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PP Pradhan
Department of Entomology, College of Agriculture, OUAT, Bhubaneswar, Odisha, India

S Sahoo
Department of Entomology, College of Agriculture, OUAT, Bhubaneswar, Odisha, India

J Hazarika
Department of Entomology, Assam Agricultural University, Jorhat, Assam, India

T Rahman
Department of Entomology, Assam Agricultural University, Jorhat, Assam, India

P Kashyap
Department of Entomology, Assam Agricultural University, Jorhat, Assam, India

Corresponding Author:
PP Pradhan
Department of Entomology, College of Agriculture, OUAT, Bhubaneswar, Odisha, India

Practice of entomophagy in North-East India: A review

PP Pradhan, S Sahoo, J Hazarika, T Rahman and P Kashyap

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Abstract
Insects, which are a traditional food in many regions of the world, are highly nutritious and, in particular, a potential source of protein. In the north-eastern parts of India, edible insects are the natural renewable source that plays a vital role in the nutritional system of different ethnic groups. Entomophagy is widely practiced in Assam, Arunachal Pradesh, Manipur, and Nagaland. Various tribes of a state prefer various species of edible insects. Diverse Indian tribes consume approximately 255 insect species of insects as sustenance. The consumption of coleopteran species was the highest, accounting for approximately 34% of all edible insect species, followed by Orthoptera (24%), Hemiptera (17%), Hymenoptera (10%), Odonata (8%), Lepidoptera (4%), Isoptera (2%), and Ephimeroptera (1%). Members of different communities consume edible insects as per their traditional beliefs, and tastes, along with regional and seasonal availability. Therefore, studying the edible and therapeutically important insect species can have economic implications, allowing countries like India to explore approaches to sustainably utilize this enormous natural resource.

Keywords: Edible insects, entomophily, North-East India, ethnic group

Introduction
The practice of eating insects by humans as food is called Entomophagy (Greek work). In many civilizations around the world, insects are considered a traditional cuisine. Entomophagy has a long history in human evolution (Fontaneto *et al*., 2011) [12]. Insects have always played an important role in human nutrition, and their dietary contributions have been widely recorded in the literature of Asia, Africa, and Latin America (Paoletti & Bukkens, 1997) [22]. Including bees, grasshoppers, caterpillars, beetle grubs, winged termites, worms, ants, cicadas, and different aquatic insects, over 1900 insect species are known to be consumed by humans all around the world (Bodenheimer, 1951) [4]. At least 52 species belonging to 45 genera, 26 families, and 10 orders are edible in South/Central Asia including India, Pakistan, Nepal, and Sri Lanka (Gope & Prasad, 1983) [16]. It is fascinating to note that more than two billion people eat insects on a regular basis, accounting for a major amount of animal protein consumption in some regions (Van Huis *et al.*, 2013) [36]. According to the "2004 United Nations Food and Agricultural Organization" (FAO) report, maggots of different edible insects are rich in calcium, potassium, magnesium, zinc, iron, and also in B-vitamins (Fromme, 2002) [13]. The insects are also a source of protein, amino acids, vitamins, fats, and trace elements (Alamu *et al*., 2013) [1]. On the other hand, the nutritional value and chemical content may vary depending on the host plants they feed on, seasonal availability, and location.
In India, insects are included in the diet of different cultures. Edible insect consumption is prevalent among ethnic groups of Northeast India, particularly among the tribes of Arunachal Pradesh, Assam, Manipur, and Nagaland. Insects are also consumed by tribes in Meghalaya and Mizoram to some extent. Several tribes in India consume almost 255 insect species as sustenance. Sangma *et al.* (2016) [28] observed the highest consumption of edible insect species in Coleoptera (34%) followed by Orthoptera (24%), Hemiptera (17%), Hymenoptera (10%), Odonata (8%), and Lepidoptera (4%) and the least in is Optra (2%). The indigenous people of India's north-eastern states use their ancestral knowledge to choose which species to be consumed at what stage. Sometimes they feed on both immature insects as well as adult stages. The edible insects are chosen by individuals of different tribes based on their traditional beliefs, taste as well as regional and seasonal availability. Insects have long been used as food, medicines, and as other products by various tribes of Northeast India.

