THE CONTRIBUTION OF INSECTS TO SUSTAINABLE FOOD SECURITY, LIVELIHOODS AND ENVIRONMENT: A REVIEW

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Abstract

Despite the strong aversion shown to entomophagy due to civilization and other socio-cultural influence, insects have played an important role in the history of man's nutrition worldwide. Hundreds of species have been used as human food and medicine. Some of the more important groups include; grasshoppers, caterpillars, beetles, winged termites, bees, wasp, cricket and a variety of aquatic insects. Insects provide food at low environmental cost, contribute positively to livelihoods, and play a fundamental role in nature. However, these benefits are largely unknown to the public. Contrary to popular belief, insects are not merely "famine foods" eaten in times of food scarcity or when purchasing and harvesting "conventional foods" becomes difficult; many people around the world eat insects out of choice, largely because of the palatability of the insects and their established place in local food cultures. Insects deliver a host of ecological services that are fundamental to the survival of mankind. They also play an important role as pollinators in plant reproduction, improving soil fertility through waste bioconversion, and in natural biocontrol for harmful pest species, and they provide a variety of valuable products for humans such as honey and silk. Insects have been reared as mini-livestock at household level or industrial scale. The exportation and domestic sale of insects' products like honey, silk, generate huge amount of revenue and thus serves as a means of livelihood to the insect farmers. Findings from the current review thus enumerate the immeasurable contributions of insects and insect products to food security, livelihoods and environment. It was recommended that Insects farming should be encouraged in Nigeria through training and sponsoring; further documentation is needed on the nutritional values of insects in order to more efficiently promote insects as healthy food.

Keywords: Entomophagy, Insects, Livelihoods, consumption, Grasshoppers.

Introduction

Insects are class of animals within the arthropod phylum that have a chitinous exoskeleton, a three-part body (head, thorax and abdomen), three pairs of jointed legs, compound eyes and two antennae. They are among the most diverse groups of animals on the planet: As a group, insects have become one singular factor that has influenced the entire life system (Abajue, Ewuim and Akunne, 2013).There are more than one

million described species, which is more than half of all known living organisms. The total number of species is estimated at 6 to10 million, and the class potentially represents over 90 percent of the differing animal life forms on earth (Camilo, Derek, Tittensor, Alastair and Simpson, 2011). Insects may be found in nearly all environments, although only a small number of species occur in the oceans, a habitat dominated by another arthropod group, the crustaceans (Food and Agriculture Organization, 2013).

The practice of eating insects as food is known as entomophagy (Astrid, 2018). It can be divided into two categories: insects used as nutrients source and others as condiments. Insects have been emphasized as a food source with a low environmental impact due to the limited requirement for arable land and water, low ecological cost, and high-quality protein provision (Fabio, Brunella, Roberto, and Pietro, 2020). In Europe and Western countries, insect farming is a growing business in which, however, some critical economic aspects must be recognized (Fabio, *et al.*, 2020).People throughout the world have been eating insects as a regular part of their diets for millennia. Entomophagy is practiced in many countries around the world but predominantly in parts of Asia, Africa, Australia and Latin America (FAO, 2013; Adeoye, *et al*, 2014). Hundreds of species have been used as human food. Some of the more important groups include grasshoppers, caterpillars, beetle grubs and (sometimes) adults, winged termites (some of which are very large in the tropics), bee, wasp and ant brood (larvae and pupae) as well as winged ants, cicadas, and a variety of aquatic insects (Adeoye*et al*., 2014).

Insects supplement the diets of approximately 2 billion people and have always been a part of human diets (Ash, *et al*, 2010; Smith, 2012; Adeoyeet *al*., 2014). However, it is only recently that entomophagy has captured the attention of the media, research institutions, chefs and other members of food and feed (Vogel, 2010; FAO, 2013). The utilization of insects as a sustainable and secure source of animal-based food for the human diet has continued to increase in popularity in recent years (Ash *et al*., 2010; Dzamba, 2010; Premalatha, Abbasi and Abbasi, 2011; Crabbe, 2012; Dossey, 2013; Van Huis, 2013). Using insects in innovative business models would environmentally, socially, and economically improve the performance of agri-food systems (Govorushko, 2019).

