DIVERSITY AND NUTRITIONAL STATUS OF CERTAIN EDIBLE INSECTS IN NAGALAND

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BY

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DEDICATION

I dedicate this work to my loving mum Late MrsImolemlaLongchar
my Inspiration and my Anchor

and my loving dad Mr. NgangnenchibaPongener
my source of Wisdom and Strength.

Their Love, Sacrifice, and Vision have brought me this far.

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Certificate

This is to certify that the thesis entitled "Diversity and Nutritional status of Certain Edible Insects in Nagaland" incorporates the results of the original findings carried out by **Mrs. AnunglaPongener** under my guidance and supervision. She is a registered Research Scholar (Regd.No. 755/2017) of the Department and has fulfilled all the requirements of Ph.D. regulations of Nagaland University for the submission of her thesis.

The work is original and neither the thesis nor any part of it has been submitted elsewhere for the award of any degree or distinction. The thesis is therefore, forwarded for adjudication and consideration for the award of degree of Doctor of Philosophy in Zoology under Nagaland University.

Dated: ______________

Place: Lumami

Head **Department of Zoology**	**Prof. BendangAo** **Supervisor**	**Prof. Sarat Chandra Yenisetti** **Co-supervisor**

DECLARATION

I do hereby declare that, except for references to works of other researchers and biochemical processes which have duly been cited, this thesis consists entirely of research conducted by me at the Department of Zoology, Nagaland University, Lumami, Zunheboto, Nagaland, India. I further declare that no part of this work has been presented for another degree elsewhere.

AnunglaPongener	**……………………**	**……………………**
Regd.no.755/2017	**Signature**	**Date**

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(AnunglaPongener)

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CHAPTERONE

INTRODUCTIONAND

REVIEWOFLITERATURE

The consumption of insects as food is termed “Entomophagy”. This term is derived from two Greek words, “entomos” which means insects, and “phagein” which means to eat. Entomophagy is reported in many countries of the world but a greater amount of research work and literature are recorded from parts of Asia, Africa and Latin America. The practice of eating edible insects was reported as early as 7000 years ago (Ramos-Elorduy, 2009) and at present about 1400 insect species of the world are reported as edible by Van Huis (2003a), while Mitsuhashi (2016) enumerated 2,141 species of edible insects of the world. Jongema(2017) listed about 2000 edible insect species from around 113 countries. Evaluation of the nutritional composition of about 1900 edible insects were also recorded (Bukkens, 1997; Cerritos, 2009). Around 80% of countries of the world consume around 1000 to 2000 species of insects as a rich source of fibre and protein. Countries that eat the most insects are Mexico, Central America, Brazil, South America, Ghana, New Zealand, Thailand, China and Netherlands (Chakravorty, 2014). Most of the insects are collected from the wild though some species are farmed on a large scale (Van Huis, 2019).

The production of animal protein from livestock, poultry, and fish are under immense pressure as the world population is rapidly increasing with demand for meat products expected to increase by more than 75% Godfray*et al.,* 2010; Gerland*et al*., 2014; FAO, 2015; Herrero *et al*., 2015). Conventional animal protein sources constitute 15% of global human diet requirement whilst 80% of agricultural land is used as pasture and one-third of all cereal production is used as animal fodder (Mottet*et al.*, 2017) which exerts enormous stress on the availability of resources in nature. Consequently, people are enduring protein undernourishment and seeking alternative resources. Research works on insects’ nutrients and minerals required by humans and animals (Van Huis *et al*., 2013a), are comparable to those of other conventional meat sources (Rumpold& Schluter, 2013a). Mean estimates show energy levels given by insects to be around 400 - 500 kcal per 100 g of dry matter, making it comparable with other energy sources (Payne *et al.,* 2016). Entomophagyis suggested as the alternative protein source (Sogari*et al.,* 2019)and as the answer to solving the requirements of nutrients especially protein, fats, vitamins and minerals and as an attainable solution to address the problem of famine (Van Huis, 2013; Tang *et al.,* 2019).Smith*et al.,*(2021) also explored an environmentally sensitive alternative in Africa and Asia to improve global nutrition by consumption of insects regionally appropriate and farmable species on total nutrient intake and population-wide risk of deficiency for specific nutrients of concern ie. protein, zinc, iron, and vitamins.

Despite the consumption of various insects by the local populace of Nagaland, no scientific study or documentation has been carried out. Other aspects like environment concerns due to entomophagy also need to be addressed.

Entomologists and nutritionists worldwide are fast redeveloping interest in the nutritional values of the various edible insects and their economic importance. However, record of investigation and documentation of these insects from this part of the country are not found, or if there are, very scarce. A study such as this is highly relevant as it aims to document some edible insects and assess their nutritional values. This will benefit the community, which is almost completely rural and hope to find non-conventional nutritional source and also hope to increase the income of the rural families who survive on subsistence farming.

The hypothesis for the present research is: insects are good sources of food for the tribals in Nagaland. The research will undertake the identification of common edible insects consumed by indigenous people of Nagaland – Angami, Ao and Sumi tribes from Dimapur, Kohima, Mokokchung and Zunheboto districts of Nagaland. Their nutritional and therapeutic values, along with other potential aspects will be studied. This work hopes to contribute towards ameliorating the nutritional and economic needs of the common people apart from enhancing the nutritional requirements of the common people.

Insects as Food in the world

Many insects found worldwide like Lepidopterans, Orthopterans, Isopterans and Hymenopterans are all regarded as common food sources in many areas (Van Huis *et al.*, 2013a). Entomophagy is observed to be prevalent in tropical and subtropical regions where the climatic condition is warm and moist (Jongema, 2017). Insects have always been a part of their diets and supplements the diets of approximately 2 billion people in tropical and sub - tropical countries namely, Zimbabwe, Mexico, Thailand and many other well-known insect-eating regions, and in more temperate regions such as Japan, and parts of China (Pal and Roy *et al.*,2014). In these countries, insects are common and are popularly eaten for their nutritional and economical benefits. In Thailand, about 164 insect species are sold in markets and supermarkets of Bangkok (Yhoung-Aree&Viwatpanich, 2005). In Southern Africa, a caterpillar called the 'mopane worm' is the most sought after edible insect which is collected and sold in bulk (Kozanayi& Frost, 2002). In regions of Central Africa, market value of edible insects are higher than other food protein sources and it is reported that at times, up to 50% of dietary protein comes from insects (Paoletti&Dreon 2005; Raubenheimer& Rothman 2011).

Favoured edible insects are the ones that are found in large quantities and considerably sized (Bukkens, 1997). Tropical insects which are generally large in size with stable life history, have the advantage of ease of harvesting (Gaston &Chown, 1999; Janzen &Schoener, 1968). Jongema (2017) categorised popularity of insects based on their sizes, viz, beetles (coleoptera, 31%), caterpillars (lepidoptera, 18%), bees, wasps and ants (hymenoptera, 14%), grasshoppers, locusts and crickets (orthoptera, 13%), cicadas, leafhoppers, planthoppers, scale insects and true bugs (hemiptera, 10%), termites (isoptera, 3%), dragonflies (odonata, 3%), and flies (diptera, 2%). Insects are consumed at various stages and with numerous methods of preparation including raw, fried, boiled, roasted or ground. The immature forms of insects (pupae and larvae) are preferred for their abundant amino acids and fatty acids, which not only ensure the nutritional value, but also provide a unique and splendid flavor**.**

Bioprospecting

Bioprospecting of edible insects as human food and medicine that are based on the knowledge of indigenous people who have been practicing the art and have this embedded in their belief system and culture is an important aspect of entomophagy and may promote economic opportunities e.g., new drugs, crops, industrial products (Srivastava, 2017). Yen (2015) has suggested that an exchange of information of traditional knowledge and modern technologies should open opportunity and bring a solution to food scarcity in underdeveloped countries (Yen, 2015). With the degradation of natural resources, rapid population growth, and increasing influence of 'westernization', the traditional wisdom of entomophagy and entomotherapy is at risk of being lost. There is thus an urgent need to record the role insects play as a component of local diets and folk remedies and to assess insect's biodiversity in the light of these uses. In addition, constraints and prospects in using insect resources should be discussed and analyzed as well that could be helpful for other countries to promote the utilization of insect resources in near future (Rongping *et al.*, 2010*)*.

Alternative source of food for humans and livestock

Conventional animal protein sources like beef, pork, and chicken constitute15% of global human diet requirement whilst 80%of agricultural land is used as pasture and one-third of all cereal production is used as animal fodder (Mottet*et al.*,2017). This insufficient production of protein products could subsequently lead to alternative sources like insect farming with more advanced farming techniques, which are presently unavailable (Smetana *et al.,* 2015). Edible insects show notable potential as an environmentally sustainable choice for future food network and is considered as a good alternative to conventional livestock production even in western countries (Van Huis, 2013c). Countries like China, Thailand, South Korea, Oceania and Africa have taken the lead in the use of insects as alternative food protein and feed sources (Kim *et al.* 2019).

Moreover, the world market has recognized the use of insect protein as an alternative ingredient in livestock feed (Rumpold& Schluter, 2013b) as its utilization emit low levels of greenhouse gases, requires minimal usage of land and water with a high conversion efficiency of feed into insect biomass: 1 kg of live animal weight of crickets requires 1.7 kg of feed, as compared to 2.5 kg for chicken, 5 kg for pork, and 10 kg for beef (Smil, 2002; Vantomme*et al.,* 2012; Van Huis,2013; Halloran *et al.,* 2014; Dicke, 2018).

Insect production systems can decrease the dependence on conventional feed products like soymeal, fishmeal, and grains, (Veldkamp*et al.,* 2012) whilst recycling back into the food chain valuable ingredients from organic waste materials from agriculture, food industries and other sectors (Smith & Barnes, 2015) thereby reducing the environmental footprint of livestock production (Van Huis *et al.,* 2015). Thus, insects plays an important role in human nutrition and can become a part of a sustainable solution having great potential to work towards the sustainable development goals (SDGs) (Sirithon and Pornpisanu, 2008; Azagoh*et al*., 2015) that can be realized with mass production of insects with high grade quality with reasonable cost effective investment (Marone, 2016 ; Veldkamp*et al.,* 2012). Rearing and harvesting insects in small scale can even uplift the socio-economic status of women (Deiner*et al.,* 2009; Halloran &Vantomme, 2013; FAO, 2014; Halloran *et al.,* 2016).

Nutrient content

Hlongwane *et al.,* (2020) reported the highest protein (range: 20–80%) and fat (range: 10–50%) content in Lepidopterans, and the highest carbohydrates (range: 7–54%) content was reported in Coleopterans. Kemsawasd(2022) also researched on the nutritive values, health-promoting properties (antioxidant, anti-inflammatory, anti-diabetic and anti-obesity), safety, allergenicity as well as the potential hazards and risks of insects for human consumption and concluded that it is safe for daily intake as a healthy alternative diet due to their high protein content and health-promoting properties. The evaluation of nutrients of species recorded were mainly focused on general ranges (Rumpold& Schlüter (2013a), further evaluation within species, different stages of development and critical determinants like diet, environmental conditions should be considered for the nutritional composition (Bukkens 1997; Ramos-Elorduy*et al*., 2002; Oonincx&Dierenfeld, 2011; Finke &Oonincx, 2014).

Edible insects contain protein comprising between 30% and 65% of the total dry matter (Bellucco*et al.*, 2013). With the exception of tryptophan and lysine being limited, 46% to 96% of all amino acids are present in insect protein (Bukkens, 1997; Ramos-Elorduy, *et al.* 1997), and digestibility is estimated to be between 77% and 98% for most species (Ramos-Elorduy*et al*., 1997). Analysis of more than 100 edible insects has shown 35–50% of all kinds of amino acid, which is close to the amino acid model proposed by the Food and Agricultural Organization of the WHO (2007). Insects' protein contents are considered comparable to good plant protein (Finke, 2004). The protein content of some insects is also higher than that of chicken eggs, meat and fowl (Ramos-Elorduy& Pino, 1989; DeFoliart, 1992).

Insect fat contains both unsaturated and polyunsaturated fats. The composition of unsaturated fatty acid is similar to that of chicken and white fish but more in case of polyunsaturated fatty acids (PUFAs) (Rumpold& Schlüter, 2013a). Overall fat content among insects ranges from 7 to 77 g/100 g of dry weight, with larvae generally having a higher overall content than adults (Ramos-Elorduy*et al.*, 1997). Highest levels of fat can be found in insect larvae and some soft-bodied adult insects, such as termites, and lower levels of fat in insects with a hard exoskeleton, such as crickets and grasshoppers (Bukkens, 1997).

Edible insects contain a significant amount of fibre mostly in the form of insoluble chitin present mainly in their exoskeleton (Finke, 2007; Van Huis *et al*., 2013a). Chitin is an indigestible fibre (Paoletti*et al*., 2007). HoweverLee *et al*., (2008), observed that chitin was antivirally active against pathogenic bacteria, viruses and tumorigenesis. A derivative of chitin called chitosan is suggested to have properties that could improve immune response and reduce allergic reactions in people (Goodman, 1989; Muzzarelli, 2010).

Micronutrients

Insects contain vitamins and micronutrients of varying levels. They contain vitamins such as A, B1–12, C, D, E, K, which will boosts normal growth and health (De Foliart,1991; Lu *et al.*, 1992; Chen & Feng, 1999; Kourimska&Adamkova, 2016). Larvae of insects are proved to contain essential vitamins like in B1, B2 and B6 (Rumpold& Schluter 2013a), bee pupa contains rich vitamins A and D and the red palm weevil, *Rhynchophorusferrugineus* is considered to be a good source of vitamin E (Finke 2005; Bukkens&Paoletti, 2005). The content of vitamin A ranges from 3 to 273 μg/100 g dry matter over insect species (Christensen *et al.*, 2006a).

Analysis of mineral elements showed that edible insects are rich in iron, magnesium, manganese, phosphorous, potassium, selenium, sodium and zinc (Rumpold& Schluter 2013a). Most insects contain a minimal amount of calcium (less than 100 mg/g of DM), with the exception of larvae of house flies and adult melon bugs. Most edible insects are particularly abundant in iron, the content of which is usually higher than that in fresh beef. The content of iron ranges from 18 to 1562 mg/100 g dry matter in insect species, with lower levels in ants, intermediate levels in termites and the higher levels in crickets (Christensen *et al.,* 2006a). The content of potassium in pupae of *Polybia occidentalis* is 54 mg/100 g and in all stages of *Apis mellifera* 1500 mg/100 g. The content of magnesium in *Macrotermesnigeriensis* was 6.1 mg/100g while in *Euschistusegglestoni* it was 1910 mg/100 g. Crickets have been reported to contain zinc in the range of 8-25 mg/100 g dry matter (Christensen *et al.*, 2006) and ants, termites and crickets to contain calcium in the range of 33–341 mg/100 g dry matter, with crickets having the highest levels (Oliveira *et al.,* 1976; Van Huis, 2003b; Finke, 2004).

Cross reactivity/sensitivity with insect consumption

Consumption of insects are known to induce allergic reactions in susceptible individuals, caused by the presence of tropomyosin, arginine kinase, glyceraldehydes 3-phosphate dehydrogenase and haemocyanin (Belluco, *et al.,* 2013; Jensen-Jarolim*et al.,* 2015; Srinroch*et al.,*2015 ; Ribeiro *et al*., 2017 ; Kemsawasd*et al.,*2022). Research works on cross reactivity/sensitivity with insects in individuals with known arthropod allergies has indicated that all patients demonstrated allergic reactions to direct consumption of insects and also to frequent exposure to insects (Jensen-Jarolim*et al.,* 2015; Ribeiro *et al.,* 2017). Taylor and Wang (2017) also reported natives in Isan region of Thailand that experienced an adverse reaction after insect consumption. Scientific attention must be paid to the cross-reactions among allergens found within some insect species, microbiological hazards and presence of anti-nutritional substances (Baiano, 2020). The allergy aspect of entomophagy is a serious issue and has the potential to adversely affect the future of entomophagy, especially in introducing the concept to western cultures.

Therapeutic uses

The therapeutic use of insects and insect-derived products is known as entomotherapy. According to Costa-Neto (1999a), since medical systems are organized as cultural systems, the use of insect-based medicines should be viewed from a cultural perspective. From time immemorial insects have been attributed therapeutic and healing properties in many cultures (Costa-Neto, 2002; Neto *et al.*, 2009; Kushwah*et al* , 2017; Raheem *et al*., 2018).

Entomotherapy is widely practised in China (Kritsky, 1987). About 300 kinds of insects belonging to 70 genera, 63 families and 14 orders have been recorded which can be used as medicines in traditional Chinese medical prescriptions (Gunter, 1973; Boyle, 1992; Zimian*et al*., 1997; Jiang, 1999; Li, 2004; Liu *et al*., 2004; Chen *et al*., 2009; Bellucco*et al*., 2013; Nongonierma and FitzGerald, 2017). In Korea, Pemberton (1999) and Kim *et al.* (2002) reported about 220 insect species for use in cases of ailments like gonorrhoea, hearing problems, impotence, stroke, lung troubles and arthritis. Fairmaire (1893) and Costa-Neto (1998, 1999, 2002) have extensively studied the use of insects in the treatment of various ailments like sore throat, dog and snake bites, asthma, arthritis, tuberculosis, sexual impotence etc. in Brazil. Similarly Ramos-Elorduy& Mott-Florac (2000) and Ramos-Elorduy (2001) enumerated the usage of 210 insect species used in the treatment of a wide range of diseases in Mexico, while Adriaeus (1951), Van Huis (1996), Fasoranti (1997) and Van der Waal (1999) have documented the use of insects for medicinal purposes in Africa.

In Europe and other Western countries, entomophagy as well as entomotherapy is quite new (Bodenheimer, 1951; Van Huis, 2013; CaparrosMegido*et al.*, 2014; Mlcek*et al*, 2014). Western society generally regards these insects as an emergent food source, and identifies consuming insects with low status and poverty (MacClancy, *et al.*, 2007; Sogari, 2015).

In India, several workers have described the local uses of insect-based remedies to treat common fever, scabies, epilepsy, violent headaches, bronchitis, hemorrhage, and dog bite, wounds etc (Tango, 1994; Azmi & Ali, 1998; Oudhia, 2002; Singh *et al*., 1998). Similarly, Sharma & Banu (2019) reported on the therapeutic values of edible insects by tribes and ethnic groups of Madhya Pradesh, Tamil Nadu, Kerala, Karnataka, Odisha, Mizoram, Manipur, Meghalaya, Nagaland, Assam, Arunachal Pradesh, Maharastra. Other notable works on entomotherapy in tribal populations in the North East India are by Meyer-Rochow&Changkija (1997), Meyer-Rochow (2004), Singh *et al*. (2007), Kato & Gopi (2009), Shantibala*et al*. (2012), Shantibala*et al*. (2014), Chakraborty *et al.* (2011). Few therapeutic uses of insects have also been reported from Nagaland (Senthilkumar*et al.,* 2008; Pongener*et al.,* 2019; Mozhui*et al*, 2021).

Researchers have worked on chemicals secreted by edible insects for self-defense for the purpose of producing antibacterial and anticancer drugs. Some examples are: pierisin, a protein purified from pupa of cabbage butterfly, exhibits cytotoxic effects against human gastric cancer; Cecropin has been reported to be cytotoxic against mammalian lymphoma and leukemia cells (Srivastava & Gupta, 2009).Traditional uses of insects as medicine have triggered multiple studies aiming to empirically and chemically determine the properties of edible insects such as the identification of antioxidant namely 2,2′azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) and 2,2-diphenyl-1-picrylhydrazyl and antidiabetic properties, as well as the ability to inhibit angiotensin converting enzyme (ACE) (Vercruysse*et al*., 2009; de Castro *et al*., 2018; Nongonierma& FitzGerald, 2017).

Potential as mini livestock

Mini livestock implies small animals under 20 kg that include both vertebrates and invertebrates, both terrestrial or aquatic by nature like mammals, amphibians, reptiles or invertebrates, including insects (Hardouin, 1995; Paoletti, 2005). Tiencheu&Womeni (2017) mentionedthe potential of insects as mini livestock. Having considered the immense diversity of nutritional, ecological and economic advantages of edible insects over conventional livestock, edible insects as minilivestock should be given importance as a means to bring about livelihood. This will help improve their availability through development of economically achievable methods of mass-rearing rearable species (Defoliart, 1995). The advantages of rearing insect is that it can be easily collected from nature and farmed with manageable methods and minimal resources requiring very less space and investment and have a fast turnover of biomass quick growth rate (Van Huis *et al.*, 2013b). Using insects can potentially solve problems related to the conventional food-supply chain, including global water, land, and energy deficits (Tae-Kyung Kim *et al.*, 2019).Insects can also be reared in constructed industrial facilities (Oonincx& de Boer, 2012). Insect farming is of great advantages as compared to livestock production as it requires less land and water, less carbon footprints, high feed conversion efficiencies, easy conversion of unused organic products into high quality food or feed (Oonincx*et al*., 2010).

Farming cricket as mini livestock has been successfully implemented in African Republic, Kenya, Uganda, China, Japan, Lao People's Democratic Republic, Thailand, Vietnam, Netherlands and Finland (Raheem *et al*., 2018). Magara et al., (2021) reported over 60 cricket species are used as food in 49 countries globally. Nutritionally, crickets contain proteins, ranging from 55 to 73%, and lipids ranging from 4.30 to 33.44% of dry matter. Dai*et al*., (2022)also reported the benefit of rearing Oriental mole cricket (*Gryllotalpa orientalis*) as an alternative source of income in China. Farmers could earn an estimated gross income ranging from US dollars 1,118 to 9,176 per annum, representing a stable and considerable revenue source. Thus there is the need to encourage rearing and farming techniques that will produce high quality edible insects in other parts of the world. The expert consultation meeting on assessing the potential of insects as food and feed in assuring food security have suggested rearing of insects as the future sustainable source of alternative food (Van Huis *et al*., 2013b).

Food security

Food security is a pressing concern today.30% of land is already in use for agro-purposes, out of which 70% is used for macro-livestock production. This has a turnover of 58 million tones of animal protein/year while requiring an input of 77 million tones of plant resources (FAO, 2015). Most of these outputs benefits mostly the developed countries (Premalatha*et al.,* 2011). With the need for affordable and sustainable protein increasing (Raheem *et al.,* 2018), and availability of agricultural land declining, there is a pressing demand to explore edible insects as the alternative source of protein (Van Huis, 2015). A number of research works have been conducted to maximize the insects' food value especially protein by comparing with other traditional protein sources (Tang *et al.*, 2019). Van Huis (2019) observed the industrial sector is increasingly engaged in rearing, processing and marketing of edible insects. Though the growth of insect industry is somewhat restricted, many innovations concerning insect processing have been patented (Melgar-Lalanne *et al.*, 2019). In order to maintain the safety, nutritional and sensory quality of processed insects protein, the use of commercial processing methods need to be rendered (Chuanhui *et al.*, 2010 ; Melgar-Lalanne *et al*., 2019; Calzada-Luna *et al.*, 2020). For insect processing, common methods practiced include lipid extraction, enzymatic proteolysis, commercial thermal processing (e.g. blanching, pasteurization, and commercial sterilization), Low-temperature processing (refrigeration and freezing), dehydration, and fermentation technology (Klunder*et al.*, 2012; House, 2016; Lesnik, 2018; Liceaga, 2021). Governments of each country can play an important role by introducing its own substantive and procedural rules for this purpose that will ensure food and feed safety (FAO, 2014; Lahteenmaki-

Uutela*et al*., 2020; Kroger *et al.*, 2022). A recent regulation of the European Union mandates that insect-based food should be shown to have been safely consumed for longer than twenty five years in third countries (Lewis, 2015). Considering the huge amount of insect biomass required to replace commonly used protein-rich ingredients, inter-cooperation of government, industrial sector, media, chefs and scholars will be a key ingredient for its success(Van Huis&Vantomme, 2014).

Environment sustainabilityand insects

Sustainability can be defined as "practices that fulfill societal needs for healthy lives when all costs and benefits are considered (Tilman *et al*., 2002)." One could say that sustainable systems should be "socially supportive" and "commercially competitive" (Gold, 2016). In tropical countries, insects are traditionally harvested from nature and contribute to food security and livelihoods of the poor (Vantomme*et al.*, 2004; Kalaba*et al*., 2013; Lindsey *et al*., 2013). However, since harvesting is mostly seasonal, with increase in human activity and high demand, this resource is overexploited and threatened (Ramos-Elorduy, 2006). About 2,100 tropic insect species consumed by humans are harvested in the wild (Jongema, 2017), and utilizing this food resource requires safeguarding their environment. Unregulated or rampant utilization of this resource could cause a local population decline or even species extinction or "anthropocene defaunation" (Van Vliet *et al*., 2016). In Australia, honey ants and wood grubs are consume by the aboriginals (Yen, 2005; Yen *et al.*, 2016), but with increasing exploitation by the indigenous population for eco-tourism and putting their foods in restaurants menus, threatened their availability (Yen, 2009). In the freshwater lake of Loktak, Manipur, India, 31 aquatic edible insect species have been recorded, but declined water quality with continuous input of pesticide and fertilisers has led to reduction in aquatic insects. The disappearance of the much favoured giant water bug *Lethocerus indicus* has impacted both on the lake ecosystem and the food tradition of the people living there (Samom, 2016).

But sustainable insect harvesting practices have also been witnessed. For example, in regions of Botswana and South Africa, the mopane caterpillar, *Imbrasiabelina* (mopane caterpillar) decreased in population due to overexploitation. This was mitigated after some communities started restricting harvesting to certain time periods and imposing a fee on harvesters (Gondo *et al.*, 2010). This approach of natural resource management initiated by the community is commendable and could do well to be institutionalized (Akpalu*et al.*, 2009). In Cambodia, the oriental ground cricket, *Teleogryllustestaceus* are farmed by utilizing resources which could have gone wasted like leaves from taro and cashew and cassava tops and several weeds, in particular *Cleome rutidosperma*. It is successfully grown on unused low-value organic resources thus converting it into high-value proteins (Megido*et al.*, 2016; Miech*et al*., 2016). Harvesting insects from agro-ecosystems can also bring about environmental sustainability and it also checks pest resurgence or secondary outbreaks as was reported of locusts and grasshoppers from Latin America, Africa, and Asia (Chen. *et al*., 1998; Hanboonsong, 2010).

In the 1960s and 1970s the Korean Government had mandated the use of insecticide in rice fields. But, this also had an adverse effect on the grasshopper of the genus *Oxya* which is a part of the traditional diet. Due to this reason the policy was reverted and in the 1980s there was a surge in its population (Pemberton 1994). Also in Japan, the population of thisgrasshopper which is a popularly consumed is in decline due to increased use of pesticide (Payne, 2015). The Asian weaver ant *Oecophyllasmaragdina* which is higlyfavoured in Laos PDR and Thailand also functions as a pest control agent of crops and mango orchards. Their farming has dual sustainable benefits - obtaining a food source and pest insects control by ecofriendly means (Offenberg&Wiwatwitaya, 2009).

Entomophagy in India

A perusal of the literature shows a substantial information on entomophagy in India. As early as 1813, the consumption of termites as food by tribal people of Mysore and other areas in Karnataka was reported (Forbes, 1813; Rajan, 1987), and insect larva by Roy and Rao (1957). Evaluation of food values of locust *Schistocerca gregaria* which is use both as human food and fertilizer in India was conducted by Das (1945)

Varshney (1997) has listed 589 families and 51450 species of insects consumed in India. Hazarika *et al.*, (2020) listed a total of 22 species of edible insects belonging to fifteen families and eight orders from different habitat types. Out of these 22 species, Orthopterans showed a maximum number of eight species followed by Hymenoptera (four), Hempitera (three), Lepidoptera (two), Blattodea (two) and one species each from Coleoptera, Odonata, and Mantodea. India could become a potential land for insect bio-resource to be utilized for their vast potential and support to revive the still existing entomophagy and some entomophagic practices that should benefit the people and the nation as a whole (Chakravorty*et al.*, 2013).

Entomophagy in North East India and Nagaland

The ethnic people of India practice entomophagy as part of their culture (Chakravorty, 2014). He listed the consumption of Coleoptera species as highest (34%) followed by Orthoptera (24%), Hemiptera (17%), Hymanoptera (10%), Odonate (8%), Lepidoptera (4%), Isoptera (2%) and the least was Ephemeroptera (1%). There is a vast range of insects in India and more than 300 species of insects are consumed by tribal communities in north-eastern states and the southern belts of India. Coleoptera, Hemiptera, Orthoptera, Hymenoptera, and Isoptera are eaten in Assam and Arunachal Pradesh, Manipur, Nagaland, Kerala and Meghalaya respectively (Chakravorty*et al*, 2011a). Food insects are chosen by members of various tribes according to their traditional beliefs, taste, regional and seasonal availability of the edible insects. Comparatively this practice is much lower (constituting about one to five insect species) among the ethnic people of Kerala, Tamil Nadu, Madhya Pradesh, Odisha of South and Central part of India. Therefore, there is an urgent need to focus on the studies related to entomophagy, and to promote entomophagy/ethno-entomological research to document all edible insects and their mode of consumption by various tribal communities in India.Chakravorty*et al.,* (2011b)listed the edible and therapeutic insects used in Arunachal Pradesh (N.E. India) by two tribal societies (i.e., the Nyishi of East Kameng and Galo of West Siang). At least 81 species of local insects, belonging to 26 families and five orders of insects, namely Coleoptera (24 species), Orthoptera (17 species), Hemiptera (16 species), Hymenoptera (15 species) and Odonata (19 species), are being used as food among members of these two indigenous societies. Langthasa*et al.,* (2017) reported theutilisation of weaver ants (*Oecophyllasmaragdina)* among the ethnic tribes of the hill district of North-eastern India viz. Dima Hasao district for varied purposes the most notable being for food, medicine and livelihood.

In North East India more than 200 species of edible insects were documented, out of which 92 different species are consumed in Nagaland, 69 species in Manipur, 67 species in Assam, 65 species in Arunachal Pradesh and few insect species in Meghalaya, Mizoram and Tripura (Thangjam*et al.*, 2020). In Assam 22 species of edible insects from 15 families and 8 orders have been recorded (Choudhary *et al.,* 2020). In Arunachal Pradesh, 81 species of local insects, belonging to 26 families and five orders are consumed as food (Chakravorty*et al*., 2011b). In Nagaland, Mozhui *et al.,* (2020) have documented a total of 106 insect species representing 32 families and 9 orders that are taken as food. Pongener *et al.,* (2019) reported on the traditional knowledge of entomophagy from Mokokchung district of Nagaland.

Thus, as is evident from the literature review, there is a need to shift focus on sustainable insect-food promotion and utilization.

CHAPTERTWO

MATERIALSANDMETHODS

Study area and the people

The study aimed to identify and assess the nutritional value of insects consumed as food by the Angami, Ao and Sumi tribes of Nagaland. Hence, the districts of Dimapur, Kohima, Mokokchung and Zunheboto were selected for the study. Figure 1A is the map of Nagaland higlighting the four study areas (districts) ie Dimapur, Kohima, Mokokchung and Zunheboto. (Courtesy: Nagaland GIS & Remote Sensing Centre, Kohima : 797001, India)

Mokokchung district is bounded in the north by the state of Assam; the districts of Longleng and Tuensang in the east; the district of Zunheboto in the south and the district of Wokha in the west. Mokokchung district lies approximately within 94°17'22.32" to 94°45'30.30" east longitude and 26°10'40.65" to 26°45'50.32" north latitude (Coordinates:

Nagaland GIS & Remote Sensing Centre, India). It has an area of about 1,615 sq. km and a population of about 193171 individuals according to the 2011 census. It is predominantly inhabited by the Ao Naga tribe. It has an average rainfall of 2039 mm per annum. The climate is moderate and pleasant throughout the year with average temperatures ranging from a maximum of 23.1°C in the summer to a minimum of 11.7°C in the winter (Census of India, 2011, District Census Handbook – Mokokchung; Mokokchung District Human Development Report, Department of Planning and Coordination, Government of Nagaland, 2013; Climate-data, 2019).

Zunheboto district is bounded in the north by Mokokchung district; in the east by Tuensang and Kiphire districts; the districts of Phek and Kohima in the south and the district of Wokha in the west. Zunheboto district lies approximately within from 94°12'38.946" to 94°42'47.976" east longitude and 26°17'37.223" to 25°43'51.26" north latitude. It has an area of about 1,255 sq. km and a population of about 140757 individuals according to the 2011 census. It is predominantly inhabited by the Sumi Naga tribe. It has an average rainfall of 1868 mm per annum. The climate is warm and temperate with average temperatures ranging from a maximum of 20.3°C in the summer to a minimum of 9.3°C in the winter (Census of India, 2011, District Census Handbook – Zunheboto; District Human Development Report, Government of Nagaland – Zunheboto, 2014; Climate-data, 2019).

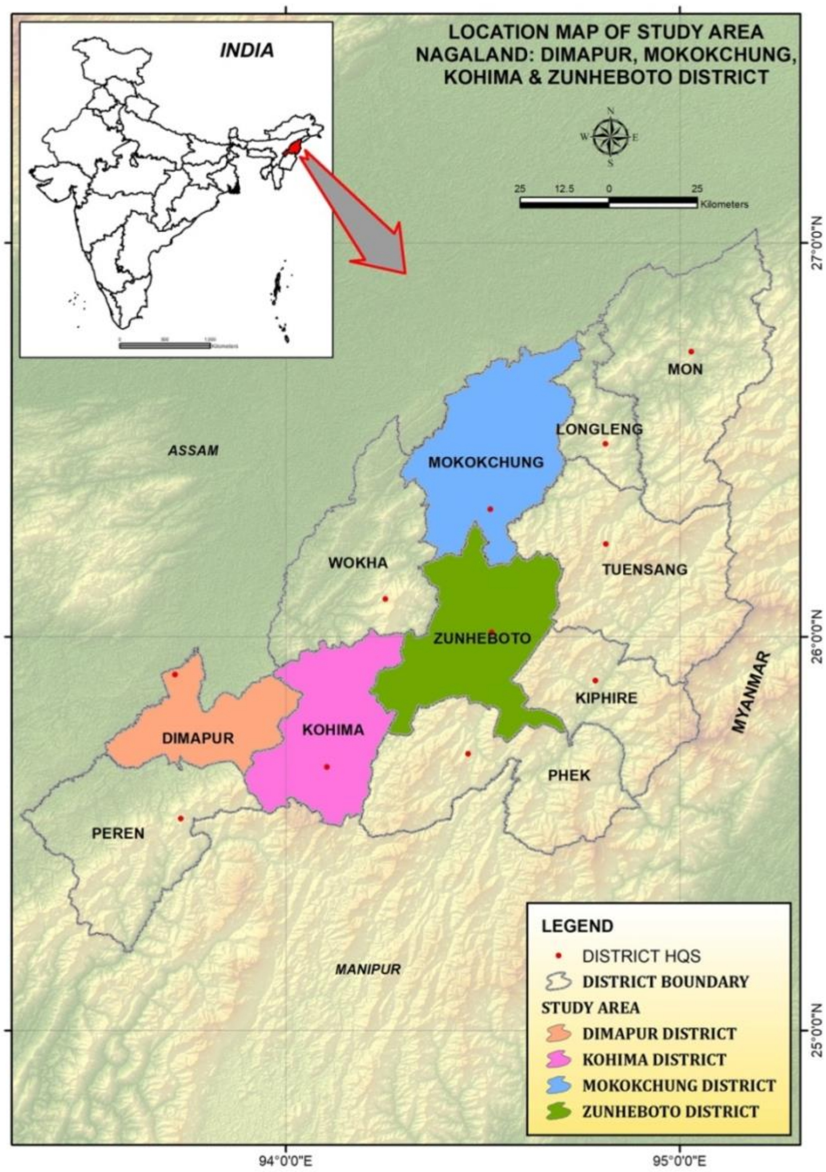


FIGURE 1 A: Map of Nagaland with four district of study highlighted (Nagaland GIS and Remote Sensing Centre)

Kohima district is bounded in the north by the district of Wokha; in the east by the districts of Zhuneboto and Phek; in the west by the districts of Dimapur and Peren and in the south by the state of Manipur. Kohima district lies approximately within 93°53'38.711" to 94°18'1.962" east longitude and 25°31'4.275" to 26°1'16.014" north latitude. It has an area of about 1,463 sq. km and a population of about 267988 individuals according to the 2011 census. It is predominantly inhabited by the Angami Naga tribe. It has an average rainfall of 1863 mm per annum. The climate is moderately humid subtropical with average temperatures ranging from a maximum of 22°C in the summer to a minimum of 11.2°C in the winter (Kohima State Human Development Report, Department of Planning and Coordination, Government of Nagaland, 2009; Census of India, 2011, District Census Handbook – Kohima; Climate-data, 2019).

