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Diversity and nutrient composition of commonly consumed Orthopteran insects in Udalguri district of Assam, India

Jayanta Kr. Das*
Assistant Professor, Department of Zoology, Barama College, Barama, Baksa, Assam, India

Abstract
Insects have long constituted a significant component of the traditional diets of various indigenous communities in Assam, India. These entomophagous practices are rooted in cultural heritage and are supported by the high nutritional value of edible insects, particularly their substantial protein content and elevated gross energy levels. Given the projected global challenges related to nutrient deficiencies- especially with respect to animal-derived proteins, insects are increasingly being recognized as a sustainable and viable alternative nutritional resource. In the present study, among the most frequently consumed taxa in the Udalguri district of Assam are Orthopteran insects, including grasshoppers belonging to the families Acrididae and Gryllidae, as well as crickets such as mole crickets and house crickets. The study assessed the diversity of Orthopteran species consumed by local tribal populations using the Shannon-Wiener Diversity Index, and estimated a total of 8 Orthopteran species, representing 3 distinct families, thus reflecting considerable entomofaunal diversity within the region.

Keywords: Edible insects, entomophagy, food security, nutrition

Introduction

The practice of eating insects is much more common in the North-Eastern states of India than in the rest of the country (Manna *et al.*, 2022) [10]. Insects have long constituted a significant component of the traditional diets of various indigenous communities in Assam, India. Throughout human history, insects have been an important source of sustenance, owing to their high protein content and little environmental impact. In the context of rising global concerns regarding food security and environmental sustainability, edible insects are gaining popularity as an alternative protein source for human consumption and animal feed due to their low greenhouse gas emissions and efficient feed conversion ratios.

Over 2,000 species of insects are eaten globally, mostly in the subtropical and tropical world. Entomophagy is an integral part of Indian northeastern states, especially of Assam, where it is rooted deep in the culture of indigenous people and tribal societies. A variety of edible insects are eaten by these groups, such as crickets (Guchingra), grasshoppers (Guma), giant water bugs (Bellostoma or Gangjema), water scavenger beetles (Angkhouri), termites (Chulung), red ant eggs (*Myrmica rubra*), some beetles, and the larvae and pupae of several different insect species. Aquatic insects like water skaters (family Gerridae) are also part of the diet.

Orthopteran insects such as grasshoppers, crickets, katydids, and locusts are all commonly eaten throughout the varying communities of Udalguri district in Assam. The main composition of people there are Assamese, Bodo, Koch Rajbongshi, Rabha, Saotal, amongst other tribes. Inclusion of these Orthopteran species as a regular component of their diet, highlights the cultural continuity of entomophagy in the country. Apart from Orthopterans, silkworms, especially *Philosomia ricini* (eri silkworm) and *Bombyx mori* (mulberry silkworm), also have immense dietary significance among the communities of the region. Amongst them, eri silkworm pupae rank as a food delicacy and are even regarded as more valuable than the silk cocoon itself, which is given secondary importance (Hazarika, 2008) [8].

Insects are not only known for containing high protein but also for having beneficial fat profiles. Most species contain proteins of high biological value and are much lower in fat than traditional animal meats (Dunkel *et al*., 2000) [4]. In developing nations such as India, where resources restrict access to quality animal protein, edible insects serve as a cheap and healthy option. Still, the unconsciousness of their nutritional value tends to result in their underuse even in long-standing consumption traditions.

