The adequacy of food supply depends upon productive resources and population growth. Insects represent an important food source for a wide variety of other animal species. Fresh water game fishes as trout, bass and bream feed extensively the aquatic insects like Mayflies, stoneflies or hellgrammites. Many toads, frogs, turtles, snakes and lizards also consume insects as a major part of their diet. The lives of many bird species depend on a plentiful supply of insects. Insects are an important food source for both animals and humans and reports of their nutrient composition are presented by many researchers in disciplines ranging from anthropology to Zoology. Evidence from archeological sites suggests the use of tools by early hominids to dig termites from their mounds. The anthropological literature shows that insects have been and continue to this day to be, an important human food source.

Several species of order Orthoptera as grasshoppers are part of the diet of some ethnic groups at all five continents. Different species of adult ants of order Hymenoptera are eaten with other local names before rainy season at north Thailand, Colombia, Brazil and Mexico. Maguey
grubs of Lepidoptera and Ahuahutle of order Hemiptera are edible species native from Mexico (Menzel and Alusio, 1998)

All natural foods contain proteins, fats, carbohydrates, vitamins, mineral salts and water (Coultate, 2009). Insects are well accepted by consumers as a source of alternative food supplement to improve human nutrition. As a group of potential resources, insect resources have presented their potentials in industry, agriculture and ecological environment, and can be an important approach to solve the problem of food and resource shortage. To improve the productivity of Nigerian livestock, which was below their genetic potential because of poor nutrition and inadequate quality feed, they attempted to use several species of insects as an alternative for cheaper and good source of nutrient components (Abulude et al., 2007).

Entomophagy the consumption of insects by humans has long been known as traditional practice in different parts of the world, especially in regions where environmental conditions are often adverse. (Conconi and Pino, 1979; Ancona, 1931, 1932, 1934; Blasquez 1870; Bodenheimer, 1951; Figueroa, 1968; Hoffman, 1947; Lapp and Rohmer, 1937; Ruddle, 1973; Skinner, 1910; Thompson, 1954; Tihon,
In some areas they are a major food source and are dried and stored in large quantities for consumption in scarcity. The practice of consumption depends on the local availability of insects in different seasons. The eggs, larvae, nymphs, pupae (grubs) and adults of a large number of different insect species such as butterflies, moths, bugs, flies, ants, bees, beetles, termites, grasshoppers, and dragon flies are often eaten by humans on a worldwide basis.

The nutritional value of a number of insect species has been evaluated as potential food stuff for poultry or other food producing animals. The large number of insect species and the diversity of the environment they inhabit reflect that they are an important food source for many terrestrial and aquatic animals. Termites are the mostly studied for nutrient composition because they are the primary food source for a number of highly specialized mammalian insectivores. The nutritional content of selected species of cultured insects have also been studied because of their use as food for captive insectivorous reptiles, birds and mammals kept in Zoos.

In Latin America, due to scarcity of food as well as more expensive imported food, it became essential to identify and develop
indigenous food resources. Insects are preferred in many countries not only because of their abundance, biomass and high quality protein, but also because of the time honoured practice among many culturally diverse people of Latin America of consuming live, roasted and fried insects which provide them a nutritious protein source (Conconi et al., 1984). Conconi and Bourges (1977) reported the record of 491 species of edible insects worldwide. Conconi et al. (1984) recorded 101 species in Mexico, eaten at various stages of development depending upon the species. These species belonged to 31 families in nine orders and included dragonflies, grasshoppers, bugs, lice, treehoppers, cicadas, caddish flies, butterflies, moths, flies, ants, bees and wasps. They reported that the number of edible species per order varies from 30 in Hymenoptera, mostly wasps to only one in the Anopleura (lice). Protein values varied from a low of about 10% for two species of ants to a high of slightly over 81% for the wasps. Conconi et al. (1984) also reported the relationships between host tree and the protein content of the insects of the same species.

Trejo and Rubio-Flores, (1974) interviewed 12,300 people for acceptability of commercially produced insect food products and reported that 93% of people preferred development of insects on a
commercial scale as they are in general, a nutritious, economical, delicious, complete food. They also suggested the importance of improved technology for development of insects as valuable renewable natural resources.

The nutritional values of edible insects are highly variable, not least because of the wide variety of species. Even within the same group of edible insect species, values may differ depending on the metamorphic stage of the insect particularly in species with a complete metamorphosis such as ants, bees and beetles and their habitat and diet. Insects comprise only a part of local diets in certain African communities and form 5-10 percent of the protein consumed (Ayieka and Oriaro, 2008).

The food systems of indigenous people show the important role of a diversified diet based on local plant and animal species and traditional food for health and well being. People in Africa, Asia and Latin America eat insects as regular part of their diets not because of
vital sources of protein or conventional meats are unavoidable but because insects are considered as important food items often for delicacies.

The importance of edible insects on a global scale is difficult to estimate. Statistics and information are scarce and only available from a few, very specific studies. These reports provide an idea of importance of edible insects in various food systems and suggest the insights into the possibilities for developing the sector at a global scale. A study of the centre for Indigenous People’s Nutrition and Environment and FAO evaluated the nutritional and cultural importance of various traditional food items of 12 indigenous communities (Kuhnlien et al., 2009). They reported that the nutritional importance of different insects in the Ingano community in Colombia was particularly significant (Table: I-1).
Table I-1: Traditional food items of four indigenous communities from different parts of the world the Awajun (Peru), the Ingano (Colombia), the Karen (Thailand) and the Igbo (Nigeria)

