts as a protein-rich natural food.
3. Examine societal acceptance of locusts as an alternative protein source amid the shift toward sustainable nutrition.
4. Explore the social, cultural, and psychological factors affecting individuals' decisions about locust consumption.
5. Evaluate the role of locusts in food security, particularly their potential to diversify protein sources and reduce reliance on traditional meats.
6. Offer recommendations to raise public awareness and promote edible insects in line with global food security and sustainability trends.

By exploring the above mentioned objectives, the study aims to provide evidence-based insights that can inform policymakers, nutritionists, and food industry stakeholders. Understanding public perceptions and nutritional awareness is essential for designing effective interventions, educational campaigns, and policy frameworks that support sustainable dietary transitions. Moreover, the findings could contribute to broader discussions on food security, environmental stewardship, and the cultural dimensions of dietary innovation in Saudi Arabia and beyond. In summary, as the world seeks sustainable solutions to feed a growing population, locusts present a unique opportunity at the intersection of tradition, nutrition, and environmental resilience. This research will help illuminate the pathways and barriers to integrating locusts into modern Saudi diets, supporting the Kingdom's vision for a more sustainable and food-secure future.

Background

Social, cultural, and psychological factors influencing locust consumption

The consumption of locusts as food is deeply embedded in the traditions of many societies, including those in the Arabian Peninsula and Africa. In Saudi Arabia, locusts have been consumed for generations and are considered a culturally accepted food source, particularly during certain periods such as Ramadan, when their consumption spikes due to beliefs about their health benefits. Locusts are commonly prepared by frying, smoking, or drying, reflecting longstanding culinary practices (Hansch, 2021; Moments, 2024; Kietzka et al., 2021).

Despite this cultural acceptance, several social and psychological factors influence contemporary attitudes toward locust consumption. Urbanization, globalization, and changing dietary preferences have contributed to a gradual decline in traditional insect consumption, especially among younger and urban populations (Batat and Peter, 2020; Russell and Knott, 2021; Khan et al., 2024). Psychological

barriers such as food neophobia (the fear of trying new foods), disgust, and concerns about food safety particularly regarding pesticide residues can deter individuals from consuming locusts, even where cultural precedent exists (Coutinho, 2017; Russell and Knott, 2021; Müller, 2022). Social perceptions also play a significant role; the degree to which edible insects are accepted often depends on social norms, religious beliefs, and the influence of family and community attitudes (Tan and House, 2018; Ochieng O. K. et al., 2023). For example, while locusts are permitted in some cultures, they are forbidden in others, such as in Jewish dietary law (Egonyu et al., 2021).

Awareness and education are critical in shaping psychological acceptance. Studies (Bao and Song, 2022; Florença et al., 2022; Kiumba and Kambale, 2023) indicate that increasing knowledge about the nutritional value and environmental benefits of edible insects can positively influence attitudes and reduce psychological resistance. However, in the Saudi context, there is limited empirical data on current awareness levels and the interplay between tradition, modernity, and psychological acceptance. Understanding these factors is essential for designing effective interventions to promote locusts and other edible insects as sustainable protein sources.

Currently, regulatory frameworks governing locust harvesting, processing, and commercialization in Saudi Arabia remain insufficiently developed (Riaz et al., 2025). This regulatory gap poses challenges for ensuring food safety, particularly regarding pesticide residues resulting from locust control operations. Managing pesticide contamination through stringent monitoring, residue testing, and certification protocols is critical to mitigating safety concerns. Establishing clear standards and regulatory oversight would not only protect consumers but also enhance trust and acceptance of locust-based foods.

Locusts and food security: diversifying protein sources

Locusts are not only a traditional food but also a potential asset in addressing food security challenges. Desert locusts, while infamous for their capacity to devastate crops and threaten food supplies, are also highly nutritious and can be harvested as a protein-rich food source (Riaz and Hakeem, 2023). Locusts are rich in protein, essential amino acids, and micronutrients, making them a valuable addition to diets, especially in regions where protein deficiency is a concern (Salama, 2020; Ahmed and İnal, 2024).

The environmental and economic impact of locust swarms is significant. Locust outbreaks can destroy vast areas of crops and pasture, exacerbating hunger and food insecurity in affected regions (Sultana et al., 2021; Arshad et al., 2022). In Saudi Arabia and neighbouring countries, locust invasions have historically resulted in substantial agricultural losses, driving up food prices and destabilizing rural livelihoods (Khalid, 2020; Riaz and Hakeem, 2023; Sokame et al., 2024). These outbreaks are becoming more frequent and severe due to climate change, which creates favourable breeding conditions and increases the risk of future infestations (The World Bank, n.d.).

From a food security perspective, utilizing locusts as an alternative protein source offers several advantages. Compared to conventional livestock, locusts require less land, water, and feed, and their cultivation produces fewer greenhouse gas emissions (Egonyu et al., 2021). They can be harvested locally during outbreaks, providing an emergency food supply and reducing dependence on imported meat. This diversification of protein sources is particularly relevant for Saudi Arabia, where food security is a strategic priority due to limited agricultural land and water resources. However, realizing the potential of locusts for food security requires addressing both practical and perceptual challenges. Ensuring the safety of harvested locusts by avoiding pesticide contamination and developing supply chains for processing and distribution are critical steps. Equally important is raising public awareness about the nutritional and environmental benefits of locust consumption, which can help shift social norms and increase acceptance (Kietzka et al., 2021).

Given the increasing global emphasis on sustainable diets and food security, there is a pressing need to explore how Saudi citizens perceive locusts as a protein source, what factors shape their willingness to consume them, and how locusts might contribute to national food security strategies. Addressing these gaps will provide valuable insights for policymakers, nutritionists, and food industry stakeholders aiming to promote sustainable protein alternatives and enhance food security in Saudi Arabia.

Methods

Study design and participants

This study employed a cross-sectional survey design to assess public perceptions, nutritional awareness, and acceptance of locusts as an alternative protein source among individuals in Saudi Arabia. Participants within each stratum were randomly selected to maintain diversity and fairness in representation. The sample size was calculated using Cochran's formula (Ahmad and Halim, 2017), based on a 95% confidence level, a 5% margin of error, and a maximum variability assumption (50% proportion), resulting in a minimum required sample of 383 respondents. A total of 564 participants were recruited using a combination of purposive and snowball sampling techniques (Egondi et al., 2013). Inclusion criteria required participants to be Saudi residents aged 18 years and above, able to read and respond to a structured questionnaire in Arabic. Participation was voluntary, and informed consent was obtained from all respondents before data collection.

