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THE ROLE OF INSECTS AS SUSTAINABLE RESOURCES IN FOOD AND TOURISM: A COMPARATIVE GLOBAL-LOCAL ANALYSIS

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ABSTRACT. *This review paper explores insects as valuable natural resources for food and their role in the nature tourism industry. Utilizing a Systematic Literature Review (SLR), the study assesses existing research on edible insects and entomotourism from a global and local perspective. Edible insects offer a sustainable and nutritious alternative to traditional livestock, with over 2000 species recognized, especially in Africa, America, and Asia. Given the growing global population and shrinking agricultural land, reliance on conventional animal protein is unsustainable. Insects can be raised in large numbers with minimal resources, presenting a viable nutritional solution. Furthermore, certain insects, like fireflies and butterflies, significantly enhance nature tourism by attracting visitors and benefiting local economies. The rise of entomotourism, particularly in Sabah, Malaysia, illustrates the revenue potential of activities such as firefly-watching. This study emphasizes insects as both a sustainable food source and a driver of economic growth in tourism, addressing food security challenges. Integrating insect-based solutions into food systems and tourism can promote ecological sustainability and nutritional security. Continuous research and policy support are essential for recognizing insects as vital components of a sustainable future. The importance of insects in ensuring food security and enhancing nature tourism cannot be overstated.*

INTRODUCTION

Importance of Insects

Insects are an incredibly valuable resource to our world. With over 1.5 million named species and an estimated 5.5 million species in total, only 1% of them can be truly considered pests (Stork, 2018; Pedigo *et al*., 2021). The rest play important roles, whether their functions are known or not. Beneficial insects such as bees, silk moths, ladybirds, and parasitic wasps provide humans with valuable resources like honey, beeswax, silk, lacquer, shellac, and cochineal dye. Additionally, insects contribute to natural ecosystems by serving as pollinators, weed killers, natural biological control agents, aiding in decomposition and nutrient cycling, and providing food for wildlife (Getanjaly, 2015). Throughout history, people from all over the world have utilized insects as valuable resources. This paper will delve into the contemporary applications of insects, specifically their role as a food source and in the tourism industry. This research utilized a Systematic Literature Review (SLR) method to thoroughly examine

existing studies on the subject by searching for pertinent research articles in Google Scholar using the specified keywords. Following an introductory evaluation of titles and abstracts, qualifying studies were chosen according to stringent inclusion and exclusion criteria, which were then followed by a detailed review of the full texts. The SLR approach improves transparency, reduces bias, and lays a structured groundwork for recognizing trends, inconsistencies, and potential research avenues in the area (Snyder, 2019).

Insects as Food

The practice of consuming insects as food and insect products such as honey, known as entomophagy, has a rich history and is enjoyed by people across Asia, Australia, Africa, and the Americas. The word entomophagy comes from two Greek words, "entomos," meaning insect, and "phagein," meaning eating (Yen, 2015). Insects can be eaten at all stages of their lives, including eggs, larvae, pupae, nymphs, or adults (Costa-Neto, 2015). They are consumed in their original form or processed and mixed with other ingredients. According to Jongema (2017), there are approximately 2,037 edible insects, including beetles, caterpillars, ants, bees, wasps, bugs, termites, dragonflies, and cockroaches. Edible insects are recognized for their potential to contribute to global food security (Nowak *et al*., 2016). Entomophagy has been viewed from two perspectives globally: first, as a vital protein source in nations facing food scarcity, and second, as an alternative protein source in developed countries, adhering to sustainable development initiatives (Skotnicka *et al*., 2021). Comparatively, ants and crickets can contain between 9% and 77% dry-weight protein, while beef contains 25% to 28% (Abril *et al*., 2022). In 2013, the United Nations Food and Agriculture Organization (FAO) emphasized this potential in a report titled "Edible Insects: Future Prospects for Food and Feed Security," highlighting the nutritional and environmentally sustainable advantages of insects as a future food source (Huis *et al*., 2013).

