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# Insect as food: search for new protein dietary sources – A review

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## Abstract

The increasing global need for food has sparked a great deal of interest in the consumption of novel and diversified sources of protein. Dietary protein not only plays a critical function in the prevention of Protein Energy Malnutrition (PEM) but also in how the human diet affects the environment. Eating insects has been practiced for a very long time. Edible insects have clear economic and environmental benefits, and recently, their huge potential in numerous industries has brought them to the forefront. Due to cultural prejudices towards hazardous insects, edible insects in Western nations are more likely to be used as animal feed than as human food, even though their abundance should be advantageous to human health. However, insects are a major source of protein for many countries in Asia, Africa, and Latin America. Insects may be used to address issues with the conservative food supply chain, such as the scarcity of land, water, and energy resources. Our analysis shows that, despite the fact that consumers affected by Western eating habits are unfamiliar with it, entomophagy is steadily growing throughout the world. Numerous studies have been done to increase their value, however questions about the security of the food supply have been raised. In this review of literature study, comparison have been made with ingestible insects with those of other conventional protein sources. The development of contemporary entomophagy was discussed along with their historical perspective. The practical methods and tactics have been also suggested to encourage the consumption of edible insects.

## Keywords

edible insects, entomophagy, nutritional value, food processing, food security

## Introduction

Humans have historically consumed the eggs, larvae, pupae, and adults of insects, and this practice continues today in some orthodox countries. In the beginning, man was an omnivore who ate a lot of insects. Prior to the invention of tools for farming or hunting, insects were a major component of human diets. The majority of humanity also resided in warm climates with a year-round diversity of insects. When there was no meat available from vertebrates, insects were often a welcome source of protein (1). One hundred and thirteen nations throughout the world still practice eating human insects. There are around 2000 bug species that can be consumed. Beetles, caterpillars, bees, wasps, and ants are the species that are eaten most frequently on a global scale. They are followed by termites, dragonflies, cicadas, crickets, flies, leafhoppers, grasshoppers, locusts, and other species. In Africa, Asia, and Latin America, people eat insects the most (2). Human ingestion of insects are exceedingly uncommon and frequently socially unacceptable or even taboo in the majority of European nations. Insects have nutritional value that is comparable to that of regular meats. Consideration should be given to using edible insects as an animal protein source given the expanding human population and the rising demand for traditional meats like beef, hog, and chicken(3).The following insect species could be raised and consumed in Europe under the right farming conditions: the house cricket (*Acheta domestica*), the Jamaican field cricket (*Gryllus assimilis*), the yellow meal-worm beetle (*Tenebrio molitor*), the superworm (*Zophobas morio*), the lesser mealworm (*Alphito biusdiaperinus*), the wax moth (*Galleria mellonella*) and the African migratory locust (*Locust amigratoria*) (4). In comparison to mammalian cattle, insects exhibit better feed efficiency index, it quantifies how well the animal converts feed bulk into body mass. Van Huis et al. (5) even claimed that the feed conversion of the house cricket (*A. domestica*) was more than 12 times higher than that of cattle, four times higher than that of pigs, and double that of chickens. A thorough overview of the usage of insects as food for humans may be found in Figure 1 below.

## Nutritional value of insects

Palatable insects have a wide range of nutritional value because of their abundance and variety of species. Even within a same species, an insect's nutritional value might differ greatly depending on its diet, source, and stage of metamorphosis (9). Payne et al. (10) found that the nutritional content of insects differed significantly between species. On the nutrient value scale, mealworms, crickets, and palm weevil larvae all scored higher than beef and poultry, and none of the six insects under study was statistically less healthy than meat. They may also include vitamins such as folic acid, pantothenic acid, biotin, and riboflavin under specific conditions (11).

## Energy value

Energy content is typically higher in larvae or pupae than in adults. In contrast, insect species with high protein content have lower energy levels (12). In 78 different insect species, Ramos- Elorduy et al. (13) assessed the calorific value, which ranged from 293 to 762 kcal per 100 g of dry mass. The energy content of a few species of edible insects, represented in kcal per 100 g of fresh weight, is shown in Table 1(5).

