

Review

Potential of grasshoppers as a halal alternative protein in Malaysia

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Abstract

As global populations rise and the demand for sustainable protein sources intensifies, entomophagy, the practice of consuming insects, has emerged as a promising alternative. However, in Malaysia, entomophagy remains a niche practice, with grasshopper consumption largely confined to rural and indigenous communities in regions such as Kelantan, Terengganu, and Sabah. This review explores the potential of grasshoppers as a halal alternative protein source in Malaysia by systematically reviewing the literature on their nutritional benefits, compliance with Islamic dietary laws, consumer acceptance, and regulatory challenges. A comprehensive literature search was conducted using Scopus, Emerald Insight, PubMed, and Google Scholar, identifying five relevant studies published between 2019 and 2024, selected based on predefined inclusion and exclusion criteria. These studies were analysed using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology, with key themes synthesised narratively, focusing on nutritional potential, religious concerns, and consumer acceptance of insects. The findings reveal that grasshoppers are considered halal according to *shariah* laws. Grasshoppers are nutritionally rich, containing high-quality protein, essential amino acids, vitamins, and minerals. However, their acceptance among Malaysian is relatively limited due to concerns about their texture, perceived food safety risks, and strong cultural taboos against insect consumption, particularly in urban areas. Additionally, the absence of insect-specific legislation adds to consumer hesitation. This review highlights the limited number of local studies, the early stage of consumer behaviour research, and the critical need for targeted educational initiatives, regulatory reforms, and innovative product development to overcome cultural and sensory barriers. These efforts are essential to realise the potential of grasshoppers as a sustainable and halal protein source in Malaysia.

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Introduction

The global food system faces mounting challenges in meeting the nutritional needs of a rapidly growing population, and specifically in Malaysia, the population is projected to increase by 15% by 2050 (UN, 2019; CEIC Data, 2021). Population surge, rising living standards, and shifting dietary preferences have led to an increasing demand for protein-rich foods. However, traditional protein sources such as livestock farming are becoming less viable due to their significant environmental impact, including high greenhouse gas emissions, excessive

water usage, and vast land requirements (Lin *et al.*, 2023; Siddiqui *et al.*, 2023a; 2024b). These challenges underscore the urgent need for alternative protein sources that can be both sustainable and culturally acceptable (Kim *et al.*, 2019; Patel *et al.*, 2019; Lucas *et al.*, 2020; Matandirotya *et al.*, 2022; Kavle *et al.*, 2022; Lisboa *et al.*, 2024).

Among edible insects, grasshoppers have emerged as a promising solution to the growing demand for protein (Krongdang *et al.*, 2023). They offer an impressive nutritional profile, with protein content ranging from 50 to 70% of their dry weight (Torruco-Uco *et al.*, 2019; Ibarra-Herrera *et al.*,

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2020), surpassing the protein found in most traditional meat sources such as beef and chicken (Rodríguez-Miranda *et al.*, 2019; Anjani *et al.*, 2023). Additionally, grasshoppers are rich in essential amino acids, vitamins, and minerals, making them a nutritionally valuable option for human consumption (Rodríguez-Miranda *et al.*, 2019; Hasnan *et al.*, 2023). While entomophagy is widespread in parts of Africa, Latin America, and Asia (Pali-Scholl *et al.*, 2019; Kohler *et al.*, 2019; Omuse *et al.*, 2024) as insects over there have been staples for centuries, the practice remains niche in Malaysia, despite the country's rich biodiversity and history of insect consumption in certain rural and indigenous communities (Sabri *et al.*, 2023; Hasnan *et al.*, 2023).

The predominantly Muslim population in Malaysia adds a unique dimension to the discussion on alternative proteins. Adherence to the halal principle is a central factor in determining the acceptance of any new food source. Under *shariah* law, grasshoppers are considered halal (Shrivastava *et al.*, 2019; Tajudeen, 2020; Suresh *et al.*, 2023), thus removing one of the key barriers to their consumption from a religious perspective. However, cultural norms, societal taboos, and limited awareness of entomophagy have restricted Malaysia's mainstream adoption of insects as a protein source. Underutilising grasshoppers may lead to missed opportunities to optimise local resources for sustainable protein production.

Numerous studies have explored grasshoppers' nutritional benefits (Torruco-Uco *et al.*, 2019; Ssepuyaya *et al.*, 2019; Paulin and Purwanto, 2020; Ibarra-Herrera *et al.*, 2020; Siddiqui *et al.*, 2023a; Nabikolo *et al.*, 2023; Kababu *et al.*, 2023) and environmental sustainability as a protein source (Wegier *et al.*, 2018; Margaret *et al.*, 2022; Das *et al.*, 2022; Sampaothong *et al.*, 2024). These studies consistently highlight high protein content in grasshoppers, alongside essential amino acids and micronutrient density, positioning them as a strong alternative to conventional meat sources. However, despite the global interest in grasshoppers, few studies have investigated their viability as a halal alternative protein source in the Malaysian context (Sabri *et al.*, 2023).

Grasshoppers align with halal principles under specific conditions as a novel protein source. Thus, as grasshoppers are permissible in Islamic dietary laws, and have the potential to fulfil Malaysia's growing

demand for halal and sustainable protein solutions, the consumption of grasshoppers warrants detailed exploration (Sabri *et al.*, 2023). Considering these challenges, this paper systematically reviews the literature to evaluate the potential of grasshoppers as a halal alternative protein source in Malaysia, focusing on their nutritional benefits, compliance with Islamic dietary laws, consumer acceptance, and regulatory challenges. This review aims to provide insights for policymakers, industry stakeholders, and researchers to facilitate the integration of grasshoppers into Malaysia's halal food ecosystem.

Literature review

Global and cultural context of entomophagy

Entomophagy, the practice of consuming insects, is widely accepted in many parts of the world, particularly in regions such as Asia, Africa, and Latin America, where insects are commonly included in traditional diets (FAO, 2021; Tagawa *et al.*, 2022; Krongdang *et al.*, 2023). In these areas, insects are recognised not only for their cultural significance but also for their nutritional value, as they contain essential nutrients (Van Huis *et al.*, 2021), including high-quality protein, vitamins, fats, and minerals (Hasnan *et al.*, 2023). This cultural acceptance often stems from economic necessity and environmental adaptation, as insects are abundant, affordable, and sustainable compared to other protein sources (Guine *et al.*, 2021; Rovai *et al.*, 2021). In addition to their nutritional benefits, insects are highly sustainable as a protein source, requiring significantly less land, water, and feed compared to conventional livestock, making them particularly valuable in regions with limited resources or where environmental impact is a major concern (Park *et al.*, 2022; Liceaga, 2022).

Historically, entomophagy has deep cultural roots, especially in agrarian societies where insects were readily available as a natural food source. In parts of Africa (Grabowski *et al.*, 2020) and Latin America (Moreno and Reyes-Prado, 2020), insects have been part of traditional culinary practices for centuries, often featured in celebratory dishes or consumed as a source of protein during lean seasons. In many parts of the world, insects also play a role in supporting local economies. For instance, in Thailand (Krongdang *et al.*, 2023; Sampaothong *et al.*, 2024) and Mexico (Moreno and Reyes-Prado, 2020), insect farming and sales have become viable economic activities, providing income for rural communities

and small businesses. This economic benefit adds to their cultural acceptance, as insects contribute not only to diet but also to local livelihoods.

Different types of insects are favoured in various regions. In Thailand, crickets and bamboo worms are commonly eaten, often fried and served as street food (Krongdang *et al.*, 2023). In Southern Africa, mopane worms are a prized source of protein, and even exported (Sabine, 2021; Manditsera *et al.*, 2022; Siddiqui *et al.*, 2024a). In Mexico, grasshoppers are a traditional delicacy, commonly roasted with spices and used in many regional dishes' condiments, snacks, or main gourmet dishes (Ibarra-Herrera *et al.*, 2020; Cruz-López *et al.*, 2022).