Various insects are consumed around the world, such as the bamboo caterpillar (*Omphisa fuscidentalis*), house crickets (*Acheta domesticus*), and giant water bugs (*Lethocerus indicus*), which are primarily consumed in Thailand (Hanboongsong *et al*., 2013). In Africa, termites (*Macrotermes* sp., Odontotermes sp.), locusts (Ornithacris magnifica, Cyrtacanthacris tatarica), and African silk moth caterpillars (*Anaphe panda*) are commonly consumed (Morris, 2004). In Borneo, people consume the larvae of the palm weevil (*Rhynchophorus ferrugineus*), mole cricket (*Gryllotalpa longipennis*), and honeybee brood (*Apis dorsata*) (Chung, 2010).

Insects are recognized as valuable sources of essential nutrients for the human body, providing energy, protein, vital amino acids, and a variety of micronutrients (Oonincx and Finke, 2021). A thorough nutritional analysis of adult crickets (*Gryllodes sigillatus*), mealworm larvae (*Tenebrio molitor*), and adult locusts (*Schistocerca gregaria*) revealed a well-balanced nutrient profile, meeting human amino acid requirements and containing significant amounts of monounsaturated and polyunsaturated fatty acids, along with specific micronutrients (Zielińska *et al*., 2015). However, their nutrient composition can vary based on species and developmental stages, as well as location, season, feed, and gut content (Nowak *et al*., 2016). Certain species, such as termites and palm weevils, have high levels of saturated fat, making them unsuitable for inclusion in the diet of populations with a high incidence of cardiovascular disease and diets centered on refined carbohydrates (Payne *et al*., 2016). Despite the wealth of literature on edible insects, significant gaps remain in available data concerning the nutritional content of major edible insect species (Payne *et al*., 2016).

The consumption of insects extends beyond developing countries in South America, Asia, and Africa; it is also practiced in developed countries in Europe and North America. In the past, entomophagy was considered normal in many European contexts (Olivadese and Dindo, 2023). However, the tradition of consuming insects in Europe has largely been avoided until recently due to the perception of insects as a threat and health risk rather than food (Mancini *et al*., 2022; Moruzzo *et al*., 2021). With a growing population and the need for substantial areas to produce livestock, the tradition of entomophagy has started to regain attention in Europe. In recent years, interest in entomophagy among European society has significantly increased. Some recent studies suggest that consumers are beginning to recognize the benefits of entomophagy (Kasza *et al*., 2023). To promote the

acceptance of entomophagy among the population in Europe, it is essential for authorities to comprehensively assess microbial contamination, toxicological hazards, and allergenic reactions (Raheem *et al*., 2018b).

The current consumption of insects has shifted from traditional practices to processing them into various forms and including them in food products to increase public acceptance (Olivades and Dindo, 2023). Studies have shown potential acceptance of entomophagy in European populations, with interest and willingness to consume insects observed in Belgium, the Czech Republic, Hungary, and Italy (Megido *et al.*, 2013; Bednářová *et al.*, 2013; Kasza *et al.*, 2023; Sogari *et al.*, 2015). However, psychological motivation and appropriate commercialization strategies are needed to mitigate the phobia of entomophagy in Italy (Toti *et al.*, 2020; Moruzzo *et al.*, 2021).

In Poland, many students are hesitant to switch from eating meat to insects due to psychological barriers such as fear and disgust (Kostecka *et al*., 2017; Orkusz *et al.*, 2020). In Switzerland, some are interested in trying insects, while others are repelled by the idea (Penedo *et al*., 2022). Although the Native people of North America, including the Inuit people of the Arctic, have a history of practicing entomophagy (Morris, 2004; Lesnik, 2019; Ferreira *et al.*, 2018), early Western settlers, much like present-day Europeans, were not prepared to adopt insects as a primary protein source. However, in recent years, there has been a growing willingness within the North American community to embrace entomophagy as a means of obtaining a more affordable protein source (Schrader *et al*., 2016).

