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THE PRACTICES OF ENTOMOPHAGY AROUND THE WORLD WITH SPECIAL REFERENCE TO NORTH-EAST INDIA: A PRIMITIVE PRACTICE THAT NEEDS TO BE SAFEGUARDED

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ABSTRACT

The indigenous people of many regions of the world have always relied on edible insects for food and livelihood. This is because edible insects possess valuable nutritional components that are comparable to conventional foods. This practice is very old and has become a crucial part of the pristine culture of the natives all over the world. However, this unique culture is day by day fading in some parts of the world by the force of 'westernization', modern culture, and 'disgust factor'. In North-East India where the status of entomophagy is impressive and widely prevalent, the same threats are being perceived. A very few edible insects have been analysed nutritionally. This article discusses the prevalence of entomophagy around the world in general and focuses on the states of North East India particularly Assam and Arunachal Pradesh's edible insects and their nutritional analyses. The results show that edible insects are the potentially good and smart choice in the case of nutrients and can also potentially suffice for other conventional food products whenever they are not available or readily accessible. These results in particular will also help the public acknowledge edible insects, spread awareness, and thereby preserve this special knowledge of the locals. Therefore, there is an urgent need to analyse the rest of the edible insects of North East India recorded in literature, which will strengthen our knowledge of edible insects and sustain the culture to continuity.

Keywords: Entomophagy, nutritional composition, edible insects, North East India, Assam, Arunachal Pradesh, indigenous.

INTRODUCTION

Insects have played an important role in the dietary system of human beings from time immemorial. They are a part of the traditional diets of approximately 2 billion people worldwide (Halloran *et al*., 2014; Tao Li, 2018). Approximately 1000 species of insects might have served as ancient foods among endemic peoples, particularly in hotter climes. Therefore these organisms have procured a very important role within the history of human nutrition (Defoliart, 1995). Mitsuhashi (2016) has arrived at a figure of at least 1,900 identified species of edible insects worldwide. Bodenheimer (1951) suggested that these insects have competed a crucial half in meeting human nutrition within Africa, Asia, and Latin America. Insects have accomplished a cardinal role in almost all the food chains of ecosystems on earth. Edible insects have benefitted a great number of human beings economically all over the world. Locusts and grasshoppers, which often occur in swarms, have been included in the diets of almost every culture (Defoliart, 1995). Grasshoppers, locusts, crickets, beetles, termites, ants, and caterpillars are among the commonly consumed insects in Nigeria. Van Huis (2013) has reported about 250 highly nutritious edible insect species in sub-Saharan Africa. Besides humans, a variety of animals including livestock are dependent on these small valuable organisms for their immense nutritional values.

Insects are an excellent food source because of their great nutritional value and huge diversity. They are found virtually everywhere and occupy diverse habitats on earth which justifies their availability. Due to this reason, they are used as a food source by a variety of organisms including humans. Edible insects are as nutritious as beef and fish. However, the nutrient composition of insects varies considerably between species, the metamorphic phases (eggs, larvae, pupas, or adults), environment, and diets of insects (Fao, 2013). Edible insects have been identified as a wide diversity of species all across the globe. The nutritional value of approximately 2000 edible species of insects is yet to be known (FAO, 2013a). The status of entomophagy is impressive in India, especially in the north-eastern region which is known for its immense biodiversity. Varshney (1997) has reported 589 families and 51450 species, as well as Alfred *et al*. (1998), recorded 589 families and 51450 species of insects from India. Besides this, a total of about 255 species of edible insects have been so far recorded from different parts of the country (Chakravorty *et al*., 2014). Out of the recorded species, North East India owes to the largest number of edible insect species. Being a biodiversity hotspot indigenous people have always relied on including insects in their meals. The species which are consumed by people rely on the palatability, availability, and nutritional value of the insect, as well as local traditions and practices (Chakraborty, 2014). Although a variety of insects have been included in the cuisines of north-eastern India, many people are still unaware of the greater nutritious value possessed by these organisms. By the onset of 'westernization' in these places often younger generations and people influenced by them have failed to acknowledge these insect species and their impressive nutritional content and tried to switch to conventional protein-rich alternatives.

Out of the huge edible insect species of Northeast India (308 so far: this number is not accurate and will probably vary in the future; based on Chowdhury *et al*., 2014; Sangma, 2016) very few of them have been analyzed nutritionally. In this study broad-based information about the nutritional contents exhibited by edible insects has been collected from numerous literature and inferences. Studies were done by Nazari *et al*. (2015); Bhattacharyya *et al*. (2018); Das *et al*. (2019); Rahman *et al*. (2018) have specified nutritional information of over 20 insect species. Mineral analysis has only been given by Bhattacharyya *et al*. (2018) of five scarab beetles (Coleoptera: Scarabaeidae). Since insects are also enriched with minerals such as zinc, calcium, iron, etc, further research needs to be done to draw more information. Studies were done by Meyer-rowchow *et al*. (2011, 2014, 2016) on 5 edible insect species that fetched almost all macronutrients and micronutrients. Arunachal Pradesh has a highly rich insect diversity (of about 158 species). People thoroughly depend upon these organisms as a source of their food. Presently, the data of nutritional analysis is incomplete and therefore further research should be carried out to derive the nutrition information of the edible insects. This will create awareness among people regarding the conservation of these insects and the valuable culture of Northeast India that is being threatened by the 'westernization and force of the modern world. Therefore in this review, we will be endeavouring to give a brief description of the edible insect species recorded in general as well as in the states of North East India including their nutritional value which has been evaluated so far (which mainly include Assam and Arunachal Pradesh). This will create a general public awakening and will help to develop a positive vibe among people especially youngsters about edible insects. And, as edible insects possess nutritional values equally compared to conventional food products (plant and animal products) this knowledge in hand will enable and encourage people from all parts of the world to include valuable insects in their plates.