In cultures where entomophagy is widespread, social norms play a major role in shaping acceptance. Insect consumption is seen as a normal part of the diet, unlike in many Western countries where psychological factors, such as aversion to eating insects, can be a significant barrier (Batat and Peter, 2020; Ardoin and Prinyawiwatkul, 2021; Kröger *et al.*, 2022). This cultural normalisation influences how new generations perceive insects as food, making entomophagy more widely accepted and practiced. Interestingly, entomophagy has also started gaining attention in Western countries, where environmental and health-conscious consumers are exploring insects as a sustainable protein option (Olivadese and Dindo, 2023). However, unlike in Asia, Africa, and Latin America, where insects are deeply embedded in the traditional diet, Western interest remains exploratory and still confronts significant cultural barriers. This global context highlights the potential for Malaysia to explore edible insects as a sustainable, culturally relevant, and halal-compliant protein source.

Nutritional benefits of grasshoppers

Grasshoppers are recognised as a valuable source of protein, with their protein content varying significantly based on species, habitat, and diet. For instance, *Oxya chinensis*, a species widely found in East and Southeast Asia, contains a protein content of 67.6%, making it one of the most protein-rich grasshopper species (Kim *et al.*, 2017; Siddiqui *et al.*, 2023b). In Indonesia, the teak grasshopper (*Valanga nigricornis*) has a protein content of around 70%, positioning it as a nutritionally superior alternative to conventional protein sources (Kuntadi and Maharani, 2018; Paulin and Purwanto, 2020). Similarly, *Locusta migratoria*, the migratory locust native to East Asia,

has a protein content of approximately 60%. These levels are comparable to or even exceed traditional protein sources such as beef and chicken (Mohamed, 2015; Kleden *et al.*, 2023).

Grasshoppers also provide essential amino acids, including lysine, often deficient in plant-based protein sources, making them a good dietary supplement (Siddiqui *et al.*, 2023a). In addition to their protein content, grasshoppers are rich in key micronutrients such as iron, zinc, phosphorus, and vitamins like B₁₂, enhancing their role as a nutrient-dense food source (Hasnan *et al.*, 2023).

Despite their significant nutritional benefits, grasshoppers are noted for their limited digestibility due to their high chitin content (Anjani *et al.*, 2023). However, traditional preparation methods, such as boiling or frying, can enhance nutrient bioavailability (Ojha *et al.*, 2021; Ochieng *et al.*, 2022; Mohd Zaini *et al.*, 2023). On the sustainability front, grasshoppers, along with other insects, require fewer resources for production compared to conventional livestock. For instance, general insect farming data shows that 1 kg of protein requires only 1.7 kg of feed and 2.8 L of water, whereas beef production demands 6 kg of feed and 43,000 L of water (Van Huis *et al.*, 2013; Pahmeyer *et al.*, 2022). These nutritional values make grasshoppers and similar insects an environmentally sustainable protein source, particularly for regions facing food security and environmental challenges. These qualities position them as a promising alternative to traditional protein sources, paving the way for further exploration of their potential in meeting rising food demands.

Grasshoppers consumption in Malaysia

Grasshoppers have been consumed in Malaysia for generations, particularly in rural communities and agricultural settings. Planters and farmers working in rice fields commonly find various types of grasshoppers (Orthoptera) as a food source. The most widely observed species include pointed-nose, short-horned, leaf-like, and *Valanga* grasshoppers (Hasnan *et al.*, 2023). These grasshoppers are typically collected after the removal of paddy crops, making their harvesting closely tied to agricultural cycles. In East Malaysia, paddy grasshoppers are often prepared by frying with turmeric powder and salt, a simple yet flavourful method highlighting their culinary appeal (Berita Harian, 2021a). Beyond personal consumption, these grasshoppers are sold on a small

scale, with a price reaching MYR70/kg (USD16.74/kg), underscoring their value as a niche food item (Wan Zulkifli, 2019).

In Sabah, grasshoppers are sought after by paddy field workers, and collected either during field slashing or at night when they are drawn to light. After removing their wings and legs, grasshoppers are boiled and simmered until dry, stir-fried, or roasted. These dishes are typically served independently, showcasing their status as a distinct delicacy (Chung *et al.*, 2002). Similarly, in Kelantan, grasshoppers are a traditional delicacy enjoyed as snacks or side dishes. Popular dishes such as *goreng kunyit* (turmeric-fried grasshoppers) and *kerutuk* (spiced stew) reflect their cultural and nostalgic significance in the region (Berita Harian, 2021a; 2021b).

Recently, entrepreneurs have started commercialising grasshopper-based snacks and shipping them nationwide. These products are available in flavours such as turmeric, *kerutuk*, and cheesy grasshoppers, catering to urban consumers and highlighting the evolving role of grasshoppers from a rural delicacy to a novel protein source with potential for both national and international markets (Berita Harian, 2021a; Utusan, 2023).

The Mufti of the Federal Territory's Office has confirmed the permissibility of consuming locusts (MUFTIWP, 2018). Grasshoppers, like locusts, are explicitly halal according to Islamic dietary laws, supported by numerous hadiths. For instance, the Prophet Muhammad (PBUH) stated:

It was narrated that Abu Ya'fur RA said:

"I asked 'Abdullah bin Abu Awfa about killing locusts and he stated: I went on six battles with the Messenger of Allah, and we consumed locusts." Sahih Muslim (1952), Sunan Abi Dawud (4357) and Sunan al - Nasa'ie (4357).

While from Ibn 'Umar RA, the Prophet PBUH said:

"Two kinds of dead meat have been permitted to us: fish and locusts," Sunan Ibn Majah (3218).

These hadiths and others emphasise the permissibility of consuming locusts without slaughter, as slaughtering these creatures is impractical. While grasshoppers are culturally and religiously acceptable, Malaysia lacks structured

regulations specifically governing the eating of insects (Suresh *et al.*, 2023). Existing laws primarily focus on pest control rather than the farming, processing, or commercialisation of edible insects (Said and Bae, 2019).

The absence of clear standards for hygiene, food safety, and farming practices creates uncertainty for producers and limits consumer trust. Despite their sustainability and nutritional benefits, these regulatory gaps pose challenges for integrating grasshoppers into mainstream food systems. To obtain Department of Islamic Development Malaysia (JAKIM) halal certification, grasshopper-based products must adhere to MS 1500:2019 Halal Food - General requirements standard. These include compliance with hygiene, absence of contamination with *najs*, and adherence to halal processing principles. The intersection of Islamic permissibility and the nutritional advantages of grasshoppers highlights their potential as a halal protein source in Malaysia.

Materials and methods

Research framework

This review explores the potential of grasshoppers as a halal alternative protein source in Malaysia by employing the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology. PRISMA is a widely recognised framework that ensures transparency, reproducibility, and comprehensive reporting of systematic reviews (Hlongwane *et al.*, 2020; Cunha *et al.*, 2023; Alhujaili *et al.*, 2023), making it ideal for addressing the research question. Specifically, this review investigates: "What is the potential of grasshoppers as a halal alternative protein source in Malaysia?". The systematic review process was conducted in November 2024.

The review process involved several essential stages to ensure a rigorous and systematic approach. First, a comprehensive literature search was conducted across multiple academic databases to identify studies published in peer-reviewed journals relevant to the research question. Inclusion and exclusion criteria were defined to ensure the selection of studies most aligned with the research objectives. Subsequently, the identified studies were screened to evaluate their relevance and appropriateness for inclusion. The data extraction phase involved systematically coding and summarising the key

findings, methodologies, and outcomes from each study (Figure 1). This review adopts a qualitative approach, emphasising narrative synthesis of thematic findings across the selected studies.