Dimapur district is bounded in the north by the state of Assam and the district of Wokha; in the east by the district of Kohima; in the west by the state of Assam and in the south by the district of Peren. Dimapur district lies approximately within 94°2'34.937" to 93°32'25.55" east longitude and 25°58'26.294" to 25°38'32.699" north latitude. It has an area of about 927 sq. km and a population of about 378811 individuals according to the 2011 census. Dimapur is a hetrogenous district as it is home to several Naga tribes including people from other states of India. It has to be noted that Nagaland Government recognized villages are concentrated in Dimapur that were form by the Aos, Semas, and Angamis therefore beside the 3 districts Dimapur was taken into account for the field survey. It has an average rainfall of 1560 mm per annum. The climate is hot and humid with average temperatures ranging from a maximum of 26.6°C in the summer to a minimum of 16.6°C in the winter (Census of India, 2011, District Census Handbook – Dimapur; District Human Development Report, Government of Nagaland – Dimapur, 2013; Climate-data, 2019).

Survey on traditionally consumed insects

To collect information on the edible insects used by the Angami, Ao and Sumi tribes, a closed type semi structured questionnaire was used (Appendix 1). Information was collected using random sampling methods from a total of 600 respondents consisting of members of both the sexes and different age groups from ten villages in each district i.e., Aoyimkum, Indisen, Padampukhuri, Diezephe, Kiyeto, Nihokhu, Nagarjan, Aoyimti, Thelikhu, Razhaphe (in Dimapur), Jotsoma, Viswema, piphema, Meriema, Phesama, Chizami, Phezucha, Botsa, Jakhama, Sechu-Zubza (in Kohima), Longkhum, Chungtia, Sungratsu, Longjang, Lirmen, Chuchuyimlang, Waromong, Moalenden, Salulamang, Dibuia (in Mokokchung), and Satakha, Lumami, Aghunato, Akuluto, V.K., Pughoboto, Asuto, Satoi, Philimi and Aoehugelimi (in Zunheboto). The questionnaire included queries related to habitat, occurrence, rearability, part(s) consumed, nutritional value, consumer and non-consumer, effects of consumption (toxic effects/allergy), preparation, harvesting methods, and medicinal uses. The respondents were made aware of the importance of documenting traditional customs and habits and validating them scientifically. They were also briefed about sustainability and the need to find the nutritional content of traditionally consumed insects, so that they can be used as food alternatives or supplements with regard to the rapidly increasing population. Elders who were knowledgeable on the use of IEIs as food were contacted and interviewed and information on certain beliefs and uses of the insects were garnered. The survey was done from January 2016 to December 2020.

Collection of insects

Edible insects from the 4 districts were collected randomly. From this random collection, ten most commonly consumed insects were selected for the research work and they are addressed as identified edible insects (IEIs). The methods applied for collection of insects were handpicking, beating and aerial netting (ZSI, 1990). A kill jar with a ball of cotton containing a few drops of chloroform was used to instantly immobilize the adult lepidopteran so that it will prevent agitation of the moth that may damage itself. Assistance of the local people were also sought to capture the IEIs. Pictures were taken, printed and put in an album which was carried to the villages and used as an identifying aid for the questionnaire during the field survey.

Preservation of Insects

All the IEIs were preserved by following the dry mounting procedure given by Gullan& Cranston (2010). Preservation work started immediately after immobilizing the insect. Dry mounting consist of the following steps: Pinning, spreading, and setting. Further adult beetles, moths and giant hornet were injected 5% formaldehyde into the abdomen to protect it from scavengers and putrefaction of soft tissues.

Identification of insects

Insects were identified with the help of insect taxonomy textbook, ZSI articles on taxonomy and by consulting key characters of the insect specimen from research literature. Dried and preserved specimen of all insect have been retained in the Entomology Laboratory, Department of Zoology, Nagaland University, Lumami and also submitted in ZSI, Kolkata, India. Only the accepted names of the insects have been used in this study.

Sample preparation(Goering & Van Soest, 1970)

For determination of proximate analysis and mineral compositions, the insects were washed with running tap water, dried at 55 ºC ±2º C in a hot air oven for two- three days depending on the size, stages and density of the samples. The appendages, wings and removable exoskeletal parts were removed, grounded to fine powder in a grinder, taken in air tight tupperware plastic container and then stored at –38ºC±2º C in a deep freezer. All the solvents and chemicals used in this study were of analytical grade and care was taken that the glassware was meticulously clean. All the analyses were carried out in triplicates to ensure reliability of the results. For proximate determinations, the results were converted to g/100 g and mineral to mg/100 g to be compared to the content of the food values in conventional food sources of animal origin (CFAO) and percentage of fulfillment of recommended dietary allowance (RDA) by man in the consumption of these IEIs. Moisture content and ash determination was completed within ten days of collection of the individual insects.

Estimation of proximate food values

1. Dry matter And Moisture(AOAC, 1990a)

Basic Principle: Moisture is evaporated from the sample by oven drying. Dry matter is determined gravimetrically as the residue remaining after drying.

Equipment

Forced-air drying oven which allows circulation of air with vents open.

Electronic scientific balance, accurate to 0.1 mg

Silica crucible with cover ≥50 mm diameter, ≤40 mm deep

Desiccator

Reagents

None.

Procedure:

1) Three (3) silica crucibles with cover were placed in the oven at 135^o C $\pm 2^o$ C for at least 2 hrs and moved to desiccators. These crucibles with lid remained in the covered dessicator and cooled for 3 hrs.

2) Then crucible with cover (W_1) was weighed to nearest 0.1 mg one by one, keeping desiccator closed between removal of crucibles.

3) Added approximately 2 g grounded sample in the crucibles. The weight of crucibles with cover and sample (W_2) to nearest 0.1 mg were recorded.

4) These crucibles with samples and lids were inserted into preheated oven at 135°C and dried for 2 hrs.

5) Then the samples were transferred to the desiccator, sealed and allowed to cool to room temperature for 2 to 3 hrs.

6) Crucible with cover and dried sample (W_3) were weighed, weight recorded to nearest 0.1 mg.

Calculation:

$$\% \text{ Total Dry matter (Total DM)} = \frac{W3 - W1\ (g)}{W2 - W1\ (g)} X\ 100$$

Where W1 = tare weight of crucible with lid in grams

W_2 = initial weight of sample and crucible in grams

W_3 = Final weight of sample and crucible in grams

Therefore % Dry matter (Total DM)

$$= \frac{\text{weight of test portion (g)} - \text{weight loss on ashing (g)}}{\text{weight of test portion (g)}} \text{ x } 100$$

Calculation:

$$\% \text{ Total moisture} = 100 - \% \text{ Total DM}$$

2. Ash (AOAC, 2000)

Basic Principle: Samples dried and grounded is ignited in a muffle furnace at 600°C±2° C to oxidize all organic matter. Ash is determined by weighing the resulting inorganic residue.

Equipment

- Silica crucibles, 30 ml capacity, with lids numbered with furnace-proof ink
- Muffle furnace
- Electronic scientific balance, sensitive to 0.1 mg
- Desiccator

Reagents

None.

Procedure:

1) Silica crucible with lid were dried at 600^o C ±2^o C for about 3 hrs, then removed from it and placed in a dessicator to cool to room temperature for 3 hrs.

2) Then these crucible with lid (W_1) were weighed to nearest 0.1 mg one by one, keeping desiccator closed between removal of crucibles.

3) Approximately 2 g grounded sample were added to each crucible. The weight of crucible with lid and sample (W2) to nearest 0.1 mg were recorded.

4) These crucibles with samples and lids were inserted into preheated muffle furnace at 600^o C ±2^o C and held for 3 hrs.

5) Then these samples were transferred to desiccator, sealed and allowed to cool to room temperature for 2 to 3 hrs.

6) Cooled dishes with lid and dried sample (W3) were weighed, recording weight to nearest 0.1 mg.

Calculation:

$$\% \text{ Total Ash (Total DM)} = \frac{\text{W3} - \text{W1 (g)}}{\text{W2} - \text{W1(g)}} \text{ x } 100$$

Where W_1 = tare weight of crucible with lid in grams

W_2 = initial weight of sample and crucible in grams

W_3 = Final weight of sample and crucible in grams

Therefore % Total Ash (Total DM)

$$= \frac{\text{weight of test portion (g)} - \text{weight loss on ashing (g)}}{\text{weight of test portion (g)}} \text{ x } 100$$

3. Crude Protein (AOAC, 1990b)

Basic principle: Protein was estimated using Kjeldahl method. The process comprises of three phases:

1) Digestion of the ground sample in sulphuric acid using anhydrous copper sulphate. The nitrogen contained in the sample is converted to ammonia; ammonium sulphate being formed.

2) Distillation of ammonia released from ammonium sulphate by addition of an excess of sodium hydroxide; ammonia being trapped in a trapping solution (sulphuric acid).

3) Back-titration of the excess of the trapping solution with a standard solution.

Equipment, materials and special laboratory glasses

- analytical scales
- digestion unit
- stand for digestion tubes (6 positions)
- digestion tubes (250 mL)
- vapour exhauster with sealing connected to a water vacuum aspirator -
- distillation unit equipped with a canister containing 30 % (w/w) solution of sodium hydroxide
- common laboratory glassware

Reagents

- double distilled water
- sulphuric acid for digestion, concentrated, 95 – 98 %
- potassium sulphate
- anhydrous copper sulphate
- alundum granules
- high purity lysine monohydrocloride, reagent grade. Dried at 110^o C for 4 hours
- methyl red indicator
- Tributyl citrate
- 45% sodium hydroxide solution

- Hydrochloric acid standard solution, 0.5 N
- Sodium hydroxide standard solution 0.1N

Standardization of Hydrochloric Acid Solution(AOAC, 1990c)

Basic Principle: An acidic solution is titrated with a standardized base solution to determine normality.

Equipment

- Burette, 50 ml, graduated to 0.1 ml
- Magnetic stirrer
- Volumetric pipette, 40 ml
- Conical flasks, 200ml
- Measuring cylinder, 500ml

Reagents

- Hydrochloric acid, concentrated, 36.5 to 38%, reagent grade
- Sodium hydroxide, standard solution (same as used in Kjeldahl method)
- Distilled water, carbon dioxide (CO_2) free
- Indicator, as used in Kjeldahl method

Procedure:

Preparation

1. Dilute appropriate volume of 36.5 to 38% HCl to 10 L with carbonate-free distilled water as indicated below and mix well:

Desired Normality	ml HCl to dilute to 10 L
0.01	8.6
0.02	17.2
0.10	86.0
0.20	172.0
0.50	430.1
1.0	860.1

Standardization

1. The pipette is washed with the acid to be standardized.

2. 40 ml of conc. HCl is measured in the pipette and transferred into a 250 or 300 ml Erlenmeyer that has been rinsed with CO_2- free H_2O.

3. Burette that was washed with standardized NaOH of approximately same concentration as acid to be standardized.

4. Add indicator used in Kjeldahl method to the acid solution and titrate, a drop at a time, with NaOH while stirring.

5. Titrated till the solution turned orange (color change from red to orange to yellow). After every titration the pipette and the burette were washed.

6. Normality was calculated and adjustment were made as necessary with HCl or water.

7. All the readings and standardization were recorded.

Calculation:

$$\text{Normality of HCl} = \frac{\text{ml of Base std x Normality of base std}}{\text{ml HCl in the flask}}$$

Base Std = NaOH

If the normality is too high, dilute solution to required normality by following formula:

$$V1 = V2 \text{ X } N2 / N1$$

Where N2 and V2 represent normality and volume of stock solution and V1 equals volume to which stock solution should be diluted to obtain desired normality, N1.

Standardization of Sodium Hydroxide Solution(AOAC, 1990d)

Basic Principle: A basic solution is titrated with a standardized acidic solution to determine normality.

Equipment

- Burette, 50 ml, graduated to 0.1 ml
- Magnetic stirrer
- Volumetric pipette, 40 ml, class A
- Analytical balance, sensitive to 0.1 mg
- Borosil glass
- pH meter with glass electrode (alternate to using phenolphthalein indicator)

Reagents

- Distilled water, carbon dioxide (CO2) free prepared either: 1) by boiling for 20 min and cooling with soda-lime protection or 2) by bubbling air, freed from CO2 by passing through tower of soda lime, through water for 12 hr.
- Sodium hydroxide solution, to 1 part reagent grade NaOH add 1 part distilled, carbon dioxide-free water by weight.
- Acid potassium phthalate, NIST SRM for Acidimetry 84, or KHP (C8H5O4K), dry for 2 hr at 120^o C and cool in desiccator.
- Buffer solution, pH 8.6, 12.00 mL 0.2 N NaOH added to 50 ml 0.2M boric acid/potassium chloride solution made as follows:
    - Boric acid-potassium chloride solution - dry boric acid (H_3BO_3) to constant weight in desiccator over CaCl2. Dry potassium chloride (KCl) 2 days in oven at 115 to 120^o C. Dissolve 12.405 g H_3BO_3 and 14.912 g KCl in water and dilute to 1 L.
- Phenolphthalein indicator, 1%,
    - Dissolve 1 g phenolphthalein in 100 ml 95% ethanol.

Procedure:

Preparation

1) Add appropriate volume of NaOH solution (1 to 1) to CO2-free distilled water necessary to make 10 L of solution:

Desired Normality ml NaOH to be diluted to 10 L

0.01	5.4
0.02	10.8
0.10	54.0
0.20	108.0
0.50	270.0
1.0	540.0

Standardization

1) Weighed (ca. 0.4 g) dried acid potassium phthalate to titrate about 40 ml of NaOH solution and transfer to 300 ml flask.

2) Added 50 ml CO2-free water, stopper flask and swirled for sample to dissolve.

3) Titrated to pH 8.6 with solution being standardized. Another flask to which is added 3 drops phenolphthalein containing 50 ml of pH 8.6 buffer and stopper is used as the reference endpoint for a pH 8.6 titration.

4) The volume of NaOH was determined that was required to produce endpoint of blank by matching color in another flask containing 3 drops phenolphthalein and same volume (50 ml) CO2-free water.

5) The volume required to titrate blank was subtracted from that used to titrate the potassium acid phthalate and normality calculated. Normality was kept slightly high.

6) The desired concentration was made with adjustment and recheck standardization.

7) Readings and concentration were recorded.

Calculation:

$$\text{Normality} = \frac{\text{gKHC8H5O4 x 1000}}{ml{,}NaOHx\ 204.229}$$

Adjust to desired concentration by following formula:

V1 = V2 X N2 / N1

Where N2 and V2 represent normality and volume of stock solution and V1 equals volume to which stock solution should be diluted to obtain desired normality, N1.

Procedure for protein estimation:

Digestion

1) 1g of ground sample was well mixed with test portion on a tared, low N weighing paper. The paper with material was dropped into a numbered 500 ml Kjeldahl digestion flask. The weight of each test portion was recorded to the nearest mg for weights of ≥ 1g, and to the nearest of 0.1 mg for weigh of < 1.0.

2) A high purity lysine monohydrocloric acid was included as a blank reagent to check the correctness of digestion parameters. A second subsample was weighed for determination of laboratory dry matters.

3) 15 g of potassium sulphate, 0.5 g of anhydrous copper sulphate and 1 g alundum granules was added to the sample and then 20 ml of sulphuric acid was added. An additional 1.0 ml sulphuric acid was added for each 0.1 g fat or 0.2 g of other organic matter, if sample weight was greater than 1g.

4) The Kjeldahl flask was then placed on a preheated burner adjusted to bring 250 ml water at 25^0 C to boiling in about 5 minutes. It was heated till white fumes were slightly cleared from the bulb of flask, swirled gently, and then heated for 3 h. It was cooled to room temperature and then 250 ml of distilled water was added. Water was added as soon as possible to reduce amount of caking.

Distillation

5) A titration flask was prepared by adding 15ml of standard HCl and 2-3 drops of methyl red indicator.

6) Blank reagent was prepared by adding 85 ml of double distilled to 1 ml of standard HCl. To the Kjeldahl flask, 2-3 drops of Tributyl citrate was added to reduce foaming and 0.5 to 1.0 g alundum granules were added to agitate the mixture.

7) To this mixture, 80 ml of 45% sodium hydroxide solution was added to make the mixture strongly alkali. Immediately, the titrating flask was connected to the distillation apparatus and distilled. The temperature was set to about 25^0C to boil 250ml of water till the boric acid captured the ammonia gas, forming an ammonium-borate complex. As the ammonia collects, a change in the color of the receiving solution to reddish pink indicated its end point.

8) The titrating flask was removed from the unit and the condenser tube was washed in distilled water.

Titration

9) Titrated excess acid with standard sodium hydroxide till the solution turned orange (colour changed from reddish red to orange to yellow) and volume to nearest 0.01ml was recorded. The blank reagent was also titrated similarly.

Calculation:

The following formula was used to calculate the nitrogen percentage content.

$$\%\ \text{nitrogen(DM basis)} = \frac{[(\text{VHCl x NHCl}) - (\text{VBK x NNaOH}) - (\text{VNaOH x NNaOH})]\text{x } 1.4007}{\text{weight of sample (g)}}$$

Where, 1.4007 = milli equivalent weight of nitrogen x100

VNaOH = ml standard NaOH needed to titrate sample

VHCl = ml standard HCl pipetted into titrating flask for sample

NNaOH = Normality of NaOH

NHCl = Normality of HCl

VBK = ml standard NaOH needed to titrate 1 ml standard HCl minus B

B = ml standard NaOH needed to titrate reagent blank carried through method and distilled into 1 ml standard HCl

W = sample weight in grams

The following formula was used to calculate the percentage of crude protein content.

% crude protein (DM basis) = % N (DM basis) x F

Where, DM = dry matter

F= 6.25 for all forages and feeds except wheat grains

4. Crude Fat(AOAC, 1990e)

Basic Principle:A dried, ground sample is extracted from which dissolved fats, oils, pigments and other fat soluble substances were removed. The ether is then evaporated from the fat solution. The resulting residue is weighed and referred to as ether extract or crude fat. Both the ether and the samples must be free of moisture to avoid co-extraction of water-soluble components in the sample such as carbohydrates, urea, lactic acid, glycerol, etc. If water-soluble components are present in large amounts in the sample, they are washed out of the sample prior to drying. Low temperatures are used to evaporate the ether and remove residual moisture to prevent oxidation of the fat. Petroleum ether does not dissolve all of the plant lipid material, and therefore it cannot be substituted for diethyl ether.

Equipment

- Soxhlet fat extraction apparatus, equipped with glass thimble holders
- Extraction thimbles, 22 x 80 mm,
- Alundum (porous clay), coarse
- Borosil beakers, with ground lip, engraved with a number, 50 x 85 mm
- Oven
- Analytical balance, sensitive to 0.1 mg
- Desiccator and tongs

- Filter paper, Whatman #1, 11 cm, or equivalent
- Steambath in a hood (optional)
- Gloves, white nylon, lintless

Reagents

Anhydrous Diethyl Ether

Procedure:

Drying

1) Weighed 1.5 to 2 g of ground sample into a thimble recording the weight to nearest 0.1 mg (W1). A second subsample was weighed for dry matter determination and dried for 5 hr at 100^{o}C.

2) Dried samples were removed from the oven to a desiccator.

3) Borosil beakers used for fat determination were dried for at least 1 hr at 100^{o}C then cooled in a desiccator. It was weighed and recorded to the nearest 0.1 mg (W2).

Extraction

4) The fat beakers were lined up in front of the extractor and match the thimbles with their corresponding fat beakers. Then slipped the thimble into a thimble holder and clip the holder into position on the extractor.

5) About 40 ml of diethyl ether was added to each fat beaker.

6) The beaker was fitted into the ring clamp and tightly clamped onto the extractor.

7) The heater was placed in position and the beaker was heated for the extraction.

Ether Distillation and Weighing of Fat Residue

8) The holder was washed with diethyl ether after removing the thimble.

9) Then the ether was distilled from the beakers leaving only a thin layer of it in the bottom and the electricity and water supply were switched off.

10) The exterior of the beaker was wiped clean with a linen cloth for further evaporation.

11) The beaker was placed in an operating hood and the ether evaporated until all traces of it was gone. Beaker was then placed in a 102ºC gravity convection oven for about not more than 1/2 hr to prevent excessive drying oxidizes fat and may give higher results.

12) Then the beaker was cooled in a desiccator and weighed to the nearest 0.1 mg (W2).

13) The fat beaker are cleaned on a steambath or on hot plate on a low mode. The thimbles are cleaned by blowing out with air.

Calculation:

Percent Crude Fat (Ether Extract), DM basis

% crude Fat (DM basis) = $\frac{W3 - W2\ x\ 100}{W1\ xlabDM/100}$

Where W1 = initial sample weight in grams

W2 = tare weight of beaker in grams

W3 = weight of beaker and fat residue in grams

5. Crude Fibre(AOAC, 1990f)

Basic Principle: An acidified quaternary detergent solution is used to dissolve cell solubles, hemicelluloses and soluble minerals leaving a residue of cellulose, lignin, and heat damaged protein and a portion of cell wall protein and minerals (ash). ADF is determined gravimetrically as the residue remaining after extraction.

Equipment

- Refluxing apparatus

- Borosil beakers (600 ml)
- Fritted glass (Gooch) crucibles (coarse porosity, 50 ml)
- Analytical scintific balance, accurate to 0.1 mg
- Suction filtering device with trap in line and valve to break vacuum
- Oven set at 100°C

Reagents

- Acid detergent solution
- 20 g Cetyl trimethylammonium bromide (CTAB), technical grade
- Acetone, reagent grade

Preparation of Acid Detergent solution:

- Mix 1 litre 1.00N Sulfuric acid ±0.005N. Normality must be verified by titration with a primary base standard (Procedure given) before adding CTAB.
- A solution approximately 1.0 N sulfuric acid can be made by adding 51.04g (27.7 mL) of concentrated reagent grade sulfuric acid (95-98% purity) to 972.3 mL water (AOAC 935.70). Titrate by method given for standardization of H_2SO_4 and add water (if normality too high) or sulfuric acid (if normality too low) to adjust normality to 1.00N ±0.005N.

Procedure for crude fibre:

1) 50 ml fritted glass crucibles were dried overnight at 100°C and weighed while still hot (W1), nearest 0.1 mg.

2) Weighed 1g finely grounded sample (W2) (approximately 0.9 to 1.1 g, record weight accurate to 0.1 mg) into beaker. Weighed a second subsample for laboratory dry matter determination.

3) To the sample 100 ml acid-detergent solution was added at room temperature. Beaker placed on heater under the cold water condenser.

4) The beaker was then placed on heater under the cold water condenser and heated to boiling in 5-10 min, taking care to prevent foaming with reduce heat and adjusting boiling to slow, even level. Reflux was allowed for 60 min from onset of boil.

5) After about 30 min, the sides of beaker was washed down with minimal amount of acid detergent solution.

6) The beaker was then removed, swirled, and filtered through tared fritted glass crucible, using minimal vacuum and then the beaker including the top edge was rinsed with boiling water while inverted over the crucible to insure quantitative transfer of all fiber particles into the crucible. This rinsing was done twice.

7) The step 6 was again repeated twice but instead of boiling water 30-40ml acetone was used.

8) The residue left in the crucible was dried in forced-air oven at100^{o}C for 3 hr and weighed hot, (W3) to nearest 0.1 mg.

Calculation:

Percent Acid Detergent Fiber (ADF)

$$\% \text{ ADF (DM basis)} = \frac{W3 - W1}{W2 \text{ x Lab DM}/100} \text{ x } 100$$

Where W1 = tare weight of gooch crucible in grams

W2 = initial sample weight in grams

W3 = dry weight of gooch crucible and dry fiber in grams

6. Carbohydrate(James C.S., 1995).

The carbohydrate content was calculated by difference method (James C.S., 1995). The percentage carbohydrate content was calculated using the following formula.

Calculation:

% Carbohydrate = 100 – [Moisture (%) + Ash (%) + Crude protein (%) + Crude fat (%) + Crude fibre%]

Estimation of minerals

The insect specimens were subjected to element analysis using ICP-OES (Inductively coupled plasma-optical emission spectrometry) (Thermo Fischer iCAP 7600).

Basic Principle:ICP, abbreviation for Inductively Coupled Plasma, is one method of optical emission spectrometry. When plasma energy is given to an analysis sample from outside, the component elements (atoms) are excited. When the excited atoms return to low energy position, emission rays (spectrum rays) are released and the emission rays that correspond to the photon wavelength are measured. The element type is determined based on the position of the photon rays, and the content of each element is determined based on the rays' intensity.

Equipment

- Light source unit,
- Spectrophotometer
- Detector
- Data processing unit

Reagents

- Conc. Nitric acid
- $HClO_4$

Procedure:

Sample preparation

Insects were collected from their natural habitat, washed with distilled water to remove any impurities, dried in oven and powdered in a kitchen blender. The samples were digested by wet acid digestion method and evaluated for minerals in the ICP-OES.

Acid Digestion(Wongwit*et al.,* 2004)

1) 5 ml of concentrated Nitric acid was added to 0.5 mg of sample in a beaker and kept overnight.

2) The following day, beaker was heated in flame till the production of NO_2 fumes stopped. The beaker was then cooled and 2 ml of $HClO_4$ was added and heated again to a small volume. The volume was then made to 50 ml using distilled water and the filtered.

3) The filtrate was subjected to ICP-OES to detect the presence of elements namely Ca, Cu, Fe, K, Mg, Na and Zn.

4) The elements were evaluated in ppm (mg/1000g).

Statistical analysis

The experimental results were expressed as mean of three replicates ± standard deviation (SD) in Origin Pro 8. Statistical calculations of the survey were carried out in Microsoft Excel. For proximate determinations, the results were converted to g/100 g. Protein and Fat values of IEIs were compared to protein and fat content in CFAO (USDA database, 2015) calculated on dry matter basis and percentage of fulfillment of recommended dietary allowance (RDA) for adult (Male and Female) as referred for protein by USDA (2020) and for fat by FSSAI, New Delhi (2020) in the consumption of IEIs in g/100g were also determined.

The elements which were evaluated in ppm (mg/1000g) were then converted to mg/100g for comparison of mineral content in mg/100g (DM basis) of IEIs with CFAO (CFAO: Data obtained from USDA database, 2019) and calculate the percentage of fulfilment of recommended dietary allowance (RDA) given in mg/100g for adult (Male and Female) obtained from the Micronutrient Information Centre (2020), by consumption of the IEIs values of mineral content in mg/100g (DM basis).

CHAPTER THREE

IDENTIFICATION AND DIAGNOSTICS

The ten (10) IEIs commonly eaten by the three tribes (Angami, Ao, Sumi) from the four districts of Nagaland belonging to six orders are as follows: *T. portentosus* (Orthoptera), *T. javanica, C. singhalanus*and *D. hardwickii* (Hemiptera), *P. linearis* (Homoptera), *A. chalybaeus* and *A. holosericea*(Coleoptera), *Cossus sp.* and *Andraca sp.* (Lepidoptera) and *V. mandarinia* (Hymenoptera). The IEIs with diagnostics are as follows:

1. *Tarbinskiellusportentosus* Lichtenstein (1796)

ZSI Regd no: 39705/H5

1796. *Acheta portenlosa*Lichtenstein, *Cat. Mus.* 2001.Humburg, 3: 86.

1838. *Brachytrupesustulatus*Serville, *Histoire naturelle des insects,*Orthopteres: 326.

1869. *Grylluspedestris*Walker, *Cat. Derm. Salt. Brit. Mus*: 13.

1931. *Brachytrypesportentosus,* Chopard, *Bull. Raffles Mus.,* 6: 128.

1964. *Brachytrypesportenlosus,* Randell, *Canad, Enl.,* 96: 1587.

1967. *Brachytrypesportentosus*, Chopard, *Orth. Cat*., 10: 42.

1969.*Brachytrypesportentosus* ,Chopard, Fauna Ind. Grylloidea,2: 15-30. *Rec. Zool. Surv.India,* Occ. Paper No.132.

1969. *Brachytrypesportentosus,* Bhowmik, *Bull. Zool. Surv. India*, 7(2-3): 186.

1986. *Brachytrypesportentosus,* Pajni& Kalra, *Research Bulletin of the Punjab University Science,* 37(1-2): 121.

1987. *Brachytrypesportentosus,* Shishodia& Tandon, State Fauna Series, 1: Fauna of Orissa, Part 1, *Zool. Surv. India*: 116.

1993. *Brachytrypesportentosus,* Shishodia& Tandon, State Fauna Series, 3: Fauna of West Bengal, Part 4, *Zool. Surv. India:* 232.

1993. *Brachytrypesportentosus,* Vasanth ,*Rec. zool. Surv. India,* Dec. Pap. No., 132: 29.

1995. *Brachytrypesportentosus,* Tandon &Shishodia, Himalayan Ecosystem Series: Fauna of Western Himalaya (U.P.) Part 1, *Zool. Surv. India*: 40. 206.

2000. *Brachytrypesportentosus,* Shishodia, State Fauna Series, 7: Fauna of Tripura, Part 2, *Zool. Surv. India*: 249.

2000. *Tarbinskiellusportentosus*, Saeed *et al*., *Int. J. Agr. Bioi.,* 2(3): 176.

Common name: Rice field cricket, large brown cricket, short tailed cricket.

Diagnostic Characters

General appearance: Large, robust, brown cricket.

Head: Plate 1A. Head dark brown to black, protruding prominently above the level of pronotum; frontal rostrum more than twice the width of first antennal segment.

Thorax: Plate 1B. Pronotum wider than long; strongly widening in front, constricted in posterior one-third, anterior margin strongly concave, posterior sinuated; disc flat, dark chocolate-brown in colour, impresses paler, more or less conspicuous.

Wings: Plate 1C. Tegmina dark brown to pale yellowish-brownreaching upto apex of abdomen. In male,tegminawith 5 sinuated oblique veins; apical field with 6 veins, and a regular reticulation of elongated areolae.

In case of female(Plate1D) the tegmina dorsal field generally with 3-4 oblique veins, the two innermost united at base, and a reticulation of squarish cells; ovipositor very short in relation to body size (Plate 1E).

Legs: Plate 1F. *Legs* stout; anterior tibiae with an oval tympanum on each face, the external one placed in a depression and double the size of internal one; spines and apical spurs of posterior tibiae strong, stout; anterior metatarsi very short, posterior metatarsi about half as long as posterior tibiae; anterior and middle tibiae with hairs.