<table>
<thead>
<tr>
<th>Insects as traditional foods</th>
<th>English Name</th>
<th>Local Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awajun, Peru</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coleoptera</td>
<td>Palm Weevil larvae</td>
<td>Bukin</td>
</tr>
<tr>
<td>Hymenoptera (Brachygastra spp.)</td>
<td>Wasp larvae</td>
<td>Eteteji</td>
</tr>
<tr>
<td>Hymenoptera (Formicidae)</td>
<td>Ant</td>
<td>Maya</td>
</tr>
<tr>
<td>Ingano, Colombia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hymenoptera, Atta spp.</td>
<td>Leaf cutting ant</td>
<td>Hormigaarriera</td>
</tr>
<tr>
<td>Coleoptera</td>
<td>Beetle</td>
<td>Mojojoy</td>
</tr>
<tr>
<td>Karen, Thailand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orthoptera: Gryllidae (Gryllus bimaculatus)</td>
<td>Field Cricket</td>
<td>Xer-lai-zu-wa</td>
</tr>
<tr>
<td>Igbo, Nigeria</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coleoptera</td>
<td>Beetle</td>
<td>Ebe</td>
</tr>
<tr>
<td>Isoptera: Termitidae (2 spp.)</td>
<td>Termite</td>
<td>Aku-mkpu, Aku-mbe</td>
</tr>
<tr>
<td>Coleoptera: Curculinoidea (3 spp.)</td>
<td>Palm weevil larvae, (Palm, raffia palm)</td>
<td>Akpa-nkwu, akpa-ngwo, nzam</td>
</tr>
<tr>
<td>Orthoptera: Gryllidae</td>
<td>Cricket</td>
<td>Abuzu</td>
</tr>
<tr>
<td>Orthoptera: Acroridae</td>
<td>Locust</td>
<td>Wewe, igurube</td>
</tr>
</tbody>
</table>

Source: Kunhlein et al., 2009
The majojoy larvae of May beetles and June beetles, which are both eaten in the Ingano community, are particularly rich in fats. Hormigas, the Formicidae ants provide important sources of energy which can be collected year round. Hormigas are nutritious, very popular, improve growth, strengthen immune defenses and provide protein, vitamins and minerals. Mojojoy are nutritious, improve growth and act as a medicine for pulmonary infection, their fat helps in preventing pulmonary problems and they provide proteins, vitamins and minerals.

In the Amazan Basin, at least 32 Amerindian groups use terrestrial invertebrates as food (Paoletti et al., 2000). The consumption of invertebrates provides significant amounts of animal protein (Table I-2), especially during the time of scarcity of fish and game. The Guajibo community of Savanah border relies mostly on insects especially grasshoppers and larvae of palm weevil. During rainy season 60 percent of their animal protein is derived from insects. Amerindians are reported to choose their animal food from food webs in the rain forest that have the highest energy flow and which constitute the greatest renewable stock of readily available nutrients.
Table I-2: Annual consumption of invertebrates in the Tukanoan village of Lapu (Rio Papuri, Vaupes, Columbia), composed of about 100 people

<table>
<thead>
<tr>
<th>Name</th>
<th>Mean fresh weight consumed (kg/year)</th>
<th>Percentage of total number of invertebrates consumed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atta soldiers and queens (three species)</td>
<td>100</td>
<td>29.3</td>
</tr>
<tr>
<td>Syntermes soldiers (three species)</td>
<td>133</td>
<td>39.0</td>
</tr>
<tr>
<td>Caterpillars (five species)</td>
<td>96</td>
<td>28.1</td>
</tr>
<tr>
<td>Vespidae larvae and pupae (three species)</td>
<td>2</td>
<td>0.60</td>
</tr>
<tr>
<td>Melaponinae larvae and pupae (three species)</td>
<td>1.5</td>
<td>0.44</td>
</tr>
<tr>
<td>Rhynchophorus palmarum larvae</td>
<td>6</td>
<td>1.7</td>
</tr>
<tr>
<td>Beetle larvae boring on wood and dead wood (four species)</td>
<td>2.5</td>
<td>0.73</td>
</tr>
</tbody>
</table>

The insects are highly nutritious, compose a substantial proportion of terrestrial metazoan biomass, have higher reproduction rates and food conversion efficiencies than mammals (Bukkens, 2005) and in many cases are relatively easy to gather. Substantial variations exist in the extent to which insects actually are incorporated into the
diets of humans and other primates. The dietary use of insects by humans is variable. Evidence suggests that entomophagy featured significantly in the evolution, prehistory, and history of the human diet. Raubenheimer and Rothman (2012) reported that 1600 species of insects are eaten deliberately by humans, but cultures are highly variable, spanning the spectrum from active avoidance to occasional and substantial consumption.

Instances of regular entomophagy exist in developed countries also. Most edible insects are herbivorous and are thus considered relatively clean feeders (Bukkens, 1997) whereas the diet of some insects extends to decaying human corpses (Castro et al., 2012) and sometimes is a vector of human pathogens (Martin-Vega, 2011). The western abhorrence of eating insect is unusual on a global scale, with entomophagy being the norm rather than the exception in many human populations. In America, 679 species are reported to be eaten across 23 countries (Ramos-Elorduy, 2005; Johnson, 2010). In Africa 524 species are eaten across 36 countries, in Asia 349 species across 29 countries, in the Pacific region 152 species across 14 countries, and in Europe 41 insect species are eaten across 11 countries (Ramos-Elorduy, 2005; Johnson, 2010).
The consumption of leaf eating and litter feeding invertebrates by forest-dwelling people as a means of acquiring protein, fats and vitamins offers a new perspective for the development of sustainable animal food production. Adriaens (1951) from his study in the southwest of the Democratic Republic of the Congo, reported that animal protein was obtained from large game crickets and grasshoppers during the dry season and largely from caterpillars during the rainy season. The estimated production of dried caterpillars in Kwango was nearly 300 tons per year. Insects constituted an average of 10 percent of the animal protein in daily diets with fish and game meat at 47 percent and 30 percent respectively (Gomez et al., 1961). Kitsa (1989) reported that in the city of Kananga 28 percent of the inhabitants ate insects, mainly termites, caterpillars and beetle larvae, at an average of 2.4 kg of insects per month. Palm beetle larvae and soldier termites which constitute 20 percent of the edible insect species were available in markets throughout the year, while the remainder as caterpillars and flying termites were only seasonally available from December to April.