**Table 1:** Energy value of edible insect (5)

| Order | Common name | Scientific name | Phase | Area | En. value (kcal/100 g) |
|---|---|---|---|---|---|
| Orthoptera | | | | | |
| | Australian plague locust | *Chortoicetes foraminifera* | Adult | Australia | 499 |
| | wo-spotted cricket | *Gryllus bimaculatus* | Adult | Thailand | 120 |
| | Japanese grasshopper | *Oxya japonica* | Adult | Thailand | 149 |
| | Brown-spotted locust | *Cyrtacanthacris tatarica* | Adult | Thailand | 89 |
| Lepidoptera | African migratory locust | *Locusta migratoria* | Adult | Netherlands | 179 |
| Hymenoptera | Silkworm | *Bombyx mori* | Pupa | Thailand | 94 |
| | Weaver ant | *Oecophyllas maragdina* | Adult | Australia | 1272 |
| Coleoptera | Mexican leaf cutting ant | *Atta Mexicana* | Adult | Mexico | 404 |
| | Yellow mealworm beetle | *Tenebrio molitor* | Larvae | USA | 206 |

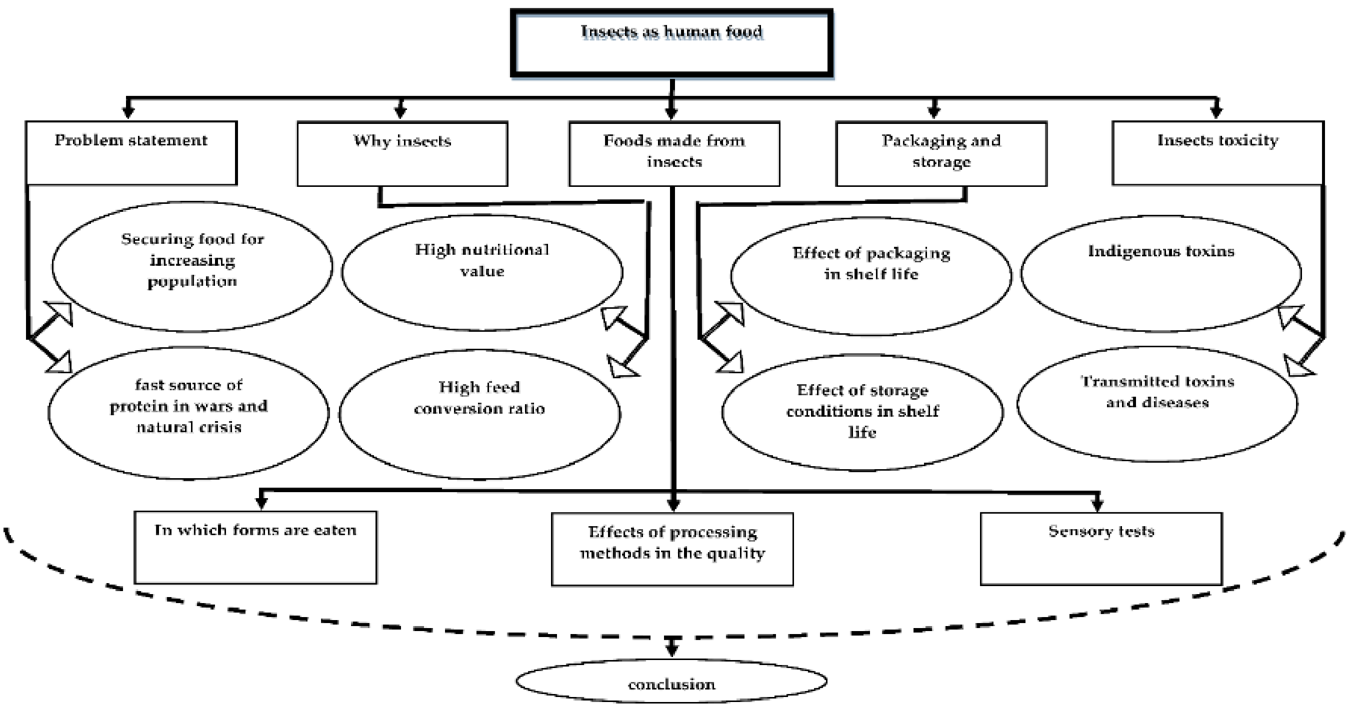


**Fig1**. Flowchart of value of insects as human food (6-8)

## Proteins

Seven kinds of insects were studied for their total protein content (12). All varieties of insects that were measured had roughly the same amounts of total protein, with the exception of the protein content of the wax moth (*G. mellonella*), which was just 38.4% (13). Yellow mealworms (*T. molitor*) made up 50.7% of the other species, while African migrating locusts (*L. migratoria*) made up 62.2%. 100 insect species' protein levels were examined by Xiaoming et al (14). Table 2 shows that, by dry matter, the protein concentration varied from 13 to 77%. Furthermore, edible insects have some essential amino acids, including threonine, lysine, and tryptophan which can be insufficient in certain plant or grain proteins (15, 16). Table 3 shows the insects from different order and their nutritional content, such as protein, fat, thiamine, and riboflavin. Overall, the edible insects may be a helpful complement to diets, especially in areas where other foods may lack certain nutrients. (5,17).

