Insects: why we need them on our plates

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Concerns about the environmental impact of animal protein production in industrialised countries have stimulated a new and rapidly growing industry of insect mass production. Making use of their natural function in nutrient recycling, insects can be produced more sustainably than traditional animal protein sources.

In the course of over ten thousand years of cultural heritage[1], more than 2,100 insect species have been recorded as being consumed by humans[2]. In other words, there is a great deal of choice; the insect world is diverse and currently we are just beginning to explore how we can leverage insects for food and feed. Most edible insect species belong to either the beetles (Coleoptera; 33%), the largest insect order with a total of over 300,000 described species; larvae (caterpillars) of butterflies and moths (Lepidoptera; 16%); larvae of ants, bees and wasps (Hymenoptera; 15%); nymphs and adults of grasshoppers and crickets (Orthoptera; 13%) and true bugs (Hemiptera; 11%) (Figure 1). Most edible insects have a vegetarian diet, whereas ants and wasps prey on other insects to feed their larvae, and still others feed on decaying organic material. The vegetarians consume a diversity of plant species which to a large extent explains the substantial variation in their body nutrient composition[3].

Insect protein content and nutritional quality

Conventional animal-based, protein-dense foods such as meat, eggs, and dairy products are considered high-quality protein sources because they meet all our indispensable amino-acid (IAA) requirements and are easily digested and absorbed in the intestine. Insects are also a protein-dense food source: on a fresh-weight basis, the protein content (g/100 g) of edible insects belonging to the five orders mentioned above ranges from 14–20, which is comparable with the fresh-weight protein content of, for example, beef (19–26) and tilapia (16–19)[3,4]. Insect proteins contain all the amino acids indispensable to human needs in favourable proportions for human protein synthesis[4].

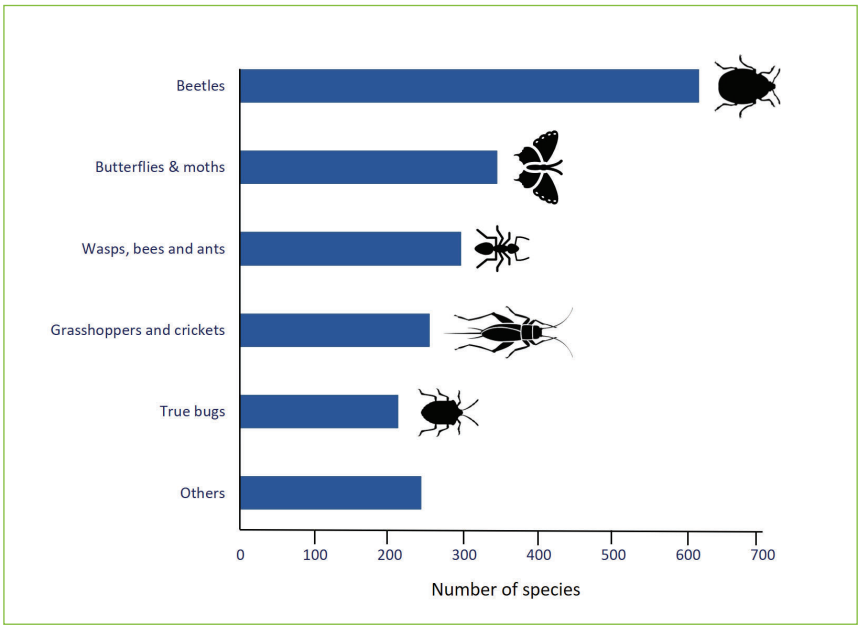

Figure 1: Number of edible insect species known for five insect orders and the remaining number of edible insect species belonging to other orders[2].

Environmental impacts of farming insects

The sustainability of current animal protein production is increasingly being questioned. This is, among other things, because the available agricultural area is not sufficient to meet the global increasing demand for meat. Livestock is also responsible for 8-15% of global greenhouse gas emissions and 70% of ammonia emissions, the latter leading to acidification of the environment. The production of insects as food is considerably more sustainable than the production of other animal proteins due to lower land and water use and lower emissions of greenhouse gases and ammonia per kilogram of protein produced.