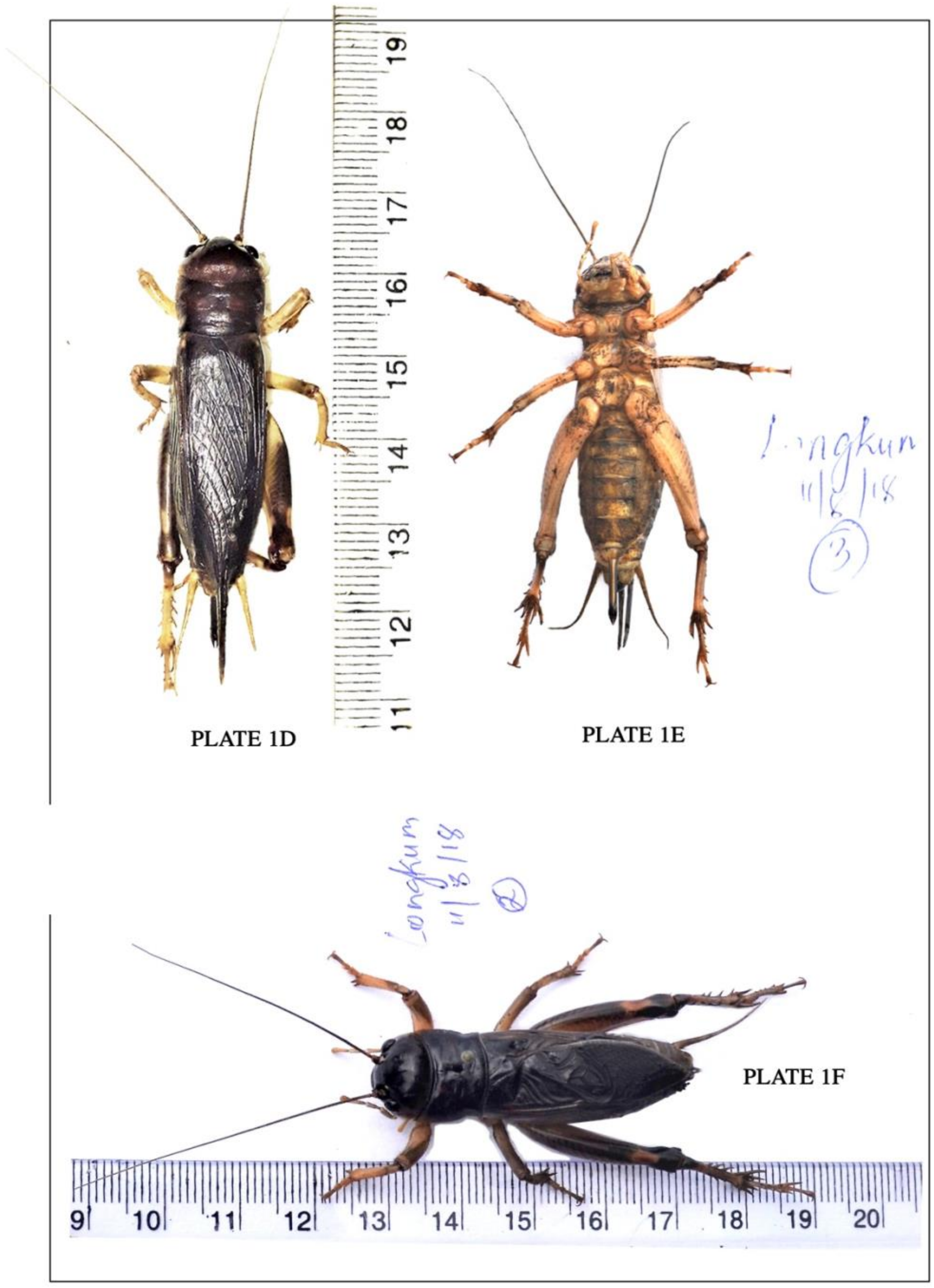
Measurement

Body length: Male 20.0- 40.0 mm, Female 33.5-39.5 mm

Length of ovipositor: 8.0-10.0 mm

Distribution:

Place	**Latitude**	**Longitude**	**Altitude MSL (in Metres)**
Longkhum (Mokokchung)	26°15'39.43"N	94°24'48.74"E	1588
Lumami (Zunheboto)	26°12'34.40"N	94°28'32.34"E	1072



Diagnostics of *Tarbinskiellus portentosus:*
PLATE 1D - Female. Tegmina dorsal field generally with 3-4 oblique veins
PLATE 1E - Ovipositor very short in relation to body
PLATE 1F - Legs

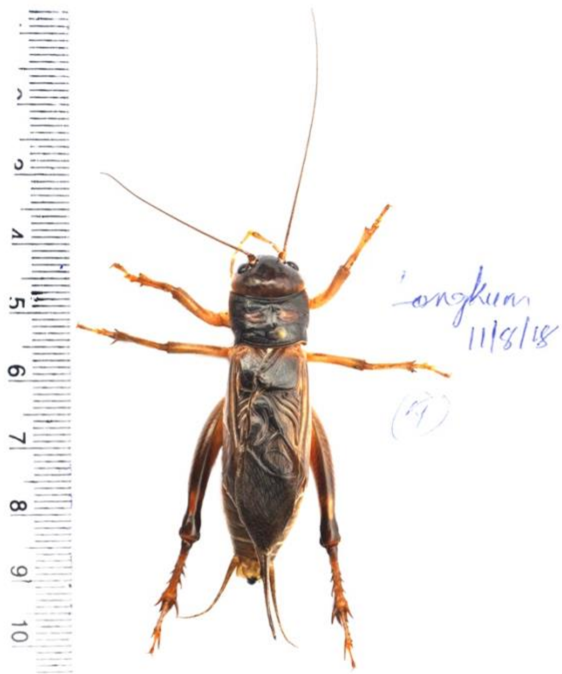


PLATE 1A

PLATE 1C

PLATE 1B

Diagnostics of *Tarbinskiellus portentosus:*
PLATE 1A - Head dark brown to black, protruding prominently above the level of pronotum
PLATE 1B - Pronotum wider than long ; strongly widening in front
PLATE 1C - Male. Tegmina with 5 sinuated oblique veins

2. ***Tessaratomajavanica Thunberg (1783)***

ZSI Reg. no:15430/H15

1866. *Tessaratoma*Lepeletier&Serville 1825, *Encycl. Meth*., x: 590. syn. With *Cimex chinesis* Thunberg, 1783 by Mayr.

1880. Cimex javanica Thunberg 1783, *Nov. Ins. spec*., 2: 45. syn. by Wolff, 1880.

1868. Tessaratoma striata, furcifera, timorensis&clara, Walk. Cat. Het. iii, pp. 463 & 464.

1902. Tessaratomajavanica: Distant, *Fauna Brit. India*, 1: 259.

1986. Tessaratomajavanica: Hegde, *East. Ghats Ins*., 1: 27.

1995. Tessaratomajavanica: Hegde, *Rec. Zool. Surv. India*, Occ. Paper No., 168: 35.

2015. *Tessaratomajavanica*: Parveeni*et al*. *Zootaxa*3936 (2): 261–271.

Common name: Lychee stink Bug

Diagnostic Characters

General appearance: Plate 2A. Body somewhat elongately ovate, brownish-ochraceous.

Head: Plate 2A & B. small, rounded at apex; head and basal prothorax extended downward; antennae 4-segmented, black, apical joint brownish yellowish brown;

Thorax: Plate 2A. Postmargin of pronotum strongly protrudented backward and covered basal mesoscutellum; lateral margin of pronotum prominent but smooth and reflexed; scutellum with apex more or less piceous (more or less dull black).

Wings: Plate 2C & D. Veins of the membrane forming cells at base.

Legs: Plate 2E. Legs and tarsi dark castaneous (bright red brown); femora with apical spine.

Abdomen: Plate 2C & F. Body above very finely and obscurely punctuate; body beneath with white powdery substance;

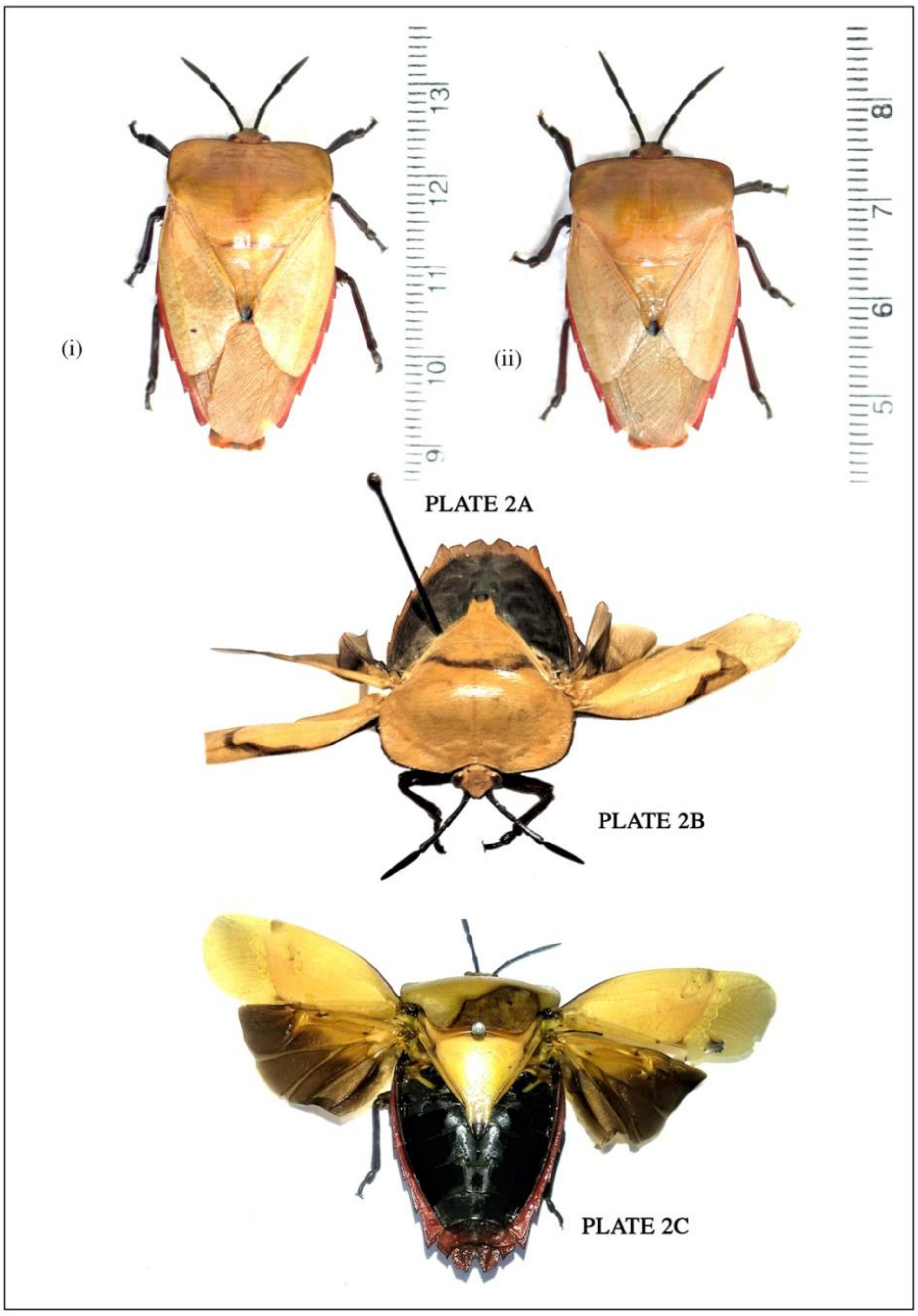
Genitalia: Plate 2F. Male with the anal appendage is truncate at its apex; beneath with white powdery substance.

Measurement:

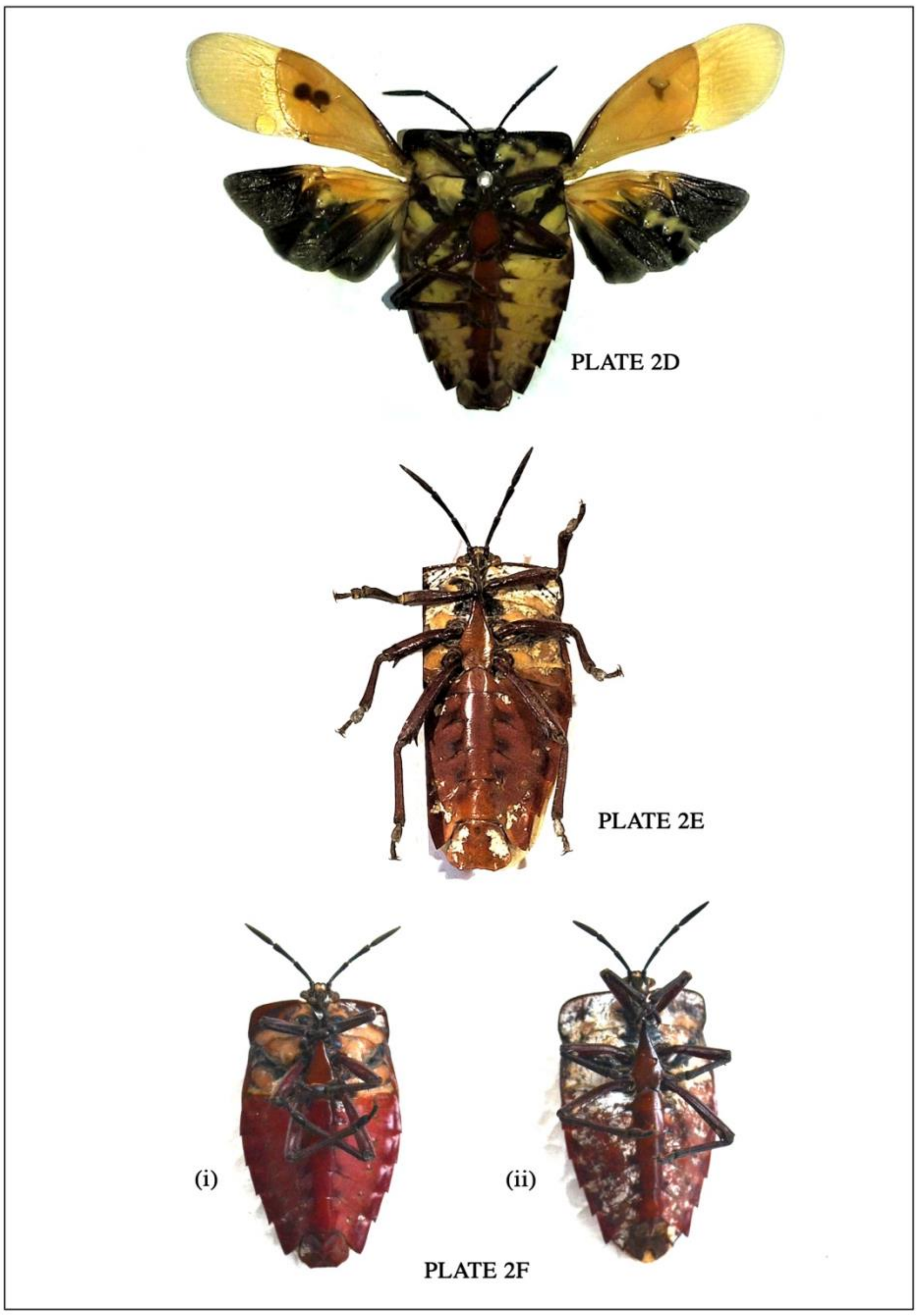
Body length: Male 32 mm; Female 36mm

Distribution:

Place	**Latitude**	**Longitude**	**Altitude MSL (in Metres)**
Aoyimkum (Dimapur)	25°53'05.19"N	93°41'29.99"E	189
Indisen (Dimapur)	25°53'51.62"N	93°41'18.80"E	168



Diagnostics of *Tessaratoma javanica:*
PLATE 2A - Female (i) Male (ii)
PLATE 2B - Head small and rounded at apex
PLATE 2C - Wings (Dorsal)



Diagnostics of *Tessaratoma javanica:*
PLATE 2D - Wings (Ventral)
PLATE 2E - Legs and tarsi dark castaneous
PLATE 2F - Ventral Abdomen Male (i) Female (ii)

3. ***Coridiussinghalanus*Distant (1900)**

ZSI Regd. No: 15431/H15

1900. Aspongopussinghalanus: Dist. A. M. X. H. (7) vi, p. 222.

1902. Aspongopussinghalanus: Dist. Fauna Brit. India, Rh. 1:283-284.

1908. Aspongopussinghalanus: Bergroth, *Mem. Soc. Ent. Belg.* 15: 188.

1909. Aspongopussinghalanus: Kirkaldy, cat. Hem. 1:257.

1913. Aspongopus (Aspongopus)singhalanus: Schouteden, *Gen. Ins*. 153: 9.

1915. Aspongopussinghalanus: Gravely, *Rec. Indian Mus*. 11: 509-510.

1986. Coridiussinghalanus: Durai, *Palnti news,* 5 (1): 6.

1986. Coridiussinghalanus: Mathew, *Rec. Zool. Surv. India,* 84 (1-4): 43-44.

1987. Coridiussinghalanus: Durai, *Oriental Ins.,* 21:190, 196-197, figs. 173-175.

1990. Coridiussinghalanus: Lis, *Ann. Upper Silesian Mus. Ent*., 1:113, 142.

1992. Coridiussinghalanus: Lis, *Ann. Upper Silesian Mus. Ent*. 3: 37.

2017. Species of Tari in Arunachal Pradesh: Morphology, ecology and toxicity of entomophagy. *Journal of Bioresources,* 4(2): 50-57.

Common name: Stink bug

Diagnostic Characters

General appearance: Plate 3A.Bronzy-brown stink bug

Head: Plate 3A, B & C. Antennae, eyes, rostrum, and legs piceous; apical joint of antennae, base of rostrum, and the tarsi ochraceous; head with the margins laminately reflexed; rostrum reaching about halfway between the anterior and intermediate coxae (Plate 3E), base of rostrum red-orange (Plate 3F).

Antennae: Plate 3B. 5-segmented; antennae thick, the second, third, and fourth joints deeply sulcate, second and third joints subequal in length or third a little longer than second, fourth and fifth joints subequal, fifth joint narrowest and cylindrical.

Thorax: Plate 3D. Scutellum short, its apex broad.

Wings: Plate 3B & D. The basal part of the outer pair relatively hard, the inner pair membranous and transparent.

Legs: Plate 3F.Legs piceous, tarsi brownish yellow (ochraceous).

Abdomen: Plate 3D**.** Dorsal side of the body finely rugulose and punctuate; abdomen above reddish.

Measurement:

Body length: Male 19mm; Female 20 mm.

Distribution:

Place	**Latitude**	**Longitude**	**Altitude MSL (in Metres)**
Tizu River, Sukhai (Zunheboto)	25°51’35.95”N	94°28’57.90”E	1671
Phesama (Kohima)	25°37’37.23”N	94°06’54.88”E	1568
Moalenden(Mokokchung)	26°15'24.78"N	94°33'16.51"E	944

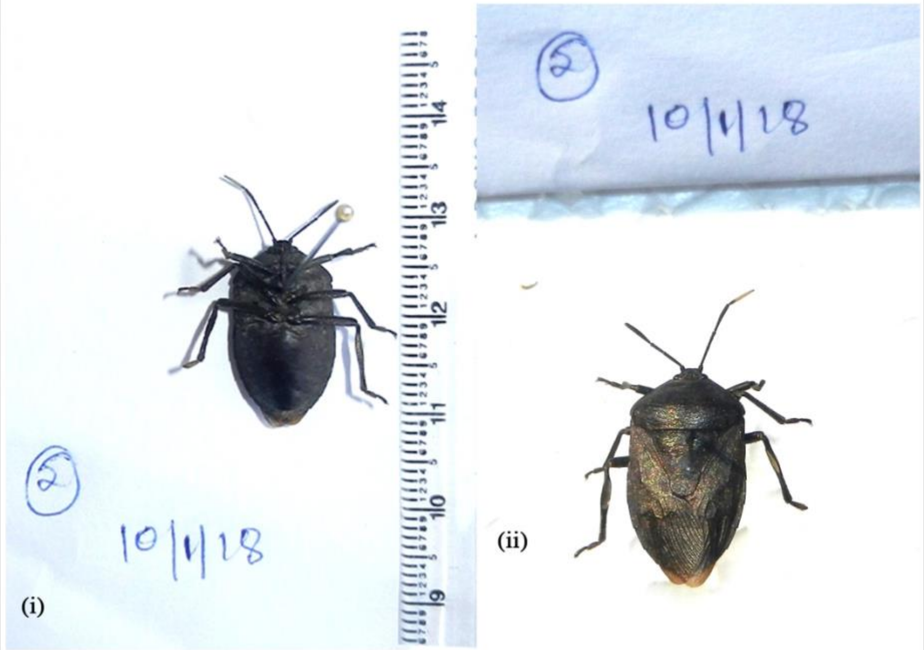


PLATE 3A

PLATE 3B

PLATE 3C

Diagnostics of *Coridius singhalanus:*
PLATE 3A - Male (i) Female(ii)
PLATE 3B - Head & Forewings
PLATE 3C - Appengages piceous with tarsi ochraceous

PLATE 3D

PLATE 3E

PLATE 3F

PLATE 3G

Diagnostics of *Coridius singhalanus:*
PLATE 3D - Scutellum & Abdomen (Dorsal)
PLATE 3E - Rostrum
PLATE 3F - Appendages
PLATE 3G - Male

4. ***Darthulahardwickii*****Gray (1832)**

ZSI Regd. no: 15432/H15

1831. Urophorahardwick: Gray, Griff. *Anim. Kingd.*, 2: 261.

1900. Darthulahardwickii: Kirkaldy, *Entomologist*, 33: 242.

1908. Darthulahardwickii: Distant, Fauna Br. India, *Zool. Surv. India,* 4: 78.

1996. DarthulaHardwickii: Homoptera, Membracidae. Fauna of India, *Zool. Surv. India,* pp.28-31.

Common name: Tree hopper

Diagnostic Characters

General appearance: Plate 4A& K. Male and female similar in terms of size and colour (piceous brown).

Head: Plate 4A & B. Head directed backward towards frontal margin of pronotum, upper margin arcuate, lower margins rounded;concealed beneath frontal edge of pronotum, the eyes visible only from above, between eyes convexly transversely ridged, before which it is foveate and beyond which it is laterally deflected; ferruginous, subglobate; ocelli small, black, closer to each other than to eyes.

Thorax : Plate 4C& D.Pronotum piceous brown, central and posterior carinations of a lighter hue; pronotum moderately compressed, finely rugosely punctate,lateral margins narrowing anteriorly, metopidium vertical above head, then gradually sloping backward to disc, finely punctate;with a central strong longitudinal lunulate ridge, as seen from above the lateral margins narrowing anteriorly, the posterior margin carinate; scutellum piceous brown, distinct, triangular, longer than wide, apical area somewhat light brown, apically subacute.

Wings: Plate 4D& E.Tegmina piceous brown, apically narrowed, the apex obtusely subacute, costal margin moderately convex, densely and reticulately veined; the veins raised and prominent, costal area very broad; hindwings shorter and narrower than tegmina, with two long apical areas, apical area divided into irregularly shaped interspaces.

Legs: Plate 4G & I. Legs with femora testaceous, moderately thickened, tibiae equal in length to femora of foreleg and midleg, tibiae longer than femora of hindlegs, black, tarsi with the terminal segment longer than the combined length of the first two basal joints together, claws very robust, dull black.

Abdomen: Plate 4F & H.Abdomen and body beneath concave and reddish brown; above convex and piceous brown with the segmental margins more or less ochraceous; abdomen provided with a long apical piceous process, about or nearly as long as the whole body, covered with long bristly hairs, with a strong triangular tubercle at base, its apex inconspicuously bituberculate (Plate 4J); posterior segmental margins ridged,

Measurement:

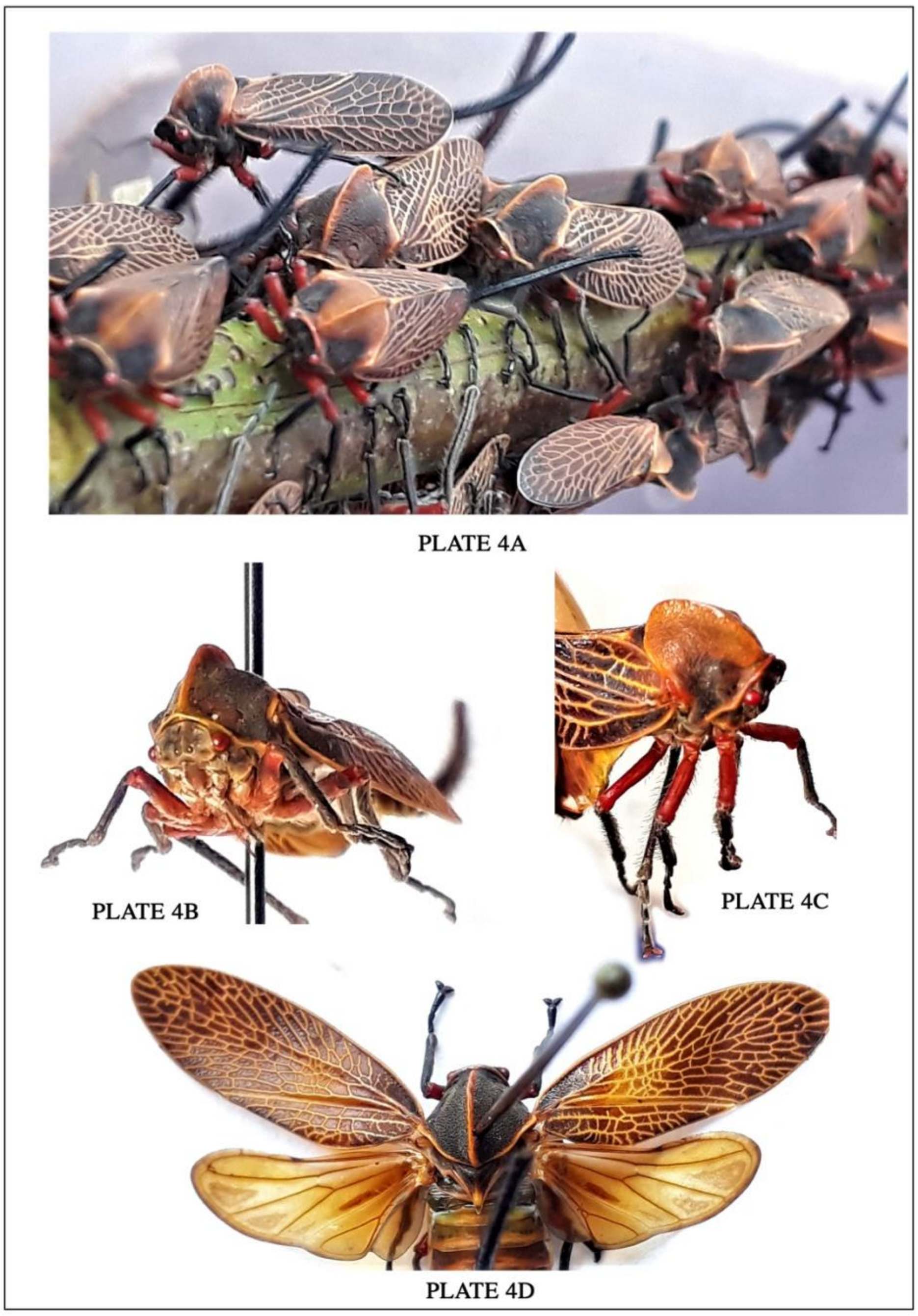
Body length: Male 30 mm, Female 26 mm

Length from frontal margin to tips of tegmina 15 mm; length of hindwing 12 mm;

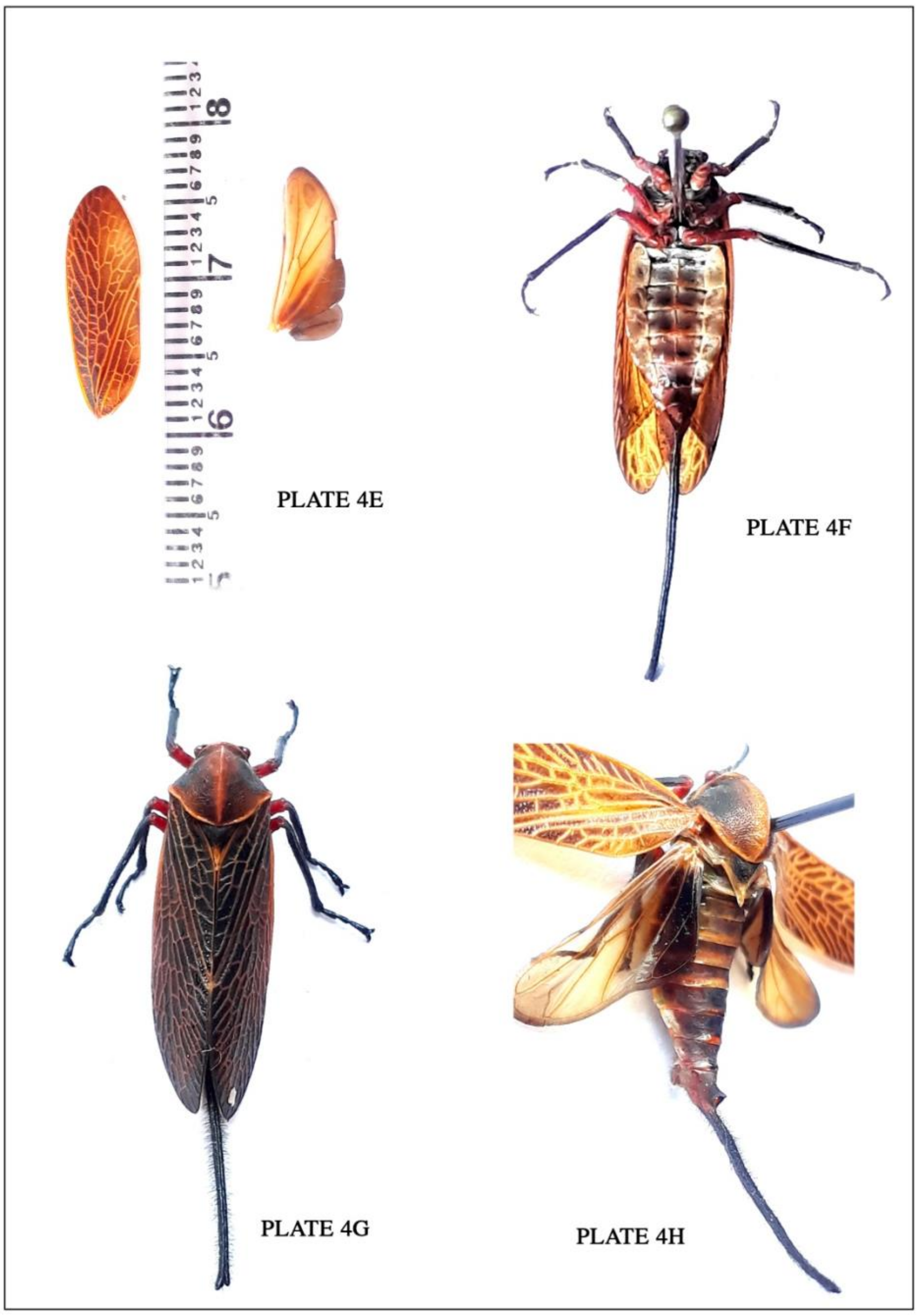
Length of abdominal posterior process 12-14 mm.

Distribution:

Place	**Latitude**	**Longitude**	**Altitude MSL (in Metres)**
Sathaka (Zunheboto)	25°55'42.07"N	94°26'43.13"E	1646
Bayavu Hill (Kohima)	25°41'12.49"N	94°06'13.04"E	1485



Diagnostics of *Darthula hardwickii:*
PLATE 4A - Crawling Leafhoppers on a branch of Alder tree.
PLATE 4B - Head directed backward towards frontal margin of pronotum
PLATE 4C - Pronotum (Lateral view)
PLATE 4D - Pronotum & Scutellum



Diagnostics of *Darthula hardwickii:*
PLATE 4E - Tegmina & Hindwings
PLATE 4F - Abdomen (ventral
PLATE 4G - Claws very robust, dull black
PLATE 4H - Abdomen (dorsal)

PLATE 4I

PLATE 4J

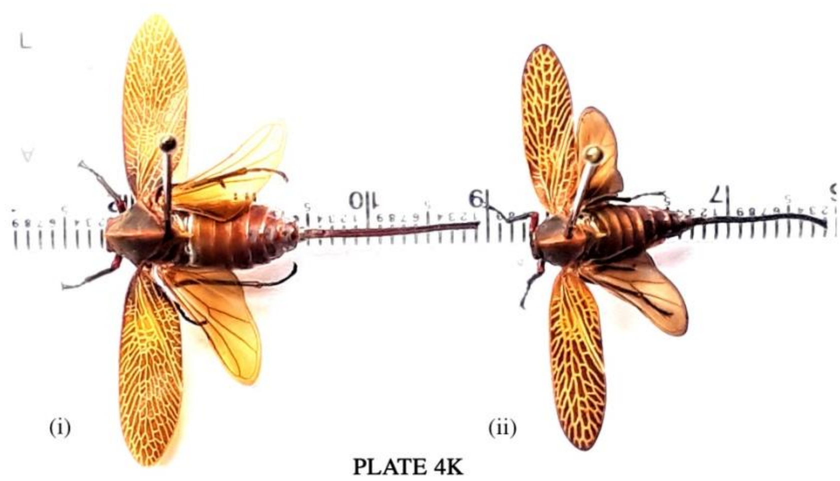


PLATE 4K

Diagnostics of *Darthula hardwickii:*
PLATE 4I - Appendages
PLATE 4J - Apical piceous process, bituberculate
PLATE 4K - Female (i) & Male (ii)

5. ***Pomponia linearis*** **Walker (1850)**

ZSI Regd. no: 15433/H15

1850. *Cicada linearis* Walker: 48. holotype: '8. Dundubia linearis, Mas', '445', '= cinctimanus&ramiferaStol.

1905. Pomponiafusca: Jacobi, *ZoologischeJahrbücher,* 21: 425–446.

1923. *Pomponia linearis*: Moulton: Cicadas of Malaysia. *Journal of the Federated Malay States Museum*, 11: 69-182, Pls. 1-5.

1963. *Pomponia linearis partim*: Metcalf, *Tibiceninae,* 845-849.

1978. *Pomponia linearis*: Hayashi, 174, fig. 16A (Central Nepal) Pomponia linearis: 174, fig. 16A (Central Nepal).

2006. *Pomponia linearis*: Duffels, & Hayashi, Pomponiapicta (Walker) (= P. fusca (Olivier)) and *P. linearis* (Walker). *TijdschriftvoorEntomologie*, 149: 189-201, figs. 1-13.

2007. *Pomponia linearis*: Sanborn *et al*.; Biodiversity… Thailand (Hemiptera: Cicadoidea: Cicadidae). *Zootaxa*, 1413: 1-46.

2008. *Pomponia linearis*: Lee, *Zootaxa,* 1787: 9.

2009. *Pomponia linearis*: Pham & Yang, A contribution to the Cicadidae fauna of Vietnam (Hemiptera: Auchenorrhyncha); *Zootaxa,* 2249:1–19.

2010. *Pomponia linearis*: Lee, *Zootaxa,* 2487: 21.

Common name: Cicada

Diagnostic Characters

General appearance: Ground colour brown yellowish

Head: Plate A & B. Triangular, as wide as pronotum and mesonotum; lateral parts of head and supra-antennal plates brownish ochraceous, remaining surface of vertex, between central brown mark and lateral brownish colouration, greenish yellow with a pair of small drop-shaped spots just below level of paired ocelli; distance between lateral ocelli and eyes about twice as wide as distance between lateral ocelli; dorsal side of head with more or less distinct brown to dark brown median mark enclosing ocelli, and broad brown to dark brown fascia along posterior margin of head.

Thorax: Plate5C. Ground colour brown yellowish, pronotum collar with greenish tinge, 80-90% of dorsal surface of thorax covered with brown or sometimes dark brown marking.

Pronotum: Plate 5C. Pronotum collar with a curved, dark brown bands along anterior margins of these large brown pronotal marks; Central fasciae brown to dark brown, narrowest at one-third of length from base, gradually widened to dark brown anterior pronotal margin, and strongly widened proximad to ambient fissure of pronotum; proximal ends of both central fasciae fused in a dark brown median triangle on pronotum collar. A pair of narrow dark brown stripes above, and another pair below, proximal parts of anterior oblique fissures. Two pairs of large, uniformly brown, marks enclosed respectively by anterior and posterior oblique fissures and by posterior oblique fissures and ambient fissure. Anterolateral margin of pronotum collar with obtuse tooth. A narrow brown fascia along anterolateral margin ends in a large, brown to dark, brown spot on posterolateral part of pronotum collar

Mesonotum: Plate 5D. Median fascia brown, narrowest at anterior mesonotal margin and strongly widened to a triangular mark on anterior half of mesonotum.

Paramedian: Plate 5D. Obconical marks with narrow, brown, median margins and much broader, dark brown, lobate lateral margins, and reaching to three-fifths of mesonotum length; center of obconical marks yellowish. A pair of very narrow twotipped brown stripes, between obconical marks and lateral fasciae, reach from anterior mesonotal margin to one-third or one-fourth of mesonotum length; mid-distal part of mesonotum in front of cruciform elevation with a pair of fused, strongly enlarged, round, brown to dark brown marks. Lateral fasciae very broad, brown to dark brown, reaching from anterior to posterior mesonotal margin.

Wings: Plate 5A, E & F. Tegmina with a distinct infuscation at base of second apical area and with another infuscation connecting the infuscate bases of third, fourth and fifth apical areas; basal vein of sixth and seventh apical areas faintly infuscated; crossings of nodal line with upper and lower branch of median vein, and basal vein of eighth apical area lightly infuscated; apices of longitudinal veins of apical areas with brown infuscations; third infuscation twice as long as other marginal infuscations.

