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Insect as feed and food – A Review

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Introduction

Since there will be more than 9 billion people on Earth by 2050, meeting human needs for food, fuel, fibre, and housing will require leaving as little of an ecological footprint as possible (Ramaswany, 2015). The way we grow and think about food today and in the future will change as a result of feeding the world's 9 billion inhabitants. Since our ancestors first emerged from the trees and began to travel over the Savannahs, insects have provided sustenance for humans (Anankware, 2013). Although eating insects is uncommon in Western countries today, they remain a significant dietary staple in many other cultures. Insects play a crucial role in ecosystems, provide nutrition with minimal environmental impact, and contribute to improved livelihoods. However, many people are still unaware of these benefits. Insects are not just "famine foods" eaten during times of scarcity or when conventional foods are difficult to obtain, as many believe. Instead, people worldwide actively choose to eat insects for their taste and their established role in local food traditions and national diets (FAO/WUR, 2012). In West Africa, both people and animals have traditionally eaten insects as food (Kenis and Hein, 2014; Riggi *et al.*, 2014). Although people in this region historically consumed fewer insect species compared to Central and Southern Africa, termites and grasshoppers are the most common. The lack of research on insect consumption in West Africa in the past shaped this perception. However, recent studies focusing on specific areas have revealed that people consume more species than previously thought (Kenis and Hein, 2014). However, there is no denying that, compared to other Sub-Saharan African regions, entomophagy—the eating of insects—is not as common in West Africa (Kenis and Hein, 2014). Over two billion people across roughly 80 nations in Asia, Africa, and the Americas eat around 1,900 different insect species (van Huis *et al.*, 2013). People consume various life stages of these insects, including eggs, larvae, pupae, nymphs, and sometimes adults. People obtain edible insects through three main methods: cultivating them, semi-domesticating wild insects, and harvesting them from the wild, with each method contributing differently based on the region. While entomophagy has declined in westernized societies, interest in edible insects has grown in several Asian countries as living conditions have improved (Yen, 2005). Entomophagy has gained attention recently for several reasons (van Huis *et al.,* 2013; Ramaswany, 2014). Many insects are healthier and more nutritious than common meats like chicken, pork, beef, and even fish, as they are higher in protein, lower in fat, and richer in calcium, iron, and zinc (van Huis *et al.,* 2013). Additionally, insects are highly efficient at converting food into protein because they are cold-blooded. For example, crickets require 12 times less feed than cattle, 4 times less than sheep, and half as much as pigs and broiler chickens to produce the same amount of protein. Their rapid metabolisms also help insects conserve significant amounts of energy and natural resources. Thirdly, using insects as food has a lower ecological footprint than traditional livestock because insects require less space and food. Fourthly, insects raised for food produce significantly lower greenhouse gas emissions compared to most livestock, with only a few species, such as termites and cockroaches, generating methane. Additionally, insect farming results in much lower ammonia emissions than raising conventional livestock like pigs (van Huis *et al.,* 2013). Insect rearing often operates outside of land-based industries, avoiding land destruction for production. Furthermore, insects have a much higher reproductive rate, making it easier to raise them in large numbers compared to other animals. Ultimately, entomophagy improves many people's lives on an economic and social level. Harvesting and raising insects is a low-tech, low-capital investment alternative that is accessible to even the most impoverished members of society, including women and the landless. Small-scale animal farming provides opportunity for both rural and urban residents to make a living. To promote the use of insects as human food, it is essential to understand various issues, including the biology of edible species, biotic and abiotic barriers to insect livestock production, health and environmental risks, food safety and regulatory frameworks, human behaviour and attitudes toward insect consumption, production challenges, and the necessary infrastructure requirements (Ramaswany, 2014).