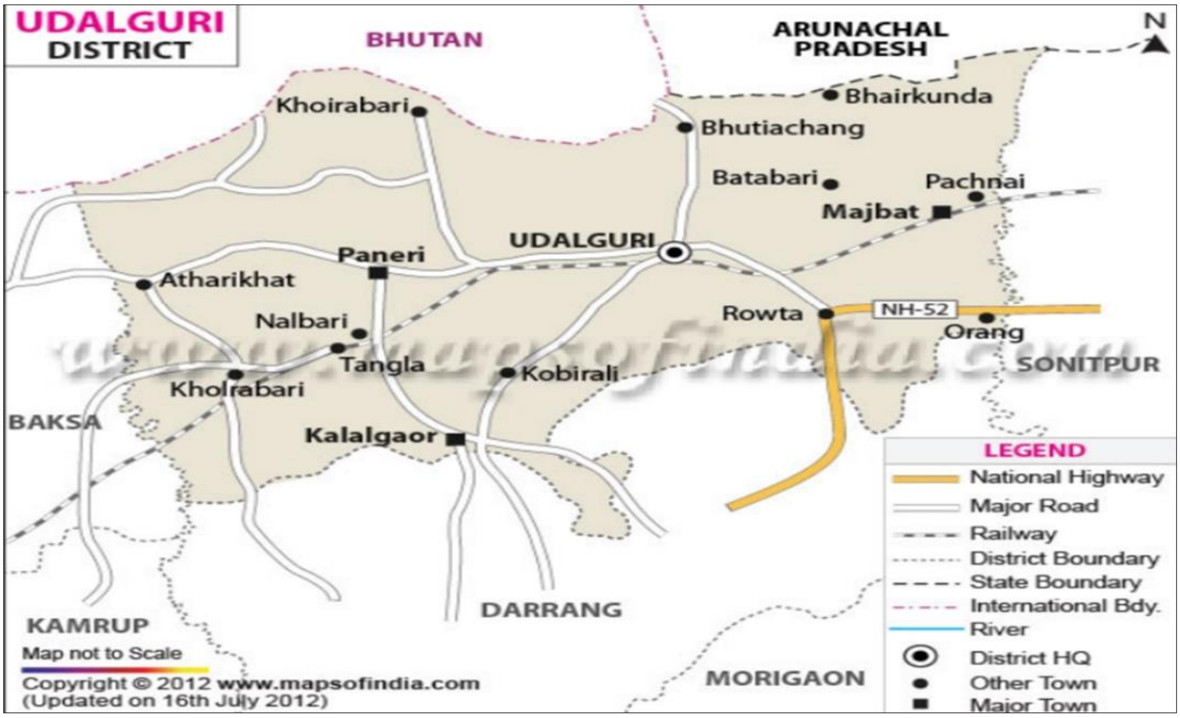
Worldwide significance of entomophagy is corroborated by vast evidence through centuries, where more than one thousand species of insects have been regularly consumed as food. They still remain an essential component of the diets and economies of many societies (Merle, 1958; Katya Kitsa, 1989; DeFoliart, 1995) [2]. In addition, some agriculturally important pest species, most notably in the order Orthoptera, otherwise requiring expensive and environmentally harmful control methods, are edible and have been added to human diets worldwide (Ramos-Elorduy, 1997; FAO, 2008; Premalatha *et al*., 2011) [13, 15].

Study Area: Udalguri district, alternatively known as Odalguri, is an administrative region found within the Bodoland Territorial Region (BTR) of Assam, Northeastern India. It is geographically located in the central region of the state, north of the Brahmaputra River, which is one of the Indian subcontinent's larger river systems. It is bordered by the Kingdom of Bhutan and the Arunachal Pradesh state on its north side, Sonitpur district on the eastern side, Darrang district on the southern side, and Baksa district on the western side.

The district covers a total geographical extent of about 1,852.16 square kilometers. Based on recent population figures, Udalguri is inhabited by a population of 832,769, and thus a population density of about 381 persons per square kilometer. The headquarters of the district is roughly

140 kilometers away from Guwahati, which is the capital of Assam.

Topographically, the Udalguri district is positioned at an altitude of about 345 feet above mean sea level (AMSL). It occupies the latitudinal range between 26°46′N to 27°77′N and longitudinal range between 92°08′E to 95°15′E. Due to this strategic geographic location and the proximity to international borders and varied ecological environments, the district has geopolitical and environmental importance to the region.



Source: Internet, https://dcmsme.gov.in/dips/District-profile-Udalguri.pdf

Fig 1: Map of Udalguri District, Assam.

Materials and Methods

Collection and Identification of Edible Insects: Edible insect samples were gathered from different habitats and markets of the study area. The specimens were identified and categorized by applying valid taxonomic keys and standard entomological books, e.g., pictorial guides and illustrations. Identification was conducted in the field with available literature, field guides, and internet taxonomic resources. For correct classification, certain specimens were preserved based on standard entomological preservation methods as outlined by Ghosh and Sengupta (1982) [7], and subsequently identified by comparative examination with authenticated reference materials.

Diversity Analysis: Two widely used ecological indices were employed to evaluate the edible insects' species diversity: the Shannon-Wiener Index (Shannon and Weaver, 1948) and the Simpson Index (Simpson, 1949). The Simpson Index was utilized to estimate species dominance, as it is not very efficient in the representation of species richness. On the other hand, the Shannon-Wiener Index offers a more complete expression, combining both species richness and evenness (Melo, 2008) [11]. But it fails to properly record the existence of unusual species, which could be of ecological importance in biodiversity analysis.

