Insects: A Protein Revolution for the Western Human Diet

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Insects’ perception changed from ancient food source to cultural taboo, and they are now returning in what is literally a revolution for the Western food supply (Evans et al., 2015). There are in fact historical traces of the use of insects as food in the world, from prehistory to the present traditional use in Third World and the novel use in Developed Countries; now the current regulations are trying to arrange a framework for their reintroduction because their nutritional and nutritive value makes them a considerable food for human consumption, as a source of important nutrients such as high quality protein, unsaturated fat, fibres and minerals (van Huis et al., 2013). Insect protein is in fact much more sustainable than protein from other conventional sources: their minimum impact on the environment and their limited use of natural resources are actually the main reasons for including insects in the market (Oonincx & de Boer, 2012).

Insects are also proposed as a remedy for world hunger, and their contribution to ensure food security in Developing Countries will be illustrated (Kelemu et al., 2015). However sustainability and security are focal needs in the Western world too, and this is why insect-based ingredients, in the form of flours, pastes and protein extracts, are recently making inroads in the market, attracting the attention of investors, farmers, chefs, food scientists and technologists, for their profit potential and their promising appealing applications on novel food products. An overview on the existing insect food products shows the prevailing trends.

In conclusion, the revolutionary impact of insects on the food supply affects sustainability, health and ethics, as well as palatability and profit.

**Nutritional value of insects**

Insects are the most diverse group of organisms: With more than 900 thousand species, and 5 to 7 times as many still waiting to be discovered, they represent approximately 80 percent of the world’s species (Pedigo & Rice, 2015). According to Wageningen University more than 2000 of them are known to be edible (Jongema, 2015) and this leaves us a big range of choice, especially because not only they are tasty (Hanboonsong et al., 2000) but they also contain very valuable nutrients (Banjo et al., 2006). Available and reliable analytical data on nutrients composition of insects are still scarce (Payne et al., 2015). A review completed by Novak et al. (2016) covers the proximate composition of 235 of more than 2000 edible insect species, showing how insects are generally rich in protein, fat and minerals, but poor in carbohydrates with the exception of fibre (Zielińska et al., 2015). The higher availability of data on the protein content and amino acid profile reflects the main interest in this food source. On a dry matter basis the average protein content ranges from 34.35 % of termites (Isoptera) to 61.32 % of grasshoppers, crickets and locusts (Orthoptera), the fat content ranges from 13.41 % of Orthoptera to 33.40 % of beetles and grubs (Coleoptera), the fibre content from 5.06 % for termites to 13.56 % for true bugs (Hemiptera), the nitrogen-free extract between 4.63 % of dragonflies and damselflies (Odonata) and 22.84 % of termites, and the ash content ranges from 2.94 % of dragonflies and damselflies (Odonata) and 41.97 % of termites. Quality evaluation is still required for insect protein, but some species of crickets have been shown to be a better source of amino acid compared to soy protein through feeding tests on weanling rats (Finke et al., 1989), and spent silkworm pupae have been found a higher chemical score regarding food intake, weight gain, protein digestibility, protein efficiency ratio (PER), and net protein utilization (NPU) compared to casein, but lower scores compared to whole egg protein (Rao, 1994). However, Rumpold & Schlüter (2013) observed that generally all insect orders meet the requirements of the WHO for methionine and methionine + cysteine, with the exception of Dipterans for cysteine. It is important to distinguish lipid content in relation to the quality and the ratio of the fatty acids: within insect orders, Saturated Fatty Acids (SFA) average amount is between 30.83 % of ants, bees, and wasps (Hymenoptera) to 41.97 % of termites. Insects are rich in...
Unsaturated Fatty Acids (UFA), the sum of Monounsaturated Fatty Acids (MUFA) and Polyunsaturated Fatty Acids (PUFA), in a degree comparable to that of poultry and fish (DeFoliart, 1991); this is a positive feature as high UFA intakes are inversely correlated with cardiovascular diseases (van Horn et al, 2008) and age-related cognitive decline (Solfrizzi et al, 2010). Finally, it is important to note that insects are high in vitamins (carotene and vitamins A, B1, B2, B6, D, E) and minerals, especially zinc, iron and, in some cases, magnesium (Sirimungkararat et al, 2010).