Search strategy

A comprehensive literature search was conducted across multiple electronic databases, including PubMed, Google Scholar, and Scopus, to identify relevant peer-reviewed articles. The search focused on articles published from 2019 to 2024 to capture the most recent developments. The following keywords were used in various combinations of

keywords like grasshoppers, locust, halal, and Malaysia (Table 1).

Inclusion and exclusion criteria

The inclusion and exclusion criteria were applied to ensure that only relevant studies were considered for the systematic review (Table 2). All articles identified during the initial search were imported into a reference management tool to remove duplicates. After de-duplication, the titles and abstracts of the remaining studies were screened to assess their relevance. Articles that met the inclusion criteria were then subjected to full-text review.

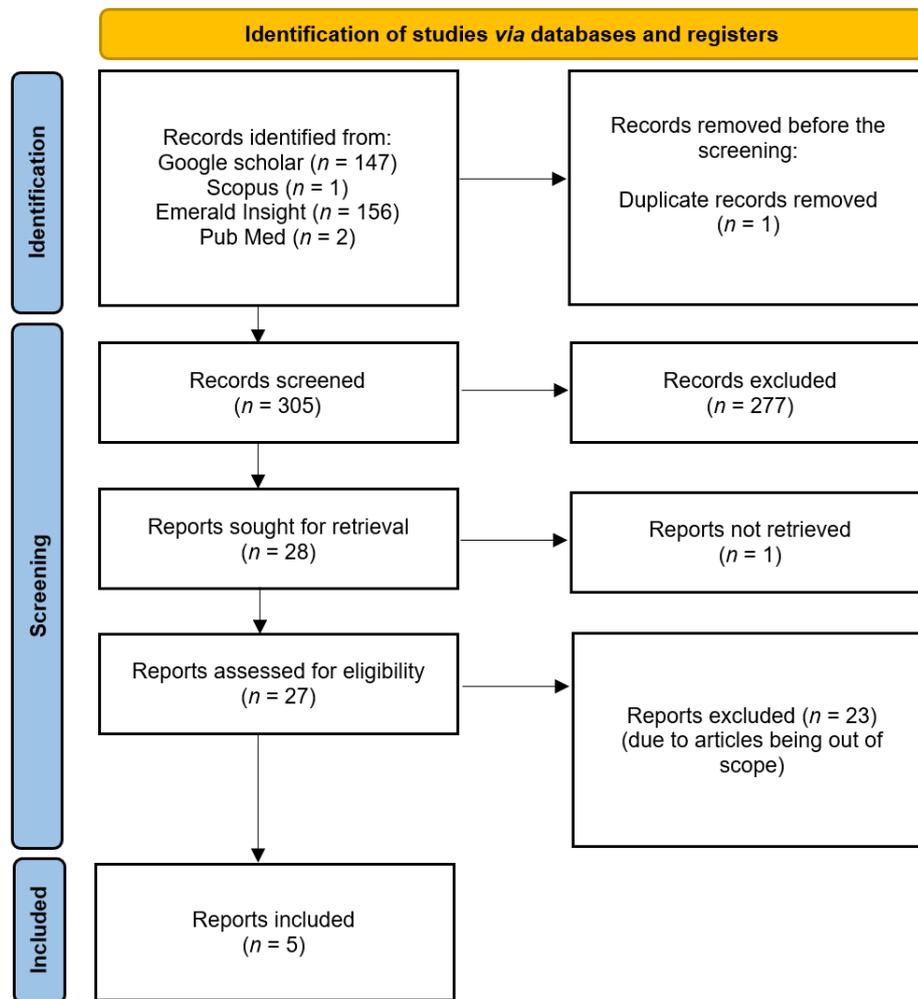


Figure 1. PRISMA flow chart (modified Page *et al.*, 2020).

Table 1. Search strings used in the selected databases.

Database	Search string
Scopus	(TITLE-ABS-KEY (grasshopper) OR TITLE-ABS-KEY (locust) AND TITLE-ABS-KEY (halal) AND TITLE-ABS-KEY (Malaysia))
Emerald Insight	(content-type:article) AND (grasshopper OR (locust) AND (halal) AND (Malaysia))
Pub Med	((grasshopper) OR (locust)) AND (halal) AND (Malaysia)
Google Scholar	"grasshopper" OR "locust" AND "halal" AND "Malaysia"

Table 2. Inclusion and exclusion criteria for the systematic review of grasshoppers as a halal alternative protein.

Criteria	Inclusion	Exclusion
Relevance to grasshoppers as a halal alternative protein	Studies that focus on or significantly relate to grasshoppers as alternative halal protein sources in Malaysia.	Studies that do not address grasshoppers or insects as halal protein sources or focus on unrelated sectors.
Publication date	Studies published within the last five years (2019 - 2024) to capture recent developments in the field.	Studies published before 2019.
Study type	Full research papers with comprehensive findings.	Conference proceedings, abstracts, or summaries without full research data.
Availability	Full-text articles or accessible abstracts that can be reviewed and analysed.	Studies without full-text availability or inaccessible abstracts.
Geographic focus	Studies focused on Malaysia or including comparative analysis involving Malaysia.	Studies solely focused on regions outside Malaysia without comparative relevance to Malaysia's context.

Data extraction

For studies that met the inclusion criteria, relevant data were systematically extracted to ensure a structured analysis. Extracted data included study characteristics such as author details, year of publication, and the journal in which the papers were published. Additionally, the focus of each study was categorised, encompassing topics such as nutritional benefits, halal certification, and consumer acceptance. Methodological approaches were also documented, specifying whether the studies employed qualitative, quantitative, or mixed methods. Key findings and recommendations about grasshoppers as a halal protein source were highlighted. To facilitate a comprehensive synthesis of the findings, the extracted data were organised into tabular form, enabling clear comparisons and thematic analysis.

Results and discussion

Study selection and characteristics

A total of 306 studies were identified through the literature search, and five full-text articles were deemed relevant after the screening process. These articles, published between 2019 and 2024, explored diverse aspects of edible insect consumption, particularly grasshoppers, focusing on nutritional benefits, consumer acceptance, religious considerations, and regulatory challenges within the Malaysian context (Tables 3 and 4).

Among these, two studies, Lim *et al.* (2022) and Sabri *et al.* (2023), specifically addressed

grasshoppers, while the others provided broader perspectives on entomophagy and its implications. Lim *et al.* (2022) investigated the acceptance of grasshoppers and other edible insects as food among adults in Klang Valley and Kuching, Malaysia. The study emphasised the halal status of grasshoppers, reinforcing their suitability for Muslim consumption, but highlighted significant barriers to acceptance, including aversion to texture, food safety concerns, and general sensory preferences. These challenges underscore the need for strategic interventions to promote grasshoppers as a viable protein source. Similarly, Sabri *et al.* (2023) provided a comprehensive review of grasshoppers and locusts from a halal perspective, focusing on their potential to address food security while being culturally acceptable in Muslim communities. The study highlighted the nutritional benefits of grasshoppers and their alignment with Islamic dietary laws, making them a promising and sustainable protein source for Malaysia and Indonesia.

The remaining studies contributed broader perspectives on entomophagy, providing complementary insights into the broader context of edible insects in Malaysia. Lim *et al.* (2024) examined the acceptance of insects as food among young adults in Malaysia and Japan, comparing cultural and sensorial perceptions. Although the study focused on insects in general, food neophobia and sensory aversion were revealed as key barriers to acceptance in Malaysia. The findings highlighted the importance of addressing these barriers through product transformation and strategic marketing. Teng

Table 3. PRISMA data extraction summary on grasshoppers as a halal alternative protein source in Malaysia.

