

## Edible Insects: The Future of Food?

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### ARTICLE DETAILS

#### Article History

Published Online: 16 Apr 2020

#### Keywords

Edible insects, Entomophagy, Nutritional value, Regulatory frameworks.

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### ABSTRACT

*The global increase in demand for animal livestock and insufficient access to land culminated in the search for alternate food sources. Edible Insects as an alternate protein source for human consumption is captivating in terms of animal welfare, environmental sustainability, and human health. There are more than 2300 species recorded as edible species throughout the world which provides high energy and nutritional value as compared to traditional protein sources. In some records, it is also reported that the consumption of insects started from very ancient times. In this review, we have discussed the six common edible insects (Caterpillar, Beetles, Cricket, Bees, Cockroach, and Spider) which are presently consumed in some parts of the world. We have also compared the nutritional values of these species. The benefits of edible insects over traditional sources, the history, and future of edible insects sector are summarised in this review. The concept of edible insects and their commercial production is improving gradually and soon the edible insect's sector will be the major sector leading the food industry.*

### 1. Introduction

Insects belong to class of animals within the broad banner of arthropod phylum. They are amongst the most diverse group of animals on the earth and have therefore colonized almost all regions of this earth i.e; from the poles to the tropics and from soaring mountains to the deep caverns (Arnold et al., 2014). As the human population is mushrooming, it is proposed that the world population will reach over 9 billion by 2050, especially with the expansion of the middle class and the pressure on the traditional protein sources, beef, and poultry meat (Suthar et al., 2019). Thus, we will not be able to sustain the increasing demand and maybe this growing population will require roughly double the live food production (Belluco et al., 2013). Therefore, insects as an alternative source of animal proteins can help us bridge the gap in nutritional needs as they have a very good conversion rate from feed to meat. The importance of insects lies not only in the fact that they are an alternative source of proteins, but it also paves the way to eating many other animal species that are further down the food chain, such as snails and algae, which can also boost the global food supply (Arnold et al., 2014).

It is estimated that the grand total of insect species around the globe is 6-10 million, amongst which more than 2300 species of 18 different orders have been announced as edible insects (Chufeï et al., 2019). Around 2 billion people habitually eat insects as part of their diet because, they are high in proteins, low in cost, eco-friendly, taste wonderful (Ligaya Mishan, 2018), and can be used both visibly and invisibly in the dishes. In the twenty first century, insects as food and alternatively feed appears to be an essential business due to rising prices of food, animal protein, food insecurity, environmental pressures, population growth and the heightening demand for protein among the working classes as mentioned. Therefore Entomophagy, ordinarily termed as consumption of insects (which is renowned in tropical and

subtropical lands due to warm and moist climate) contributes positively to the surroundings, human health and sustenance.