Survey instrument

The research instrument was a structured questionnaire specifically developed for this study. It was divided into five key sections:

1. General Information: Included demographic and anthropometric data such as gender, age, educational level, marital status, employment status, household income, region of residence, weight, height, and Body Mass Index (BMI).
2. Locust Consumption: Assessed participants' experience with and frequency of locust consumption, preferred preparation methods, reasons for consumption, sources of locusts, and comparative taste perceptions.
3. Nutritional Awareness: Evaluated beliefs about the nutritional value of locusts, including perceived protein richness, specific nutrients, and views on sustainability as a protein alternative.

4. Community Acceptance: Measured psychological and cultural barriers to locust consumption and willingness to try processed locust-based products if certified safe by authorities.
5. Perception Measures: Utilized a Likert-type scale (1 = No, 3 = Not Sure, 5 = Yes) to capture the intensity of agreement regarding locusts as a sustainable protein source and willingness to consume processed locust-based foods.

The questionnaire was pilot tested on a small sample ($n = 25$) to ensure clarity, internal consistency, and cultural appropriateness, and assessed the questionnaire's reliability, with Cronbach's alpha exceeding 0.7, confirming its suitability for broader distribution (Taber, 2018). Minor modifications were made based on feedback.

Data collection procedure

The survey was distributed online using Google Forms and shared through social media platforms such as WhatsApp and Twitter. Data were collected over a four-week period. Anonymity and confidentiality of participants were strictly maintained throughout the research process. By the close of the data collection phase, a total of 662 responses were received. After careful screening for completeness and consistency, 98 incomplete or invalid responses were excluded. The final dataset consisted of 564 fully completed surveys, which formed the basis for the subsequent data analysis.

Ethical considerations

Ethical approval was obtained from Institutional Review Board, King Faisal University (KFU-REC-2025-MAY-ETHICS3450) and all participants provided informed consent. The study adhered to the ethical standards of the Helsinki Declaration.

Data analysis

Data were analyzed using IBM SPSS Statistics (Version 28). Descriptive statistics were used to summarize demographic variables and response distributions, including frequencies, percentages, means, and standard deviations. For inferential statistics: ANOVA (Analysis of Variance) was conducted to examine differences in participants' nutritional awareness and willingness to consume processed locust-based products across demographic groups such as gender, age, education, and income; and Pearson correlation analysis was performed to explore the relationship between participants' perception of locusts as a sustainable protein source and their willingness to consume processed locust products. A p-value of < 0.05 was considered statistically significant. In addition to ANOVA and correlation, binary logistic regression was employed to predict willingness to try processed locust-based products (Yes vs. No) using predictors such as nutritional awareness, demographic characteristics, and psychological barriers. This allowed for identification of key factors influencing acceptance beyond bivariate associations.

Parametric analyses including ANOVA were conducted under standard assumptions of normality, homogeneity of variance, and interval-level measurement of data. Normality was assessed via Shapiro–Wilk tests, and homogeneity of variances verified using Levene's test, with no substantial violations detected. Likert scale responses, although ordinal by nature, were treated as interval-level data to calculate means and standard deviations and perform parametric tests, consistent with common practice supported by Norman (2010), who demonstrated the robustness of this approach with sufficiently large samples. Nonetheless, we acknowledge this assumption may oversimplify the ordinal response structure; therefore, descriptive statistics including medians and confidence intervals were also examined to more fully characterize response variability.

This approach of treating Likert scales as interval data is well-supported in quantitative social science research (Norman, 2010), particularly with large sample sizes which tend to mitigate bias from equidistance assumptions. Despite this, we acknowledge the ordinal nature of Likert scales means some subtleties may be lost. Hence, complementary examination through non-parametric statistics and visualization of median responses were used to validate parametric results and better represent data distribution.

Results

Table 1 presents the demographic characteristics of the 564 participants surveyed. The gender distribution was relatively balanced, with 48.6% male and 51.4% female respondents. The age group of 25–39 years constituted the largest portion of the sample at 40.8%, followed by the 18–24 age group at 30.3%, indicating a predominantly young to early middle-aged population. In terms of education, 41.7% of participants held a university degree, while 25.5% had completed postgraduate studies, reflecting a relatively well-educated sample. Marital status data showed that more than half (51.8%) were married, with singles comprising 39.0% of the sample.

Employment status revealed that 45.0% were employed in the government or private sector, while 29.6% were students. Self-employed individuals and the unemployed made up 15.8 and 9.6% of the respondents, respectively. Monthly household income varied, with 36.0% earning between 5,000 and 10,000 SAR and 30.3% earning between 10,000 and 15,000 SAR, suggesting that most participants were from low to middle-income households. Regionally, the sample was well-distributed, with the Western and Southern regions each accounting for 21.5% of participants, followed closely by the Eastern (20.0%), Central (18.8%), and Northern (18.3%) regions.

In terms of physical attributes, the average weight of participants was 74.61 kg, average height was 164.77 cm, and the average Body Mass Index (BMI) was 27.84, which falls in the overweight category, indicating potential public health relevance for nutrition-related inquiries.

Table 2 illustrates participants' experiences and perceptions related to locust consumption. A substantial majority (75.9%) reported never having eaten locusts, while only 24.1% indicated prior consumption, highlighting the low prevalence of locust consumption within the sample. Among those who had eaten locusts, most did so infrequently: 8.3% consumed them rarely, 8.7% occasionally, and only 7.1% regularly (more than six times per year), suggesting that even among consumers, locusts are not a common dietary item.

When asked about preferred preparation methods, responses were fairly evenly distributed among fried (6.2%), boiled (6.2%), and grilled (5.3%) forms, with 6.4% expressing no preference for consuming locusts in any form. The primary reason for consumption was

TABLE 1 Participants demographics.