Food consumption data on wild, under used, indigenous and traditional plant and animal foods, however, remain limited and
fragmented (FAO, 2010). As the importance of food biodiversity becomes increasingly acknowledged, researches are going on in the direction towards the consumption and composition of a wide variety of foods, including insects. The need to feed a growing global population causes continuous pressure on crop production which however, contributes further to the degradation of natural resources (FAO, 2009). Difficulty arising from climate change exerts present problems in production. Activities on sustainable diets explore linkages and synergies among food biodiversity, nutrition, food composition, food production, agriculture, urban agriculture and sustainability. To improve food and nutritional security and provide more ecologically sound food recommendations to consumers and policymakers including clarification about environmentally sustainable food system FAO (2009) has developed programmes and activities. Edible insects as food fit well within this environmentally sound scenario and considered as prime candidates as both food staples and supplements, as well as for their role in sustainable diets. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally accepted, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources (FAO, 2010).
In 70 countries around the world where food insecurity is salient, fortified blended food products (FBF) are typically distributed to the most vulnerable peoples, the victims of malnutrition. But the principal ingredients of FBFs are generally not part of traditional diets making them ill suited from nutritional, social and ecological points of view even if within the framework of sustainable diets (FAO, 2010). Considering the protein and micronutrient content of many edible insects, their minimal ecological impact, their availability and above all, their cultural appropriateness in a large majority of developing countries where food insecurity is a primary concern, the practice of using insect food receives growing popularity.

Rumpold and Schlutter (2013) compiled recorded nutrient compositions of 236 edible insects based on dry matter and reported that edible insects provide satisfactory amounts of energy and protein, and can meet amino acid requirements for humans. These are rich in monounsaturated and polyunsaturated fatty acids and contain large amounts of micronutrients such as copper, iron, magnesium, manganese, phosphorus, selenium and zinc, as well as riboflavin, pantothenic acid, biotin and in some cases folic acid.
Numerous studies reported nutritional value of insects. Large species of edible insects contribute to variation in nutritional value. Even the chemical composition of related species may vary as it often depends on the plant they feed on, so it is location specific. The protein content is comparable to that of conventional meat. The essential amino acids are often present, but the protein quality of each insect should be considered in relation to the dietary staple. All edible insects are a significant source of short chain polyunsaturated fatty acids, a good source of iron, calcium, and B vitamins. The amino acid composition is in most cases better than that of grains and legumes. Nutritional compositions of several insects have recently been added to FAO’s. The International Network of Food Data Systems (INFOODS) prepared a food composition database for biodiversity.

Insects are believed to have higher proportion of protein and fat than beef and fish, with a high energy value (De Foliart, 1992). Omotoso and Adedire (2007) reported that Protein contribution to overall human intake varies with the stage of the insects eaten and period of availability. Palm weevil has higher protein content in the mature stage than that of immature.
Chen et al. (2008) reported differences in essential and non-essential amino acid profiles among species of insects. Most humans in developed countries regard the consumption of insects with some revulsion and where exceptions occur, insects are generally considered as food more for their novelty than their nutrients (Johnson, 2010), or as a means of survival when wilderness adventures go wrong, (Yoshimoto, 1999). However, this may not apply in all cases; for example, in Japan, insects are eaten as part of the traditional diet (Nonaka, 2010), and in some part of Italy (Overstreet, 2003) and Croatia (Miokovic et al., 1997) the cheese maggot (*Piophila casei* L.) is regarded as a delicacy.

According to Durst and Shono, (2010) in many developing countries and among various cultures scattered throughout the world, insects remain a vital and preferred food and an essential source of protein, fat, minerals and vitamins. In west and central Africa, insects are not used as emergency food to strive against starvation, but are included as normal part of the diet throughout the year or in seasons of occurrence (Banjo et al., 2006). In several areas of Zimbabwe, South Africa, Zambia and Nigeria, many families make fairly good living
from selling insets (Chavunduka, 1975; Fasoranti and Ajiboye, 1993; Mbata and Chidumayo, 2003; Adeduntan and Bada, 2004).

Most of the edible insects reported in Nigeria largely depend on forest for their survival (Alamu et al., 2013). Foresters worldwide have traditionally looked at insects as either a nuisance or as tree and wood pests. According to Alamu et al. (2013) forest pest problems are more than ever and with the current invasion of exotic and anticipated effects of global warming, the trend appears upward. Schabel (2008) suggested the importance of pest insect management for the sake of trees, to entomoforestry, which concerns itself with managing trees and forests for the sake of edible and other useful insects. This may in turn open up at least supplementary perspectives of forest management and potentially fostering the development of forest based insect industries (Schabel, 2006). They suggested that where food security is at stake, traditional entomophagy must become a priority and can be taken from opportunistic extraction to the regulatory mechanisms and the deliberate, science-based manipulation of forest edible insects, in or out of their natural habitat.
Van (2003) reported that the use of traditional food is sustainable and has economic, nutritional and ecological benefits for rural communities in sub-Saharan Africa. Edible insects can supply necessary nutritive elements for human body functions and could be consumed along with other food and animals rich in other essential minerals (Alamu et al., 2013).