Abundance and practice of entomophagy distributed among the continents and bio-geographical realms

According to Costa-Neto and Dunkel, (2016) approximately 2 billion people belonging to 3071 ethnic groups in 130 countries practice entomophagy daily. Using the biogeographical realms proposed by Udvardy (1975), high insect consumption of ~350 to ~700 edible insect species can be observed in the African, Neotropical, Oriental, and Palearctic Realms. There are several major orders in class Insecta, however, insects belonging to Coleoptera, Hymenoptera, Isoptera, Diptera, and Orthoptera are mostly eaten as food. Neotropical realm has been recorded with the highest number of species (639 species), followed by Oriental (540 species), African (400 species), Palearctic (344 species), Australian (95 species), and Nearctic region (90 species). Pioneer entomologist and researcher Gene D foliart (2002) has recorded 163 species in Central and Eastern America, 151 species in Southern Asia, 148 species in Mexico, 84 species in Oceania, 83 species in Southern Africa, 66 species in Eastern Asia, 65 species in South America, 52 in Southern-Central Asia, 25 species in Northern and Western Africa, 16 species in Southwest Asia and 12 species in Central America and Caribbean Islands. Most of the underprivileged groups of populations all around the globe routinely consume insects as part of their diet, particularly in Africa, Asia, Neotropics, and the Palearctic (Gahukar, 2011; Manary and Sandige, 2008; Nonaka, 2009; Ramos-Elorduy, 2009). Entomophagy is generally not seen in Canada, the United States, and Europe but previously it has been perceived that ancient Greeks and Romans enjoyed insects particularly grasshopper and cicadas (Liu and Zhao, 2018). Recently these countries are also trying to incorporate insects in diets, motivated by modern youth, awareness, media, and institutions that emphasize entomophagy as a potential way of deriving foods shortly (FAO, 2008; Gahukar, 2011; Polis, 2011; Liua and Zhao, 2018).

The biogeographical distribution of edible insects has been influenced by significant barriers like narrow passage, high mountains, deserts, oceans, or straits and fauna that prevented the expansion of species within each biogeographic region (Govorushko, 2019). Insects of various orders are widely eaten, out of which Coleopterans are preferred the most (may vary with regions) and Dipterans the least. Coleopterans are eaten both in their adult and larval stages. They remain at the top of the list probably due to their large sizes and diverse habitats. Entomophagy is primarily seen in the subtropical and tropical parts of earth. China, Japan, and Mexico are the only countries entirely or partially located in the temperate zone where entomophagy is practiced in higher proportions (Jongema, 2017). The consumption of edible insects among countries in the world is depicted in Fig. 1.

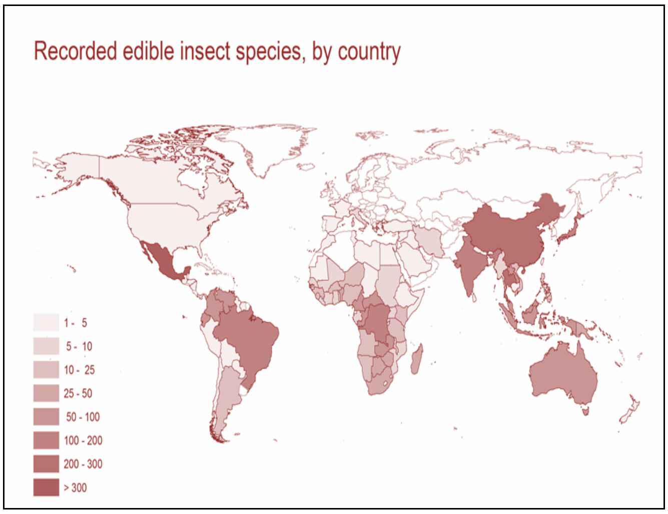


Fig. 1: Distribution of edible insects in various countries around the globe. Source: Centre of Geoinformation by Ron van Lammeren, Wagwningen University, based on data compiled by Y de Jongema, 2015

Entomophagy: An age-old practice in Africa, Asia, and among the natives of Australia, North America, and South America supporting appetites and livelihoods.