### 2. History

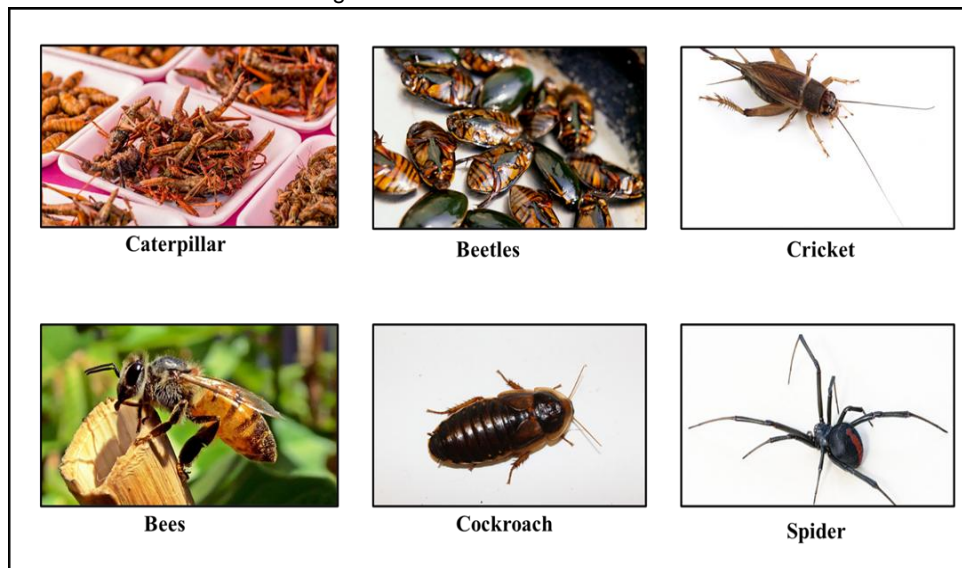
For at least 400 million years insects have been in existence, which makes them amongst the earliest land animals on this diverse planet (Tiencheu Bernard and Hilaire Macaire Womeni, 2017). Nearly 7000 years ago people started consuming insects. Palaeontological studies have shown that insects were included in the diet of early humans (Arnold et al., 2014). Bugs were eaten by the early hunters and gatherers to survive because of their nutritional properties like – sufficient proteins, fats, and adequate micronutrients. Native Americans consumed June beetles by roasting them over coal and then ate them like popcorn. They also ate cicadas, cooked up in garlic and salt. Termites have a history of consumption throughout the African continent and Southeast Asia (Aly Moore, 2019). Insects were also dietary part of the ancient Romans and Greeks. The Roman scholar of the first century, Pliny, who is the author of *Historia Naturalis*, wrote that Roman aristocrats loved to eat beetle larvae reared on flour and wine. Even the fourth-century Greek philosopher and scientist Aristotle, reported in his writings the supreme time to harvest cicadas. The Christians along with the Jews were encouraged by the old Testament to consume grasshoppers, beetles and locusts (Sharon Guynup, 2004). In West Africa too insects have been used as human food and animal feed from long back (Kenis, M. and Hein, K., 2014). Insects have also been used by the traditional healers to treat diseases in both humans and animals as medicine (Tiencheu Bernard and Hilaire Macaire Womeni, 2017). The promotion of entomophagy basically started in Netherland and in 2008, dutch companies started the production of insects for the consumption of human. The issue of entomophagy was addressed during an international conference in May 2014, organized by Wageningen University in conjunction with the Food and Agricultural Organisation of the United Nations (Arnold et al., 2014).

### 3. Common Edible Insects

The total number of insect species around the globe is estimated to be 6-10 million, with over 2300 species of 18 different orders are identified as edible insects. The information on each and every species of edible insects cannot be discussed. Therefore, in this review paper, we have covered the

details about six common edible insects of various orders under the class 'Insecta' that are consumed worldwide. These species are Caterpillar, Beetles, Cricket, Bees, Cockroach, and Spider (Figure 1).

Figure 1: Six common edible insects



#### • Caterpillars

Caterpillars belong to the order 'Lepidoptera'. Edible caterpillars are known as the 'Madora', 'Mopane worm', or 'Amacimbimasontia' as they feed primarily but not only on mopane tree leaves. In 1849, John O. Westwood described the species for the first time (Wikipedia contributors, 2020). Caterpillars are superior sources of proteins and fats for many natives and are therefore most consumed, traded, and economically beneficial and costly edible insects in the tropics (Ngute et al., 2020). The conventional method of preservation of mopane worms includes boiling the worms without adding any additional water after washing, followed by addition of significant amount of salt. They are then either sun dried or smoked, so as to enable them to gain extra flavor. In industries, caterpillars are usually canned in brine. In Southern Africa, tins of mopane worms can be found easily in rural supermarkets and markets. The maximum rate of consumption of caterpillars is found in countries such as Congo, the Central African Republic, Cameroon, Uganda, Zambia, Zimbabwe, Nigeria, and South Africa (Nissay and Ekesi, 2017)

#### • Beetles

Beetles belong to the order 'Coleoptera'. Typically, only beetle larvae and not fully developed beetles are eaten by people. The species of beetles that are consumed in large amount is palm weevil, and other species including aquatic beetles, wood-boring larvae, and dung beetles (Naveed Saleh, 2020). Beetles are consumed by people living in the Amazon basin, parts of Africa, and other forested regions, both tropical and temperate, as various species are easily found in trees, fallen logs, and on the forest floor (Jennifer S Holland, 2013). The amount of proteins in beetles is more than that of meat, poultry, and egg products, as well as they have low-fat content.