Variables		N	Relative frequency
Gender	Male	274	48.6%
	Female	290	51.4%
Age (in years)	18–24	171	30.3%
	25–39	230	40.8%
	40–49	102	18.1%
	50 and above	61	10.8%
Education level	Less than secondary school	63	11.2%
	Secondary school	122	21.6%
	University degree	235	41.7%
	Postgraduate studies (master's or PhD)	144	25.5%
Marital status	Single	220	39.0%
	Married	292	51.8%
	Divorced	34	6.0%
	Widowed	18	3.2%
Employment	Student	167	29.6%
	Employee (Government or Private Sector)	254	45.0%
	Self-employed	89	15.8%
	Unemployed	54	9.6%
Household income	Less than 5,000 SAR	110	19.5%
	5,000–10,000 SAR	203	36.0%
	10,000–15,000 SAR	171	30.3%
	More than 15,000 SAR	80	14.2%
Region of residence	Central Region	106	18.8%
	Eastern Region	113	20.0%
	Western Region	121	21.5%
	Northern Region	103	18.3%
	Southern Region	121	21.5%

TABLE 2 Locust consumption.

Items		N	Relative frequency
Have you ever eaten locusts?	Yes	136	24.1%
	No	428	75.9%
If yes, how often do you consume locusts per year?	Rarely (once a year or less)	47	8.3%
	Occasionally (2–5 times per year)	49	8.7%
	Regularly (more than 6 times per year)	40	7.1%
In what form do you prefer consuming locusts?	Fried	35	6.2%
	Grilled	30	5.3%
	Boiled	35	6.2%
	I do not prefer consuming them in any form	36	6.4%
What is your reason for consuming locusts?	Taste	27	4.8%
	Nutritional value	63	11.2%
	Medicinal use	18	3.2%
	Curiosity/Experimentation	28	5.0%
	I do not consume them	428	75.9%
Where do you usually obtain locusts?	Local markets	62	11.0%
	Caught by family members	41	7.3%
	Online / electronic order	33	5.9%
	I do not consume them	428	75.9%
How would you describe the taste of locusts compared to poultry or red meat?	Better than poultry and red meat	59	10.5%
	Similar to poultry and red meat	40	7.1%
	Inferior to poultry and red meat	37	6.6%
	I do not know/Never tried	428	75.9%

nutritional value (11.2%), followed by curiosity or experimentation (5.0%), taste (4.8%), and medicinal use (3.2%), while a dominant 75.9% reaffirmed that they do not consume locusts at all.

In terms of sourcing, 11.0% obtained locusts from local markets, 7.3% from family members, and 5.9% through online or electronic orders, with the rest (75.9%) again indicating non-consumption. Regarding taste perception, 10.5% rated locusts as better than poultry or red meat, 7.1% found them similar, and 6.6% considered them inferior, while 75.9% either had no experience or chose not to compare. Overall, these findings reflect cultural and psychological barriers to locust consumption, despite a small segment recognizing nutritional and experiential value.

Table 3 presents participants' nutritional awareness regarding locusts as a food source. When asked which food they believed to be richest in protein, 36.5% of respondents selected locusts—surpassing traditional options like chicken (30.7%), fish (17.7%), and red meat (15.1%). This indicates a notable level of awareness about the high protein content of locusts among the surveyed population.

Regarding the specific nutrients believed to be present in locusts, the majority recognized locusts as rich in protein (72.3%), fibre (68.6%), and vitamins and minerals (64.2%). Over half (54.8%) also identified healthy fats as a component, while only 13.1% admitted they did not know about the nutritional content of locusts. These findings reflect a relatively high degree of nutritional awareness, particularly in comparison to the traditionally low public knowledge around insect-based foods.

When asked whether locusts could serve as a sustainable alternative to conventional animal protein, half of the participants (50.0%) responded affirmatively, 28.9% were unsure, and 21.1% disagreed. This distribution suggests a growing openness to sustainable protein alternatives, tempered by a degree of uncertainty, likely tied to cultural unfamiliarity or limited exposure to factual information. Overall, the responses point to a promising foundation for public education campaigns focused on the environmental and nutritional benefits of entomophagy.

Table 4 explores community acceptance of locust-based foods and the psychological and social barriers associated with their consumption. Among participants who do not consume locusts, the most frequently cited deterrents were disgust or psychological aversion (64.2%) and the appearance of the insects (54.6%), followed

TABLE 3 Nutritional awareness.

Items		N	Relative frequency
In your opinion, which food is richest in protein?	Chicken	173	30.7%
	Fish	100	17.7%
	Locusts	206	36.5%
	Red meat	85	15.1%
Which of the following nutrients do you believe locusts are rich in? (You may select more than one)	Protein	408	72.3%
	Vitamins and minerals	362	64.2%
	Fiber	387	68.6%
	Healthy fats	309	54.8%
	I do not know	74	13.1%
Do you think locusts can be a sustainable alternative to conventional animal protein?	Yes	282	50.0%
	No	119	21.1%
	Not sure	163	28.9%

TABLE 4 Community acceptance.

Items		N	Relative frequency
If you do not consume locusts, what are your reasons for not accepting them? (You may select more than one)	Taste	85	15.1%
	Appearance	308	54.6%
	Hygiene/Food safety	155	27.5%
	Disgust/Psychological aversion	362	64.2%
Are you willing to try processed food products made from locusts if they are proven safe and approved by relevant authorities?	Yes, I am willing	210	37.2%
	Not sure	192	34.0%
	No, I am not willing	162	28.7%
In your opinion, which types of locust-based food products would be more acceptable in society? (You may select more than one)	Protein powder (to be added to foods)	188	33.3%
	Snacks (chips, cornflakes, biscuits, protein bars)	263	46.6%
	Burgers or meatballs (kofta)	179	31.7%
	Baked goods (bread, pizza)	431	76.4%
	Cereal products (pasta, granola)	219	38.8%
	Desserts (cake, cookies)	368	65.2%

by concerns about hygiene and food safety (27.5%) and taste (15.1%). These findings underscore the strong cultural and emotional resistance to eating whole insects, which may impede broader acceptance.

Despite these reservations, attitudes toward processed locust-based foods appear more open. When asked if they would be willing to try such products if proven safe and officially approved, 37.2% of respondents expressed willingness, while 34.0% were uncertain, and 28.7% were unwilling. This cautious optimism suggests that scientific validation and regulatory approval can play a significant role in increasing acceptance.

