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Insects as a Food: An Overview

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Abstract
Trends towards 2050 predict a steady population increase to 9 billion people, forcing an increased food/feed output from available agro-ecosystems resulting in an even greater pressure on the environment. Edible insects contain high quality protein, vitamins and amino acids for humans. Insects have a high food conversion rate, e.g. crickets need six times less feed than cattle, four times less than sheep and twice less than pigs and broiler chickens to produce the same amount of protein. Tiny insect taste as pumpkin seeds. Compared to their vertebrate counterparts in traditional husbandry, insects are extremely efficient at converting organic matter into animal protein and dietary energy.

Keywords: edible insects, protein, amino acids, vitamins

Introduction
Insects for human food consumption and animal feed are attracting increasing attention for their potential ability to address some of the most poignant issues threatening our environment. The main reason for this is the high feed conversion efficiency of insects and their ability to feed on various feed sources (Van Huis *et al*., 2013; Halloran *et al*., 2014) [18]. In the face of growing threats to global food security, insects are being considered as a new source of human food and animal feed in Europe and the US (Van Huis *et al.*, 2013) [18]. The reported benefits of the human consumption of insects as an alternative to conventional food animals are numerous, including comparable levels of protein (Testa *et al.*, 2016) [15]. Insect rearing can be done not only in large-scale producing units, but also on a small scale in the backyard. Setting up small cricket-rearing units is possible for even a single person, as well as in urban areas and with little investment. Rearing insects can help the poor to grow additional food and earn money by selling off excess production to local markets. (Halloran *et al.*, 2014). While insects as food may seem like some new high in protein ‘superfood’ for a growing but still quite limited number of ‘adventurous’ consumers in the West, insects are and have always been part of the traditional diets of approximately 2 billion people worldwide (FAO, 2013; Van Huis, 2013) [18]. Some 2000 species of insects are used for food (Jongema, 2012) [7]. Levels of acceptance of insects as a human foodstuff are generally found to be low (Vanonhacker *et al.*, 2013; Verbeke, 2015) [17, 16]. Study, which found that 64% of American research participants were reportedly willing to consume some form of insect-based food. Studies have also identified contradictory findings relative to age, with youth predicting acceptance in some cases (Verbeke, 2015) [16] but not others (Hartmann *et al.*, 2015) [6]. Substantial differences in findings are possibly attributable to differences in the country of study and research design (Payne *et al.*, 2016) [11]. Insects as both food and animal feed has developed rapidly over the past decade. A growing number of scholars from a variety of scientific fields such as entomology, livestock science, protein chemistry, human nutrition, and environmental science have become interested in this new interdisciplinary area. By now, the use of edible insects is rapidly outgrowing their novelty status and they are starting to be seriously considered as food on national, regional, and local levels (Halloran *et al.*, 2015). While insects for food and feed show great potential as an environmentally friendly choice, there is still very limited information to enable an assessment of the sustainability of the production systems to be undertaken. (Notarnicola *et al.*, 2015) [8]. Historically, most insects consumed for food have been harvested from natural forests. But, even though insects account for the greatest amount of biodiversity in forests, they are the least studied of all fauna by far. Surprisingly little is known, for example, about the life cycles, population dynamics and management potential of many edible forest insects. Similarly, little is known of the impacts that overharvesting of forest insects might have on forest vegetation, other forest fauna and the ecosystems themselves. In many parts of the world where insect eating has been a common element of traditional culture, the practice is waning due to modernization and changing attitudes. In these areas, reviving the tradition of eating insects has significant potential to improve rural

livelihoods, enhance nutrition and contribute to sustainable management of insect habitats. The outcome will not be the reduction of hunger *per se*, but could contribute to revitalizing traditional cultures, instilling a sense of connection with nature and fostering a better understanding of the role of humans in the natural world.

