Chapter 1
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Insects encompasses a variety of species with huge populations. Insects are extensively acknowledged for ecological services hosted to humankind. Amongst 1.4 million described animal species on earth one million species are insects. (Van Huis *et al* 2013). The role of insects as food has been depicted in histories of human nutrition. Important roles of edible insects in human nutrition have been observed around the world especially in Africa, Asia and Latin America (Bodenheimer 1951). Insect foods have more potential nutrients than other conventional foods. Although insects form a small part of the bulk of the diet, they are important in compensating for the general deficiency in animal proteins, fats, and calories that occurs among marginal societies (De Foliart 1975; DeFoliart 1992). The world population has been predicted to increase from 4 billion in 1980 to 12 billion in 2030, with an estimated 500 million peoples from developing countries who will get inadequate protein (Jana and Jana 2003). Continuous increase in human population and decreas in agricultural production have become major factors leading to inadequate protein diet in developing countries. This resulting protein deficiency is the root of ill health and death in many of these regions (Elemo *et al* 2011). Because of the presence of a wide variety of insect species the nutritional values offered by edible insects are highly variable. Nutritional values may vary based on the metamorphic stage of the insects, their diets and habitat. Studies conducted on the nutritional values of edible insects mostly convey that they provide satisfactory amounts of energy and protein, congregate amino acid requirements for humans, supply micronutrients such as iron, copper, zinc, magnesium, manganese and phosphorous, possesses elevated levels monounsaturated or polyunsaturated fatty acids, as well as furnish vitamins like riboflavin, pantothenic acid, biotin and folic acid. People around the globe consume insects as delicacy, as culture and mostly because they taste good. Normally insects that can be collected in huge figures as well as meet the organoleptic preferences of the consumers are selected and consumed as food (Dube *et al* 2013). Good amount of fats stored in the insect's body gives it a very luscious taste. Some insects like *Lethocerus indicus* have potent odorants that gives out a very pleasant and mouth

watering aroma. Insects are selected for food depending on its availability, taste, nutrient contents, traditions and culture. Assam in Northeastern part of India is a land with varied traditions and great cultural diversity. The land of Assam is the meeting ground of diverse cultures resided by a mixture of ethnic races such as Mongoloid, Indo-Burmese, Indo-Iranian and Aryan. Insect consumption is a traditional and cultural practice among many tribes of Northeast India. Among such tribes, the Bodo tribe of Assam is worth mentioning because entomophagy is an age old practice among them.

1.1 Entomophagy among the Bodos in Assam

The Bodos are an ethnic and linguistic aboriginal community and a major mongoloid tribe of Assam, Northeast India. They follow a unique tradition, culture, dress and exotic way of life. According to the census of India, the Bodos constitutes 3,151,047 of the total 31,205,576 populations of Assam and this tribe is categorized under Scheduled tribe by the Government of India. They are the major tribe in Bodoland territorial Area Districts (BTAD) in the state of Assam, India. It is in the foothills of Bhutan and shares international boundary with Bhutan. According to "The Kacharis" by Rev. Sidney Endle, the Bodos lived in scattered hamlets along the foothills of the Himalayas in Northern Bengal and Assam. So in Assam proper the Hindus called them Kacharis; in Bengal they are known as Meeches and their own name for their own name is Boro or Bodo. History reveals that they reached the Brahmaputra Valley via Tibet and settled in the eastern Himalayan ranges. They communicated in the Tibeto-Burman language (Endle 1911). The Bodos have close resemblances to the other mongoloid races of the world. The Bodos bear rich knowledge of ethno zoology and insect consumption is an age old practice among them. Edible insects form an important part of their diet and traditional culture as well. Varieties of insect species are found abundantly in regions dominated by the Bodo tribe so this tribe is actively indulged in entomophagy since time immemorial (Narzari and Sarmah 2015). Research based on entomophagy in Northeast India is scanty and therefore information on nutritional composition of insects is sparse. Identification and uses of insects in different fields among different tribes of Northeast India have been documented from a few studies. Various tribes in

Northeast India collect varieties of wild edible insects for food. This reflects that Northeast India is a habitat for diverse species of edible insects and it clearly portrays the necessity for their documentation. A great deal of what is known about the nutritional and health benefits of local insect species is based on hand down information from one generation to the other, with no scientific considerations among the Bodos. The traditional knowledge of entomophagy among the Bodos of Assam is rich but confined. To make the practice of entomophagy known and popularize the high nutritional value of edible insects its documentation is necessary. The utilization of insects among the Bodos ranges from edible to medicinal use. Selected insects are consumed as traditional food during festivals, a few for therapeutic purposes and a number of them as a constituent of remedial folk medicine. The use of insects in various rituals has been observed among the Bodos. Consumption of the larvae of *Oecophylla smaragdina* during 'Bwisagw' festival which is celebrated to welcome the spring season is an event when insects are consumed by the tribe. "Bilwgw Khanai' is a very popular ancient ritual almost forgotten at recent times practiced by the Bodos. In this ritual two friends are bonded in eternal friendship. At the end of this ritual the adults of *Oecophylla smaragdina* are sprinkled with flowers for recreation. Therapeutic uses of insects have been reported but reports from this study are even scantier than those of the edible insects available. A more precise study design is required for studying the therapeutic role of insects among the Bodos.