To achieve a similar protein yield, the production of one kilogram of crickets requires approximately 2 kg of feed, while one kilogram of beef requires 25 kg of feed. Thus, insect protein production requires much less agricultural land. Moreover, several insect species can be reared on residual streams or by-products of agriculture and regular food production, which further reduces agricultural land use. In addition, production of one kilogram of cricket protein requires only 20% of the volume of water compared to the same quantity of beef protein. This makes insects a valuable source of high-quality animal proteins with a relatively small ecological footprint. After the insects are harvested,

a residue remains called 'frass': the uneaten feed mixed with insect faeces and moulted skins, a residue which appears extremely suitable as organic fertiliser. Its application promotes crop growth and strengthens resistance to pests. This in turn can contribute to a reduced need for chemical fertilisers and chemical pest control and thus to more sustainable crop production[5]. Rearing insects on food crop residues like potato peel, grain residues from beer production, or fruit peels, enhances the overall circularity of agricultural production (Figure 2).

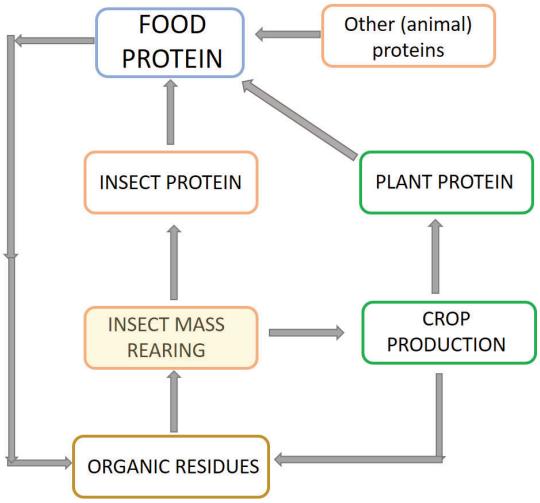

Figure 2: Insect protein production as central component in a circular food system as outlined in the text.

Insects are vital for nutrient cycling

A large part of the environmental benefits stems from the fact that insects can play a crucial role as nutrient recyclers. An estimated 25% of the one million insect species live on decaying organic material such as plant remains and animal excrement: these substrates are their natural food. The conversion of organic material into insect biomass fulfils an important ecological function in the cycle of nutrients because they form high-quality food for many other animals, including fish, birds and mammals. In today's livestock production systems, manure, the surplus of undigested food, is a major problem. Insects provide a solution by converting manure into insect proteins. Recent research has shown that insect species living on organic residual streams have entered into a sustainable and successful collaboration with microorganisms that perform important functions in the digestion in the insect gut and in the defence against harmful microorganisms. We are only at the beginning of unravelling the long evolutionary history of these collaborations that to date have played

no or little role in food production. There is still much to discover about how insects contribute to closing nutrient cycles.

Insects and the United Nations Sustainable Development Goals

Ensuring both food security and food quality for the future of humankind requires innovative developments. Increasing food production as practised thus far has not proven a solution, given planetary constraints and the resulting global climate change. Felling forests may provide a temporary solution but this will lead to a further reduction of biodiversity. As the world faces many challenges, the United Nations has drawn up a coherent set of 17 Sustainable Development Goals (SDGs). The first of these is 'no poverty' and the closely linked second goal is 'no hunger'. Other goals include responsible consumption and production (SDG 12), climate action (SDG 13), and conservation and sustainable use of marine and terrestrial resources (SDGs 14 and 15 respectively).

The use of insects as food or animal feed has thus gained momentum due to the opportunities they provide for obtaining a sustainable protein source. It has gradually become apparent that this development will have positive effects on the achievement of various other SDGs. Replacing regular meat, especially beef, with insects as a source of animal protein and other nutrients supports SDG 12 and greatly reduces the contribution of food production to climate change (SDG 13). Replacing fishmeal with insect meal can ease pressure on fish stocks in the oceans (SDG 14). Moreover, as insect production uses less land than livestock, it can reduce the pressure on terrestrial biodiversity (SDG 15). Because several edible insect species can be produced by small farmers with little investment and can thus offer an alternative to expensive imports of animal feed, local economies can also be stimulated. In this way, small-holder farmers in developing countries can increase their productivity and standard of living (SDGs 1 and 2), thereby raising their social status and societal integration. The combined effects can lead to social stability and peace (SDG 16).

Make it happen but how?

