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CAN ENTOMOPHAGY BE A GOOD OPTION FOR NUTRITION AND FOOD SECURITY?

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ABSTRACT

As the population increases, so does the demand for food and resources. Insects are rich in proteins, unsaturated fats and low in carbohydrates. They contain all the essential minerals and vitamins like iron, zinc, calcium, potassium, sodium, copper, riboflavin, biotin, and vitamin B9. Food and Agricultural Organization (FAO), estimated that the world need to increase its food production to feed a worldwide population of more than nine billion by the year 2050. Insects offer so much potential as an alternative food source to meet this need. More than two billion people including various ethnic communities around the world practice entomophagy and consume more than 2000 species of edible insects. Southeast Asian countries and African countries are one of the biggest consumers of edible insects. Due to its health and nutritional benefits, there is an increased demand and interest in European and American countries. Government policymakers, entrepreneurs, educationists, and chefs worldwide are exploring and promoting edible insects. Promoting novel insect-based food that is made of insects or insect ingredients such as insect flour, and insect protein powder could increase consumers and consumption. This review highlights insects as an alternative protein source for future food production. Insects like black soldier flies are used as insect feed for animals in poultry, pigs, and cows and are high in demand. Insects produce significantly less greenhouse gas emissions compared to other livestock. Edible insect farming and entomophagy present an important and sustainable opportunity for the future of food. This could also help generate employment for the rural women and youths as an alternate source of livelihood. Entomophagy has the potential to solve the world's food hunger and at the same time save the environment.

Key words: Entomophagy, edible insects, ethnic communities, food crisis, greenhouse gas, insect farming, insect feed, insect-based foods, livelihood, nutritional benefits, protein, sustainable

Insects have been a part of the human diet since time immemorial. They are highly nutritious and are rich in proteins, fats, carbohydrates, vitamins, and micro minerals (Dalal et al., 2019). They are easily accessible to us and abundantly found in their natural habitats. More than 2086 species of edible insects are reported and recognized as edible by more than 3071 ethnic communities in 130 countries (Lange and Nakamura, 2021; Ramos-Elorduy, 2009). The practice of entomophagy can be found in many countries mostly in Sub-Saharan Africa, Central and South America, or in Southeast Asia and the Pacific. With the growing population estimated to increase to 10 billion by 2050, the demand for food and resources is also increasing rapidly (Population 2020). From 2005 to 2050, the expected meat demand will increase by 76% globally (Alexander and Bruinsma, 2012) and the livestock sector is expected to grow fast, especially in European countries (FAO, 2008; Landgeist, 2021). Meat production requires large space and depends on a large amount of feed and water to grow and reproduce. So, there is a need to find an alternative source of food to fight the growing world hunger. Apart from this, more than 14% of all greenhouse gases which contributes to climate change and are responsible for increasing global warming are caused by livestock rearing (Gerber et al., 2013) and livestock production is also responsible for 59-71% of global agricultural ammonia emission (Beusen et al., 2008). Previous studies on the practice of entomophagy have shown that accepting edible insects and substituting them with animal protein has environmental benefits (Bao and Song, 2022).

The United Nations has recommended everyone practice entomophagy and mentioned edible insects as a potential solution to the scarcity of global food production. Insects are both sustainable and environment-friendly. Insects offer one of the finest alternative sustainable sources of protein as food to cope with the forthcoming problems faced due to malnutrition in developing and developed countries of the world (Mishyna et al., 2020). In comparison to livestock rearing, they produce more proteins and generate fewer greenhouse emissions; they consume

less food, less water, and cover less space/land while they reproduce more rapidly, they have more effective feed conversion and can be potentially easily grown on by-products which are organic waste and is produced globally 1.3 billion tons per annum (FAO, 2011). Insects are Poikilothermic or cold-blooded animals, so they put their energy into their growth and development instead of keeping their body warm. For example, it takes about 1.7 kilos of food to grow one kilogram of crickets whereas it requires 10 kilos of food to grow one kilogram worth of cow (Collavo et al., 2005). Furthermore, compared to other animals, insect food production has a low risk of spreading or transmitting zoonotic diseases (Van Huis, 2020). More than 1 million species of insects are believed to be found on Earth, and yet 80% remain to be discovered. They are the largest groups of species present on the entire planet (Altincicek, 2008). Insects are not only used as food, but they also play a significant role in our ecosystem. Insects like bees, butterflies, beetles, and wasps act as major pollinators. In addition, they help in decomposition, improving soil structure by cycling nutrients and maintaining soil fertility. Beside these, insects also provide other valuable products like honey, wax, silk, dyes, etc. In folk medicine and traditional healing practices, different ethnic tribal communities around the world use insects to treat many diseases and entomo-therapy has become an integral part of traditional healing practices of many ethnic communities.

Insect farming and rearing can offer great advantages to rural communities by enhancing their livelihood strategies. Insect harvesting can provide entrepreneurship opportunities in both developed and developing countries. Also, the cost of running an insect farm is lesser as compared to other livestock rearing. Insects provide high-quality proteins and nutrients compared to other sources of animal proteins. Recent studies in many years have shown that products made from insect proteins are a source of both macronutrients, micronutrients, and bioactive food components (Lange and Nakamura, 2021). Giving more importance to edible insects will help boost measures and steps towards the conservation of threatened biodiversity of insects in the future.

A. Global status

Entomophagy is an age-old practice that continues to the present day. Many instances of the practice of entomophagy by various communities have been recorded around the world. Such as, Chinese people consume the larvae of Silkworm *(Bombyx mori)* (Hu and Zha, 2009), and over 300 edible insect species are reported to be consumed in China and the number is still growing (Guine et al., 2021). In African countries especially in rural parts, children suffering from malnutrition and undernourished due to poor diet are fed with flour made from dried caterpillars commonly called Mopane worms to cure malnutrition. The mopane worm is quite nutritious, high in proteins, and contains significant amounts of phosphorous, iron, and calcium (Nantanga and Amakali, 2020). Silkworm larvae (*Oxya chinensis sinuosa* and *Bombyx mori*) are consumed by the people of South Korea and are considered representatives of edible insects (Han et al., 2017). In Southeast Asian countries like China, Thailand, Vietnam, Cambodia, and Laos, insects are considered a delicacy and have been accepted as part of their tradition (Young-Aree and Viwatpanich, 2005). Several tribal communities from different parts of the world including the Pedi tribe of South Africa (Quin, 1959) and the Yukpa tribe of Colombia and Venezuela (Kenneth, 1973) prefer eating traditional insect food over readily available fresh meat and other options. The ethnic tribes of Bangladesh consume a total of 36 insect species out of which nine insect species are also used as medicine against cough, fever, burns, etc (Dev et al., 2020).