In terms of product types perceived as socially acceptable, baked goods such as bread and pizza received the highest support (76.4%), followed by desserts (65.2%) and snacks (46.6%). Cereal products like pasta and granola (38.8%), protein powders (33.3%), and burgers or meatballs (31.7%) were also seen as moderately acceptable. These preferences indicate that consumers are more receptive to locusts when incorporated into familiar, processed formats that obscure their original appearance—further supporting the importance of product form in overcoming food neophobia and cultural aversion.

Table 5 presents the results of ANOVA tests examining differences in participants' perceptions of locusts as a sustainable alternative protein source and their willingness to try processed locust-based foods, based on demographic variables. The perceptions were measured using a Likert-type scale ranging from 1 (No) to 5 (Yes), with higher scores indicating greater agreement or willingness.

Across all demographic groups gender, age, education level, and household income—no statistically significant differences were observed ($p > 0.05$), suggesting that perceptions were relatively consistent among participants. For gender, females scored slightly higher than males in viewing locusts as a sustainable alternative (mean = 3.65 vs. 3.50) but were slightly less willing to try processed locust products (mean = 3.10 vs. 3.25). However, these differences were not statistically significant ($p = 0.2793$ and $p = 0.2661$, respectively).

When comparing age groups, the 18–24 and 25–39 age brackets reported the highest belief in locusts as a sustainable option (means = 3.63 and 3.62, respectively), while the 40–49 group scored the lowest (mean = 3.43). Willingness to try processed locust products showed minor fluctuations across age, with the youngest group again showing slightly more openness (mean = 3.25), although differences were not significant ($p = 0.8362$).

Educational level showed marginal variation, with postgraduate participants and those with secondary education rating locusts as more sustainable (mean = 3.67 each). Willingness to try processed products was lowest among those with less than secondary education (mean = 2.90) and highest among those with postgraduate degrees (mean = 3.25). These patterns suggest a possible association between higher education and acceptance, although not statistically significant ($p = 0.5571$).

Regarding income, those in the 10,000–15,000 SAR bracket showed the highest belief in locusts' sustainability (mean = 3.71), while the highest income group (>15,000 SAR) had the lowest (mean = 3.40). Interestingly, willingness to try processed products was highest among the highest income group (mean = 3.30), though again, the differences did not reach statistical significance ($p = 0.6842$).

Overall, while descriptive trends hint at slightly more positive perceptions among younger, moderately educated, and middle-income participants, the ANOVA results suggest that these differences are not statistically meaningful, indicating a broad baseline of perception across Saudi society.

Correlation between participants' opinions on locusts as a sustainable protein source and their willingness to try processed locust-based product is −0.0246, which is very close to zero and negative. This

TABLE 5 Differences across the participants perceptions on nutritional awareness and willingness using ANOVA.

Variables		Locusts as a sustainable alternative to conventional animal protein (1: No; Not sure: 3; Yes: 5)		*p*-value	Willingness to try processed food products made from locusts if they are proven safe and approved by relevant authorities (1: No; Not sure: 3; Yes: 5)		*p*-value
		Mean	SD		Mean	SD	
Gender	Male	3.50	1.60	0.2793	3.25	1.61	0.2661
	Female	3.65	1.57		3.10	1.62	
Age (in years)	18–24	3.63	1.56	0.7352	3.25	1.54	0.8362
	25–39	3.62	1.56		3.15	1.67	
	40–49	3.43	1.68		3.18	1.62	
	50 and above	3.52	1.63		3.03	1.65	
Education	Less than secondary school	3.60	1.63	0.5682	2.90	1.62	0.5571
	Secondary school	3.67	1.62		3.18	1.65	
	University degree	3.47	1.58		3.19	1.60	
	Postgraduate studies	3.67	1.55		3.25	1.62	
Household Income	Less than 5,000 SAR	3.60	1.57	0.4711	3.04	1.48	0.6842
	5,000–10,000 SAR	3.52	1.61		3.22	1.64	
	10,000–15,000 SAR	3.71	1.57		3.14	1.67	
	More than 15,000 SAR	3.40	1.57		3.30	1.63	

indicates a very weak and negligible inverse relationship—essentially suggesting that there is no meaningful linear association between believing in the sustainability of locusts and being willing to try processed locust products. In practical terms, this means that even if individuals perceive locusts as a sustainable alternative, it does not necessarily increase or decrease their willingness to consume locust-based products in processed forms. These findings point to the importance of addressing other factors such as psychological barriers, cultural acceptance, and product presentation rather than assuming that sustainability awareness alone will influence consumer behavior.

Logistic regression analysis (see Table 6) was conducted to examine predictors of willingness to try processed locust-based products. The model included nutritional awareness, sustainability beliefs, gender, age, and education as independent variables. The results showed that neither nutritional awareness nor sustainability beliefs were significant predictors of willingness, indicating that knowledge of protein content or environmental benefits alone did not increase acceptance. Gender and age also did not significantly influence willingness.

However, education emerged as a notable factor: participants with postgraduate qualifications were significantly more likely to express willingness compared to those with lower educational attainment (OR = 1.60, 95% CI = 1.02–2.52, $p < 0.05$). This suggests that higher educational exposure may increase openness toward novel protein alternatives, even in the presence of cultural and psychological barriers.

Discussion

This study provides critical insights into the current patterns of locust consumption, nutritional awareness, and societal acceptance in Saudi Arabia. The findings illuminate complex interactions among cultural traditions, psychological responses, and sustainability perceptions, highlighting both challenges and opportunities in promoting edible insects as viable protein alternatives.

Locust consumption patterns and influencing factors

Only 24.1% of participants reported ever consuming locusts, with regular consumption limited to 7.1%. This corresponds with previous reports that, despite locusts being part of Saudi Arabia's culinary tradition (Hansch, 2021; Moments, 2024), consumption has declined due to urbanization, modernization, and evolving food preferences (Russell and Knott, 2021; Khan et al., 2024). Nutritional value (11.2%) and curiosity (5.0%) were the main motivators for those who consumed locusts, whereas psychological aversion (64.2%) and insect appearance (54.6%) dominated reasons for non-consumption. These barriers are consistent with global evidence highlighting food neophobia, disgust, and hygiene concerns as significant deterrents, even in culturally familiar settings (Coutinho, 2017; Müller, 2022). The frequent sourcing of locusts from local markets (11.0%) or family members (7.3%) reflects informal and limited supply chains, while lack of structured procurement and regulatory oversight likely exacerbates safety concerns, reinforcing consumer reluctance (Kietzka et al., 2021).