## Lipids

Between 10% and 60% of the dry mass in edible insects is made up of fat (Table 4). In comparison to adults, this is higher in the larval stages (14). According to study by Tzompa-Sosa et al. (20) per 100 g of Lepidopteran caterpillars contains about 8.6 to 15.2 g of the total fat content, placing them among the insects with the greatest fat content. In comparison, grasshoppers and similar orthopteran species have a fat content from 3.8 g to 5.3 g per 100 g of insects. In the insect, fat can be found in a variety of forms. The second-most significant category is phospholipids. Phospholipids make up less than 20% of fat in most cases, but this varies depending on the phases of life cycle and species of insect (20,21). The cholesterol is the highly predominant sterol in insects. The cholesterol level of the fat from two regularly eaten animals in Nigeria: the caterpillar *Imbrasia belina* and the termite *Macrotermes bellicosus* was investigated by Ekpo et al (21) and found that the lipid fraction had an average cholesterol level of 3.6%. Besides cholesterol, palatable insects may also provide other sterols such as campesterol, stigmasterol, and sitosterol (22).

**Table 2:** Protein content of some insect species (12)

| Insect name | Order | Life Stages | Protein content (% in dry matter) |
|---|---|---|---|
| Beetles | *Coleoptera* | Larvae and Adults | 23–66 |
| Butterflies | *Lepidoptera* | Larvae and Pupae | 14–68 |
| Hemipterans | *Hemiptera* | Larvae and Adults | 42–74 |
| Homopterans | *Homoptera* | Eggs, larvae and Adults, | 45–57 |
| Hymenopterans | *Hymenoptera* | eggs, larvae, Adult and pupae | 13–77 |
| Dragonflies | *Odonata* | naiads and Adults | 46–65 |
| Orthopterans | *Orthoptera* | nymphs and Adults | 23–65 |

**Table 3**: Some pertinent insects' nutritional qualities in relation to other high-protein diets (18, 19)

| Order | Insect's common name | Scientific name | Protein (g/kg) | Fat (g/kg) | Calories (kcal/kg) | Thiamine (mg/kg) | Riboflavin (mg/kg) |
|---|---|---|---|---|---|---|---|
| Diptera | Blacksoldier | *Hermetia illucens* | 175 | 140 | 1994 | 7.7 | 16.2 |
| | Fly(larvae), Housefly(adults) | *Musca domestica* | 197 | 19 | 918 | 11.3 | 77.2 |
| | Housecricket (adults) | | | | | | |
| Orthoptera | Superworm (larvae) | *Acheta domestica* | 205 | 68 | 1402 | 0.4 | 34.1 |
| | | *Zophobas morio* | 107 | 177 | 2423 | 0.6 | 7.5 |
| | | *Tenebrio molitor* | 187 | 134 | 2056 | 2.4 | 8.1 |
| | Mealworm(larvae), Mealworm(adult), | *Tenebrio molitor* | 237 | 54 | 1378 | 1 | 8.5 |
| Coleoptera | Giant mealworm (larvae), Waxworm(larvae) Silkworm(larvae) | *Tenebrio molitor* | 184 | 168 | 2252 | 1.2 | 16.1 |
| | | *Galleria mellonella* | 141 | 249 | 2747 | 2.3 | 7.3 |
| | Silkworm(Moth) | *Bombyx mori* | 93 | 144 | 674 | 3.3 | 9.4 |

**Table 4**: Percentage of fat in dry material of edible insects (12)

| Order | Common name | Scientific name | Life Stage | Fat content (% in dry matter) |
|---|---|---|---|---|
| Coleoptera | Silkworm | *Bombyx mori* | Pupa | 29 |
| | Yellow mealworm | *Tenebrio molitor* | Larva | 36 |
| | Giant mealworm | *Zopho basatratus* | Larva | 40 |
| Hymenoptera | Western honey bee | *Apis melifera* | Brood | 31 |
| Lepidoptera | Wax moth | *Galleria mellonella* | Caterpillar | 57 |
| Orthoptera | African migratory locust | *Locust amigratoria* | Nymph | 13 |
| | Jamaican field cricket | *Gryllus assimilis* | Nymph | 34 |