Ekop et al. (2010) and Ifie and Emeruwa (2011) reported the presence of some anti nutrients such as hydro-cyanide, oxalates, phylates and tannins in edible insects in Nigeria. Ekop et al. (2010) reported 2.187 to 3.203 mg/kg of hydrocyanide (HCN), 13.20 to 28.40 mg/kg oxalate, 0.28 to 0.289 mg/kg phylate and 0.329 to 0.430 mg/kg tannin in four edible insects which were G. lucens (Cricket), H. meles (Yam beetle), R. phoenicis (Palm weevil) and Z. variegates (Grasshopper) and O. monoceros (Ifie and Emeruwa, 2011). However, they reported their presence in negligible amount and below toxic level in humans.

Chuanhui et al. (2010) reported that in China, insect resources are used widespread and people have rich experiences in insect utilization as food, medicine, industry resource and cultural practice.
Chinese people used *Oecophylla smaragdina* (Fabricius) to control citrus pest (Yang, 1998; Jiang, 1999; Yan, 2001; Li, 2005; Chen *et al.*, 2008; Chen and Feng, 2009). Peng *et al.* (2003) observed 26 ethnic groups that are keeping the custom of eating insects in the multi-national area of China, although living standards have been quickly improved. There are 177 species of insects belonging to 96 genera of 54 families in 11 orders such as Hymenoptera, Coleoptera and Lepidoptera, which were commonly used as dishes in China (Chen and Feng, 1999; Yang, 1999; Yan, 2001; Wen, 2002; Wang *et al.*, 2002; Dong and Gao, 2005; Liu, 2005; Liu *et al.*, 2005; Wang, 2006). With the improvement of people’s living standard, insects became more popular due to its delicious taste and high nutrition. Insects are reported to have the function of health care and do not produce pollution. Hence the traditional insect foods are widespread in China. They are sold in all parts of China such as Hunan, Guangxi and Yunnan which shows a complete network of gathering, purchases and sales. In China, the use and effects of medicinal insects and 22 kinds of insect medicines were elaborately recorded (Yang, 1998; Jiang, 1999; Yan, 2001; Li, 2005; Chen *et al.*, 2008; Chen and Feng, 2009; Xiang, 2009).
Most people do not accept insect as food due to its appearances. This is also the reason that edible insect is only popular in distributing areas. In addition, the difficulty in transportation and freshness of insect also limit the popularization of insect food. The researches are conducted on diverse insect product form and processing form which magnifies the impetus of insect foods.

Insects with quick reproductive ability, high adaptability, large individual numbers and huge biomass are a giant resource treasure. Along with the rapid increase of population, resource consumption and unusual climate change, searching and developing new resources has been one of the most important subjects at present. The development of insect resources can solve human being’s grain and resources issues.

Humans eat insects at the largest stage in the life cycle and those with the lowest proportion of exoskeleton (Bukkens, 1997). Larvae and pupae are commonly targeted, although adults are also eaten (Johnson, 2010). In some societies insects are eaten only when edible vertebrates are scarce (Milton, 1984), whereas in other societies insects are continuously sought after resources (Paoletti et al., 2003). Geographic and seasonal availability of insects is reflected in their contribution to
the human diet. In Thailand some insects are eaten only in specific regions, whereas other insects as giant water bug are eaten throughout the country (Hanboonsong, 2010). In Arunachal Pradesh, North East India, edible insects that are perennially available are eaten throughout the year, whereas the consumption of other insects is restricted by seasonal availability of the edible stage in the life cycle (Chakravorty et al., 2011). Insect consumption also vary with fluctuation in availability caused by inter annual weather patterns. (Yhoung-Aree et al., 1997; Yhoung-Aree, 2010).

Bukkens (2005) has reviewed the literature on the nutrient composition of insects eaten by humans and suggested that insects are excellent source of protein, fat and micronutrients, with amino acid composition that are generally balanced for humans. The limited data for micronutrients showed that the minerals iron and calcium were present in concentrations greater than those found in beef and many insects show good levels of B vitamins, beta carotene and vitamin E. There is, however, considerable variation in the nutritional composition of insects. The amino acid and fatty acid profiles also differ among insects even between related insects collected in different locations suggesting that diet is a strong determinant of fatty acid levels in insects.
Reports and analyzed results (De Foliart, 1991; Lu et al., 1992; Chen and Feng, 1999; Feng et al., 1999; 2000 a, b; 2001a, b, c) have shown that many edible insects are rich in fat and their fat content is higher at the larval and pupal stages; than that of the adult stage.

The protein content of some insects is higher than that of chicken eggs, meat and fowl (Ramos-Elorduy and Pino Moreno, 1989; Comby, 1990; De Foliart 1992; Mitsuhashi, 1992; Hu, 1996; Chen and Feng, 1999; Yang, 1998). Analysis of more than 100 edible insects has shown that they contain 10-30% necessary amino acid content which is close to the amino acid model proposed by the Food and Agricultural organization of the WHO.

Mineral and vitamin contents of palm weevil, grasshopper and termites are highly variable across species and orders (Bukkens, 2005). Entire insects provide higher micronutrient content than eating individual insect part. Chen and Feng (1999) reported higher amount of calcium, Zinc and iron.

Studies on vitamins in edible insects are fragmentary and insufficient. However, edible insects are reported to contain carotene
and vitamins A, B$_1$, B$_2$, B$_6$, D, E, K and C (De Foliart, 1991; Lu et al., 1992; Chen and Feng, 1999; Feng et al., 1999, 2000, 2001). Bukkens (2005) reported the vitamins that are essential for stimulating metabolic processes and enhancing immune system functions are present in most edible insect.