Nutritional awareness and perceptions of sustainability

A major objective of this study was to assess public awareness regarding the nutritional value of locusts. Encouragingly, 36.5% of

TABLE 6 Logistic regression predicting willingness to try processed locust products.

Predictor	Odds Ratio (OR)	95% CI (Lower–Upper)	*p*-value
Nutritional awareness (locusts = richest protein)	1.15	0.78–1.70	0.42
Belief locusts are sustainable	1.08	0.75–1.56	0.65
Gender (Male = 1)	1.20	0.85–1.70	0.29
Age 25–39 (ref: 18–24)	1.35	0.92–1.98	0.11
Age 40–49	0.88	0.55–1.40	0.62
Age 50+	0.74	0.42–1.31	0.28
Secondary education	1.10	0.71–1.70	0.64
University degree	1.25	0.80–1.95	0.31
Postgraduate studies	1.60	1.02–2.52	**0.04**

Bold values indicate statistically significant results ($p < 0.05$).

respondents identified locusts as the richest source of protein, surpassing conventional options like chicken (30.7%) and red meat (15.1%). Moreover, over 70% of participants recognized protein as a key nutrient in locusts, with strong awareness also shown for fibre (68.6%) and vitamins/minerals (64.2%). These figures align with international evidence supporting the nutritional density of locusts, including high-quality protein and essential micronutrients (Salama, 2020; Ahmed and İnal, 2024).

However, while half the respondents (50%) agreed that locusts could serve as a sustainable protein alternative, nearly 30% remained unsure. This suggests that although awareness of nutritional benefits is relatively high, public understanding of the environmental advantages of insect-based proteins is still developing. Previous research highlights that insects like locusts offer substantial ecological benefits, including minimal land use, low water requirements, and reduced greenhouse gas emissions compared to traditional livestock (Van Huis and Oonincx, 2017; Jafir et al., 2024). Yet, these sustainability aspects may not be fully appreciated by the general public, underlining the need for targeted educational initiatives.

Community acceptance and processed product potential

Community acceptance remains a central barrier to mainstreaming locust consumption. While psychological aversion was the most reported deterrent, the study found greater receptivity to processed locust-based products. About 37.2% of participants expressed willingness to try such products if proven safe and approved by authorities, indicating that food form and safety certification are pivotal to overcoming cultural resistance. These findings echo previous observations that integrating insects into familiar food matrices (e.g., baked goods, protein bars) enhances acceptability (Florença et al., 2022; Kiumba and Kambale, 2023). Comparative evidence from neighboring and regional contexts strengthens these observations. In Pakistan, Khan et al. (2024) found that while nutritional awareness of locusts among university students was high, willingness was low due to disgust and modern dietary preferences—mirroring the Saudi case. In Kenya and Uganda, Ochieng B. O. et al. (2023) reported that urban populations showed declining insect consumption compared to rural households, despite food insecurity pressures. Likewise, Müller (2019) observed in Southeast Asia that modernization and urbanization reduce entomophagy practices even where cultural familiarity exists. Collectively, these studies suggest that psychological and cultural barriers are not unique to Saudi Arabia but part of a broader regional challenge in normalizing insect-based diets.

Indeed, when asked about socially acceptable locust-based food types, baked goods (76.4%) and desserts (65.2%) topped the list, followed by snacks and cereal products. This strong preference for processed forms over whole insects supports the strategy of product reformulation to mask the insect's appearance and texture—tactics validated by international entomophagy studies (Russell and Knott, 2021; Bao and Song, 2022). Promoting such formats, especially under trusted regulatory frameworks, may gradually shift consumer attitudes and reduce stigma.

The strong psychological aversion reported by participants aligns closely with constructs in the Theory of Planned Behavior. Specifically, disgust represents a negative attitudinal factor, while the absence of visible social endorsement and weak cultural norms function as barriers at the normative level. Concerns about pesticide residues and hygiene reflect perceived behavioral control challenges. Together, these elements explain why nutritional awareness alone does not readily translate into behavioral intent.

Demographic differences and psychological considerations

Although descriptive trends suggested higher sustainability and willingness scores among females, younger adults, and more educated participants, ANOVA tests revealed no statistically significant differences across demographic groups. These results suggest that perceptions toward locust consumption in Saudi Arabia are broadly similar across the population. However, the absence of strong group differences does not imply uniform acceptance but rather reflects a generally cautious societal stance, heavily shaped by non-demographic factors such as food culture, sensory expectations, and risk perceptions.

While household income was analyzed, other socioeconomic factors such as education quality, urban–rural residence, and cultural context likely influence locust consumption patterns. Urbanization and associated shifts in food preference may reduce traditional insect consumption, particularly among youth in cities. Educational attainment appears to foster greater openness to novel proteins. These factors collectively suggest that scaling sustainable protein alternatives like locusts requires tailored strategies that address such socioeconomic diversity, including targeted educational initiatives in both urban and rural areas.

Notably, the Pearson correlation between belief in sustainability and willingness to try processed products was negligible ($r = -0.0246$), suggesting that recognizing locusts as sustainable does not necessarily translate into behavioral intent. This weak link further underscores that awareness alone is insufficient; emotional and cultural drivers must also be addressed. As highlighted by previous authors (Müller, 2022; Ochieng O. K. et al., 2023), interventions aimed at promoting edible insects must combine factual information with sensory education and positive social cues to foster deeper engagement.

The negligible negative correlation between sustainability awareness and willingness highlights an important "attitude–behavior gap" widely observed in sustainable consumption research. Consumers

may intellectually acknowledge the environmental benefits of insect proteins but remain emotionally constrained by disgust, cultural stigma, or lack of familiarity. Similar findings have been reported in studies of plant-based meat and organic food, where awareness does not always predict purchasing behavior (Batat and Peter, 2020). In the Saudi context, sustainability may be viewed as an abstract societal good rather than a personal motivator, reducing its direct influence on willingness. This underscores the importance of targeting emotional and social drivers alongside rational awareness. However, intellectual recognition of environmental benefits alone does not translate into behavioral intent, likely due to persistent psychological, cultural, and sensory barriers. To better understand these complex factors, future research employing qualitative or mixed-methods approaches is recommended. Such studies can explore the nuanced emotional and cultural dimensions underpinning consumer reluctance and inform more effective intervention strategies.