By applying the science of geographical distribution of animals and plants, more insect consumption of ~350 to ~700 species of edible insects can be found in the parts of African, Neotropical, Oriental, and Palearctic regions (Udvardy, 1975). The countries that consume the most edible insects include the Democratic Republic of the Congo, Congo, Central African Republic, Cameroon, Uganda, Zambia, Zimbabwe, Nigeria, and South Africa. However, in Europe, 11 countries practice entomophagy (Ramos-Elorduy, 2009). In the Republic of Benin, the majority of surveyed people about 79.1% were found to have consumed edible insects for ages (Anagonou et al., 2023). In the year 2016, in Hungary due to the growing attention of media on foods containing insects or insect-based products, not only it became more familiar to the people (Smith, 2022) but in 2021, for the first-time insect food products were introduced and authorized as novel food in Europe (European Commission, 2021). In the year 2017, the Swiss Federal Office for Food Safety and Veterinary Affairs (FSVO) released official technical guidelines that inform and describe all the conditions of authorized insect foodstuffs and their production (FSVO, 2022). In Switzerland, three edible insect species that are the larval stages of the insect Yellow mealworm (*Tenebrio molitor)*, the House cricket (*Acheta domesticus),* and the Migratory locust (*Locusta migratoria)*

have been approved as food (Penedo et al., 2022). In countries like Kenya, undernourished children are fed complementary food based on edible termites. These were developed with adequate nutrient density and processed safely and affordably to fight and eradicate child malnutrition (Kinyuru et al., 2015). To encourage the practice of eating insects or entomophagy in Kenya, conventional consumer products such as sausages, muffins, crackers, and meatloaf are processed from termites and lake flies which are baked, boiled, and cooked which increases the shelf life (Ayieko et al., 2010). While countries like Australia and Thailand, many people enjoy consuming crispy fried locusts (Melgar-Lalanne et al., 2019). In terms of pest management, consuming insects proved to be the best way to reduce pests. Bodenheimer (1951) stated that countries like India, China, Bangladesh, Benin, Cameroon, Mexico, Nigeria, the Philippines, and Sudan are harvesting plant pests which help them reduce the use of synthetic insecticides. In developing countries, most of the insects are collected from farmlands, forests, and their wild vegetation. To make the harvest more productive, some species are semi-domesticated by taking certain measures (Van Itterbeeck and Van Huis, 2012) while some are fully domesticated like the silkworm with intensive care from eggs till the adult stage. It is reared for the production of silk from the cocoon as well as for human consumption. In Myanmar where about 30% of children aged under five are undernourished and suffer from malnutrition (USAID, 2020), studies have documented that consumer acceptance is 67% towards edible insects considered as food yet it is occasionally consumed by the people (Aung et al., 2023). Consuming Insects in countries like Myanmar where conventional meat consumption is low, can help solve the problem of food scarcity, and famine, and alleviate malnutrition because edible insects are rich sources of protein and other essential nutrients (Eurocham, 2019; Smith et al., 2021; Tuhumury, 2021).

Concerning allergies, people react differently to different foods. Some are allergic to grasshoppers, some to silkworms and some even to the exoskeleton of insects. In some cases, individuals with allergies to house dust mites and crustaceans may experience allergic reactions to foods containing insect ingredients like the yellow mealworm, *Tenebrio molitor* (a type of beetle from the Tenebrionidae family (Verhoeckx et al., 2014). Therefore, proper labeling of insect-based products should be mandatory before selling in the market to minimize the risk of allergic reactions among consumers. In comparison to the 1.1 million described insect species globally, it is believed that it can reach up to 6 million species (Hamilton et al., 2010) which are yet to be discovered, only a fraction of the estimated number of edible insect species are reported and many species of insects which can be consumed as food and feed remain unexplored.

B. Scenario in India

India is a diverse country consisting of different cultures and traditions. The population in India is around 1 billion and is expected to reach 1.66 billion by 2050, according to the United Nations (UN). The conventional meat and plant diet alone won't be enough to meet the food demand. So, there is an urgent need to find an alternate food source. FAO has already recommended edible insects as one of the best options to fight this growing demand. In India, 342 species of edible insects are already being consumed by different tribal communities across the country (Manna et al., 2022). Out of these, Arunachal Pradesh consumes up to 109 species (Manna et al., 2022). Nagaland with a total of 106 different species of edible insects being consumed by different tribes (Mozhui et al., 2020). In Manipur, the ethnic tribes consume a total of 119 species while in Assam, the number of edible insects reaches up to 80 (Manna et al., 2022). Meghalaya in the Northeastern region reported a smaller number of edible insect species being consumed. In other parts of the country such as Central Indian states which include Madhya Pradesh, Chhattisgarh, and Jharkhand consume 10 insect species. In contrast, South Indian states like Kerala, Karnataka, Tamil Nadu, and Telangana consume 5 insect species. The East Indian states like Odisha and West Bengal consume 4 species of edible insects (Manna et al., 2022). Most of the tribal people consume insects as a condiment, in the Ahom community during the festival of 'Bohag Bihu', a special type of dish is made in which the main ingredient is *Oecophylla smaragdina,* red ants (Chowdhury et al., 2015). Bodos, one of the major tribes in Assam, consumes a total number of 25 species of edible insects (Narzari and Sarmah, 2015). The red ant, *Oecophylla smaragdina* has been reported as one of the most common insects that have been consumed as food in 15 different states of India which includes Arunachal Pradesh, Assam, Chhattisgarh, Jharkhand, Karnataka, Kerala, Manipur, Mizoram, Madhya Pradesh, Nagaland, Odisha, Tripura, Tamil Nadu, Telangana, and West Bengal, they enjoy eating all the developmental stages of this insects because of its taste and it's easily available and nutritious (Jena et al. 2020; Mitra, 2020).

In Arunachal Pradesh, more than 100 indigenous communities live together with different cultures, traditional practices, and beliefs. The Nyishi and the Galo tribes consume at least 81 species of edible insect species out of which mostly Coleoptera and Hemiptera are consumed by Nyishi people whereas the tribals of Galo prefer Orthoptera and Odonata (Chakravorty et al., 2011). The Adi and Apatani tribes of Arunachal Pradesh have at least 65 insect species. All kinds of dragonflies are highly appreciated and preferred as food over other edible insects by Apatani tribes whereas the ethnic people of the Adi community like to consume Orthopterans mostly (Chakravorty et al., 2018). The Eastern part of Arunachal Pradesh which consists of different ethnic tribes like Wancho, Nocte, Tangsa, Singpho, and others were found to consume more than 50 insect species (Chakravorty et al., 2013), and also some insect species are used for treating diseases as traditional medicines.

In Nagaland, people from various ethnic groups belonging to Ao, Sumi, Angami, Lotha, Chakhesang, Konyak, and others have been using insects as part of their diet. During the festival of "Te-l Khukhu" held in July celebrated by Angami tribes of Southern region of Nagaland use the insect namely Carpenter worms locally called as "Loungu" that has culturally significant value (Aochen et al., 2020). They are considered as a popular delicacy and enjoyed by all the Naga tribes. These worms are also known to have medicinal value and are considered as one of the most expensive insects in Nagaland that are freshly sold in the market. There are some members of the Naga tribes who consider the insects bush cricket, *Elimaea securigera* as a "healthy food". After cooking or frying, these insects are served as a main dish with rice. Conventional meat like beef, pork, and chicken is replaced by these insects and is more preferred by the tribals (Mozhui et al., 2020). Vendors from the different tribal communities can be seen in the local market of Nagaland selling edible insects like red ants, dragonflies' nymphs, grasshoppers, stink bugs, honey bees, hornets, edible caterpillars, etc. The majority of the vendors in the local market are womenfolk from tribal communities, they sell the insects according to their availability in the natural vegetation as per the season and most of the edible insects are freshly harvested or sun-dried. They earn extra income by selling the insects which help them sustain themselves and their family. The larva stages of the insect *Tipula* are collected while digging the soil during cultivation. They are fried and consumed by the Mao and the Poumai tribes of Manipur and are also used for medicinal purposes (Kapesa et al., 2020). In Mizoram, Assam, Manipur, and Tripura, the Cinnamon Bug, *Ochrophora (Udonga) montana* is collected in large numbers during its season from the wild forest are fried in oil and consumed as food (Thakur and Firake, 2012). Thus, insects are traditional food; they are prized delicacies and they are free. Table 1 provides information on species, consumption patterns, habitat, and phases of consumption of 207 commonly consumed edible insects by various ethnic communities in the Northeastern states of India (adapted by Chakrovorty et al., 2011, 2013, 2014, 2018; Mozhui et al., 2017, 2020; Pradhan et al., 2022).