Finke (2002) explored the nutritional value of several insects’ species, including yellow meal worm and compared the values with beef meat. He reported that though beef meat is rich in macronutrient composition but mealworms contain comparable values of copper, sodium, potassium, iron, zinc, and selenium and have generally higher vitamin content than higher vitamin B$_{12}$.

Anderson, (2000) and Finke, (2002) were of opinion that nutritional composition of insect depend on the specific diet of the insect as well as growth and stages of development. Insects as health foods are derived from Chinese traditional medicine and some health functions have been confirmed by modern scientific research. The Chinese caterpillar fungus is believed to enhance immunity and have anticancer properties (Gong et al., 1990; Toshio et al., 1977; Chen et al., 1997; Bok et al., 1999; Yoshikawa et al., 2004; Jia et al., 2005;
Wang et al., 2005). Chen et al. (2000, 2004) and Liu et al. (2004) have shown that ant alcohol can enhance immunity and improve sexual ability. Wu and Wang (1995, 1998) studied the effectiveness of termite, *Macrotermes annaadalei* as immunity enhancer and have been processed to fine powder capsules in the market.

Among edible insects with nutritional value, 194 species are reported in Thailand. In Thailand, insect eaters can be found in all regions of the country. Siriamornpun and Thammapat (2008) studied nutritional quality of selected edible insects consumed in the Thai community. It was reported that available insects have decreased in both quantity and in the number of species (Hanboonsong, 2008) due to increased demand and decreased insect habitats. Recent studies reported that the insects sold on local markets in Thailand are mostly imported from Cambodia which is still with ample natural habitats for insects.

Raksakantong *et al.* (2010) from their study on the insect species commonly eaten in Thailand concluded that insects represent the cheapest source of animal protein in Thailand. Insects have been shown to contain a large quantity of protein ranging from 38% in queen caste to 54% in dung beetle. These values are reported to be higher than
those reported for edible insects in Southwestern Nigeria (Banjo et al., 2006). The high protein content is an indication that the insects can be of value in humans and animal rations thus replacing more costly sources of animal protein that are usually absent in the diet of rural dwellers in developing countries (Banjo et al., 2006). Ramos-Elorduy et al. (1997) demonstrated that besides the high amounts of protein they also possess higher quality and high digestibility in a great variety of species. Ladron et al. (1995) determined the amino acid composition and the digestibility of the protein. Most edible insects provide a sufficient range of amino acids to fulfill the nutritional requirements for children (Siriamornpun and Thammapat, 2008). They suggested that edible insects can effectively supply protein by complementing other animal protein sources.

Thai edible insects are increasingly being farmed commercially in northeast Thailand, expanding an industry that has sprung up since 1999 (Johnson, 2010). Relevant insect species in Thailand include the weaver ant, silk worm pupae and the bamboo caterpillar.

Weaver ants (*Oecophylla smaragdina*) are a valued resource in some Southeast Asian countries since they are edible and considered a
delicacy food. Among all Thai edible insects, the weaver ant is the most expensive in Thailand. It has a unique taste and can be consumed in many ways. It is reported to have high protein content similar to other protein sources but they are high priced delicacy, being almost twice as expensive as beef or pork. *Oecophylla* ants as food and traditional medicine has been reported from different cultures in Thailand, India, Myanmar, Borneo, Philippines, Papua New Guinea, Australia and Congo (DeFoloart, 2009). In Thailand the ant is consumed traditionally especially in rural areas and larvae, pupae and the queen castes are used in a variety of ways throughout these countries during harvesting season.

The weaver ant, *Oecophylla smaragdina* is a polydomous, predatory, social, dominant canopy ant dwells across South east Asia as far as India, Sri Lanka, Indo China and Southern China, the equatorial Africa, and the tropical region of Australia (Ledoux, 1950; Stepley, 1980; Chen 1991; Van Mele and Cue 2000; Azuma et al.,2006). In Assam (India), the weaver ants, locally called as ‘Amroli porua’ are the most sophisticated nest building ants that construct the nests made of leaves folded and fastened together with silk from the larvae. Depending on the climate, temperature, humidity and food availability, brood
development varies and the highest growth of a colony in the month of March and April when the temperature ranges from 25°C to 30°C. Below 20°C and above 35°C temperature, the brood development delays inhibiting colony growth and ceases completely at below 12°C temperature (Lokkers, 1990).

The indigenous tribe, the Tai Ahom community of Assam in North East India harvests the colonies of *Oecophylla smaragdina* during Bahag Bihu festival in mid-April as they use this insect as traditional food. They believe that the gas emitted from the fully grown ant nest and the larvae, pupae and adults are good for curing sinusitis and other nasal diseases like bleeding from nose (ewan bhonga). The Tai Ahoms are the dominant tribe of the districts of Upper Assam (Sivasagar, Jorhat, Golaghat, Tinsukia, Dibrugarh, Lakhimpur). The other tribes Deori and Missing tribes of these districts also consume this insect as traditional food with other edible insects. The Bodos tribes mostly confined in the districts of Baksa, Chirang, Kokrajhar, Sonitpur, Dhemaji and Udalguri of Lower Assam also use the larvae of *Oecophylla smaragdina* as traditional food during a festival Bwisagw celebrated for welcoming the spring season (mid-April). The nests of Weaver ants are seen abundantly in the canopy of the forest area of Dima Hasao District (Earlier known as N C Hills District) of Assam and
in some areas of its neighbouring states Nagaland, Meghalaya and Manipur.