Author(s)	Title	Journal	Research methodology	Sample size/ scope	Key findings
Lim <i>et al.</i> (2022)	Factors influencing acceptance of grasshoppers and other insects as food: A comparison between two cities in Malaysia.	Foods	Cross-sectional online survey using self-administered questionnaires.	292 respondents, split between Klang Valley (144 respondents) and Kuching (148 respondents).	Sensory characteristics, food safety concerns, and aversion toward insects were identified as primary barriers to the acceptance of grasshoppers and other edible insects.
Lim <i>et al.</i> (2024)	Cross-cultural comparison of acceptance of insects as food among young adults in Malaysia and Japan.	Journal of Insects as Food and Feed	Cross-sectional study with online questionnaires measuring food neophobia and willingness to consume insects.	1,954 respondents (1,071 Malaysians and 883 Japanese young adults).	Malaysians were more willing to try insects (10.5%) than Japanese (7.6%), but Japanese participants were more willing to adopt them daily. Appearance was a key barrier.
Said and Bae (2019)	Legislation to foster and support the insect industry: Something for Malaysia to ponder.	Serangga	Socio-legal analysis with comparative study of South Korean legislation.	Analysis of legislation in Malaysia and South Korea.	Malaysia needs structured legislation to support the edible insect industry, including halal certification concerns.
Teng <i>et al.</i> (2022)	The future of entomotourism: The sustainable bugs appetite.	Journal on Tourism and Sustainability	Quantitative analysis with structural equation modelling (SEM).	240 respondents from Klang Valley, Malaysia.	Tourists show interest in edible insects, including grasshoppers, as part of entomotourism; pricing and perceived benefits drive behaviour.
Sabri <i>et al.</i> (2023)	Future aspects of insects' ingestion in Malaysia and Indonesia for human well-being and religion regulation.	Future Foods	Theoretical exploration, focusing on the intersection of human well-being, nutrition, and religious (halal) regulations in the context of insect consumption.	No respondents, theoretical and literature-based analysis.	The paper investigates the potential for integrating insects into the diets of Muslim populations, emphasising the need for halal certification and the nutritional advantages of insects.

Table 4. Summary of research findings on the potential of grasshoppers as a halal alternative protein source in Malaysia.

Author(s)	Nutritional potential	Consumer acceptance	Halal compliance	Regulatory framework	Recommendations
Lim <i>et al.</i> (2022)	Grasshoppers are nutrient-dense, offering protein, fat, vitamins, and minerals comparable to animal protein.	Consumers are hesitant due to sensory issues like taste and smell; certification could aid acceptance.	Recognised as halal by Islamic jurisprudence, but not a focus of consumer perception in this study.	Absence of specific regulations for edible insects in Malaysia; this gap contributes to consumer hesitation.	Provide consumer education on the nutritional benefits of insects and address sensory barriers through product development and marketing.
Lim <i>et al.</i> (2024)	It was not directly addressed.	Malaysians showed higher willingness to try insects; Japanese were more open to adopting insects into daily life. Appearance and food neophobia were key barriers.	Not directly addressed.	Not discussed in the study.	Develop cross-cultural strategies tailored to motivations for acceptance (<i>e.g.</i> , food safety in Malaysia, nutrition in Japan).
Said and Bae (2019)	Insects, including grasshoppers, are recognised for their nutritional value and are highly sustainable compared to conventional livestock.	Consumers hesitant due to lack of familiarity and clear assurances about safety and compliance.	Halal certification critical for trust, requiring detailed and structured guidelines.	Emphasises the need for structured legal frameworks, citing South Korea's model as a benchmark.	Develop comprehensive legislation addressing insect food safety and halal certification to foster consumer confidence.
Teng <i>et al.</i> (2022)	Insects, including grasshoppers, offer environmental sustainability and high nutritional benefits.	Tourists show moderate interest, but consumer behaviour indicates a preference for hidden insect-based foods.	Not directly addressed; focus is on entomotourism strategies for marketability.	No specific insect industry regulations; potential for market development <i>via</i> entomotourism.	Promote entomotourism to introduce edible insects subtly into familiar foods and focus on their environmental benefits.
Sabri <i>et al.</i> (2023)	Grasshoppers provide essential nutrients and could support human well-being as a protein source.	Religious and cultural considerations are key; acceptance could improve with clear halal guidelines.	Emphasizes the necessity of clear halal certification for Muslim consumers.	Urgent need for religious and safety guidelines for edible insect consumption in Malaysia and Indonesia.	Conduct localised nutritional studies, collaborate with halal authorities, and develop consumer-targeted halal marketing strategies.

et al. (2022) explored entomotourism, examining consumer behaviour and acceptance of insect-based products among Malaysian tourists. While the study did not focus specifically on grasshoppers, it emphasised the potential of edible insects, including grasshoppers, to contribute to food tourism and sustainability. The findings suggested integrating insect-based products into tourism marketing strategies to raise awareness and acceptance.

Finally, Said and Bae (2019) addressed the legislative landscape for the edible insect industry in Malaysia, highlighting the absence of a structured regulatory framework. The study suggested adopting South Korea's "Act on Fostering and Support of the Insect Industry" as a model for Malaysia to develop a comprehensive legal framework. Although not specific to grasshoppers, the study emphasised the importance of regulation in supporting the growth of the insect industry and ensuring food safety, which would benefit grasshoppers and other edible insects.

Collectively, these studies provide a comprehensive understanding of the potential for grasshoppers and other edible insects as sustainable protein sources in Malaysia. While Lim *et al.* (2022) and Sabri *et al.* (2023) focused specifically on grasshoppers, the remaining studies offer valuable insights into the broader sociocultural, economic, and regulatory aspects of entomophagy in Malaysia, enriching the discourse on their adoption and acceptance.

The limited number of studies included in this review ($n = 5$) reflects the nascent stage of research on grasshoppers as a halal alternative protein source, particularly within the Malaysian context. While the focus on recent studies ensures relevance, it also highlights the scarcity of comprehensive research in this field. This limitation underscores the urgent need for more localised and targeted investigations, especially considering the potential nutritional, cultural, and economic implications of integrating grasshoppers into mainstream diets.

Nutritional potential of grasshoppers

Grasshoppers are recognised as a nutrient-dense food source with a composition, making them a viable alternative to traditional protein options. Although none of the five reviewed studies included original nutritional analysis, broader literature and food composition databases offer valuable insight into their nutritional potential.

Grasshoppers have been reported to contain approximately 45 - 78 g of protein per 100 g dry weight, significantly surpassing the levels found in conventional protein sources such as chicken breast (27 g), beef (26 g), and eggs (13 g) (Ahmad *et al.*, 2018; Heines *et al.*, 2022; Kababu *et al.*, 2023; Ahmed and Inal, 2025). Their fat content ranges between 4 - 20 g, with beneficial polyunsaturated fatty acids such as omega-3 and -6 (0.4 - 0.6 g). Grasshoppers also deliver high levels of iron (217 - 220 mg/100 g) and zinc (14.2 - 14.6 mg/100 g), far exceeding values in most conventional meats and eggs. In addition to these macronutrients, grasshoppers provide all nine essential amino acids, with particularly high levels of lysine, leucine, and valine. They also contain up to 12.17 g of dietary fibre, primarily derived from chitin (Siddiqui *et al.*, 2023b).

Based on the systematic review findings, all five selected studies consistently acknowledged grasshoppers as both a halal and nutritionally viable alternative protein source. Lim *et al.* (2022) emphasised that grasshoppers offer a comprehensive nutritional profile, providing high-quality proteins, fats, fibres, vitamins, and minerals comparable to other animal-based foods. These nutrients make them a strong candidate for addressing the growing global protein demand, particularly as a sustainable and environmentally friendly alternative. Grasshoppers are also considered halal, aligning with Islamic dietary laws, and this cultural acceptability is crucial for their adoption in Muslim-majority countries such as Malaysia.

Sabri *et al.* (2023) supported their nutritional value, highlighting that grasshoppers are rich in essential amino acids that meet the dietary requirements established by global health organisations. They also provide vital micronutrients such as zinc, iron, and magnesium, which are critical for preventing deficiencies, particularly in developing nations. Their fat content includes beneficial fatty acids like omega-3 and -6, which contribute to overall health. These nutritional attributes place grasshoppers as an optimal protein source, particularly in regions facing food security challenges.