A common misconception of insects as food is that they are only consumed in times of hunger. However, in most instances where they are a staple in local diets, insects are consumed because of their taste, and not because there are no other food sources available (Van Huis, Itterbeeck, Klunder, Mertens, Halloran, Muir and Vantomme, 2013; FAO, 2013). Certain insect species, such as mopane caterpillars in southern Africa and weaver ant eggs in Southeast Asia, can fetch high prices and are hailed as delicacies (Rumpold and Schlüter, 2013).Entomophagy is heavily influenced by cultural and religious practices, and insects are commonly consumed as a food source in many regions of the world (Nonaka, 2009; Ramos-Elorduy, 2009). In most Western countries, however, people view entomophagy with disgust and associate eating insects with primitive behaviour. This attitude has resulted in the neglect of insects in agricultural research. Insects as food and feed emerge as an especially relevant issue in the twenty first century due to the rising cost of animal protein, food and feed insecurity, environmental pressures, population growth and increasing demand for

protein among the middle classes (Vantomme, *et al,* 2012; FAO, 2013).The traditional production of animal feed such as fishmeal, soy and grains needs to be further intensified in terms of resource efficiency and extended through the use of alternative sources. By 2030, over 9 billion people will need to be fed, along with the billions of animals raised annually for food and recreational purposes and as pets. Moreover, externalities such as land and water pollution from intensive livestock production and over-grazing are leading to forest degradation, thereby contributing to climate change and other environmentally destructive impacts. (FAO, 2013). Thus, alternative solutions to conventional livestock and feed sources urgently need to be found.

One of the many ways to address food and feed security is through insect farming (FAO, 2013; Adeoye*et al*., 2014). Insects are everywhere and they reproduce quickly, and they have high growth and feed conversion rates and a low environmental footprint over their entire life cycle. They are nutritious, with high protein, fat and mineral contents (Adeyeye and Olaleye, 2016). They can be reared on waste streams like food waste, moreover, they can be eaten whole or ground into a powder or paste and incorporated into other foods (FAO, 2012,). The use of insects on a large scale as a feed ingredient is technically feasible, and established companies in various parts of the world are already leading the way in this regard. Insects as feedstock for aquaculture and poultry feed are likely to become more prevalent within the next decade (Rumpold and Schluter, 2013).The consumption of insects, or entomophagy, therefore contributes positively to the environment and to health and livelihoods (Wageningen University and Research Centre (WUR), 2013).

Insect and Food Security

Insect as Source of Sustainable Human Food

It is estimated that insects form part of the traditional diets of at least 2 billion people. More than 1900 species have reportedly been used as food. Insects deliver a host of ecological services that are fundamental to the survival of humankind (FAO, 2012). They also play an important role as pollinators in plant reproduction, in improving soil fertility through waste bioconversion, and in natural biocontrol for harmful pest species, and they provide a variety of valuable products for humans such as honey and silk and medical applications such as maggot therapy (Atanu, 2017).

Insects can be found in abundance throughout the African continent and when staples are scarce they become important sources of food (Adeoye*et al*., 2014). During the rainy season, when hunting game or fish can be problematic, insects play an important role in food security. Caterpillars are especially popular during the rainy season, although their availability can vary even within the same country depending on climatic conditions (Vantomme and N'Deckere-Ziangba, 2004). The seasonal availability and correlated consumption of insects is well documented by Takeda and Sato (1993). A study carried out in tropical rainforest in the Democratic Republic of the Congo shows the remarkable resourcefulness of the Ngandu people, who obtain nourishment from what is seasonally available, cultivated and wild-gathered plants, mushrooms, mammals, birds, fish, reptiles and insects (Latham,1999).

FAO (1995) notes that insects are also important Non Wood Forest Products that poor people gather, particularly women and children. Insects are a popular food in many cultures all over the world, be it as an occasional delicacy or as a replacement food in

times of shortages, droughts, floods or war. Insects and meat play the same role in the human body (Nkouka, 1987). As food, caterpillars are regulars in the village but meat is a stranger. Insects can be a good source of not only protein, but also vitamins, minerals and fats (Atanu, 2017). Many insects contain abundant stores of lysine, an amino acid deficient in the diets of many people who depend heavily on grain (Defoliart, 1992; Van Huis, 2003; Astrid, 2018).

In addition, insects have assumed their place in human cultures as collection items and ornaments and in movies, visual arts and literature. Globally, the most commonly consumed insects are beetles (Coleoptera) (31 percent), caterpillars (Lepidoptera) (18 percent) and bees, wasps and ants (Hymenoptera) (14 percent). The following are grasshoppers, locusts and crickets (Orthoptera) (13 percent), cicadas, leafhoppers, planthoppers, scale insects and true bugs (Hemiptera) (10percent), termites (Isoptera) (3 percent), dragonflies (Odonata) (3 percent), flies (Diptera) (2percent) and other orders (5 percent) (Jongema, 2012) (Figure 1). Lepidoptera are consumed almost entirely as caterpillars and Hymenoptera are consumed mostly in their larval or pupal stages. Both adults and larvae of the Coleoptera order are eaten, while the Orthoptera, Homoptera, Isoptera and Hemiptera orders are mostly eaten in the mature stage (Cerritos, 2009).In Nigeria, many insects are edible and can be consumed to combat hunger and malnutrition. Fasoranti and Ajiboye (1993) reported the consumption of 7 edible insect species by the people of Kwara State.