Venation: Plate 5E. In basal half of tegmen dark brown variegated with yellow, in apical half light brownish; venation of wings pale brown.

Legs: Plate 5E & G. Yellowish tinged brown; fore femora with subapical, ochraceous to dark brown mark on outer side and with light brownish streaks on upperside. Underside with three spines: a slightly adjacent, conical spine at one third of length from base, a flat, triangular spine at three-fourths of length and a subapical, small, conical spine. Fore tibiae brownish, middle tibiae with a brown ring at one-sixth of length from base and with brown subapical one-third. Hind tibiae with basal one-sixth brown and subapical brown ring; Hind femora with brownish streak on apical half or one-third of posterior side; Tarsi of fore and middle legs brown, tarsi of hind legs yellowish.

Abdomen: Plate 5E. Dorsal surface light castaneous, posterior part of segment 7 and whole segment 8 often uniformly dark brown; posterior rims of all tergites dark brown, ventral surface uniformly light brown; widest at hind margin of segment 3.

Timbal cover/operculum: Plate 5G. Greenish ochraceous, rim brown to dark brown from one fourth of lateral margin to about half-length of distal margin, broader than long, reaching just beyond hind margin of abdominal segment 2, with weakly concave lateral margin, weakly convex medial margin, and strongly convex anterior margin.

Measurement:

Body length: Male 49 mm, Female 44 mm

Length of tegmina: 50-55 mm

Distribution:

Place	**Latitude**	**Longitude**	**Altitude MSL (in Metres)**
Asuto Area (Zunheboto)	26°07'06.17"N	94°38'55.52"E	1507
Meriema (Kohima)	25°42'49.88"N	94° 5'28.24"E	1477

PLATE 5A

PLATE 5B

PLATE 5C

PLATE 5D

Diagnostics of *Pomponia linearis:*
PLATE 5A - Head, triangular, as wide as pronotum and mesonotum
PLATE 5B - Distance between lateral ocelli and eyes about twice as wide as distance between lateral ocelli
PLATE 5C - Thorax
PLATE 5D - Mesonotum & Paramedian

PLATE 5E

PLATE 5F

PLATE 5G

Diagnostics of *Pomponia linearis:*
PLATE 5E - Wings (dorsal)
PLATE 5F - Wings (Ventral)
PLATE 5G - Appendages & Timbal cover

6. ***Aeolesthesholosericea*Fabricius (1787)**

ZSI Regd. no: 29509/H4A

1787. *Aolesthesholosericea,* Fab. (Cerambyx) *Mant. Ins*. i, p. 135.

1865. *Pachydissusvelutitnus*: Thoms. *Syst. Ceramb*. p. 576.

1890. *Pachydissussimilis*: Gahan, *A. M. N. H.* (6) v, p. 52.

1889. *Neocerambyxholosericeus,* Cotes, *Ind. Mus. Notes*, i, no. 2, pp. 60 & 89, pI. 5, fig. 3.

1906. *Aeolesthesholosericea*: Gahan, Fauna British India, Cerambycidal. *Zool. Surv. India*, 1: 127.

1914. *Aeolosthesholosericea*: Stebbing, *Indian Forest Insects* (Coleoptera): 301- 305.

1939. *Aeolesthesholosericea*: Beeson and Bhatia, *Indian Forest Records* (New Series) *Entomology*, S(1): 15-16.

1945. *Aeolesthesholosericea* F.: (Cerambycidae: Coleoptera), Khan & Khan, *Proc. Indian Acad. Sci.*, Section B, 15: 181–185.

1959. *Aeolosthesholosericea*: Shexiang*et al*., Beijing. *Science Press*, 1-120.

2008.*Aeolesthes (Aeolesthes) holosericea:* Makihara*et al*., Bulletin of the FFPRI., Vol.7 No.2 (407): 99.

Common name: Wood borer

Diagnostic Characters

General appearance: Plate 6A& G. Moderately long, somewhat parallel-sided, dorsal surface blackish to reddish brown, covered with greyish or golden brown silky pubescence.

Head: Plate 6B. Head moderately long and narrow, eyes coarsely facetted and anterior part of head somewhat wrinkled. There is a longitudinal ridge/groove between the compound eyes in the center of the head.

Antennae: Plate 6C & D. Antennae with a thinner and more uniform greyish pubescence; third joint of the antennae smooth, gradually thickened at the apex; antenna of male, markedly long, joints 1-5 slightly thickened, joints 5-11 progressively long and thin, and joint 11 twice as long as joint 10; female antennae are shorter and slightly longer than the body.

Thorax: Plate 6A& B. Prothorax rounded at each side; as broad as long, irregularly wrinkled above, lateral margins slightly wavy, with a subcentral smooth space which is limited on each side by a longitudinal impression and marked sometimes, especially near its anterior end, with a median groove; prothorax covered with very fine silky pubescence; scutellum transverse, triangular and covered with 'whitish pubescence.

Elytra: Plate 6A.the elytra exhibit bands or patches, some duller, some brighter, like watered silk, which change in brilliancy according to the incidence of the light; dorsal surface of elytra covered with fine silky pubescence in patches, apex truncated, the base end of the elytra is slightly wider than the end, the two sides are parallel.

Legs: Plate 6E& G. Legs moderately long covered with a thinner and more uniform greyish and whitish pubescence.

Abdomen: Plate 6F.The front chest is slightly wider than long, with rounded sides; the front chest back panel has irregular folds, and the rectangular area in the center of the rear end is slightly wrinkled, except for the longitudinal grooves on both sides.

Measurement:

Body length: Male 30 mm, Female 32 mm

Length of Antennae: Female 34 mm (Plate 6C), Male 50 mm (Plate 6D)

Distribution:

Place	**Latitude**	**Longitude**	**Altitude MSL (in Metres)**
Phesama (Kohima)	25°37'37.23''N	94°06'54.88''E	1568
Akuluto (Zunheboto)	26°10'21.82''N	94°29'42.98''E	1132

PLATE 6A

PLATE 6B

PLATE 6C

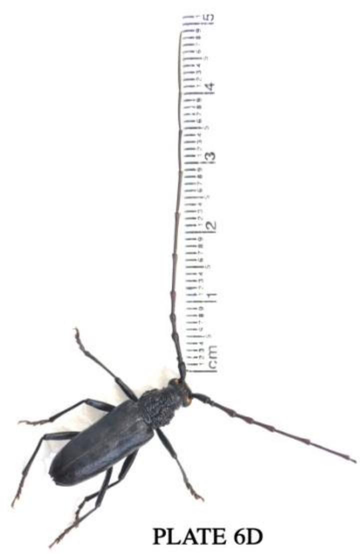


PLATE 6D

Diagnostics of *Aeolesthes holosericea:*
PLATE 6A - Body covered with greyish or golden brown silky pubescence
PLATE 6B - Head
PLATE 6C - Antennae Female
PLATE 6D - Antennae Male

PLATE 6E

PLATE 6F

PLATE 6G

Diagnostics of *Aeolesthes holosericea:*
PLATE 6E - Appendages
PLATE 6F - Abdomen (ventral)
PLATE 6G - Body moderately long, somewhat parallel-sided 6Ha

7. ***Aplosonyxchalybaeus*Hope (1831)**

ZSI Regd. no: 29508/H4A

1831. *Callerucachalybaeus* Hope, in Gray's, *Zool. Miscellany,* London, 1831: 28.

1936. *Aplosonyxchalybaeus*: *Maulik, Fauna Brit. India, Chrysomelidae: Galerucinae, London:* 614.

1963. *Aplosonyxchalybaeus*: Gressit and Kimoto, *Pac. Ins. Mon.,* 1 (B): 653.

1967. Kimoto, Zoological, Museum, Berlin.*Esakia* 27: 1-241.

1892. *Haplosonyxchalybaeus:* Hope, *Ann. Soc. Ent. Belg.* 34: 440.

1863. *Aplosonyx elongate:*Baly. *Trans. Ent. Soc. Lond.* 3(i): 6 24.

1886. New species of Galerucinae: Baly. *Zool. J. Linn. Soc,* 20: l-27.

1889. Notes on Aulacophora and allied genera: Baly. *Trans. Ent. Sot. London*: 297-309.

Common name: Beetle, Grub, Corm borer

Diagnostic Characters

General appearance: Plate 7A.Body moderately oblongated, metallic or shining blue-green elytra, golden reddish, ochraceous head and brown and violet tinge antennae.

Head: Plate 7B**.** Head distinctly broader than long, anteocular distance about half the length posterior of head including eyes, upper surface background finely shagreened, sparsely and finely punctate; frontal tubercles broad, flattened, a depression behind them. Eyes not strongly convex, raised area on which each eye is placed rather prominent.

Antenna: Plate 7C. Antenna not very long nor very robust, generally extending to the middle of elytron; antennae 11-segmented, generally the three basal segments shining, the rest dull and thickly covered with short hairs; first segment long and cup-shaped; second small and rounded, third slightly more than twice as long as second; fourth much longer than third; fifth somewhat shorter than fourth; sixth slightly shorter than fifth; seventh slightly shorter than sixth; eighth slightly shorter than seventh; eighth, ninth and tenth equal; eleventh somewhat longer than tenth and bluntly pointed at the apex; basal shortest, second longest; fifth to eighth segments black.

Thorax: Plate 7D.Pronotum almost rectangular-shaped, length shorter than broad. Each lateral margin more strongly convex before the middle, a certain area on inner side of this strongly convex margin is conically raised, between it and the middle is another smaller conically raised area, so that in front of the transverse middle line are four raised areas. Across the middle a transverse depression, the depression always containing large strongly impressed punctures. Scutellum triangular-shaped, slightly longer than broad, apex truncate and the surface finely shagreened and impunctate.

Elytra: Plate 7E.Each elytron, with about eight irregular double rows of punctures, counting the rows from the suture; the punctures are deeply impressed holes, becoming very fine and confused on the apical area. Elytra large, broad at base, apex rounded.

Legs: Plate 7A & F.Apices of tibiae and tarsi black with a metallic sheen; legs long, slender; hind tibia somewhat longer than either the middle or front tibia, first segment of hind tarsus slightly longer than the corresponding segment of either the middle or front tarsus, second segment of tarsus shorter than first, third deeply bilobed, claw-segment long and projecting much beyond the bilobed segment; claws appendiculate.

Abdomen: Plate 7G.Abdomen: Convex beneath, basal segment truncately produced.

Measurement:

Body length: 16 mm

Length of antennae: 8 mm

Distribution:

Place	Latitude	Longitude	Altitude MSL (in Metres)
Sungratsu (Mokokchung)	26°23'37.20''N	94°33'09.84''E	1023
Khensa (Mokokchung)	26°20'45.41''N	94°29'21.60''E	1217
Chungtia (Mokokchung)	26°22'59.40''N	94°26'33.15''E	998
Lumami (Zunheboto)	26°12'34.40''N	94°28'32.34''E	1072
Merhulietsa (Kohima)	25°39'50.37''N	94°05'35.66''E	1424

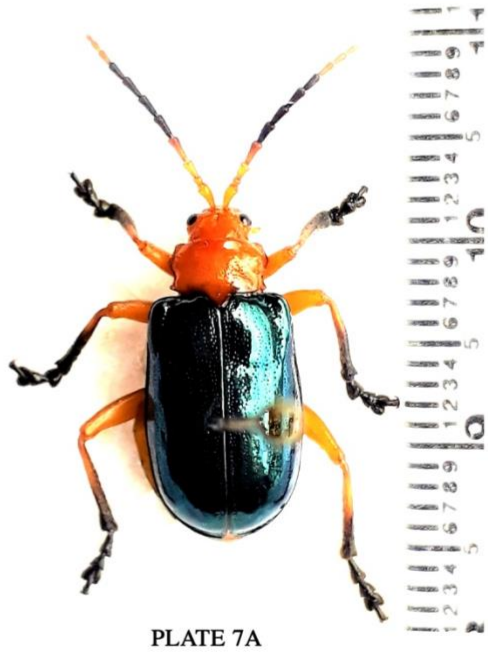


PLATE 7A

PLATE 7B

PLATE 7C

PLATE 7D

Diagnostics of *Aplosonyx chalybaeus:*
PLATE 7A - Body moderately oblongated, metallic or shining blue-green elytra, golden reddish
PLATE 7B - Head
PLATE 7C - Antennae
PLATE 7D - Thorax

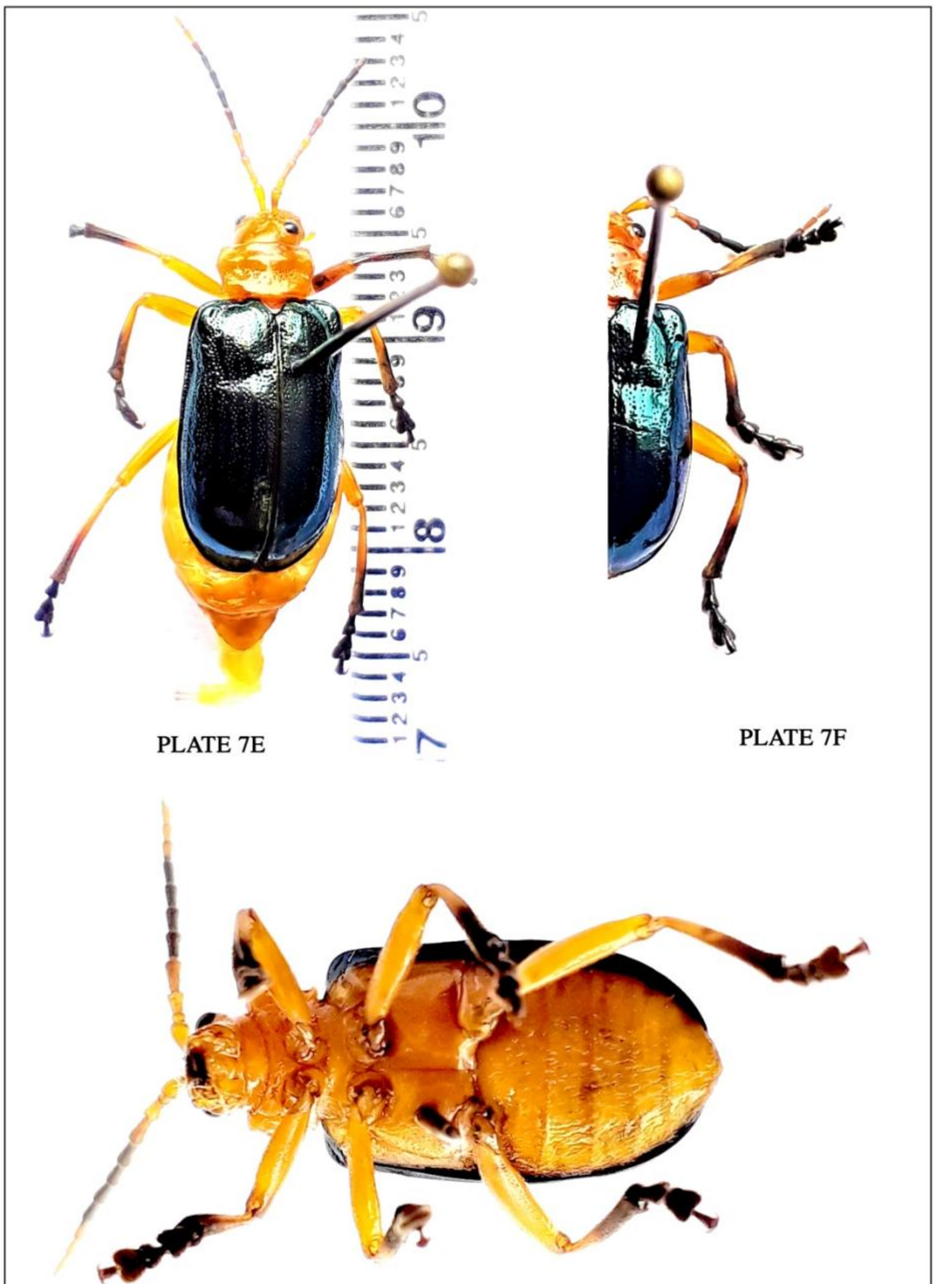


PLATE 7E

PLATE 7F

PLATE 7G

Diagnostics of *Aplosonyx chalybaeus:*
PLATE 7E - Elytra
PLATE 7F - Appendages
PLATE 7G - Abdomen (ventral)

8. ***Andraca Sp.*****Walker (1865)**

ZSI Regd. no: 11446/H10

1865. *Andraca* Walker, List specimens lepid. *Insects Colln Br. Mus*. 32: 581.

1887. *Andracabipunctata*: Wlk. Cat. xxxii, p. 582; C.& S. no. 1328.

1894. *Andracabipunctata:* Hampson, The fauna of British India, including Ceylon and Burma. Moths-Vol.I. *Zool. Surv. India*, pp.30 - 41.

*1976. Andracaapodecta*Swinhoe: Holloway, *Malayan Nature Society*: 85.

1995. Andracaflavamaculata: Yang, *Insects of Baishanzu Mountain, Eastern China*: 354.

2002. Andracanabesan: Owada*et al*., *Spec. Bull. Jpn. Soc. Coleopterol*., (5): 464.

*2009. Andracaapodecta*Swinhoe: Zolotuhin& Witt, *Entomofauna*, Suppl. 16: 261- 262.

2011. Genus *Andraca:* Wang, *et al.*,ZooKeys, (127): 29–42.

2016. Andracayauichuisp: Wu & Chang, *Zootaxa*, 4200 (4): 515–522.

2020. *AndracaBipunctata*: Pande *et al*., *Journal of environmental biology*, 41: 782-787.

2021. *Andraca:* Chandra *et al.*, Faunal Diversity of Agroecosystems in India. *Zool. Surv. India*: pp.14.

Common name: Glory Moths, bunch caterpillars, leaf feeder.

Diagnostic Characters

General appearance: Plate 8A.Ground color varying from shades of brown, chestnut-brown to orange-brown.

Body shape: Plate 8A & 8B. The male adults of this species are about 15-18 mm long, and the females are about 18-26 mm; the male body and wings are dark. Brown, chestnut-brown or orange-brown in females.

Head: Plate 8A & 8B.Head densely covered with dark brown hairs.

Antenna: Plate 8C & 8D.Male: Antenna bipectinate except apex; antenna length 6–8 mm; female filiform.

Wings: Plate 8C & E. Forewing apex inconspicuously falcate, exterior margin straight, the outer margin smooth suffused with grey. Forewing and hindwing each with a black discal spot. The darker fascia and discal spot having pale grey scales associated with them The inner edge of hindwing is wrinkled, Underside: hind wing with the lines more prominent and hardly waved.

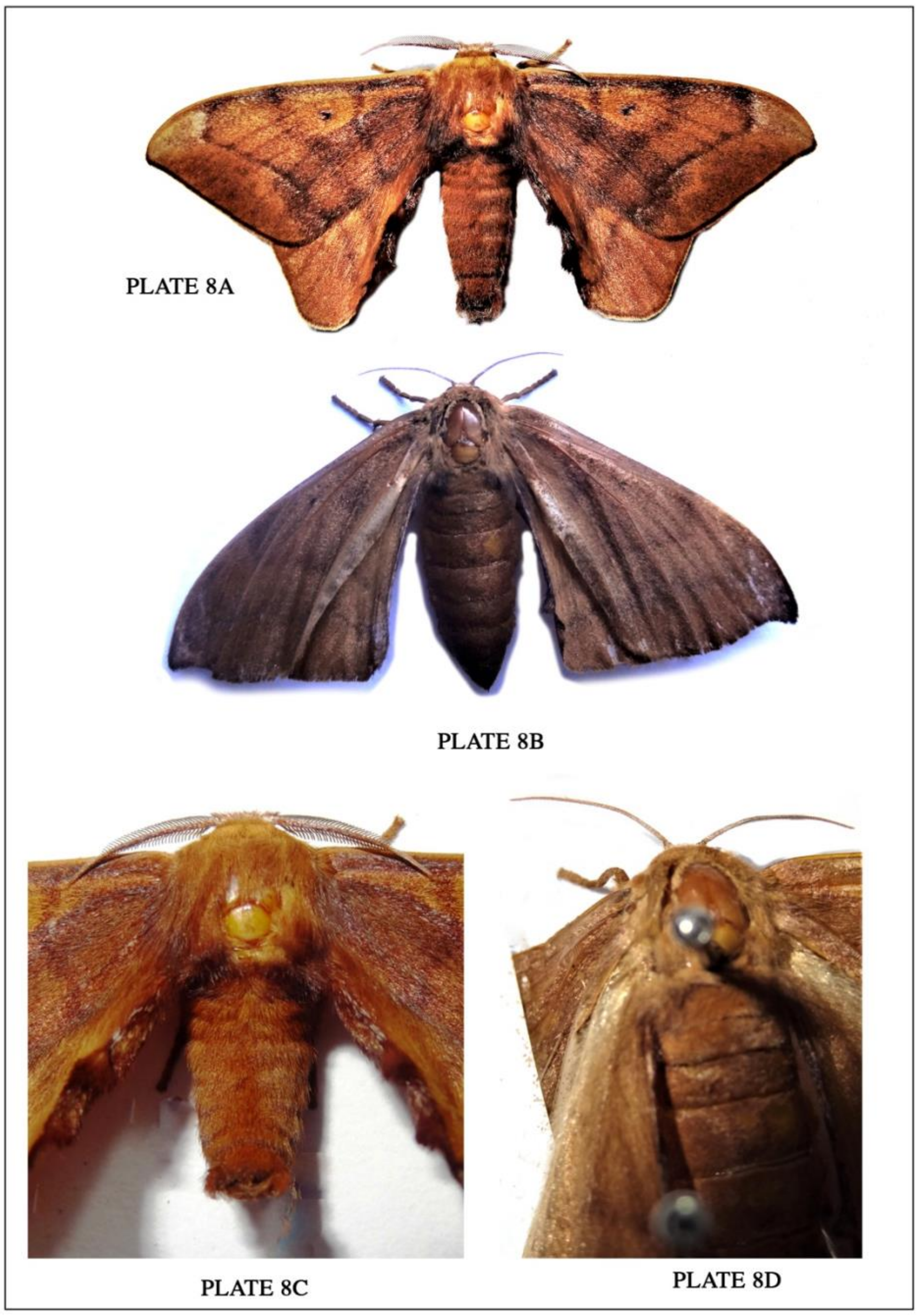
Difference: Plate 8F & 8G.The female is larger, paler, but similarly fascinated.

Measurement:

Body length: Male 16 mm; Female 24 mm

Distribution:

Place	**Latitude**	**Longitude**	**Altitude MSL (in Metres)**
Lumami (Zunheboto)	26°12'34.40"N	94°28'32.34"E	1072
Sungratsu (Mokokchung)	26°23'37.20"N	94°33'09.84"E	1023
Chungtia (Mokokchung)	26°22'59.40"N	94°26'33.15"E	998



Diagnostics of *Andraca sp*.
PLATE 8A - Body-chestnut-brown to orange-brown
PLATE 8B - Head
PLATE 8C - Male Antennae
PLATE 8D - Female Antennae

PLATE 8E

PLATE 8F

PLATE 8G

Diagnostics of *Andraca sp*.
PLATE 8E - Wings (ventral)
PLATE 8F - Andraca Male
PLATE 8G - Andraca Female

9. ***Cossus Sp.*****Fabricius (1793)**

ZSI Regd. no: 11447/H10

1794. Cossus, *Fabr. Ent. Syst.* iii, pt. ii, p. 3.

1867. Brachylia, *Feld. Reis. Nov. Lep. 4tl.* pI. 82, fig. 7, *Erk.* p. 2.

1892. Cossus Genus, Hampson, Moths Vol. 1. London, *Taylor & Francis,* pp. 303-305.

1976. Taxonomic revision of the Indian species of the family Cossidae: Arora, *Rec. Zool. Surv. India*, 69(1–4):160.

2006. Carpenter worm: Walker, PaDIL - http://www.padil.gov.au

Common name: Wood borer, Carpenters worm

Diagnostic Characters

General appearance: Plate 9A & 9B.Body is heavily covered with grey-silver hairs with legs banded.

Head: Plate 9C & D.Palpi slight and flattened in front of face; Proboscis absent.

Antenna: Plate 9A & 9E.Antennae unipectinated with distal half in male, wholly simple in female (filiform).

Wings: Plate 9F, G & H. Forewings with mottled colours of grey, ash, brown and white. Forewing with vein 11 given off from the subcostal nervure; each forewing with two distinct triangles (one in the chorda - the base of the R veins; and a second at the base of the CuA and CuP veins) of white, yellow and black scales; an areole formed by veins 7 and 10; veins 7 and 8 forking after the areole; with no bar between veins 7 and 8; vein 8 free from the base. Hind wing dark red brown; the inner margin black, suffused with grey scales; underside of hind wing with the lines more prominent and hardly waved; the outer margin suffused with grey.

Legs: Plate 9E.Legs banded; mid tibiae with one, hind tibiae with two pairs of minute spurs.

Abdomen: Plate 9H & I.The side of the abdomen has banded black and brown hair.

Measurement:

Body length: Female 30-40mm; Male 34- 49mm Males

Distribution:

Place	**Latitude**	**Longitude**	**Altitude MSL (in Metres)**
Phesama (Kohima)	25°37'37.23"N	94°06'54.88"E	1568
Viswema	25°33'45.44"N	94° 8'46.64"E	1658
Kuzama	25°32'5.01"N	94° 8'4.51"E	1718

PLATE 9A

PLATE 9B

PLATE 9C

Diagnostics of *Cossus sp*.
PLATE 9A - Antennae filiform (Female)
PLATE 9B - Body is heavily covered with grey-silver hairs
PLATE 9C - Palpi erected

PLATE 9D

PLATE 9E

PLATE 9F

Diagnostics of *Cossus sp*.
PLATE 9D - Palpi flettened in front of face
PLATE 9E - Unipectinated Antennae in Male moth
PLATE 9F - Forewing -an areole formed by veins 7 and 10

PLATE 9G

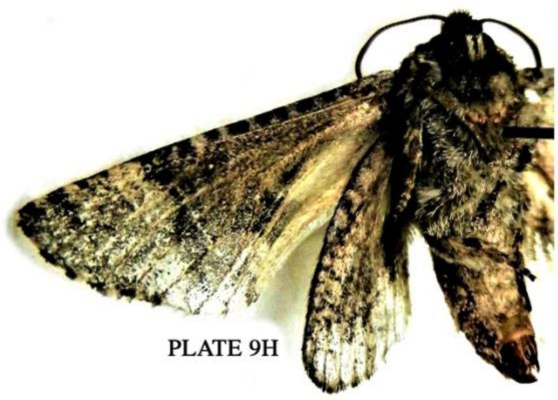


PLATE 9H

PLATE 9I

Diagnostics of *Cossus sp*.
PLATE 9G - Wings- underside of hind wing with the lines more prominent and hardly waved
PLATE 9H - Abdomen (lateral view)
PLATE 9I - Abdomen (ventral)

10. ***Vespa mandarinia* Smith (1852)**

ZSI Regd. no: 28377/H3

1852. *Vespa mandarinia* Smith, Downes, *Ann. Mag. Nat.Hist.* 9 (2): 44-50.

1852. *Vespa mandarinia* Smith, *Trans. Ent. Soc. Lond.* 2 (2): 38, pI. VIII fig. 1.

1959. *Vespa (Vespa) mandariniamagnifica*Smith: van der Vecht, *Zool. Meded.,* 36 (13): 220.

1897. Fauna of British India, including Ceylon and Burma. Wasps and Bees. *Taylor and Francis, London*.

1986. A field key to the hornets *(Vespa)* of India. *Ann. Ent.* 4 (l): 51-52.

1989. The social wasps of India and the adjacent countries (Hymenoptera: Vespidae). *Oriental Insects Mon.* 11: 1-292.

2000. *Vespa (Vespa) mandariniamagnifica*Smith: Jonathan *et al., Zool. Surv. India, State F.,* 4(7): 117-160.

2003. State Fauna Series 9, Fauna of Sikkim. Alfred. *Zool. Surv. India,* Kolkata, (Part-4) 1-512.

2010. *Vespa mandarinia* Smith: *Rec. Zool. Surv. India:* 110 (Part-2): 57-80.

2017. *Vespa mandarinia* Smith: Hymenoptera: Vespinae: *Journal off Threatened Taxa,* 9(4): 10102–10108, Image 1. A, B & C.

Common name: Giant hornet, Hornet wasps

Diagnostic Characters

General appearance: Plate 10A. Large black wasp with orange red head.

Head: Plate 10A, B & C.Head orange red and strongly widened and produced behind eyes; gena enlarged behind the eyes; at least 1.8 x as wide as the eye; scape orange red; flagellum black; area around ocelli without black markings; proportionately wider gena; clypeus coarsely punctate; lateral lobes largely and broadly rounded.

Thorax: Plate 10A**.** Orange red and black markings crisscross across middle 2/3 from anterior.

Wings: Plate 10D. Wings fuscous brown;

Abdomen: Plate 10D & E. Abdomen or gaster reddish-brown with narrow yellowish apical bands on 1^{st} – 5^{th} terga, and last (6^{th}) tergum orange-yellow.

Measurement: Plate 10F.

Body length: Female 50mm; Male 42 mm

Distribution:

Place	**Latitude**	**Longitude**	**Altitude MSL (in Metres)**
Kohima (Jotsoma)	25º40’21 “N	94°03’47”E	1472
Zunheboto Town	26° 0'37.55"N	94°31'22.46"E	1840
Longjang (Mokokchung)	26°27'15.22"N	94°32'55.20"E	774

PLATE 10A

PLATE 10B

PLATE 10C

Diagnostics of *Vespa mandarinia*
PLATE 10A - Giant Hornet with orange red head
PLATE 10B - Head (front view)
PLATE 10C - Antennae & Ocelli

PLATE 10D

PLATE 10E

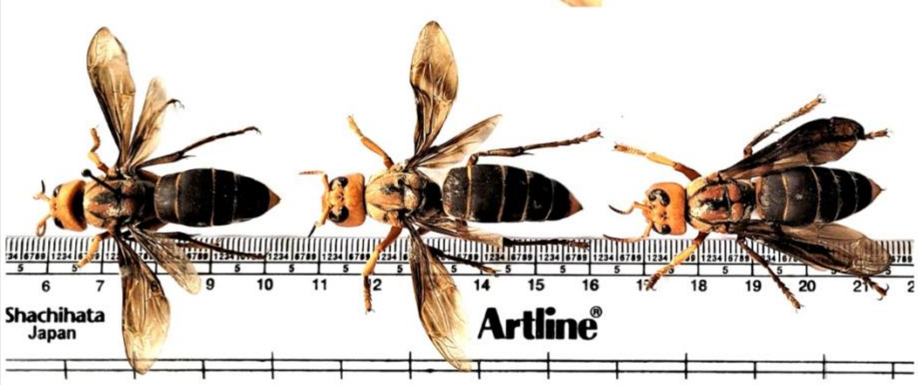


PLATE 10F

Diagnostics of *Vespa mandarinia*
PLATE 10D - Wings
PLATE 10E - Abdomen (lateral view)
PLATE 10F - Different types of wasp caste A. Fertile female ; B. Sterile female ; C Male

CHAPTER FOUR

RESULTS AND DISCUSSION

Survey analysis

During the survey ten (10) insects which are commonly used for consumption by the indigenous people of Angami, Ao and Sema tribes in the four districts of Nagaland were identified and addressed as identified edible insects (IEIs). These IEIs belong to 10 genera, 6 orders and 10 families with 1 species from Orthoptera, 3 species from Hemiptera, 1 species from Homoptera, 2 from Coleoptera, 2 from Lepidoptera and 1 from Hymenoptera as shown in Table 1. The table also shows the traditional knowledge of use of the IEIs as food, period of occurrence, procured wild or reared, part eaten, edible stage, medicinal value and preparation method.

Piechart 1shows percentage of consumption by Taxa Order of the IEIs with Lepidoptera and Hymenoptera having 22.86% each followed by Coleoptera having 18.37%, Hemiptera with 17.96%, Orthoptera with 10.20% and lastly Homoptera with 7.76%. *D. Hardwickii*, an Hemipteran was documented for the first time as insect food (Pongener*et al.*, 2019a) from Nagaland.

Figure 1 represents percentages calculated from the responses given by the 600 respondents on the knowledge of use of the IEIs as food, medicine, consumption of the insects, awareness of nutritional values and side effects of consumption. Awareness of use of these 10 IEIs was 100% for all except *T. javanica* with 91%. 5 of the IEIs were reported for use as medicine namely *Cossus sp.* (90%), *C. singhalanus* (33%), *A. holosericea* (17%), *D. hardwickii* (10%) and *T. javanica* (9%). Awareness of its nutritional values was also quite notable with *Cossus sp*. (100%), *V. mandarinia* (93%), *A. holosericea* (75%) and the others standing between 12-42% whereas for 2 of the IEIs namely *T. javanica* and *D. hardwickii* it was zero percent. The consumers also reported on experiencing side effects, a sort of allergic reaction on consumption of 6 IEIs namely *Andraca sp.* (50%), *T. javanica*(37%), *V. mandarinia*(35%), *A. holosericea* (27%), *C. singhalanus* (23%) and *Cossus sp.* (19%).