These nutritional values are highly variable between different species, and also within the same species there can be a lot of variations between different developmental stages, diets or places of origin; in addition, various measuring methods can lead to different results (Chen et al, 2009): for these reasons, precise nutritional values cannot be given for edible insects in general, but have to be referred to the case examined.

Consumption of insects: history and geographical distribution

The word ‘entomophagy’ comes from ancient Greek éntomos ‘insect’ and phăgein ‘to eat’; it indicates the practice of eating insects and, for extension, other arthropods such as arachnids and myriapods, especially when referred to humans.

Starting from prehistory, before switching to fruits, vegetables and meat, human diet was insectivorous (Valadez, 2003). The habit of eating insects originated back in the Palaeolithic era and this is testified by pictorial and sculptural finds (Hernández-Pacheco, 1921), and ashes and fossil excrements (Tommaseo-Ponzetta & Paoletti, 2005). The ability to hunt and to cultivate developed only later, determining the establishment of sedentary lifestyle and the growing of the population (Abrams, 1987). The Holy Bible is the first written document in which the use of insects as food is recorded, in the book of Leviticus (Lev 11, 20-25). Subsequently, other traces can be found on the writings of Herodotus, Aristotle and Pliny (Belluco, 2009).

Since then, entomophagy has survived only in certain countries, mainly in Africa, Asia, Latin America and Oceania, due to both ecological and cultural reasons (Fig. 2), the availability of big and numerous edible insects is higher in those ecosystems (van Huis, 2013), and only rarely their consumption is only due by necessity; in those cultures in fact, the use of insects as food is traditional and not just a pure way to forfend starvation: as a matter of fact, certain insects are highly appreciated, and sometimes preferred to meat (Quin, 1959).

The FAO assessed that insects are part of the diet of more than 2 billion people (van Huis et al, 2013). However, it is believed that the real distribution of entomophagy is underestimated, due to two main factors: the first one is that, conscious of the Western disgust, indigenous people deny it when interviewed (Ruddlé, 1973; Paoletti & Drecon, 2005); the second reason depends on the nature of the food: since it is often gathered and eaten ‘on the spot’, it is impossible for the investigators to record exact quantitative data (Posey, 1987).

Due to the Western world’s influence, where insects are considered a bizarre, poor and unhygienic food, developing countries are starting to abandon these food habits, while their increasing welfare contributes to the growing meat demand (FAO, 2009). At the same time, environmental awareness is recently starting to bring insects in the diet of Northern Americans and Europeans, due to the sustainability of this alternative protein source (Michail, 2015).

Insects as a sustainable alternative protein source

A large increase in the human population, up to 9.7 billion, is foreseen by 2050 (UNDESA, 2015) and much of this growth is occurring in least developed countries; at the same time, demand for food is expected to grow by 70%, especially with regard to meat and animal-derived products (UNDESA, 2000), and this will put a lot of pressure on the food supply chain. Despite the improvement that technological advances have brought on the average yield per hectare of productive area, population growth determined a reduction of biocapacity per capita: biocapacity is ‘the capacity of ecosystems to regenerate what people demand from those surfaces’, while ecological footprint is ‘a measure of how much area of biologically productive land and water an individual, population or activity requires to produce all the resources it consumes and to absorb the waste it generates’ (Global Footprint Network, 2015). This means that even though the productivity of the Earth has risen, it is still not enough to compensate the growing demand of its inhabitants. According to the WWF, our demand of natural resources and services is equal to 1.5 Earths every year: this means that every year we consume more than what the planet can renew (WWF, 2014).