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Review Literature

A Historical Overview of Insect Consumption by Humans

The popularity of the most commonly eaten insect species comes from their availability and small size (Bukkens 1997). Ideally, these insects should be easy to locate and capture in large, predictable quantities to make the effort worthwhile. The popular edible insect species include the following categories: Beetles make up 31% of the insect class (Coleoptera), caterpillars account for 18%, bees, wasps, and ants represent 14%, grasshoppers, locusts, and crickets comprise 13%, cicadas, leafhoppers, planthoppers, scale insects, and true bugs make up 10%, termites constitute 3%, dragonflies account for 3%, and flies make up 2% (Van & Pelozuelo, 2022). People consume insects in various ways throughout their life stages, such as raw, fried, boiled, roasted, or pulverized. In Thailand, people consume around 150 different insect species, mostly collected from the wild, which are considered staple foods (Yhoung-Aree 2010). Entomophagy also serves as an effective method for controlling agricultural pests. In 1978, the Thai government launched an initiative to promote the edibility of locusts following an outbreak of (*Patanga succincta).* As a result, locusts, once seen as crop pests, became a popular snack, and some farmers now grow crops specifically to feed them due to their high market value (Hanboonsong *et al.*, 2013). Thailand's growing demand for insects as food has led to the establishment of mass-rearing facilities, replacing the natural collection of insects (Hanboonsong *et al.*, 2013). Individual farmers primarily raise crickets, which provide an important additional source of income. Similarly, in Burkina Faso and Kenya, people have a long history of consuming insects. In Kenya, the most well-known insect is the larvae of the palm weevil (*Rhynchophrus phoenicis*), which farmers semi-cultivate and collect from the wild by felling raffia trees (El-Shafie, 2024). In Burkina Faso, the sheatree caterpillar (*Cirina butyrospermi*) is the most commonly eaten insect, despite being considered a pest to shea butter tree plantations (Anvo *et al.* 2016). People typically cook the larvae in water, then fry them in butter for immediate consumption, or boil and sun-dry them to sell in markets.

In many parts of Africa, Asia, and large regions of South America, native communities consume a wide variety of insect species in different types of meals. However, in recent years, insect consumption has declined, partly due to the growing Western perception that insects are repulsive and unfit for eating (Looy *et al.* 2014). Many people view insects as "starvation food," meant only for consumption during severe food shortages (Dobermann *et al.* 2017; Looy *et al.* 2014). The media's negative portrayal of entomophagy and Westerners' reluctance to embrace the practice have reduced insect consumption, harming the health of communities that relied on the nutrition insects provided (Hanboonsong *et al.* 2013). However, recent research suggests that demand for insects may be rising in some countries, such as Laos and Thailand (Durst & Hanboonsong 2015). These changing perspectives likely result, in part, from the growing recognition that eating insects is not exclusive to underdeveloped nations facing starvation (El-Shafie, 2024).

People frequently include insects in their regular meals. In 1919, people recorded 55 edible insect species, and insects continue to be a common part of Japan's traditional diet (Bukkens 1997). Although environmental and socioeconomic changes have reduced insect populations, people still consume some species today, often as luxury or delicacy foods (Nonaka 2010). In Japan, wasps hold a special place in the food culture and remain highly prized. An annual celebration honors their consumption, with participants competing to own the largest wasp nest, whether collected from the wild or raised. Communities unite to commemorate the wasp harvest, share information on techniques for collecting and cultivating wasps, and indulge in a variety of wasp delicacies (Nonaka 2010). Despite the fact that wasp husbandry techniques are frequently ineffective and expensive, farmers nonetheless strive to improve them, suggesting that wasp keeping is mostly done for fun and tradition (Boppre & Vane-Wright, 2019).