Sample Preparation and Preservation: After collection, the body parts of healthy insect specimens that were edible were removed and freshly homogenized for biochemical analysis. The majority of the insect samples were stored at -20 °C until analysis in the laboratory. Before biochemical assays, the frozen specimens were thawed at room temperature after they were thoroughly washed with tap water followed by distilled water to clear them of debris and impurities.

Estimation of Protein Content: The protein content of insect edible tissues was approximated by employing the Lowry *et al*. (1951) [9] procedure based on the Folin-Ciocalteu reaction. In brief, an equal volume of 10% trichloroacetic acid (TCA) was mixed with the tissue homogenate to precipitate the proteins. The mixture was then kept at a low temperature (10-15 °C) for about 30 minutes and then centrifuged at 6000 rpm for 10 minutes. The obtained protein pellet was dissolved in 10 ml of 0.1 N sodium hydroxide.

Appropriate aliquots of unknown samples and stock protein solutions were pipetted into a set of test tubes and then topped up to 1 ml with 0.1 N NaOH. To each tube, 5 ml of solution C (alkaline copper reagent) was added and left standing at room temperature for 10 minutes. Then 0.5 ml of Folin-Ciocalteu phenol reagent was added to each tube, mixed, and incubated at room temperature for 30 minutes. Blue coloration signified the presence of proteins, which was measured using a spectrophotometer at 750 nm. A blank with only NaOH and reagents was used to set the spectrophotometer at zero.

Estimation of Carbohydrate and Lipid Content: Total carbohydrate content was analyzed by the Anthrone method reported by Sadasivam and Manickam (2008) [16]. Lipid estimation was done by the chloroform-methanol extraction method of Folch *et al*. (1956), which provides effective recovery of total lipids from biological materials.

Estimation of Mineral Elements: For the analysis of minerals, the insect samples were initially washed thoroughly with running water and oven-dried overnight at 60 °C. AAS was used to find the concentration of essential and trace mineral elements such as magnesium (Mg), zinc (Zn), iron (Fe), copper (Cu), nickel (Ni), cadmium (Cd), chromium (Cr), lead (Pb), and manganese (Mn) by following the procedure of John and Van (1980).

Results and Observation

Diversity: A total of 8 (eight) species belonging to order Orthoptera are tabulated showing the scientific name, order, family along with their eaten part, seasonal availability and mode of eating (Table-1).

Table 1: Diversity of 8 Orthopteran edible insect species in the district along with the consumed part, seasonal availability, and mode of consumption.

Scientific Name	Order	Family	Consumed part	Seasonal availability	Mode of consumption
Tarbinskiellus portentosus	Orthoptera	Gryllidae	Whole body	Whole year	Fried, burned chutney
Gryllotalpa africana	Orthoptera	Gryllotalpidae	Whole body	April-August	Fried, burned or chutney
Eupreponotus inflatus	Orthoptera	Acrididae	Whole body	Sept- Nov	Fried, boiled or chutney
Choroedocus robustus	Orthoptera	Acrididae	Adults, Whole body	May-August	Boiled, roasted and as vegetable paste
Chondracris rosea	Orthoptera	Acrididae	Adults, Whole body	May- Sept	Boiled, roasted and as paste
Heiroglyphus banian	Orthoptera	Acrididae	Adults Whole body	May- Sept	Fried, burned
Oxya hyla hyla	Orthoptera	Acrididae	Whole body	May- Sept	Fried, Boiled, chutney
Aceta domestica	Orthoptera	Gryllidae	Whole body	Whole year	Fried, Boiled, chutney

Seasonal Variation: A seasonal variation in abundance was observed in edible insects. Some edible insects are abundance in a particular season whose number may decline in another season. Species namely, *Heiroglyphus banian*, *Choroedocus robustus, Oxya hyla hyla, Eupreponotus inflatus* were found to be the most abundant species found in pre-monsoon, monsoon, retreating monsoon, and winter seasons.

Table 2: Data of edible insect species found in different seasons in the study area.

Species	PM	M	RM	W
Acheta domestica	452	234	121	44
Chondracris rosea	233	724	131	0
Choroedocus robustus	268	879	157	0
Eupreponotus inflatus	162	811	192	113
Heiroglyphus banian	489	614	187	0
Oxya hyla hyla	201	432	198	0
Tarbinskiellus portentosus	130	294	116	10
Gryllotalpa africana	220	394	159	52

Biochemical composition: Amongst the eight species considered, significantly higher amount of protein [F (7,23) = 20.85], lipid [F (7,23) = 454.2], and carbohydrate [F (7,23) = 6.038] were observed in species *Chondracris rosea*, *Oxya hyla hyla*, and *Gryllotalpa africana* respectively.