Assam is biogeographically situated in the Eastern Himalayan Biodiversity region and is one of the two Biodiversity hotspots of India characterized by diversity of ecological habitats harboring a very rich and fascinating diversity of insect fauna. Insects are particularly collected by rural communities by traditional ways. Edible insects are consumed raw, roasted, fried, smoked or blended into paste by adding garlic, ginger and lots of chilies which they commonly called as "bathwn". "Bathwn" has remained the favorite dish of many Bodos for many years. Bodos from rural areas are mainly dependent on forest for livelihoods and they have considerable understanding of their local biological resources. Edible insects with other wild products are often harvested from wild and consumed or sold in the

market by local people especially in rural areas. Most insects are regarded as pests to valuable forests trees and vegetations and most edible insects consumed by the Bodos of are pests. Grasshoppers are potent pests of paddy fields and tea gardens in Assam. Consuming pest species do not pose much threat to biodiversity instead it controls the population of pest insects as well as helps to reduce the use of pesticide and insecticides in cultivated areas. However insect harvesting methods that engages in manipulating the normal environmental conditions or the habitat of the insect prey, is likely to create wider ecological and environmental consequences which focus key areas for research (Choo 2008). Traditional activities related to insect utilization and commercialization are all locally based and enormously unrecognized. Westernization is rapidly eroding age old traditions especially in urban areas of Assam.

Insects rearing for the production of Eri and Muga cocoon are other ancient traditional practice among the Bodos. Many Bodo women are involved in this trade and it substantially contributes to their livelihoods. The larvae harvested out of the cocoon are sold for consumption in the market at a high rate as it is very much preferred by the local people. Insect rearing is a low capital investment option that offers entry even to the poorest section of people including women and children and in many cases gives dual income opportunities for the poor. Moreover; other benefits gained from insects as pollinating agents, pest biocontrol and waste biodegradation are also worth mentioning. Indigenous uses of insects in many regions among various ethnic communities have yet to be inspected. If the numerous uses of insects are not witnessed and documented immediately, it possibly may be behind schedule for as human habit changes and traditions go astray information on the role of insects in human traditions and culture will become irretrievable (Meyer-Rochow and Changkija 1997). Ideally, each country should have an established program to manage its own food resource data including as much indigenous food, considered an important national resource, as important as any other national compilation data. Food composition tables and nutrient databases are important resources of information for nutrition and health studies.

1.2 Wild Edible Insects

Food biodiversity is the new food associated challenge to combat food insecurity. To gratify this, acknowledgement of traditional and indigenous food systems of the indigenous people is a requisite. Little is known about how to extract full potentials of wild insects as food. In recent years, with growing areas of research on edible insects, these are preferred to other terrestrial meats due to increased awareness on protein composition. Besides being treated as a valuable source of proteins, insects are also enjoyed as a delicacy that is relished within their short terms of seasonal availability each year (Van Huis 2003: Egan *et al* 2014). Communities that can maintain their traditional food systems can in a better way conserve their local food specialties (FAO 2009). Data compilation on edible insects and their nutrients showed that majority of wild edible insects belongs to order Coleoptera, Lepidoptera, Hemiptera, Hymenoptera, Odonata and Orthoptera (Xiaoming *et al* 2010; Kuhnlein *et al* 2009; Van Huis *et al* 2013). Consumption pattern of the edible insect stages differs across the globe; the larvae stages are the most preferred stage of insect metamorphosis for consumption in many insects. Grasshoppers, termites and caterpillar are the most studied species for nutrition and human consumption. In Mexico; twenty five species of order orthoptera alone with a majority of grasshoppers were deemed as edible through a study (Ramos Elorduy *et al* 2012). Commencing on environmental point of views the production of insect biomass for human consumption is far superior and profitable to conventional cattle farming as cattle's on average consume ten times more matter than insects do to produce the same biomass (Begon *et al* 2006). Research on farming wild edible insects is still at its infancy, due time may be required for implementing modern tools and techniques for cultivating wild species for human consumption. Foraging for grasshoppers in cultivated paddy fields during summer in Assam is a common scenario in Bodo dominated rural areas. Some grasshoppers are harvested during the onset of cultivating season and some till the end of harvesting. A number of aquatic insects including bugs and water beetles are harvested by the Bodos from rivers and small streams. Variety of water beetles as water scavenger beetles and predacious diving beetles are sold and consumed in China, not as a result of poverty or of