Key Groups of Edible Insect Species Consumed Globally

Beetles account for 31% of all insects ingested worldwide (van Huis et al., 2013). Considering that the category comprises over 40% of all known insect species, this is not unexpected. It is believed that 18% of people consume caterpillars, which are particularly common in sub-Saharan Africa. Third position goes to bees, wasps, and ants, which are particularly prevalent in Latin America at 14%. After them come the following: termites (3%), dragonflies (3%), flies (2%), grasshoppers, locusts, and crickets (13%); cicadas, leafhoppers, plant-hoppers, scale insects, and real bugs (10%); and others (5%) (van Huis et al., 2013). Most people consume hymenoptera as larvae or pupae, while they nearly exclusively eat lepidoptera as caterpillars. People primarily consume members of the Orthoptera, Homoptera, Isoptera, and Hemiptera orders in their mature forms, although they also eat both adults and larvae from the Coleoptera order (Cerritos, 2009). Table 1 presents the total number of documented edible insect species worldwide.

Order	Common English Name	Number of Species
Thysanura	Silverfish	1
Anoplura	Lice	3
Ephemeroptera	Mayflies	19
Odonata	Dragonflies	29
Orthoptera	Grasshoppers, Cockroaches, Crickets	267
Isoptera	Termites	61
Hemiptera	True Bugs	102
Homoptera	Cicades, Leafhoppers, Mealybugs	78
Neuroptera	Dobson Flies	5
Lepidoptera	Butterflies, Moths (Silkworm)	253
Trichoptera	Caddis Flies	10
Diptera	Flies, Mosquitoes	34
Coleoptera	Beetles	468
Hymenoptera	Ants, Bees, Wasp	351
Total		**1681**

Table 1: Count of Edible Insect Species Documented Worldwide (Ramos & Pino, 2002).

Coleoptera (beetles)

There are many different types of edible beetles, such as dung beetles, water beetles, and larvae that bore into wood. According to Ramos Elorduy and his colleagues, there are 78 species of edible aquatic beetles, mostly in the families Hydrophilidae, Gyrinidae, and Dytiscidae (Ramos *et al.,* 2009). Usually, people exclusively consume these species as larvae. The palm weevil, or *Rynchophoru spp.*, is the most widely consumed edible beetle in the tropics. This major pest of palm trees occurs in South America, southern Asia, and Africa (van Huis *et al.*, 2013). The oil palm weevil (*R. ferrugineus*) inhabits Asia, (*R. phoenicis*) lives in tropical and equatorial Africa, and (*R. palmarum*) occurs in the tropical Americas. Farmers in the Netherlands raise mealworm larvae from the Tenebrionidae family, including the yellow mealworm (*Tenebrio molitor*), lesser mealworm (*Alphitobius diaperinus*), and superworm (*Zophobas morio*), as pet food for fish, birds, and reptiles. Additionally, people consider them especially suitable for human consumption, and specialty stores sell them as food.

The Palm Weevil

In Africa (*R. phoenicis*), Latin America (*R. palmarum*), and Asia (*R. ferrugineus*), people eat the larvae of the palm weevil (*Rynchophorous spp*.). Some attribute its flavour to the high fat content (Fasoranti and Ajiboye, 1993; Cerda *et al.*, 2001). The insects stay present year-round throughout the tropics, where their hosts live. Often, other insects like rhinoceros beetles (*Oryctes spp*.) or the local practice of tapping palm trees to produce palm wine damage these host trees (Fasoranti and Ajiboye, 1993). People sometimes deliberately destroy fallen palms, as they can sustain hundreds of larvae and serve as breeding grounds. According to Anankware *et al.* (2013), this is a customary behavior among the Akans and Ewes in Ghana. Semi-cultivation techniques can boost the availability and predictability of the palm weevil, according to van Itterbeeck and van Huis (2012), who observed that many indigenous people had excellent ecological understanding of the species. Anankware (2014) stated that researchers are currently investigating more sustainable methods of breeding and producing oil palm weevils (*R. phoenicis*) in the Ghanaian districts of Kade and Jema without destroying the oil palm trees.

Lepidoptera (Butterflies and Moths)

People commonly eat moths and butterflies as adults, but they also consume them in their larval (caterpillar) stages. Indigenous Australians have consumed cutworm moths (*Agrotis infusa*) (Flood, 1980), and in the Lao People's Democratic Republic, people have eaten hawkmoths (*Daphnis spp.* and *Theretra spp.*) after removing the wings and legs (Van Itterbeeck and van Huis, 2012).