## Fibre

A substantial amount of fibre can be found in edible insects. The most prevalent type of fibre in an insect's body is insoluble chitin, which is primarily found in the exoskeleton. In commercially farmed insects 2.7 to 49.8 mg of chitin were found in per kilogram of fresh weight (i.e. equivalent to 11.6 to 137.2 mg per kg of dry matter) (5, 23). Chitin is still considered an indigestible fibre even though human stomach contents contain the enzyme chitinase (24). Additionally, insects can be a source of fibre and contain variable levels of fat, including essential fatty acids. Chitin, a component of insect exoskeletons, may also have immune-boostering and anti-allergenic properties (25, 26,27). It implies that more investigation into the dietary and health advantages of edible insects may result in higher consumption and broader acceptance of insects as beneficial food sources (Table 5).

## Minerals

When it comes to the nutritional value of minerals like calcium, phosphorus, magnesium, manganese, and copper, as well as iron, zinc, potassium, sodium, and potassium, edible insects can be an intriguing option (5). For instance, 8-20 mg per 100 g of dry matter of the grasshopper *L. migratoria* and 31-77 mg per 100 g of dry matter of the big mopane larva of the moth *Gonimbrasia belina*are combined showed high in iron content (28). When 26.5 mg per 100 g of dry matter of palm weevil larvae *Rhynchophorus phoenicis* combined with14 mg per 100 g of dry matter of mopane caterpillars found to be an effective source of zinc (7). However, Hyun et al. (29) found that an edible grasshopper, Oxya *chinensis formosana*, have the heavy metal concentration which was minimal and safe for human consumption. It had plumbum at 0.01–0.03 mg/100 g, cadmium at 0.002–0.005 mg/100 g, arsenic at 0.07–0.17 mg/100 g, and mercury at 0.0003–0.0007 mg/100 g. All this concentration of heavy metal in these insects found to be safe of human consumption.

## Vitamins

Numerous water-soluble or lipophilic vitamins are found in insects (17,30,31). Bukkens (17) provided a list of several insects that contain thiamine. Its concentration was 0.1 to 4 mg per 100 g of dry matter while each 100 g of dry matter of some insects contains riboflavin retinol and 6.8–8.2 g of beta-carotene. Some levels of retinol that were less than 20 g per 100 g of dry matter and -carotene that were less than 10 g per 100 g of dry matter were found in yellow mealworms *T. molitor*, superworms *Z. morio*, and house crickets *A. domesticus* (data shown in figure 2) (17,30). Vitamins A, D, and E may be found in eggs and escamoles from the Formicidae family. They included 2.22 mg of each100 g of alpha-tocopherol, 3.31 mg per 100 g of cholecalciferol, and 505 g per 100 g of retinol. In general, insects are high in riboflavin, pantothenic acid, and biotin, according to Rumpold and Schlüter (11). Nevertheless, these are not a dependable source of thiamin, vitamin A, vitamin C or niacin. Oonocx and Dierenfeld (31) also noted the low vitamin E contents (6–16 mg/kg DM) in the majority of the examined insect species, except *Drosophila melanogaster* and *Microcentrum rhombifolium* they have 112 and 110 mg per kg DM respectively. All specimens had low levels of retinol, a marker of vitamin A activity, but these levels varied widely between samples of 0.670–886 mg/kg DM. It is important to note that the vitamin and mineral content of wild edible insects' changes with the season and, for farm-bred species, can be controlled by feed.

**Table 5**: In the dry matter of edible insect's content of neutral-detergent fibre (12)

| Order | common name | Scientific name | Life Stages | Fibre content (% in dry matter) |
|---|---|---|---|---|
| Hymenoptera | Honey bee (western) | *Apis melifera* | Brood | 11 |
| Orthoptera | migratory locust(African) | *Locust amigratoria* | Nymph | 27 |
| | Jamaican field cricket | *Gryllus assimilis* | Nymph | 8 |
| | | | | 18 |
| | Yellow mealworm | *Tenebrio molitor* | Larva | 17 |
| Coleoptera | Giant mealworm | *Zopho basatratus* | Larva | 14 |
| | Silkworm | *Bombyx mori* | Pupa | 21 |
| | Wax moth | *Galleria mellonella* | Caterpillar | |