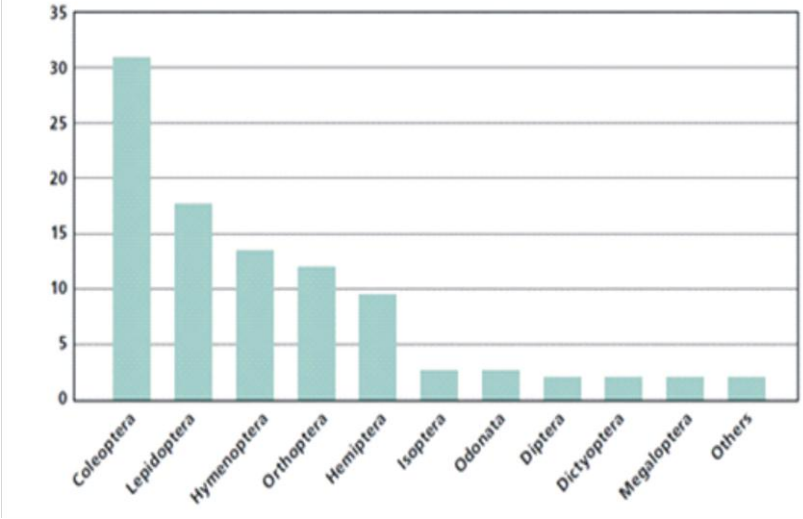

Figure 1: Number of insect species, by order, consumed worldwide
Source: Jongema, (2012).

Examples of Important Insect Species Consumed
Caterpillar

Caterpillars are among the world's most diverse groups of edible insects. They are not only valuable sources of protein and other micronutrients, they also make valuable contributions to livelihoods in many parts of the world. Among the most renowned are the witchetty grubs consumed in Australia (Meyer-Rochow, 2005) and the bamboo caterpillar (*Omphisafuscidentalis*), which is popular in Thailand and the Lao People's

Democratic Republic (Yhoung-Aree and Viwatpanich, 2005).The consumption of caterpillars (Figure 2), is especially pervasive in sub-Saharan Africa including Nigeriawhere 30 percent of all edible insect species are caterpillars (Van Huis, 2003; Agbidye, Ofuya and Akindele, 2009).Listed 38 species of edible caterpillars on the basis of intensive studies in the region inhabited by the Bemba (Bantu-speaking people in the northeastern plateau of Zambia and neighbouring areas of the Democratic Republic of the Congo and Zimbabwe). In the Democratic Republic of the Congo, caterpillars make up 40 percent of the total animal protein consumed (Latham, 2003). The most popular and profitable caterpillar on the African continent is undoubtedly the mopane caterpillar, Imbrasia (Gonimbrasia) belina and in Nigeria, *Anaphevenata* (Adeoye*et al*., 2014).

Plate 1: Freshly prepared caterpillar
Source: Wild School Food (2013)

Palm Weevil

Larvae of the palm weevil (*Rynchophorous* spp.) are consumed in Asia (*R. ferrugineus*), Africa (*R. phoenicis*) and Latin America (*R. palmarum*). Their delicious flavour (Cerda *et al.*, 2001) is credited by some to their elevated fat content (Adeyeye and Olaleye, 2016). In the tropics, the insects occur year round where hosts are found. Often these hosts are trees under stress; that is, trees previously damaged by other insects, notably rhinoceros beetles (*Oryctes*spp.) or by the local traditional tapping for palm wine (Adeyeye and Olaleye, 2016).Palm weevil larvae are typically collected, washed and fried for consumption(Figure 3). (Agbidye*et al*., 2009; Adeyeye and Olaleye, 2016). It is unusual to add oil because the larvae are high in fat and exude oil during the frying process. Common condiments include onion, pepper and salt. Barbecuing the larvae is also common practice. In Nigeria, adults discourage children

from eating palm weevil larvae. It is thought that this is done to prevent children from felling palm trees, which can increase breeding sites for the available stock of number of larvae to be harvested in the short term but would cause irrevocable long-term damage to host trees (Adeyeye and Olaleye, 2016).

