REVIEW OF LITERATURE

According to FAO, (2009) edible insects can provide solution to food insecurity and can act as an alternative sustainable food source. 92% of edible insects are sourced by the wild. Insects used for human consumption generally have high nutritive content and may significantly contribute to the total nutritive value for protein, essential amino acids and micronutrients during specific seasons of the year at certain stages of the life cycle. Most of the terrestrial edible insect species are herbivores. Although meager but recent research in this field focus on nutritional values of these insects. Scientific reports from various sources and preliminary findings by this group showed that these insects are the rich source of protein. They have diversified amino acid profiles which are the requirements as food for human consumption. Moreover insects are rich source of micro-nutrients, Cu, Mn, Fe,P, Mg, Zn and Se. Insect’s fats are also rich source of MUFA and/or PUFA. Most of the insects and their larvae contain more protein than do equal amounts of beef or fish, and insects are of a higher calorific value than meats, maize, soybeans, lentils, or other legumes. Dietary constituents of these insects might be the breakdown product of primary metabolic pathway or may originate secondarily as by product of the biochemical pathways. Some insects sequester toxic chemicals from food plants (Blum, 1978; Duffey, 1980; Wirtz, 1984). Phytochemicals including simple phenolics, flavin, tannins, terpenoids, polyacetylenes, alkaloids, cyanogens, glucosinolates and mimetic amino acids are sequestered by various insects.

Insects, the most successful group of all the animals due to their survivality, high reproductive ability, potentiality to consume varieties of food and adaptability to their environments (Kumar, 2001). Insects shows diversity in terms of number of species
ranges from 7-30 million. Moreover they occupy each and every feasible habitat on the planet, except the oceans.

Insects are found enormously in tropical countries and also taken as delicious. The common concept regarding the consumption of insects solely in tropical countries is not completely correct. Moreover, insects are taken partly or completely as delicious item in temperate countries, such as Japan (Mitsuhashi, 2008), China (Feng and Chen, 2003), and Mexico (Ramos Elorduy, 1997b).

**International status:**

Entomophagy is practiced in many parts of the world; for example in all Asia, Africa or Australia, Central America, Brazil, Equator, Peru, Venezuela, Colombia, Canada and United States of America (Bergier, 1941; Bodenheimer, 1951; Ramos-Elorduy and Conconi, 1994; Menzel and Aluisio, 1998; Costa-Neto and Ramos-Elorduy, 2006). However, there are also instances of regular entomophagy in developed countries. Insect are taken normally depending on their availability and the acceptance of insects as food depends on their pattern of distribution. De Foliart, (2002), Meyer-Rochow, (2005), Nonaka, (2005), Mitsuhashi, (2008) and Chakravorty et al., (2011a and 2013) has been assembled the detailed information regarding the diversity of edible insects, pattern of consumption and economic value in all the regions of the world. According to Van Huis, (2003) approximately 250 edible insect species in sub-Saharan Africa, 535 in Mexico Ramos-Elorduy, (2004), and at least 1,900 species of edible insects have been taken as food item around the world. Yen, (2009) documented 1417 species of edible arthropods.

Recently, a list of edible insect comprising 1959 species worldwide has been compiled by Dept. of Entomology, Wageningen University, Netherlands (adopted from
www.wageningenur.nl, updated 1st April, 2013). Review of the articles reveals that the edible insects generally belongs to orthoptera, odonata, coleoptera, lepidoptera, dictyoptera, hemiptera (heteroptera), hymenoptera, diptera and isopteran orders and insects are consumed in all the developmental stages- eggs, larvae, pupae and adults.

Many studies have been conducted on the nutritional potentialities of edible insects however yet to compile all the information and the nutrient contents on edible entomophana. The possible reason for this is due to the species difference, different developmental stages, sex, season of availability and habitat. In addition the number of species evaluated for their nutritional contents are less than the insects species reported as edible throughout the world. Mostly in Africa, few to South American countries and Asia, the works on nutritional aspects of insects are confined where insects are taken as delicacy. From recent review on nutritional potential of insects by Belluco et. al., (2013) and Rumpold and Schluter, (2013), the edible insects have the potentiality as a food and good protein source can. Edible insects can fulfil the amino acid, fat and fatty acids and minerals and energy requirement of humans.

**Edible insect as source of protein and amino acid:**

The review on the study of protein contents of edible insects indicates that insects are rich source of crude protein (on dry weight basis) and as well as of essential amino acids which have been reported equivalent or superior to the soy protein (Finke, deFoliart and Benevenga, 1989). Moreover the insect’s proteins have been reported as comparable to the casein (Ozimek et al., 1985).