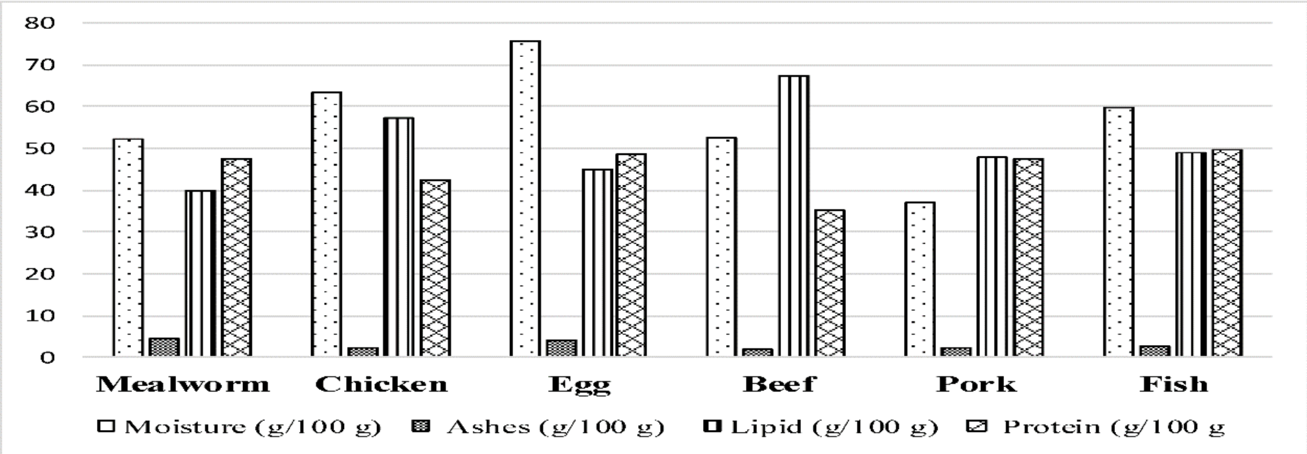


**Figure 2**. Nutritional evaluation of standard diets and yellow mealworm larvae. values for protein, lipids, and ashes based on dry weight. Source: Based on data from Alves et al. (32).

## Insect food and its acceptance

There are several ways to prepare and eat insects, including

**Whole insect:** Certain insects, including crickets, are edible intact after they've been cooked. Mealworm larvae can also be eaten whole after they have been cooked (33, 34).

**Dehydrated and crushed:** To add protein or other nutrients to a variety of food products, such as frankfurters, insects can also be dried and crushed (Figure 3) (35).

**Added fresh, without drying, to food products after killing:** Mealworms can be used to make processed foods like burgers by adding them whole to beef after they have been killed but before drying (34).

**As extracted nutrients:** Insects nutrients can be extracted and incorporated into diet. For instance, in order to increase the protein composition of food products, Zhao et al. (36) extracted and characterised mealworm protein.


**Figure 3.** The freeze-dried whole yellow mealworm larvae (A) and the milled and freeze-dried larvae (B) (Photo by Xue Zhao, SLU, Sweden)

Although mealworm larvae have high protein content, but neophobia and cultural conditioning make it difficult for people to accept them as food (37). To prevent phobias that can skew the results, sensory testing on foods made from insects might need to be carried out on people from cultures where eating insects is a tradition (37,38). According to some research, adding entire mealworm larvae powder to meals may be acceptable, and flavouring mealworm-based goods may increase their attractiveness (33,34,39). However, the kind of food matrix and the quantity of mealworm added are important factors influencing consumer approval, as adding too much mealworm to a meal in place of meat can increase off-flavour and reduce juiciness (34).

## Historical perspective of taking insects as food

Ancient tribes probably consumed insects often since they had well-developed hunting skills and few advanced tools (40). However, insect-eating customs have been disappearing in many places since the introduction of farming and the domestication of animals (41). Due to evolving societal attitudes, insects have evolved from being a primary food source to snacks, gourmet delicacies, and bait (42). Nevertheless, several nations continue to this day to use insects as stable food sources (43).

- In Asia, there are some nations, like China, where there are no explicit rules for the regulation of insects, where they have long been utilised as food and feed. Canned silkworm pupae and Silkworm(*Bombyx mori*) consumed in Korea (44,45,46,47,48). Fried grasshoppers are used in the Japanese cuisine (45). In China, Silkworm *(Bombyx mori*), Tussar silkworm (*Anthera eapernyi*), Mealworm *(Tenebrio molitor*) etc. being devoured (45,46,49,50,51). In India, the pupae of the Eri silkworm *(Samiaricini*) are prized (47). In Thailand, peoples consumed Silkworm *(Bombyx mori*), Ground cricket *(Allonemobius fasciatus)*, Weaver ant (*Oecophyllas maragdina*) etc. (45,48, 49, 50,51).