Edible Insects

There are more than 1900 edible insect species and the most important ones are in the orders of *Coleoptera* (beetles), *Lepidoptera* (butterfly and moths), *Hymenoptera* (bees, wasps and ants), *Orthoptera* (grasshoppers and crickets), *Isoptera* (termites), *Hemiptera* (true bugs), and *Homoptera* (cicadas).(Anonymous, 2013) [1].

The consumption of 250 insect species in Africa, 549 in Mexico, 180 in China, and 160 in the Mekong area. Although Japan is not a tropical country, a number of insect species are popular food.

Insect as Food and Feed

Edible insects contain high quality protein, vitamins and amino acids for humans. Insects have a high food conversion rate, e.g. crickets need six times less feed than cattle, four times less than sheep, and twice less than pigs and broiler chickens to produce the same amount of protein. Besides, they emit less greenhouse gases and ammonia than conventional livestock. Insects can be grown on organic waste. Therefore, insects are a potential source for conventional production (mini-livestock) of protein, either for direct human consumption, or indirectly in recomposed foods (with extracted protein from insects); and as a protein source into feedstock mixtures Since 2003, FAO has been working on topics pertaining to edible insects in many countries worldwide. FAO's contributions cover the following thematic areas (Anonymous, 2013) [1].

Preparation and processing of edible insects

Insects are often consumed whole, but can also be peeled and processed. Western societies might be reluctant to consume whole insects and therefore insect-based flour, granules and pastes that are included in other products can offer alternatives (FAO, 2013). It is also possible to extract protein, fats, chitin, minerals and vitamins from insects. However, these procedures can be costly and development is needed to make them applicable for industrial use (FAO, 2013). Products such as protein-enriched porridge, taco bread, muffins and snacks have been developed. Preservation of insects and insect products is an area that needs to be further developed.

Nutrient composition and nutritional value of insects

The nutrient content of insects varies considerably between species and also between the different development phases. The crude protein and fat content is generally high. The amino acid profile differs between insect species, but it appears that many species may contribute well to an optimal diet for humans, even very small children. The nutrient data available are from samples of animal feed where intact insects are likely to have been used. When consumed by humans, insects are often peeled (wings and legs are removed), which should result in an increase in the relative protein and fat contents, since wings and legs are part of the exoskeleton, which is high in carbohydrates such as chitin. In addition, further studies are needed on whether the nutrient composition is affected by other types of processing prior to consumption
(Anonymous, 2015) [2].

Table 1: Nutrient composition and nutritional value of insects

Edible insects (based on dry matter)	Protein (%)	Fat (%)	Fibre (%)	Energy content (kcal/100g)	Origin
African palm weevil (larvae) *Rhynchophorus phoenicis*	35.63	19.50	-	479.14	Nigeria
Western honey bee (larvae) *Apis mellifera*	42	19.00	1.00	475	Mexico
Asian weaver ant *Oecophylla smaragdina*	53.46	13.46	15.38	-	Thailand
Domesticated silkworm (larvae) *Bombyx mori*	58.00	35.00	2.00	555.00	Mexico
Mopane caterpillar (larvae) *Imbrasia belina*	54.26	23.38	-	-	Nigeria

Source: adapted from (Rumpold and Schlüter, 2013) [12]

Interaction between edible forest insects and forest ecosystems

Insects, edible and non-edible alike, are key life forms in forest ecosystems, functioning as pollinators, aiding in the decomposition of dead plants and animals and aerating soil through their burrowing. Insects are important food sources themselves for birds, reptiles, etc. and even provide food directly to carnivorous plants such as the Venus Flytrap (*Dionaea muscipula*). In some cases, mutualistic symbiotic relationships have evolved; for example, between ants and acacia trees, where apparently in exchange for nutritious leaf sap the ants protect the leaves from leaf-cutting caterpillars. The scientific identities and details about the life cycles of many forest insects are not known. Forest degradation and clearing may unintentionally disrupt the life cycle of an insect species and could result in its extinction. Globally, this represents the leading cause of insect extinctions. Insects account for the greatest amount of biodiversity in forests, but are the least studied of the biota.