At the same time, the climate is changing; according to the Intergovernmental Panel for Climate Change (IPCC, 2014. p. 2) ‘warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are
unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen. In particular, it has been estimated that global medium temperature rose by + 0.85 °C in the period 1880 – 2012. This led to an increase in extreme weather events and the diminishing of Earth’s productive surface. Due to the complexity of the planet’s climate system, it is very difficult to make precise estimations or previsions, but a causal correlation has been observed between the increasing emission of anthropogenic greenhouse gases (GHGs) and the rising of the temperature: the IPCC established that those anthropogenic effects are extremely likely to be the cause of the global warming, where extremely likely means with a probability of 95-100% (IPCC, 2014).

The biggest part of our footprint on the environment is due to the food sector: agriculture alone accounts for the 70–85% of water footprint and 30% of world GHGs emissions (EEA, 2006; Garnett 2014; Pfister & Bayer, 2014). In particular meat and other animal-derived food, such as dairy and egg products have an ecological footprint significantly higher than plant-based food (FAO, 2009). The effects of climate change and the acceleration in the resources depletion that results from it have contributed to an increasing environmental awareness and thus to the development of meat analogues or meat substitutes, i.e. food products that resemble aesthetic and/or chemical characteristics of certain types of meat, usually based on plant material (soy, pulses, rice, etc.), animal-origin proteins (milk, fish, insects, lab grown cells), and mycoproteins (Tijhuis et al, 2011).

Insects are a sustainable and economical source of good quality protein, therefore they have been promoted by the FAO as alternative source of protein in order to meet the world protein demand without compromising irreversibly its ecosystems (van Huis et al, 2013). Insect protein is up to 20 times more efficient to be raised than beef, as insects require fewer resources in terms of food (Fig. 3), water and land space (Fig. 4), and emit considerably less GHG (Fig. 5) compared to livestock (van Broekhoven et al, 2015; Nakagaki & DeFoliart, 1991; Smetana & Mathys, 2016; Oonincx et al, 2010; Oonincx & de Boer, 2012; van Huis et al, 2013). Moreover, insects can be fed with organic waste or by-products instead of consuming food that could be used directly by humans (Li et al, 2013).

Furthermore insects have been pinpointed as a solution for the hunger and malnutrition that affect more than the 50% of the world population, the majority of which lives in the least developed countries (van Huis et al, 2013; Hanboonsong & Durst, 2014). There is in fact the necessity to rethink the global food supply chain, and to root sustainable and adequate diets among both the vulnerable and wealthy populations, and insects meet all the requirements of sustainable diets (Kelemu et al, 2015; van Huis, 2013). The importance of insects in indigenous diets has been readily recognized (Denevan, 1971; Ruddlé, 1973; Chavunduka, 1975) and many projects have been carried out for the development of mass-harvest and mass-rearing methods to assure food security and species conservation at the same time (FIRDP, 1986; Ramos-Elorduy, 2009).

Insects as a novel ingredient: the revolution in Western markets

Following the entry of insect products in North American markets, both in the US and Canada, insect food seems to
be a growing trend in Europe too (Dinkovski, 2016). In the European Union, insects fall under the Novel Food Regulation (EC) No 258/97: that rules the introduction in the market of food and food ingredients which have not been consumed significantly in the EU before 1997, or are produced utilizing new technologies. A regulatory framework on insect food products is still waiting for approval and the sale and consumption of edible insects in Europe is still subject to a patchwork of regulations, but in the meanwhile hundreds of insect start-up companies were set up in Europe and America in the last few years, and more than 100 of them in 2015 alone (Whitehead, 2016). The industry of insect food is in fact forecast to be worth more than £230 million ($360 million) within the next five years, according to New Nutrition Business (2014). So far, the European Food Safety Authority’s opinion is that properly farmed insects can be safe in regard to both biological and chemical potential hazards as well as allergenicity and environmental hazards, as their microbiological hazard is comparable to non-processed food of animal-origin (EFSA, 2015). All the competent authorities underline that much research is still required to provide scientifically-based guidelines in order to determine optimal insect species and farming techniques, risks and benefits for human health, and the environmental impact of this alternative protein source.