These findings highlight that awareness of nutritional and sustainability benefits does not directly translate into behavioral willingness, reinforcing the attitude–behavior gap noted in sustainable food consumption literature. Instead, higher education appears to play a more consistent role in shaping openness toward edible insects, possibly due to greater exposure to global dietary trends and scientific discourse. This aligns with international studies showing that education level is positively associated with acceptance of entomophagy (Florença et al., 2022). Therefore, interventions may need to target not only awareness campaigns but also tailored educational strategies that address psychological aversion and cultural norms across different population segments.

Food security and strategic potential

Locusts represent a unique food security opportunity for Saudi Arabia. As desert insects endemic to the region, they can be harvested locally during swarming events, reducing reliance on imported meats and alleviating pressure on scarce water and agricultural resources. Their resilience and adaptability also make them well-suited to climate-stressed environments (Akande et al., 2022; Makkar et al., 2022; Riaz and Hakeem, 2023). However, to unlock this potential, coordinated strategies must be developed to ensure safety in harvesting (i.e., avoiding pesticide-contaminated swarms), and to build infrastructure for farming, processing, and distribution. Public education campaigns, grounded in scientific evidence and cultural sensitivity, will be essential to overcome psychological barriers and reposition locusts as a viable future food.

However, one of the most pressing challenges is food safety, particularly pesticide contamination during locust swarm control operations. Public trust could be seriously undermined if locust-based foods were perceived as unsafe. Establishing clear regulatory frameworks for harvesting, residue testing, and certification of pesticide-free locusts is therefore essential. Without such assurances, the promotion of locusts as a sustainable protein source risks backfiring, eroding consumer confidence and reinforcing psychological aversion.

One of the most pressing barriers to scaling locust-based foods is ensuring safety from pesticide contamination, especially during locust swarm control activities. Public trust in locust products hinges on transparent and enforced regulatory frameworks that include residue analysis and guarantees of pesticide-free produce. Without such safeguards, efforts to promote locusts as sustainable protein risk undermining consumer confidence and reinforcing psychological aversion.

Recommendations

Overcoming disgust requires a combination of psychological and structural strategies. Product innovation is critical—incorporating locust protein into familiar processed foods such as bread, cookies, and pasta can reduce visibility and minimize aversion. Social marketing campaigns, led by nutritionists, chefs, and social media influencers, can normalize edible insects by associating them with modern lifestyles and sustainability narratives. Importantly, religious endorsement plays a pivotal role in Saudi Arabia: since locusts are considered halal, engaging religious scholars to reaffirm this status in public campaigns could significantly reduce cultural resistance. Together, these strategies provide a multi-level approach to transforming perceptions. Based on the findings, several recommendations emerge:

1. **Public awareness campaigns** should highlight both the nutritional and environmental benefits of locusts, leveraging multimedia tools and educational institutions.
2. **Policy support** is needed to develop locust farming and processing standards, ensuring product safety and fostering market trust.
3. **Food industry innovation** should focus on incorporating locust proteins into familiar, culturally acceptable products like baked goods, pasta, and desserts.
4. **Community-based engagement** programs can normalize edible insects through tastings, cooking demonstrations, and endorsement by respected figures (e.g., chefs, health professionals).
5. **Interdisciplinary collaboration** among nutritionists, policymakers, marketers, and behavioral scientists is critical to designing effective strategies for sustainable dietary transitions.

Implications

Theoretically, this study advances the understanding of entomophagy within the Saudi context by integrating cultural, psychological, and nutritional perspectives, thereby enriching the literature on food choice determinants in rapidly modernizing societies. It highlights the dynamic interplay between tradition and modernity, demonstrating how social norms, food neophobia, and nutritional awareness collectively shape attitudes toward edible insects. By empirically identifying the factors that influence locust consumption, the research extends existing models of food acceptance and provides a framework for future studies on alternative proteins in culturally complex settings. Practically, the findings offer actionable insights for policymakers, nutritionists, and food industry stakeholders aiming to diversify protein sources and promote sustainable nutrition. The study underscores the need for targeted educational campaigns to raise awareness about the nutritional and environmental benefits of locusts, the development of regulatory standards to ensure food safety, and the creation of culturally appropriate locust-based products to increase acceptance. These steps are crucial for integrating locusts into the national food security strategy, reducing reliance on imported

meats, and aligning with global trends toward environmental sustainability and resilient food systems.

Limitations

This study has several limitations that should be acknowledged. The reliance on self-reported survey data may introduce response bias, as participants could underreport or overreport their attitudes and behaviors regarding locust consumption due to social desirability or recall inaccuracies. The sample, while diverse, may not fully represent all demographic groups within Saudi society, particularly marginalized or rural populations with distinct dietary practices.

While the sample included participants from all five regions of Saudi Arabia, rural and marginalized groups may be underrepresented due to reliance on online distribution methods. The use of purposive and snowball sampling likely introduced a bias toward younger, urban, and more educated respondents, limiting generalizability to the broader Saudi population Additionally, the cross-sectional design restricts the ability to infer causality between identified factors and consumption patterns. Future research should employ stratified random sampling to achieve more representative insights.

The cross-sectional survey design captures perceptions and self-reported attitudes at a single point in time, limiting the ability to infer causal relationships between variables. Additionally, actual consumption behaviors and changes over time were not assessed, which restricts understanding of dynamic behavioral patterns. Longitudinal and experimental studies are needed to elucidate causal mechanisms and track behavioral adoption of locust-based foods.

Conclusion

This study provides valuable insights into the current status of locust consumption, nutritional awareness, and societal acceptance among Saudi citizens in the context of shifting toward sustainable nutrition and food security. The findings reveal that while locusts are deeply rooted in Saudi culinary tradition, their actual consumption rate is low, particularly among younger and urban populations. Social, cultural, and psychological factors including food neophobia, concerns about food safety, and the influence of social norms play a significant role in shaping attitudes toward locust consumption. Although awareness of the nutritional value and environmental benefits of locusts is moderate, there is a notable openness to trying processed locust-based products if they are certified safe, indicating potential for increased acceptance with proper education and regulation. From a food security perspective, locusts offer a promising, locally available, and environmentally sustainable alternative to traditional protein sources. However, realizing this potential requires addressing both perceptual and practical barriers through targeted public awareness campaigns, the establishment of robust food safety standards, and the development of culturally appropriate locust-based food products. The study underscores the importance of integrating locusts and other edible insects into national food security strategies, not only to diversify protein sources but also to reduce reliance on imported meats and mitigate environmental pressures.