C. Insects as source of nutrition

Insects are highly nutritious. There are 87 species of edible insects whose protein content has been analyzed and reported. The protein present in these insects ranges from 15- 81% (Ramos-Elorduy, 1997). Insects contain not only all the essential amino acids, highly rich in proteins but also all kinds of macro and micro minerals. Insects like silkworms, mopane worms, palm weevils, beetles, and termites are rich in phosphorous, zinc, calcium, magnesium, iron, vitamins, etc. (Kim-Tae et al., 2019) which are important for the growth and development of the body. In some places in African countries, children and pregnant women are fed mopane worms to meet their daily requirements of nutrients (Illgner and Nel, 2000). In countries like Laos and Cambodia, where a larger population especially children, are malnourished or living in poor conditions, they rely on hunting and catching wild insects (crickets, grasshoppers) from their natural habitats (Tao and Li, 2018). A previous study reported that insects like *Oecophylla smaragdina* and *Odototermes* sp. not only contain proteins but have high antioxidant properties (Chakravorty et al., 2016). Compared to other conventional foods like green plants and fruits, these two insects show more flavonoids, phenolics, and other antioxidant properties (Raza et al., 2022). It has been reported that the antioxidant capacity of water-soluble extracts of edible insects like grasshoppers, silkworms, and crickets is 5 times greater than the antioxidant capacity of fresh juice in vitro (Di Mattia et al., 2019). Many studies on a wide variety of edible insects by researchers from the nutritional point of view have shown that edible insects present exceptional nutritious properties compared to other sources of food (Cappelli et al., 2020). Honey as a by-product, has been used to treat several diseases by humans since time immemorial (Banerjee et al., 2003). It is used both as food and as medicine.

Table 1. List of edible insects in Northeast India

Sl. No.	Common name	Taxonomic order	Scientific Name	Stage of an insect used	Mode of eating	Habitat
1.	Formosan subterranean termite	Blattodea	*Coptotermes formosanu*s	Adult, larvae	Raw, dried fried	Fields, underground burrows
2.	Bark cockroach	Blattodea	*Laxta* sp	Adult, larvae	Fried and boiled with local herbs.	Forest snag (decaying trees), underground burrows
3.	Madagascar hissing cockroach	Blattodea	*Gromphadorhina portentosa*	Adult, larvae	Fried and boiled with local herbs.	Forest snag (decaying trees), underground burrows)
4.	Termites	Blattodea	*Macropanesthia rhinoceros*	Adult, nymph	Fried	Fields, home lawns, and underground
5.	Weevil	Coleoptera	*Cyrtotrachelus buqueti*	Adult	Fried, roasted	Bamboo plants
6.	Stag-horned beetle	Coleoptera	*Prosopocoilus giraffa*	Adult, grubs	Roasted	Forest, fields
7.	Weevil	Coleoptera	*Sipalus hypocrite*	Adult	Fried, roasted	Crops, Grains
8.	Long horn beetle	Coleoptera	*Batocera davides*	Adult	Fried, roasted	Forest, trees
9.	Longhorn beetle	Coleoptera	*Stromatium longicorne*	Adult	Fried, roasted	Forest, Trees
10.	Longhorn beetle	Coleoptera	*Aphrodisium gibbicolle*	Adult	Fried, roasted	Forest, trees
11.	Long horn beetle	Coleoptera	*Hoplocerambyx* sp.	Adult, grubs	Roasted, fried and boiled	Forest, decaying trees, fields
12.	Long horn beetle	Coleoptera	*Batocera rubus*	Larva, adult. pupa	Cooked, boiled and roasted	Forest, trees
13.	Long horn beetle	Coleoptera	*Anoplophora* sp.	Larvae Adult	Boiled, roasted	Tree trunks, forest
14.	Long horn beetle	Coleoptera	*Batocera royle*i	Adult, grubs	Roasted, fried and boiled	Trees, stems, shaded forests
15.	Long horn beetle	Coleoptera	*Aristobia* sp.	Adult, grubs	Roasted, fried and boiled	Trees, stems, shaded forests
16.	Long horn beetle	Coleoptera	*Oplatocera* sp.	Adult, grubs	Roasted, fried and boiled	Trees, forest
17.	Long horn beetle	Coleoptera	*Orthosoma* sp.	Adult, larvae	Roasted, fried, boiled	Trees, forest
18.	Long horn beetle	Coleoptera	*Xylorhiza* sp.	Adult, grubs	Roasted, fried and boiled	Trees, forest
19.	Long horn beetle	Coleoptera	*Pseudonemophas versteegi*	Adult, grubs	Roasted, fried and boiled	Trees, forest
20.	Click beetle	Coleoptera	*Melanotus* sp.	Larvae, adult	Fried, Boiled	Dead trees, logs and plants
21.	Vine chafer	Coleoptera	*Mimela* sp.	Adult	Fried, Roasted	Forest, field, gardens
22.	Longhorn beetle	Coleoptera	*Xystrocera globosa*	Adult	Fried, roasted	Trees
23.	Giant Beetle	Coleoptera	*Eurytrachelus titan*	Adult	Roasted	Forest, trees
24.	Longhorn beetle	Coleoptera	*Machrochenus isabellinus*	Adult	Fried, roasted	Forest, trees
25.	Long horn beetle	Coleoptera	*Aegosoma sinicum*	Adult	Fried, roasted	Forest, Trees, grassland
26.	Beetle	Coleoptera	*Agrypnus* sp.	Adult	Fried, roasted	Low forest, grassland
27.	Palm weevil	Coleoptera	*Rhynchophorus phoenicis*	Adult, larvae	Fried and boiled	Forest edge, trees, open field
28.	Beetle	Coleoptera	*Analeptes* sp.	Adult	Roasted	Forest and Trees
29.	June beetle	Coleoptera	*Phyllophaga portoricensi*s	Adult	Fried and roasted	Trees, gardens, and forests, are mostly found in the evening

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(contd. Table 1)