Edible insects consumed by people of Northeast India

About 158 species of insect species are eaten by people of Arunachal Pradesh (Chakravorty *et al*., 2011) [7]. Nyishi and Galo tribes of Arunachal Pradesh consume about 102 species of insects (Chakravorty *et al*., 2013) [6]. Of which, 40 are of order Coleoptera; 26 of Orthoptera; 12 of Hymenoptera; 8 of Hemipterans; 5 of Homopterans; 4 of Odonata; 3 each of Diptera, Dictyoptera, and Ephemeroptera; and 2 each of Odonata, Isoptera, and Plecoptera. In comparison to other tribal populations in India, the tribes of Arunachal Pradesh prefer mostly the Orthopterans as feed (Singh & Chakravorty, 2008). Different tribes of Eastern Arunachal Pradesh (Nocte, Wangcho, Singpho, Tangsa, Deori, and Chakma) consume about 51 insect species belonging to nine different orders (Meyer-Rochow & Chakravorty, 2013) [6]. Mostly, the coleopterans are highly consumed, nearly 34 percent followed by orthopterans (24%), hemipterans (17%), hymenopterans (10%), odonata (8%), lepidopterans (4%), isoptera (2%) and few of ephemeropterans (1%). The preference for edible insects is varying according to different tribes in different regions. The choice of insects as food by the indigenous people of India is influenced by the insect's palatability, availability, nutritional content, habits, and traditions.

About 15 edible insect species from 15 different genera and 12 families were recorded in the Mishing tribes of Assam's Dhemaji district (Doley and Kalita, 2012) [9]. The Mishings mostly preferred Giant Water Bugs (*Lethocercus indicus*), Muga Silk-worm (*Antheraea assama*), Eri silkworm (*Samia ricini*), and House cricket (*Acheta domesticus*) as edible insects. Green Weaver ant (*Oecophylla smaragdina*) is used as food by Assamese during the Bohag Bihu festival. Diseases like scabies, malaria, toothaches, stomach disorders, blood pressure anomalies, etc. are treated using formic acid, which is found in these edible insects (Chakravorty *et al*., 2011) [7]. It was also documented that members of the Mishing tribe consume both the immature stages (egg, larva, pupa, and nymphs) as well as adult insects.

According to Dutta *et al*. (2016) [11], 16 terrestrial edible insect species belonging to 6 various orders were observed in the Dhemaji district of Assam. They found three species of Lepidoptera order, five of Orthoptera, three Hymenopterans, one each of Isoptera, Blattodea, and Hemiptera. Mulberry silkworm (*Bombyx mori*) and Muga silkworm (*Antheraea assamensis*) pupa and larvae are used to cure continuous itching and soreness of the throat. They have also used the Eri silkworm (*Samia cynthia ricini*) pupa and larvae for curing "dudmur" or infection of the mouth and tongue in infants. Locals consume cicada (*Pomponia* sp.), short-horned grasshopper (*Eupreponotus* sp.), and long-horned grasshopper (*Mecopoda elongate elongate*), adult cricket (*Tarbinskiellus* sp.), and the mole cricket (*Gryllotalpa* sp.) for their delicacy. Nose and throat infections are cured by using toxins from the green weaver ant (*Oecophylla smaragdina*). People consume the later stage of termite (*Odontotermes* sp.) for its food value. The larvae and eggs of yellow jacket wasp (*Vespa orientalis*, *Vespa magnifica*) and the "nest" of potter wasp (*Eumenus* sp.) are used to treat stomach-related problems. The egg, larvae of honeybee (*Apis* sp.), and its other products are used to get rid of whooping cough. The cockroach (*Periplaneta americana*) was used to alleviate asthma symptoms.

Rahman *et al*. (2018) [25] documented entomophagy among the Tiwa group of the Morigaon district, reporting that they consume 15 species of insects from 6 orders belonging to 14 various families. Of which, 3 species belong to Hemiptera, 2 to Coleoptera, 4 to Orthoptera, 3 to Hymenoptera, and one each to Lepidoptera, Odonata, and Isoptera. They recorded the highest amount of protein (19.8%) and lipid (8.3%) in Giant water bug and a high carbohydrate content (5.1%) in cricket.