A few edible insects enhance their habitat in specific ways. For example leaf-cutter ants in South America, cultivate "fungus gardens" that convert cellulose into carbohydrates; termites in Africa increase local plant species diversity because some plants can only grow on termite mounds (DeFoliart, 1997) [4]. Overexploitation of food insects for socio-economic purposes is a danger in some areas. In Hidalgo, Mexico, field studies revealed that out of about 30 species of insects used as food, 14 species are under threat as a result of current levels of commercialization. Previously, insects primarily had been gathered for local subsistence purposes. Because edible insects are not recognized at the national level as a food resource, there are no regulations on the exploitation of natural populations. The culture of edible insects would seem to be the most practical remedy because their care is simple and has minimal environmental impact (Ramos-Elorduy, 2006) [13].

Technical support for rearing edible insects

The culture of eating insects is based on its collection from the wild. It is possible to treat them as mini-livestock. Some arthropods are already reared on an industrial scale such as edible scorpions in China. Others, such as crickets and water beetles, are reared on semi- industrial scales. In temperate zones, insect rearing companies produce insects as feed for reptiles and primates. In the Netherlands three such insect growers have set up special production lines to produce for human consumption. In other parts of the world attempts are being made to rear insects artificially such as palm weevil, mopane worm, and wasps. Mass rearing methods for maggots and soldier flies as livestock feed are available. These are grown on side streams reducing organic waste disposal problems.

Energy consumption

Insects are poikilothermic; therefore, their core temperature varies with environmental conditions, and thus, they have a limited ability to metabolically maintain core temperature when compared to birds and mammals (NRC, 2011) [9]. As such, (Clifford and Woodring, 1990) [3] recommend the use of incubators, temperature cabinets, or rooms with heat blowers to keep the ambient temperature above 25 °C when rearing A domesticus, temperatures below 25 °C have been found to be detrimental to growth and even threatening to survival. Metabolic heat generation should also be considered. Larger larvae in mealworm production systems in the Netherlands were found to produce a surplus of metabolic heat and suggesting that this heat could be used to generate heat for smaller, more heat-demanding larvae (Oonincx and De Boer, 2012) [10].

At this point, insect-rearing systems have not been mechanically optimized and depend greatly on manual labor (Rumpold and Schlüter, 2013) [12]. Technically sophisticated systems will, in turn, require higher energy inputs for mechanicalm operation and temperature control. Thus, larger, climatecontrolled facilities also bare their own environmental burdens, often through the use of fossil fuels (Oonincx and De Boer, 2012) [10]. Found high energy use on a T. molitor farm in the Netherlands.

While this may certainly be the case in Europe and North America, tropical climates are better suited to providing relatively high temperatures for rearing insect species such as A domesticus, Therefore, geographical location plays a particular role in influencing the amount of energy required to regulate temperature. According to (Oonincx and De Boer, 2012) [10], low ambient temperatures will require higher energy inputs in insect production. In an LCA comparing mealworm, pork, milk, beef, and chicken production, mealworm production required more energy than chicken and milk production. Therefore, energy use may contribute significantly to total GHG emissions and energy use from a given production system.

Conclusion

Insects can contribute to food security and be a part of the solution to protein shortages, given their high nutritional value, low emissions of greenhouse gases, low requirements for land and water, and the high efficiency at which they can convert feed into edible mass (edible body parts). In the Western world, consumer acceptability will be determined, in large part, by pricing, perceived environmental benefits, and development by the catering industry of tasty insect-derived products. However, most of the main factors affecting repeat consumption were notably more practical and contextual, and associated with the routine consumption of more conventional foods. These were the price, taste, and availability of products, and their degree of fit with established dietary practices, including the accommodation of other people's preferences.

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