In summary, locusts represent a unique intersection of tradition, nutrition, and sustainability in Saudi Arabia. By leveraging cultural heritage, enhancing nutritional education, and ensuring food safety, locusts can play a significant role in supporting the Kingdom's vision for a resilient, sustainable, and food-secure future. Continued research and multi-sectoral collaboration will be essential to overcome challenges and fully realize the benefits of edible insects as part of a modern, sustainable diet.

Data availability statement

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics statement

The studies involving humans were approved by Ethical approval was obtained from Institutional Review Board, King Faisal University (KFU-REC-2025-MAY-ETHICS3450) and all participants provided informed consent. The study adhered to the ethical standards of the Helsinki Declaration. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

AA: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. This work was supported by the Deanship of Scientific Research, Vice Presidency for Graduate Studies and Scientific Research, King Faisal University, Saudi Arabia (KFU252317).

Conflict of interest

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

Generative AI statement

The author declares that no Gen AI was used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Ahmad, H., and Halim, H. (2017). Determining sample size for research activities. *Selangor Bus. Rev.* 2, 20–24.

Ahmed, I., and İnal, F. (2024). The nutritional value of grasshoppers and locusts: a review. *Ann. Anim. Sci.* 25, 455–465. doi: 10.2478/aoas-2024-0077

Ajzen, I. (1991). The theory of planned behavior. *Organ. Behav. Hum. Decis. Process.* 50, 179–211. doi: 10.1016/0749-5978(91)90020-T

Akande, O. A., Oluwamukomi, M., Osundahunsi, O. F., Ijarotimi, O. S., and Mukisa, I. M. (2022). Evaluating the potential for utilising migratory locust powder (*Locusta migratoria*) as an alternative protein source in peanut-based ready-to-use therapeutic foods. *Food Sci. Technol. Int.* 29, 204–216. doi: 10.1177/10820132211069773

Arshad, I., Rabbani, M. U., Khan, Z. A., and Ali, W. (2022). Desert locust invasions its aftermath and myth of its existence: a review. *PSM Vet. Res.* 7, 101–109.

Babar, T. K. (2023). "Risks of deserts locust and its mitigation," in *Disaster risk reduction in agriculture* (pp. 361–392). Singapore: Springer Nature Singapore.

Bao, H. X. H., and Song, Y. (2022). Improving food security through entomophagy: can behavioural interventions influence consumer preference for edible insects? *Sustainability* 14:3875. doi: 10.3390/su14073875

Batat, W., and Peter, P. (2020). The healthy and sustainable bugs appetite: factors affecting entomophagy acceptance and adoption in Western food cultures. *J. Consum. Mark.* 37, 291–303. doi: 10.1108/jcm-10-2018-2906

Coutinho, J. M. P. d. C. (2017). Insects as a legitimate food ingredient: barriers & strategies

Egondi, T., Kyobutungi, C., Ng, N., Muindi, K., Oti, S., Vijver, S. V. d., et al. (2013). Community perceptions of air pollution and related health risks in Nairobi slums. *Int. J. Environ. Res. Public Health* 10, 4851–4868. doi: 10.3390/ijerph10104851

Egonyu, J. P., Subramanian, S., Tanga, C. M., Dubois, T., Ekesi, S., and Kelemu, S. (2021). Global overview of locusts as food, feed and other uses. *Glob. Food Secur.* 31:100574. doi: 10.1016/j.gfs.2021.100574

FAO (2013). Edible insects: future prospects for food and feed security. Rome: Food and Agriculture Organization of the United Nations.

Florença, S. G., Guiné, R. P. F., Gonçalves, F. J. A., Barroca, M. J., Ferreira, M., Costa, C. A., et al. (2022). The motivations for consumption of edible insects: a systematic review. *Foods* 11:3643. doi: 10.3390/foods11223643

Food and Agriculture Organization of the United Nations (FAO) (2024). Desert locust bulletin, no. 554. Available online at: https://openknowledge.fao.org/server/api/core/bitstreams/feced01b-9f35-4675-a92f-ce63416826ad/content (Accessed July 27, 2025).

Furst, T., Connors, M., Bisogni, C. A., Sobal, J., and Falk, L. W. (1996). Food choice: a conceptual model of the process. *Appetite* 26, 247–266. doi: 10.1006/appe.1996.0019

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Res. Policy* 31, 1257–1274. doi: 10.1016/s0048-7333(02)00062-8

Gil, M., Rudy, M., Duma-Kocan, P., Stanisławczyk, R., Krajewska, A., Dziki, D., et al. (2024). Sustainability of alternatives to animal protein sources, a comprehensive review. *Sustainability* 16:7701. doi: 10.3390/su16177701

Hansch, S. (2021). Locusts add to world hunger in Africa, the Arabian peninsula and South Asia 2021. World Hunger News. Available online at: https://www.worldhunger.org/locusts-add-to-world-hunger-in-africa-the-arabian-peninsula-and-south-asia-2021/

Jafir, M., Abbas, M., Irfan, M., and Zia-Ur-Rehman, M. (2024). "Greenhouse gases emission from edible insect species" in Advances and technology development in greenhouse gases: emission, capture and conversion (Amsterdam, Netherlands: Elsevier), 205–225.

Khalid, T. (2020). Saudi Arabia says 'invasion' of locusts almost over, threat from neighbors remains. Al Arabiya English. Available online at: https://english.alarabiya.net/News/gulf/2020/05/31/Saudi-Arabia-says-invasion-of-locusts-almost-over-threat-from-neighbors-remains

Khan, A. A., Khan, A. A., and Meraj, M. (2024). Exploring locust consumption acceptance factors among Pakistani university students: insights for sustainable food adoption. *Pak. J. Humanit. Soc. Sci.* 12, 987–1000. doi: 10.52131/pjhss.2024.v12i2.2158

Kietzka, G. J., Lecoq, M., and Samways, M. J. (2021). Ecological and human diet value of locusts in a changing world. *Agronomy* 11:1856. doi: 10.3390/agronomy11091856

Kiumba, N. M., and Kambale, S. (2023). Individual and collective factors influencing consumer acceptance of edible insects in Kinshasa, Democratic Republic of Congo. *Cogent Soc. Sci.* 9, 1–15.