Entomophagy was also recorded in the Karbi anglong district of Assam (Ronghang and Ahmed, 2010) [26]. The Karbis and the Rengma Nagas were the biggest insect consumers among the ethnic tribes, consuming 32 types of edible insect species of different orders such as Hymenoptera, Orthoptera, Coleoptera, and Hemiptera according to their variable seasonal availability. The Eri-Silk worm (*Samia ricini*) and red ants (*Myrmica rubra*) are the most popular among the tribes in the Karbi Anglong district. During the Assamese festival, Bohag Bihu, the Ahom Community utilizes red ants (*Myrmica rubra*) as one of the Bihu delicacies.

23 species of edible insects belonging to the order Hemiptera, Coleoptera, Hymenoptera, Orthoptera, Lepidoptera, Isoptera, and Odonata were recorded among Bodos of the Udalguri district of Assam (Hazarika and Goyari, 2017) [18]. Giant water bug (*Lethocerus indicus*) and the Eri silkworm larvae (*Samia ricini*) were the most preferred edible insect species in this community.

Looking into Manipur, a total of 41 insect species were recorded as edible which are from 8 orders under 24 different families and 36 genera, where a total of 10 species of Hemiptera were consumed (Shantibala *et al*., 2012) [30]. It has been reported that Manipur's 5 ethnic tribes eat 46 different insect species. Hemiptera has the largest number of edible insect species, whereas, Dictyoptera and Isoptera have the least edible insect species (Ayekpam *et al*., 2014) [3]. Manipur's ethnic groups prefer more bugs. Brood collection and consumption from bee and wasp hives on trees, jungles, or local nurseries is similar to that of Mizo tribes. Hymenopterans are preferred when they are at the larval stage, and pentatomid bugs are eaten both raw and roasted. Among the 46 edible insect species of Manipur, 5 are reported of having medicinal significance for a variety of diseases.

Nagaland's Ao tribes consume nearly 42 types of insect species, from which the maximum species were Orthopterans and Coleopterans (Meyer-Rochow & Changkija, 1997) [21]. In Nagaland, eating silkworm larvae and pupae is a popular tradition. The edible insect list has been expanded to over 60 species (Meyer-Rochow, 2005) [19]. Nagaland's tribal people fed on red ants, grasshoppers, crickets, and mulberry silkworms' pupa. Green color larvae feeding on Gulmohar trees from March to April are also eaten by these people (Srivastava *et al*., 2009) [32].

Termites available at Meghalaya are regarded as a source of protein and carbohydrates (Paul and Dey, 2011) [23]. An edible pentatomid bug, commonly known as cinnamon bug or seed bug (*Ochrophora montana*), is locally called Thangnang, appears in huge quantity only after the flowering of bamboos, and for the tribes of Mizo hills in Northeast India, it is quite a delicious cuisine (Sachan *et al*., 1987; Thakur & Firake, 2012) [27, 34]. The bugs are serious pests of bamboo and become a valuable source of food for the local communities. These bugs are being collected after a light shower and consumed either fried or sometimes as chutney. Some traditional method is followed for the extraction of oil from these bugs. In case of natural calamities and scarcity, it serves as a vital food supplement to the local population. Pentatomid bugs are also devoured by the people of Mizoram, people living on the borders of Manipur, Tripura, Assam, and Myanmar.