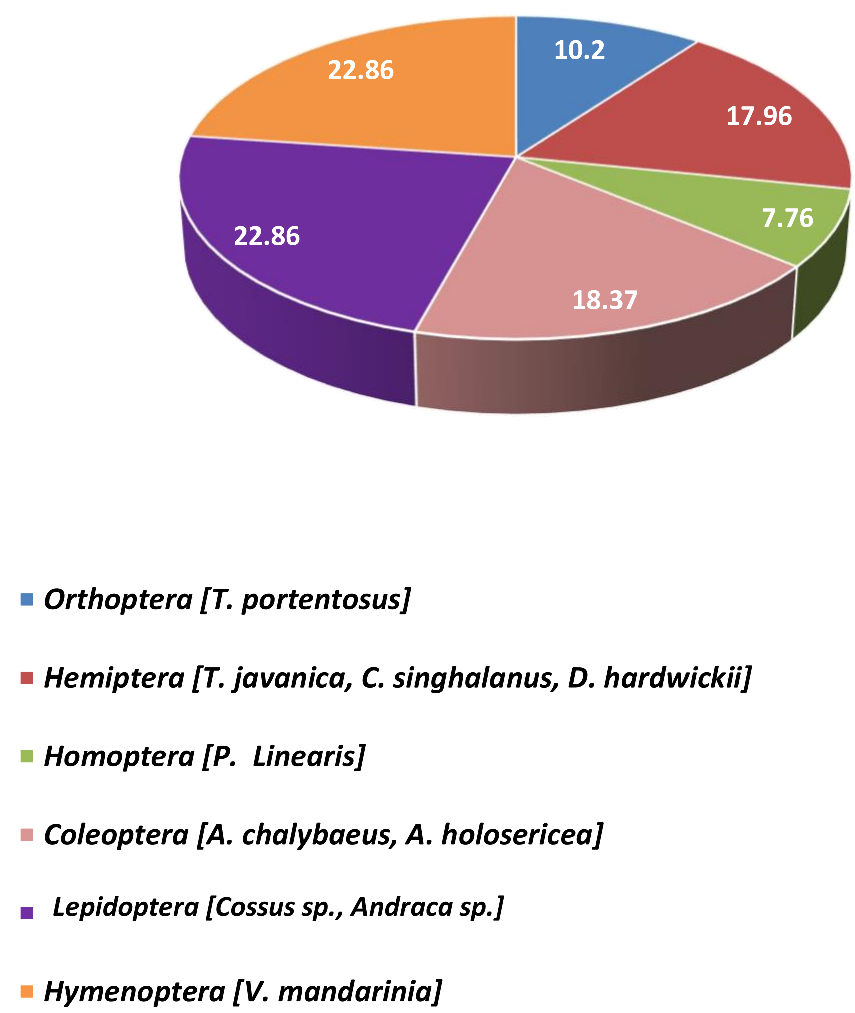
Data shows *V. mandarinia* is the most popular and highest amongst the insects consumed with 95% followed by *A. holosericea* (73%), *T. javanica*(55%), *T. portentosus* (54%), *Andracussp* (52%), *C. singhalanus*(49%), *Cossussp*.(48%), *P. linearis* (47%), *D. hardwickii*(22%), and the least favoured food insect with 9% is *A. chalybaeus.*

The reason for the high percentage *V. mandarinia*consumption is that it is a much-sought food item with delicious flavor. The local names of the giant hornet are *Kwiti/Phiti* (Angami), *Nati* (Ao), and *Nati/Akiri* (Sumi) *(Photo 1).* The ethnic groups in Nagaland consider giant hornets as a gourmet dish and a small hive may cost around Rs. 3000 whereas a large hive can fetch between ₹. 5000-7000 (Pongener*et al.* 2019a). Even though it is the costliest in comparison to the prices of the other insects, it is still in great demand and one always gets a means to procure it for consumption. The reasons given by the respondents for its high cost are (a) risk factor of getting stung while handling it (could sting a man even to death if severe), (b) the rarity of the wasp and (c) the degree of difficulty in its semi domestication. Moreover, semi-domestication is practiced by just a handful of indigenous people leading to a low harvest rate, hardly able to meet the demand of the population. However collection sites are usually easily accessible to indigenous people who know the habits of this species well and are aware of their nesting places and when, where and how to best collect them (Bendang and Aokumla, 2013; Kiewhuo*et al.,* 2021). People consider wasps to be a healthy food, rich in essential nutrients, and a good protein source. In rural Japan people believe that eating wasps can aid stamina, and belong to a larger category of ‘virile’ foods (Payne and Evans, 2017). *V. mandarinia* is available throughout the year, but it is found in the market mostly from August to December.

Table 1: Tabulation of Knowledge of Use of the Identified Edible Insects (IEIs) as Food, Period of Occurrence, Wild or Reared, Part Eaten, Edible Stages, Medicinal Value and Preparation Method.

Scientific name		***Tarbinskiellu sportentosus***	***Tessaratomaj avanica***	***Coridiussing halanus***	***Darthulahar dwickii***	***Pomponia linearis***	***Aeolesthesho losericea***	***Aplosonyxch alybaeus***
Vernacular name	Ao	Yimpichokok	Tsuknu, Tsungi	Bholo	Atsurangdang, Longmi	Loyang/ Jangjangkok	Tsuka	Melongtevu
	Angami	Petoa	Kongya	Poluo	Teiziteipu	Chievutuo	Jevisenoali	Tzununokhu
	Sumi	Awusho	Akhano, Michika	Akhano	Shothapo, Lakha	Zuwu, Choi	Aphisukulho	Akhala
Order		Orthoptera	Hemiptera			Homoptera	Coleoptera	
Family		Gryllidae	Pentatomidae	Dinidoridae	Aetalionidae	Cicadilidae	Cerambycidae	Chrysomeli
Period of occurrence		May - July	Jun – Sep	Nov - Feb	Mar-Jun	Jun - Aug	Jul - Oct	May - Aug
Is it reared/ cultured		No	No	No	No	No	No	No
Part eaten		Whole	Whole	Whole	Whole	Whole	Whole	Whole
Edible stage		Adult	Adult, Nymph	Adult, Nymph	Adult, Nymph	Adult, Nymph	Larva, Pupa	Larva
Medicinal value			Wart removal	Hypertension	High blood pressure & Diabetes		Malnutrition, mouth sores & ulcer	
Preparation		Roasted or fried	Dried and fried	Dried, fermented and roasted	Dried and roasted	Roasted or fried	Roasted or fried	Dried and fried or steamed
Catching method		Pouring hot water into the hole and digging	Hand picking	Hand picking	Hand picking	Traditional trap	Chopping wood	Hand pickin

Pie Chart 1: Percentage of Consumption of Identified Edible insects (IEIs) by Taxa Order



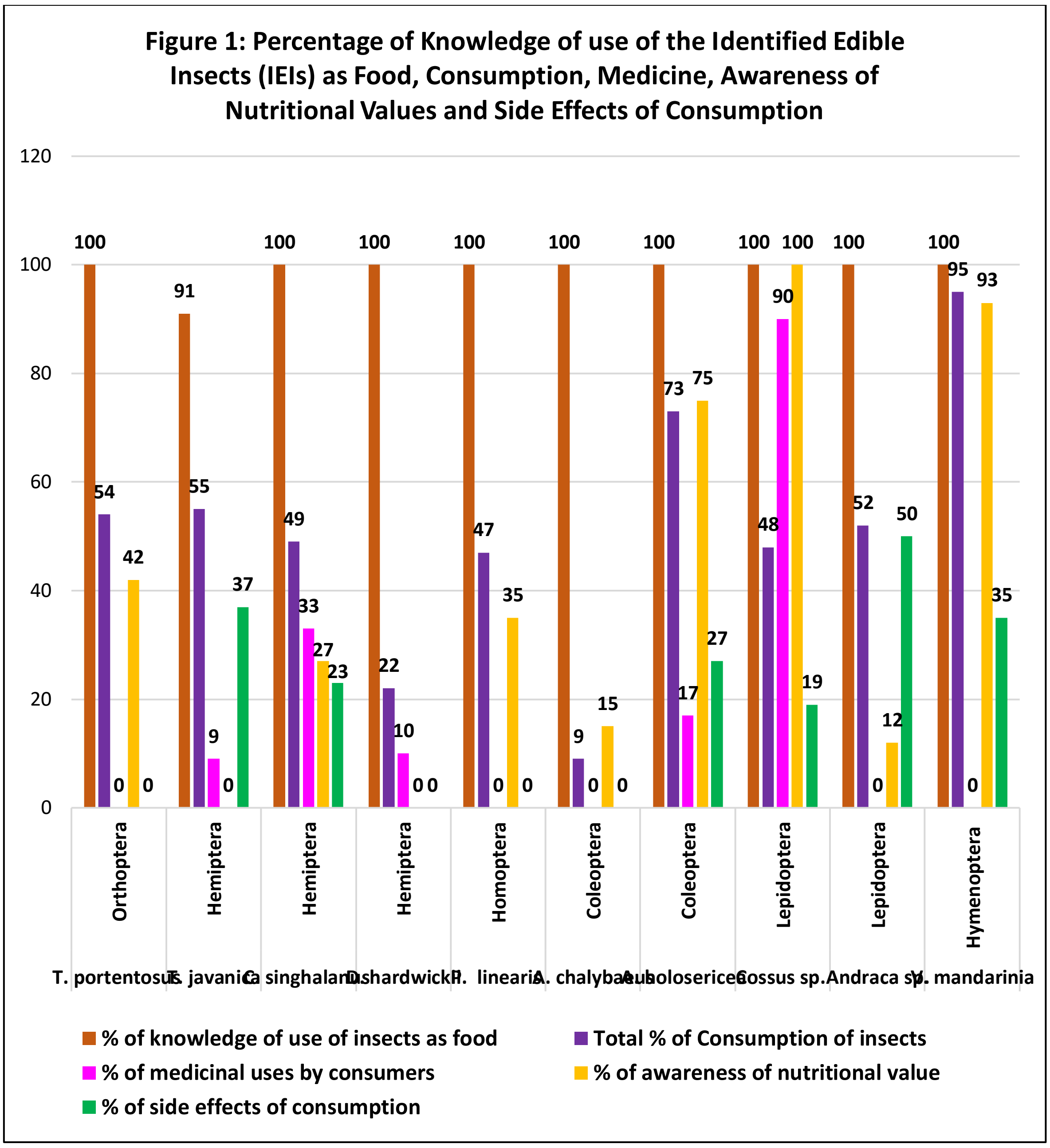


Figure 1: Percentage of Knowledge of use of the Identified Edible Insects (IEIs) as Food, Consumption, Medicine, Awareness of Nutritional Values and Side Effects of Consumption

The whole of larvae, pupae and adults, are prepared by steaming/cooking with fermented bamboo paste, chilly, garlic and salt. It is also sometimes, though rarely, fried in oil or dried after cooking as usual in the bamboo paste and stored above the fireplace for later consumption.

In many areas of Kohima, the Angamis practice the semi-cultivation type of rearing of *V. mandarinia* for personal consumption as well as for commercial purpose. They either find and claim ownership over a naturally formed wasps nest or construct one.

Conturedstructures are constructed that will allow proper alignment of hive building by the wasps and placed in a pit 2.5-3ft deep upon which a polythene/plastic sheet is spread and with loose soil topped to level it. Farmers then collect a few wasps along with the comb from the wild, and introduce them to the new nest by tying this comb at the entrance (small opening for wasp entry) of the pit (Bendang and Aokumla, 2013). Once these wasps enter and settle inside they will begin their usual routine of building, feeding, growing and reproduction. The time for harvestation of semi domesticated hornet nest is about five to six months after the wasps are introduced to the newly constructed nest.

The traditional technique for locating a wild nest is a very intricate activity and requires a lot of expertise and patience. A bait consisting of an insect or sugar coated cotton ball is attached to a long bamboo stick and when the wasp is enticed and kept busy with the bait, a strand of rope/thread is looped around the abdomen carefully and tightened around the portion between the thorax and abdomen, the other end being tagged with a very light feather or bright colored polythene material. As the wasp flies back to the nest, its flight direction can be traced via the feather/polythene material, and follow the hornet to the nest. Farmers relocate wasp colonies in springtime, when nests are small and manageable.

The Aos and Sumis do not semi-domesticate the giant hornets, but rather practice opportunistic harvesting or collection of wasps from the wild after marking the site of the nest. Both the tribes apply a technique similar to the Angamis to locate the nest. It consists of capturing a lone wasp after baiting it with a tiny piece of fresh meat, gently tying a knot with a thread about 3-4 feet in length, girded between the thorax and abdomen, and the other end tangled with shavings (white colour and light in weight) from inner wall of bamboo. As the wasp flies back to the nest with the shavings trailing behind, spotters posted at high vantage points or trees in the forest will observe the pathway of the returning wasp and mark its location. Thus, locating the nest requires coordination amongst the team members. In

Japan, a similar capture method of attaching a tiny marker made with cotton ball, lightweight polypropylene or white plastic bags to the bait and following the wasp when it takes the bait has been reported by Payne and Evans (2017). Scholars working across five continents-North and South America, Africa, Oceania and Asia have documented long traditions of collecting social wasps' nests in order to harvest larvae for food (Chakravorty*et al.,* 2013).

Harvesting of the hornet brood combs is done by smoking the nest from the entrance to kill or chase away the worker wasps. Collections are preferably done in the night time when the workers are least active or the time when they are resting (Nonaka, 2010). Popoloca people of Los Reyes Metzontla in Mexico also harvest hornet nests only when the moon is between its waning gibbous and last quarter since it is believed that this is the time when the nests are full of larvae. At other times, the larvae are considered to be either in the last larval stage, pupae, or have already become a wasp (Acuna *et al.,* 2011). No medicinal uses were mentioned during the survey except for recommendable comment on its food value.

A. holosericea or longhorn beetle is called as *Jevisenoali* (Angami), *Tsüka* (Ao) and *AphisuKulho* (Sumi) (Photo 2). This worm is considered a delicacy and usually taken as an appetizer. High popularity for consumption of larvae of *A.holosericea* is observed from the respondents with 73 % (Figure1) and 75 % for awareness of its nutritious value indicating those nonconsumers are also familiar with the insects used as food and there is no innate aversion for these insects. The high rate of consumption of the insects is credited to its high content of fat and very rich flavor and it is considered a good food supplement for growing children (Pongener*et al.*, 2019b). Because of its high-fat content, people with hypertension are cautioned not to eat it as it may aggravate the ailment. Traditionally, it is used as a remedy to relieve pain and heal mouth ulcers by sucking the freshly boiled or dried larva. Some species of beetles used in traditional medicines are recorded by other workers (Ronghang& Ahmed, 2010; Meyer &Changkija, 1997). Senthilkumar*et al.* (2008) have recorded eleven

(11) species of Coleoptera that are used as traditional medicines for several ailments by tribals in India.

The preparation for consumption consist of roasting or frying it in a pan/tawa and eating it as it is or making chutney of it with chilly, tomatoes and ginger. In reference to coleopteran, many species of *Dytiscus* sp. are cooked in different ways (roasted, made as soup, ground in sauces, mixed with eggs or with legumes in different salads, etc). It is only boiled in many countries all over the World, like *Cybisterhova* in Madagascar, *C. japonicus* in Japan, *C. explanatus* in America, *Hydroushastatus* in Asia or *Tropisternumtinctus* and Gyrinusparcus in Mexico, eaten as a traditional, nutritive, abundant and for free food principally for rural people (Ramos-Elorduy*et al.*, 2009).

A. holosericea grubs are commonly collected opportunistically by the indigenous people of Nagaland from rotten or fallen tree trunks during their visits to the fields or forests for collection of firewood (Photo 3). Grubs are collected mainly for family consumption and partly for sale in local markets. During midsummer (July-October) the larvae, if collected in large quantities, are wrapped in banana leaves and sold in local markets. The whole package weighs approximately about 600-700 g and commands a price of ₹200-300. Thus during the available season it can serve as a means to provide temporal monetary profit for the tribals. Though this coleopteran is considered a savory treat among the Nagas in general, it was reported that the Aos however, are not fond of this insect as food, inspite of them being aware of its rich food value. It was also reported that the larvae as well as the adult form was mostly collected for use as feed for poultry and fish farms (Pongener*et al*., 2019b).

In 2011, combined world feed production was estimated at 870 million tones and FAO estimates this production will increase by 70% in 2050. Recent high demand and consequent rise in prices for these feeds plus elevating pressure of production on aquaculture has led to research into the development of insect feeds for aquaculture and livestock (Van Huis *et al.*, 2013a). Insect feed could be the alternative, sustainable protein and eventually become a successful meal replacement for conventional fish and animal meals. As insects are cold-blooded invertebrates, they are highly efficient in converting input feed to edible matter (Halloran &Vantomme, 2013; Van Huis *et al.*, 2013c; Anankware, 2015). An estimate suggests that around 25 kilograms of feed are required per kilogram of edible beef, yet this reduces to around two kilograms for edible insects (van Huis, 2013b; Smil, 2002), thus insect rearing exerts far lower land and environmental pressure. Insects also emit far lower levels of greenhouse gases and ammonia than cattle and swine livestock (Halloran &Vantomme, 2013; Van Huis *et al.*, 2013c ;Oonincx*et al.*, 2010), and can be raised on organic waste substrates, recycling these in the process reducing feedstock demand relative to other agro-species. Using organic waste substrates can reduce waste volume and convert this into nutritious insect meal and useful co-products such as fertilizers and soil conditioners (Lalander*et al.*, 2015). Mealworm beetle, *Tenebrio molitor* Linnaeus has been shown to be the most dependable, accessible to breed insects that are rich in protein and meet the amino acid requirements for livestock (Selaledi*et al*., 2020). Diener *et al.*, (2011) documented a 70% reduction in organic waste matter by*Hermetiaillucens* larvae, whilst Sheppard *et al.*, (1994) documented over a 50% reduction in manure waste.

Edible insects play an important role in the nutrition and economy of rural people. They are highly prized and are also subject to national or international trade. International trade in edible insects has picked up in African countries like Sudan and Nigeria that export edible insects to France and Belgium. According to the FAO (2013), these two countries import about 5 and 3 tons, respectively, of a type of dried caterpillars from the Democratic Republic of Congo. For example, the annual exports of these caterpillars to Belgium have a value of $ 41,500 US dollars.

Some economists have investigated the potential for edible insects to provide income and generate jobs for the rural population (Mitsuhashi, 2003). This income could be via raising them as "protocultures" in order to avoid falling stocks because of predation, parasitism or lack of food as well as changes in temperature, for example, increasing the organic matter content in the water where beetles and other aquatic insects are present or doing formal cultures, which also then could be transported to urban or semi-urban areas to sell (Ramos-Elorduy, 1997; Ramos-Elorduy*et al.*, 2009). Due to the reasons mentioned, *A. holosericea* can serve as food for humans as well as be a major ingredient in the production of feeds of animals. However their production is seasonal and knowledge of their life-cycle scarce, so production under greenhouse conditions is unfeasible to date. Studies by researchers on their biology and life cycle would pave way to strategies and systems for experimentations in order to generate mass reproduction policies under sustainable greenhouse conditions that would promote the incorporation of these insects into functional foods.

T. javanica ranks third (3^{rd}) with 55% consumers. Indigenous names given to this stinkbug are *Kongya* (Angami), *Tsüknü / Tsüngi* (Ao) and *Akhano / Michika* (Sumi) (Photo 4). Adult stage and nymph are all used as food mainly because of the scent. It is considered as an appetizer which is also addictive as reported by the consumers. However its consumption have also been reported to cause dizziness, lethargy and vomiting in some cases. In such cases, over the counter medicines like Avil and some anti-allergic local medicine called *tangmo (Rhus semialata*Murr) (Pongener*et al.* 2019a) are used. The bug is also highly savored for its fatty flavor which is very similar to that of *C. singhalanus. It* inhabits areas where climatic conditions are hot with temperatures ranging from 24^0 to 40^0 C from June to September.

Wings and calcareous portions are removed and washed in hot water 2-3 times. These processed insects are then fried in oil or prepared as chutney with chilly, *tangmo(Rhus semialata*), fermented bamboo shoot paste and salt, as a side dish and relished with wine as well as with rice. After drying, the surplus is stored in an indigenous way to be used in the seasons when it is not available. Sturdy hollow bamboo containers made by retaining the nodal diaphragm on one side (Closed end) and cutting off obliquely at the internode near the node on the other side (open end), shaving the external skin for smoothness and scraping the inner skin clean of any tissue residues. This container is then kept above the fireplace for drying. Once it is dried, dried stinkbugs are stored in it in an airtight condition by closing the open end with compact compressed dried banana leaves. This traditional method of storage effectively preserves the food for months and even to a year, nonetheless low levels of the human carcinogen mycotoxin (aflatoxin B1) has also been identified in edible stink bugs that are stored in traditionally woven wooden, dung-smeared baskets and gunny bags previously used to store cereals (Musundire*et al.*, 2016). Therefore, awareness of better handling, storage methods and use of eco-friendly non-toxic containers can help eliminate contamination of the edible stink bug with such carcinogens and other toxic substances and ensure its safety as human food.

They are handpicked from the stem and leaves of lychee trees taking immense care and precaution not to agitate the bug because an agitated stinkbug ejects a chemical secretion which accidentally could enter the eyes causing excruciating pain and blurred vision for 2-3 days. In South Africa, collection of stinkbugs is more systematic. It is done between dusk and dawn when the cooler temperatures immobilize them. Being cold-blooded, it is more active when environmental temperature is high and tends to fly away or drop to the ground and fake death or scurry beneath leaf-litter to escape harvesting. Native people climb trees or use wooden poles about three-metres long to bend branches and access clumps of stinkbugs. When it is not possible to collect in this manner, branches of trees are cut-off (Dzerefos*et al.,* 2013). They also take no measures to protect the eye from the chemicals spewed by the bug but wear multiple layers of clothing with the neck and sleeves tightly closed/drawn. Short-term exposure to the stinkbugs' defence chemical stains the skin orange-brown and cause local swelling. They also use protective hand-gear such as rubber gloves, woolen mittens or plastic bags during the collection.

The chemical secreted from the metathoracic scent gland of adult *T. javanica* causes a lethal effect even on the black ants and small red ants (Janaiah*et al.,* 1979). It may cause burn like wounds in the skin and hence, precautions have to be taken by the collector to prevent such an accident (Pongener*et al.,* 2019a). Janaiah and his team analyzed the chemical composition of the scent glands of adults and nymphs of the *T. javanica* and found trans hex-2-enal, trans hex-2-enyl acetate and n-tridecane in the adult scent, while trans oct-2-enal and n-tridecane were detected in the abdominal scent glands of nymphs. However, the defensive secretion released by the live stink-bugs is not yet analyzed nor its significant effects on human eyes (Teffo*et al.,* 2007). Wearing safety protective goggles during collection and handling the insects is therefore suggested.

In Nagaland, the locals apply secretion of the stinkbug on warts to remove them. The wart's epidermis is gently scraped off with a clean blade to expose the internal cells over which the chemical is applied leading to a burning sensation in the exposed area. Ironically, ethnic groups in South Africa, the Vhavenda and Mapulana, claim that long-term harvesting (over decades) of edible stinkbugs (*Encosternumdelegorguei*) caused nails to lift off the nail bed and also wart growth. These opposing effects of healing of wart and causing wart formation have not been investigated yet. In South Africa, dead stinkbugs are also used in traditional medicine for curing headaches, hangovers and sore throats, controlling diabetes, treating arthritis or skin cancer (Dzerefos*et al.,* 2013).

T. portentosus stands in the fourth (4th) position with 54% consumers. The local names are *Petoa* (Angami), *Yimpichokok / Angor* (Ao), and *Awusho* (Sumi) (Photo 5). Indigenous Nagas consider cricket as a good source of various nutrients required by humans for proper growth and development. It is much savored because of its rich palatable taste and rich fat content. Edible crickets are excellent sources of proteins, lipids, carbohydrates, mineral salts, and vitamins (Henlay*et al.*, 2021). Moreover, these insects are rich in micro-nutrient elements such as calcium, potassium, magnesium, phosphorus, sodium, iron, zinc, manganese, copper, and vitamins like folic acid, pantothenic acid, riboflavin, and biotin, which are the most deficient nutrients in humans (Rumpold and Schlüter, 2013a; Ghosh*et al.*, 2017; Orinda , 2018).

T. portentosus is found in collectible amounts during May-July. Traditionally, their underground burrows are filled with water thereby forcing them to come out of their homes. Shallow burrows are simply dug. They are also often collected abundantly during floods when their underground burrows get flooded and they escape to the surface. Harvesting is also done during nighttime when the crickets emerge out from their burrows by using illuminating light sources to attract the insect. For the village kids, collection of crickets becomes a recreational activity during the daytime (Pongener&Ao, 2019). The cricket is deep-fried in oil or roasted without oil and consumed with or without salt. These dried or roasted crickets are also mixed in a chutney prepared with slightly charred green chillies and tomatoes, ginger, dried bamboo shoot, salt, and a sprinkle of local basil.

In Thailand, cricket farming has improved the lives of many rural farmers not only through the provision of an alternative income source, but through strengthening human and social capital (Sverdrup-Jensen, 2002; Halloran *et al.*, 2016). Insects, along with other mini livestock, support diversified markets because they can be sold to consumers across the rural–urban spectrum. In many cases, rural people will sell their mini livestock within their villages; however, due to their transportability, insects can easily be moved to urban markets by bus, truck or bicycle (FAO, 2011). The insect is a much sought-after food in many villages surveyed (Pongener&Ao, 2019) but is collected only from the wild. Initiatives from governments and assistance programmes to introduce cricket farming to the indigenous peoples should be a worthwhile outcome of this research work.

Andraca sp. commonly called glory moth and bunch caterpillar ranks fifth (5^{th}) amongst the 10 insects with 52% consumers. Vernacular names given to this caterpillar is *Meshokhu* (Angami), *Mejanglong / Mesanglong* (Ao) and *Mejining* (Sumi) (Photo 6). The caterpillar feeds exclusively on the leaves of the oak tree (*Schimawallichii)*. It is one of the most valued species of edible insects in the Mokokchung and Zunheboto regions but hardly consumed by the Angamis. Larva is considered a delicacy because of its chicken-like flavour. During its availability (July-December), it is collected by the tribals for their own consumption and also by some to sell. The insects inhabit mature branches in the crown of big trees and therefore, collectors are usually men and boys, and when it is out of reach they cut the branches on which the insect clusters. Clusters in hundreds are found in more than 2-3 main branches. It is sold in the markets at a price of around ₹ 1000/kg. These caterpillars are consumed either dried in the sun after washing with hot water and cold water for 2-3 times after frying in oil or stewed in dried fermented bamboo strips, tomatoes and green chilies. The dried ones are used in chutney prepared with tomatoes and chilies roasted in charcoal.

The population of this moth worm has been reported to be declining due to cutting of *S. wallichii* for firewood, and unsustainable rampant collection of caterpillar without sparing any clusters for continuation of its life cycle (Photo 7 and 7A) (Pongener*et al.,* 2019a). Further research and statistical analysis on the consumption, methods of collection, period of availability, feasibility of farming as a ministock animal and population of the insect are required that can provide the foundation for generation of new knowledge to address current problem of decreasing population of the insect. This is vital for preserving biodiversity, since insects are good indicators of climate change as it influences their development, reproduction, and survival (Selaledi*et al.,* 2021). By doing research on its biology, life cycle and factors influencing its reproduction, a model for rearability of this *Andraca* sp. could also be strategised. Caterpillar of *Cirinabutyrospermi*Vuillet which feeds on theleaves of the shea tree is successfully reared in enclosed systems but strategies to rear on a commercial scale is not reported (Bama *et al.* 2018; Rémy *et al.* 2017).

*C. singhalanus*stands in the sixth (6th) position with 49% consumers. Local names are :*Poluo* (Angami), *Bholo* (Ao) and *Akhano*(Sumi) (Photo 8). It has a high fat content and a distinct smell which is reported to be addictive once the consumer is familiarised with it. Choice of these insects as a source of food in North East India has been reported as early as the beginning of the 20th century by Distant (1906).

Photo 1: Hive of *Vespa mandarinia*
Photo 2: Larvae of *Aplosonyx chalybaeus*
Photo 3: Wood borer larva of *Aplosonyx chalybaeus*
Photo 4: *Tessaratoma javanica*: Nymph and adult stages
Photo 5: *Tarbinskiellus portentosus*
Photo 6: Dried larvae of *Andraca sp.*
Photo 7: Live larvae of *Andraca sp.* collected from a chopped tree
Photo 7A: *Schiima wallichi* (Mejangsung), the host plant of *Andraca sp.*

C. singhalanus are collected mainly from dry river beds underneath rocks in groups of 10 to 20, stuck on the rock surface during winter from late November to February.

Interestingly there is swarming of stinkbugs during monsoon (June-September), particularly in years when bamboo begins to flower as reported from the Jangpetkong range of Mokokchung. The locals handpick the nymphs and the adults infesting the foliage and branches of bamboo and other trees in swarming areas called ‘bholotemtenem’ meaning ‘place where the *bholo*swarms’. The best time for the collection of swarms is early in the morning, at night, or during rains when the insects are least active. It is collected usually for family consumption. However, some farmers sell those caught during the swarming when the insect is collected in huge amounts of 3-4 gunny bags. Insects collected are washed in cold water for 2-3 times and then in warm water to get rid of any impurities and to remove the chemicals secreted by them. A similar practice is reported from South Africa (Dzerefos*et al.*, 2013). Ethnic people collect the stinkbugs in bags which are shaken before opening so the stinkbugs are disorientated and cannot fly-away. This shaking agitates the stinkbugs to release their defensive secretion. The bugs are rinsed with warm water and the process repeated about three times until the smell and dirt are removed. In the event of collection, bamboos and other tress are rarely cut as the bugs fall to the ground simply by shaking the plants.

They are usually fried or mixed with chutney. This chutney prepared by the tribals is a simple concoction of tomatoes and chilies either stewed or roasted in charcoal with a sprinkle of salt as desired. Another interesting traditional method reported is the processing of the insects for preservation and storage. After the usual process of cleaning via several washes, the insect is pounded into a paste and the concentrated liquid extracted from it is used as a sauce to flavour curries. The paste is then fermented and used as a flavouring ingredient in various food preparations (Photo 9 & 10). Both the sauce and the paste are stored without spoilage for many months. However, these cleaning, handling and processing for preservation are likely to have an effect on the nutritional value and food safety quality or properties of the bugs. Some insects are toxic and may create allergy problems (Gullan*et al.,* 1986). It is felt that the traditional preparation of insects is amenable to improvement, to avoid contamination and wastage. Mpuchane *et al.,* (2000) reported on the deterioration of the mopane worm's nutritional quality by bacteria, fungi and insects during storage.

It has been reported that the consumption of the male bug has an intoxicating effect on the consumer with symptoms like headache, drowsiness, fever and vomiting (Pongener*et al.,* 2019a). A kind of psychiatric disorder and seasonal ataxia caused by consumption of *Aspongopusnepalensis* was reported by Chakravorty*et al.,* (2011). Severe vertigo and recurrent vomiting with acute kidney injury following the consumption of the insect is reported from Bhutan (Rinchen, 2016). It was reported the intoxicating effect was cause by consumption of the male without removing the stink gland however Strickland (1932) put forth evidence inclining to disprove beliefs that these insects causes intoxicating effects if eaten without removing the bi-lobed stink gland located in between the abdomen and metathorax. Further scientific biochemical analysis is required in regard to this opposing say so and other evidences.

When such symptoms are reported after consumption, the patient is treated with over the counter medicines like Avil, some anti-allergic local medicine called *tangmo (Rhus semialata*), garlic etc (Pongener*et al.* 2019a). *R. semialata* has great application in the traditional medicine to cure various ailments (Bidyalakshmi*et al.,* 2016). Traditionally, the fruits of *R. semialata* are used for the treatment of colic and other gastrointestinal problems, while seeds are effective against cough, dysentery, fever, jaundice and malaria (Gogoi*et al.,* 2021). Leaves and roots are known to have depurative and blood circulation stimulating properties. Its decoction is used in the treatment of haemoptysis, inflammations, laryngitis, snakebite, stomach-ache and traumatic fractures (Duke and Ayensu, 1985; Ouyang *et al.,* 2007). Bose *et al.,* (2008) found that fruit extract possesses anti-diarrhoeal activity through his works in rat. Fruits are ground into powder and taken during indigestion, stomach ache and food poisoning by the Ao-Naga tribe (Khruomo& Dev, 2018).

Respondents also reported that stinkbug is used as a remedy to cure blood pressure. Literature reveals therapeutic uses of stinkbugs by tribals who eat them for urinogenital disorder (Hoffman 1947) and by the Chinesewho use *C. chinensis* to treat pain, erectile dysfunction, and other diseases (Li *et al*., 2017). Recently, Sharbidre*et al.,* (2020) and his team evaluated a closely related species *C. nepalesis'* medicinal property using aqueous extract (CN. Aq. Ex.) which showed significant antioxidant, antiglycation and antiamyloid activity. Liu *et al.,* (2019) also reported increase in antioxidant activity and decrease in apoptosis in rats after treatment with hot water extract from *C. chinensis.*

Cossus sp. commonly called carpenter worm (Lepidoptera: Cossidae) ranks seventh (7^{th}) in position in its consumption with 48%. Vernacular names are *Lingho* (Angami), *Temeremtsüka*(Ao) and *Akuhu/Auskulo* (Sumi) (Photo 11). The worm is a favoured delicacy among the indigenous people of Nagaland because of its taste, high content of fat and unique aroma. Ironically the same unique and strong smell this caterpillar emits also contributes to its avoidance as food by respondents who do not consume this insect. This worm is a wood-boring insect that bore into the bark of the members of the red oak group, particularly *Quercus serrata* in Nagaland. The farmers collect the larva by chopping the tree (Photo 12) which is infested with it. It is worth noting that in this process of procurement of the larvae many trees are randomly cut which may lead to consequential imbalance of diversity of the forest and gradual decrease in the population of the species. Similarly, these worms bore into the wood and bring consequential damage degrading the value of the wood. *Q. serrata* isan important economic tree for the indigenous peoples for sale as firewood. Programs and assistance by civil bodies and government sectors along with research based statistical analysis of the uses of worm as well as the chopping of tree will promote conservation of the tree species and eventually safeguard the population of the carpenter worm through sustainable use of the worm as well as sustainable chopping of tress. This will promote viable income generation for the rural population from marketing both firewood and worm. Research oriented programmes and civil organization funded projects are also required to garner knowledge on biology and life cycle of *Cossus sp.* which will immensely promote its conservation and popularity.

The larvae are consumed either raw or steamed/stewed with local spices. It is also dried after cooking in a small amount of water and salt for later use as an ingredient in chutney preparation with green chilies and tomatoes charred in charcoal.

Traditionally, the larva is considered a vital food item for tuberculosis patient who are under medication. It is reported that TB patients who were on this insect diet were cured without any side effects and quicker too (Pongener*et al.,* 2019a). This claim might either suggest the insects rich content of fat and protein are supplementing the nutrient requirement of the patient who is on strong medication from 6-9 months or other biochemical content maybe giving a curative effect. All these hypotheses need thorough biochemical research work and testing before this insect can be accepted as having ethno-medicinal properties. The insect larva is also used in prescriptions for anaemia whereas pregnant women are discouraged from consuming it because it is believed to cause miscarriages. Also, the broth obtained after boiling the caterpillar is used as an embrocation for arthritis, and body pain.

Insects and the substances extracted from them have been used as medicinal resources by human cultures all over the world (Costa-Neto, 2002). The belief that insects exist for the benefit of human beings can be found in the book 'Insectotheology', published in 1699 (Berenbaum 1995). Molina-Vega *et al.,* (2021), reported on consumption of two *Cossus* species, *Comadiaredtenbacheri* Hammerschmidt (red agave worm) and *Aegialehesperiaris* Walker (white maguey worm) which are considered as exquisite food by local people of Mexico and foreign tourists. These worms have high content of protein, fat and essential minerals therefore offering significant health benefits. These organisms have been attributed mystical and magical roles in the treatment of several illnesses in a range of cultures. Science has already proven the existence of immunological, analgesic, antibacterial, diuretic, anesthetic, and anti-rheumatic properties in the bodies of insects (Schultz & Arnold, 1977; Castaldo &Capasso, 2002; Ramos-Elorduy& Motte-Florac, 2000). Several authors have surveyed the therapeutic potential of insects, either recording traditional medical practices (Adriaeus, 1951; Van Huis, 1996; Antonio, 1994; Zimian*et al.,* 1997; Mbata, 1991; Singh *et al.,* 1998; Pemberton, 1999) or employing insects and their products at the laboratory and/or clinical level (Bankova*et al.,* 1999; Beattie *et al.,* 1986; Konno *et al.,* 1998; Yamakawa, 1998). Thus, insects seem to constitute an almost inexhaustible source for pharmacological research. Chemical studies are required to identify and analyse biologically active compounds present within insect bodies and determine their efficacy. The therapeutic potential of insects represents a significant contribution to the debate on biodiversity conservation, as well as opening perspectives for the economic and cultural valorization of animals traditionally regarded as useless. Their use needs to be at a sustainable level to avoid overexploitation.