FAO, (2013) reported that the protein contents (dry matter) in different analyzed insect species were ranged between 13-81% (van Huis et al., 2013). The proportion of
protein depends on the feed and developmental stages of the insects species. The protein quantity was reported as 69.05% in coleoptera, 2.84 to 74.35% in lepidoptera, 6.25 to 77.13% in orthoptera, 20.91 to 9.45 to 81.69% in hymenoptera, 20.4 to 65.62% in isoptera, 25.35 to 71.52% in hemiptera and 35.9 to 61.54% in dipteran (de Conconi et al., 1984; Agbidye et al., 2009; Banjo et al., 2006; Omotoso, 2006; Okaraoye and Ikewuchi, 2009; Ramos-Elorduy, 1998). According to Banjo et al., (2006) the protein content (DM) in the insect species varies from 6.25% to 81.69% for Brachytrupes and Polybia sp. (de Conconi et al., 1984) respectively. Though in some insects the protein contents recorded higher in larval stages however in another study on 100 analyzed edible insects it was found that at almost in all the metamorphic stages the amount of raw protein varies between 20 to 70% (De Foliart, 1992; Yang, 1998; Hu, 1996; Mitsuhashi, 1992; Chen and Feng, 1999; Ramos-Elorduy and Pino, 1989; Comby, 1990). For raw protein content in ephemeroptera larvae was 66.26%, in odonata larvae it was 40 to 65%, hemipteran larval stage 42- 73%; 23- 66% in coleopteran larvae; in homopteran larvae and eggs 40-57% recorded (Xiaoming et al., 2010).

Banjo et al. (2006), reported the protein content of adult Zonocerus variegates (Orthoptera) as 26.8% by while in Adedire and Aiyesanmi (1999), reported as 53.10±0.56% for the same species of insects..

In the larval stage of Cirina forda (lepidoptera) protein content was recorded 20.2%, 55.50±1.20, 55.50±1.20% and 74.35±0.09% (Banjo et al., 2006; Omotoso, 2006; Agbidye et al., 2009). In Rhchoprus pheonics larvae it was 28.42% and 22.06±0.26% (Banjo et al., 2006 and Ekpo et al., 2009) respectively. Protein content varies depending on
geographical location, climatic conditions of the habitat of insects and developmental stages.

As far as lepidopteran species is concern, Ramos-Elorduy et al., (2011) identified 67 species of edible lepidoptera in Mexico. Among them 16 species were belonging to saturniidae family and one species i.e. Bombyx mori was belonging to Bombycidae family. In another study Ramos-Elorduy, (1997) reported nutrient content of 11 lepidopteran species. The study revealed that crude protein content varies in a range from 15% for Phasus triangularis to 60% for Catasticta teutila on dry weight basis and the range for fat was 7% for Latebraria amphipyrioides to 77% for Phasus triangularis. Banjo et al., (2006) reported proximate nutrient content of 5 edible lepidoptera of south western Nigeria. Among them Anaphe venata was reported to contain the highest protein and lipid content (25.7% and 23.21% dry weight basis respectively) and Anaphe sp. was reported to contain the lowest amount of protein (18.9% dry weight basis). The lowest amount of fat was found in Anaphe recticulata. Another lepidopteran species Cirina forda was studied by Omotoso, (2006). Protein content of Bombyx mori was reported 9.3% as is basis by Finke, (2002) whereas Ramos-Elorduy, (1997) reported the protein content 58%.

However the reported edible insects are high in protein and amino acid only a few insects have been assessed for amino acid content. According to the review 20 proteinogenic amino acids including both the EAAor non EAA were present in the insects in different percentage. According to Rumpold and Schluter, (2013) it is difficult to explain the trend of amino acid distribution in insect’s protein of different orders due to unavailability of data. Finke, (2004) reported the amino acid contents in insects ranges
between 40-95%. Generally, insects have considerable amount of Thr and Leu, (Okaraonye and Ikewuchi, 2009; Ekpo et al., 2010; Idolo and Henry, 2011), but lower quantity of both Meth and Cyst (DeFoliart, 1992).

In respect of the quality of the protein, Ramos-Elorduy, (1997b) reported that 96% amino acid score can be obtained from insect’s proteins following amino acid score pattern WHO/FAO/UNU (1985).

As the insects are phytophagous and feeds on different host plants therefore the protein contents as well as the amino acid contents may vary depending on the season of availability. But no any report on silkworm’s seasonal variations in nutritional contents has been reported till date.