30.	White beetle	Coleoptera	*Lepidiota stigma*	Adult	Roasted, fried	Field, trees, forest
31.	Jewel beetle	Coleoptera	*Buprestis* sp.	Adult	Roasted, fried	Forest, woodland
32.	Jewel beetle	Coleoptera	*Sternocera* sp.	Adult	Roasted, fried	Fields, gardens
33.	Bess beetle	Coleoptera	*Basilianus stoliczkae*	Adult, larvae	Fried and boiled with bamboo shoot	Forest snag (decaying trees)
34.	Bess beetle	Coleoptera	*Odontotaenius* sp.	Adult, larvae	Roasted, boiled, fried	Forest snag (decaying trees)
35.	Taro beetle	Coleoptera	*Aplosonyx chalybaeus*	Adult, larvae	Roasted, fried, boiled	Taro plant
36.	Large green Beetle	Coleoptera	*Anomala* sp.	Adult	Boiled, fried, roasted	Field, gardens
37.	Dung beetle	Coleoptera	*Copris lunaris*	Adult	Roasted	Field and forest.
38.	Bamboo weevil	Coleoptera	*Cryotrachelus dux*	Adult	Roasted, boiled, fried	Bamboo shoot
39.	Water beetle	Coleoptera	*Cybister* sp.	Adult	Boiled, Fried	Paddy fields, ponds
40.	Water beetle	Coleoptera	*Cybister limbatus*	Adult	Fried, roasted	Fresh water, Aquatic
41.	Water beetle	Coleoptera	*Cybister confuses*	Adult	Fried, roasted	Fresh water, Aquatic
42.	Water beetle	Coleoptera	*Cybister posticus*	Adult	Fried, roasted	Fresh water, Aquatic
43.	Water beetle	Coleoptera	*Cybister tripunctatus asiaticus*	Adult	Fried, roasted	Fresh water, Aquatic
44.	Long horn beetle	Coleoptera	*Batocera rufomaculata*	Larva, pupa	Cooked, roasted	Forest, Trees
45.	Beetle	Coleoptera	*Sandracottus manipurensis*	Adult	Cooked, roasted	Ponds, slow streams
46.	Japanese rhinoceros beetle	Coleoptera	*Allomyrina dichotoma*	Adult	Roasted, boiled, fried	Decaying trees and rotting barks
47.	Stag beetle	Coleoptera	*Odontolabis gazella*	Larvae	Roasted, boiled, fried	Forest, fields
48.	Scarab beetle	Coleoptera	*Propomacrus* sp.	Adult	Roasted	Trees, Field, Park
49.	Coconut Worm	Coleoptera	*Oryctes* sp.	Larva	Bamboo steamed, Boiled	Coconut trees and others.
50.	Water beetle	Coleoptera	*Hydrophilus caschmirensis*	Adult	Cooked	Aquatic, streams, lakes
51.	Stag beetle	Coleoptera	*Dorcus* sp.	Both Larva and adult	Fried	Inside tree
52.	Beetle	Coleoptera	*Anoplophora* sp.	Larva, adult, pupa	Fried and roasted	Forest snag, Decaying trees
53.	Borer beetle	Coleoptera	*Trictenotoma* sp.	Adult	Roasted	Forest
54.	Bamboo grub	Coleoptera	*Purpuricenus temminckii*	larvae	Boiled, fried	Inside bamboo plant
55.	Beetle	Coleoptera	*Holotricha* sp.	Adult	Roasted	Forest
56.	Scarab beetle	Coleoptera	*Polyphylla* sp.	Adult and Larvae	Fried and boiled	Orange trees
57.	Cow dung beetle	Coleoptera	*Catharsius* sp.	Adult	Roasted	Cow dung and soil
58.	Rhinoceros beetle	Coleoptera	*Xylotrupes gideon*	Adult	Boiled and roasted	Forest, trees, woodlands
59.	Earwig	Dermaptera	*Forficula* sp.	Adult	Fried	Cool moist places
60.	Crane flies	Diptera	*Tipula* sp.	Larvae	Boiled and steamed with local herbs	Streams, moist soil

(contd.)

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61.	Blowfly maggots	Diptera	*Lucilia* sp.	Maggots	Boiled, Maggots are eaten along with the meats	Rotten meat
62.	Housefly	Diptera	*Musca domestica*	Maggots	Boiled, Maggots are eaten along with the meats	Rotten meat
63.	Fly	Diptera	*Sericata* sp.	Maggots	Boiled and fried and sometimes cooked along with rotten meat	Rotten meat
64.	Mayflies	Ephemeroptera	-	Nymphs	Boiled	Streams and still water
65.	Bug	Hemiptera	*Anoplocnemis compressa*	Adult	Fried, roasted	Trees, forest, crop field
66.	Giant water bug	Hemiptera	*Lethocerus indicus*	Adult	Chutney paste, Roasted	Freshwater ponds, marshes, slow-moving pools in streams
67.	Cinnamon bug	Hemiptera	*Udonga montana*	Adult	Cooked, chutney, fried	Forest
68.	Shield bug	Hemiptera	*Cantao ocellata*	Adult	Fried, Roasted	Treetops, Various plants
69.	Litchee Bug	Hemiptera	*Tessaratoma javanica*	Adult	Roasted	Trees and litchee trees
70.	Litchee giant bug	Hemiptera	*Tessaratoma quadrata*	Adult	Chutney paste	Litchee trees and other trees
71.	Water striders	Hemiptera	*Geris* sp.	Adult	Fried, roasted	Aquatic, Slow water
72.	Stinkbug	Hemiptera	*Coridius* sp.	Adult,	Raw as Chutney paste with spices, Dry fried, Boiled, Bamboo steamed	Rocky riverbanks and under rocks
73.	Yellow spotted stink bug	Hemiptera	*Erthesina fullo*	Adult	Paste as chutney	Various plants
74.	Bug	Hemiptera	*Cosmoscarta* sp.	Adult	Fried, roasted	Forest, trees
75.	Shield bug	Hemiptera	*Dolycoris* sp.	Adult	Cooked as chutney	Trees and Shrubs
76.	Stink bug	Hemiptera	*Halyomorpha picus*	Adult	Raw or chutney	Rocky riverbanks and under rocks
77.	Shield bug	Hemiptera	*Eusthenes* sp.	Adult	Fried, chutney	Various Pants , crop field
78.	Bug	Hemiptera	*Asiarcha* sp.	Adult	Fried, roasted	Various plants, crop field
79.	Leaf footed bug	Hemiptera	*Dalader planiventris*	Adult	Cooked as chutney	Various plants
80.	Coreid bug	Hemiptera	*Anoplocnemis phasiana*	Adult	Cooked and as chutney	Various plants
81.	Stink bug	Hemiptera	*Catacanthus incarnatus*	Adult	Fried, roasted	Crop field, Various plants
82.	Red pumpkin bug	Hemiptera	*Coridius janus*	Adult	Cooked, fried	Crop field, Various plants
83.	Stink bug	Hemiptera	*Cresson vallida*	Adult	Fried, roasted	Trees, forest
84.	Stink bug	Hemiptera	*Coridius chinensis*	Adult	Cooked	Crop field, Various plants
85.	Cicada	Hemiptera	*Cryptotympana* sp.	Adult	Fried, Roasted	Deciduous trees

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(contd. Table 1)