Indigenous people living in Dimapur, Mokokchung and Zunheboto mainly purchase the worm from markets for consumption since it is rarely collected from the forests in these areas. One reason for its scarcity can be that the tree species *Q. serrata* is rarely seen in the forests of these regions. Thus, even though this worm is highly valued as a nutritious main menu item, supply cannot match demand in these districts. In Kohima it is found in the forest as well as in the local markets at a very high price of Rs. 5000/kg. The Angamis of Kohima serve carpenter worms as the main dish during the Te-l Khukhu festival in the month of July that is held annually, which just shows how significant this insect is as food.

P. linearis ranks eighth (8^{th}) in the consumption of the edible insects recorded with a score of 47%. The local people called it *Chievutuo* (Angami), *Loyang/Jangjangkok* (Ao) and *Zuwu/Choi* (Sumi) (Photo 13). In Nagaland the tribals consume both the adult and nymph stages but the reason for its low ranking among the insects tabulated is that it is a seasonal insect with the adults difficult to catch as they usually dwell in the canopy of tree foliages and the nymph's hibernating site are known to only a handful of farmers who will collect it for their own consumption. Though a very delicious insect food, it is not readily available in the market. After nymphs emerge in late spring when soil temperatures warm sufficiently, and moult to adults, they disperse along woodland edges and sunlit canopies of mature deciduous trees in order to mate and reproduce (Forsythe, 1977; Johnson & Lyon, 1991). The nymph is a long-term immature stage which is much longer than the adult stage, lasting several years underground (Boulard, 1965; Pachas, 1966; Logan, 2006). Their life histories were first described in detail by Marlatt (1907) and Snodgrass (1919). Though these cicadas' life cycles can vary from 1–9 or more years as underground larvae, their emergence above ground as adults is not synchronized, so some members of each species appear every year (Fitzgerald, 2016). In Borneo, collecting cicadas is normally done at night (Chung, 2010). Their presence and abundance on a tree can be detected through their collective sound produced by the male cicadas and the excess water excreted by them (sometimes known as 'raining tree'). The water in fine droplets is produced after feeding on the plant sap. Once the host tree with cicadas has been identified, a fire is set on the ground beneath the tree. The insects will eventually drop onto the ground when the tree is being smoked.

The locals collect adult cicadas from trunks and leaves of trees with the help of long bamboo poles to the ends of which, upturned plastic bottles are stuck via the neck of the bottle while the bottom part, turned upward is cut off at the side forming a sort of mouth through which the cicada falls into the bottle (Photo 13A). The nymphs are favoured over the adult cicada and can be found a few centimetres below the ground. They feed on the roots of oak species and are dug out during the emergence season from June-August. The insect is washed clean several times before preparation. The traditional recipe is simple and consists of roasting in oil and adding other condiments like chilly, salt, garlic and tomatoes. Similar way of cooking in Borneo is recorded by Chung (2010) of stir-frying it with a bit of salt and other flavourings, but without oil after the wings are removed. It is also cooked in water with a few tablespoon of bamboo stem juice and the usual condiments added in. Information garnered from the elders of Ao tribe of Mokokchung is that their forefathers did not eat the adult cicadas and regarded it as having no beneficial value because it consists mainly of body shell (exoskeleton) and appendages with very less tissue contents.

Cicada is considered as a traditional food item in many of the South East Asian countries. In Malaysia (Essig, 1942), the adult giant cicada, *P. imperatoria* is used as food. In Vietnam and Laos they are collected from the tree trunks with bird-lime which are eaten fried or sold in the market (Nguyen-Cong-Tieu, 1928; Bodenheimer, 1951). Distant (1892) and Bodenheimer (1951) reported the consumption of nymph of cicada by the Burmese as very popular and a luxury. Singh *et al.* (2007), has listed the consumption of the roasted larva and adult of *P.linearis* by the Nishi tribe of Arunachal Pradesh, India.

Shells of cicadas are employed in traditional Chinese medicines (Dharmananda, 2005). In China, the exuviae of the black and scarlet cicada, *Huecbys sanguine* ((De Geer) are reportedly used in prescriptions for migraine and ear infections (Kritsky, 1987; Costa-Neto, 2005). In various Chinese provinces (e.g., Fujian, Guangdong, Guangxi, Jiangsu, Sichuan, Zhejiang), the cicadas are collected in summer and autumn to be sun-dried for treating amenorrhoea, rabies, scrofula, and scabies (Zhao, 2004). Biochemical laboratory works have revealed that buffer extracts from the black and scarlet cicada demonstrated potential anti-cancer activity (*Ahn et al.,* 2000). Regardless of its possible medical applications to us, we must also treasure this, and other species of cicadas as integral components of the entire native biodiversity and ecosystem.

Photo 8: Washed *Coridius singhalanus*
Photo 9: Pound and fermented *Coridius singhalanus* stored in a bamboo container
Photo 10: Pound and fermented *Coridius singhalanus* in a plate
Photo 11: Larvae of *Cossus sp.*
Photo 12: Chopping tree to collect larvae of *Cossus sp.*
Photo 13: Nymph of *Pomponia linearis*
Photo 13A: Catching adult *Pomponia linearis* with a long bamboo stick
Photo 14: Nymph and adult *Darthula hardwickii*
Photo 15: *Darthula hardwickii* form aggregations on the branches of *Alnus nepalensis*
Photo 16: Climbing an Alder tree to collects *Darthula hardwickii*

*D. hardwickii*ranks ninth (9th)with 22% consumers. Vernacular names given are *Teiziteipu*(Angami), *Atsu rangdang/ Longmi* (Ao) and *Shothapo/ Lakha* (Sumi) (Photo 14).

Consumption of this treehopper is not very popular as reflected in the data amongst all the 3 tribes of Nagaland. During the survey many of the respondents were unaware of its consumption. It was introduced as food to the Aos from the neighbouring districts (Pongener*et al.,* 2019a). Traditionally, this insect was considered unpalatable for human consumption because of its queer odour which would be intolerable for a first timer. However, the smell disappears after several washes in warm water and then cooked. *D. hardwickii* is eaten in parts of China and India (Xiaoming*et al.,* 2009). Feng *et al.,* (1999) recorded the consumption and the utilization of both nymphs and adults of this insect in China and evaluated the nutrient values of the same that have shown it to be rich in protein, amino acid, fat, micro elements and vitamins.

D. hardwickii is a membracid, hemipterous insect that feeds on the sap of trees like *Acacia dealbata* (Bhowmik *et al*., 1990),*Alnusnepalensis* (Alder) and willow trees (*Salix sp*.). They form aggregations on the branches of trees (Photo 15)where they produce honeydew and are associated with ants and stingless bees (Almeida-Neto *et al.*, 2003). During on-field survey it was observed that the treehopper emerges only once in the year during springtime in places with moderate climatic condition and average temperature ranging from 18 to 27^{o} C. The insects start swarming from late February to May. The indigenous people climb these trees (Photo 16) and handpick the clusters in handfuls. Nymphs as well as adults are collected. Sometime branches that are out of reach are cut but trees are rarely cut during collection. This simple but effective environmentally-friendly harvesting method can be advocated to the indigenous people in the collection of other edible insects like *Andraca sp*. and *T. javanica.* In recent years, valuable indigenous knowledge to either store or process such insects by native people have been recorded. Thus, there is a need to strike a balance between the use of indigenous and scientific knowledge to produce and process these delicacies.

This species is collected chiefly for family consumption and rarely sold. They are savoured for their high content of fat and used as appetizer. They are washed in warm water for 2-3 times to wash off the secretion thereby reducing their strong odour, then fried to be eaten. Preparation consist of frying it in a small amount of oil till crispy for direct consumption, roasting it without oil till cooked then mixing it to a chutney made with green chillies, tomatoes, dried bamboo shoots and a sprinkle of salt as desired. It is also dried above the fireplace to be stored for use during off season.

It is claimed that this insect has hypoglycaemic property and cures diabetes and high blood pressure (Pongener*et al*, 2019a). They consider it as an alternative medicine professing its efficacy and admitted they rather take this indigenous source as medicine than the prescribed allopathic medicine with few side effects. Many of the traditional medicinal uses of insects are dismissed as being superstitious. In different cases, this is correctly so; nevertheless, some of even the most incredulous practices could possess merit (Meyer-Rochow, 2017). Medically, the use of insects in diets has been implemented for specific health effects, including diabetes and associated health complications such as CVD (Cardiovascular disease). Some authors mentioned the consumption of insects having several health benefits beyond nutrition like the Chinese caterpillar fungus that is believed to have immunostimulatory and anticancer properties or evidence that suggests that termites have immunostimulatory effects (Chen *et al.*, 2009; Kim *et al*., 2019).

Insect fats have been shown to be rich in polyunsaturated fatty acids such as linoleic and α-linolenic acids (Womeni*et al.*, 2009; Tiencheu&Womeni, 2017). It has been shown that the consumption of PUFA has several health benefits, such as improved cognitive development and the reduction in glucose tolerance, thereby reducing the risk of diabetes, lowering blood pressure, and preventing insulin resistance (Tiencheu&Womeni, 2017; Ayensu*et al.*, 2019). Diets with a high amount of unsaturated fatty acids may be used to prevent cardiovascular diseases that are associated with diabetes, and this suggests that the use of several insect species in diets may have potential for the management of certain coronary heart diseases (Womeni*et al.*, 2009). Another insect that is historically believed to have beneficial effects in ameliorating T2DM is the bug *Thasus gigas* Klug, which is commonly eaten in Mexico (Nallely *et al.*, 2014).

Impact of *D. hardwickii* on diabetes has not been scientifically researched. Future focused and detailed studies of both insects and plants could provide safe standardized natural remedies for diabetes that would be of high value for the local people as the majority is not able to afford modern antidiabetic medicines. In addition, developed countries might learn of new opportunities for treating or preventing diabetes and collaborative scientific studies could lead to the isolation and identification of bioactives (Verheyen*et al.*, 2021), which may lead to production of more effective medicines having fewer side effects than the current antidiabetic medicines.

*A. chalybaeus*commonly called corm borer stands in the tenth (10^{th}) and last position amongst the edible insects identified in the districts of Dimapur, Kohima, Mokokchung and Zunheboto with 9% consumers. The indigenous people called it *Tzununokhu* (Angami), *Melongtevu* (Ao) and *Akhala* (Sumi) (Photo 17). The reason given for its low popularity is that traditionally it was not used as an edible insect because of its distinctive colocasia plant-like smell which is a real turn off for the natives. It is also a pest that destroys the colocasia plants which is cultivated for consumption and for the sale of the leaves, stems and corms which afford them food security and monetary benefits. Therefore, the indigenous people's priority is protection of the plant and control of pest in the cultivation area (Photo 18).This plant is an important tuber crop with high nutritious value and widely accepted in the whole world. Total area under colocasia cultivation in the world is about 10.8 million hectare of which Asia's share is about 1.5 million hectares (FAO, 1990).

A. chalybaeus is a seasonal and endemic pest that infests both the leaf sheath and the corm. The adult beetles feed on the leaves by making circular holes of different sizes generally half to one-inch size. This results in damage of the leaves and corms, causing great losses to the tribal farmers of the region. The grub hibernates in the corms during winter and emerges in the monsoon season with a build-up from July-August (Korada, 2012). Yellowing of the leaves indicate that the plant is infected and such plants are pulled out and the larvae are collected from the corm. During the build-up of the beetle, farmers collect and kill the adult beetle from the fields thereby keeping a check on the increase of the insect population.

Larvae are collected for the purpose of private consumption. Consumers said that the beetle larva was introduced as food by other migrant tribals just in recent years, hence, only a miniscule population of Nagaland consume this insect as food (Pongener*et al.,* 2019b). Its consumption is yet to be popularized and it can be highly recommended as an alternative food in the rural areas. It is considered palatable and taken as an alternative source of proteins and fats. The adults and grubs are reported to be consumed as a seasonal food by the tribes of Meghalaya and Arunachal Pradesh in India. They are also considered to be rich sources of proteins (Pathak & Rajasekhara, 2000; Chakravorty, 2009).*A. chalybaeus* is recorded in the world list of edible insects from the family Chrysomelidae by Jongema (2015). Preparation consists of cleaning larvae 2-3 times in warm water or cold water, drying above the fire or stewing it fresh in a pot after mixing with green chillies and fermented bamboo paste or fermented bamboo juice

Photo 17: Larvae of *Aplosonyx chalybaeus*
Photo 18: Control of pest by killing both larvae and adult *Aplosonyx chalybaeus* in the colocasia cultivation area
Photo 19: Collecting *Aplosonyx chalybaeus* from colocasia plants
Photo 20: Couple who consumes *Darthula hardwickii* for hypertension and diabetus
Photo 21: Drying insect larvae for food test

Photo 22: Drying silica crucibles
Photo 23: Fat estimation in Soxhlet apparatus
Photo 24: In the lab. performing Kjeldahl digestion
Photo 25: In the lab. performing Kjeldahl digestion
Photo 26: Pouring water into the crickets burrows
Photo 27: Village elders interviewed for traditional information of edible insects
Photo 28: With cooperative respondents
Photo 29: With a respondent

Colocasia plants have low fat content and superior protein, including minerals such as calcium, phosphorus, iron, and vitamins like vitamin C, thiamine, riboflavin and niacin, mineral and vitamin contents (Onwueme, 1978; Onayemi&Nwigwe, 1987; Baruah, 2002). The crop is also very rich in dietary fibre, and could be employed in the treatment of diseases such as obesity, diabetes, cancer and gastrointestinal disorders (Saldanha, 1995). Being the beetle's main food, its chemical constituent will also chemically define the composition of the insect and its consumption will certainly bring forth beneficial outcome to the consumers. Thus, the alternative food potential of this insect represents a significant contribution to the debate on opening perspectives for the economic and cultural valorization of it traditionally regarded as useless.

Proximate Analysis

Proximate nutritional composition of ten (10) IEIs is shown in Table 2 with standard deviation and Figure 2with bar representation**.**The contents of protein were highly variable (11.29-51.89%). Four species contained high amount of protein with low variations between 48-51%, with *T. portentosus* possessing the highest amount (51.89%) followed by *A. holosericea* (49.84%), *V. mandarinia* (49.61%) and *P*. Linearis (48.15%). Four species contained comparatively low protein with variation between 11- 19% with *A. chalybaeus* having the least amount of protein (11.29%) then *T. javanica* (13.13%), *D. hardwickii* (17.51%) and *C. singhalanus* (19.82%). Two species *Cossus sp.* and *Andracus sp.* have medium range protein contents i.e., 23.64% and 37.06% respectively.

The fat contents were also variable ranging from 17.72 to 58.72% with *Cossus sp.* possessing the highest amount (58.72%) and *P. linearis* the lowest amount (17.72%). Others rank in between with *A. chalybaeus* (44.42%), *C. singhalanus* (43.64%), *D. hardwickii* (33.65%), *T. javanica* (27.65%), *T. portentosus* (26.15%), *A. holosericea* (19.80%), and *V. mandarinia* (18.14%).

Carbohydrate content was quite variable with *T. javanica* having the highest amount (33.51%) and *Cossus sp.* possessing the least (6.59%). These findings are comparable to those reported by Ekop*et al.* (2010), Blasquez*et al.* (2012) and Rumpold and Schluter (2013a) for other edible insect species.

The crude fibre which is the indigestible part of the insect or the non structural carbohydrates were high ranging from 6.7–9.9%, which is within the range (0.12–29.13%) that was evaluated for edible insects orders (on a dry matter) by Rumpold and Schluter (2013a).

The ash content was highest in *Andracus sp.* (4.50%) followed by *A. chalybaeus* (3.68%), P. *linearis* (3.65%), *T. portentosus* (3.13%), *C.singhalanus* (2.87%), *D. hardwickii* (2.55%), *T.*javanica (2.47%), *V.mandarinia* (2.32%), *Cossus sp.* (1.96%) and the least in *A. holosericea* (1.37%).

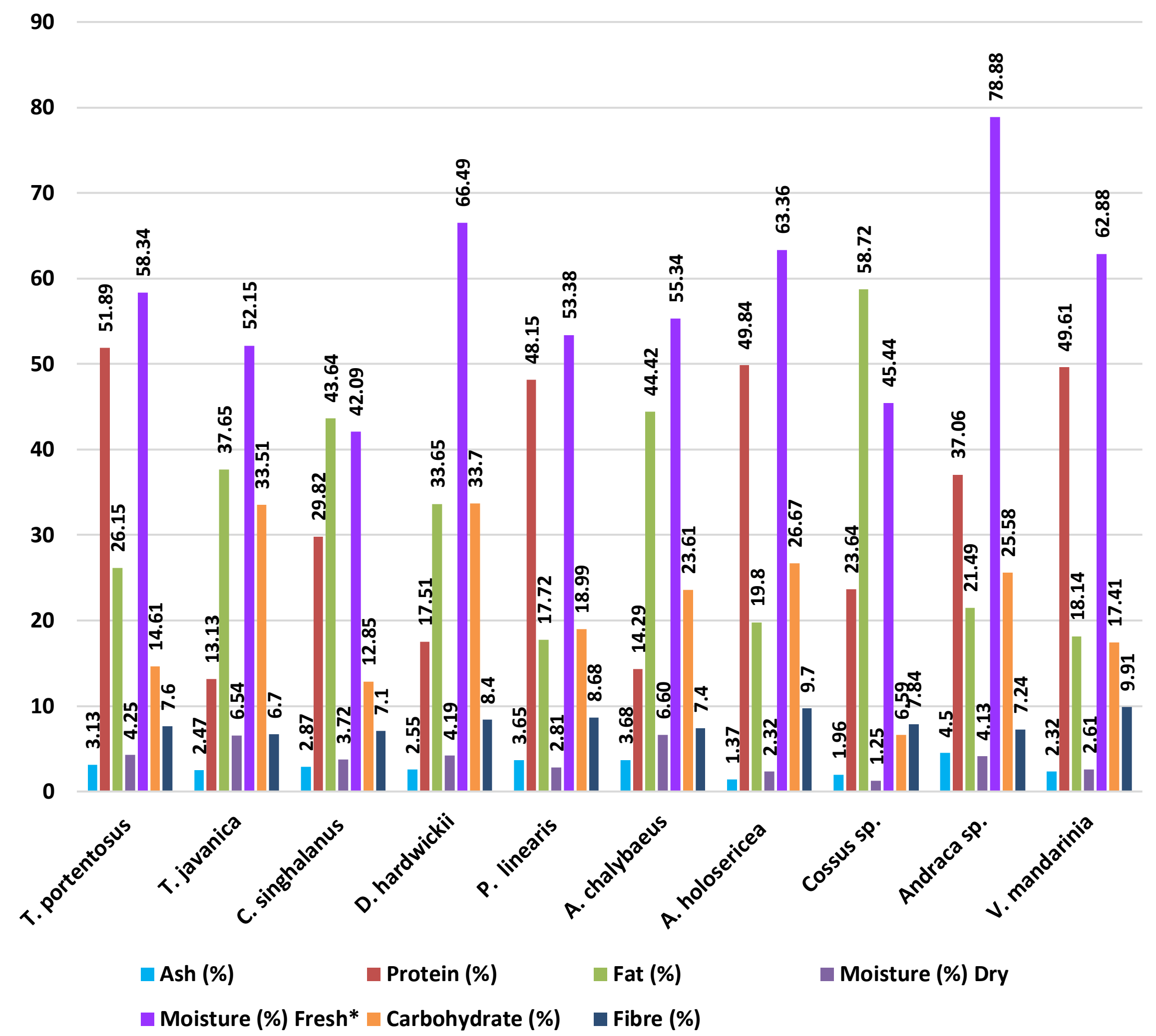
Table2:Proximate Nutrient Composition of Identified Edible Insects (IEIs) in g /100g (DM basis) with (±)Standard Deviation

Sl No.	Scientific name	Ash (%)	Protein (%)	Fat (%)	Moisture (%)		Carbohydrate (%)	Fibre (%)
					Dry	Fresh*		
1	*T. portentosus*	3.13±1.09	51.89±1.02	26.15±0.23	4.25±0.42	58.34±0.61	14.61±1.66	7.6±0.21
2	***T. javanica***	2.47±0.04	13.13±0.27	37.65±0.06	6.54±0.28	52.15±0.29	33.51±0.06	6.7±0.31
3	***C. singhalanus***	2.87±0.28	29.82±0.23	43.64±0.27	3.72±0.40	42.85±0.04	12.85±0.18	7.1±0.20
4	***D. hardwickii***	2.55±0.132	17.51±1.98	33.65±1.860	4.19±0.68	66.49±5.82	33.70±1.87	8.40±0.61
5	***P. linearis***	3.65±0.78	48.15±1.86	17.72±1.25	2.81±0.31	53.38±2.01	18.99±2.11	8.68±0.81
6	***A. chalybaeus***	3.68±0.026	14.29±0.11	44.42±0.37	6 .60±0.52	55.34±0.45	23.61±0.26	7.4±0.14

7	***A. holosericea***	1.37±0.090	49.84±0.01	19.80±0.44	2.32±0.35	63.36±0.39	26.67±0.22	9.7±0.22
8	***Cossus sp.***	1.96±0.410	23.64±1.23	58.72±0.114	1.25±0.16	45.44±3.85	6.59±1.61	7.84±0.65
9	***Andraca sp.***	4.50±0.01	37.06±1.09	21.49±0.92	4.13±0.20	78.88±1.179	25.58±1.24	7.24±0.51
10	***V. mandarinia***	2.32±0.30	49.61±1.35	18.14±3.48	2.61±0.48	62.88±0.45	17.41±1.76	9.91±0.76

*Moisture content of fresh sample. Data expressed as mean of 3 replicates ± standard deviation

Figure 2: Proximate Nutrient Composition of Identified Edible Insects (IEIs) in g /100g (DM basis)



The moisture content of IEIs in fresh form was between 42.09–78.88% which is in consonance with data for the ranges of moisture contents of other insects (Finke, 2004).

Proteins are polypeptide structures that are made up of long chains of smaller units of amino acids. There are 20 different types of amino acids that can be bonded in thousands of ways to make a protein. Of these, eight amino acids are necessary for human nutrition as they cannot be synthesized in the human body (Wu, 2009). Proteins play important roles in the body including replication of DNA, transportation of molecules, catalyzing metabolic reactions, and give structural base to cells (Alberts *et al.,* 2002). Analysis of more than 100 edible insects have shown that the amino acid composition of insects ranges from approximately 40% to 95% of all nitrogenous substances encompassing 35% to 50% of all kinds of amino acid, which is close to the amino acid model proposed by the Food and Agricultural Organization of the WHO. Parts of insects have similar protein contents and are comparable to good plant protein (Finke, 2004).

Nitrogen (N) is a key nutrient, and proteins directly participating in N contribution consist of 16.5% of an adult human body (Melo *et al.,* 2011). The content of protein in edible insects ranges from 35%–60% dry weight or 10%–25% fresh weight (Melo *et al.,* 2011; Schluter *et al.,* 2017), which are higher than the protein acquired from plant sources like cereal, soybeans, and lentils (Bukkens, 1997). Insects contain more protein than even conventional meat and eggs (Mlcek*et al.,* 2014).

Orthopterans like crickets, grasshoppers and locusts are particularly protein-rich (Rumpold and Schlüter, 2013a) which is reflected in the present work i.e., *T. portentosus* (51.89%) (Pongener and Ao, 2019). Other workers have reported slightly higher or lower values - 58.87% (Linn, 2016), 25.20% (Grabowski *et al*., 2021), 20.17% (Paul *et al.,* 2020).

This variability can be explained on the basis of compositional changes of south-eastern Asian insects during processing as observed by Yjoung-aree (2010).

However, insect protein digestibility is not considered constant because of the chitinous exoskeleton in insects (van Huis, 2016; Schluter *et al.*, 2017) with Muzzarelli*et al.*, (2012) even doubting whether humans are capable of digesting chitin. However, the removal of chitinous parts through a part of processing is a feasible approach (Rumpold and Schlüter, 2013b). Defoliart (1992) reported the protein digestibility of insects ranges from 77%–98%.

Adults and larvae of Hemipterans show a high protein content in the range of 42% - 74% of dry matter, and a minimum of 27% (Xiaoming*et al.*, 2010; Rumpold and Schluter, 2013a). In the present study, the Hemipterans show protein contents that range from 13.13-29.82% which is lower than that of other stinkbugs like *Encosternumdelegorguei* with 35.2% and *Tessaratomapapillosa* with 50.54% (Teffo*et al.*, 2007; Raksakantong et al., 2010). But, *C. singhalanus* has 29.82% content of protein which is higher than its relative C. nepalensis with 10.6% (Chakravorty*et al.*, 2011). According to Yjoung-aree (2010) this variation in edible insects could be due to analysis of unprocessed and processed insects. Data collected also indicate that blanching reduced the protein content by 20-30% and fat by 48% approximately (Yjoung-aree, 2010).

The Homopteran *P. linearis* has a protein content of 48.15% which is higher than that of *Meimunaopalifera* (47.23%) (Raksakantong*et al.*, 2010).

Coleopterans and Lepidopterans are mostly eaten in their larval form and the average content of protein ranges from 8.85-71.10% and 13.17-74.35 respectively (Rumpold and Schluter, 2013a) however the nutrient content evaluated in our coleopteran and lepidopteran are notably higher. Both fresh (wet) and dry protein content of several insects species was evaluated by Bukkens (1997) which revealed the protein content to be higher when fried or smoked and lower content when raw. The difference was due to the varying water content in the two different forms.

The protein content of the longhorn beetle larva *A. holosericea* (49.84%) is at par with another beetle larvae *T. mollitor* (49.1%) as reported by Finke (2004), and higher than longhorn beetle *Analeptestrifasciata* (39.63%), *Oryctesrhinoceros* larva (34.76%) and *Prionoplus reticularis* (30.5%) (Anaduaka*et al*., 2021; Mokwunye*et al.,* 2021; Kavle*et al.,* 2022) and lower than in *Holotrichia parallela* (70%) (Yang *et al*., 2014; Anaduaka*et al.,* 2021; Mokwunye*et al.,* 2021; Kavle*et al.,* 2022). It also has higher than the average protein content (33.40%) in coleopterans mentioned by Rumpold and Schlüter (2013a). This study finds that the larva have high nutritional qualities, which compare favourably with other documented 100 edible coleopterans which have protein content between 23-66% of dry matter for adult and larval stages (Xiaoming*et al.,* 2010). The protein content of the taro beetle *A. chalybaeus* (14.29%) is notably lower than other mentioned coleopterans.

Protein content in *Cossus sp*. and *Andraca sp.,* are 23.64 and 37.06% respectively which are higher than that in *Anaphe spp*. and *Cirinaforda* with 18-23% and 20.2% respectively (Banja *etal.* 2006), *Samiaricinii* has 16 % (Longvah*et al.* 2011) and lower than *Omphisafuscidentalis* with 38.25% and *Bombyx mori* with 69.84% (Grabowski *et al*., 2021).

V. mandarinia evaluated in the present work has a protein content 49.61% which is lower than the evaluated value of the same species by Kim & Jung (2013) and comparatively at par with *V. velutinaNigrithorax* (48.64%) as recorded by Jeong*et al*., (2020). These values are similar to the average protein content of Hymenopteran species (46.47%). Owing to their high protein content, Vespa species could be a valuable bioresource.

Fat content of *T. portentosus* (26.15%) was high when compared to same sp. (23.70%) and other cricket spp. containing on average, 4.30–33.44% of lipids in dry matter basis (Magara *et al.,* 2021). Fat content in the Hemipterans *T. javania, C. singhalanus* and *D. hardwickii* are 37.65%, 43.64% and 33.65% respectively which are lower than in Encosternumdelegorguei (50.5 %) (Teffo*et al*., 2007) but for *C. singhalanus* the content is higher than the value in *C. nepalensis* (38.4%) (Chakravorty*et al.*, 2011b).

P. linearis had a fat content of 17.72% which is higher than Raksakantong's cicada with 8.53% (Raksakantong*et al.,* 2010).

The content of fat in *A. holosericea* (19.80%) was moderately higher than*Rhynchophorusphoenicis* (15.36%) (Okunowo*et al.,* 2017) but lower for the same species (31.40%) (Banjjo*et al.,* 2006). The value was also found to be higher than in June beetle (13.4%), buffalo dung beetle (17.2%) *Oryctesrhinoceros* larva (10.23%) and *Analeptestrifasciata (*8.57 %) (Das & Hazarika, 2012; Anaduaka*et al*., 2021; Mokwunye*et al.,* 2021). The fat value in *A. chalybaeus* was 44.42% which is significantly higher than the above mentioned Coleopterans. Also, Its content of fat is higher than reported by Ghosh *et al*. (2017) in *Allomyrinadichotoma* (20.24%) and *Tenebrio molitor* (34.54%) and lower than *Prionoplus reticularis* (58.4%) as reported by Kavle*et al*. (2022).

The Lepidopterans *Cossus sp.* and *Andraca sp.*, fat content which is 58.72 and 21.49% respectively is notable and at par with other larva and pupa such as *Omphisafuscidentalis*(55.3%) *Pectinophoragossypeilla*(49. 48%), *Ostriniafurnacalis*(46. 08%), *Anaphevenata*(23.21%) and higher than in *Cirinabutyrospermi*(14.51%), *Anapheinfracta*(15.20%), *Anapherecticulata* (10.20%) and *Cirinaforda* (14.20%) (Banja *et al*., 2006; Chen *et al.*, 2009; Anvo*et al*., 2016; Grabowski *et al*., 2021).

V. mandarinia showed a high content of fat (18.14%) that is less than the value in the same species with 20.6% recorded by Kim & Jung (2013) and higher than 13.23% as present in *V. velutinaNigrithorax* as recorded by Jeong*et al*., (2020).

The content of fat in edible insects is different from animal fat due to the fact that they have a higher essential lipid composition, such as phosphatide, which the human body requires (Defoliart, 1991). Research works have shown that phosphatide can make crop healthy, reduce fat in the blood, check cholesterol, heal cirrhosis and fatty liver, rejuvenate cells and skin, and delay senility (Lu *et al.,* 1992; Chen *et al*., 2004; Yoshikawa *et al*., 2004). Therefore, edible insects have quality fat with health benefits.

Most meat foods are rich in fat and protein but deficient in complex carbohydrates like dietary fiber (Sanchez-Zapata *et al.,* 2010). However edible insects could turn out to be alternative source of carbohydrates as it is reported to contain a notable amount of it. Rumpold and Schluter (2013a) listed the average carbohydrate composition of edible insect orders ranging from 5.31-13.56%. The present study finds that *T. javanica* as having the highest amount (33.51%) and *Cossus sp.* possessing the least (6.59%). These findings are comparable to those reported by Ekop*et al.* (2010) and Blasquez*et al*. (2012) for other edible insect species.

Crude fibre which is the indigestible part of the insect or the non structural carbohydrates were high ranging from 6.7–9.9%, which is within the range (0.12–29.13%) that was evaluated for edible insects orders (on a dry matter) by Rumpold and Schluter (2013a). Crude fibre content of the insect evaluated is comparable to the dietary fibrecontent (g/100g) of rice (4.1), wheat (12.5), lentil (15.8), cabbage (2.8), green colocasia (6.6) and yam (4.2) (Gopalan *etal*., 2004).

Fibre rich food has a nutritional advantage as it aids in minimising constipation and other gastro- intestinal problems. Various reports have shown that fibre intake decreases the risk of such diseases (NCI, 1984; Eastwood, 1992; Johnson & Southgate, 1994). Research findings also show that a diet high in fibre usually boosts a better life style (Kritchevsky, 2000). In modern society, many of the processed foods and fast foods have been adapted in their daily diets but fail to meet the recommended amounts of dietary fibre intakes for adults in European countries, and in the US are between 30–35 g per day for men and between 25–32 g per day for women (Stephen *et al.*, 2017). With the developing countries quickly copycatting this dietary trend the need to add the dietary fibre into processed food has become one of the principal issues. Currently manufacturers of nutrient rich food use dietary fibre as a key ingredient in order to promote health by decreasing cholesterol and glycaemic levels, trapping mutagenic and carcinogenic substances that can be dangerous for the human organism (mutagenic and carcinogenic agents), (Beecher, 1999; Heredia *et al.* 2002; Puupponen-Pimïa*et al.*, 2002).

Ash is the inorganic residue from the incineration of organic matter and a measure of the total amount of minerals present within a food. The determination of ash content is a useful criterion in identifying the authenticity of a food (Park, 1996). The ash content in our IEIs shows value between 1.37-4.50%, which is significant and present the probability of valuable mineral content.

Moisture content of food is generally used as a measure of the stability and susceptibility to microbial contamination (Scott, 1980). The moisture content in our IEIs ranges from 1.25-6.60%. Since less moisture content in food is known to boost the shelf life of the food, the relatively high moisture content of the insects would not assist in keeping the quality of dead specimens (unless deep frozen). Yet, the high moisture content also implies that most of the essential nutrients in the insect's body will be in a condition which facilitates nutrient uptake by the digestive system (Bradley, 2010). Therefore taking these reasons into consideration our IEIs were kept and stored in deep freezer at -38 0 C to be used for other proximate values.

Figure 3represents comparison of protein and fat content in the IEIs with CFAO (USDA database, 2015), allowing us to appreciate the nutritional profile of insects as possible contributors to a wholesome diet for humans. Protein content of *T. portentosus, A. holosericea, V. mandarinia, P. linearisand Andracus sp*. are at par with that of egg, chicken and beef and much higher than in pork. Beef and pork, the two most accepted animal meats around the world have significantly lower protein than some of the insects. Protein content (13.13%) in *T. javanica* is the lowest among the 10 insects analysed.

Fat content is higher in *Cossus sp., A. chalybaeus* and *C. singhalanus* than reported in egg, veal, chicken and beef. Fat content in *P. linearis* is found to have the least amount with 17.72%.

Figure 4& 5shows the comparison of protein and fat content in g/100g dry weight of analyzed insects and recommended dietary allowance (RDA) for adult male and female respectively. The RDA fulfillment of protein for adult (male and female) as referred by USDA (2020) for consumption of the IEIs in g /100g (DM basis) were variably good ranging from 23.24 – 92.66% for male and from 28.54-112.80% for female. All these RDA fulfillment results suggest the use of these insects as good alternatives for protein supplement. Non-essential amino acid like glutamic acid and essential amino acid like lysine and arginine were found in considerable amount in some insects analysed (Rumpold& Schluter, 2013a; Chakravorty*et al.,* 2016; Ghosh *et al.,* 2016; Ghosh *et al.,* 2017), which are a necessity for an adequate dietary protein intake and indicates that insects can replace other animal protein in our diet and animal feeds especially in developing countries (Banjo *et al.*, 2006).