#### • Cricket

Crickets belong to the order 'Orthoptera'. The edible species of crickets recommended are *Achetadomesticus* or *Gryllodessigillatus*, but some other species of commercially available crickets are also suitable for human consumption (Brian Barth, 2018). As adult crickets are ambient source of iron, protein, and vitamin B12. They can be used to make many products by adding them in different forms, as they are added in powder form in protein shakes, bars and flour. We can already find "cricket flour" in one brand of chips available in America (webmd.com). Consuming them in regular diet will support the growth of beneficial gut bacteria and also reduce inflammation in the body (Claire Stam, 2018). South Africa, Congo, the Central African Republic, Zambia, Zimbabwe, Nigeria, Cameroon and Uganda, the consumption of crickets is maximum here (Nissay and Ekesi, 2017).

#### • Bees

Bees belong to the order 'Hymenoptera'. Consumption of honey bee brood is a common cultural practice in regions: as diverse as Mexico, Ecuador, China, Thailand, Senegal, Zambia, and Australia. So, another particularly promising edible resource is a brood of the honey bee (*Apis mellifera*), as honey bees are kept by humans worldwide and in many cultures, they are eaten as a delicacy. Various nutrients such as proteins, fatty acids, vitamins, and minerals are richly found in sufficient amount. Apart from the nutritional aspect, it is also consumed for its pleasing taste and versatility in culinary preparations. As far as the texture and flavor is concerned, Honey bee brood can be eaten, cooked and dried giving them a particular nutty and crunchy texture with slightly sour taste (Chen et al., 1998). High content of amino acids, B vitamins, and other nutrients are also found in the larvae of bees which adds a point in eating the larvae as a part of meals. Buttery, kind of fatty texture have

made bees to be a part of staple food in Thailand. Even Australian aborigines use stingless bees as a source of sugar.

#### • Cockroach

Cockroach belongs to the order 'Blattodea'. They can actually be very smooth and tasty insects, mainly if they are fed on freshly harvested fruits and vegetables. The species *Blatta lateralis* (Turkistan roach) and *Blattella germanica* (German cockroach) are edible as they have high amount of nutrients in it ( Leah Bessa, 2020). Cockroaches can be eaten in different ways according to traditionality of particular country, some examples are fried, toasted and boiled. Madagascar Hissing Cockroaches have ability to impart taste and texture like greasy chicken. A study shows that the Pacific beetle cockroach are capable to produce milk to feed its offspring and the same ability can be found in mammals too. And this milk contains "lactates" which is highly nutritious, rich in protein (dense crystal), sugars, amino acids and healthy fat. Some researchers also suggest this milk can be considered as complete food because this milk give good nutritional value and provide more than three times the calorie content than that of buffalo milk. It is also stated that producing crystal in large quantity could be possible because "They are very stable. They can be a fantastic protein supplement." (Kendell wood, 2016).

#### • Spider

Spiders belong to the order 'Arachnida'. *Cyriopagopus altostratus*, or *Haplopelma albobriatum*, are known as the edible spider or Thailand Zebra Leg tarantula. It is a species of spider found in Myanmar, Thailand, and Cambodia (Megsy, 2019). Huntsman spiders (*Sparassidae* gene) comprises of over a 1000 species and are present in the tropical climate everywhere. These spiders are capable to grow up to 12 inches in leg span and they don't have ability to build webs. Whereas tarantulas provide good source of protein needed for normal people. The consumption pattern of Tarantulas is quite similar to other insects, it can be eaten whole and it taste like a soft-shell crab (Matt Anderson, 2018).

#### 4. Nutritional Value

Superbly nutritious, edible insects constitute an adequate source of nutrients essential for the human diet. Insects have a good food source and are comparable with traditional animal sources with high protein content. The nutrients are also easy for the human body to assimilate (Ayieko et al., 2012; van Huis et al., 2013). Nutritional values within a class of insects can vary considerably and these values can differ significantly, depending on metamorphosis level, insect origin, and diet (Finke et al., 2014). Generally, the nutritional value of insects has clear benefits. The nutritional composition is also somewhat similar to that of conventional animal foods (Raubenheimer & Rothman, 2013). Insects are generally a good source of energy and are especially rich in digestible proteins, fat, and a variety of micronutrients (Kinyuru et al., 2009; Kinyuru et al., 2013; Makkar et al., 2014). They are particularly rich in potassium, phosphorus, iron, zinc, copper, manganese, sodium, vitamin B1 and B2 and niacin. Some insects are rich in fat particularly in the larval stage and contain many essential vitamins and minerals. Like most foods, the nutritional composition will also be influenced by preparation and processing methods (e.g. drying, boiling, or frying) applied before use.