Like the natives of North America, the aborigines of Australia also consume insects (Yen, 2005). Some insects and insect products are still enjoyed by the aborigines, such as witchetty grubs, leps from psyllid beetles, honey, and honey ants (Si and Turpin, 2015). However, surveys in Australia showed low acceptance of entomophagy by Australians of European origin due to factors such as neophobia, disgust for insects, and perceptions of masculinity (Sogari *et al*., 2019). Other influencing factors include appearance, taste, quality, and safety (Wilkinson *et al*., 2018). Nonetheless, entomophagy is expected to gain popularity in Western society, and education about it should be disseminated more widely to increase acceptance (Olivades and Dindo, 2023; Lensvelt and Steenbekkers, 2014). Unlike in Europe, Australia, and North America, the people of Asia, Africa, and South America are more inclined toward entomophagy, although many people in these areas still do not eat insects due to disgust. Historically, entomophagy has been established for a long time in these areas because insects have traditionally been food for generations (Durst and Shono, 2010).

The traditional use of insects for nutrition in Africa is significant, with insects consumed as a delicious delicacy, for emergency sustenance, or as a staple food (Hlongwane *et al.*, 2021). Entomophagy is prevalent in both urban and rural communities, with insects readily available in the environment, such as alates and termites, serving as a cost-effective source of protein. Notably, edible insects and their products are widely available in African markets (Das, 2020). Termites and alates are particularly important as a food source for Africans due to their abundance and accessibility, with villagers often collecting them for free as their primary source of protein (Morris, 2004). These insects can be consumed raw or cooked. Furthermore, a survey conducted in Côte d'Ivoire, West Africa, revealed that over half of the population practiced entomophagy, with nine common insect species being consumed, particularly saturniid moth larvae and termites, which are widely available in markets, with palm tree caterpillars preferred by 40% of respondents (Ehounou et al, 2018). Similarly, a survey in South Africa indicated that 95% of respondents occasionally consume insects, with primary reasons being nutritional benefits and cultural traditions (Hlongwane *et al*., 2021). Overall, insects are not only consumed as food in rural Africa but also serve as a livelihood, as they can be traded in other regions as a source of sustenance (Muvatsi *et al*., 2021).

The practice of entomophagy is widespread in Latin America, particularly in countries like Mexico, Peru, Brazil, Venezuela, Colombia, and Ecuador due to their rich sociocultural heritage. Mexico stands out in the region, with 450 documented species, making it the country with the highest number of recorded edible insects in Latin America. In total, there are 735 species of edible insects identified in Latin America. Additionally, Latin America is the world's second-largest market for edible

insects after the Asia-Pacific region. The larvae of beetles, butterflies, and wasps are the preferred stage for consumption due to their flatter body structure compared to adult insects with an exoskeleton. Given the considerable potential and interest in sustainable protein sources, there are ongoing efforts to further develop the edible insect food industry in Latin America, leveraging the region's rich culinary traditions and biodiversity to attract both domestic and international consumers.

As mentioned above, Asia-Pacific is the largest area for the edible insect market, with 932 species of edible insects recorded in Asia alone. In Asia, people eat a variety of bugs. In Yunnan Province, China, people eat common wasps, teak caterpillars in Java, edible wasps in Japan, edible bugs in Laos, edible bugs in the Philippines, Sri Lanka's potential as a gene pool of edible bugs, and insect nutrition in Thailand. In contrast to Europeans, Asians typically consume insects without transforming them into other forms, often eating the insects whole or with visible body parts. Consequently, it is common to find cooked insects being sold in markets.