Plate II: Freshly Prepared Palm weevil
Source: Wild School Food (2013)

Termites

In the Western world, termites are generally synonymous with pests and are renowned for their capacity to devour wood. Damage from termites is said to cost over half a billion dollars per year in the United States of America alone. Yet termites are considered a delicacy in many parts of the world (Adeoye, *et al.*, 2014). They are consumed both as main and side dishes, or simply eaten as snack foods after they have been de-winged, fried and sun-dried (Kinyuru, Kenji, and Njoroge, 2009).Queen termites are considered particularly important delicacies, (Figure 4) often reserved for

special occasions (Van Huis, 2003). Their nutritional value is so high that in Uganda and Zambia they are fed to undernourished children. However, digging queens which are capable of laying 2000 eggs per day and measure up to 10 cm in diameter is laborious, and their removal causes the death of entire colonies (FAO, 2013).

Plate III: Freshly Prepared Termites
Source: Adeoye*et al.* (2014)

Insects as Animal Feed

In addition to the tremendous potential that insects hold as primary sources of human food and other directly consumed products, they also present a promising opportunity in their use as intermediate products such as animal feed (Van Huis, 2013; Jozefiak and Engberg 2015). Considering the substantial efficiency, sustainability, and nutritional aspects of insects as described in this chapter, the logic easily follows as to how they might provide similar value when utilized in the vertebrate livestock industry, or even in vertebrate animal production at the subsistence level. For example, early stages of poultry, fish, ostrich, and pig, which were raised on insects, had conversion efficiency values of 1.24:1–2.83:1 (Ramos-Elorduy, 2008).Insects fed with biomass such as manure and certain forms of agricultural or other organic waste may not be safe, suitable, or acceptable if used directly as a human food ingredient. However, such insects can be perfectly safe when used as feed for vertebrate animals, such as fish and chicken, which are more commonly eaten by most human populations. Using insects in this way can also provide some of the aforementioned food production sustainability benefits while avoiding social stigmas or food safety concerns. For example, in some studies, insects such as the black solder fly have been explored and developed for chicken and fish feed in a sustainable and efficient nutrient-recycling paradigm due to their ability to be reared entirely on waste such as animal manure and other agricultural or food industry waste streams (St-Hilaire, Cranfill, McGuire, Mosley, Tomberlin, Newton, Sealey, Sheppard and Irving, 2007). Indeed, several companies and organizations around the world, even in the United States, are beginning to develop various insects as animal feed. Black soldier fly appears to be one of the species favored for this type of application. The topic of use of insects as animal feed is fascinating and

critical for the larger picture of how insects can greatly improve human food security (St-Hilaire*et al.*, 2007).

Insects as Engine for Improving Livelihood

For most people living in rural areas, especially the poor, insects are important sources of food and cash income. Some 350 million of the world's poorest people including 60 million indigenous peoples depend on insects for their daily subsistence and long-term survival (FAO, 2012). Insects are a major source of animal protein in many communities and are critical for diet diversification but, in most countries, eating insects is not a matter of survival but a question of personal choice. In fact, the vast majority of insect consumption is by choice, not necessity, and insects are a part of local culture. Nevertheless, insects do provide valuable buffers against seasonal shortages of food (Dufour, 1987). As well as acting as important food items, insects provide additional cash for basic expenditure, including on food, farming inputs and education

(Agea, Biryomumaisho, Buyinza and Nabanoga, 2008; Hope, Frost, Gardiner and Ghazoul,2009).Cooked edible insects are sold commercially at roadside food stalls as well as markets in various cities of Nigeria (Agbidye, *et al.*, 2009).Agbidye *et al*. (2009) reported 4 commercially marketed edible forest insect in Benue State. Most of these insect species are found in the order Isoptera (termites), Lepidoptera (Moths), Orthoptera (Grasshoppers/crickets), Coleoptera (Beetles) and Hymenoptera (Bees).Gathering and/or farming insects can offer unique employment and income earning opportunities in developing countries, particularly, but not exclusively, for the poor in urban and rural areas. In many cases, insect collection and cultivation can serve as a livelihood diversification strategy that provides multiple income generating opportunities for households (Agbidye *et al*., 2009). For example, silkworms, ants and bees can be considered as multipurpose production systems: silkworms can be used for food and fibre, and weaver ants (*Oecophylla*spp.) combat pests and can be used as food (Offenberg and Wiwatwitaya, 2009). In the case of bees, both the honey and the larvae can be harvested as food. For example, the Hazda foragers of Tanzania do not remove the bee larvae from the combs when eating the honey (Murray, Schoeninger, Bunn, Pickering and Marlett, 2001).Honeybee (*Apismellifera*) supply to humankind millions of kilograms of honey and beeswax. Beeswax is obtained from its combs and is used in making candles, cream, polish, carbon ribbons, papers, cosmetics and certain oilments. Honey is a natural antiseptic and valuable tonic for human body. The lac insects, *Tacchardialacca*, secrete lac in the form of protective covering. The lac is used in the manufacture of shellac, varnish, polish, buttons, bangles, pots, sealing wax, toys and some electrical items (www.entomoljournal.com).