**Edible insects are a considerable source of fat and fatty acids:**

Lipid or fat is the energy-rich macro-nutrient of food consists of triglycerides and has three fatty acids and a glycerol molecule. According to Womeni et al., (2009) oils extracted from several insects are rich in PUFA and contain linoleic and α-linolenic acids. These two essential fatty acids help in the well development of children and infants (Michaelsen et al., 2009). Now a days the deficiency of omega 3 and 6 is of major concern and it can be defeated by consuming insect (N. Roos, personal communication, 2012). As the insects feed on plants hence their fatty acid composition influenced by the food plants they feed (Bukkens, 2005). The presence of UFA in insects can also cause oxidation of insect food products through the processing that result easy spoilage.

The lipid content (DM) of the insect species ranges from 0.66±0.12% to 66.61±0.35 for *Oryctes rhinoceros* larvae and *Rhynchophorus pheonicis* larvae
(Okaraonye and Ikewuchi, 2009; Ekpo et al., 2009). The fat content varies from 4.6 to 36.1% in lepidoptera, 2.34 to 53.05% in orthoptera, 7.54 to 12.3% in hymenoptera, 0.6 to 66.6% in coleoptera, 21.35 to 55.2% in isoptera, and 4.3 to 57.3% in hemiptera (Ekpo and Onigbinde, 2007; Banjo et al., 2006; Omotoso, 2006; Leung, 1972; Agbidye et al., 2009; Okaraonye and Ikewuchi, 2009; Fleming, 1968; Davis, 1918; Ashiru, 1988). In both the larval and pupal stages of edible insects, fat content is higher however during the adult stage, the fat content is relatively lower (Xiaoming et al., 2010) and the trend was similarly in Anaphe venata (Adeduntan, 2005; Banjo et al., 2006). While, fat content of larvae of Rhynchophorus phoenicis was reported as 66.61±0.35% and 31.40% (DM) by Ekpo et al., (2009) and Banjo et al., (2006). Omotoso, (2006) reported the lipid content in Cirina forda larvae was 4.68±0.01% whereas Agbidye et al., (2009) and Banjo et al., (2006) reported 14.30±0.12% and 14.20% of fat content respectively for the same species Cirina. forda larvae.

The review, revealed that, palmitic acid was the dominant SFA in all the studied sericigenous insects followed by stearic acid. Next predominated monounsaturated fatty acid (MUFA) was Oleic acid (Okaraonye and Ikewuchi, 2009; Bophimai and Siri, 2010; Ekpo and Onigbinde, 2007; Due et al., 2009; Ekpo et al., 2009). More often the edible insects contain (PUFA) which includes linoleic acid, α-linolenic acid, γ-linolenic acid, arachidonic acid etc. Out of them Linoleic acid present in Nasutitermes sp., Oryctes owariensis, Morpho peleides (both adults and larvae), Acheta confirmata, Syntermes sp., Gryllotalpa africana Cybister limbatus, , Lethocerus indicus, Onthophagus seniculus, O. mouhoti, Onitis sp., Liatongus rhadamitus, Rhynchophorus palmarum larvae. According to Bophimai and Siri, (2010) linoleic acid in C. nevinsoni was recorded 234.9±5.5
mg/100g DM whereas Raksakantong et al. (2010) could not detected it for the same species. γ-linolenic acid was found in Rhynchophorus phoenicis, Macrotermes bellicosus, Oryctes owariensis, Gonimbrasia belina, Imbrasia truncata, Nudaurelia oyemensis, Homorocoryphus nitidulas, Protohermes grandis, Stenopsyche griseipennis while α-linolenic acid was present in Oryctes owariensis, Rhynchophorus phoenicis, Oecophylla smaragdina (queen and weaver), Copris nevinsoni, Macrotermes bellicosus, Antheraea assama, Gonimbrasia belina, Imbrasia epimethea, Morpho peleides (both the larvae and adult), Philosamia ricini, Acheta confirmata, Chondacris rosea, Gryllotalpa africana, Homorocoryphus nitidulas, Hydrous cavistanum, Lethocerus indicus, Stenopsyche griseipennis. However, the amount of these fatty acids varies in different species. Similarly eicosapentaenoic acid and arachidonic acid were recorded in varieties of edible insect species (Fontaneto et al., 2011). The ω-3 fatty acid comes from α-linolenic acid while ω-6 fatty acids origins from linoleic acid. Arachidonic acid is one of the important products of linoleic acid which gives rise to 20 carbon derivatives of fatty acid including, lipoxines, leukotropes that affect the inflammation and coagulation of blood. Eicosapentaenoic acid and docosahexanoic acid the two ω-3 fatty acids are synthesized from α-linolenic acid. Fontaneto et al., (2011) investigated for the differences in fatty acid content in aquicalous and terricolous insects consumed by human being and conclude that insects have the potentialities to provide the PUFA. Thus insect lipids with substantial amount of PUFA can attribute in nutraceutical and pharmacological appliances for human health.
**Edible insect as source of fibre:**