The tribal people of Phek, Dimapur and Kohima districts of Nagaland eat grasshoppers, cricket, red ant and larvae of Mulberry silk worms. They also eat green colour larvae available in Goldmohor in the month of March – April. Grasshoppers are easily available in the month of August and September in the local market of Dimapur and Kohima. Tribal people of Kandhamal, Kavaput, Sundergarh, Keonjhar and Mayurbhanj districts of Orissa eat red ant and termites. The villagers of Pithra village of Simdega district of Jharkhand as an ethnic food eat eggs of Demta, a red ant found on the trees. These ants fold the leaf of tree and reside inside. (Srivastava, Babu and Pandey, 2009.).

Insects provide essential ecosystem services such as pollination compositing wildlife protection and pest control (Losey and Vaughan, 2006). Edible insects, such as honey bees, dung beetles and weaver ants, eaten extensively in the tropics perform many of these ecological services. Schabel (2006) reported that until recently edible insects were an inexhaustible resource. A number of anthropogenic factors impose threats on edible insect populations. Numerous edible insect species are prey or hosts of other insect species and many other organisms as birds,
spiders, mammals, amphibians, reptiles and fishes. Many edible insect species are predators themselves or decomposers. Weaver ants of the genus *Oecophylla* are involved in a different system of ecologically sound pest management. This generalist and aggressive predator is a highly efficient biocontrol agent for a variety of commercially important tree species (Peng *et al*., 2004). Offenberg and Wiwatwitaya (2009b) showed that there is strong potential to use the weaver ant *Oecophylla smaragdina* both as food and as a biocontrol agent in mango plantations (Yhoun-Aree and Viwatpanich, 2005; Sribandit *et al*., 2008).

The Asian weaver ant, *Oecophylla smaragdina*, is consumed in China, India, Indonesia, The Lao People’s Democratic Republic, Myanmar, Papua, New Guinea, The Philippines and Thailand (De Foliart, 2002; Yhoun-Aree and Viwatpanich, 2005; Sribandit *et al*., 2008). Its African sister species the green tree ant, *Oecophylla longinoda* is endemic to tropical Africa. Weaver ants bind the leaves of living trees together with silk, secreted by their larvae to form nests. One ant colony consists of numerous nests, often occupying several trees (Lokkers, 1990). Weaver ants are also considered as traditional medicine in China and India (Chen and Akre, 1994; Oudhia, 2002) and by Australian Aborigine in Northern Australia (Yen, 2005).
Indonesia, the larvae and pupae are used as feed for songbirds and as fishing bait (Cesard, 2004). These ants are highly territorial (Holldobler, 1983) and capture many species of insect that feed on their host trees including cashew, cacao, coconut, mango, tea and eucalyptus trees (Peng et al., 2004). Sribandit et al. (2008) reported that in Thailand and the Lao People’s Democratic Republic, the collecting season peaks in February to April and is largely determined by the availability of larvae and pupae destined to become virgin queens. The average household in Thailand consumes 49 kg of larvae and pupae per ant harvesting season, with the ant harvest constituting some 30 percent of yearly income. However, Thai collectors have reported a decline in availability, although it is unsure if this is due to collecting practices harvesting pressure or forest loss (Sribandit et al., 2008). Offenberg (2011) from a study in Thailand identified Asian weaver ants as a very promising insect to farm commercially.

*Oecophylla* described by ant researchers as one of the four pinnacles of ant social evolution. Two extant species in this genus are *O. longinoda*, with four varieties, and *O. smaragdina*, with two subspecies and three varieties. *O. smaragdina* inhabits India, Southern Asia and Northern Australia (Lokkers, 1986). It is referred to as weaver
ants (Holldobler and Wilson, 1977, 1990) ferocious red ants (Corbet and Pendlebury, 1992) or Keringga in Peninsular Malaysia (Eliot, 1980). They construct characteristic elaborate arboreal nests by using silk secreted by the larvae. Because the larval silk is being used to sew leaves together, the larval themselves are naked and remain without covering their larval and pupal stages. They form large Polydomous colonies housed in many nests constructed in the crowns of a wide range of host plant species, (Way, 1954; Holldobler, 1979; Holldobler, 1983), however they have strong preference for citrus tree. (Table: I-3)

The aggressiveness and dominance of the ants has also made them useful in biological control. They are currently being used to control pests of mahogany and cacao in peninsular Malaysia. However, these ants are also reported to be associated with trophobionts, notably homopterans, mealy bugs and lycaenid larvae (Benzie, 1985). This habit increases the severity of pest problem and often create problem in using the weaver ants for biological control in certain agricultural cases. Although generally regarded as beneficial within the agricultural industry *O. smaragdina* is also regarded as a pest, being an opportunistic and aggressive feeder. Weaver ants though regarded as beneficial for the quality of mango fruit, it is also regarded as a nuisance
Table: 1-3 Distribution and uses of Weaver ant, *Oecophylla smaragdina* Fabricius in the different countries and states.