86.	Treehopper	Hemiptera	*Darthula hardwickii*	Adult, nymph	fried	Various trees
87.	Stink bug	Hemiptera	*Cyclopelta siccifolia*	Adult	As chutney	Certain plant species, crop field
88.	Green stink bug	Hemiptera	*Nezera viridula*	Adult	Raw and as chutney	Trees, shrubs and forest
89.	Pentatomid bug	Hemiptera	*Eurostus grossipes*	Adult	As Chutney	Various plants
90.	Green stink bug	Hemiptera	*Chinavia hilaris*	Adult	As chutney	Forest, crop field
91.	Water scorpion	Hemiptera	*Laccotrephes maculates*	Adult	Boiled and fried	Streams, ponds
92.	Cicada	Hemiptera	*Euterphosia crowfoooti*	Adult	Fried, Roasted	Forest and trees
93.	Cicada	Hemiptera	*Cosmopsaltria* sp.	Adult	Fried, Roasted	Forest, trees
94.	Cicada	Hemiptera	*Dhundubia spiculata*	Adult	Roasted	Forest and trees
95.	Cicada	Hemiptera	*Dhundubia intermerata*	Adult	Fried, roasted	Forest
96.	Cicada	Hemiptera	*Dhundubia oopaga*	Adult	Roasted	Forest and trees
97.	Cicada	Hemiptera	*Pomponia fusca*	Adult	Fried, roasted	Forest
98.	Bug	Hemiptera	*Notobitus* sp.	Adult	Fried	Various trees
99.	Pharaoh Cicada	Hemiptera	*Magicicada* sp.	Adult	Roasted	Forest and trees
100.	Greengrocer cicada	Hemiptera	*Cyclochila virens*	Adult	Fried, roasted	Forest and trees
101.	Annual cicada	Hemiptera	*Tibicen pruinosus*	Adult	Roasted, fried	Forest and trees
102.	Cicada	Hemiptera	*Pomponia* sp.	Adult	Roasted	Forest and trees
103.	Cicada	Hemiptera	*Pycna repanda*	Adult	Roasted	Forest and trees
104.	Honeybee	Hymenoptera	*Apis indic*a	Adult, Larvae and honey	Boiled, fried and roasted	Domesticated and forest
105.	Little bee	Hymenoptera	*Apis florea*	Adult, Larvae and honey	Boiled, fried and roasted	Forest and trees
106.	Carpenter bee	Hymenoptera	*Xylocopa* sp.	Eggs and larvae	Boiled with bamboo, salt, ginger	Forest and trees
107.	Carpenter bee	Hymenoptera	*Xylocopa aestuans*	Larvae	Fried, boiled	Roofs, Eaves, Wood, Tree trunk
108.	Carpenter bee	Hymenoptera	*Xylocopa irridipensis*	Larvae	Fried, boiled	Roofs, Eaves, Wood, Tree trunk
109.	Weaver ant	Hymenoptera	*Oecophylla samaragdina*	Eggs and adults	Boiled and as a chutney with garlic, ginger, and chilly	Shrub, tree, Forest
110.	Lesser banded hornet	Hymenoptera	*Vespa affinis*	Larva, pupa	Roasted, Boiled, Fried	Nests found in trees and shrubs and on houses and buildings.
111.	Honeybee	Hymenoptera	*Apis mallifera*	Larvae, honey	Roasted, Boiled, Fried	Underground or hollow wood
112.	Stingless bee	Hymenoptera	*Apis* sp.	Larva, honey	Roasted, Boiled, Fried	House, forest
113.	Paper wasp	Hymenoptera	*Ropalida rufoplagiata*	Larvae, pupa, adult	Cooked, fried	Shrubs, Tree branches, Forest
114.	Honey bee	Hymenoptera	*Apis dorsata*	Larva, pupa	Boiled, fried	Rocky cliffs

(contd.)

(contd. Table 1)

115.	Wasp	Hymenoptera	*Vespa auraria*	Larva, pupa, adult	Cooked, fried, Boiled,	Forest, woodlands
116.	Wasp	Hymenoptera	*Vespula orbata*	Larvae, pupa, adult	Cooked, fried	Forest, tree trunk, woodland
117.	Paper wasp	Hymenoptera	*Polistes stigmat*a	Larva, pupa	Boiled, Fried	House roofs, Lawn furniture
118.	Yellow jacket	Hymenoptera	*Vespula vulgaris*	Larva, pupa	Boiled, fried	Treetops
119.	Yellow hornets	Hymenoptera	*Delta conoidium*	larvae	Fried	Near houses, hollow cavities
120.	Wasp	Hymenoptera	*Rhynchium brunneum*	Larvae	Fried	Hollow cavities
121.	Hornet	Hymenoptera	*Vespa soror*	Larva, pupa, adult	Boiled, fried	Underground nests
122.	Wasp	Hymenoptera	*Vespa ducalis*	Larva	Boiled, fried	Trees and forest
123.	Giant honeybee	Hymenoptera	*Apis* sp.	Larva, eggs and honey	Boiled, Fried, Bamboo steamed	Tree bark hole
124.	Paper wasp	Hymenoptera	*Polistes olivaceus*	Larva	Boiled, Fried, Bamboo steamed	Terrestrial
125.	Japanese hornet	Hymenoptera	*Vespa* sp.	Larva	Boiled, Bamboo steamed	Forest and underground nest
126.	Asian Giant hornet	Hymenoptera	*Vespa mandarini*a	Larva	Roasted, Dry fried, Boiled	Live underground in subterranean nest and found in low mountain and forests
127.	Potter Wasp	Hymenoptera	*Eumenes* sp.	Larvae	Boiled	Shrub, trees
128.	Common oriental hornet	Hymenoptera	*Vespa tropica*	Eggs and larvae	Boiled with bamboo shoot	Nest are found in tree cavities, above grounds, forest
129.	Wasp	Hymenoptera	*Vespa bicolor*	Larvae, eggs	Boiled, fried	Make underground nest and in the cavities of hollow trees, attics, burrows and buildings.
130.	Black-bellied Wasp	Hymenoptera	*Vespa basalis*	Eggs and larvae	Boiled, steamed and fried	Nests on branches, rock crevices, buildings, and under the ground.
131.	Night hornet	Hymenoptera	*Provespa* sp.	Eggs, larvae	Boiled steamed and fried	Nests found in trees, buildings, hollow walls of houses etc.
132.	Lesser paper wasp	Hymenoptera	*Parapolybia varia*	Adult, pupa, larvae, egg	Boiled steamed and fried	Orchards, woodlands, Shrubs, cliff overhangs
133.	Stingless bee	Hymenoptera	*Lepidotrigona arcifera*	Adult, larvae, pupa	Boiled, fried	Forest edge, hollow trunk
134.	Tree ant	Hymenoptera	*Liometopum lindgreeni*	Adult, egg, pupae and larvae	Boiled steamed and fried	Forest, Tree holes
135.	Underground stingless bee	Hymenoptera	*Lophotrigona canifrons*	Adult, larvae, pupa	Boiled steamed and fried	Underground
136.	Ditch jewel	Odonata	*Brachythemis contaminata*	Larvae and nymph	Boiled and raw mixed with bamboo shoot	Near streams, rivers, or freshwater bodies
137.	Clubtail dragon fly	Odonata	*Stylurus* sp.	Larvae and nymph	Boiled and raw mixed with bamboo shoot	Near streams, rivers, or fresh water bodies

(contd.)