- The African food culture places a significant emphasis on edible insects (52). Insects from order Lepidoptera, Orthoptera, and Coleoptera are also frequently consumed (45,53). *Macrotermes spp.* (Termite), *Ruspolia nitidula* (Grasshopper), *Chaoborus edulis* (Lake fly), *Ruspolia differens* (Grasshopper)are consumed by Uganda people (54). Silk moth, termites are eaten by Congo people and in Kenya black ant (*Carebara vidua*), Grasshopper (*Ruspolia differens*), Winged termite (*Macrotermes subhylanus)* insects are also consumed (45,51,52).

- In Papua New Guinea, a common edible insect is the sago grub (*Rhynchophorus ferrugineus*) and is the centrepiece of an annual grub festival (55). According to Meyer- Rochow and Changkija (56), mole-crickets, mantises, crickets, locusts, and even spiders are eaten locally. According to Macfarlane (57), indigenous cultures ingested a diverse range of insects from the Cossidae, Noctuidae, Cerambycidae, and bees (58, 55,56, 57). Here insects are now offered on restaurant menus (59).

- In the Americas, Women and children actively go out hunting for edible insects, which are an important source of protein for Amazonian tribes (60). Palm weevil (*Rhynchophorus palmarum*), Ant (*Liometopuma piculatum*), Stink bug (*Atiziestax coensis*) are consumed in Mexico and consumed type are larvae, adult, pupae (45,61,62). Beetles (*Caryobruchus scheelaea*), Wasps (*Poly biaignobilis*), Grasshopper (*Aidemona Azteca*) are consumed in Colombia (61,62). The Federal Food and Drug Administration (FDA) in the USA is in charge of policing the safety of animal feed in North America (63) where a list of edible insects is classified as food additives.
- A concern to consumer health and safety is posed by Bovine Spongiform Encephalopathy (BSE), which has an impact on European regulations regarding the use of insects as feed (64, 65). Yellow mealworm, lesser mealworm, house cricket, banded cricket, field cricket, black army fly, and common housefly are among the insects that can be used (66, 67, 68). Many insect species like *Apis mellifera, Bombyx mori,Acheta domesticus, Locust amigratoria, Tenebrio molitor,Galleria mellonella, Gryllus assimillis, Hermetia illucens* consumed in Europe (69).

## Food processing of edible insects

Millions of people worldwide eat edible insects, which are high in protein, vitamins, and minerals (70). Food processing of edible insects can enhance their palatability, digestibility, and safety. Here are some common food processing methods used for edible insects:

**1.Cleaning:** Before processing, insects need to be cleaned to remove any dirt, debris, or unwanted material.

**2.Roasting:** Roasting is a common processing method that improves the flavour of insects. It involves heating the insects at high temperatures, which also helps to kill any bacteria.

**3.Drying:** Drying is a good way to save insects for future use. It entails drying out insects by placing them under an extended period of low heat.

**4.Grinding:** Using insects as an ingredient in different culinary products can be accomplished by grinding insects into a fine powder. A protein-rich item that can be utilised in baked products, snacks, and other foods is insect flour.

**5.Fermentation:** Enhancing the flavour and digestibility of insects through fermentation. In order to break down the insects' proteins and other nutrients, this technique includes adding healthy bacteria or yeast to the insects.

**6.Extraction:** By crushing or grinding the insects, it is possible to acquire insect oils and extracts. These can be incorporated into a variety of food items, such as salad dressings, sauces, and marinades.

**7.Freezing:** Freezing insects is a common method for preserving them for later use. Soups, stews, and stir-fries are just a few of the recipes that can benefit from using frozen insects (70). Insects are increasingly seen as the meal of the future as conventional methods of consuming animal protein are questioned (71). According to studies aiming at adapting insects for Western tastes, some insects (such as locusts and mealworms) are now sold at retail markets in the Netherlands as part of efforts to encourage entomophagy (72). To reduce visual associations and improve palatability, insects have been treated into powder or meal (73). Table 6 summarises previous studies on the useful properties of edible insects for food processing. In addition, appropriate extraction techniques, such as zymolysis, sonication, defatting, pH adjustments are being studied by Mishyna et al.;