From an environmental perspective, Said and Bae (2019) discussed insects in general and their advantages over traditional livestock in terms of sustainability. Grasshoppers, like other insects, require significantly less water, land, and feed to

produce comparable amounts of protein, while emitting lower greenhouse gases. These attributes make grasshoppers a more sustainable choice, aligning with global efforts to reduce the environmental footprint of food production.

While Lim *et al.* (2024) did not specifically focus on grasshoppers, the study emphasised that insects, in general, possess nutritional properties that are essential for addressing protein shortages globally. Teng *et al.* (2022) similarly noted that edible insects, including grasshoppers, could support sustainable food systems by providing a high-quality protein source with minimal environmental impact. Both studies reinforce the potential of grasshoppers when viewed within the broader category of edible insects.

To maximise the nutritional benefits of grasshoppers while addressing consumer hesitations, Lim *et al.* (2022) suggested transforming grasshoppers into more palatable forms, such as powders or processed products. This approach could help mitigate sensory aversion and increase their appeal to consumers. Additionally, ensuring food safety and promoting their halal status could enhance their acceptance among Muslim populations.

While specific data on the nutritional composition of Malaysian grasshopper species remains unavailable, the reviewed literature offers insights into the general nutritional attributes of grasshoppers relevant to their application in Malaysia. Future research is recommended to establish specific nutritional data for locally available grasshopper species.

Religious concerns

The reviewed literature highlights that grasshoppers are considered halal under Islamic dietary laws, provided they are prepared and processed in accordance with halal standards. This permissibility is supported by scholarly consensus across the four main Sunni schools of jurisprudence (Hanafi, Maliki, Shafi'i, and Hanbali) (Lim *et al.*, 2022; Sabri *et al.*, 2023).

This permissibility ensures that grasshoppers can be consumed by the Muslim population, aligning with the dietary requirements of Malaysia's majority Islamic demographic. However, ensuring proper adherence to halal guidelines in the sourcing, processing, and preparation of grasshoppers is critical for widespread acceptance within the Muslim community (Lim *et al.*, 2022).

The reviewed papers emphasise the importance of halal certification for grasshopper-based food products to address consumer trust and confidence. Such certification can play a pivotal role in facilitating the integration of grasshoppers into halal food systems in Malaysia (Lim *et al.*, 2022; Sabri *et al.*, 2023).

In conclusion, grasshoppers offer a promising halal alternative protein source, making them a suitable choice for the Malaysian market. Obtaining halal certification for grasshopper-based food products would further ensure compliance with halal standards and foster greater acceptance among consumers.

Consumer acceptance and cultural barriers

The acceptance of grasshoppers and other insects as food remains a significant challenge in Malaysia, driven by various cultural and sensorial barriers. Lim *et al.* (2022) specifically examined grasshoppers and highlighted that, despite their halal status and nutritional benefits, acceptance levels among Malaysian adults are low. The study, conducted in Klang Valley and Kuching, found that only 30.1% of respondents were willing to accept grasshoppers and other insects as food, and only 18.2% expressed willingness to include them in their daily diets. Major barriers included the texture of grasshoppers, concerns about food safety, and general aversion to the idea of consuming insects.

Cultural perceptions also play a pivotal role in shaping consumer attitudes. Sabri *et al.* (2023) found that the consumption of grasshoppers is rare in Malaysia due to limited traditional knowledge and uncertainty about the permissibility of insect consumption among younger generations. Although grasshoppers are recognised as halal under Islamic law, their consumption is not widespread, reflecting a cultural disconnect and lack of awareness about their potential as a protein source. The study emphasised the need for educational campaigns to bridge this gap and promote grasshoppers as a sustainable food choice.

From a broader perspective, Lim *et al.* (2024) explored the acceptance of insects as food among young adults in Malaysia and Japan. While this study did not focus exclusively on grasshoppers, it revealed that Malaysian consumers exhibited higher levels of food neophobia compared to their Japanese counterparts. This neophobia, or reluctance to try new foods, was a major barrier to accepting insects as part

of the diet. Sensory aversion, particularly to the visual appearance and texture of insects, was identified as another key factor deterring consumption.

Teng *et al.* (2022) expanded the discussion to include the potential for integrating insect-based foods, including grasshoppers, into tourism. The study noted that while edible insects are gaining recognition for their environmental and health benefits, tourists and domestic consumers often hesitate. Factors such as unfamiliarity and a lack of exposure to insect-based products in mainstream cuisine contribute to this reluctance. The study suggested that transforming grasshoppers into processed or hidden forms, such as powders or protein bars, could help mitigate these cultural barriers and increase acceptance.

Lastly, Said and Bae (2019) discussed the need for a structured regulatory framework to support the edible insect industry in Malaysia. While the study did not specifically focus on grasshoppers, it noted that the absence of clear guidelines on food safety and production standards contributes to consumer scepticism. Establishing robust legislation and certification processes could enhance consumer trust in grasshopper-based products and address concerns about food safety.

In conclusion, while edible insects hold significant potential as a sustainable protein source, addressing cultural perceptions and presentation preferences through targeted strategies is crucial for their broader acceptance in Malaysia.

Regulatory and market implications

The development of the edible insect industry in Malaysia, including the use of grasshoppers as a halal protein source, is closely tied to regulatory frameworks and market readiness. Said and Bae (2019) provided a detailed analysis of the regulatory gaps in Malaysia's edible insect industry, emphasising the need for a structured and comprehensive legal framework. Currently, Malaysia's legislation regarding insects is fragmented, primarily addressing pests or disease-bearing insects, such as the Destruction of Disease-Bearing Insects Act 1975. The absence of specific regulations for edible insects hinders the growth of the industry, and creates uncertainty among producers and consumers. Drawing inspiration from South Korea's "Act on Fostering and Support of the Insect Industry", Said and Bae (2019) proposed the creation of a dedicated regulatory framework to foster

innovation, ensure food safety, and promote consumer trust.

The lack of clear regulations also affects the perception of safety and quality, which are key concerns for consumers considering grasshoppers and other insects as a food source. Lim *et al.* (2022) identified food safety as a critical barrier to the acceptance of grasshoppers in Malaysia. Clear guidelines for farming, processing, and certification of grasshoppers as food products could alleviate these concerns, and build consumer confidence.

In addition to safety regulations, halal certification plays a crucial role in the market potential of grasshoppers in Malaysia. As noted by Sabri *et al.* (2023), the halal status of grasshoppers makes them a culturally acceptable protein source for Muslim-majority populations. However, formalising halal certification processes for insect-based products could further strengthen their marketability and appeal. Integrating halal certification with sustainable farming practices would also align with Malaysia's goals for environmentally friendly and culturally sensitive food systems.

From a market perspective, Teng *et al.* (2022) highlighted the economic opportunities associated with edible insects, including grasshoppers, through innovative initiatives like entomotourism. The study emphasised the potential of positioning grasshopper-based products as part of Malaysia's food tourism sector, leveraging their nutritional and environmental benefits. Marketing strategies that target tourists and health-conscious consumers could create new revenue streams while promoting the cultural uniqueness of edible insect consumption.

Broader insights into the market implications of edible insects were provided by Lim *et al.* (2024), who compared consumer acceptance in Malaysia and Japan. This study underscored the importance of addressing food neophobia and sensory aversion through product innovation. Transforming grasshoppers into more familiar forms, such as powders or protein-enriched snacks, could enhance their appeal and market penetration. Additionally, educating consumers about the environmental and nutritional benefits of grasshoppers could increase demand among health-conscious and eco-friendly segments of the population.