(contd. Table 1)

138.	Azure bullet	Odonata	*Enallagma* sp.	Larvae and nymph	Boiled and raw mixed with bamboo shoot	Near streams, rivers, or fresh water bodies
139.	Blue dasher	Odonata	*Pachydiplax* sp.	Larvae and nymph	Boiled and raw mixed with bamboo shoot	Near streams, rivers, or fresh water bodies
140.	Club tail dragon fly	Odonata	*Ictinogomphus rapax*	Larvae and nymph	Boiled and raw mixed with bamboo shoot	Near streams, rivers, or fresh water bodies
141.	Dragon fly	Odonata	*Urothemis* sp.	Larvae and nymph	Boiled and raw mixed with bamboo shoot	Near streams, rivers, or fresh water bodies
142.	Cardinal meadow hawk	Odonata	*Sympetrum* sp.	Larvae and nymph	Boiled and raw mixed with bamboo shoot	Near streams, rivers, or fresh water bodies
143.	Yellow tailed ashy skimmer	Odonata	*Potamarca congener*	Adult, larvae and nymph	Boiled and raw mixed with bamboo shoot, steamed in bamboo	Near streams, rivers, or fresh water bodies, open field, paddy field and jungle
144.	Wandering glider	Odonata	*Pantala flavescens*	Adult, larvae and nymph	Boiled and raw mixed with bamboo shoot, steamed in bamboo	Near streams, rivers, or fresh water bodies, open field, paddy field and jungle
145.	Forest skimmer	Odonata	*Neurothemis fluvia*	Adult, larvae and nymph	Boiled and raw mixed with bamboo shoot, steamed in bamboo	Near streams, rivers, or fresh water bodies, open field, paddy field and jungle
146.	Crimson marsh hawk	Odonata	*Orthetrum pruinosum*	Adult, larvae and nymph	Boiled and raw mixed with bamboo shoot, steamed in bamboo	Near streams, rivers, or fresh water bodies, open field, paddy field and jungle
147.	Slender skimmer	Odonata	*Orthetrum sabina*	Adult, larvae and nymph	Boiled and raw mixed with bamboo shoot, steamed in bamboo	Near streams, rivers, or fresh water bodies, open field, paddy field and jungle
148.	Skimmer dragonfly	Odonata	*Neurothemis* sp.	Adult, larvae and nymph	Boiled and raw mixed with bamboo shoot, steamed in bamboo	Near streams, rivers, or fresh water bodies, open field, paddy field and jungle
149.	Blue-tailed	Odonata	*Ischnura senegalensis*	Adult, larvae and nymph	Boiled and raw mixed with bamboo shoot, steamed in bamboo	Near streams, rivers, or fresh water bodies, open field, paddy field and jungle
150.	Common picture wing	Odonata	*Rhyothemis variegata*	Adult, larvae and nymph	Boiled and raw mixed with bamboo shoot, steamed in bamboo	Near streams, rivers, or fresh water bodies, open field, paddy field and jungle
151.	Slender skimmer	Odonata	*Orthetrum* sp.	Adult, larvae and nymph	Boiled and raw mixed with bamboo shoot, steamed in bamboo	Near streams, rivers, or fresh water bodies, open field, paddy field and jungle

(contd.)

(contd. Table 1)

152.	Keyhole glider	Odonata	*Tramea* sp.	Adult, larvae and nymph	Boiled and raw mixed with bamboo shoot, steamed in bamboo	Near streams, rivers, or fresh water bodies, open field, paddy field and jungle
153.	Migrant hawker	Odonata	*Aeshna mixta*	Adult, larvae and nymph	Boiled and raw mixed with bamboo shoot, steamed in bamboo	Near streams, rivers, or fresh water bodies, open field, paddy field and jungle
154.	Chalky percher	Odonata	*Diplacodes trivialis*	Adult, larvae and nymph	Boiled and raw mixed with bamboo shoot, steamed in bamboo	Near streams, rivers, or fresh water bodies, open field, paddy field and jungle
155.	Emperor dragonfly	Odonata	*Anax imperator*	Adult, larvae and nymph	Boiled and raw mixed with bamboo shoot, steamed in bamboo	Near streams, rivers, or fresh water bodies, open field, paddy field and jungle
156.	Flame skimmer dragonfly	Odonata	*Libellula saturata*	Adult, larvae and nymph	Boiled and raw mixed with bamboo shoot, steamed in bamboo	Near streams, rivers, or fresh water bodies, open field, paddy field and jungle
157.	Scarlet Skimmer	Odonata	*Crothemia servilia*	Adult, larvae and nymph	Boiled and raw mixed with bamboo shoot, steamed in bamboo	Near streams, rivers, or fresh water bodies, open field, paddy field and jungle
158.	Crimson marsh glider	Odonata	*Trithemis aurora*	Adult, larvae and nymph	Boiled and raw mixed with bamboo shoot, steamed in bamboo	Near streams, rivers, or fresh water bodies, open field, paddy field and jungle
159.	Asian widow/ Blue-tailed yellow skimmer	Odonata	*Palpopleura sexmaculata*	Adult, larvae and nymph	Boiled and raw mixed with bamboo shoot, steamed in bamboo	Near streams, rivers, or fresh water bodies, open field, paddy field and jungle
160.	Rice Short-horned grasshopper	Orthoptera	*Oxya hyla intricat*a	Adult	Dry fried, Smoke dried and fried	Rice field
161.	Oriental long-headed grasshopper	Orthoptera	*Acrida cinerea*	Adult	Raw, Dry fried	Fields
162.	Mole cricket	Orthoptera	*Scapteriscus* sp.	Adult, nymph	Roasted, Fried,	Underground hole
163.	House cricket	Orthoptera	*Acheta domestic*us	Adult	Roasted, Fried,	House lawns, bushes, fields
164.	Grasshopper	Orthoptera	*Schistocerca gregaria*	Adult, nymph	Raw, Roasted, dry fried	Crop field
165.	Citrus locust	Orthoptera	*Chondracris rosea*	Adult	Roasted, fried, wings and limbs are discarded	Paddy field
166.	Short-horned grasshopper	Orthoptera	*Acrida exaltata*	Adult	Roasted, dry fried	Paddy field
167.	Two stripped grasshoppers	Orthoptera	*Melanoplus bivattatus*	Adult	Roasted, fried	Paddy field

(contd.)

(contd. Table 1)