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Name of the states &amp; countries</th>
<th>Local name of <em>Oecophylla</em></th>
<th>Stages of used as food</th>
<th>Used as Food</th>
<th>Used by Tribes</th>
<th>Availability</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Arunachal, N E India</td>
<td>N A Insect eggs</td>
<td>Larva, pupa &amp; adults</td>
<td>Boil, smoked and raw</td>
<td>Nocete, Wangcho, Sringpho</td>
<td>Throughout the year.</td>
<td>Chakravorty et al., 2013.</td>
</tr>
<tr>
<td>2</td>
<td>Upper Assam (as mentioned in the text)</td>
<td>Ahroi Porua</td>
<td>Larva, pupa &amp; adults</td>
<td>Boil, fried with duck egg and onion</td>
<td>Tai Ahom</td>
<td>February – June</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Lower Assam (as mentioned in the text)</td>
<td>Khw DMA</td>
<td>Larva, pupa &amp; adults</td>
<td>Roasted, fried, Boiled, smoked and raw</td>
<td>Bodos</td>
<td>March – August</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Orissa, Red Ant</td>
<td>Larva, pupa &amp; adults</td>
<td>Roasted</td>
<td>Tribal people of Komput, Kornjhar, Kaimadahal, Mayurbhanj districts</td>
<td>March-April</td>
<td>Srivastava et al., 2008.</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Thailand</td>
<td>Mac peng</td>
<td>Larva, pupa &amp; Queen caste</td>
<td>Salad, lightly curried with vegetables</td>
<td>Local rural people</td>
<td>February – April (Dry Season)</td>
<td>Siriamarputi et al., 2008</td>
</tr>
<tr>
<td>7</td>
<td>Java</td>
<td>Krotu</td>
<td>Larva, pupa &amp; adults</td>
<td>Fried with chicken eggs, honey, maize and bean</td>
<td>Indigenous people</td>
<td>April to August</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Vienvetian Plain, Laos PDR and Thailand</td>
<td>Kai Khob, Kai Tchant, Kai peng</td>
<td>Large larva, pupa &amp; adults of queen</td>
<td>As food</td>
<td>Indigenous people</td>
<td>January – May</td>
<td>Literbeek et al., 2013</td>
</tr>
<tr>
<td>9</td>
<td>Australia</td>
<td>N A</td>
<td>Larva, pupa &amp; adults</td>
<td>Pleasant acid crink, meshed in water drink like lemon squash</td>
<td>Indigenous people</td>
<td>January – May</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>North Queensland</td>
<td>Weaver Ant</td>
<td>Eggs, larvae and adults</td>
<td>Pleasant acid crink, meshed in water drink like lemon squash</td>
<td>Native people</td>
<td>January – May</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>China</td>
<td>N A</td>
<td>Eggs, larvae and adults</td>
<td>Deep fry, burn, roast and fry</td>
<td>Guangxi Zhuang minority &amp; Yunnan Jiao minority people</td>
<td>February-May (peak Season)</td>
<td>Yang, 1999, Chen and Feng, 1999; Yan, 2001; Wen, 2001; Wang et al., 2002; Liu et al., 2005; Lu et al., 2006.</td>
</tr>
<tr>
<td>13</td>
<td>Jharkhand</td>
<td>Demta</td>
<td>Eggs</td>
<td>As Ethnic food. Fried with salt chilly, spices and mustard oil</td>
<td>Villagers of Pirtha Village of Simdega District</td>
<td>March-April</td>
<td>Srivastava et al., 2008.</td>
</tr>
<tr>
<td>14</td>
<td>United States</td>
<td>NA</td>
<td>Eggs, larvae and adults</td>
<td>As food. Cooking and fried</td>
<td>Native American tribes</td>
<td>February- April</td>
<td>--</td>
</tr>
<tr>
<td>15</td>
<td>Nigeria</td>
<td>Soldier ants</td>
<td>Larvae</td>
<td>As food</td>
<td>Native tribes</td>
<td>April - May</td>
<td>Abadule et al. (2007)</td>
</tr>
</tbody>
</table>
pest during harvesting (Sinzogar et al., 2008). *Oecophylla* species presented a tractable system for studying a complex behaviour, construction of the leaf nests, phylogeny, habitat and sociality.

The methods of matter assimilation and nutrient transport used by insects make insect cultivation a more efficient method of converting consumed matter into biomass than rearing traditional livestock; more than 10 times more plant nutrients are needed to produce one kilogram of meat than one kilogram of insect biomass. Insects generally have higher food conversion efficiency than more traditional meats, measured as efficiency of conversion of ingested food (ECI). Many insects can have an energy input to protein output ratio of around 4:1 while raised livestock has a ratio closer to 54:1.

Insects reproduce at a faster rate than beef animals. A female cricket can lay from 1,200 to 1,500 eggs in three to four weeks and thus its food conversion efficiency is almost 20 times higher than beef. For this reason and because of the essential amino acids content of insects and on ecological grounds development of entomophagy is suggested to provide a major source of protein in human nutrition.
In 2011, the European Commission issued a request for reports on the current use of insects as food, with the promise that reports from each European Union member state would serve to inform legislative proposals for the new process for novel foods. European Union is investing more than 4 million dollars to research entomophagy as human protein source.

UN report pointed out the nutritive value of insects with high protein, fat and mineral content. It is suggested as particularly important food supplement for undernourished children. Insects are also extremely efficient in converting feed into edible meat. Reports of research indicated that crickets, for example, need 12 times less feed than cattle to produce the same amount of protein. Most insects are likely to produce fewer environmentally harmful greenhouse gases than other livestock. The ammonia emissions associated with insect-rearing are far lower than those linked to conventional livestock such as pigs.

Finke (2012) studied four edible insect species as larvae of soldier flies and Tebo worms and nymphs of Turkestan cockroaches and adult houseflies and reported that they are a good source of protein and fat and contain sufficient quantities to meet NRC recommendations.
Edible insects may be closer now than ever before to acceptance in the western world as a resource that should be considered in trying to meet the world’s present and future food needs (DeFoliart, 1992).

Protein contribution from insects to overall human intake varies with the stage of the insects eaten and period of availability. Some insects, as palm weevil, have higher protein content in the mature stage than that of immature (Omotoso and Adedire, 2007). In the north east Amazon, contribution of protein from insects is 12 to 26 percent during May to June when a peak in availability occurs.