Africa has been dependent on insects for nourishment since ancient times considering the immense biodiversity of insects that is harbored by the continent. Some African countries encourage children, pregnant women as well as people who are anemic to eat caterpillar meal which is rich in protein, calcium, and iron (Illgner *et al*., 2000; Kruse *et al*., 2004; Malaisse *et al*., 2005). *Gonometa postica* pupae is a Pedi food in South Africa (Quin, 1959) whereas *Borocera cajani* pupae are a food source in Madagascar (Decary, 1937) obtained from the wild silk producers, belonging to the Lasiocampidae family. Caterpillars are consumed by around 85 percent of the population of the Central African Republic. Bangui, a capital city of Central African Republic produces caterpillars accounts for 29 percent annual intake of animal protein per person per year (14.6 kg) (n'Gasse *et al*., 2004). Guajibo and Colombia becomes highly rich in insects diversity in the rainy season with 60% of their animal protein content (paoletti *et al*., 2000; Melo *et al*., 2011). The marketing of edible insect species has resulted in the economic development of the country by helping people financially. A study indicated by n'Gasse *et al*. (2004) states that about 5 tonnes of dried caterpillars were traded between Paris and Central Africa, as well as 3 tonnes between Brussels and Central Africa per year. The mopane caterpillar, and larvae of the mopane emperor moth *Imbrasia belina*, is endemic to the mopane woodlands of Angola, Botswana, Mozambique, Namibia, South Africa, Zambia, and Zimbabwe (Halloren *et al*., 2014). In South Africa, an estimated 9.5 billion mopane caterpillars are harvested per year. This output has an economic contribution of about $85 m (Ghazul, 2006). Another research carried out by Shackelton and Shackelton (2004) of South Africa reveals in their study that more than half of rural households depend on insects as a source of food.

Entomophagy practices in Asia excel any other records and contain the largest number of countries in the queue. *Bombyx mori* (mulberry silkworm) is perhaps the most extensively tamed insect used by humans. It has been cultivated for 5000 years in China. On account of such a long period, silkworm bears little resemblance to its ancestral species and it would probably not survive in the wild state. Since silk moth pupae have been prepared for commercial production of silk in most countries of Eastern and Southeastern Asia, it is not surprising that pupae are widely used in food and animal feed (Defoliart 1994). In China, Japan, Thailand, and Vietnam the Thai Silk Moth is particularly valuable for its taste and is a delicacy (Costa-Neto & Dunkel, 2016). The larvae and pupae of silkworm (eri and muga silk moth) have been a delicacy in North East India along with its immense silk production value (Chowdhury, 1982; Bora and Sharma, 1965; Chakraborty 2011, Sangma *et al*., 2016). Vara-asavapati *et al*. (1975) said that silkworm pupae are common and very expensive in the market of Thailand. In addition to other traditional dishes, crickets are popular street food in Thailand. They are a source of roughly 60% proteins, 20% fat, 20% fiber, and 450 kcal/100g (Rumpold and Schlüter, 2013). In south-eastern Asia, two seasonal insects are commonly collected and consumed: Bamboo worms (*Omphisa fuscidentalis*) and Weaver ants (*Oecophyla smaragdina*). These insect species significantly contribute to rural subsistence and can attract high market prices. Another popular Thailand food, Weaver ants, is collected from host wild trees. Seasonally, around 2 kilograms of weaver ants are harvested and the income amounts to 360$ per month and this continues for a period of 4-5 months. The total annual income generated by weaver ant collectors in Thai nakhon rachasima was estimated to be $620,000 (Sribandit *et al*., 2008)

Wichitty grubs, feeding on Wichitty Bush (*Endoxyla leucomochla*) are a delicacy among the indigenous people of Australian deserts. They are considered as a staple food known for their high protein and fat contents. In the wilderness of Australia the honey pot ants, gorged with honey-like sweet substances are eaten as desserts by the natives (Costa-Neto & Dunkel, 2016). *Camponotus inflatus* and *Myrmecocystus* sp. are the two examples of honey pot ants (Morgan, 1991). A total of 54 insect species are used by the various Native American tribes for food. Cicadas are widely preferred by the Algonquin tribes of America and are presented as a special dish during the festivals. Brine flies frequently known as 'kutsavi' are collected by the natives in California and are highly relished as food (Steward, 1933). Mormon crickets are another preferred edible insects used by the natives in the Prairies and Rockies of North America (Sutton, 1988). In Mexico, grasshoppers commonly known as 'chapulin' are greatly preferred food items. Mexican grasshoppers such as *Sphenarium* spp. are highly desired edibles because of their potential nutritious values. Ant eggs vernacularly known as escamoles and agave larvae are also greatly in demand. Agave larvae are also sold at a very high price. In the year 2000, its estimated value was USD 45 per liter (Rehder and Dunkel, 2009).

Entomophagy is an emerging trend among Europeans & European-Americans penetrating through culture, disgust factor, and food regulations.

Entomophagy practices are emerging among the other groups of the world which include Europeans and European-Americans. Mealworms and some migratory locusts like *Tenebrio molitor* (Tenebrionidae) & *Locusta migratoria* (Acrididae) are reaching the plates of Europeans commercially now. *T. Molitor* as well as *Galleria mellonella* & *Acheta domesticus* are eaten by European-Americans (Costa-Neto & Dunkel, 2016). "Culture" is one of the major reasons why insects are not widely accepted for food. There is a strong emotion of disgust when insects are taken as food by many different countries and societies (Looy *et al*., 2014; Rozin *et al*., 2008). But according to Halloran *et al*. (2014), food choices change over time, driven by factors like socio-economics, food innovation, and progress in the agro-food and technology industries through chefs, trendy food magazines, television showcases, slow food concepts, health and/or environmental/social issues. Another key barrier to the widespread adoption of insects as foods by western countries is that they cannot be sold as (semi-) processed food products that are easily integrated into food preparation from home cooking to industrialized catering at any level. Because insects have never before been considered food, there is still almost no regulatory framework governing the production, trade and consumption, and derivatives of insects (Grabowski *et al*., 2013). In Europe, insects as food legislation are a fairly growing concept because the general food regulations do not explicitly include insects (Belluco *et al*., 2013). Accordingly, unique foods and ingredients not consumed 'to a considerable extent' before 1997 may require authorization before they enter the market, as required by Regulation (e) 258/1997. Modern studies show that attitudes to entomophagy are shifting and insects can become an approved ingredient of food (Caparros *et al*., 2013) The honey bee could be a valuable instrument for restoring insect-like attitudes in the