Table 3: Nutritional composition (protein, lipid, carbohydrate) of the selected orthopteran species

Sl. No.	Name of the Species	Protein Content (g/100g)	Lipid content (g/100g)	Carbohydrate content (g/100g)
1	*Tarbinskiellus portentosus*	20.67 ± 0.90^{ac}	133.33 ± 6.66^{a}	28.67 ± 1.53^{ac}
2	*Gryllotalpa africana*	15.20 ± 0.40^{b}	72.33 ± 3.51^{b}	61.67 ± 3.00^{b}
3	*Eupreponotus inflatus*	18.10 ± 1.51^{ad}	76.00 ± 4.00^{b}	35.33 ± 3.51^{abc}
4	*Choroedocus robustus*	18.20 ± 1.11^{ae}	70.33 ± 1.53^{b}	46.33 ± 6.51^{ab}
5	*Chondracris rosea*	23.17 ± 1.36^{c}	66.67 ± 2.08^{b}	24.67 ± 4.04^{c}
6	*Heiroglyphus banian*	19.77 ± 0.55^{a}	107.00 ± 5.29^{c}	25.67 ± 2.52^{c}
7	*Oxya hyla hyla*	15.73 ± 0.31^{bde}	208.33 ± 4.16^{d}	23.00 ± 3.0^{c}
8	*Aceta domestica*	19.43 ± 1.00^{a}	134.33 ± 1.53^{a}	24.33 ± 1.53^{c}

Values are expressed as Mean±SD, n=3 Different superscripts along the column differ significantly.

Mineral composition: In context to minerals, macrominerals such as Calcium (Ca), Magnesium (Mg), and Manganese (Mn); while microminerals such as Iron (Fe), and Zinc (Zn) were estimated for the eight species considered.

For the macrominerals studied, significantly higher concentrations of Ca [F (7,23) = 1366], Mg [F (7,23) = 383.9], Mn [F (7,23) = 6.59] were observed in species *Aceta domestica, Gryllotalpa africana,* and *Heiroglyphus banian* respectively.

Among the microminerals evaluated, significantly higher concentrations of Fe [F (7,23) = 232.6] and Zn [F (7,23) = 738.1] were observed in *Choroedocus robustus* and *Heiroglyphus banian* respectively.

Table 4: Macronutrient composition of the eight edible insects found in study area.

Sl. No.	Name of the Species	Ca (mg/100g)	Mg (mg/100g)	Mn (mg/100g)
1	*Tarbinskiellus portentosus*	6.74±0.60[a]	7.02±0.01[ac]	1.66±0.59[a]
2	*Gryllotalpa africana*	18.65±0.23[b]	30.35±1.30[b]	2.55±0.27[a]
3	*Eupreponotus inflatus*	19.35±0.31[b]	5.99±0.57[a]	3.02±0.03[ab]
4	*Choroedocus robustus*	34.71±1.14[c]	10.31±0.64[c]	2.16±0.26[a]
5	*Chondracris rosea*	20.71±0.57[b]	14.35±0.57[d]	2.76±0.60[a]
6	*Heiroglyphus banian*	18.87±0.24[b]	22.03±0.98[e]	5.94±2.84[b]
7	*Oxya hyla hyla*	23.35±0.56[d]	13.07±0.02[d]	2.38±0.52[a]
8	*Aceta domestica*	62.73±1.57[e]	9.00±0.79[c]	0.33±0.05[a]

Values are expressed as Mean±SD, n=3 Different superscripts along the column differ significantly.

Table 5: Micronutrient composition of the eight edible insects found in study area.

Sl. No.	Name of the Species	Fe (mg/100g)	Zn (mg/100g)
1	*Tarbinskiellus portentosus*	12.18±0.28[a]	5.72±0.55[a]
2	*Gryllotalpa africana*	7.41±0.44[b]	7.93±0.15[b]
3	*Eupreponotus inflatus*	5.85±0.31[c]	11.05±0.01[c]
4	*Choroedocus robustus*	15.98±0.07[d]	13.30±0.52[d]
5	*Chondracris rosea*	12.29±0.41[a]	16.05±0.05[e]
6	*Heiroglyphus banian*	13.67±0.53[e]	19.04±0.02[f]
7	*Oxya hyla hyla*	11.37±0.54[a]	11.06±0.04[c]
8	*Aceta domestica*	9.65±0.06[f]	14.13±0.01[g]

Values are expressed as Mean±SD, n=3 Different superscripts along the column differ significantly.