**Table 6:** Studies conducted in the past on edible insects' ability to metabolise food

| Order | Scientific name | Stages of insects | Observation | Reference |
|---|---|---|---|---|
| Lepidoptera | *Cirina forda, Bombyx mori* L. | Larvae, Larvae | Protein solubility<br>Oil absorption capacity<br>Frothing stability<br>Water absorption capacity<br>Emulsion capability | (78) |
| Orthoptera | *Gryllodes sigillatus*<br>*Acheta domesticus*<br>*Schistocerca gregaria* | Larvae,<br>Cricket,<br>Grasshopper | Protein solubility<br>Water holding ability<br>Oil holding capacity<br>Frothing capacity<br>Emulsion capacity | (79) |
| Coleoptera | *Tenebrio molitor*<br>*Oryctes owariensis*<br>*Zophobas morio*<br>*Alphitobius diaperinus* | Cricket,<br>Larvae,<br>Larvae,<br>Larvae | Water binding capacity<br>Oil immersion capacity<br>Water absorption capacity<br>Frothing capacity<br>Frothing stability | (80)<br>(81) |
| Diptera | *Hermetia illucens* | Larvae | Frothing stability<br>Emulsion capacity<br>Emulsion stability<br>Fat binding capacity | (73) |
| Blattodea | *Blaptica dubia* | Cockroach | Protein solubility<br>Frothing stability<br>Gel formation | (82) |

Nongonierma and FitzGerald; Purschke et al., and Yi et al. (74,75, 76,77). These investigations will support the usage of insects as food components in conventional dishes.

## Product made from insects

In cultures where eating insects intact is common and considered a culinary tradition, the practice dates back centuries. Eating them as snacks, stir-frying them, grilling them over coals, or adding them to stews or soups. They are occasionally ground, used as flavour, and occasionally processed into powder and blended with salts and spices (83,84). Table 7 represents the Product made from insects, their nutritional component and types of insects used.

**Table 7**: List of products made from insects

| Product made from insects | Nutritional component | Product named | Insects used | References |
|---|---|---|---|---|
| Insect Protein bars | Protein | Chapul | Several bugs<br>Cricket | |
| Bread | Protein<br>Minerals<br>Vitamin B12 | Crunchy Cricket Loaf | Ground crickets<br>Mealworms | |
| Burgers | Iron<br>Calcium<br>Manganese | Bug Burger | Bug | |
| Candy & chocolate covered insects | Protein<br>Carbohydrate | Ant wafers, worm suckers, cricket and mealworm chocolate, insect marshmallows, mealworm lollipops, | Grasshopper<br>Ant<br>Mealworm<br>Black soldier flies<br>Silkworm pupae<br>Scorpions<br>Super worms<br>Sago worms | |
| Coffee | Vitamin<br>Magnesium<br>Potassium<br>Phenolic compounds | Japanese Cricket Blend coffee | Japanese Cricket<br>Ground insect<br>Crickets<br>Grasshoppers<br>Silkworm pupae | |
| Cookie | Carbohydrate<br>Protein<br>Fibre | Bitty's cookies | Bugs | |
| Crisps/chips | Carbohydrate<br>Fat | American Chirps | Cricket | |
| Crisps bread | Vitamin B12<br>Omega-2<br>Iron | *Swedish Eat:em.* | Mealworm<br>Cricket | |
| Ice cream | Protein | *"ento milk"* | *black soldier fly larvae*<br>*Cricket* | |
| Meat replacement (replacing minced meat) | Protein | *Sirkkis* | *Cricket* | |
| Noodles | Fat<br>Carbohydrate<br>Dietary fibre<br>Sodium | Bugsfarmsudo noodles<br>Nutribugs cricket rice noodles | *Bug*<br>*Cricket* | (83) |
| Pancake mix | Protein<br>Minerals<br>Pre-biotic fibre | *ZIRP pancake mix* | *Cricket* | |
| Pasta | Protein<br>Iron<br>Vitamin B12 Content | Hoppa Foods Eat<br>Crawlers Circle<br>Harvest Jimini's<br>Nutribug | *Cricket*<br>Mealworms Silkworm pupae | |
| Pasta sauce | Potassium<br>Carbohydrate | Gryllies Tomato Sauce | *Cricket* bolognese | |
| Pâté / bread spread / butters | Protein<br>Fat and fibre<br>Minerals | Crickster | *Bugs* | |
| Powder (sometimes called Flour) | Protein | Bug flour<br>Cricket flour | *Acheta domesticus* Cricket<br>Black Soldier Fly larvae | |
| Powder / baking flour | Calcium<br>Vitamin B12<br>Fatty acids | Cricket flour | *Cricket*<br>*Bug* | |
| Shakes and protein powder | Iron<br>Zinc<br>Vitamin B12<br>Protein | Cricket protein powder | Crickets<br>Mealworms<br>Bugs | |
| Protein Snacks | Protein | *Insect meal* | *Cricket* | |
| Roasted whole insect (with different flavours) | Protein | Chilli lime crickets | Grasshoppers Mealworms<br>Crickets | |
| Sausages | Protein<br>Fat | Sirkkanakki," or "cricket sausage | *Cricket* | |
| Shakes and smoothies | Protein | Sirkka smoothie | Crickets<br>Mealworms | |
| Spices & seasoning | Protein<br>Vitamin<br>Essential amino acid<br>Omega - 3 | Short-Horn super seasonings | Ant<br>Cricket | |
| Soft drinks | Carbohydrate<br>Sugar | Japanese Tagame Cider | Giant Water bug | |