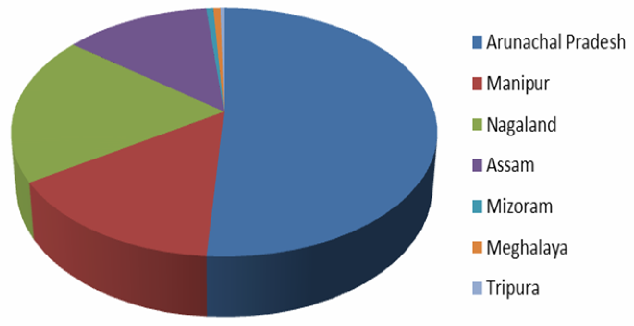
USA due to its excellent public image (Defoliart,1989). In recent years, start-ups specializing in food based on insects have experienced a boom. This trend has been seen at its strongest in France, the Netherlands, and the USA.

Figures from North East India and insect classes preferred by indigenous people

Entomophagy is a promising choice among the indigenous people in the North-Eastern parts of India. A huge array of insects plays the dietary role of the indigenous people. Entomophagy is a common practice in North East India, particularly seen in the tribes of Arunachal Pradesh, Assam, Manipur, and Nagaland (Sangma *et al* 2016). The indigenous people of Arunachal Pradesh are experts in consuming the largest number of 158 edible insect species. Manipur, Assam, and Nagaland host around 16 to 40 species (Chakroborty, 2014). In a separate study, the researcher contributed to amounting the number of edible insects eaten by the Nyishi and the Galo tribes of Arunachal Pradesh. The study reported about 102 species of insects are consumed by the two tribes. A separate study carried out reveals that Wangho, Nocte, Shingpo, Tangsa, Deori, and Chakma tribes depend upon about 51 insect species for food in Arunachal Pradesh. The Coleopteran species are mostly used as meals in Arunachal Pradesh followed by Orthoptera, Hymenoptera, Hemiptera, Lepidoptera, Isoptera, Ephemeroptera, Odonata, and Mantodea (Meyer-Rochow *et al*., 2013; Sangma *et al*., 2016). In Manipur, the edible insects were listed as 46 species of 39 genera, 23 families, and 7 orders. Out of the 46 species, 16 species of Coleopteran, 15 species of Hemipteran, and 7 species of Hymenoptera were identified. Apart from this, there were other 4 orders included (Ayekpam *et al*., 2014). The largest number of edible insect species belongs to Hemiptera, while Dictyoptera and Isoptera represent the least number of edible insects. The Meitei, Tarao, Tangkhul, Chothe and Thadu tribes of Manipur feed on the highest number of insects as compared with other groups (Shantibala *et al*., 2012).

In Assam, about 40 insect species are included in the diet of the tribal people inhabiting the Karbi Anglong District. The Karbis and Rengma Naga tribes eat at least 32 insects in compliance with seasonal accessibility. These 32 species belong to various groups of insects such as the Hymenoptera, Coleoptera, Orthoptera, Hemiptera, and Odonata. In Nagaland, the Ao tribes eat approximately 42 different insect species. Orthopteran species are eaten as most followed by Coleoptera, Lepidoptera, Hemiptera, Mantodea, and Odonata (Meyer-Rochow *et al*., 1997). Several species of silkworm larvae are also used in the diets. Pentamoid bugs (*Ochrophora montana*) are eaten in Mizoram and Tripura (Sachan *et al*., 1987; Thakur and Firake 2012). Termites are one of the widely eaten insects in Meghalaya and some part of Assam (Chowdhury *et al*., 2015). Pre pupa silk-worms are also consumed in Meghalaya (Sangma *et al*., 2016). Other records of edible insects are currently not known for the two states but it could be stated that due to the biodiversity and different tribes existing, there is a possibility of other edible insect species to be flourishing. Usage and abundance of edible insects among the states of North East India are highlighted in Fig 2.

Fig 2: Usage of edible insects among north-eastern states



Dependence on edible insects by indigenous tribes of North East India

The edible insect species in North East are loaded with nutrients although most of the indigenous people are not aware of them. They are rich in proteins, carbohydrates, fats, vitamins, minerals, etc. The nutritional components of the insects are comparable to conventional sources such as fish, meat, and eggs. For example, the silkworm moth is utilized for producing silk in Assam as well as its pupa is a high-protein rich food for humans. In Nagaland, it was also found that the consumption of silkworm larvae and pupas has been widely practiced (Meyer Rochow, 2004). As per nutritional background, silkworm pupae increase immunity, protect the liver, and prevent cancer. The approximate study of pupa has shown that it contains 55%–60% of protein, 25%–30% lipid, 4.96% fiber, etc. Thus it could be a good protein source for various purposes in the human diet (Chowdhury *et al*., 2015).