Lisboa, H. M., Nascimento, A., Arruda, A., Sarinho, A., Lima, J., Batista, L., et al. (2024). Unlocking the potential of insect-based proteins: sustainable solutions for global food security and nutrition. *Foods* 13:1846. doi: 10.3390/foods13121846

Makkar, H., Heuzé, V., and Tran, G. (2022). Locusts and grasshoppers: nutritional value, harvesting and rearing for animal feed, and other applications. *CABI Rev.* doi: 10.1079/cabireviews202217038

Michalk, D. L., Kemp, D. R., Badgery, W. B., Wu, J., Zhang, Y., and Thomassin, P. J. (2018). Sustainability and future food security—a global perspective for livestock production. *Land Degrad. Dev.* 30, 561–573. doi: 10.1002/ldr.3217

Moments, S. (2024). Savoring locust delights exploring traditional Saudi culinary treasure. Saudi Moments. Available online at: https://www.saudimoments.com/savoring-locust-delights-exploring-traditional-saudi-culinary-treasure-632623.html

Müller, A. (2019). Insects as food in Laos and Thailand. *Asian J. Soc. Sci.* 47, 204–223. doi: 10.1163/15685314-04702003

Müller, A. (2022). Insects as food for capitalism: the entomophagy frontier in Laos, Thailand and beyond (insights from Southeast Asia 6). Glienicke (Nordbahn), Germany: Galda Verlag.

Nadathur, S. R., Wanasundara, J. P. D., and Scanlin, L. (2016). "Proteins in the diet," in *Sustainable protein sources*. eds. S. R. Nadathur, J. P. D. Wanasundara and L. Scanlin (Cambridge, MA: Academic Press), 1–19.

Norman, G. (2010). Likert scales, levels of measurement and the "laws" of statistics. *Adv. Health Sci. Educ. Theory Pract.* 15, 625–632. doi: 10.1007/s10459-010-9222-y

Ochieng, B. O., Anyango, J. O., Nduko, J. M., Mudalungu, C. M., Cheseto, X., and Tanga, C. M. (2023). Aroma characterization and consumer acceptance of four cookie products enriched with insect (*Ruspolia differens*) meal. *Sci. Rep.* 13:11145 (2023). doi: 10.1038/s41598-023-38166-x

Ochieng, O. K., Mukhebi, A., and Orinda, M. (2023). Effects of social, cultural and economic factors on consumption of edible insects for household food security. *East Afr. J. Arts Soc. Sci.* 6, 39–53. doi: 10.37284/eajass.6.1.1060

Peng, W., Ling, N. M. A., Zhang, D., Zhou, Q., Yue, X., Khoo, S. C., et al. (2020). A review of historical and recent locust outbreaks: links to global warming, food security and mitigation strategies. *Environ. Res.* 191:110046. doi: 10.1016/j.envres.2020.110046

Pliner, P., and Hobden, K. (1992). Development of a scale to measure the trait of food neophobia in humans. *Appetite* 19, 105–120. doi: 10.1016/0195-6663(92)90014-w

Riaz, U., and Hakeem, K. R. (2023). Locust outbreaks: management and the world economy: CRC Press.

Riaz, M. N., Irshad, F., and Sazil, A. Q. (2025). Halal perspectives on grasshoppers (LOCUSts): a path to sustainable and nutritionally acceptable alternative protein source. *Compr. Rev. Food Sci. Food Saf.* Malden, MA: Wiley-Blackwell. 24:e70283. doi: 10.1111/1541-4337.70283

Russell, P. S., and Knott, G. (2021). Encouraging sustainable insect-based diets: the role of disgust, social influence, and moral concern in insect consumption. *Food Qual. Prefer.* 92:104187. doi: 10.1016/j.foodqual.2021.104187

Salama, S. M. (2020). "Nutrient composition and bioactive components of the migratory locust (*Locusta migratoria*)" in African edible insects as alternative source of food, oil, protein and bioactive components (Cham: Springer International Publishing), 231–239.

Shepherd, R. (1999). Social determinants of food choice. *Proc. Nutr. Soc.* 58, 807–812. doi: 10.1017/S0029665199001093

Siddiqui, S. A., Ghisletta, M., Yunusa, B. M., Jiddum, F. A., Saraswati, Y. R., Fernando, I., et al. (2023). Grasshoppers and locusts as human foods – a comprehensive review. *J. Insects Food Feed* 9, 1247–1264. doi: 10.3920/JIFF2023.0010

Sokame, B. M., Agboka, K. M., Kimathi, E., Mudereri, B. T., Abdel-Rahman, E. M., Landmann, T., et al. (2024). An integrated assessment approach for socio-economic implications of the desert locust in eastern Africa. *Earths Future* 12, 1–26. doi: 10.1029/2023ef003841

Sultana, R., Kumar, S., Samejo, A. A., Soomro, S., and Lecoq, M. (2021). The 2019–2020 upsurge of the desert locust and its impact in Pakistan. *J. Orthoptera Res. [Internet]*. 30, 145–54. doi: 10.3897/jor.30.65971

Taber, K. S. (2018). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Res. Sci. Educ.* 48, 1273–1296. doi: 10.1007/s11165-016-9602-2

Tan, H. S. G., and House, J. (2018). "Consumer acceptance of insects as food: integrating psychological and socio-cultural perspectives" in Edible insects in sustainable food systems (Cham: Springer International Publishing), 375–386.

The World Bank (n.d.). The World Bank Group and the desert locust outbreak. Available online at: https://www.worldbank.org/en/topic/the-world-bank-group-and-the-desert-locust-outbreak

Van Huis, A., and Oonincx, D. G. A. B. (2017). The environmental sustainability of insects as food and feed. A review. *Agron. Sustain. Dev.* 37, 1–14. doi: 10.1007/s13593-017-0452-8