Discussion

In India, in the state of Assam, different tribal groups, especially the Bodo and Rabha tribes, conventionally eat a wide variety of edible insect species. These include, crickets (locally known as Guchingra), grasshoppers (Guma), water giant bugs (Belostoma, Gangjema), water scavenger beetles (Angkhouri), termites (Chulung), red ant eggs (Myrmica rubra), beetles, larvae, pupae of different insects, and water skaters (family: Gerridae), among others. Of these, species of the order Orthoptera are the most diverse and numerically dominant.

The indigenous people of the study area consume these insects by frying, roasting, or making them in paste form (usually called chutney), which they usually take with their normal meal or traditional homemade rice beer (Jwakhai). For example, the crickets (family Gryllidae) and grasshoppers (Acrididae) are eaten regularly after wing removal, frying in oil, and addition of salt. The people of Kom al and Meitei community in Manipur, India have their culinary habit of entomophagy. These people eat the eggs, larvae, pupae and adults of certain insect species collected from forests or other suitable habit. They enjoy eating the insect roasted, fried, made into chutney and curry.

Crickets are considered a particularly palatable delicacy among the Bodo community across several districts of Assam. Globally, most grasshopper species are considered edible (Ramos-Elorduy *et al*., 2012) [14]. Being ectothermic, grasshoppers are easily collected during the early morning when ambient temperatures are low, making them less active and more accessible (van Huis *et al*., 2013) [17].

The methods of consumption of insects are diverse across various ethnic groups in the research location. Insects are mostly eaten fried, roasted, or in paste form, and occasionally raw. There was a clear seasonal pattern of availability of Orthopteran insects, which is most common between May and September, while Coleopteran insects are mostly available between April and September.

Several food-consuming Orthopteran species are also recognized agricultural pests, inflicting harm on crops and yield loss. Their consumption, although, is not only an efficient means of controlling pests but is also an extremely nutritious source of food. Wang *et al*. (2005) assert that the field cricket (*Gryllus testaceus*) has high nutritional content and is even utilized as poultry feed owing to its high protein composition. The current research also shows interspecific differences in the nutritional value of Orthopteran insects, with protein ranging from 15.20 g to 23.17 g per 100 g fresh body weight. These values show the important role of edible insects as a cheap, protein-rich food item, especially in areas where there is limited access to normal animal protein (e.g., fish or meat) due to financial limitations. Naga tribe of Nagaland in N.E. India regard orthopteran species such as *Elimaea securigera* as a "health food" and prepare the insects as cooked or fried to be served as the main dish, replacing conventional meat sources. They fry grasshoppers and cook with local spices. while giant katydids (e.g., *Mecopoda nipponensis*, *Mecopoda elongata*, and *Pseudophyllus titan*) are roasted/toasted and eaten as snacks (Mozhui, *et al.*, 2020) [12].

With this backdrop, there is a pressing need for systematic documentation and scientific validation of traditional knowledge surrounding harvesting, rearing, and sustainable use of edible insects. Such an initiative would not only assist in nutritional security but also be beneficial for the conservation of insect biodiversity.

Protein-energy malnutrition (PEM) continues to be an essential public health concern, responsible for more than 50% of mortality in children below five years of age in developing nations (National Health Commission Report). Protein, an important growth factor, is the most concentrated macronutrient of the human body and is important for sustaining life (Okuzumi and Fujii, 2000). Encouraging edible insect consumption can therefore be a sustainable way of preventing PEM and maintaining dietary protein adequacy in resource-poor populations.

Conclusion

The incorporation of edible insects into human and animal diets has a viable solution in solving protein deficiency, especially in the economically challenged areas. The high protein value of these insects makes them an ideal candidate as a viable and cheap substitute for traditional animal protein sources. Entomophagy-the act of eating insects-is not only beneficial from a nutritional standpoint but also environmentally advantageous. The ethnic groups' traditional diet that includes the intake of Orthopteran insects has the natural effect of less dependence on chemical pesticides by naturally controlling pests, thus creating ecological balance and less environmental pollution. With the nutritional, economic, and environmental benefits, edible Orthopterans present a significant potential to enhance food security. With a growing protein demand in the world, the contribution of insect protein is set to become more and more critical. Additional scientific studies, publicity, and documentation of indigenous knowledge regarding edible insects are required to promote their acceptance and mainstreaming in diets-especially among the poor and vulnerable groups that do not have access to costly animal-based foods.

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