Table 1; Edible insects consumed by various ethnic tribes of Arunachal Pradesh

Scientific name	Order	Family	Vernacular name	Seasonal availability	Consumption approach	Tribe
Chondacris rosea	Orthoptera	Acrididae	Okuk, Macherie, Phoring, Phiring	Sept- Nov	Head, appendages, and wings are discarded and bodies are roasted with mustard oil	Wangcho, Singpho, Deori, Chakma
Aspongopus nepalensis	Hemiptera	Pentatomidae	Longvia, Longheto/ Seve, Chammah, Shiphon,	Dec- Feb	Raw paste with chili and Ginger	Wangcho, Nocte, Singpho, Tangsa,
Brachytrupes orientalis	Orthoptera	Gryllidae	Okuk, Loothong/ Idmon/ Churu, Gdun, Shingapok, Gumro,	May-Sept	Head, appendages, and wings are discarded, bodies are roasted with mustard oil	Wangcho, Nocte, Singpho, Deori, Chakma
Apis mellifera	Hymenoptera	Apidae	Nakat, Nyakui, Lagat, Yakay, Moumakhi	Nov- Jan	Honey and sometimes larvae, pupae and queen boiled	Wangcho, Nocte, Singpho, Tangsa, Deori
Apis (cerana) indica	Hymenoptera	Apidae	Nyakui, Lagat, Yankung/ Yakay, Tangik	Nov- Jan	Immature stages are consumed, boiled, or roasted	Nocte, Singpho, Tangsa, Galo
Oecophylla smaragdina	Hymenoptera	Formicidae	Thajao, Aukhithio/ Thapi/Khawa, Makhao, Saisho, Semete	Round the year	Pupae are consumed	Wangcho, Nocte, Singpho, Tangsa, Deori,
Xylocopa sp	Hymenoptera	Xylocopidae	Nakat, Nyakui	Nov- Mar	Immature stages are consumed, boiled or roasted	Wangcho, Nocte,
Odontotermes sp.	Isoptera	Odontotermitidae	Akhun, Khukan	May- June	Roasted with local edible leaves, wings discarded	Nocte, Singpho,
Mictis tenebrosa	Hemiptera	Pentatomidae	Waekhoi, Chammah,	April- Aug	Suck the sting in cold and Cough	Wangcho, Singpho,
Vespa orientalis	Hymenoptera	Vespidae	Yandok	Nov- Feb	Immature stages are boiled	Wangcho
Eumenes sp.	Hymenoptera	Vespidae	Katpatkai, Longli	Nov- Dec	Generally larval stages are being consumed, when wings are not developed, fried	Singpho, Tangsa
Nezara viridula	Hemiptera	Pentatomidae	Jakwikhoi	Dec- Feb	Wings are discarded, roasted	Wangcho
Dorcus sp.	Coleoptera	Lucanidae	Mogap magai	Aug-Oct	Appendages discarded, Roasted	Wangcho
Macrolyristes sp.	Orthoptera	Tettigoniidae	Kokchug/ Headboon	Sept- Oct	Antennae, wings and anal cerci discarded, bind with local leaves and roasted	Nocte
Xylotrupes gideon	Coleoptera	Scarabaeidae	Chingie	May- July	Legs discarded, roasted or Fried	Singpho
Bombyx mori	Lepidoptera	Bombycidae	Palu	May- Sept	Large caterpillar stages, pupae boiled and fried	Deori
Lucanus laminifer	Coleoptera	Lucanidae	Komrengpok	June- Sept	Roasted or fried with oil	Chakma
Coridius chinensis	Hemiptera	Pentatomidae	Tari	Dec–Feb	Raw/cooked	Galo
Belostoma indica	Hemiptera	Belostomatidae	Mosap	Throughout the year	Roasted	Galo
Locusta sp.	Orthoptera	Acrididae	Mirbo	Aug–Sept	Cooked	Galo
Vespa bicolour	Hymenoptera	Vespidae	Gapu	Aug–Sept	Roasted	Galo

***Source*:** Chakravorty *et al.*, 2013 [6] & Sangma *et al.*, 2016 [28]

Table 2: Edible Insect species consumed by various ethnic tribes of Assam

Scientific name	Order	Family	Stage consumed	Tribe	Mode of consumption
Analeptes Trifasciata	Coleoptera	Scarabaeidae	Grub	Bodo	Fried/roasted
*Hydrochera Ricksecker*i	Coleoptera	Dytiscidae	Grub	Rengma Nagas, Karbis	Fried/roasted
Odontotermes obesus, Macrotermes natalensis, Macrotermes sp.	Isoptera	Rhinotermitidae, Termitidae	Winged adults, queen	Boro, Dimasa, Karbis, Rengma Nagas	Fried
Dorylus orientalis, Atta spp.	Hymenoptera	Formicidae	Grub and adult	Dimasa, Rengma Nagas, Karbis, Bodo	Fried/cooked
Vespa orientalis	Hymenoptera	Vespidae	Grub	Rengma Nagas, Karbis, Bodo	Fried/chutney
Apis indica	Hymenoptera	Apidae	Egg	Tribes of Dhemaji district	Raw/fried
Acheta domestica, Brachytrupes spp., *Bombina orientalis*	Orthoptera	Gryllidae	Adult	Rengma Nagas, Karbis, Bodo, Dimasa	Fried/roasted
Cytacanthacris aeruginosus unicolour,	Orthoptera	Acrididae	Adult	Rengma Nagas, Karbis, Bodo,	Fried/