Insects are traditional protein sources in human diets globally, except in the western world

Insects are commonly eaten in various parts of the world, in particular in South-East Asia, Africa, and Central and South America. In these areas insects are traditional dietary components, for example, grasshoppers can be found at food markets in Mexico, while in southern and central Africa, mopane caterpillars are for sale. They are seasonally collected and considered a delicacy. Insects are rich in proteins, poly-unsaturated fatty acids, minerals and vitamins, making them an excellent food source. They are closely related to shrimps and lobsters and the Aborigines in Australia call grasshoppers the 'shrimp of the land'. In the western world, however, insects are not a traditional dietary component and in the European Union only 2% of the population was estimated to have consumed insects in 2019. New strategies are being developed to increase the willingness of western consumers to eat insects or insect-containing products. Examples of these are incorporating insect ingredients in common food products such as protein bars, pasta, burgers, nuggets, and spreads; ensuring excellent taste; providing a tasting experience at events; giving information about sustainability and health effects; using role models such as TV or sport celebrities to promote products; and offering these products at competitive prices.

Upscaling insect protein production

It is only recently that in Europe and North America insects are increasingly mass-reared for human consumption, particularly crickets, grasshoppers and flour beetle larvae, i.e., yellow mealworm and buffalo worm. The insects are sold whole or as a processed product. A range of insect-containing products are rapidly reaching the market including tofu-like products and dried insects ground to powder as protein-rich ingredients of pasta or bread. In the European Union, legislation has been developed to ensure that the production of insects for food meets the same quality and hygiene requirements as other animal products.

Global mass production of edible insects for both food and animal feed was estimated at 10,000 metric tons in 2020, most of which is used in animal feed. Predictions are that this will increase to 730,000 metric tons by 2030. To date, in Europe, North America and China, mass production has been limited to only a

few of the 2,100 edible insect species known, i.e., black soldier flies, house crickets and mealworms, and it takes place in large facilities that require substantial financial investments and transport of organic residues to these facilities. In Africa, Latin America, and South-East Asia, insects are produced on individual farms or in small cooperatives that make use of locally available agricultural or food market residues.

Obstacles in realising the full potential of insects as protein sources and ways to overcome them

As noted above, edible insects generally meet protein nutritional requirements, however, some cases of antinutritive components and harmful ingredients have been reported. Harmful ingredients that deserve attention are heavy metals, some of which may accumulate to toxic levels in insect species where the feed substrate on which they are reared contains currently permitted levels. It is thus important to monitor heavy metal concentrations in residual organic streams to avoid accumulation. Allergic reactions to insect proteins, for which in particular people with a known allergy to shrimp or house dust mite are at risk, can be prevented by proper labelling as is customary for other food products. Mechanisation, automation and personal protection against inhalation can contribute to prevention of excessive exposure to airborne insect allergens for personnel in large-scale production facilities. Another known hazard is the contamination of insects with microbial pathogens during production, processing or storage. Such pathogens may occur in the insect feed and scarce information is available on their fate in the insect body. Prevention relies on hygiene and monitoring protocols and standards as is common for other food products.

Whereas in other parts of the world regulations are less restrictive, insects are considered novel food under European Union food legislation. Due to the costs and time associated with filing insect products for approval by the regulatory EU authorities, the potential of insects as a novel and sustainable animal protein source has been curtailed. An important step forward was EU approval granted in 2021/22 for both yellow and lesser mealworms and crickets as the first insect species approved for food use. This is expected to pave the way for admission of other insect species on the EU food market. A major step forward in the use of insects as animal feed is the August 2021 EU approval for poultry and pig feed, opening up new opportunities for the EU feed market.

Conclusions

Insect mass production for food and feed is an upcoming sector, currently tapping the potential of just a handful of species. From a nutritional perspective, insects are protein rich with favourable indispensable amino acid profiles. From an environmental perspective, production of insect protein has two major benefits compared to traditional animal protein. Firstly, insects are able to retrieve nutrients from organic residues that are unsuitable as feed for other animals, contributing substantially to nutrient cycling, and secondly, insect mass production has a considerably lower environmental impact due to lower land and water use and lower greenhouse gas emissions. Moreover, insect production supports several environmental and socio-economic SDGs. In order to increase the future share of insect proteins in global protein needs while paying due attention to food and feed safety, both increased western-world consumer acceptance and upscaling insect production are required.

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