Insect and Environment

Edible insects inhabit a large variety of habitats, from aquatic ecosystems and farmed land to forests. Until recently, insects were seemingly inexhaustible resource obtainable by harvesting from nature. However, some edible insect species are now in peril. A number of anthropogenic factors, such as overharvesting, pollution, wildfire and habitat degradation, have contributed to a decline in many edible insect populations.

Climate change will likely affect the distribution and availability of edible insects in ways that are still relatively unknown (FAO, 2013).

Insects promoted as food emit considerably fewer greenhouse gases (GHGs) than most livestock (methane, for instance, is produced by only a few insect groups, such as termites and cockroaches). Insect rearing is not necessarily a land based activity and does not require land clearing to expand production. Feed is the major requirement for land, the ammonia emissions associated with insect rearing are also far lower than those linked to conventional livestock, such as pigs. Because they are cold-blooded, insects are very efficient at converting feed into protein (crickets, for example, need 12 times less feed than cattle, four times less feed than sheep, and half as much feed as pigs and broiler chickens to produce the same amount of protein). Insects can be fed on organic waste streams (Premalatha, *et al*., 2011; Wageningen University and Research Centre (WUR.). **(**2013).

Insects deliver a host of ecological services fundamental to the survival of human kind.For instance, insects play an important role in plant reproduction (Crespo-perez, kazakou, Roubik and Cardenas, 2020). An estimated100 000 pollinator species have been identified and almost all of these (98 percent) are insects (Ingram, Nabhan and Buchmann, 1996; Atanu, 2017). Over 90 percent of the 250 000flowering plant species depend on pollinators. This is also true for three-quarters of the 100 crop species that generate most of the world's food (Ingram *et al*., 1996). Domesticated bees alone pollinate an estimated 15 percent of the species. The importance of this ecological service for agriculture and nature more generally is undisputed. Insects play an equally vital role in waste biodegradation (FAO, 2012). Beetle larvae, flies, ants and termites clean up dead plant matter, breaking down organic matter until it is fitto be consumed by fungi and bacteria. In this way, the minerals and nutrients of dead organisms become readily available in the soil for uptake by plants. Insects also maintain soil structure and fertility and control pollution of other organisms e.g. *Chaloids* and *Icheumon* flies are parasitic forms which lay eggs in cocoons and larvae of phytophagous Lepidoptera. Similarly, larvae of *Tachina* fly are parasites of the lepidopterous larvae (Astrid, 2018).

Conclusion

This review confirms the existence of entomophagy in Nigeria. Considering the economic, nutritional and ecological advantages of this traditional food source, its promotion deserves more attention both from national governments and assistance programmes. To manage insects in the interest of food security more attention should be given to environmentally sustainable harvesting methods. In other words, most preferred edible insects, especially those with high nutritional content, can be reared or cultivated in the home gardens with the application of modern tools and techniques and sold to the people, who regard them as delicacies. In the long run, this may serve the twin purpose of insect (natural resource) use as food and conservation.

Finally, there is need for research on industrial scale mass-production of edible insects, for increased recognition of the nutritional and environmental importance of insects by national governments, and for increased involvement of the media and academia in dispelling unfounded cultural biases inthe urban dwellers toward insects as food. Collecting these forest edible insects would not only protect their host plants but it could benefit the environment by reducing the need to use pesticides (DeFoliart, 2005).

Recommendations

Based on the findings of the review, the following recommendation were made: Insects farming should be encouraged in Nigeria through training and sponsoring; further documentation is needed on the nutritional values of insects in order to more efficiently promote insects as healthy food; the environmental impacts of harvesting and farming insects should be investigated to enable comparison with traditional farming and livestock rearing practices that may be more environmentally damaging; clarification and augmentation of the socio-economic benefits that insect gathering and farming can offer is needed, particularly to enhance the food security of the poorest of society; a clear and comprehensive legal framework at national levels is needed to pave way for more investors, leading to the full development from the household to the industrial scale of production and international trade in insect products as food and feed sources.

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