168.	Two stripped grasshoppers	Orthoptera	*Melanoplus* sp.	Adult	Roasted and fried	Paddy field
169.	Tobacco grasshoppers	Orthoptera	*Atractomorpha* sp.	Adult	Roasted, fried	Paddy field
170.	Short horned grasshoppers	Orthoptera	*Hieroglyphus banian*	Adult	Roasted, fried	Paddy field
171.	Cricket	Orthoptera	*Gryllus* sp.	Adult	Roasted	Under burrows, soil and forests
172.	Cricket	Orthoptera	*Teleogryllus* sp.	Adult	Roasted	Under burrow and field
173.	Cricket	Orthoptera	*Tarbinskiellus portentosa*	Adult	Roasted, fried	Under burrow, field
174.	Cricket	Orthoptera	*Tarbinskiellus orientalis*	Adult	Roasted, fried	Under burrow, field
175.	Sand Cricket	Orthoptera	*Schizodactylus monstrosus*	Adult	Roasted, fried	Sandy areas
176.	Katydid	Orthoptera	*Conocephalus* sp.	Adult	Fried, roasted	Trees, field, bushes and grasses
177.	Katydid	Orthoptera	*Arachnacaris* sp.	Adult	Roasted, fried and boiled	Trees, field, bushes and grasses
178.	Katydid	Orthoptera	*Chloracris brullei*	Adult	Roasted, fried. Wings and antennae are discarded	Trees, field, bushes and grasses
179.	Katydid	Orthoptera	*Microcentrum* sp.	Adult	Roasted, fried, and boiled	Trees, field, bushes and grasses
180.	Clown grasshopper	Orthoptera	*Diabolocanthops innotablis*	Adult	Roasted, fried, smoked	Fields
181.	Cricket	Orthoptera	*Brachytrypes* sp.	Adult	Roasted, fried,	Sandy area, ground
182.	Bush-cricket	Orthoptera	*Mecopoda elongata*	Adult	Roasted, fried, smoked	Paddy fields
183.	Bush-cricket	Orthoptera	*Mecopoda* sp.	Adult	Roasted, smoked, fried	Fields, bushes
184.	Giant false leaf katydid	Orthoptera	*Pseudophyllus titan*	Adult	Roasted	Fields, forests
185.	Shield backed katydid	Orthoptera	*Tettigonia sp.*	Adult	Roasted	Fields, forests
186.	Round-headed katydid	Orthoptera	*Amblycorypha* sp.	Adult	Roasted	Fields, forests
187.	Giant katydid	Orthoptera	*Tettigoniidae* sp.	Adult	Roasted, fried	Rice field
188.	Cricket	Orthoptera	*Ornebius Kanetataki*	Adult	Roasted	Under burrow and soil
189.	Cricket	Orthoptera	*Meloimorpha cincticornis*	Adult	Roasted, fried	Field
190.	Grasshopper	Orthoptera	*Choroedocus robustus*	Adult	Roasted, fried, dry fried	Rice field
191.	Katydid	Orthoptera	*Ruspolia nitidula*	Adult	Roasted, fried	Rice and paddy field
192.	Katydid	Orthoptera	*Arachnacris* sp.	Adult	Roasted, fried	Rice and paddy field
193.	Eri Silkworm	Lepidoptera	*Samia ricini*	Larva, Pupae	Boiled, Fried	Home reared
194.	Muga silkworm	Lepidoptera	*Antheraea assamensis*	Larva, Pupae	Boiled, Fried	Home reared, trees
195.	Carpenter worm	Lepidoptera	*Cossus* sp.	Larva,	Boiled	Oak and other hardwood trees
196.	Tent caterpillar	Lepidoptera	*Malacosoma* sp.	Larva,	Boiled	Tree and shrubs
197.	Mulberry silkworm	Lepidoptera	*Bombyx mori*	Larva	Boil, Fried	Home reared

(contd.)

(contd. Table 1)

198.	Moth	Lepidoptera	*Pericyma cruegeri*	Larva	Cooked, fried	Trees, Forest
199.	Banana Skipper	Lepidoptera	*Erionota torus*	Larvae	boiled	Inside banana leaf
200.	Pine tree caterpillar	Lepidoptera	*Kunugia* sp.	Larva, pupa	Boiled, fried	Pine tree and other trees
201.	Bamboo caterpillar	Lepidoptera	*Omphisa fuscidentalis*	larvae	Boiled and fried	Found inside bamboos
202.	Caterpillar	Lepidoptera	*Antheraea mylitta*	Larvae	Cooked	Trees
203.	Praying mantis	Mantodea	*Heirodula unimaculata*	Adult	Fried, roasted	Crop field, forest
204.	Praying mantis	Mantodea	*Heriodula coarctata*	Adult	Roasted	Crop field, forest
205.	Mantis	Mantodea	*Humberteilla* sp.	Adult	Fried, roasted	Crop field, forest
206.	Mantis	Mantodea	*Mantis religiosa*	Adult	Roasted	Crop field, Forest
207.	Praying mantis	Mantodea	*Tenodera sinensis*	adult	Roasted	Crop field, forest

Insects like mealworms, caterpillars, crickets, and grasshoppers are highly rich in protein content and contain fiber, minerals, and vitamins (Rumpold and Schluter 2013). Insects such as crickets have been found to contain all the essential amino acids for adults including histidine, isoleucine, leucine, lysine, threonine, tryptophan, and valine (Raheem et al., 2019). Insects contain more protein than beef or fish and have a very high calorific value compared to pigs, cows, and other meats (Srivastava et al., 2009). The kind of protein found in insects is much more digestible than other forms of protein. In fact, 80% of cricket body is edible and digestible while only 55% of chicken and 40% of cattle and pigs are edible in comparison (Nakagaki and De Foliart, 1991). In recent years, various surveys and studies on consumer acceptance of entomophagy have increased significantly (Onwezen et al., 2021). People around the globe are exploring and developing innovative products made from insects. Also, culinary education has an important role to play in the mindset of people toward novel food products, therefore people who are aware of culinary education tend to like and explore these innovative products. Thus, educated people who are aware of the benefits of entomophagy consume insects more frequently (Liu et al., 2020). A renowned chef Joseph Yoon, an edible insect ambassador and founder of Brooklyn Bugs, is advocating and promoting the potential of edible insects as future food all around the globe (Brooklyn Bugs). In many Western countries, many entrepreneurs are rearing insects on a grand scale (Aspire Food Group). Cricket flour is one such product made from insects and it has 68% protein, essential fatty acids, minerals, and a lot of vitamins b12, cricket protein can offer many nutritional and health benefits to human health (Nowakowski et al., 2022). It has been reported that compared to men, women in Liberia and China prefer consuming insects. Edible Insects are beneficial to health so women who are pregnant consume more insects (Castro and Chambers, 2019; Coley et al., 2020).

When it comes to entomophagy, it is sustainable and environment-friendly. Insects as food have a better feed conversion ratio and also insect food production emits fewer greenhouse gases (Bisconsin-Junior et al., 2022). When compared to other livestock, to produce 1kg of protein, mealworms require only 10% land needed for beef production (Biano 2022). With a fast-growing population and demand for food, the carbon footprint of every individual is increasing. Major greenhouse gases like carbon and methane have increased in the atmosphere in the past few years (Kweku et al.,

2018). Live stocks or cattle and poultry farming alone generate 80% of greenhouse gases and contribute 14.5% to global temperature (Gerber et al., 2013). By replacing meat with insects, the carbon footprint can be minimized as insects generate a negligible amount of greenhouse gas. Over-harvesting of some species due to their high demand can threaten insect species and lead to a decline in population and even extinction if not harvested responsibly. So, it is important to identify what is being consumed and how it is being consumed. Other important factors include sustainable harvesting, potential impacts on ecosystems due to over-harvesting, production, food safety, nutritional and health benefits, and education. A regional information system is necessary to address these issues. For example, in Hidalgo, Mexico 14 out of 30 edible insect species are now threatened due to an increase in commercialization which leads to over-harvesting in most cases. Changes in environment and climate are also responsible for the decline of some edible insect species (Ramos-Elorduy, 2006). Awareness of the negative aspects of over-harvesting of edible insects and the promotion of sustainable harvesting must be regulated.