Table 1 shows the nutritional value of some common species which are consumed throughout the world. The data were summarised from different research papers. This data includes the protein, fat, carbohydrates, mineral composition, and energy values of common species per 100 grams on a dry weight basis. In this review paper, species like Caterpillar, Beetles, Cricket, Bees, Cockroach, and Spider are encompassed to compare the variability in their nutritional composition. The nutritional composition differs from species to species. But irrespective of that, the edible insects provide high nutritional benefits and also help in the fulfilment of energy requirements.

Table 1: General nutritional value of insects g/100g dry weight

| Sr. No. | Species (Order)           | Botanical Name               | Protein | Fat   | Mineral | Carbohydrate | Energy Kcal |
|---------|---------------------------|------------------------------|---------|-------|---------|--------------|-------------|
| 1.      | Caterpillar (Lepidoptera) | Larva                        | 15-60   | 7-77  | 3-8     | 2-29         | 323-450     |
| 2.      | Beetles (Coleoptera)      | Coleoptera                   | 21-54   | 18-52 | 1-7     | 6-23         | 138-447     |
| 3.      | Cricket (Orthoptera)      | Gryllidae                    | 8-25    | 34    | 2-17    | 4-11         | 120-323     |
| 4.      | Bees (Hymenoptera)        | Apis                         | 1-81    | 4-62  | 0-6     | 1-6          | 416-655     |
| 5.      | Cockroach (Blattodea)     | <i>Periplaneta americana</i> | 20-23   | 6-8   | 1-2     | 5-7          | 200-220     |
| 6.      | Spider (Arachnida)        | Araneae                      | 63      | 9-10  | 0.5-1   | 0            | 320-390     |

The data were summarised by following references: Verkerk et al. (2007), van Huis et al. (2013), Belluco et al., (2013) and Xiaoming et al., (2010).

The energy value of edible insects depends on the composition of their macro and micronutrients, mainly on fat content. Larvae or pupae are generally richer in energy when compared to adults. On the other hand, high protein insect species provide lower calorie content (M. Bednarova, 2013). Table 1 presents the energy values expressed in kilocalories per 100 gm of weight of selected insects. The energy value of bees was in the range of 416-655 Kcal which is higher and Cricket was showing less energy value which is around 120-323 Kcal.

The protein content is essential part of our diet. Protein requirements in our body should fulfilled according to daily intake. And compared to other livestock animals, edible insects provide good amount of protein. Table 1 shows that protein content was in the range of 1-81 gm/100gm and there were large number of variation between the species. Some researchers have concluded that the protein content of insects varies in dry-roasted processing as compared to normally dried. Within insects, the protein content is high and so insects as food can enhance the quality of food, including proteins from animal sources.

Fat is the food's most energy dense macronutrient. This consists of triglycerides, all of which have a glycerol molecule in their chemical structure and three fatty acids. Insects are usually rich in fats. On average, edible insects contain 10 to 60 per cent of fat in dry matter. In larval stage this is higher than in adults (Xiaoming et al., 2010). Caterpillars belong to the highest fat content among the insects. Fat is present in numerous forms in the insect like 80% of triacylglycerols and less than 20% of about phospholipids. Fat present in insects are responsible for higher energy intensity.

In terms of nutritional content of minerals such as iron, zinc, potassium, sodium, calcium, phosphorus, magnesium, manganese, and copper, edible insects may be of good interest (van Huis et al., 2013). Throughout biological processes, minerals play a significant role. In general, the recommended dietary allowance (RDA) and adequate intake is used to measure suggested daily intake of minerals. Edible insects are good source of iron and by boosting iron status it could prevent anaemia disease by adding to the daily diet.

## 5. Regulatory Frameworks

Development, trade and use of edible insects as food and feed affect a broad range of regulatory areas, from product quality control to the effect of insect farming on the ecosystem. Regulatory frameworks stated in this paper include legislation, standards at both national and international level. And these regulatory standards play an important role in regulating the use of insects as food and feed (FAO, 2013). The lack of specific and insect legislation, standards, can directly put impact on use and exchange of insects in food and feed chains and can work as big obstacle to the growth of the edible insect sector, especially in developed countries.