protein deficiency but rather as a matter of tradition (Jach 2003). Caterpillar species such as mopane worm is a very popular insect food exploited by the indigenous people of South Africa and Zambia for food and income generation. Insect species are exploited as a renewable natural resource through traditional resource use practices and management in Africa and Zambia (Mbata *et al* 2002). Traditional Knowledge on ecology of wild edible insects assists the local insect harvesters to ensure sustainability of overexploitation of the consumable species which creates a balance in the environment. Primitive methods followed by indigenous people have permitted sustainable use of resources that leads to the survival of species as a fact 90% of the planet's germplasm is conserved by the indigenous people (Ramos Elorduy 2009; Posey 1990). *Rhynchophorus phoenicis* is an edible insect documented for its high nutritional value in Africa and is renowned as a pest of palm trees (Santos Oliveira *et al* 1976). Many edible insects of Assam that are yet to be identified are also pests to valuable trees as bamboo and palm. Cultivation of some unidentified species in rotten tree wood is widely practiced among the Bodos. Some wild edible insects especially species of order Hymenoptera build their nest in gardens and households. The nest of this species are marked and allowed to develop until they can be harvested by the owner of the house or garden. Many edible insects consumed in Thailand were similar to that consumed in Northeast India. Insects namely dung beetle (*Copris nevinsoni* Waterhouse), short tailed cricket (*Brachytrupes portentosus* Lichtenstein), june beetle (*Holotrichia* sp.), queen caste (*Oecophylla smaragdina* Fabricius), weaver ant (*Oecophylla smaragdina Fabricius*), termite (*Termes* sp.), longan stink bug (*Tessaratoma papillosa*), cicada (*Meimuna opalifera* Walker) were reported to be consumed in Thailand (Raksakantong 2010). Termites are the most studied species of edible insects. A review study on termite population consumed worldwide summarized that about 43 species of termites are used in human diet of which Africa had the highest record followed by Asia and America (Reis de Figueiredo *et al* 2015). Several species of edible insects as well are consumed by the Bodos. It has been ascertained that the value of edible insects as a source of food is widespread in many countries of the world. Insects are the largest group of organism on this planet. Combinations of

morphological and ecological characters are considered in identifying and classifying organisms. Ethnotaxonomy present a store of information about the characters in consideration to identify and classify an enormous variety of taxonomic groups. Yet, more research is needed to provide a comparison of the characters employed in the description of taxons for classifying insects elaborately (Zamudio *et al* 2012). Many popular edible insects in Assam are yet to be identified but have not been identified due to lack of proper taxonomic keys for insect identification and lack of entomological experts. In spite of this hurdles in identification researchers are still persuing research in this field with the hope of documenting as much of the traditional knowledge that remains embedded within the indigenous people thereby popularizing them. Whatever may be the situation wild edible insects will likely remain the favourite food for the consumer and a source of livelihood for the poor in insect food preferred regions.

1.3 Role of wild edible insects in human nutrition

Human beings uncontrolled utilization of natural resources often leads to the depletion of natural resources. The first step to overshadow this problem is to identify and classify as much of the species in a quick and sequential manner to tackle this problem. Identification and classification of wild edible insects can give us an idea of their conservational status. Common people for using it in communication locally name plants and animals. Varieties of species are named differently in various languages. An internationally accepted unique name is therefore given to each species in the scientific world. (Biosystematics Division, ARC – PPRI, South Africa 1996). Effort to scientifically identify the edible insects can help bridging the connection between tradition and science. Knowledge across numerous fields has highlighted the importance and remuneration to be gained from bridging traditional knowledge and approaches with current science. Similar cases are observed with wild edible insects. The seed of entomophagy was sown thousands of years back. In modern times it is sometimes ridiculed as old-fashioned and unhealthy. The best way to deal with this situation would be to consider the value of customary knowledge before discarding it too readily through scientific analysis. Scientific analysis can confirm the outstanding nutritional benefits of many