In Asia-Pacific, most edible insects are sourced from three main outlets: wild harvesting, semi-domestication of wild insects, and farming. Harvesting insects from their natural habitats is the primary method of sourcing them for consumption in the Asia-Pacific and Africa, but this practice puts pressure on insect populations in their native habitats when insects are collected for commercial use. Establishing small- to medium-scale insect farms in residential areas is a viable way to produce edible food sources in many Asian and African countries. Insects can be reared in areas not suitable for other uses and can be fed with human food waste. The growth of the insect food market in Thailand presents an accessible opportunity for innovative entrepreneurs and small companies to offer affordable and more readily available insect-based food products, which could potentially be marketed as alternatives to meat, benefiting underprivileged communities.

Recently, the Singapore Food Agency has approved 16 species of insects for human consumption after a thorough scientific assessment. The approval follows a comprehensive scientific assessment that considered the practices of other countries and regions, such as the European Union, Australia, New Zealand, South Korea, and Thailand, where certain insects are already consumed as food, allowing the import of certain insect species and products with low regulatory concerns. As a country well-known as a global financial hub and highly developed economy, this recent development in Singapore will enhance the trade of edible insects in this region.

In a 2010 study, it was found that there are at least 80 species of edible insects consumed in Borneo, with over 60 species recorded in Sabah. These insects include sago grubs, grasshoppers, honeybee broods, crickets, termites, cicadas, rice bugs, beetles, and weaver ants. In the context of species diversity, beetles are notably the most consumed insects by the community in Sabah. There have been records of 9 beetle species consumed as edible insects in this region. Notably, the larvae of sago grubs, known as Butod in Sabah and Si'et in Sarawak, are popular in these regions. There are various methods for preparing these edible insects, ranging from simple boiling to frying with local spices and herbs. In Sarawak, the Lelamas, an edible leaf caterpillar, is highly valued, particularly among the Melanau community. This exotic food is only available from January to August and can fetch a price ranging from RM300 to RM600 per kilogram, providing additional income to the local residents. Furthermore, in Kalimantan, over 25 species of edible insects have been documented.

Regrettably, there is a noticeable deficiency in entomophagy research conducted in Borneo, particularly regarding the local community's willingness to engage in entomophagy and the sustainable harvesting of edible insects from natural habitats. Most of the available information on entomophagy in Borneo is limited to newspaper reports. Additionally, edible insects are solely sourced from the wild environment, and there is currently no established edible insect farming industry in Borneo.

Insects in Tourism Industry

The concept of entomological ecotourism traces its origins to the expeditions of renowned naturalists such as Charles Darwin and Alfred Russel Wallace, whose travels to uncharted territories provided them with the opportunity to gather, investigate, and marvel at insects from diverse global regions. While the term "entomotourism" appears to have entered formal discourse relatively recently, this niche form of tourism, which centers around insects, has captivated travelers with a penchant for observing, studying, or engaging with insects in their native habitats. Evolving as a distinctive and valuable facet of eco-tourism, entomotourism represents a burgeoning field focused on the observation and study of insects, offering educational, conservation, and experiential benefits (Fiffy *et al*., 2023).

By raising awareness regarding the significance of insects and their ecosystems, entomotourism, through sustainable practices, holds promise for the preservation of insect biodiversity while nurturing a deeper connection with the natural world. Its allure lies in the opportunity it affords to explore the often-overlooked realm of insects, fostering both appreciation and understanding of these vital yet frequently underestimated organisms. In essence, entomotourism emerges as an expanding domain offering significant educational, conservation, and experiential advantages; thereby, it assumes a pivotal role in promoting awareness about the importance of insects and their habitats, supporting conservation endeavors, and delivering distinctive and enriching travel experiences. Through the advocacy of sustainable practices and responsible tourism, entomotourism stands poised to contribute to the safeguarding of insect biodiversity while fortifying the profound connection between individuals and the natural world.