Hieroglyphus banian, Schistocerca gregaria, Chondracris rosea				Dimasa	Roasted/chutney
Gryllotalpa africana, Gryllus campestris	Orthoptera	Gryllotalpidae	Adult	Rengma Nagas, Karbis, Bodo	Fried/roasted
Mantis religiosa	Dictyoptera	Mantodea	Adult	Rengma Nagas, Karbis, Bodo	Fried/roasted
Lethocerus indicus	Hemiptera	Belostomatidae	Adult	Rengma Nagas, Karbis, Bodo, Dimasa	Fried/ roasted
Ochrophora Montana	Hemiptera	Pentatomidae	Adult	Rengma Nagas, Karbis, Bodo, Dimasa	Fried
Pomponia Imperatoria	Hemiptera	Cicadidae	Adult	Rengma Nagas, Karbis, Bodo	Fried
Philosoma ricini, Antheraea assama	Lepidoptera	Saturniidae	Larva and pupa	Rengma Nagas, Karbis, Bodo	Deep fried in oil, cooked fresh
Bombyx mori	Lepidoptera	Bombycidae	Pupa	Tribes of Dhemaji district	Deep fried in oil, cooked fresh
Anaphe infracta, A. reticulata, A. venata	Lepidoptera	Notodontidae	Larva	Bodo	Fried

***Source*:** Sangma *et al.*, 2016 [28]

Table 3. Edible insects consumed by various ethnic tribes of Manipur

Order	Family	Local name	Common name	Scientific name	Ethnic group	Edible stage	Consumption approach
Coleoptera	Curculionidae	Yangkrungpui, nengson, tuinin, gulung, waktubi	Weevil	*Cyrtotrachelus buqueti*	Kabui, Rongmei, Chothe, Meitei	Adult	Fried/roasted
	Curculionidae	-	Weevil	*Sipalus hypocrite*	Kabui	Adult	Fried/roasted
	Lucanidae	Faochet, phaochiat	Stag beetles	*Lucanus lunifer*	Kabui	Adult	Fried/roasted
	Cerambycidae	Uchet, ange samjabi	Long horned beetle	*Batocera davidis*	Kabui, Chothe, Meitei	Adult	Fried/roasted
		Samjabi	Long horned beetle	*Stromatium longicorne*	Meitei		Adult fried/roasted
	Elateridae	Thu	Beetle	*Agrypnus* sp.	Chothe	Adult	Fried/roasted
	Dytiscidae	Tengbi	True water beetle	*Cybister limbatus*	Chothe, Meitei	Adult	Fried/roasted
	Dytiscidae	Tengbi	True water beetle	*Cybister posticus*	Meitei	Adult	Fried/roasted
Dermaptera	Forficulidae	Meicheppi	Earwig	*Forficula* sp.	Chothe	Adult	Fried/ roasted
Dictyoptera	Mantidae	Pang, uishom, uicho, timbong	Praying mantis	*Hierodula unimaculata*	Kabui, Rongmei, Chothe, Meitei	Adult	Fried/ roasted
Hemiptera	Tessaratomidae	Tameng, usingsa	Bug	*Eusthenes* sp.	Rongmei, Meitei	Adult	Fried/ roasted
		Usingsa	Bug	*Tessaratoma* sp.	Meitei	Adult	Fried/ roasted
		Tameng, usingsa	Bug	*Asiarcha* sp.	Kabui, Meitei	Adult	Fried/ roasted
	Pentatomidae	Usingsa	Stink bug	*Catacanthus incarnatus*	Meitei	Adult	Fried/ roasted
		Thangde Thangkili	Stink bug	*Nezara viridula*	Chothe, Kabui	Adult Raw	Fried/roasted
	Cicadidae	Thu, rengchiang, hari, ngiang	Cicada	*Cryptotympana* sp.	Kabui, Rongmei, Meitei	Adult	Fried/roasted
	Coreidae	Konglongpui, usingsa	Bug	*Anoplocnemis compressa*	Kabui, Meitei	Adult	Fried/roasted
	Scutelleridae	Usingsa	Bug	*Cantao ocellatus*	Meitei	Adult	Fried/roasted
	Gerridae	Huinaopi		*Geris* sp.	Chothe	Adult	Fried/roasted
	Cercopidae	Asamchitak		*Cosmoscarta* sp.	Chothe	Adult	Fried/roasted
Hymenoptera	Apidae	Khoigoupui, huimu, wakhoi	Carpenter bee	*Xylocopa iridipennis*	Kabui, Chothe, Meitei	Larva	Fried
	Vespidae	Khoijin, areihui, khoingal	Yellow hornets	*Delta conoidium*	Kabui, Chothe	Larva	Fried
		Khoirang, huibe, lamdou	Wasp	*Vespa tropica*	Kabui, Rongmei, Meitei	Larva	Fried
	Formicidae	Tenkhiang, tenkhiang khoi, kakcheng ningjaobi	Weaver ants	*Oecophylla smaragdina*	Kabui, Rongmei, Meitei	Adult	Fried/roasted
Isoptera	Termitidae	Talhum, leithapunu, tarum	Termite	*Odontotermes* sp.	Kabui, Chothe, Rongmei	Adult	Fried/roasted
		Timbukang, phulim	Termite	*Macrotermes* sp.	Kabui	Adult	Fried/roasted