### Insect protein vs meat protein

Even more so than mammals, insects can serve as a source of protein. According to a research in the European Journal of Clinical Nutrition, insect such as crickets have a protein content of 9.96 to 35.2 grammes per 100 grammes, compared to 16.8 to 20.6 grammes in meat. However, depending on the kind of bugs fed, protein density does vary significantly. Options abound with approximately 2,100 different edible bug species available. Crickets, various ant species, and mealworms are the catalyst of insect protein movement mostly because of their high calorie and protein density (85).

### Food security

Food security can benefit from edible insects, especially in areas with limited or difficult-to-access traditional food sources. Insects are a more sustainable and effective source of food since they can be raised with a fraction of the land, water, and feed resources needed for raising conventional livestock (86,87). Due to their high adaptability and ability to be raised in a range of habitats, including urban ones, insects may be able to help solve difficulties with urban food deserts and food insecurity (88). Additionally, there may be concerns related to the safety and quality of insect-based food products, particularly if they are not produced and processed under appropriate conditions. The hazards of bacterial infection cannot be completely eliminated by boiling (89, 90). During the production and storage phases, precautions must be taken. Overall, a variety of factors, such as the development of suitable production and processing methods, the availability of suitable feed sources, and the implementation of appropriate regulatory structures to guarantee the security and excellence of food items derived from insects, will determine the food security potential of edible insects (91, 92).

### Consumer acceptance of edible insect

Consumer acceptance of edible insects varies depending on region and culture, with insects being a traditional food source in many parts of South America, Asia, and Africa, but not widely accepted in North America and Europe (93, 94, 95). Factors such as cultural norms, taste preferences, and perceived health and environmental benefits can influence acceptance. Efforts to increase consumer acceptance include education campaigns to promote the nutritional and sustainability benefits of insect consumption (96, 97).

### Future direction

A growing global population's nutritional needs may be met by edible insects in a different and sustainable way (98, 99). Although it is unknown how much agony and pain insects experience, they appear to pose little difficulties for animal welfare. Multidisciplinary research on edible insects is being conducted, for instance, at the Pan-African International Centre of Insect Physiology and Ecology (ICIPE) in Nairobi, Kenya. A scientific research organisation, ICIPE's primary goals are to improve the health and food security of those who live in tropical areas. ICIPE creates and implements innovative approaches and technologies for managing insects that are practical, efficient, non-harmful, economical for resource-strapped communities, and acceptable from a cultural and social standpoint (100). In order to assure the necessary investments and corporate structures, comprehensive legal frameworks for the production and trade of insect products are needed on a national and worldwide basis.

## Conclusion

In conclusion, edible insects may supply significant quantities of proteins, lipids, vitamins, and minerals with significant economic and environmental benefits. Entomophagy holds the answer to meeting the world's expanding nutrient needs. Insects can be used in a variety of besides being consumed as foods and snacks. The thorough study of insects has led to the development of numerous contemporary items. Eating edible insects is becoming more and more common in different countries worldwide. In addition to eating insects for food, people do so for entertainment. Still, there are worries about the potential security and health hazards associated with employing edible insects. Currently, the market for edible insects is not in line with the advantages they may offer. To entice and reassure, production and promotion strategies are suggested. It is advised to use semi-cultivation because it can successfully increase the output of some insects. Both insect and insect products should be of high quality, hence farming and processing practices need to be standardised. For effective collaboration and increased earnings, communications between farmers and industries are encouraged. The creation of new insect products, advancements in cultivation, and production optimisation are anticipated to lead to agricultural industrial integration.

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## Author's contributions

I.P. and A.G. wrote the main manuscript text and J.K. prepared tables and figures. A.R. supervised the whole work. All authors read and approved the final manuscript.

## Compliance with ethical standards

**Conflict of interest:** Authors do not have any conflict of interests to declare.

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