In 2010, the Lao PDR delegation submitted a project document during the 17th FAO/WHO Codex Alimentarius Coordinating Committee for Asia (CCASIA), proposing the development of a regional Codex food standard for edible crickets and cricket products. This standard will help to protect the health of consumers and ensure fair practices in exchanging goods (edible insect products) in international market form the Lao PDR. The Committee considered the 'Proposal for new work on development of regional standard for edible crickets and their products'. This proposal was prepared by both Lao PDR delegation and technical assistance from FAO in Laos. In the context of the FAO project Sustainable insect farming and harvesting for better nutrition, improved food protection and household income generation, FAO has been working with the Ministry of Health to prepare this new standard proposal for the Codex Committee (FAO, 2010).

The lack of clear regulations is not because the threats are ignored but because the quantity of insects in food and feed is actually negligible at present. If insects were going to become a more commonly used as food and feed product, a risk assessment method would need to be implemented and a suitable regulatory structure must be developed. There is still a lot of work to be done and many problems to be taken into account when drafting normative guidelines and adjusting to insect-inclusive food laws.

## 6. Future of Edible Insects

The demand for meat is increasing globally and the meagre land area available gives rise to the hunt for substitutive protein sources. And now, even the question has been put on the sustainability of meat production. Apart from being an alternative protein source for human food and animal feed, edible insects are engrossing in terms of low green house gas emissions, high feed conversion efficiency, low land used and they even have the potential to alter low value organic side streams into high value protein products (Arnold Van Huis, 2016). These aspects of insects directly urges the need to consume insects in the near future. Even in India, insects have always been a part of our culinary tradition, from eesal in Tamil Nadu to the red-ant chutney made by the Gond tribals of Chhattisgarh (Simrit Malhi, 2018). The reason being, insects have sufficient proteins and are cold-blooded, so they spend their calories on growth, instead of maintaining consistent body temperature (William Poor, 2019). Insects have the potential to eat animal waste or plants that can not be eaten by humans and animals, and this simply means that insects do not have any competition with human food sources and, if ingested, can also help mitigate environmental pollution in the future. In future, India can possibly be the land for insect bio-resource being a tropical country (Richa Badola, 2018) and as the awareness on environmental impact of edible insects continues to grow it's importance, the technological advancements make insect farming more efficient, thus we can expect to see insect based products hitting our supermarket shelves in the not too distant future (Jamie Attenborough, 2019). Thus, if we want edible insects to become an ordinary food source in the coming future, then focus should be laid on the current farming techniques along with the technologies which can struggle with the increasing demand (Amy Murphy, 2019). Wherefore in the upcoming future, Indians and other nations can constitute edible insects as an important part of the daily diet which will directly aid in battling against various worldwide issues: chiefly malnutrition and food insecurity (Richa Badola, 2018).

## 7. Consumer Perspective

"Consumer perception refers to the process by which a customer selects, organizes and interprets information/stimuli inputs to create a meaningful picture of the brand or the product" When a consumer sees or acquires knowledge about a specific product, the whole process of customer perception begins. The process continues until the customer starts to make a judgement on the product. As far as eating insects in developing countries like India is concerned, it is unlikely to be accepted by the entire nation at this point of time and even to provide tags to insects as the part of daily meals. But if the food scarcity occurs in the upcoming future years, then switching to insects along with the traditional food is no harm, as insects are highly nutritious and healthy. In the future, they can also be enriched with some more nutrients and be flavored accordingly as per the public preferences, so as to attract more and more consumers. The consumption of insects would also increase the employment in this particular food sector and will also help in raising the economy respectively.

## 8. Conclusion

In this literature, it is portrayed that how edible insects could be an alternate food source for increasing human population. The world's population is expected to hit up to 9 billion by 2050. So, there would not be that much food available to feed the entire growing world. Hence, edible insects may be a way out to the food crisis ahead. Edible insects are rich in protein, fats and micronutrients and could be able to fulfill body's nutritional requirements. The energy content of edible insect is estimated at about 400-500 kcal per 100 gm of dry matter as compared to other protein sources and edible insects

also possess higher economic value as compared to other livestock protein sources. But, it is still worrying that the use of edible insects could cause health and safety problems. So both the development and food safety should move parallel to obtain better advantages in terms of health and safety. Proper rules and regulation should be made to deal with food safety issues. This review also concludes, that the ongoing status of edible insects remains inadequate to replace conventional animal feed worldwide, whereas edible insects have the potential to become primary nutrient sources in the near future.

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