According to the reviews, insects can also be a good source of fibre. Diet rich in fibre reduces constipation, cholesterol and coronary heart diseases. It was revealed that quantity of fibre varies in different insect species, from 1.01% to 26.4% in *Brachytripes sp.* (Banjo et al., 2006) and *Polyrhachis vicina* (Bhulaidok et al., 2010). The fibre content about 2.20 to 5.71% was recorded in isoptera, 1.68 to 3.10% in lepidoptera, 1.96 to 3.40% in coleoptera (Blasquez et al., 2012; Bhulaidok et al., 2010; Igwe et al., 2011; Adedire 2007; Melo et al. 2011).

**Edible insect as source of minerals:**

Minerals are categorized as macrominerals as well as micronutrients, plays significant role in nutritional quality of a food. Minerals are required in different biological processes and deficiency results health problems like improper growth, immune function, physical and mental development which is of major concern in many developing countries (FAO, 2011).

In insects the minerals contents varies from species to species and moreover the metamorphic stage and diet influence the nutritional value of insects. For that reason consumption of entire insects may provide higher nutrient contents in comparison to the taking of individual parts of insects (N. Roose, personal communication, 2012).

According to the review it was found that insects are good sources of minerals. The amount of Calcium in reported edible insects ranges between 33.16 mg/100g-2000mg/100g in *Cirina ford* and *Busseola fusca* (Omotoso, 2006 and Ghaly and Alkaoik, 2010). Calcium is the main component of bone health and in addition it is present in the extra cellular fluid in ionized form and the functions of many of the neuromuscles and
cells depends on this ionized form of calcium. Absorption of calcium is largely depends on the Ca and vitamin D and deficiency of calcium results osteoporosis. According to Gopalan and Ramachandran, (2008) calcium intake is low (344mg in average) in developing countries than the developed countries (average 850mg).

Magnesium is available in plants and animal foods, results the rare deficiency of magnesium. Mg acts as a cofactor in protein synthesis, many enzymatic reactions, RNA and DNA synthesis and maintenance of electrical potential of neural tissues and cellular membrane. Mg content of some edible insects was reported to be ranged from 62.31mg/100g for Cirina forda (Omotoso, 2006) to 1470 mg/100g for Anthoaea zambezena larvae (Ghaly, 2009). According to Bhulaidoko et al., (2010) minerals content in edible insects species varies depending on locations.

Likewise, sodium content in the insects ranges from 45.26mg/100g in Cirina. forda larvae (Omotoso, 2006) to 440mg/100g for Oryctes. monoceros larvae (Idolo and Henry, 2011). In another study on Anthoaea zambezena and Gonimbrasia belina larvae Na content was reported to be much higher 3370 and 3330mg/100g respectively

Similarly potassium content of reported edible insects ranged from 38.40mg/100g to 412.52mg/100g for Oryctes monoceros larvae (Idolo and Henry, 2011) and Agonoscelis pubescens (Mariod et al., 2011). However, (Ghaly, 2009; Ghaly and Alkoaiik, 2010) reported higher K contents in insects. Sodium is the main cation which controls the body fluid and osmolarity and hence, the volume of body fluid is dependent on sodium ions. Nerve transmission and muscle contraction also need sodium and potassium.
Fe content in edible insects ranges from 5.34mg/100g to 280mg/100g in Cirina forda larvae (Omotoso, 2006) and B. fusca (Alkoaik, 2010). Ghaly (2009) reported that Anthoraea zambezina and Gonimbrasia belina larvae possess 1290 and 1270mg/100g, which is higher than the reported insects. An extensive review on iron has been reported by Dallman, 1986; Bothwell et al., 1979 and Mascotti et al., 1995). Fe act as a oxygen carrier from lungs to tissues by haemoglobin and an integrated part of various enzymatic reactions.

Copper quantity in the insects varies from 1mg/100g to 2.4mg/100g for Oryctes monoceros larvae (Idolo and Henry, 2011) and P. vicina China (Bhulaidok et al., 2010). However, in Anthoarea zambezina and Gonimbrasia belina larvae, Cu content was much higher 160 and 150mg/100g respectively (Ghaly, 2009).