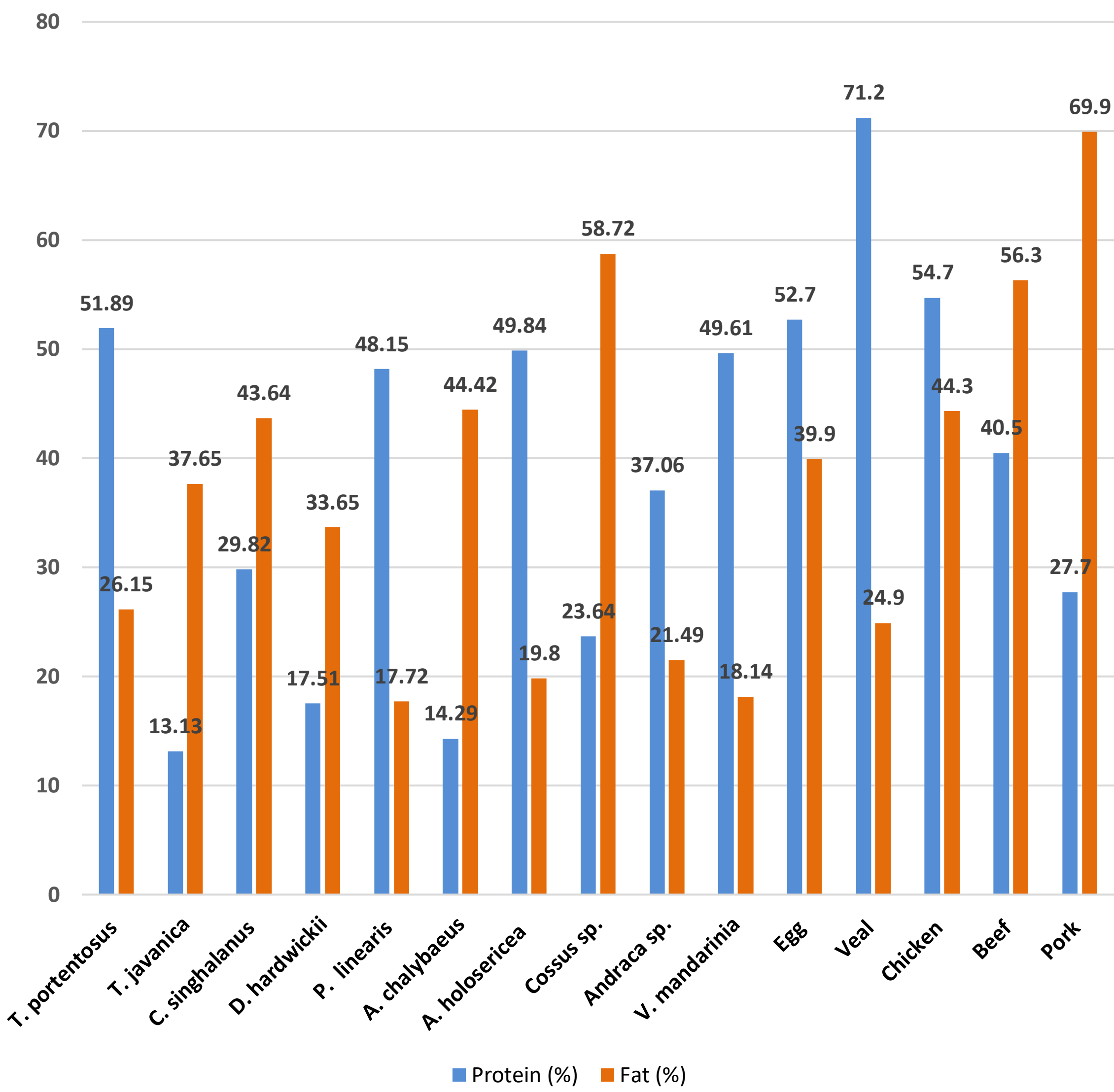


Figure 3: Comparison of Protein and Fat content in g /100g (DM basis) of Identified Edible Insects (IEIs) with Conventional Food sources of Animal Origin (CFAO) (Data other than Insects were Obtained from USDA database (2015) in DM basis

Figure 4: Percentage of Fulfilment of Recommended Dietary Allowance (RDA) for Adult (Male and Female) as Referred for Protein by USDA (2020) for Consumption of the Identified Edible Insects (IEIs) with Crude Protein Content in g /100g (DM basis).

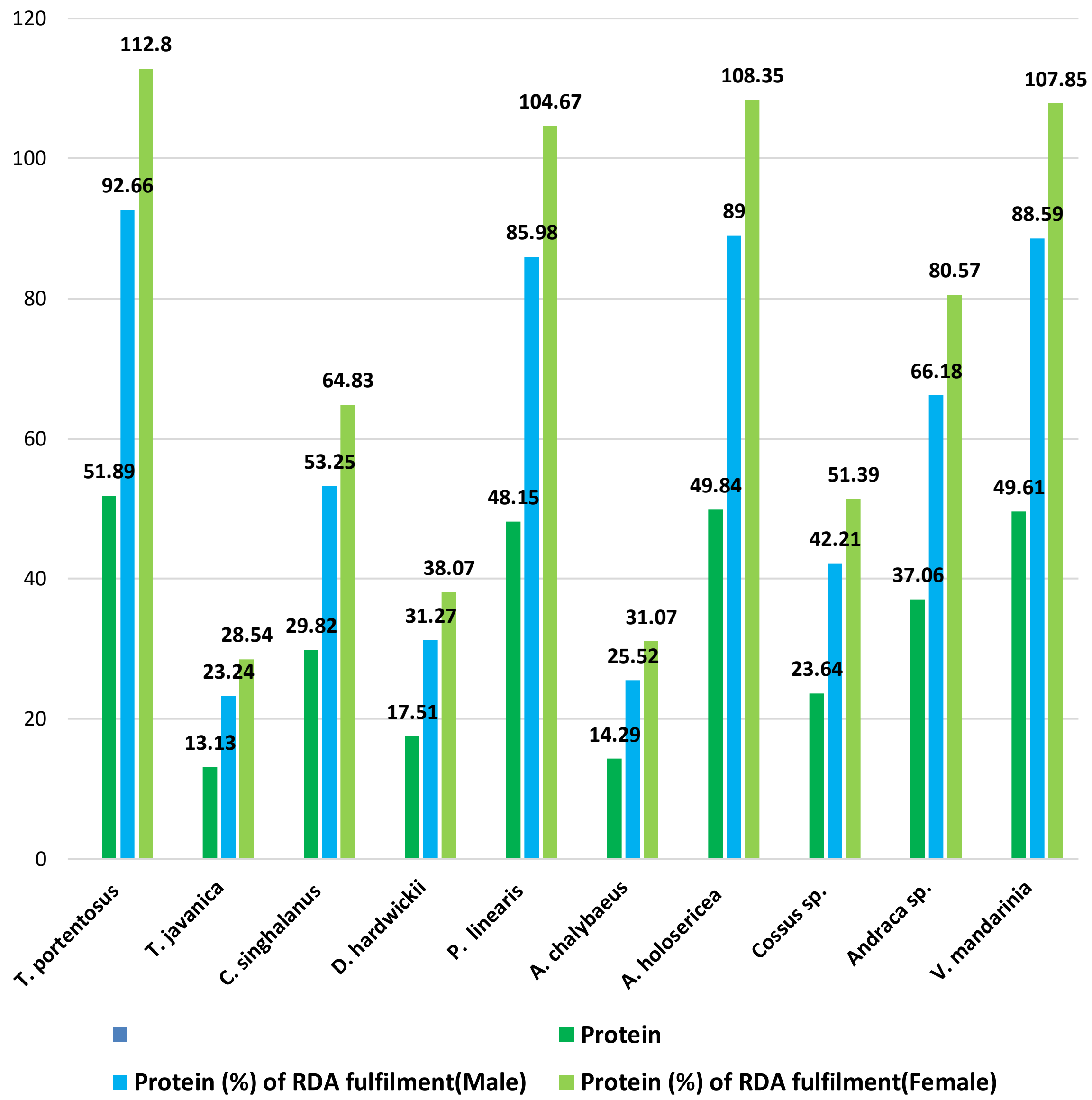
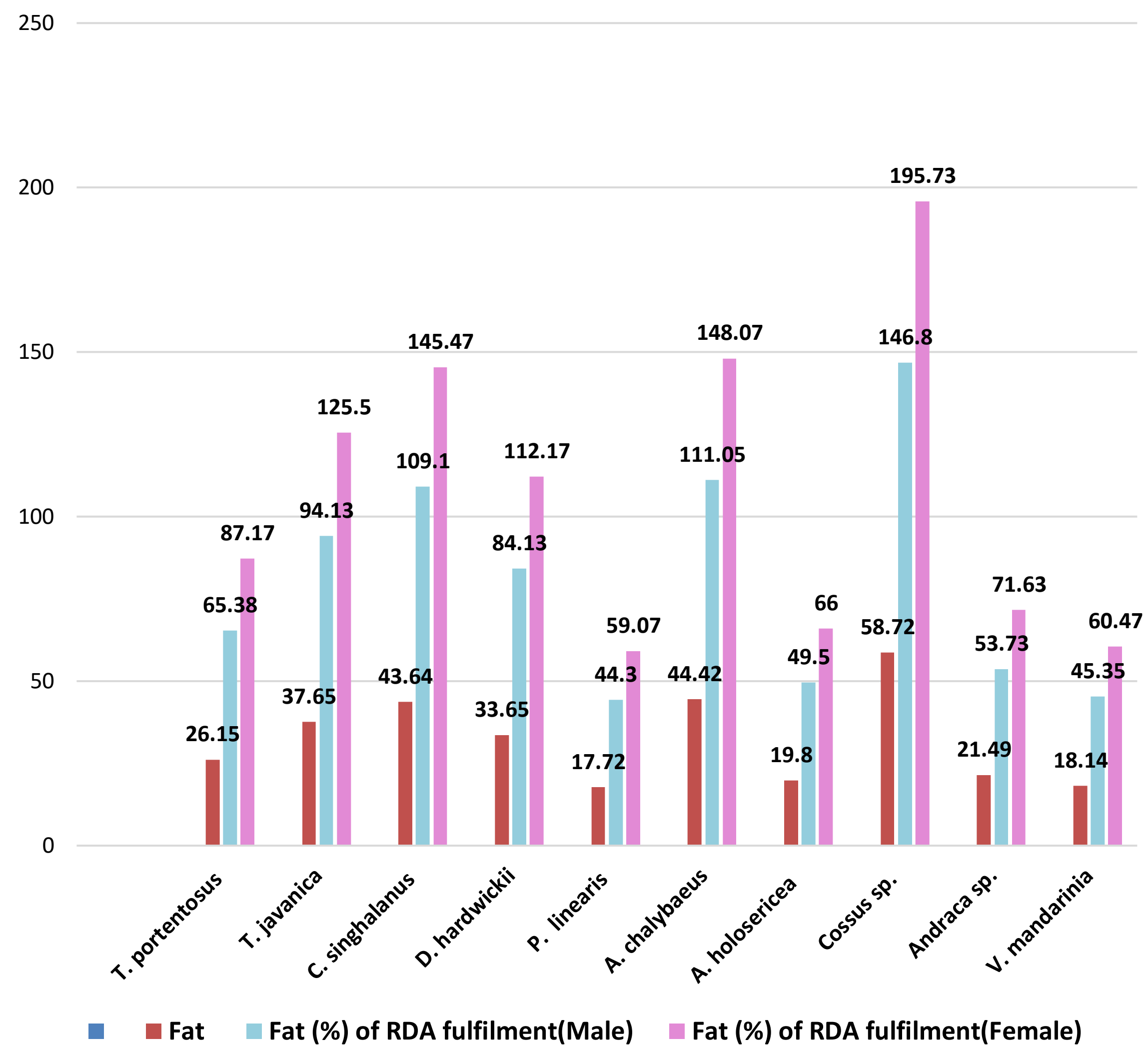


Figure 5: Percentage of Fulfilment of Recommended Dietary Allowance (RDA) for Adult (Male and Female) as Referred for Fat by FSSAI, New Delhi (2020) for Consumption of the Identified Edible Insects (IEIs) with Crude Fat Content in g /100g (DM basis).



For Fat, percentage of fulfillment of RDA for adult as referred by FSSAI, New Delhi (2020) for consumption of the insects were very high ranging from 44.30- 146.8 % for male and from 59.07- 195.73% for female. The RDA fulfillment in female is above 100% for 5 insects. Therefore, IEIs have quality fat which will give health benefits. Thus having these curative properties, the insects' high RDA fulfillment is significant in emphasizing the requirement of their fat as a source for replacing other fats derived from conventional meat sources.

Mineral analysis

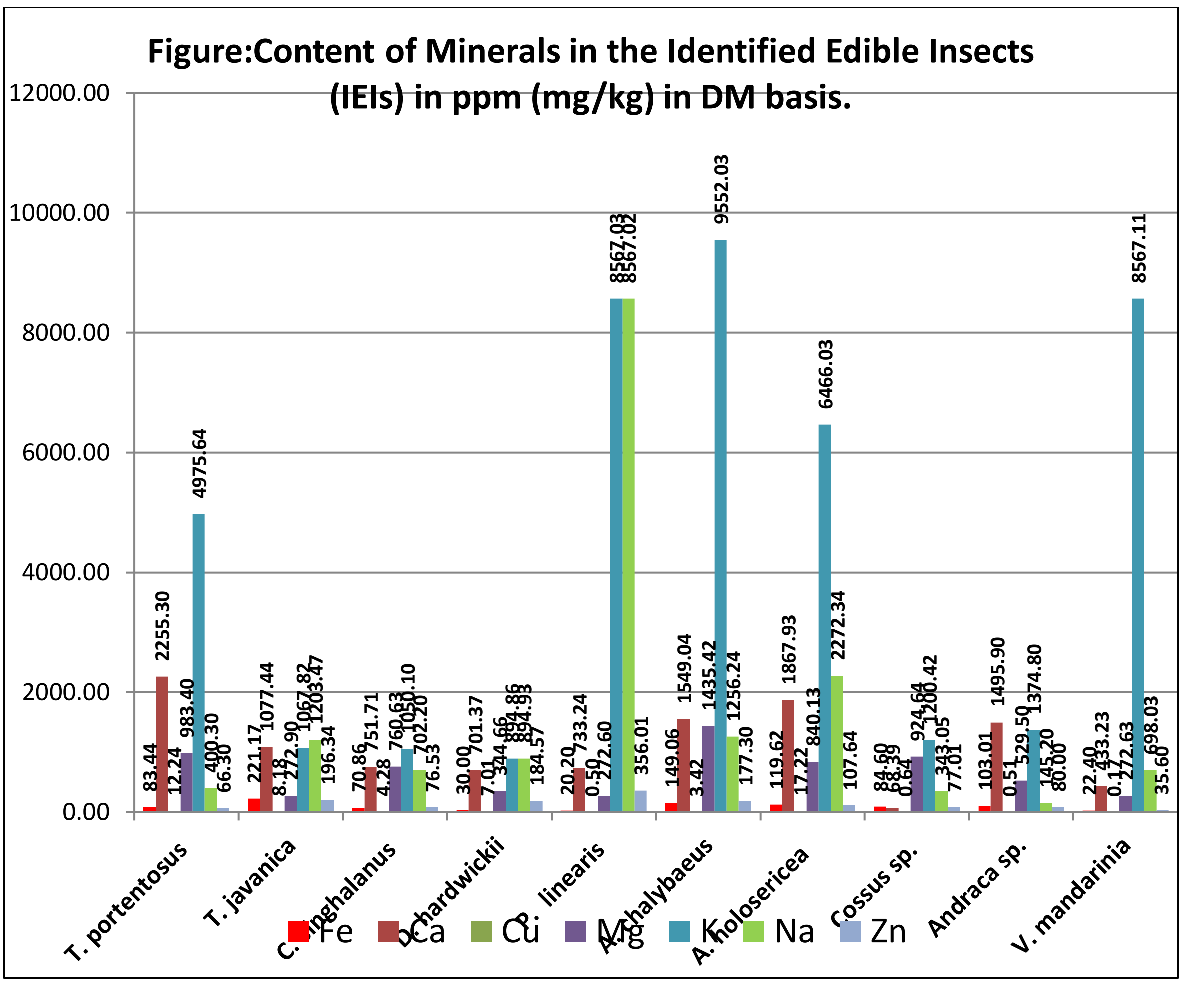
Table 3represents content of some minerals in ppm in the IEIs with standard deviation andFigure 6 represents in bars the evaluated mineral contents in mg/100g i.e., four macromineralsnamely sodium, potassium, calcium and magnesium, and three microminerals namely copper, iron and zinc.

Table 3: Content of Minerals in the Identified Edible Insects (IEIs) in ppm (mg/kg) (DM basis).
Data Expressed as Mean of 3 Replicates with (±) Standard Deviation.

Sl No.	Scientific name	Elements						
		Fe	**Ca**	**Cu**	**Mg**	**K**	**Na**	**Zn**
1	*T. portentosus*	83.436±0.512	2255.303±0.321	12.240±0.001	983.403±0.100	4975.643±0.810	400.304±0.002	66.30±0.011
2	*T. javanica*	221.171±0.083	1077.440±0.213	8.181±0.012	272.902±0.112	1067.822±0.086	1203.473±0.214	196.34±0.019
3	*C. singhalanus*	70.861±0.082	751.714±0.195	4.283±0.017	760.633±0.165	1050.101±0.116	702.204±0.002	76.530±0.018
4	*D. hardwickii*	30.002±0.116	701.366±0.060	7.014±0.006	344.664±0.135	894.860±0.058	894.931±0.011	184.573±0.032
5	*P. linearis*	20.201±0.012	733.240±0.121	0.501±0.007	272.600±0.068	8567.026±0.114	8567.022±0.024	356.011±0.058
6	*A. chalybaeus*	149.056±0.042	1549.044±0.232	3.420±0.007	1435.416±0.017	9552.031±0.112	1256.235±0.014	177.304±0.007
7	*A. holosericea*	119.623±0.023	1867.932±0.110	17.221±0.005	840.127±0.060	6466.029±0.171	2272.337±0.060	107.641±0.014

8	*Cossus sp.*	84.603±0.011	68.392±0.219	0.640±0.008	924.635±0.188	1200.422±0.185	343.054±0.009	77.014 ±0.002
9	*Andraca sp.*	103.012±0.006	1495.902±0.184	0.505±0.001	529.501±0.145	1374.800±0.165	145.202±0.014	80.001 ±0.004
10	*V. mandarinia*	22.401±0.012	433.23±0.121	0.171±0.001	272.628±0.068	8567.110±0.114	698.032±0.040	35.601 ±0.058

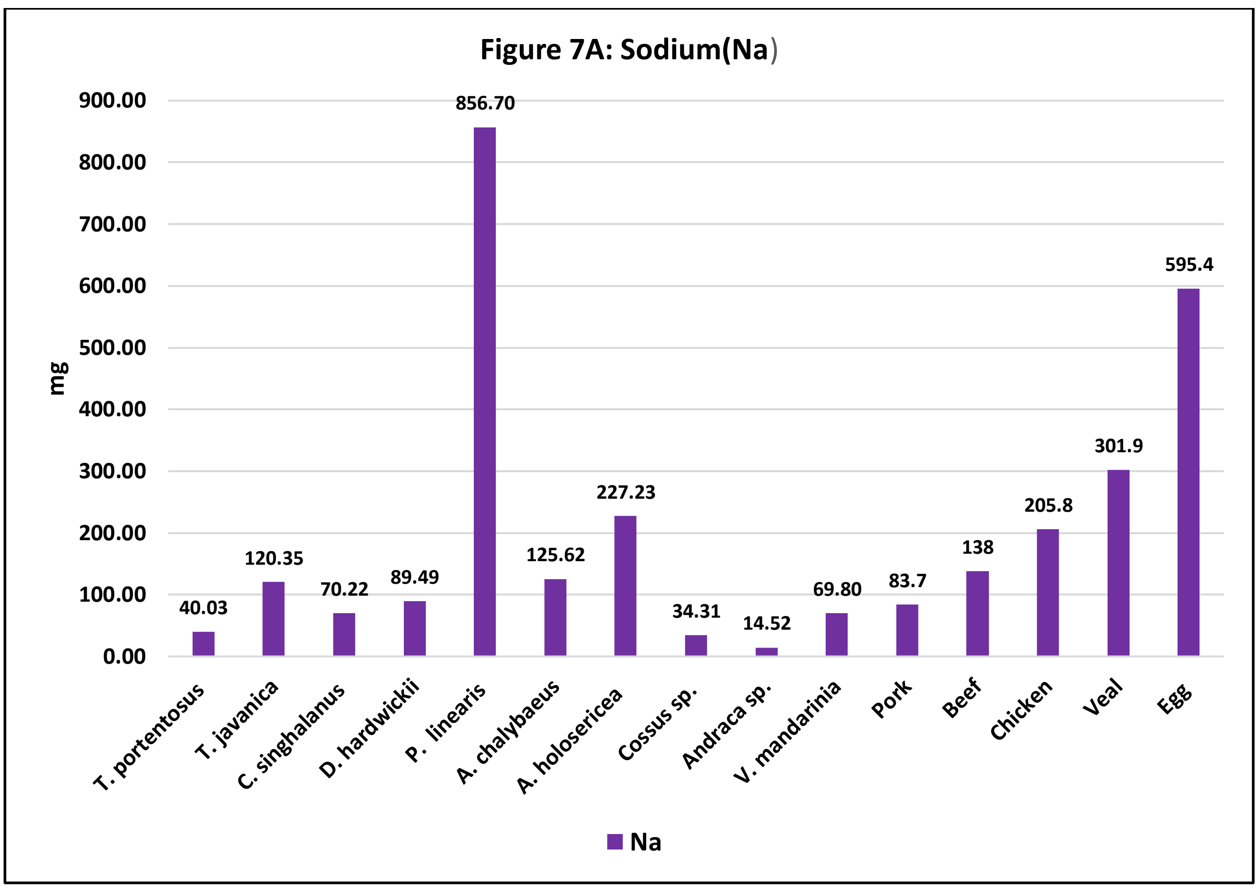
(Analysed in SAIF, North Eastern Hill University, Shillong, Meghalaya, India).



Sodium which is an essential nutrient and is needed by the body in relatively small amounts was estimated highest in *P. linearis* (8567.02 ppm) and lowest in *Andraca sp*. (145.202ppm). Potassium was notably abundant (9552.031 – 1050.101 ppm) except for *D. hardwickii* (894.860 ppm). Calcium was highest in *T. portentosus* (2255.303 ppm)

(Pongener& A0, 2019) and lowest in *Cossus sp*. (68.392 ppm). Iron content was found to be highest in *T. javanica* (221.171 ppm) and lowest in *P. linearis* (20.201ppm). Copper content was found to be notably low ranging from 0.171-17.22 ppm where highest was in *A. holosericea*and lowest in *V. mandarinia.*Zinc which is a micronutrient and a constituent of many enzymes that promote structural integrity of proteins and gene expression is highest in *P. linearis* (356.011 ppm) and lowest in *V. mandarinia*(35.601 ppm). Magnesium content ranges from 272.600 – 1435.416 ppm) where *A. chalybaeus* has the highest and *P. linearis* has the lowest content.

Figures (7A–G): Represents the Comparison of Mineral Content (mg/100g) of Identified Edible Insects (IEIs) with Conventional Foods of Animal Origin (CFAO, USDA Database, 2019) in DM basis



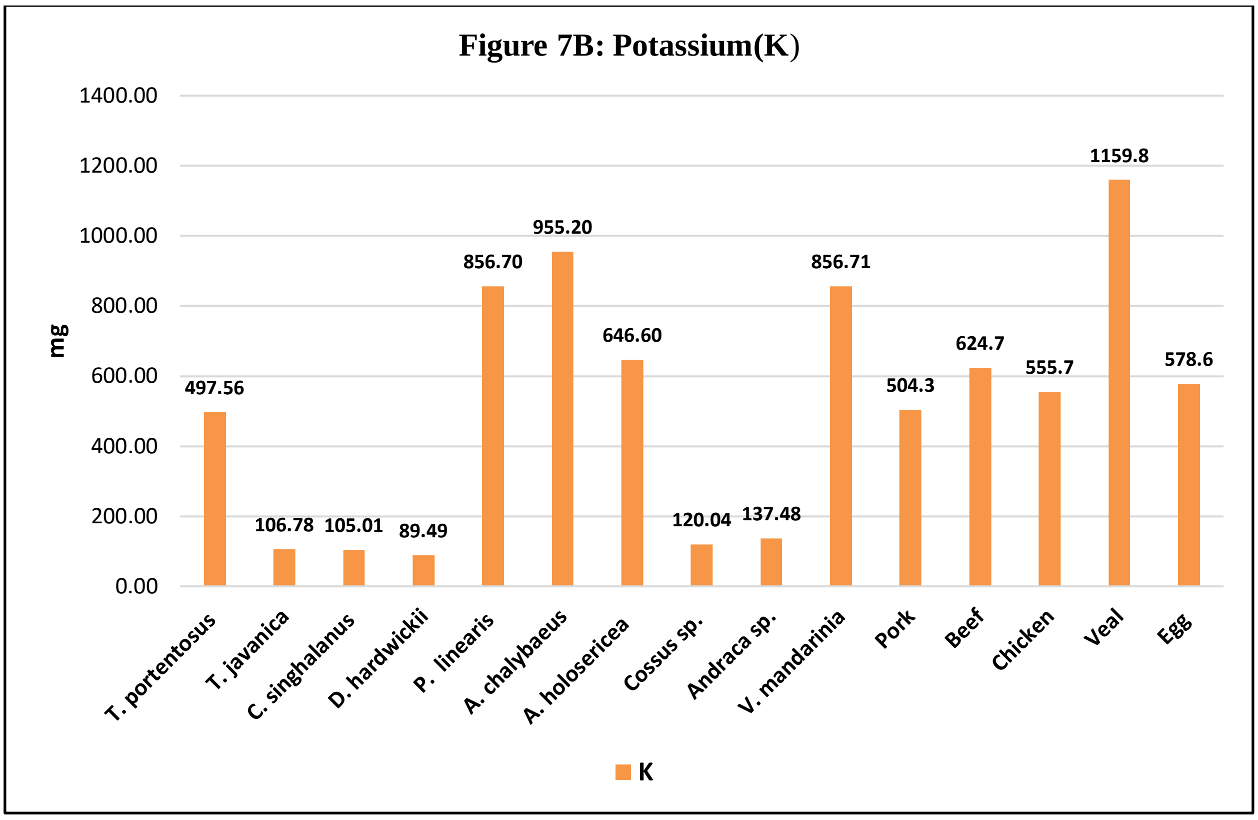


Figure 7B: Potassium(K)
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
mg
497.56
106.78
105.01
89.49
856.70
955.20
646.60
120.04
137.48
856.71
504.3
624.7
555.7
1159.8
578.6
T. portentosus
T. javanica
C. singhalanus
D. hardwickii
P. linearis
A. chalybaeus
A. holosericea
Cossus sp.
Andraca sp.
V. mandarinia
Pork
Beef
Chicken
Veal
Egg
K

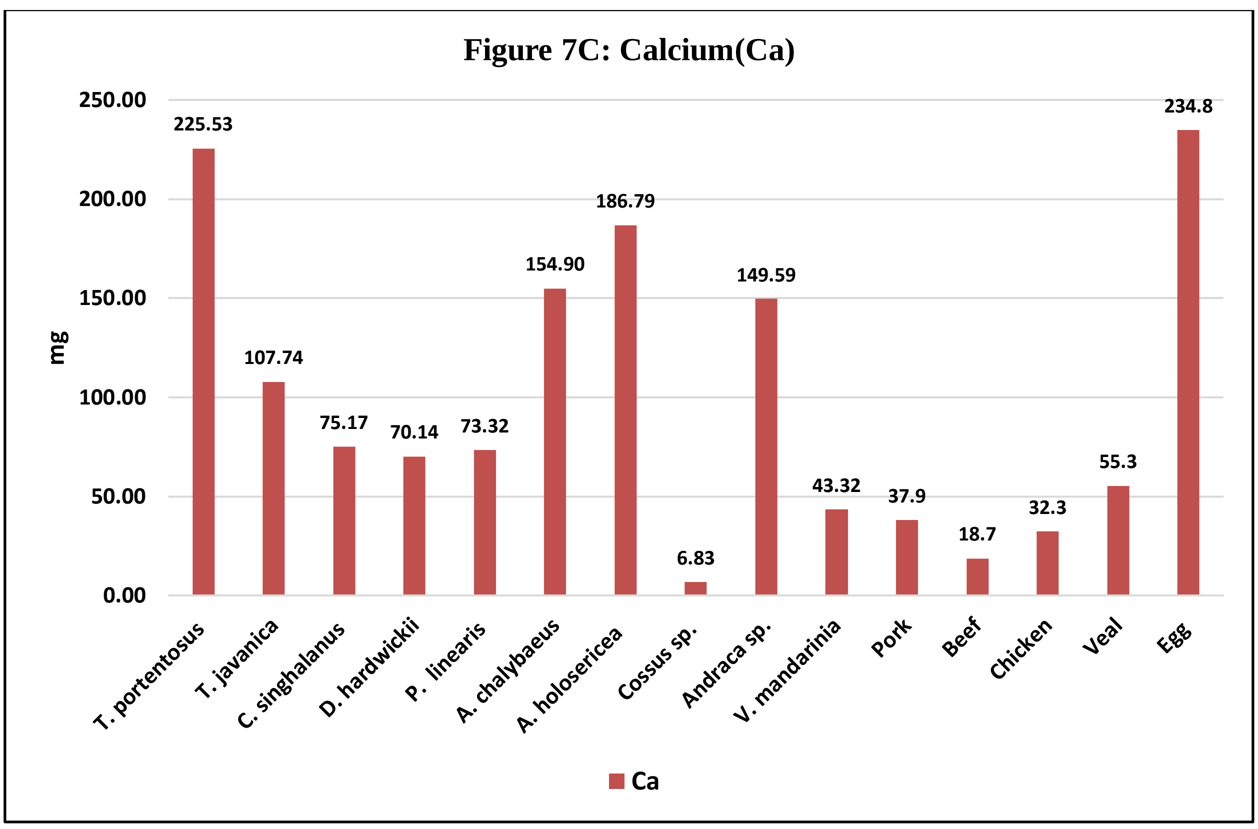


Figure 7C: Calcium(Ca)
250.00
200.00
150.00
100.00
50.00
0.00
mg
225.53
107.74
75.17
70.14
73.32
154.90
186.79
6.83
149.59
43.32
37.9
18.7
32.3
55.3
234.8
T. portentosus
T. javanica
C. singhalanus
D. hardwickii
P. linearis
A. chalybaeus
A. holosericea
Cossus sp.
Andraca sp.
V. mandarinia
Pork
Beef
Chicken
Veal
Egg
Ca

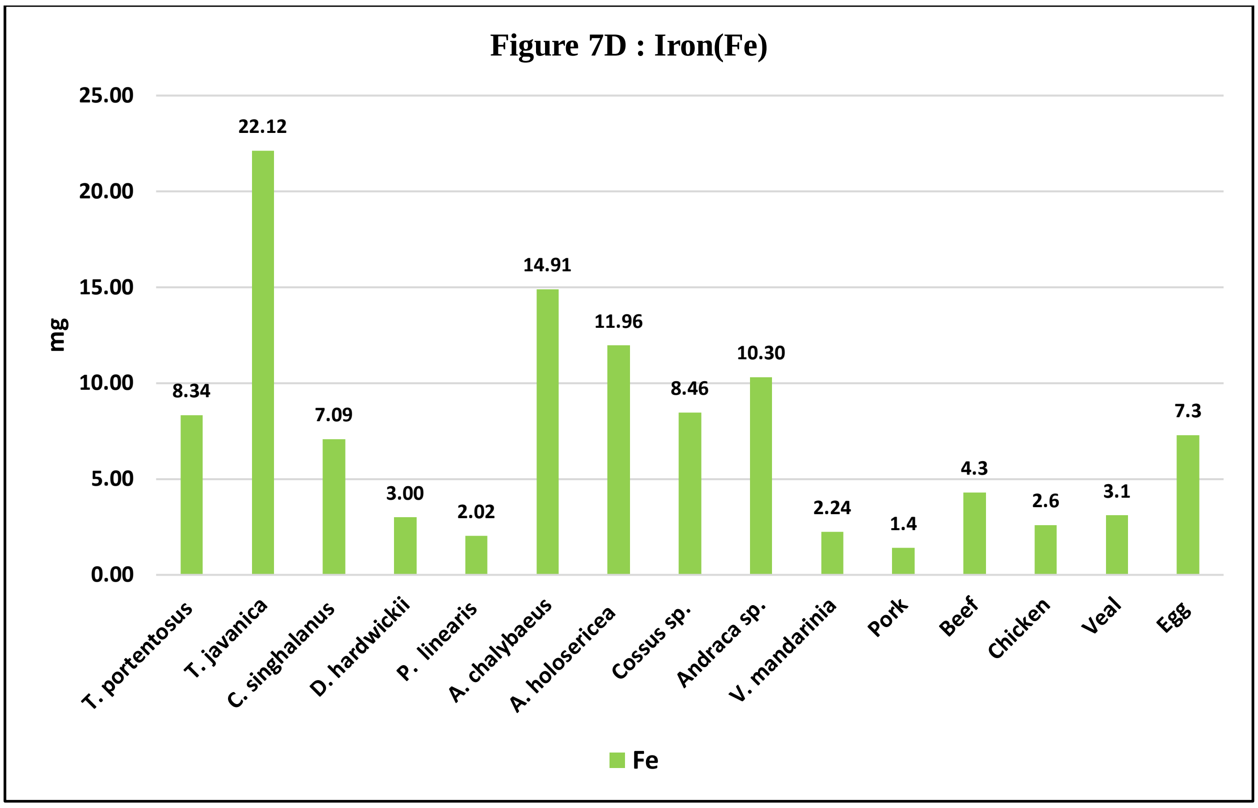


Figure 7D : Iron(Fe)
mg
25.00
20.00
15.00
10.00
5.00
0.00
8.34
22.12
7.09
3.00
2.02
14.91
11.96
8.46
10.30
2.24
1.4
4.3
2.6
3.1
7.3
T. portentosus
T. javanica
C. singhalanus
D. hardwickii
P. linearis
A. chalybaeus
A. holosericea
Cossus sp.
Andraca sp.
V. mandarinia
Pork
Beef
Chicken
Veal
Egg
Fe