Red ants (*Oecophylla smaragdina*) are thought to be nutritious and healing, used by Mishing and Ahom groups of Assam as special food during the festival of Bohag Bihu (Doley and Kalita, 2012). Shrivastava *et al*. (2009) reported red ants are also rich in calcium. Termites are a precious source of protein, fat, and important amino acids (Solavan *et al*., 2006). Termites are a valued resource in some Southeast Asian countries and are considered as a delicacy food. Since its flavor is exceptional due to which it can be eaten in many different ways. This insect has a protein content of 40-50% (dried weight) which is similar to other protein sources but they are a high-priced delicacy, being almost twice as expensive as beef or pork (De Foliart and Food, 2009). Termites are a great source of proteins and carbohydrates owing to which they are eaten in many parts of Meghalaya. An abundant load of minerals are also present in termites which surpasses the quantities found in salmon, fish, broiler chicken, and other vegetables (Paul and Dey, 2011). *Ochrophora Montana* commonly known as 'Thangnang', a pest of flowering bamboo plants is a favorite food in Mizoram (Sachan *et al*., 1987; Thakur and Firake, 2012). Oil is also prepared from 'Thagnang' which is saved for later to be used in/as food at difficult times. In Arunachal Pradesh Asian dune crickets (*Schizodactylus monstrosus*) are left inside bamboo for a week and prepared into a delicious chutney that is eaten with rice or local alcoholic drinks (Sangma *et al*., 2016)

Known nutritional composition of some edible insect species of Assam, a lot more yet to be known

Assessment of nutritional information of some edible insects has been done by workers from time to time, although much information about their composition is still not available. Hence further research should be carried out to study the abundant amount of nutrients like proteins, carbohydrates, fats, minerals, etc. present in them. A study done by Nazari *et al*. (2015) revealed the nutritional values of 20 edible insect species of Bodo tribe of Assam. *Nephilia maculata* was found to have the highest protein content of about 84.56% in contrast to *Ruspoliya baleyi* which exhibited the least protein content. *R. baleyi* was found to contain the highest fat content of about 40.65%. The findings also show the highest protein-containing species has the lowest fat content and the fattiest species have less protein content.

Table 1: Proximate composition % of dry matter (g/100g).Source: Nazari *et al*. (2015)

S. No.	Order	Scientific Name	Consumed state	Proteins	Carbohydrates	Fats	Calorific value
1.	Hymenoptera	*Vespa affinis continentalis Bequaert*	Larvae	50.13	13.29	25.33	483.45
2.	Hymenoptera	*Polistis (Gyrostoma) olivaceus*	Larvae	51.06	17.89	19.92	455.08
3.	Hymenoptera	*Parapolybia varia*	Larvae	53.63	20.31	15.38	438.18
4.	Hymenoptera	*Oecophylla smaragdina*	Larvae	52.13	13.65	22.72	467.60
5.	Hymenoptera	*Pompilidae*	Larvae	55.88	7.47	25.33	481.37
6.	Hemiptera	*Lethocerus indicus*	Adult	67.31	10.51	13.73	434.84
7.	Hemiptera	*Laccotrephes ruber*	Adult	47.13	28.18	10.13	392.41
8.	Orthoptera	*Tarbinskiellus portentosus*	Adult	58.00	3.88	23.70	460.82
9.	Orthoptera	*Gryllotalpa africana*	Adult	58.31	13.36	15.69	427.89
10.	Orthoptera	*Eupreponotus inflatus*	Adult	75.38	4.89	11.61	425.25
11.	Orthoptera	*Choroedocus robustus*	Adult	64.50	14.04	15.73	413.61
12.	Orthoptera	*Chondracris rosea*	Adult	68.88	6.00	17.52	457.20
13.	Orthoptera	*Phlaeoba infumata*	Adult	71.75	11.49	10.15	424.31
14.	Orthoptera	*Oxya fuscovittate*	Adult	78.31	1.58	12.33	430.33
15.	Orthoptera	*Mecopoda elongate elongate*	Adult	59.50	13.67	20.11	473.67
16.	Orthoptera	*Ruspolia baileyi*	Adult	30.25	22.35	40.65	580.25
17.	Orthoptera	*Mantis inornate*	Adult	33.00	47.98	12.29	434.53
18.	Coleoptera	*Dytiscus marginalis*	Adult	59.00	12.21	20.74	434.87
19.	Isoptera	*Macrotermes natalensis*	Adult	39.44	37.78	18.22	472.86
20.	Aranea	*Nephila maculata*	Adult	84.56	8.96	4.01	410.17

In another study carried out by Bhattacharyya *et al*. (2018) on 5 different species of scarab beetles in Assam where he analyzed different nutrients and the minerals contents of these insects. *Xylotrupes gideon* contained the highest protein content of about 79.33% and *Lepidiota mansueta* was the source of high energy of 379.29 kcal. *Lepidiota mansueta* also contained a high amount of calcium. On contrary to this *Lepidiota albistigma* has the least quantity of zinc. Fiber content was seen to be highest (8.28%) in *X. gideon* which is probably due to their feeding nature on the woody parts of trees (Bedford, 1975) and lowest in *L. mansueta* (5.16%) which the author inferred, based on a different study carried out by him in 2015.