The mopane caterpillar (*Imbrasia belina*) arguably stands out as the most popular and economically significant caterpillar that people consume. This caterpillar inhabits mopane forests in Angola, Botswana, Mozambique, Namibia, South Africa, Zambia, and Zimbabwe, spanning over 384,000 km^2 of forest (FAO, 2003). In southern Africa, people gather an estimated 9.5 billion mopane caterpillars each year, generating US$85 million in revenue (Ghazoul, 2006). People also consume other caterpillars to a lesser extent. Malaisse (1997) identified 38 distinct caterpillar species in Zimbabwe, Zambia, and the Democratic Republic of the Congo, while Latham (2003) found 23 edible species in the Democratic Republic of the Congo's western province of Bas-Congo.

Hymenoptera (Wasps, Bees and Ants)

Del Toro *et al.* (2012) state that many regions of the world highly prize ants as delicacies. While researchers document some adverse consequences, ants also play a crucial role in providing ecological services, such as nutrient cycling and serving as insect predators in orchards (Del Toro *et al.*, 2012). In Asia, farmers commonly use the larvae and pupae of the reproductive form, known as queen brood or ant eggs, as a food source. Farmers utilize the weaver ant (*Oecophylla spp.)* as a biological control agent on various crops, including citrus and mangoes (Van Mele, 2008). In Thailand, people find them available in cans. According to Shen *et al.* (2006), the black weaver ant (*Polymachis dives*) inhabits subtropical regions of southeast China, Bangladesh, India, Malaysia, and Sri Lanka. Manufacturers in China process ants into various tonics and health meals, using them as a nutritional ingredient. Since 1996, the State Food and Drug Administration and the State Health Ministry have approved over 30 health products that contain ants.

Consumption of (*Vespula* and *Dolichovespula spp.),* the larvae of yellow jacket wasps, is widespread in Japan. Food items produced from wasp larvae are so popular at the annual Hebo Festival (Nonaka *et al.*, 2008) that imports from Australia and Vietnam are required to meet demand due to a shortage of the local supply (Govorushko, 2019).

Orthoptera (Locusts, Grasshoppers and Crickets)

Most grasshopper species are edible, with about 80 species consumed worldwide. Locust, which form large swarms, are easy to gather. In Africa, people commonly eat desert, migratory, red, and brown locusts. However, because farmers and large-scale international programs often treat locusts with pesticides to control them as agricultural pests, there are risks involved (van Huis *et al.,* 2013). For instance, locusts collected for food in Kuwait contained high levels of organophosphorus pesticide residues (Saeed *et al.*, 1993).

Vendors frequently sell grasshoppers in local markets or as roadside snacks in Niger. Interestingly, researchers found that grasshoppers collected from millet fields sold for higher prices at local markets than those harvested from millet grains (van Huis, 2012).

In Latin America, the chapuline is likely the most well-known edible grasshopper. For decades, this small grasshopper has been a staple in local cuisine and remains popular in several regions of Mexico (Cohen et al., 2009; Durst, 2010).

Hemiptera: Homoptera (Cicadas, Leafhoppers, Planthoppers and Scale Insects)

In Malawi, people highly value many cicada species as food, including *Ioba*, *Platypleura*, and *Pycna*. They gather cicadas from tree trunks using long reeds (*Phragmites mauritianus*) or grasses (*Pennisetum purpureum*) coated with a glue-like residue, such as latex from the *Ficus natalensis* tree. Cicada wings stick to the latex, and people remove them before eating the insects. Some members of the Homoptera order, like the cochineal insect (*Dactylopius coccus*), produce products consumed by humans, such as carmine dye (E120), a bright red pigment sourced from cacti (Yen, 2005). Psyllid larvae create lerp, a crystallized, sweet fluid that people consume as well (Yen, 2005).