In conclusion, the regulatory and market implications of promoting grasshoppers as a halal protein source in Malaysia are substantial. Establishing a clear legal framework, including food

safety and halal certification standards, is critical for fostering consumer trust and industry growth. Market opportunities such as entomotourism and product innovation offer avenues to integrate grasshoppers into mainstream diets while leveraging their environmental and cultural advantages. By addressing regulatory gaps and adopting targeted marketing strategies, Malaysia can unlock the full potential of grasshoppers as a sustainable and culturally compatible food source.

Future directions

The promotion of grasshoppers as a sustainable halal alternative protein source in Malaysia requires a multifaceted approach that addresses cultural, regulatory, and market barriers. Based on the reviewed studies, the following directions are proposed:

- i. **Develop a Comprehensive Regulatory Framework:** As emphasised by Said and Bae (2019), Malaysia must establish a structured legal framework to regulate the production, processing, and marketing of edible insects, including grasshoppers. This framework should include clear guidelines on food safety, halal certification, and environmental sustainability to ensure consumer confidence and industry compliance. Inspiration can be drawn from South Korea's "Act on Fostering and Support of the Insect Industry".
- ii. **Enhance Consumer Awareness and Education:** Grasshoppers, despite being halal and nutrient-dense, face barriers such as food neophobia and sensory aversion (Lim *et al.*, 2022; 2024). Educational campaigns emphasising grasshoppers' halal status, nutritional benefits, and environmental sustainability can help reshape public perceptions. Sensory trials, food tastings, and cooking demonstrations can provide practical exposure to these products, reducing reluctance among consumers.
- iii. **Conduct Nutritional Analysis of Malaysia's Grasshoppers:** Although several studies have analysed the general nutritional composition of grasshoppers, there is a need for localised nutritional analysis of species native to Malaysia. Research should focus on determining the specific nutritional profiles, including protein content, amino acids, vitamins, and minerals of grasshoppers found in Malaysia. This will provide more accurate data on their viability as a halal protein source, and may reveal unique health benefits tailored to the local population. Such research would strengthen the scientific basis for promoting grasshoppers as a dietary staple in Malaysia.
- iv. **Leverage Product Innovation:** To overcome the cultural aversion to the appearance and texture of grasshoppers, as noted by Lim *et al.* (2022) and Teng *et al.* (2022), transforming the product into more palatable forms is crucial. Processed forms such as powders, protein bars, or as ingredients in familiar foods like bread or biscuits can make grasshoppers more acceptable while retaining their nutritional value.
- v. **Integrate Grasshoppers into Food Tourism and Marketing Strategies:** The potential of edible insects, including grasshoppers, extends beyond nutritional benefits to economic opportunities through entomotourism (Teng *et al.*, 2022). Promoting grasshopper-based products in Malaysia's food tourism initiatives can attract domestic and international tourists. Collaborative efforts with restaurants, food festivals, and local entrepreneurs can create unique culinary experiences centred around grasshoppers.
- vi. **Invest in Research and Development:** Further studies are needed to optimise the farming, processing, and nutritional enhancement of grasshoppers. As suggested by Sabri *et al.* (2023), ongoing research can explore innovative uses of grasshoppers in functional foods or medicinal applications, broadening their market potential and consumer appeal.
- vii. **Promote Sustainability in Insect Farming:** The environmental advantages of grasshoppers, such as their low resource use and minimal carbon footprint, should be a key selling point (Said and Bae, 2019; Teng *et al.*, 2022). Initiatives promoting

sustainable insect farming practices can align with Malaysia's broader goals of reducing the environmental impact of food production.

The future of grasshoppers as a sustainable and halal protein source in Malaysia hinges on addressing key barriers through targeted regulatory, educational, and market-driven interventions. Malaysia can unlock the full potential of grasshoppers by focusing on localised nutritional research, product innovation, and integration into food tourism. Coupled with robust regulatory frameworks and sustainability initiatives, these measures will support food security and establish grasshoppers as a viable and culturally compatible protein alternative for the Malaysian population.

Conclusion

The successful promotion of grasshoppers as a sustainable and halal protein source in Malaysia requires a strategic and multidisciplinary approach. Addressing regulatory gaps through a comprehensive legal framework that encompasses food safety standards and halal certification is crucial to establishing consumer trust. Simultaneously, targeted educational campaigns can reduce cultural barriers by emphasising the nutritional benefits, halal status, and environmental advantages of grasshoppers. Localised nutritional analysis of Malaysia's grasshopper species will provide precise data to reinforce their viability as a dietary staple. Additionally, product innovation, such as transforming grasshoppers into more palatable forms and integrating them into food tourism initiatives, can enhance their acceptance and market appeal. By coupling these efforts with sustainable farming practices and ongoing research into grasshopper applications, Malaysia can position grasshoppers as a viable, culturally appropriate, and environmentally sustainable protein alternative. These measures not only address food security but also pave the way for Malaysia to lead in the growing edible insect industry.

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References

- Ahmad, R. S., Imran, A. and Hussain, M. B. 2018. Nutritional composition of meat. In Arshad, M. S. (ed). Meat Science and Nutrition. United Kingdom: IntechOpen.
- Ahmed, I. and Inal, F. 2025. The nutritional value of grasshoppers and locusts - A review. *Annals of Animal Science* 25(2): 455-465.
- Alhujaili, A., Nocella, G. and Macready, A. 2023. Insects as food: Consumers' acceptance and marketing. *Foods* 12: 886.
- Anjani, G., Pratiwi, R. N., Fathimatuzzahrah, N. F., Kusuma, R. A., Nuryanto and Afifah, D. N. 2023. Protein quality and physical characteristics of wood grasshopper (*Melanoplus cinereus*) hydrolysate flour. *Food Research* 7(3): 97-106.
- Ardoin, R. and Prinyawiwatkul, W. 2021. Consumer perceptions of insect consumption: A review of western research since 2015. *International Journal of Food Science and Technology* 56(10): 4942-4958.
- Batat, W. and Peter, P. 2020. The healthy and sustainable bugs appetite: Factors affecting entomophagy acceptance and adoption in Western food cultures. *Journal of Consumer Marketing* 37(3): 291-303.
- Berita Harian, 2021a. Nak cuba makan belalang goreng berempah? Retrieved from Berita Harian website: <https://www.bharian.com.my/berita/wilayah/2021/08/855661/nak-cuba-makan-belalang-goreng-berempah>
- Berita Harian, 2021b. Belalang goreng kerutuk, kunyit juadah istimewa Aidiladha. Retrieved from Berita Harian website: <https://www.utusan.com.my/terkini/2021/07/belalang-goreng-kerutuk-juadah-istimewa-aidiladha/>
- CEIC Data. 2021. Malaysia demographic projection. Retrieved from CEIC Data website: <https://www.ceicdata.com/en/malaysia/demographic-projection/my-population-projection-mid-year>
- Chung, A., Khen, C., Unchi, S. and Binti, M. 2002. Edible insects and entomophagy in Sabah, Malaysia. *Malayan Nature Journal* 56: 131-144.
- Cruz-López, S. O., Álvarez-Cisneros, Y. M., Domínguez-Soberanes, J., Escalona-Buendía,