In Western countries such as Europe and North America, and now in Asia, butterfly and insect pavilions in museums and zoos have become international tourist attractions. In the past, people visited museums to see preserved insect collections. Insect collecting, especially butterflies, is a leisure activity in most countries, with collectors primarily being naturalists from the West (Veltman, 2013). Today, live butterfly exhibits have become attractions in North America, Europe, and Asia, leading to the importation of live specimens from Central and South America, Africa, and Asia (Veltman, 2013). Apart from live butterflies, various types of live insects are also exhibited, such as beetles, stick insects, and leaf insects.

Recently, there has been a growing interest in observing insects in their natural habitats, attracting international tourists to engage in entomotourism activities. Notable examples include butterfly watching in various locations such as Turkey, the United States, and Costa Rica (Çelik and Topsakal, 2017; Quinn and Klym, 2009; Henderson, 2002), monarch butterfly (Danaus plexippus) watching tourism in Mexico (Monterrubio *et al*., 2013; Solis-Sosa *et al*., 2019), firefly watching in Thailand, Malaysia, and the United States (Nurancha et al., 2013; Syazlina *et al*., 2016; Lewis *et al*., 2021), glow-worm tourism in Australia and New Zealand (Hall, 2013), and insect festivals in Europe (Hvenegaard *et al*., 2013). Entomotourism is often associated with entomophagy, where tourists visit countries known for their edible insects, such as Thailand, to indulge in insect delicacies.

The Malaysian rainforest is home to a diverse range of insects, offering significant potential for entomotourism. Travelers are attracted by the opportunity to observe and study the behavior and morphology of these insects. For example, the enchanting spectacle of fireflies in Kuala Selangor serves as a major attraction for visitors, thereby contributing to the economic growth of local tourism operators (Nadirah and Wan Norhidayah, 2020; Nadirah *et al*., 2021; Li and Nitanan, 2022). This firefly viewing tourism activity is not only able to provide additional income to the locals but also indirectly helps conserve the mangrove swamp area that is the habitat of the fireflies (Mahadimenakbar *et al*., 2009). In Sabah, there are also numerous tourist areas that offer firefly-watching activities, such as Weston, Sungai Garama, Sungai Klias, Kota Belud, and Lower Kinabatangan (Mahadimenakbar *et al*., 2003; Mahadimenakbar *et al*., 2007; Mahadimenakbar and Fiffy, 2016). Additionally, butterflies have captured substantial attention from tourists in various regions of Malaysia, including Kuala Lumpur, Penang, Malacca, Cameron Highland, and Sabah. Over recent years, entomotourism has emerged as a family-friendly recreational tourism option in Malaysia, often categorized under nature or ecotourism, thus playing a crucial role in raising public awareness for insect conservation (Fiffy *et al*., 2023). There are several notable butterfly farms that merit exploration. These include the Kuala Lumpur Butterfly

Park in the capital city of Kuala Lumpur, Entopia by Penang Butterfly Farm situated in Penang, the Melaka Butterfly and Reptile Sanctuary in Malacca, as well as the Poring Butterfly Garden and Kipandi Butterfly Park in Sabah. These establishments not only house various species of butterflies but also feature an array of unique insects and small creatures, including reptiles, for public viewing and study.

CONCLUSION

The practice of entomophagy is gaining increasing attention in developed countries like Europe and North America due to rising awareness of environmental sustainability. Various studies assessing the acceptance of edible insects among residents have shown a positive response, especially when the insects are processed before consumption. Additionally, authorities in developed countries have issued specific guidelines that must be followed before a species of insect can be commercially utilized, underscoring the importance of ensuring consumer safety. In contrast, there is a significant lack of research on entomophagy in Malaysia, including studies that evaluate consumer willingness to adopt entomophagy practices. Furthermore, the commercial conservation and production of edible insects in Malaysia remain limited.

Entomotourism, however, has considerable potential for promoting conservation efforts in local communities and attracting international visitors. By embracing entomotourism, developing countries have acknowledged the positive outcomes resulting from increased tourist engagement. This trend is particularly advantageous for environmental conservation efforts.

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