Mahanta *et al*. (2014) analyzed the protein composition of various developmental stages and castes of *Oecophylla Smaragdina* commonly known as 'Amroli porua' during different seasons. It is served as a traditional food in the Ahom community of Upper Assam. The author found that from March to June, the protein content was 27-59% in queen larvae, 26-46% in queen pupa, and 26% in adult queen. The worker castes were found to be comparatively lower in protein content. The worker larvae contained 15-35% of protein, worker pupa (12-27%), and adult workers (10-18%). The results from the study revealed noticeable fluctuations to the studies done in the past as the present study was conducted on weaver ants fed on the mango host plant. The host plant variation plays an important role in the nutrient composition of edible insects (Alamu *et al*., 2013). The detailed list of nutritional contents analyzed by various researchers is given in Tables 1, 2, 3, 4 and 5.

Table 3 : Elemental composition (mg/100 g) of five species of scarab beetle; Source: Bhattacharya *et al*. (2018)

Sl. No.	Order	Species	Na	K	Ca	Fe	Cu	Zn	Mn
1.	Coleoptera	*Lepidiota mansueta*	27.76±.57^{d}	14.20±.31^{e}	33.33±.13^{a}	1.64±.05^{d}	6.52±.46^{b}	15.55±.62^{a}	1.30±.06^{d}
2.	Coleoptera	*Lepidiota albistigma*	29.57±.43^{c}	144.33±.45^{a}	29.94±.14^{b}	1.41±.09^{d}	2.01±.21^{c}	2.38±.28^{b}	1.09±.16^{d}
3.	Coleoptera	*Xylotrupes gideon*	31.47±.82^{b}	53.68±.58^{d}	29.30±.10^{c}	22.73±.87^{b}	14.99±.54^{a}	15.86±.61^{a}	5.60±.27^{b}
4.	Coleoptera	*Sophrops iridipennis*	23.16±36^{e}	64.32±.56^{b}	33.37±.14^{a}	19.86±.87^{c}	16.13±.63^{a}	15.38±.64^{a}	2.63±.36^{c}
5.	Coleoptera	*Catharsius molossus*	35.91±.46^{a}	58.06±.68^{c}	23.33±.18^{d}	37.05±.57^{a}	15.93±.78^{a}	15.64±.37^{a}	19.66±.52^{a}

Table 2 : Proximate and energy analysis of five species of scarab beetles All values are mean 6 SE. Means in the same column with different letters are significantly different (p < 0.05). Source: Bhattacharya *et al.* (2018)

Sl. N	Order	Scientific Name	Moisture (%)	Crude protein (%)	Crude fat (%)	Crude fiber (%)	Total mineral (%)	Carbohydrate (%)	Energy (kcal/100g)
1.	Coleoptera	*Lepidiota mansueta*	2.16± 0.03^{c}	76.42±.77^{a}	4.10±.10^{c}	5.16±.09^{d}	2.98±.07^{b}	9.18±.84^{a}	379.29±.08^{a}
2.	Coleoptera	*Lepidiota albistigma*	2.55±.04^{a}	68.54±.77^{b}	5.50±.15^{a}	6.73±.06^{c}	4.83±.15^{a}	11.84±.08^{a}	371.04±.73^{c}
3.	Coleoptera	*Xylotrupes gideon*	2.04±.04^{d}	79.33±.29^{a}	4.00±.15^{c}	8.28±.13^{a}	0.80±.08^{d}	5.55±.37^{b}	375.54±.66^{b}
4.	Coleoptera	*Sophrops iridipennis*	2.42±.04^{b}	70.29±.27^{b}	4.75±.08^{b}	8.15±.09^{a}	4.98±.13^{a}	9.41±.19^{a}	361.55±.34^{d}
5.	Coleoptera	*Catharsius molossus*	2.39±.04^{b}	78.17±.27^{a}	4.60±.12^{b}	7.18±.13^{b}	2.38±.11^{c}	5.28±.99^{b}	375.19±.61^{b}

Table 4: Protein, lipid, and carbohydrate content in different insects in mg/gm. Fresh wet weight (values are mean ± SD of three replicates). Means having different superscripts (a,b,c…) differ significantly (P<0.05) Source: (Das, 2018)