Furthermore, consumers’ acceptance needs to be addressed to allow a full development of the new resource: insects in fact are still taboo among Westerners, and generally not yet acceptable as food (Lensvelt & Steenbekkers, 2014). To overcome the barrier, the consciousness of its healthiness and sustainability is not enough (Tan et al, 2015); people’s food choices are more driven by taste and exposure, so a better strategy would be to make insect products more enjoyable in terms of taste, texture and smell, and to make the consumers identify insects not as a substitute of something more appealing (be it beef, pork or chicken), but a food in itself (Deroy et al, 2015). However, studies among Western consumers indicate a higher willingness to eat insects as processed food (Hartmann et al, 2015) e.g. in the form of flour, paste or protein extracts, due to human preference for similarity with familiar food (Verkerk et al, 2006).

The media are also reserving much attention at the entomophagy phenomenon: e.g., the BBC released the documentary ‘Can Eating Insects Save the World?’ (Kari, 2013) and Dr. Marcel Dicke presented the TED Talk ‘Why not eat insects?’ (Dicke, 2010). There are also references to entomophagy and revolution, e.g. 2016 edition of the TEDxLUISS (TED talks independently organized by Luiss University), whose theme was (r)evolution, hosted the ento-chef Roberto Flore and the entomophagy researcher Afton Halloran (Flore & Halloran, 2016).

A comprehensive picture of the spread of novel insect products can be obtained by BUGSfeed, a website that deals with entomophagy communication and promotion: according to them, the most consumed insects are crickets (150 entries), mealworms (58), grasshoppers (43), ants (28) and silkworms (22) (Table 1) (Note: this categorization is arbitrary and doesn’t reflect the division in Linnaean species). The products available are mostly ingredients like flours (55 entries) and whole insects (43) (Fig. 6), followed by fancy food products that are the best form to make consumers try new foods, like protein bars (41) (Fig. 7), snacks (37) (Fig. 8), cookies (25) and candies (18) (Table 2). Its directory collects 215 between restaurants and stores (physical and online) worldwide (Table 3), and shows how in Europe they are present mostly in United Kingdom (35 entries), France (17), Belgium (10), and Netherlands (8) (Table 4). (BUGSfeed, 2016).
Research at the Dublin Institute of Technology

‘A Sustainable Food Supply for the Future: A Study of the Potential for Developing Food Products Made with Protein from Insects’ is a 4 year PhD project started at the end of 2015. The project aims to develop and characterize two kinds of insect ingredients (flour and protein extracts) in terms of nutritional value and functional properties, and to incorporate them in novel food products that are both healthy and enjoyable. Sustainability will be the key component of the study. A database of edible insects and existing food products was built and used to select three insect species to use: cricket (adult) *Gryllodes sigillatus*, silkworm (pupa) *Bombyx mori* and mealworm (larva) *Tenebrio molitor*. Different extraction methods will be tested and optimized to isolate and concentrate the protein, both for characterization and product development purposes: feasibility and yield will be assessed. Nutritional analysis, as well as digestibility and protein bioavailability assays will be performed. Then the functional properties of both the flours and the protein extracts will be explored: different tests will be carried out to determine water holding capacity, solubility, emulsifying, foaming and gelling ability, rheology and
thermal stability under different experimental conditions. Based on the qualitative and quantitative results and surveys of consumers, one or two food products will be developed using mixed design and Molecular Gastronomy principles, along with sensory analysis to meet consumers’ tastes and expectations.

Conclusion

Insects have an extraordinary high content of good quality protein, with all the essential amino acids. They also contain unsaturated fatty acids, minerals, vitamins and fibres. Due to their extremely low impact on the environment and use of resources, they have the potential to be the protein of the future. Much research is still required in terms of characterization, rearing, safety and product development, but the biggest hurdle remains consumers’ perception. Researchers have many challenges to address these issues, however entomophagy is not only possible but also a necessary revolution in our food habits, in order to meet future food demand and to overcome the 21st century protein crisis.

Works cited


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