***Source*:** Sangma *et al.*, 2016) [28]

Table 4: Edible insects used for treating different ailments by different tribes and communities of Assam, Nagaland, and Arunachal Pradesh

Insect	Scientific name	Family	Order	Parts used	Ailments
Honeybee	*Apis indica*	Apidae	Hymenoptera	Honey	Mouth ulcer, burns, cold asthma, chest infection, throat pain, etc.
				Bee eggs	Back pain, chest pain, chest infection
				Beehive	Bee poison
Honeybee	*Apis indica, A. florea, A. mellifera*	Apidae	Hymenoptera	Baked powder of body mixed with honey	Cure boil, snakebite and cough
Common red ant	*Myrmica rubra*	Formicidae	Hymenoptera	Larva and pupa	Increasing fertility in human
Weaver ants	*Oecophylla smaragdina*	Formicidae	Hymenoptera	Grub and adult	Stomach-ache and dysentery
Potter wasp	*Eumenes* sp.	Vespidae	Hymenoptera	Wasp nest	Headache burns
Erisilkworm	*Philosamia ricini*	Saturniidae	Lepidoptera	Cocoon	Protection from evil spirit such as Chekema (Karbi)
Dragonfly	*Aeshna mixta, Neurothemis fluctuans*	Aeshnidae, Libellulidae	Odonata	-	Curing urinary disorder in young children
Locust	*Schistocerca gregaria*	Acrididae	Orthoptera	Body or body oil	Curing the cracking of lips
Short horn Grasshopper	*Hieroglyphus banian*	Acrididae	Orthoptera	Nymphs and adults	Cure liver disorder
Cerambycid Beetle	*Batocera titana*	Cerambycidae	Coleoptera	Larva	Eaten alive to heal wounds
Termite	*Odontotermes* sp.	Termitidae	Isoptera	Winged termite	Ulcer
American Cockroach	*Periplaneta americana*	Blattidae	Dictyoptera	Roasted extract	Asthma and tuberculosis
Mayfly	*Ephemera danica*	Ephemeridae	Ephemeroptera	Nymphs after boiling	Stomach disturbances

Availability of edible insects in varied seasons

Although edible insects can be found around the year, their densities and diversities are influenced by both their host plants and seasonal conditions. Edible Coleopterans are abundantly found from the month of June to September (pre-monsoon and monsoon) and subsequently decline during winters and early spring season (Chakravorty *et al*., 2011) [7]. Some insects like Odonata and Orthopterans were found most commonly during September and October (late summer), and the insects of Hemiptera and Hymenoptera orders were found to be restricted during winters i.e., November to February. But some bugs and ants are available throughout the year. From March to May, *Oecophylla smaragdina* Fabricius (red weaver ant), also known as Amroli porua (Assamese) is available, and there is an age-old practice of its consumption during the Bihu festival in some parts of Assam.

Cultural practices associated with edible insect's collection and consumption

The ethnic people rely on traditional local knowledge to quickly identify edible and poisonous insects, as well as where to find them. The habits and habitat of an insect species at a given time determine the collection techniques used. Baskets and cloth nets, as well as manual handpicking, are commonly used methods for the collection of edible insects. In Manipur, tribal people build smoke beneath bee and wasp hives at night to calm and settle the bees before collecting the entire nest. During the swarming period, the hemipteran bugs are collected by shaking the infested plants. Insect species such as *Cybister* are collected using light traps or scooping gear. The tribal communities of Arunachal Pradesh collect aquatic insects, *viz*. *Crocothemis servilia* at the young stage (naiads) and Oso nyobuk (vernacular name) from the ponds along with the fishes. These tribes also collect *Hydrophilus triangularis* and *Cybister fimbriolatus* from the water bodies at the larval stage. During the winter, some edible insects, such as *Coridius chinensis* and *C. viduatus*, hibernate beneath the stones in river/stream beds (Sangma *et al*., 2016) [28].