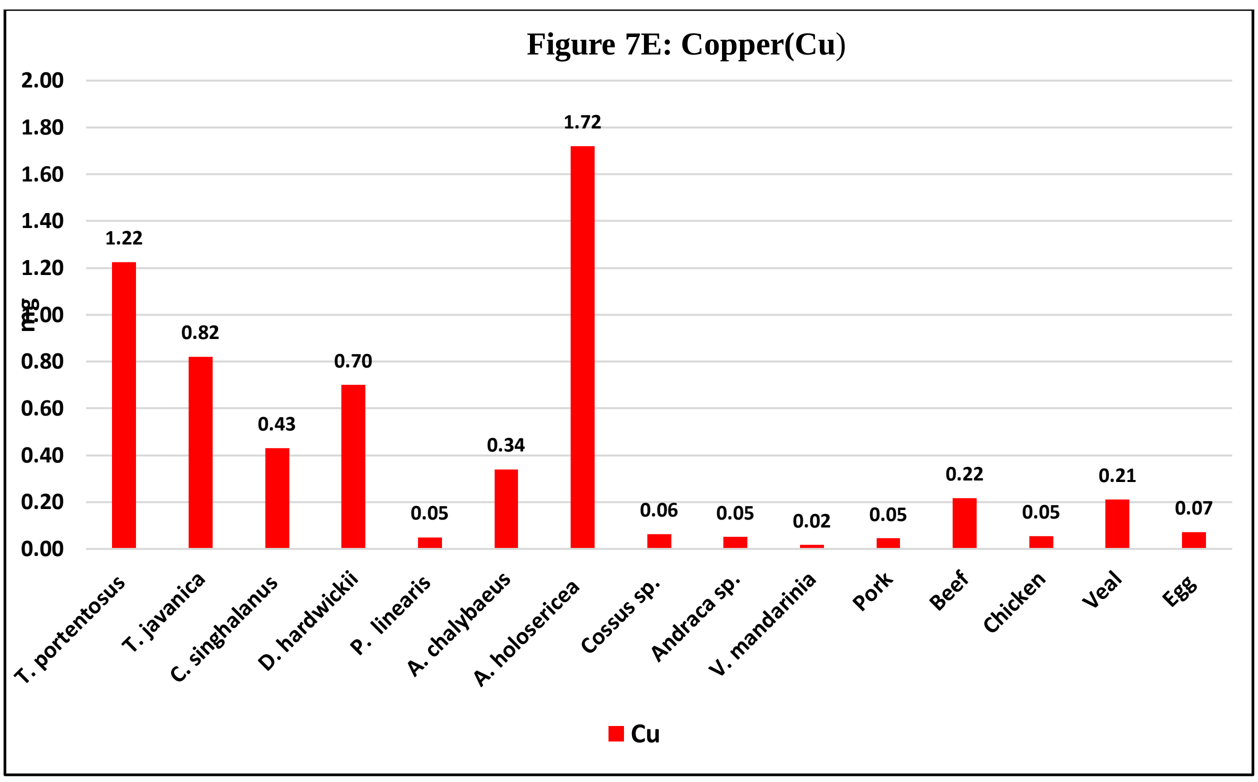


Figure 7E: Copper(Cu)
mg
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1.22
0.82
0.43
0.70
0.05
0.34
1.72
0.06
0.05
0.02
0.05
0.22
0.05
0.21
0.07
T. portentosus
T. javanica
C. singhalanus
D. hardwickii
P. linearis
A. chalybaeus
A. holosericea
Cossus sp.
Andraca sp.
V. mandarinia
Pork
Beef
Chicken
Veal
Egg
Cu

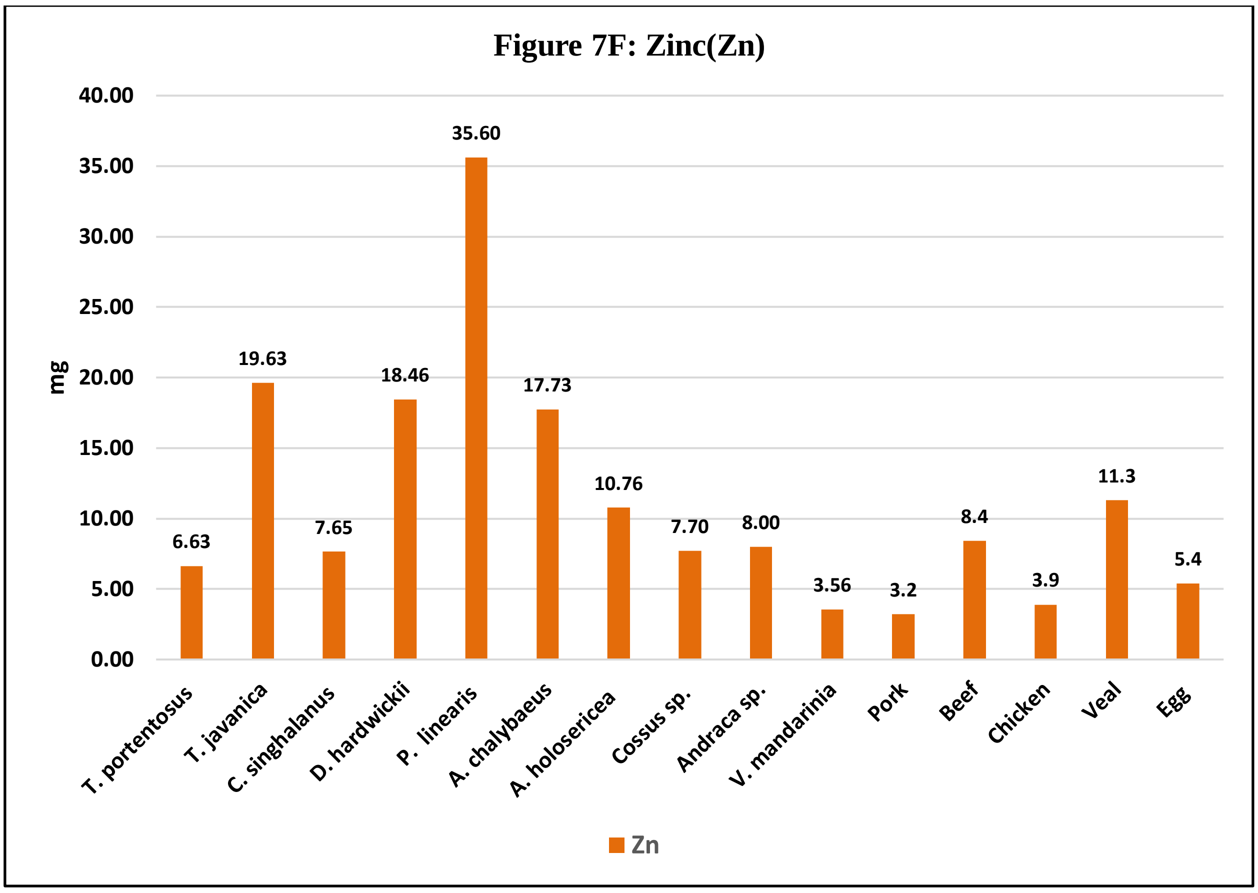


Figure 7F: Zinc(Zn)
mg
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
6.63
19.63
7.65
18.46
35.60
17.73
10.76
7.70
8.00
3.56
3.2
8.4
3.9
11.3
5.4
T. portentosus
T. javanica
C. singhalanus
D. hardwickii
P. linearis
A. chalybaeus
A. holosericea
Cossus sp.
Andraca sp.
V. mandarinia
Pork
Beef
Chicken
Veal
Egg
Zn

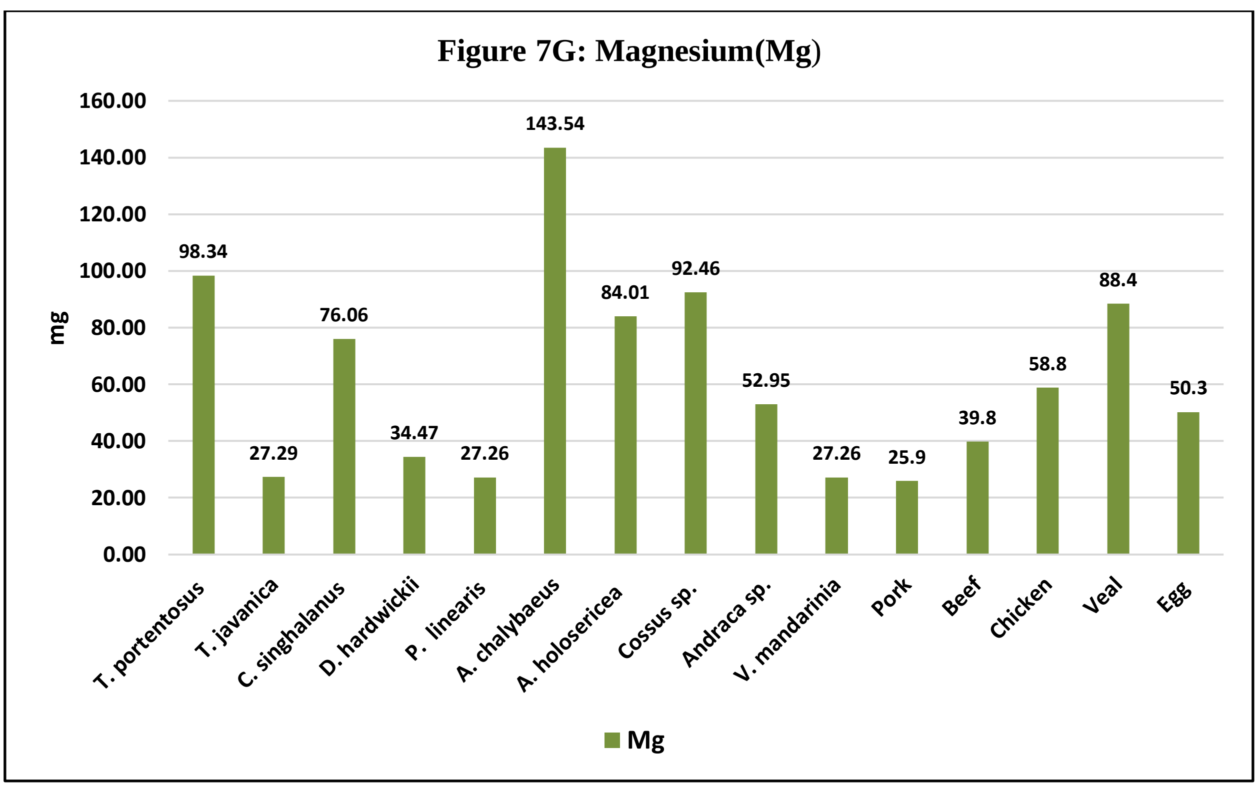


Figure 7G: Magnesium(Mg)
mg
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
98.34
27.29
76.06
34.47
27.26
143.54
84.01
92.46
52.95
27.26
25.9
39.8
58.8
88.4
50.3
T. portentosus
T. javanica
C. singhalanus
D. hardwickii
P. linearis
A. chalybaeus
A. holosericea
Cossus sp.
Andraca sp.
V. mandarinia
Pork
Beef
Chicken
Veal
Egg
Mg

Figures (7A–G) represents the comparison of mineral content (mg/100gDM) of IEIs with CFAO (USDA database, 2019).

Sodium was lower in five of the IEIs and the other five at par with values of CFAO namely *P. linearis, A. holosericea, A. chalybaeus, T. javanicaand D.hardwickii*(Fig.7A). Potassium in four IEIs namely *A. chalybaeus*, *P. linearis, A. holosericea* and *T. portentosus*was at par with the conventional foods value and the other six insects have lower amounts than in conventional foods (Fig.7B). Calcium in the IEIs ranges from 6.83–225.53 mg/100g where nine insects except *cossus sp.* have all higher content than in pork, beef, chicken and veal (Fig.7C). Iron in six of the IEIs were higher with a value above 8.34/100g than in the conventional foods which have iron content ranging from 1.4–7.3mg/100g. *P. linearis* (2.02 mg/100g) and *V. mandarinia* (2.24 mg/100g) have similar iron content to chicken (2.6 mg/100g) ((Fig.7D). Copper content in the IEIs ranges from 0.02–1.72 mg/100g of which with the exception of *V. mandarinia*(0.02mg/100g), the other nine have higher values than its content in the CFAO (0.045–0.217 mg/100g) ((Fig.7E). Zinc content was higher in 4 identified edible insects (17.73–35.60 mg/100g) than in all CFAO (Fig.7F). Magnesium content in *A. chalybaeus* (143.54 mg/100g), *T. portentosus*(98.34 mg/100g) and *Cossus sp*. (92.46mg/100g) was higher than its content in the CFAO (Fig.7G).

This comparative analysis indicates the significance of these edible insects as good sources of mineral salts of great health benefits as mentioned in earlier.

Table 4 & 5 indicates percentage of fulfillment of RDA of minerals in mg/100g for adult (Male and Female) obtained from the Micronutrient Information Centre (2020), by consumption of the IEIs with mineral content in mg/100g (DM basis).

The RDA fulfillment of sodium by consumption of 10 IEIs for male and female ranges from 0.38-57.11%. For potassium it ranges from 2.63-28.09% for male and 3.44-36.74% for female. For calcium, the RDA fulfillment is lowest for *Cossus sp.* with 0.68% in both male and female and highest for *T. portentosus* scoring 22.53% in both sexes. For iron it ranges from 25.25- 276.5% and in female from 12.44- 122.89%. For copper, it ranges widely with lowest for *V. mandarinia.* (2.22%) and highest for *A. holosericia* (191%). For zinc, RDA fulfillment in male is from 32.36-323.64% and in female from 44.50-445.00% which substantially fulfills RDA by consumption of 8 of the IEIs with zinc content ranging from 7.70–35.60 mg/100g and sufficiently for *V. mandarinia* and *T. portentosus* having 3.56 and 6.63 mg/100g respectively. The RDA fulfillment of magnesium in male is between 6.82-35.89% and in female, between 8.79- 46.30%.

Rumpold and Schluter (2013a) summarized the average level of minerals in some commonly eaten insect species in mg/100g dry matter where the iron content ranges from 5.46-161.00, calcium from 17.48-171, potassium from 259.7-1826.59, magnesium from 33.1-424.00, sodium from 39.76-609.00, zinc from 7.00-42.00 and copper from 0.5-2.08. The mineral composition generally reflects the food sources of insects, both those that are contained in the gastrointestinal tract and those which are absorbed into the insect's body from food it consumed (Finke, 2004). Although micronutrients levels vary across insect species, it can be deduced that the 10 IEIs contain a reasonable amount of essential minerals.

Table 4: Percentage of Fulfilment of Recommended Dietary Allowance (RDA) of Minerals for Adult (Male and Female) Obtained from the Micronutrient

Information Centre, by Consumption of the Identified Edible Insects (IEI) with Values of Mineral Content in mg /100g (DM basis).

Sl No.	Scientific name	Elements And % of RDA Fulfillment							
		Fe	**M F**	**Ca**	**M F**	**Cu**	**M F**	**Mg**	**M F**
1	*T. portentosus*	8.34	104.25 46.33	225.53	22.53 Do	1.22	135.56 Do	98.34	24.59 31.72
2	***T. javanica***	22.12	276.5 122.89	107.74	10.77 Do	0.82	91.11 Do	27.29	6.82 8.80
3	***C. singhalanus***	7.09	88.63 39.39	75.17	7.52 Do	0.43	47.78 Do	76.06	19.02 24.54
4	***D. hardwickii***	3.00	37.5 16.67	70.14	7.01 Do	0.70	77.78 Do	34.47	8.6211.12
5	***P. linearis***	2.02	25.25 11.22	73.32	7.33 Do	0.05	5.56 Do	27.26	6.82 8.79
6	***A. chalybaeus***	14.91	186.37 82.83	154.90	15.49 Do	0.34	37.78 Do	143.54	35.89 46.30
7	***A. holosericea***	11.96	149.5 66.44	186.79	18.68 Do	1.72	191.11 Do	84.01	21.00 27.1
8	***Cossus sp.***	8.46	105.75 47.00	6.83	0.68 Do	0.06	6.67 Do	92.46	23.12 29.83
9	***Andraca sp.***	10.30	128.75 57.22	149.59	14.96 Do	0.05	5.56 Do	52.95	13.24 17.08
10	***V. mandarinia***	2.24	28.00 12.44	43.32	4.33 Do	0.02	2.22 Do	27.26	6.82 8.79
RDA*	M	8		1000		0.9		400	
	F	18		1000		0.9		310	

***RDA values were obtained from the Micronutrient Information Centre, Linus Pauling Institute, Oregon State University [www.Ipi.oregon-state.edu/mic/minerals (2020). All the values are provided in mg/day . M=Male; F=Female.**

Table 5: Percentage of Fulfilment of Recommended Dietary Allowance (RDA) of Minerals for Adult (Male and Female) Obtained from the Micronutrient Information

Centre, by Consumption of the Identified Edible Insects (IEI) with Values of Mineral Content in mg /100g (DM basis).

Sl No.	Scientific name	Elements And % of RDA Fulfillment								
		K	**M**	**F**	**Na**	**M**	**F**	**Zn**	**M**	**F**
1	*T. portentosus*	497.56	14.63	19.14	40.03	2.67	1.05	6.63	60.27	82.88
2	***T. javanica***	106.78	3.14	4.11	120.35	8.02	3.17	19.63	178.45	245.38
3	***C. singhalanus***	105.01	3.09	4.04	70.22	4.68	1.85	7.65	69.55	95.63
4	***D. hardwickii***	89.49	2.63	3.44	89.49	5.97	2.36	18.46	167.82	230.75
5	***P. linearis***	856.70	25.20	33.0	856.70	57.11	22.54	35.60	323.64	445.00
6	***A. chalybaeus***	955.20	28.09	36.74	125.62	8.37	3.31	17.73	161.18	221.63
7	***A. holosericea***	646.60	19.02	24.87	227.23	15.15	5.98	10.76	97.82	134.5
8	***Cossus sp.***	120.04	3.53	4.62	34.31	2.29	0.90	7.70	70.00	96.25
9	***Andraca sp.***	137.48	4.04	5.29	14.52	0.97	0.38	8.00	72.73	100.00
10	***V. mandarinia***	856.71	25.20	32.95	69.80	4.65	1.84	3.56	32.36	44.50
RDA*	M	3400			1500			11		
	F	2600			3800			8		

*RDA values were obtained from the Micronutrient Information Centre, Linus Pauling Institute, Oregon State University [www.Ipi.oregon-state.edu/mic/minerals (2020). All the values are provided in mg/day. M=Male; F=Female.

Sodium is an essential nutrient and is needed by the body in relatively small amounts. It is the primary regulator of extracellular fluid volume and helps in the distribution of fluids in the tissues and it is very important in nervous coordination (Kaltreider, 1941). Deficiency of sodium occurs rarely. It is manifested by prolonged bouts of fluid loss due to diarrhea, vomiting, or perspiration, nausea, dizziness, and muscle cramps (Bellows & Moore, 2013). Sodium is the principal cation in extracellular fluid in the body, and is an essential nutrient necessary for maintenance of plasma volume, acid–base balance, transmission of nerve impulses and normal cell function. In healthy individuals, nearly 100% of ingested sodium is absorbed during digestion, and urinary excretion is the primary mechanism for maintaining sodium balance (Holbrook *et al.*, 1984).

Potassium is important for heart function and in skeleton and muscle contraction. Low levels of potassium in humans have been connected to a variety of physiological disorders like respiratory and renal ones and hypertension (Cohn *et al*., 2000).

Calcium is a major component of bone and it plays important roles in physiological functions such as nerve conduction, muscle contraction, blood clotting, and membrane permeability (RDA, 1989). It is to be noted that deficiency of calcium causes muscle cramping, dry skin, brittle nails, increased PMS symptoms and bone fracture and breakage (Pravina*et al*., 2013) thus the significance of this mineral in the dietary intake of a person is emphasised.

Iron is a constituent of haemoglobin, myoglobin, enzymes and an essential nutrient for humans (Bothwell, 1979)

Copper is a vital element for all vertebrates and some lower animal species. Several abnormalities have been observed in copper-deficient animals, which include anemia, degeneration of the nervous system and myocardial, defects in skeletal growth, pigmentation and structure of hair or wool, reproductive failure, and decreased arterial elasticity (Davis, *et al.*, 1987).

Zinc plays a major role in growth of cell, differentiation of tissue and metabolism (Brown *et al.,* 2001). Deficiency of Zinc results in anemia, hypogonadism and dwarfism (Prasad *et al.*, 1963). Zinc metalloenzymes include alcohol dehydrogenase, ribonucleic acid polymerases, alkaline phosphatase and carbonic anhydrase. About 85% of total body zinc are found in skeletal muscles and bones (King, 1999).

Magnesium is another important element which regulates numerous vital processes in the body. As the complex Mg-ATP2, magnesium is essential for all biochemical processes, glycolysis, formation of cyclic-AMP, stimulation of hormone secretion (Wacker, 1980). Deficiency of magnesium may contribute to the development of diseases of cardiovascular neuromuscular, and endocrine glands as well as the bone, kidney, immune, stress and ageing (Durlach*et al.,* 1997; Durlach, J. 1988). Low magnesium is also reported to be associated with diabetes both type I and II, obesity and hypertension (Altura *et al.*, 1984; Vanroellen*et al.*, 1985; Paolisso*et al.* 1990; Lima *et al,* 1998).

Assuming good bioavailability of the mineral contents, consumption of these IEIs as food can boost dietary value. In today’s world, the root cause of malnourishment is poverty and edible insects could well be an answer to resolve this issue by attempting to reduce the risk of malnutrition because of micronutrient deficiencies wherein insects could be procured easily in seasons of availability or cultured for consumption (Banjo *et al.,* 2006; Cerritos, 2011; Van Huis *et al*., 2013c; Raheem *et al*., 2018).

CHAPTER FIVE

CONCLUSION

It is seen that the 600 respondents from the 4 districts demonstrated a positive attitude towards entomophagy. All the respondents have the knowledge that the IEIs were used as food. Out of the 10 IEIs, consumption of 8 of them were above 47% with the highest being

95%. For the respondents, the unavailability and unfamiliarity of the IEIs were the main reasons for low consumption (9 & 22%). Consumption of 6 IEIs decreased in percentage due to allergic reaction on consumption. 5 IEIs besides having food values were popularly used therapeutically for ailments like mouth ulcer, TB, diabetes, low blood pressure, hypertension and removal of warts. However there was no information on any scientific work done in the insects from biochemical aspects to evaluate the efficacy of the active substances present in it if present. Therefore thorough research in this direction is required to prove that insects do have ethno-medicinal properties.

The awareness that the insects are nutritious was excellent, giving highest positive response to *Cossus sp.* (100%). The respondents' responses encourage the principal that insects could become an inexpensive and available alternative source of protein and phospholipid in the community.

On query of sustainable management and collection of insects, 9 IEIs were generally collected seasonally from the wild with the exception of *V. mandarinia* which are semi reared. Semi rearing of *V.mandarinia*was practiced only by a few tribals and sold off at exorbitant prices (₹ 7000 for a big hive) which upraises the challenge on the prospect of mass production and reasonably, could reduce the cost of this insects and make it available to the tribals who could not afford it. Oak trees (*Quercus serrata)* in which *Cossus sp.* inhabits were felled to procure the red larvae giving rise to challenges to create awareness on the sustainable management of the tree species that eventually can promote the increase of the worm population by which means of income generation for the tribals can be realized by selling both the worm and firewood. The cricket, which are collected from the fields only seasonally, have the potential to be reared as minilivestocks as being practiced in countries like Korea, Thailand and Laos which has uplifted the living standard of the rural farmers by giving them an alternative source of income as well as better social life and improved nutritional adequacy (Halloran *et al.*,2016 ; Weigel *et al.*, 2017).

When it came to preparation and cooking of the IEIs, they were commonly prepared in the usual Naga tribal style by first washing and cleaning it and then steaming with chilly, fermented bamboo either wet or dried, roasting in a little oil and deep frying. Two of the IEIs were stored to be used during its unavailability. *C.singhalanus*was pounded into a paste, fermented and stuffed into a bamboo container and *D.hardwickii*was roasted and stored in plastic containers. It was noted while surveying, method of hygienic handling and storing in non toxic eco-friendly containers that can help eliminate contamination with toxic substances of the edible insects and ensure its safety for human consumption were very less. Traditional preparation of insect should also be improved to avoid contamination and wastage, thereby providing for a high quality and acceptable product. With food contamination being regarded as a serious public health problem worldwide (WHO, 2015; Fakuda, 2015) people eating insects should be educated on the safety of food.

This research has attempted to give an accurate analysis on the proximate nutritional values and essential minerals of 10 IEIs and the results were significant. The results were compared by weight to other edible insects of the same taxa order and conventional food of animal origin (CFAO) namely egg, veal, chicken, beef and pork. Both proximate values and minerals values of the IEIs were found to be at par and in some cases, show values that indicate an even higher source of protein, fat and minerals as compared to egg, chicken, beef and pork. The results showing high protein content point to the high nutritional value that insects can add to the diet of both men and animals and by extension, the assimilation of insects in a diet could eventually replace conventional animal protein which is usually absent in the diet of rural residents in developing countries (Banjo *et al.*, 2006). The high content of protein content in these IEIs indicates volume in general that the insects can be of value as food for both man and animal and can eventually use as an alternative source of protein especially in rural regions of developing countries [Banjo *et al.*, 2006].

Fat is one of the main constituent nutrients of the human body. Fat reserves and gives energy as well as supports and protects different organs. Fat can also aid in the absorption of vitamins and bond with protein as integral parts of many cell membranes and tissues. Unsaturated fatty acids function in growth, preserve the skin, and help in preventing the formation of thrombus and clotting of platelets (Chen, *et al.*, 2009). Edible insects having a notable amount of fatwith higher essential lipid composition, such as phosphatide, could be suggested as an accessible source of fat for the people especially in the rural areas.

The RDA fulfillment of protein, fat and minerals by weight were also very impressive. RDA fulfillment for protein by adult were significant with values from 23.24 – 92.66% in male and from 28.54 – 112.80% in female, for fat from 44.30 – 146.8 % in male and from 59.07- 195.73% in female. For minerals the RDA fulfillment by weight (DM) was notably positive, presenting wide ranges of percentage (2.22 – 276.5%). RDA fulfillment is an indication that the insects are good nutrient sources and affordable food supplement.

Although there are high content of protein, fat and minerals in those insects, we are yet to conserve and mass produce it (cricket farming and wasp rearing) for market. Thusfurther studies and experimentations are required to propose standardized farming techniques for sustainability and income generation. Because of the study focusing on a total of 10 different species, this research has been constrained from performing an in-depth experimentation and analysis of each species.

According to the *Annual Global Report on Food Crises (2022) by the Global Network against Food Crises (GNAFC),*over 193 million people globally experienced acute food crisis in 2021. Moreover this situation should have been aggravated affecting the life and livelihood of the people in the following years with the pandemic in 2019 (FAO, 2019) and the Ukraine war which started in February 2022 (OECD, 2022; World Bank Commodity Markets Outlook, 2022). It is therefore very relevant as suggested by FAO, 2012 and other authoritative scholars (Van Huis*et al.*, 2013a) that entomophagy could be a probable answer to the shortage of global food crisis.

Suggestion and future prospect

Globally this research work will contribute significant information to the documentation of some of the edible insects and its nutrient contents and locally it should become an index of the huge scope available to do outstanding and valuable researches on the edible insects and entomophagy in Nagaland for larger benefit of the common people in terms of bioprospecting, nutrient enrichment, economical benefit to the community, marketing and sustainable management of the environment. Policy makers, environmental NGOs, and expert scholars should collaborate to encourage and launch programmes and projects with focuses on revivingentomophagic practices, alternative nutrient sources and feedstuffs, studies on their biology and life cycle, preservation and processing, sustainable harvesting and scientific research on the medicinal aspects.

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APPENDIX

Appendix 1: Questionnaire on Edible Insects

Appendix 1

Questionaire on Edible Insects

Survey Conducted by Mrs. AnunglaPongener on Edible insects (IEIs)

Date…………… Village ………………………. District………………

1. Name of the informant:……………………………… Contact no:……………………
2. Qualification/Profession:
3. Name of the insect (local name)& color:
4. In which season/month does it occur?
5. What does the insect feed on?
6. Where is it found? (root, leaf, bark, trunk.soil)…………………..
7. What stage of the insect is eaten? (egg, larva, pupa, imago)
8. Which part of the insect is eaten?
9. Is it eaten
   (a) Food?
   (b) medicinal purpose?
10. If the answer is (b), what are the ailments or disease that it is eaten for?
11. Are you aware of its nutritious value? What benefits do you find in eating it?
12. How is it prepared or cooked before being eaten?
    ....
    ……………………………………………………………………………….
13. How do you catch the insect?
    ……………………………………………………………………………….
14. Is the insect also reared/ cultured? …………………………………………………
15. Does it have any allergic effects/detrimental ailments on the person having it?
    ……………………………………………………………………………….
    ……………………………………………………………………………….
16. If so how is the problem treated/solved? ………………………………………….

Thank You
AnunglaPongener
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Zunheboto

Appendix 2: Result of trace element analysis by- Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES): Model: iCAP^{TM}, 7600 ICP-OES; SAIF/NEHU, Shillong, India

To,
Ms.AnunglaPongener , Date: 17.08.18
Department of Zoology,
NAGALAND UNIVERSITY,
Lumami- 798627

SAIF/NEHU, SHILLONG

Result of Trace Element Analysis by- **Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES)**

Model: iCAP^{TM}. 7600ICP-OES

All concentrations in **ppm** (parts per million),**ND-** Not detectable						
SI. No	**Codes**	**E L E M E N T S**				
	Codes	**Fe**	**Ca**	**Cu**	**Mg**	**K**
1	1	103.012±0.006	1495.902±0.184	0.505±0.001	529.501±0.145	1374.800±0.165
2	2	84.603±0.011	68.392±0.219	0.640±0.008	924.635±0.188	1200.422±0.185
3	3	149.056±0.042	1549.044±0.232	3.420±0.007	1435.416±0.017	9552.031±0.112
4	4	221.171±0.083	1077.440±0.213	8.181±0.012	272.902±0.112	1067.822±0.086
5	5	30.002±0.116	701.366±0.060	7.014±0.006	344.664±0.135	894.860±0.058
6	6	70.861±0.082	751.714±0.195	4.283±0.017	760.633±0.165	1050.101±0.116
7	7	20.201±0.012	733.240±0.121	0.501±0.007	272.600±0.068	8567.026±0. 114
8	8	83.436±0.512	2255.303±0.321	12.240±0.001	983.403±0.100	4975.643±0.810
9	9	119.623±0.023	1867.932±0.110	17.221±0.005	840.127±0.060	6466.029±0.171
10	10	22.401±0.012	433.230±0.121	0.171±0.001	272.628±0.068	8567.110±0.114

To,
Ms.AnunglaPongener Date: 17.08.18
Department of Zoology
NAGALAND UNIVERSITY
Lumami- 798627

SAIF/NEHU, SHILLONG

Result of Trace Element Analysis by- **Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES)**

Model: iCAP™. 7600ICP-OES All concentrations in **ppm** (parts per million),**ND-** Not detectable						
SI.No	**Codes**	**E L E M E N T S**				
	Codes	**Na**	**Zn**			
1	1	145.202±0.014	80.001±0.004			
2	2	343.054±0.009	77.014±0.002			
3	3	1256.235±0.014	177.304±0.007			
4	4	1203.473±0.214	196.34±0.019			
5	5	894.931±0.011	184.573±0.032			
6	6	702.204±0.002	76.530±0.018			
7	7	8567.022±0.024	356.011±0.058			
8	8	400.304±0.002	66.30±0.011			
9	9	2272.337±0.060	107.641±0.014			
10	10	698.032±0.040	35.601±0.058			

CERTIFICATES OF PARTICIPATION

Certificate 1: National Conference on Recent trends in Zoological Research in North-East India from 19th -20th April, 2018, jointly organized by the Department of Zoology, North-Eastern hill University, Shillong and the Zoological Survey of India. Poster Presentation on An investigatory survey on the entomophagy of Malacosoma species by Aotribt in Mokokchung district, Nagaland.

Certificate 2: UGC Sponsored National Conference on “Contemporary Excitement in New Biology” organized by the Department of Zoology, Nagaland University, Lumami, Nagaland on 30th - 31st October, 2018, Platform talk on *Tessaratomajavanica* and *Coridiussinghalanus* (Hemiptera) in the practice of Entomophagy in Nagaland: An assessment of their nutritional quality.

Certificate 3: International Symposium on "Integrated Land use Management in the Eastern Himalayas. Focus on Nagaland" organized by the Department of Botany, Kohima Science College, Jotsoma, Nagaland, India in collaboration with the University of Minnesota, USA, on 12-14 March, 2019. Paper presentation on Nutritional Evaluation and Prospects of Farming the edible field cricket *Tarbinskiellusportentosus* in Mokokchung, Nagaland, India.

Certificate 4: Two day technical workshop on "Edible Insects for Sustainable Livelihood" conducted from 11th to 12th March, 2021 organized by Ashoka Trust for Research in Ecology and the Environment and Department of Zoology, Kohima Science College, Jotsoma, Kohima under the aegis of the Department of Biotechnology, New Delhi funded network program 'Bioresource and Sustainable Livelihoods in Northeast India'. Talk on Know what Insects we eat.

Certificate 5: Certificate of Publication on the paper ID: ART20196016 entitled "An Assessment of the Nutritional Quality and Future Prospects of AplosonyxChalybaeus and AeolesthesHoloserícea (Coleoptera) in Nagaland, India" in Volume 8 Issue 3, March 2019 in International Journal of Science and Research (IJSR).

Certificate 6: National workshop on "Scientific Writing, Research Communication & IPR Issues" organized by International Biotech Hub & Department of Botany Nagaland University, Lumami on August 28th- 29th, 2014.

Certificate 7: International Webinar on "Self-care in the Time of Covid- 19" organized by IQAC, Kohima Science College, Jotsoma, Nagaland on 30th July, 2020.

Certificate 8: Webinar on the topic "Introduction to the Realms of Research" organized by Department of Chemistry, Immanuel College, Dimapur, India on 7th August, 2020.

Certificate 9: Webinar on "Bats: Biases, Prejudices and Conservation Research" organised by North Eastern Regional Centre, Zoological Survey of India, Shillong on the 25th August, 2020.

Certificate 10: National Webinar on : “Structure and Genome of Covid 19” organized by PG and Research Department of Zoology, Vivekanand College, Tiruvedakam West, Madurai on 31st August, 2020.

Certificate 11: Webinar on “Perpetual Darkness: The Amazing World of cave Animals” organised by North Eastern Regional Centre, Zoological Survey of India, Shillong, on the 23rd September, 2020.

Certificate 12: National Level Virtual Training on “DNA Barcoding” conducted by Department of Zoology & Research Centre, Lady Doak College, Madurai held on 11th and 12th January, 2022.

PUBLICATIONS

Publication 1: Ethnozoology and entomophagy of Ao tribe in the district of Mokokchung, Nagaland. *Indian Journal of Traditional Knowledge*, Vol. 18(3): 508-515.

Publication 2: An Assessment of the Nutritional Quality and Future Prospects of *AplosonyxChalybaeus* and *AeolesthesHolosericea* (Coleoptera) in Nagaland, India. *International Journal of Science and Research (IJSR)*, Vol. 8(3): 550 – 556.

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