Hemiptera: Heteroptera (True Bugs)

In sub-Saharan Africa, especially in southern Africa, people commonly consume pentatomid bugs as food sources. In the Republic of Sudan, people roast and eat the pentatomid *Agonoscelis versicolor*, a pest of rain-fed sorghum that causes significant damage. Additionally, people use oil from these insects to prepare meals and treat camel scab illness (van Huis *et al.*, 2013). However, most pentatomids consumed are aquatic. Ahuahutle, a well-known Mexican caviar, consists of eggs from at least seven different species of aquatic Hemiptera, mainly from the *Corixidae* and *Notonectidae* families. For millennia, people in Mexico have based their aquaculture, or water farming, on these insects.

Because people can semi-cultivate these species using customary local methods, the process is easy and affordable (Yen, 2015). During Semana Santa (the week before Easter), the insects command exorbitant prices. However, severe pollution and dried-up water basins threaten Hemiptera semi-cultivation (Ramos Elorduy, 2006).

Isoptera (Termites)

The most commonly consumed termites are the large species of Macrotermes. At the end of the dry season, after the first rains, winged termites emerge from holes near their nests. In Africa, people strike termite hills to mimic heavy rainfall, causing the termites to come out (van Huis, 20013). In the Amazon, the largest termites consumed are from the Syntermes species. People retrieve the soldier termites by inserting a palm leaf rib into the nest's galleries, where the soldiers bite onto it (Lesnik, 2019). In Northern Ghana, particularly in Navrongo and nearby areas, markets frequently sell termites (Anankware *et al.*, 2013).

Insects as animal feed

According to van Huis *et al.* (2013), the world produced an estimated 870 million metric tons of feed in 2011, and the global commercial feed manufacturing industry generated around US$ 350 billion in revenue. In addition to human consumption, people have used insects as feed for pigs and poultry. In West Africa, people harvest termites in the wild and use them as fodder for poultry (Kenis and Hein, 2014). Farmers gather termite mound trimmings and feed them to farm animals, especially chicks (Kenis and Hein, 2014).

Farmers in families in the northern region of Ghana harvest several termitaria each day to augment the protein needs of their chickens. Using dried grass, cow dung, and/or corn cobs or stalks, they gather them early in the morning (before sunrise) and feed them to the birds. They feed the hens this stuff first thing in the morning and then let them go outside to graze. Farmers continue this practice in the afternoon and at night, depending on what is available (Anankware *et al.*, 2015). By feeding the birds cheap, high-quality food in this way, farmers can better manage their flocks since the birds always return on schedule for "midday lunch and dinner." This acts as a safety measure and keeps the birds from straying too far from their residence.

smaller mealworm larvae (*A. diaperinus*), and superworm larvae (*Z. morio*) as pet food for fish, birds, and reptiles.

Conclusion

Insects provide a sustainable source of protein for both human consumption and animal feed. The practice of entomophagy, or eating insects, dates back to prehistoric times and has been part of human diets for thousands of years. However, challenges remain, including the need to develop clear regulatory frameworks and adapt food laws to account for insects. To support the industry's self-regulation, scientists, businesses, and regulators must collaborate proactively. It is important to review the current rules and policies regarding food and feed ingredients. This involves contacting key regulatory bodies, identifying any obstacles, and determining areas where the existing framework needs improvement. Developing new policies will also be necessary. Collaborating with retailers, understanding consumer demands for specific standards, and engaging with authorities will help clarify what is required. For instance, organizations like Codex Alimentarius require a premarket safety assessment. Therefore, promoting both public and private standardization at national and global levels for insects used as food and feed is essential. Supporting the development of appropriate national and international standards and regulatory frameworks is crucial for the growth and formalization of the insect-based food and feed industry. Additionally, when creating and implementing regulations for insect rearing and production, it is essential to consider the potential environmental impacts and the effects of insect movement on trade and ecosystems. Regulators must give serious attention to laws related to biodiversity, disease prevention, phytosanitary measures, and environmental protection.

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