During spring ploughing, some Naga tribes (Karbi and Rengma) collect orthopterans such as *Gryllotalpa africana*, *Schizodactylus monstrosus*, and *Gryllus campestris* by pouring water into gullies and ravines. They collect grasshopper (*Chondracris rosea*) from the bushes in villages, towns, and agricultural fields. *Bombina orientalis*, a bush cricket, is collected in urban areas using light traps, but in rural areas, it is found in the burrows of *B. orientalis.* To attract termites, a bowl of water is placed beneath the light source. Because the weaver ant, *O. smaragdina*, is available all year, people collect it as needed. These are harvested by removing the nest from the tree and placing it in a bucket of water before removing it for use in the preparation of delicacies. Tribal farmers in Mizoram collect up to 20–30 kg of cinnamon bug, *Ochrophora montana*, in gunny bags or bamboo containers (Sangma *et al*., 2016) [28].

At various stages of life cycles, a diverse variety of edible insect species can be consumed. Healthy insects, according to locals and their traditional knowledge, must be caught alive and processed as soon as possible. In general, members of ethnic tribes in North East India consume both immature and adult stages of insects. The Assamese Ahom community consumes the silkworm in its mature pupal stage, whereas other ethnic groups (Bodo, Garo, Naga, Khasi, Mishing, and so on) consume it in its prepupal stage (Sarmah, 2011) [29]. The majority of Odonata species are consumed at the immature stage, whereas adult Orthopteran and Hemipteran insects are more highly preferred. Katydids were an exception, preferring to be wingless and immature. Hymenopterans were consumed at all developmental stages (eggs, larvae, pupae, and adults), as well as their products

such as honey, wax, and propolis are used for a variety of purposes. Only the adult stages of termites are eaten, whether roasted, dry-fried, or raw. Most of the adult edible beetles were preferred, but some like *Xylorhiza* sp. were consumed in their larval stages. Both larvae and adults of the beetles *Prosopocoilus* sp. and *Odontolabis gazella* were consumed. Preference for larval or adult stages is determined by the palatability of the insects (according to developmental stages), availability, and ease of obtaining the desired insects, in addition to taboos or religious beliefs. It is easier to collect the aquatic larvae of Odonata and wood-boring grubs of Coleopterans than their adults. In the case of Dictyoptera, Isoptera, Orthoptera, Hemiptera, and Coleoptera, both the larval/grub and adult stages are heavily consumed (Sangma *et al*., 2016) [28].

Some methods for preparing edible insects for human consumption include roasting, frying, and boiling. The hard-bodied insects are usually fried or roasted, while the softer ones are cooked or eaten raw. On the other hand, Pentatomid bugs, ants, honeybees, and termites are preferred both raw and roasted. To enhance the flavour of an insect dish, ethnic tribes add garlic, pepper, and salt. Ethnic communities living in the Karbi Anglong district of Assam eat orthopteran insects by grilling, roasting, or smoking. The insects can be stuffed in a bamboo pipe and smoked for 3-4 days before being mixed with pepper and salt and served with rice meals. Long-horned grasshoppers are collected in smaller numbers than short-horned grasshoppers due to their solitary habit and they are roasted or oil-fried after the wings are removed. During the summer nights of May and July, crickets and mole crickets are usually collected. However, among the Galos, Asian dune crickets of the species *Schizodactylus monstrosus* are the most preferred and valued orthopteran food insects. Freshly collected specimens are smoked inside a bamboo pipe and dried for nearly one week and then it is crushed into a powder. It is then combined with pepper, salt, and bamboo shoot to prepare a unique chutney (traditional recipe). This chutney is served with rice or with Apung, a local drink (fermented rice beer). Pentatomid bugs such as *Coridius chinensis*, Aspongopus *nepalensis*, *Pentatomid* sp., etc, are collected from river banks and are consumed mostly in the form of chutney. Only the adult stages of termites are consumed either roasted or dry-fried after removing wings (Chakravorty, 2014) [5].