Sl. No.	Order	Scientific Name	Protein content (mg)				Lipid content (mg)				Carbohydrate content (mg)			
1.	Hemiptera	*Diplonychus rusticus*	216.33	hi	±	2.52	133.00	f	±	7.21	29.00	c	±	3.61
2.	Isoptera	*Microtermes obesi*	145.67	cd	±	7.09	186.33	g	±	7.64	45.35	fg	±	5.78
3.	Orthoptera	*Gryllotalpa africana*	169.00	e	±	7.94	65.00	de	±	4.36	58.00	ij	±	3.46
4.	Orthoptera	*Acheta domestica*	198.00	fg	±	8.54	69.00	de	±	4.36	53.00	hi	±	2.65
5.	Orthoptera	*Hieroglyphus banian*	152.67	d	±	6.66	72.01	e	±	6.25	32.02	cd	±	3.44
6.	Hymenoptera	*Oecophylla smaragdina*	82.00	b	±	5.57	35.00	b	±	4.58	2.90	a	±	0.17
7.	Coleoptera	*Hydrophilus olivaceus*	246.00	j	±	8.72	62.00	d	±	3.61	38.00	de	±	2.65
8.	Lepidoptera	*Philosamia ricini (pupae)*	194.00	f	±	6.56	73.00	e	±	3.61	18.03	b	±	1.62
9.	Lepidoptera	*Philosamia ricini (4th instar)*	136.00	c	±	6.08	46.10	c	±	2.85	32.17	cd	±	2.25
10.	Blattodea	*Periplaneta americana*	136.00	c	±	6.08	192.04	g	±	8.49	2.10	a	±	0.10
11.	Coleoptera	*Phyllophaga spp.*	244.33	j	±	6.66	22.28	a	±	2.41	35.67	de	±	2.52
12.	Lepidoptera	*Eretes stictus*	25.36	a	±	1.49	16.30	a	±	0.97	45.35	fg	±	3.75

Aspongopus nepalensis (Pentatomoid bug): A common bug eaten across Arunachal Pradesh has potential nutritious values

A pioneering study was conducted by Meyer-Rochow *et al.* (2011) on a common edible insect of Arunachal Pradesh *A. nepalensis* (pentatomoid bug). In this study, a detailed list of macronutrients and micronutrients were analyzed and enlisted. It was concluded that ash content (2.160±0.202%) was found to be lower than some insects but higher than common crickets, ants, and some meal bugs (Adeduntan, 2005) however when compared with common meat products it was found to be nearly similar (Quasem *et al.*, 2009). *A. nepalensis* had a lower protein content (10.620±0.644%) compared with other insects but exceeds the value found in a cow or soy milk (Banjo *et al.*, 2006; Meyer-Rochow, 1976; Bukkens, 1997). Lipid content (38.357±1.050%) was noticeably higher than most edible insects in literature with few exceptions (Fast, 1970; Meyer-Rochow, 1982). It was also surprisingly higher than animal products like beef, chicken, pork, or eggs (Quasem *et al.*, 2009). The specimen also had good crude fiber content with 33.47±1.12%. Moisture with 41.9% was noteworthy for an edible insect, which decreases the vulnerability to microbial infections and thereby increase the shelf life (Scott, 1980). Minerals individually were also analyzed and gave astonishing results: Calcium with 1200 µg g^{-1} and Zinc with 70mg/kg was found to be higher than common foods. *A. nepalensis* also had impressive iron and magnesium content, vitamin A was found to be higher than C, D, E, and B-complex in the specimen.

Chondacris rosea & Brachytrupes orientalis : Two highly proteinaceous insects consumed by the tribes of Arunachal Pradesh

In another ground-breaking study done by Meyer-Rochow *et al.* (2014) on *Chondacris rosea* & *Brachytrupes orientalis* of Arunachal Pradesh in which a thorough nutritional analysis of the two species was carried out. Note-worthy results were obtained that stated *C. rosea* showed higher crude fibre content of 12.4% as compared to *B. orientalis* having 8.8% fiber. This study also justified the results given by Blasquez *et al.* (2012) for 25 Orthopteran species. C. rosea (373.24 kcal) and *B. orientalis* (380.65 kcal) calorific values were surprisingly higher than wheat, whole grains, and eggs but fall within the values of other Orthopteran edible insects (Ramos-Elorduy *et al.* 1997; Malaisse, 2005 Srilakshmi, 2012). The protein content *of C. rosea* (69%) and *B. orientalis* (66%) surpassed the range of other Orthopteran species and were found close to the range found in grasshoppers (Meyer-Rochow, 1982; Conconi *et al.*, 1984 and Blasquez *et al.*, 2012). The authors in this particular study concluded that the protein contents of the specimens are also remarkably greater than all the convention meats (except a bit lower to veal; veal: 71%) and can also suffice for protein deficiency. Furthermore, the specimen also contained all essential amino acids and passes the recommended level; however methionine levels were a bit lower. *C. rosea* and *B. orientalis* showed fat compositions value of 7.88% & 6.326% respectively which were comparatively lower than the other insects and common fat-based foods (Malaisse, 2005; Banjo *et al.* 2006; Ekpo *et al.* 2009; Chakravorty *et al.* 2011b; Blasquez *et al.*, 2012). The two specimens also possessed good ash contents of 4.16 and

4.33% respectively, similar to other insect species (Ashiru, 1988; Banjo *et al*., 2006; Blasquez *et al*., 2012). The authors in the study also supported the two species to be potential sources of dietary minerals.