D. Role of edible insects in economy and livelihood

Insect farming is considered as an alternative to conventional animal husbandry to combat food scarcity, hunger, and malnutrition and produce food for the future (Van Huis, 2019). Farmers in countries like Cambodia, Thailand, Vietnam, South Africa, Mexico, and China generate income through insect farming and they are sold in the market which is usually in great demand by the locals as well as vendors (Guine et al., 2021). In Thailand, over 20,000 insect farms of edible insects mostly crickets, and mealworms are listed (Feng et al., 2018). Entomologists, entrepreneurs, chefs, and environmentalists in developed countries like the USA, and Australia are now marketing flours, protein bars, protein shakes, etc. made from powdered insects as an alternative for people who are disgusted to directly consume insects (Meyer-Rochow and Hakko, 2018). People worldwide consume 344 beetle species, 313 ant species, 235 butterflies and moth species, 239 grasshoppers, crickets and cockroach species, 39 termite species, and many other species of cicadas and dragonflies (Gasca-Alvarez and Costa-Neto, 2021; De Foliart, 1989). Cricket powder have been found to contain high amounts of minerals like iron, magnesium, zinc, and copper (Montowska et al., 2019). One of the advantages of edible insect farming is that they can be bred on organic waste including human waste, compost, and manure. They can be reared sustainably and help us save from environmental contamination.

In aquaculture and livestock, recent studies have shown that insects as an ingredient for feed are growing and are in high demand. One of the most common insects that are used as feed for chicken, pigs, channel catfish, African catfish, rainbow trout, turbot, and tilapia is the use of black soldier fly (Adeniyi and Folorunsho, 2015; Tschirner and Simon, 2015). The use of insects as feed for fish in aquaculture has been in practice and allowed since 2013 by the European Union regulation (EU) 56/2013. Studies have shown that insects provide a good source of protein for farmed salmon in Norway (Lock et al., 2015). It has been reported that depending on animal species edible insects can replace 25-100% of soymeal or fishmeal as feed to many livestock such as farm pigs, poultry animals, fish species, and ruminants (Makkar et al., 2014). Thus, numerous companies all around the world are exploring the insect feed business to produce livestock meals (FAO 2011). During the preliminary field survey on the edible insect diversity, it was observed that In the North-Eastern region of India, local people in states like Nagaland, Manipur, and Arunachal Pradesh earn a good income regularly, based on selling insects in the local market. In Arunachal Pradesh and Nagaland, seasonal insects are being sold at a very high price, and they are usually in great demand. Insects like locusts, hornets, red ants, bamboo worms, silkworms, stink bugs, grasshoppers, and some species of beetles are found in some local markets. An estimation of per capita income generated by rearing and selling silkworms in Nagaland is shown below.

In the rearing of eri-silkworm, a farmer can earn a minimum of Rs. 20,950/ batch of eri-silkworm and Rs. 1,04,750/ year. For space, a normal room will be enough to rear a batch of Eri-silkworm but the plant (Castor) to feed them must be planted at least 1 acre of land. Since the lifecycle of Eri-silkworm is about 30-40 days and for better production, March-October is the best month. In a year, 5-6 batches of silkworms can be reared. One batch of disease-free layings yields 35-40 kg of silkworm and 8-9 kg of cocoon, with each kg selling for Rs. 450-500 in the local market. Rearing 5-6 batches can yield Rs. 1,04,750. The demand for Eri-silkworm is huge in the market therefore large-scale rearing of Eri-silkworm will not only generate good income but will also provide employment opportunities in rural as well as urban areas. The establishment of insect farming sectors can help us enhance the livelihood of the poor section of society by bringing extra income as well as offering a solution to food insecurity. Thus, creating awareness, providing training in insect farming and production,

Fig. 1. a) Women selling red ants in Tirap district, Arunachal Pradesh; b) Hornets selling in Mao market, Kohima, Nagaland; c) and d) Women vendors selling edible insects and local vegetables in Mao market, Kohima, Nagaland; e) One of the most expensive insects (Carpenter worm) being sold in the market, Kohima, Nagaland; f) Selling locust in supermarket in Dimapur, Nagaland

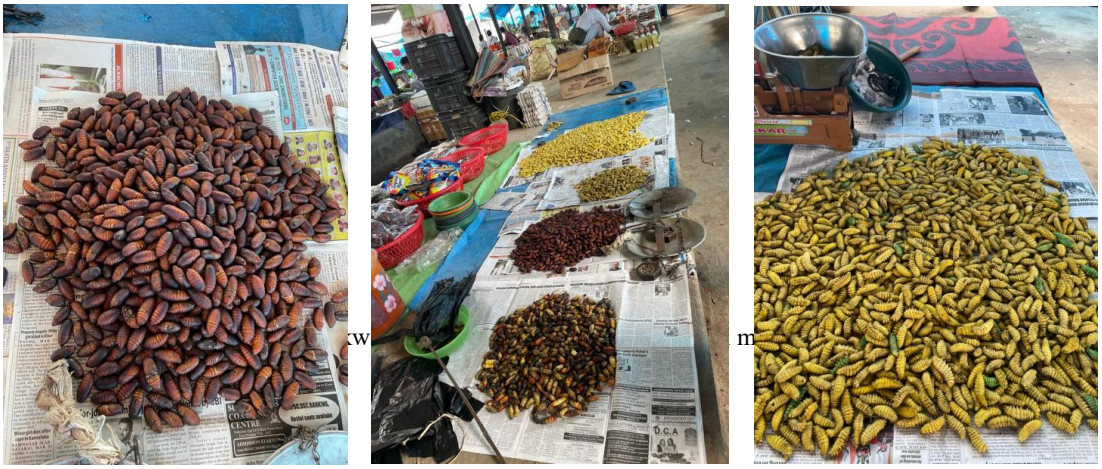

Fig. 2. Large quantities of silkworm pupa are being sold in the local market of Nagaland

proper harvesting and management, and marketing can boost economic growth and also enhance the livelihood of less deprived sections of society.

CONCLUSIONS

Edible Insects with regular market demand always provide better livelihood options for farmers. Despite their huge potential in terms of market demand, the rearing of edible insects is measurable. Due to the lack of awareness of the nutritional value of insects and rearing training, the rearing of insects on a large scale is yet to be started. Educating people from rural areas, especially women and the unemployed section of society about sustainable insect farming and rearing, can not only contribute to the environment but also improve their living and health conditions, apart from bringing them extra income. Sustainable insect farming would also emphasize conservation of overexploited species which are economically valuable and in high demand. Preliminary market analysis reveals that approximately Rs. 1,04,750.00 can be earned annually by a farmer by rearing silkworm. Considering its high value in terms of market demand and a potential source of nutrition, the following recommendations can be drawn; Entomophagy, the consumption of edible insects, is a sustainable food option that can help combat ecological imbalance and global warming. It is essential to conduct nutritional research on insect consumption and educate people with allergies and health conditions on food safety. Insect farming can significantly impact the global market, and organizations like NGOs, agricultural organizations, and ICAR should promote its economic importance. Scientists, entrepreneurs, and agricultural engineers can provide innovative insect-based products to those hesitant about insect consumption. The traditional habit of eating insects should be passed down to younger generations to preserve cultural identity. Government departments can promote commercial insect rearing, particularly in the northeastern region of the country. Entomophagy could play a vital role in alleviating food insecurity and helping protect the environment.

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COFLICT OF INTEREST

No conflict of interest.

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