In Manipur, people consume the insects in fried form. They consume Pentatomid bugs both raw and roasted. The cinnamon bug, also known as Thangnang by the Mizo tribes, is consumed by various ethnic tribes in the north-eastern states. Silkworm larvae and pre-pupal forms are eaten in Nagaland deep-fried in oil or boiled with fermented bamboo shoots and spices. Meghalaya tribes consume deep-fried silkworm pre-pupa (Sangma *et al*., 2016) [28].

Insects used for therapeutical purposes

Traditional knowledge and the habit of eating insects as food by the ethnic people provides an idea for local therapies, but that is limited to folks who reside traditionally and have had a limited amount of 'westernization'. The therapeutic uses of insects are a closely guarded secret, and many people are unaware of them. In the Karbi tribe of Assam, dragonflies (*Aeshna mixta*) and red grasshawk dragonflies (*Neurothemis fluctuans*) are used to treat urinary ailments in the infants. Lip cracking is cured by using body oil of Desert Locust (*Schistocerca gregaria*). The larva and pupa of the European fire ant (*Myrmica rubra)* are used to boost human fertility. To treat cold and cough, *Apis mellifera indica* honey is commonly eaten (Solanki & Chutia, 2008) [3] as well as for cosmetic purposes (Ronghang & Ahmed, 2010) [26]. In Nagaland, the larvae of mango borer (*Batocera titana)* are consumed alive to heal the wounds (Alemla & Singh, 2004) [2]. Several compounds with immunological, antibacterial, diuretic, analgesic, anesthetic, and antirheumatic properties are found in insects (Yamakawa, 1998; Costa-Neto, 2005). To treat asthma and tuberculosis, Arunachal Pradesh's ethnic tribes mix the extract of roasted *Periplaneta americana* (Dictyoptera: Blattidae) with water. To cure the bolis, cough, and snakebite, baked powder of the *Apis indica*, *A. mellifera*, and *A. florae* (Hymenoptera: Apidae) is mixed with honey (Solanki & Chutia, 2008) [31]. According to some beliefs, stomach disturbances can be cured by using the roasted or boiled nymphs of the mayfly, *Ephemera danica* (Chakravorty *et al*., 2011) [7].

Use of edible insects as industrial resources in North-eastern states

Northeast India is considered a hub for a number of silk-producing insects as well as a centre for traditional silk production (Peigler & Nauman, 2003) [24]. Assam accounts for nearly 90% of Muga silk production and 65% of Eri silk production (Talukdar, 2009) [33]. Meghalaya and Manipur, the other two states in northeast region, have also emerged as non-mulberry silk-producing states. The foliage from the sericulture industry is fed to cattle, and the pupae are used as fertilizer, human food, and cattle feed. The sericin powder, a by-product of waste liquor obtained from the degumming of silk fibre, is used in different industries to produce food, medicines, cosmetics, etc. (Gulrajani, 2008) [17]. Honey production is also a lucrative business. In the coming years, the untouched forest areas of Northeast India will provide a vast opportunity for honeybee studies to unfold and describe new species of bees. Assam becomes the highest honey-producing state among the north eastern states by producing 1.20 metric tonnes of honey per year.

Edible insects contribute significantly to the socio-economic development of rural communities. Consumers in Belgium, Netherland, France, Mexico, USA, and China have expressed a preference for mixing cricket powder in insect-based food products, implying that insect-based meat substitutes could be sustainable (Gahukar, 2016) [14]. Indian insect species with high nutrient content, ease of rearing, and local processing capability can thus be investigated for export potential (Gahukar, 2018) [15].

Conclusion

In different tribal communities of Northeast India, insects are found to be an important part of their diet, thus entomophagy should be much promoted. Insects benefit us in a variety of ways, including their high nutritional value, ability to reproduce quickly, ease of maintenance, and ability to rear on waste material. Furthermore, insect pest species can contribute to narrowing the world's growing protein gap. Many people find insects as a source of income for their livelihood, either by directly collecting and selling insects as food or by selling their by-products (honey, silk). For medicinal purposes, some specific insect species are preserved and exported to other countries. As a result, more research should be conducted to rear insects artificially so that they can become an important part of our diet. We should also recognize the potential of these bioresources for economic prosperity. Indeed, preserving and restoring existing entomophagy can benefit mankind and the nation as a whole.

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