Oecophylla smaragdina and _Odontotermes sp_: Two common edible insects with impressive fat and calorific values in Arunachal Pradesh

A separate study was done by the same group of authors (Ghosh *et al*., 2016) on another two common insects *Oecophylla smaragdina* and *Odontotermes sp*. The following results were derived: In comparisons with Odontotermes sp. (45,78% and 33,67%), *O. smaragdina* had a greater moisture and protein content (70.48% and 55.28%). *Odontoterms sp*. showed good protein contents compared with other plant-based products except for soybean. Both the specimens contained almost all essential amino acids except methionine. *Odontotermes sp*. with higher fat (50.93%) surpassed almost all animal fat products except beef and pork; *O. smaragdina* (14.9%) exceeded the amounts found in cauliflower and bamboo shoot. The calorific value of *Odontotermes sp.* (617.41 kcal) was significantly higher than *O. smaragdina* (385.26 kcal). Crude fiber amounts in *O. smaragdina* (19.84%) exceeded *Odontotermes sp.* (6.30%). *Odontotermes sp.* showed higher fiber contents compared to other termite species and also fall within the limits found in other fiber rice foods (Gopalan *et al*., 2004, Igwe *et al*., 2011). Ash content for both species *O. smaragdina* (2.59%) and *Odontotermes sp.* (3.01%) were almost similar.

Table 5: Nutritional amounts of proteins, fats, fiber and minerals, energy and moisture of five common edible insects of Arunachal Pradesh; Mineral contents for *A. nepalensis* is taken in % (dry weight). Source: Meyer-Rochow *et al*., 2011, 2014, 2016). For more detailed information on all macronutrients and micronutrients refer DOI: 10.1016/j.aspen.2016.07.001; DOI: 10.1024/0300-9831/a000050; DOI: 10.1016/j.aspen.2014.03.007.

Nutrients	*Aspongopus nepalensis*	*Chondacris rosea*	*Brachytrupes orientalis*	*Oecophylla smaragdina*	*Odontotermes sp.*
Crude Protein %(dry weight)	10.6±0.6	68.883 ± 1.118	65.740 ± 0.825	55.279 ± 1.024	33.672 ± 0.329
Crude fat %(dry weight)	38.4±1.1	7.883 ± 0.123	6.326 ± 0.290	14.993 ± 0.136	50.930 ± 1.097
Crude fibre%(dry weight)	33.5±1.1	12.383 ± 0.778	8.753 ± 0.228	19.840 ± 0.259	6.298 ± 0.088
Ash	2.2±0.2	4.161 ± 0.301	4.326 ± 0.162	2.586 ± 0.345	3.014 ± 0.313
Total SFA %(dry weight)	13.47 ± 0.0068	2.27 ± 0.0060	4.03 ± 0.0032	5.13	25.95
Total MUFA %(dry weight)	20.15 ± 0.0051	1.49 ± 0.0012	0.54 ± 0.0040	6.8	21.84
Total PUFA	2.3 ± 0.0017	2.68 ± 0.0121	0.14 ± 0.0046	1.08	1.27
Calcium	0.12 ± 0.0020	340	76.282	74.670 ± 0.321	68.346 ± 0.098
Copper	0.002 ± 0.0000	3.620	1.543	0.850 ± 0.000	1.720 ± 0.001
Iron	0.02 ± 0.0015	7.810	18.664	15.660 ± 0.268	8.763 ± 0.028
Magnesium	0.16 ± 0.0010	120	87.214	93.140 ± 0.523	47.705 ± 1.020
Manganese	0.001 ± 0.0000	2.760	4.986	10.350 ± 0.823	1.686 ± 0.008
Potassium	0.35 ± 0.0010	1130	412.276	710.000 ± 3.095	507.270 ± 1.925
Sodium	1.02 ± 0.0020	21.350	112.030	150.000 ± 1.023	92.739 ± 0.950
Zinc	0.007 ± 0.0000	10.830	8.500	18.970 ± 0.809	12.239 ± 0.028
Energy (kcal/100 g)		373.239 ± 14.071	380.646 ± 7.706	385.257 ± 10.088	617.406 ± 13.437
Moisture %(fresh weight)	41.9± 0.7	(43.617 ± 1.77)	(72.298 ± 2.498	70.475 ± 0.421	45.777 ± 0.371.

CONCLUSION

Entomophagy is part of the normal diets of 2 million people worldwide. Consuming insects is not a new practice around many parts of the world. This behaviour of people is valid as edible insects carry enormous amounts of nutrients including both macronutrients and micronutrients found in other conventional foods. This ancient practice is now penetrating new regions of the world whereas in some cases it has started losing its existence due to pressure of modern culture and 'westernization'. In North-Eastern India entomophagy is a normal behaviour, a part of their culture and heritage, which is practiced regularly by the indigenous tribes. More than 300 species of insects are consumed in this region encompassing different states. People have always depended on the practice of eating insects. However, the force of modern culture and the lack of proper knowledge of edible insects' nutritional potentials is failing to sustain this ancient practice. Studies done in the states of Assam and Arunachal Pradesh harbour a huge diversity of edible insects and practices of eating insects. The nutritional information of several edible insects has been derived but the list is not complete yet. According to the studies carried out in the Assam & Arunachal Pradesh the edible insects are found to be rich in proteins, fats, fiber and provide impressive calorific values. Micronutrients are also abundant in insect species like Zinc, Iron, Potassium, Calcium, Copper, Sodium, Magnesium, and various classes of vitamins. The nutritional values of insects are found to be comparable to conventional food sources, and in certain cases, the values surpass the values of common food sources which validate the edible insects to be potential and suitable to be fit in the diets. So, there is an urgent need to evaluate and document the nutritional knowledge of edible insects in literature. More and more research and studies on the nutritional impact of edible insects in the North East will make the public aware and help younger generations to acknowledge the value of edible insects that are part of their rich culture.

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