wild insects and their potentiality as food thereby widening their scope of acceptance. Through entomophagy nutritionally rich insects can provide a significant dietary factor in the poorer regions of the world. Malnutrition as well as scarcity of food resources has become one of the major problems of the world (Ramous Elourdy *et al* 1984). The nutritive value offered by insects is an attraction for many nutritionists, health workers and physicians (Xiaoming *et al* 2010). Nutrition scientists around the world are in quest for innovative means to feed the world's ever increasing population. Search for new food resources including identification and development of localized ethnic ones therefore continues. Reviving old traditions that are relevant to human nutrition is a key step in this field (Hodges 2005). On this ground; edible insects as a suitable source of protein is gaining attention. Edible insects are readymade sources of useful and essential nutrients that needs to be popularized and well exploited to overcome nutrient deficiency. Insects are food that can be obtained at low environmental cost and hence can contribute to livelihoods among the poor. Insufficiency of nutrients from daily intake of food can be seen in all populations, living in ample abundance as well as in dearth of food resources. Populations having easy access to abundant food resources possibly might suffer from certain nutrient deficiency due to ignorance in food habits which results into incomplete diets (Melo *et al* 2011). Convincing that we consume the standard recommended daily intake level of nutrients is the first move towards keeping a sound physic and mind (Mutalik *et al* 2011). This prophecy in case of edible insects can be improved through approval and receipt of current food technology standards to endorse that insects are safe and excellent food for human consumption. (FAO/WHO 1973). With the dawn of time scientific value of entomophagy has become well established. Numerous literatures documenting the undisputed nutritional value of many edible insects show that the nutrient profiles obtained from them are often very favourable in terms of dietary references values and daily requirements for normal human health and growth (Bukkens 2005; Ramous Elorduy 2005). Most edible insects have higher protein and fat content in comparison to Beef (Bukkens 2005). Edible insects are classified as Non Wood Forest Products (NWFP). Edible insects bear a lot of similar characteristics with

mushrooms for instance both of them are popular for their protein content and both of them are delicious food for the people. Human mortality through consumption of wild edible insect is rare but is not totally unheard (Blum 1994).

Westernization is the biggest threat to any local based culture and traditions at present times. Entomophagy is also a rich tradition and culture among indigenous tribes especially in developing countries. Negative view processed in the view of people regarding edible insects often masks their ecological benefits as well. Only a major change of attitude in westernized societies towards entomophagy can resolve these views. Getting entomophagy into westernized societies would be a very challenging task. People in developing countries may accept entomophagy in terms of its high protein quality but in western societies where protein is largely derived from domesticated animals' insects find no dignity and hence are regarded as disgust (Yen 2009; Van Huis *et al* 2013). Overall through nutritional analysis of edible insects and the comparision of their nutrients to other food standards as chicken, pork and beef.

1. 4 Rationale of the study

Knowledge on wild edible insects stored among the Bodos is an excessive combination of tradition and culture. The community is quite possessive about this rich traditional knowledge and hence information is leaked down through generations along with experiences of utilizing insects as a useful resource without misbalancing the environment. Insect gatherers mostly have poor access to scientific concepts. Combining traditional knowledge with modern research can lead to a better understanding of the wild insects' ecology and their values as food. Active participation of the local people in research specifically in fieldwork research will sow the seed of scientific research in them and make them understand of the valuable resources they possess. Research focused on the wild edible insects consumed by the Bodos of Assam will be valuable hence this attempt has been made to:

1. Document the rich traditional culture of entomophagy among the Bodos.
2. Contribute considerably to the local, national and global knowledge on wild edible insects as food.

3. Provide data on the beneficial, nutritive and safety aspects of insect food.
4. Endorse the significance of this local food resource.
5. Develop an understanding of the Wild edible insect resources and its sustainability.

1.5 Objectives

Specific objectives of the study were to:

1. Investigate the practice of entomophagy in Assam, India with reference to the Bodos of Assam through random surveys.
2. Collection and morphological identification of wild edible insects consumed as food by the Bodos.
3. Investigate the proximate composition of wild edible insects.
4. Investigate the mineral contents.
5. Investigate the compositions of non essential and essential individual amino acids and determination of fatty acid profiles.
6. Biochemical evaluation of protein quality and toxicity in selected insects through animal experiments on male albino rats.

a) Protein quality – Protein Efficiency ratio (PER), Net Protein Utilization (NPU), Biological Value (BV), Net Protein Ratio (NPR), True Digestibility (TD).
b) Organ weight - Liver, Spleen, Kidney, Testis, Heart and Brain
c) Liver enzymes - Aspartate Serum transferase (AST), Alanine Amino Transferase (ALT), Alkaline Phosphatase (ALP), Gamma Glutamyl Transferase (GGT).
d) Serum cholesterol - Total cholesterol, Triglycerides, High Density Lipoproteins (HDL) and Low Density lipoproteins (LDL),
e) Haematological parameters - Whole blood count.
f) Renal function test – Urea and Blood Urea Nitrogen (BUN).
g) Histological examinations of liver, spleen, kidney and testis.