- H. B. and Sánchez, C. N. 2022. Physicochemical and sensory characteristics of sausages made with grasshopper (*Sphenarium purpurascens*) flour. *Foods* 11: 704.
- Cunha, N., Andrade, V., Ruivo, P. and Pinto, P. 2023. Effects of insect consumption on human health: A systematic review of human studies. *Nutrients* 15: 3076.
- Das, A., Ghosh, D., Manna, B., Dolai, A., Pati, A., Mandal, S. and Mukherjee, K. 2022. Does space matter? Estimation and evaluation of required space for commercial mass culture of grasshoppers (Acridoidea: Orthoptera). *PLoS One* 17(6): e0265664.
- Food and Agriculture Organization (FAO). 2021. Looking at edible insects from a food safety perspective. Challenges and opportunities for the sector. Rome: FAO.
- Grabowski, N. T., Tchibozo, S., Abdulmawjood, A., Acheuk, F., Guerfali, M. M. S., Sayed, W. A. A. and Plotz, M. 2020. Edible insects in Africa in terms of food, wildlife resource, and pest management legislation. *Foods* 9(4): 502.
- Guine, R. P. F., Correia, P., Coelho, C. and Costa, C. A. 2021. The role of edible insects to mitigate challenges for sustainability. *Open Agriculture* 6: 24-36.
- Hasnan, F. F. B., Feng, Y., Sun, T., Parraga, K., Schwarz, M. and Zarei, M. 2023. Insects as valuable sources of protein and peptides: Production, functional properties, and challenges. *Foods* 12: 4243.
- Heines, W., Ristic, D., Rosenberger, S., Coudron, C., Gai, F., Schiavone, A. and Smetana, S. 2022. Eggs or meat? Environmental impact and efficiency assessment of chicken protein production with potential of *Hermetia illucens* use in feed. *Resources, Conservation and Recycling Advances* 16: 200121.
- Hlongwane, Z. T., Slotow, R. and Munyai, T. C. 2020. Nutritional composition of edible insects consumed in Africa: A systematic review. *Nutrients* 12: 2786.
- Ibarra-Herrera, C. C., Acosta-Estrada, B., Chuck-Hernández, C., Serrano-Sandoval, S. N., Guardado-Félix, D. and Pérez-Carrillo, E. 2020. Nutritional content of edible grasshopper (*Sphenarium purpurascens*) fed on alfalfa (*Medicago sativa*) and maize (*Zea mays*). *CyTA - Journal of Food* 18(1): 257-263.
- Kababu, M., Mweresa, C. K., Subramanian, S., Egonyu, J. P. and Tanga, C. M. 2023. Variability in nutrient composition of the edible long-horned grasshopper (*Ruspolia differens*) in Uganda and its potential in alleviating food insecurity. *Food Science and Nutrition* 11: 3558-3574.
- Kavle, R. R., Pritchard, E. T. M., Bekhit, A. E. D. A., Carne, A. and Agyei, D. 2022. Edible insects: A bibliometric analysis and current trends of published studies (1953-2021). *International Journal of Tropical Insect Science* 42: 3335-3355.
- Kim, S., Weaver, C. M. and Choi, M. 2017. Proximate composition and mineral content of five edible insects consumed in Korea. *CyTA - Journal of Food* 15(1): 143-146.
- Kim, T. K., Yong, H. I., Kim, Y. B., Kim, H. W. and Choi, Y. S. 2019. Edible insects as a protein source: A review of public perception, processing technology, and research trends. *Food Science of Animal Resources* 39(4): 521-540.
- Kleden, Y. L., Mukkun, L., Ndapamuri, M. H. and Pramata, F. 2023. The migratory locust (*Locusta migratoria*) as a potential source of protein and biopolymer compounds in the future. *Biodiversitas Journal of Biological Diversity* 24(11): 5979-5987.
- Kohler, R., Kariuki, L., Lambert, C. and Biesalski, H. K. 2019. Protein, amino acid and mineral composition of some edible insects from Thailand. *Journal of Asia-Pacific Entomology* 22: 372-378.
- Kröger, T., Dupont, J., Büsing, L. and Fiebelkorn, F. 2022. Acceptance of insect-based food products in western societies: A systematic review. *Frontiers in Nutrition* 8: 759885.
- Krongdang, S., Phokasem, P., Venkatachalam, K. and Charoenphun, N. 2023. Edible insects in Thailand: An overview of status, properties, processing, and utilization in the food industry. *Foods* 12: 2162.
- Kuntadi, A. Y. and Maharani, K. E. 2018. Nutritional compositions of six edible insects in Java. *Indonesian Journal of Forestry Research* 5(1): 57-68.
- Liceaga, A. M. 2022. Edible insects, a valuable protein source from ancient to modern times. *Advances in Food and Nutrition Research* 101: 129-152.

- Lim, S. M., Ng, Y. I., Kagawa, M., Wong, J. E., Shinde, M., Tochinali, F. and Poh, B. K. 2024. Cross-cultural comparison of the acceptance of insects as food among young adults in Malaysia and Japan. *Journal of Insects as Food and Feed* 11(1): 1-14.
- Lim, S. M., Thien, C. N., Toure, A. K. and Poh, B. K. 2022. Factors influencing acceptance of grasshoppers and other insects as food: A comparison between two cities in Malaysia. *Foods* 11: 3284.
- Lin, X., Wang, F., Lu, Y., Wang, J., Chen, J., Yu, Y., ... and Peng, Y. 2023. A review on edible insects in China: Nutritional supply, environmental benefits, and potential applications. *Current Research in Food Science* 7: 100596.
- Lisboa, H. M., Nascimento, A., Arruda, A., Sarinho, A., Lima, J., Batista, L., ... and Andrade, R. 2024. Unlocking the potential of insect-based proteins: Sustainable solutions for global food security and nutrition. *Foods* 13: 1846.
- Lucas, A. J. S., Oliveira, L. M. and Rocha, M. 2020. Edible insects: An alternative of nutritional, functional and bioactive compounds. *Food Chemistry* 311: 126022.
- Manditsera, F. A., Mubaiwa, J., Matsungu, T. M., Chopera, P., Bhatasara, S., Kembo, G., ... and Macheke, L. 2022. Mopane worm value chain in Zimbabwe: Evidence on knowledge, practices, and processes in Gwanda district. *PLoS One* 17(12): e0278230.
- Margaret, K., Collins, M. K., Subramanian, S., Egonyu, J. P., Nakimbugwe, D., Ssepuuya, G., ... and Murandu, C. V. 2022. Edible insects consumption in Africa towards environmental health and sustainable food systems: A bibliometric study. *International Journal of Environmental Research and Public Health* 19: 14823.
- Mohamed, E. H. A. 2015. Determination of nutritive value of the edible migratory locust *Locusta migratoria* Linnaeus, 1758 (Orthoptera: Acrididae). *International Journal of Advances in Pharmacy, Biology and Chemistry* 4(1): 1758.
- Mohd Zaini, N. S., Lim, E. J., Ahmad, N. H., Gengatharan, A., Wan-Mohtar, W. A. A. Q. I. and Abd Rahim, M. H. 2023. The review of cooking, drying, and green extraction methods on general nutritional properties of mealworms and locusts. *Food and Bioprocess Technology* 16: 1904-1918.
- Moreno, J. M. P. and Reyes-Prado, H. 2020. Commerce of edible insects in the state of Morelos, Mexico. *Journal of Insect Science* 20(5): 19.
- Mufti of Federal Territory's Office (MUFTIWP). 2018. Al-Kafi #963: The ruling of eating locust. Retrieved from MUFTIWP website: <https://muftiwp.gov.my/en/artikel/al-kafi-li-al-fatawi/2884-al-kafi-963-the-ruling-of-eating-locust>
- Nabikolo, D., Njue, L., Abong, G. and Tanga, M. 2023. The potential contribution and challenges of edible grasshopper (*Ruspolia differens*) to food and nutrition security in Uganda - A literature review. *East African Journal of Science, Technology and Innovation* 4 (3): 1-17.
- Ochieng, B. O., Anyango, J. O., Nduko, J. M., Cheseto, X., Mudalungu, C. M., Khamis, F. M., ... and Tanga, C. M. 2022. Dynamics in nutrients, sterols and total flavonoid content during processing of the edible Long-Horned grasshopper (*Ruspolia differens* Serville) for food. *Food Chemistry* 383: 132397.
- Ojha, S., Bekhit, A. E. D., Grune, T. and Schluter, O. K. 2021. Bioavailability of nutrients from edible insects. *Current Opinion in Food Science* 41: 240-248.
- Olivadese, M. and Dindo, M. 2023. Edible insects: A historical and cultural perspective on entomophagy with a focus on western societies. *Insects* 14: 690.
- Omuse, E. R., Tonnang, H. E. Z., Yusuf, A. A., Macheke, H., Egonyu, J. P., Kimathi, E., ... and Niassy, S. 2024. The global atlas of edible insects: Analysis of diversity and commonality contributing to food systems and sustainability. *Scientific Reports* 14: 5045.
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D. et al. 2020. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ* 372: n71.
- Pahmeyer, M. J., Siddiqui, S. A., Pleissner, D., Gołaszewski, J., Heinz, V. and Smetana, S., 2022. An automated, modular system for organic waste utilization using *Hermetia*