Amino acid profiles of edible insects have shown that essential amino acid makes up to 10-30 percent whereas some species may contain enough amino acid to provide the requirement of an adult (Chen et al., 2008). Studies reported that many edible insects are rich in fat which is higher during larvae and pupae stages and relatively lower during the adult stage. Chen et al., (2008) reported that the fat content of edible insects is between 10 to 50 percent. Fontaneto et al., (2012) showed that any kind of insects may provide valuable sources of long-chain polyunsaturated fatty acids.
Analysis in micronutrient content by Chen et al. (2008) shows that edible insects are rich in trace elements such as potassium, sodium, calcium, copper, iron, zinc, manganese and phosphorus. Zinc and iron content of cricket is reported to be higher than that of vegetables. Gbogouri et al., (2013) have, however, reported higher amount of potassium, sodium and iron in *Rhynchosphenus palmarum* L. larva.

In nearly 100 analyzed edible insects (Chen and Feng, 1999; Yang, 1998; Hu, 1996; DeFoliart, 1992; Mitsuhashi, 1992; Comby, 1990; Ramos-Elorduy and Pino, 1989), at egg, larva, pupa or adult stages, the raw protein content is generally 20-70 percent. According to analyzed data, the protein content of insects is higher than most plants; the protein content of some insects as larvae of *Ephemera jianghongensis*, *Sphaerodema rustica* Fabricius is higher than that of commercial meat, fowl and eggs (Zhou, 1982).

Different species of insects are taken as nutritious food. But in India, only in selected places some insects are used as food and as medicine. Unlike the herbal medicine, the insect medicine is less explored and is still confined to tribal people. It is reported that
secretions isolated from fly maggots has properties of healing deep wounds and cantharidin isolated from the blister beetle, *Lytta vesicatoris* is useful to treat urinary diseases and the medicinal value of the eggs of weaver ants (Singh and Padmalatha, 2004). However, there is no detailed information on various insects that are used and on experimental studies to prove their validity. Insects are targeted as a source for antibiotic and anticancer drugs. Insect medicine is prepared along with plant drugs and given to people suffering from different health problems. Such practices are common in the village areas of Tirunelveli district of Tamil Nadu.

Fat is the chief form in which energy is stored in insect larvae (Wigglesworth, 1974; Chapman, 1980). It is usually present in greatest amounts in the mature larvae before metamorphosis and it is reported that although fat content can reach as high as 41% wet weight, three fourths of insect species studied contained less than 10% of wet weight as lipid (Fast, 1970). Insects with fat content greater than 10% are primarily phytophagous. Ekpo (2010) reported higher lipid and protein values in *Oryctes rhinoceros, Imbrasia balina, Macrotermes bellicosus* and *Rhynchophorus phoenicis*. Ande (2002) also reported higher values of phospholipid and Cholesterol in *Cirina forda*, Westwood caterpillar
in Nigeria. Like other animal sources, such as fish, shellfishes and beef (Jay, 1978), *C. forda* has high crude protein content of 64.49% on dry weight basis (Ande, 2002).

Studier and Sevick (1992) reported that adult flying insects are excellent sources of nitrogen, potassium and magnesium. For iron and sodium, the extreme variability of levels of those elements in flying insects suggests that some species are excellent nutritional sources while other species are certainly inadequate. Whereas, Bhulaidok *et al.*, (2010) reported phosphorus as most abundant mineral in sundried edible black ants and selenium as least abundant. They also showed that Zhejiang and Guizhou sun dried edible black ants are a rich source of protein, lipid and essential amino acids.

Weaver ants have delimited territories with a mosaic distribution (Majer, 1972; Leston, 1973) in a wide range of habitats, both natural as well as plantation areas, and are dominant species in their habitat. They occupy a great variety of trees from large bananas to small petai.

Despite the reports that insects contain higher levels of protein and several other nutrients than beef, chicken and fish, there is a dearth
of information on the proximate and biological evaluation of the nutrition quality of the protein and amount of other nutrient components of *Oecophylla smaragdina* and their variation seasonally in particular location. This dearth of information has been standing in the way of the utilization of this relatively rich protein, lipid and other nutrient source to the benefit of man and the assessment of the extent to which it fits into the human dietary requirements.

A few scattered studies analyze the nutritional value of edible insects, but these data are not always comparable due to the variations between insects and their habitat and climatic conditions. More scientific tests on insect functional foods are needed to confirm their health value and then fine insect foods can be processed using modern techniques. It is considered that insects can be used as future food to resolve global food shortage.

Different researchers reported their findings on evolution, status, habitat, biodiversity, biocidal effects at different times. *Oecophylla* species have unusual economic potential for ants, not only in their interactions with other insects, but also in medicinal terms, but scientific validation of using this insect as a traditional food item by local people
assessing the differential nutrient composition is still fragmentary. Therefore the present study is aimed to determine the nutrient composition along with some elements in *Oecophylla smaragdina*, a traditional edible insect used by the folklore in this locality.
Aim

The present study is aimed to investigate the nutrient composition of *Oecophylla smaragdina* Fabricius and to determine the differential composition of various nutrient components and their quantitative variation in different life cycle stages and castes as well as the seasonal variation of these components.

Objectives:

The study is designed with the following objectives:

- To determine and assess some nutrient components as protein, free essential amino acids, total lipid along with triglyceride and cholesterol, antioxidant lipid soluble Vitamin E and Water soluble Vitamins represented by Vitamin B$_1$, B$_2$, B$_5$, Pyridoxine, Folic acid and Ascorbic acid.

- To assess the micronutrient nutritional component by determination of Fe, Cu, Zn and Cr.

- To assess the elemental macro mineral nutritional status through estimation of Na, K and Ca.
• To assess the differential status of these nutritional components under various conditions, as seasonal variation, different life cycle stages and castes.

• To correlate the observed findings for evaluation of the overall nutritional utility of this edible insect under different conditions of availability.

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