- illucens* larvae: Design, sustainability, and economics. *Journal of Cleaner Production* 379: 134727.
- Pali-Scholl, I., Binder, R., Moens, Y., Polesny, F. and Monso, S. 2019. Edible insects-defining knowledge gaps in biological and ethical considerations of entomophagy. *Critical Reviews in Food Science and Nutrition* 59: 2760-2771.
- Park, S. J., Kim, K. Y., Baik, M. Y. and Koh, Y. H. 2022. Sericulture and the edible-insect industry can help humanity survive: Insects are more than just bugs, food, or feed. *Food Science and Biotechnology* 31: 657-668.
- Patel, S., Suleria, H. A. R. and Rauf, A. 2019. Edible insects as innovative foods: Nutritional and functional assessments. *Trends in Food Science and Technology* 86: 352-359.
- Paulin, I. G. and Purwanto, M. G. M. 2020. Nutritional characteristics of teak grasshopper (*Valanga nigricornis* Burmeister), cricket (*Brachytrupes portentosus* L.), and mealworm (*Tenebrio molitor*) as alternative food sources in Indonesia. *Indonesian Journal of Biotechnology and Biodiversity* 4(1): 52-61.
- Rodríguez-Miranda, J., Alcántar-Vázquez, J. P., Zúñiga-Marroquín, T. and Juárez-Barrientos, J. M. 2019. Insects as an alternative source of protein: A review of the potential use of grasshopper (*Sphenarium purpurascens* Ch.) as a food ingredient. *European Food Research and Technology* 245: 2613-2620.
- Rovai, D., Michniuk, E., Roseman, E., Amin, S., Lesniasukas, R., Wilke, K., ... and Lammert, A. 2021. Insects as a sustainable food ingredient: Identifying and classifying early adopters of edible insects based on eating behavior, familiarity, and hesitation. *Journal of Sensory Studies* 36: e12681.
- Sabine, S. 2021. Mopane worms – A true delicacy in southern Africa. Retrieved from The Travelling Chilli website: <https://www.thetravellingchilli.com/mopane-worms-true-delicacy-southern-africa/>
- Sabri, N. S. A., Kamardan, M. I. F., Wong, S. X., Azman, N. F., Akhir, F. N. M., Othman, N., ... and Hara, H. 2023. Future aspects of insects' ingestion in Malaysia and Indonesia for human well-being and religion regulation. *Future Foods* 8: 100267.
- Said, S. M. and Bae, Y. J. 2019. Legislation to foster and support the insect industry: Something for Malaysia to ponder. *Serangga* 24(2): 90-103.
- Sampaonthong, S., Dokchan, P. and Punyawattoe, P. 2024. Application of blockchain technology for commercial grasshopper farming supply chain traceability in Thailand. *International Journal of Agriculture and Biosciences* 13(3): 325-332.
- Shrivastava, S. K., Prakash, A., Rao, J., Saxena, S. and Arif, M. 2019. Grasshopper: An untapped halal food source for future India. *Journal of Applied Zoological Research* 30(2): 93-132.
- Siddiqui, S. A., Ghisletta, M., Yunusa, B. M., Jiddum, F. A., Saraswati, Y. R., Fernando, I., ... and Dar, B. N. 2023a. Grasshoppers and locusts as human foods – A comprehensive review. *Journal of Insects as Food and Feed* 9(10): 1247-1264.
- Siddiqui, S. A., Mahanta, D. K., Bhoi, T. K., Ahmad, A. and Fernando, I. 2024a. Mopane worm (*Gonimbrasia belina*)—An exclusive African edible insect as human food—A comprehensive review. *Future Food* 10: 100438.
- Siddiqui, S. A., Ngah, N., Eddy-Doh, A. M., Ucak, I., Afreen, M., Fernando, I., ... and Castro-Munoz, R. 2023b. Edible Lepidoptera as human foods – A comprehensive review. *Journal of Insects as Food and Feed* 10(1): 25-49.
- Siddiqui, S. A., Yuksel, A. N. Sahin Ercan, S., Abdul Manap, A. S., Afzal, S., Wu, Y. S., ... and Ibrahim, S. A. 2024b. Edible beetles (Coleoptera) as human food – A comprehensive review. *Journal of Insects as Food and Feed* 2024: 1-59.
- SSepuuya, G., Smets, R., Nakimbugwe, D., Borght, M. V. D. and Claes, J. 2019. Nutrient composition of the long-horned grasshopper *Ruspolia differens* Serville: Effect of swarming season and sourcing geographical area. *Food Chemistry* 301: 125305.
- Suresh, S., Zaini, N. S., Abd Rahim, M. H. and Ahmad, N. H., 2023. Insects and worms as an alternative protein source in the halal food industry. In Nizar, N. N. A., Abidin, S. A. S. Z. and Bujang, A. (eds). *Innovation of Food Products in Halal Supply Chain Worldwide*, p. 127-148. United States: Academic Press.

- Tagawa, K., Hosoya, T., Hyakumura, K., Suzuki, D., Yoshizawa, S. and Praxaysombath, B. 2022. The effects of season, geography, and urbanization on the diversity of edible insects at food markets in Laos. *PLoS One* 17: e0267307.
- Tajudeen, A. L. 2020. Halal certification of insect-based food: A critique. *International Journal of Islamic Business Ethics* 5(2): 100-112.
- Teng, P. K., Abdullah, S. I. N. W. and Heng, B. L. J. 2022. The future of entomotourism: The sustainable bugs appetite. *Journal on Tourism and Sustainability* 6(1): 63-75.
- Torruco-Uco, J. G., Hernández-Santos, B., Herman-Lara, E., Martínez-Sánchez, C. E., Juárez-Barrientos, J. M. and Rodríguez-Miranda, J. 2019. Chemical, functional and thermal characterization, and fatty acid profile of the edible grasshopper (*Sphenarium purpurascens* Ch.). *European Food Research and Technology* 245: 285-292.
- United Nations (UN). 2019. World population prospects 2019 - Highlights (ST/ESA/SER.A/423). United States: UN.
- Utusan. 2023. Belalang goreng cheese lauk sahur. Retrieved from Utusan website: <https://www.utusan.com.my/nasional/2023/04/belalang-goreng-cheese-lauk-sahur/>
- Van Huis, A., Rumpold, B., Maya, C. and Roos, N. 2021. Nutritional qualities and enhancement of edible insects. *Annual Review of Nutrition* 41: 551-576.
- Van Huis, A., Van Itterbeeck, J., Klunder, H., Mertens, E., Halloran, A., Muir, G. and Vantomme, P., 2013. Edible insects: Future prospects for food and feed security. Rome: Food and Agriculture Organization (FAO).
- Wan Zulkifli, W. Z. I. 2019. Belalang padi sedap dimakan, cecah RM70 sekilogram. Retrieved from Bernama website: <https://www.bernama.com/bm/news.php?id51783276>
- Wegier, A., Alavez, J., Pérez-López, L., Calzada, L. and Cerritos, R. 2018. Beef or grasshopper hamburgers: The ecological implications of choosing one over the other. *Basic and Applied Ecology* 26(1): 89-100.