Manganese (Mn) content in edible insects was ranged from 25.9mg/100g to 60mg/100g for Polyrhachis vicina (Bhulaik et al., 2010) and Anthoarea zambezina larva (Ghaly, 2009).

Another important micro-mineral is zinc which varies between 3.81mg/100g to 250 mg/100g for Cirina forda larvae (Omotoso, 2006) and Anthoraea zambezina larva respectively (Ghaly, 2009).

Silkworms are cultured in different parts of the oriental region among which the most countable are India, Indonesia, China, Japan, and Thailand for commercial purposes. Silk production is widespread in Asia and Brazil (Speight, 2001), so there is potential to encourage the use of silkworm for both a valued product (silk) and a food source. Among 50 edible insect species in Thailand the most common are silkworm pupae; bamboo worms, locusts, beetles, crickets, red ants, and other insects (Young-Aree
et al. 1997). Silkworm pupae, the by product of sericulture is widely consumed in Asian countries like Indonesia, China, Vietnam, Korea (Baker et al., 2016). Moreover silkworms also occupies a high proportions of edible insects of the world (Nowak et al., 2016).

In recent years Bombyx mori nutrition research has finally started to yield decent results to at least partial replacement of feeding material with alternates for fresh mulberry leaves which can be difficult to obtain depending on season (Cristina and Marghitas, 2011). Research is also underway on the use of the silkworm Bombyx mori Linnaeus (Lepidoptera: Bombyciidae) as part of bio-regenerative life support system for space travel (Yu et al., 2008). However the pupae of B. mori are a high quality source of protein and are comparable to the dietary profile recommended by FAO/WHO (De Foliart1995; Zhou and Han, 2006). Banjo et al., (2006) reported that insects and meat play same role in human body.

National status:

In India, the potential of edible insects used as food or medicines is far from appreciation. Few literature surveys revealed fragmentary information regarding edible insects in India. In 1945, Das assess that locust Schistocerca gregaria contains higher crude protein and lipid and used as human food and fertilizer. According to Roy and Rao, (1957), the Muria tribes of Madhya Pradesh also consume edible insects. Insects as food was used by Negrito tribes of Andaman Islands in India Sharief, (2007), while as reported by Gope and Prasad (1983), 20 species of insects used as food by different tribes of Manipur. Kavita, (2010) enclosed different managing skills for honey bees in Nicobar
Shompen Islanders. Srivastava et al.,(2009) reviewed the insect bio prospecting in India. Meyer Rochow and Changkija (1997) identified and named at least 42 species of edible insects used as food by Ao-Nagas in Nagaland. It includes 9 species each of coleoptera, 8 species of hemiptera and 11 species of orthoptera and the rest distributed among the remaining insect orders with mantodea and odonata taking a leading role. An edible bug (*Ochrophora. montana*) had been mentioned by Sachan et al., (1987) as food for people of Mizo Hills in NE India. Meyer-Rochow, 2005 extended the list to around 60 edible species of insects in which few insects of the Meeteis tribes of Manipur and the Khasis of Meghalaya was included. The use of edible insects as food among the tribes of Arunachal has been shown in several reports (Singh et al., 2007; Chakravorty et al., 2011a, 2011b; Chakravorty et al., 2014, 2016) and showed that 102 edible species belongs to 13 different orders of insects and consume greater numbers of Orthopteras insects than the other ethnic people(Singh and Chakravorty, 2008). Nevertheless, this given lists is incomplete due to the preferences of insects as food varies among different tribes, depending on their availability, ethnic traditions and beliefs. Therefore, it is the need for initiation of documentation of edible insects of Northeast, India.

As far as sericigenous lepidopteran species is concern, few works have been reported addressing different directions of problem. Sarmah et al., (2009) illustrated the traditional practices in muga and eri culture. Devi et al., (2011) elaborated biodiversity of different sericigenous insects and their food plants. In another study by Doley and Kalita, (2011) reported lepidopteran as edible insects and importance was given on their role in the development of socio economic condition of rural populations of Dhemaji district of Assam. Kakati and Chutia, (2009) reported the diversity of different sericigenous insects
in Nagaland. However, no work has been reported addressing the nutritional point of view. Mishra et al., (2003) also worked on the nutritional perspective of saturnids in Assam. The research has shown that tribals of Arunachal consume comparatively greater numbers of Orthopterans than other tribals (Singh et al., 2007; Singh and Chakravorty, 2008).

Although some of the lepidopteran species are also consumed by the tribes of Arunachal Pradesh and some section of people in Assam, hence they are to be added up in the lists. Therefore, in the present work the attention has been focused on edible lepidopterans specially the sericigenous insects i.e. silk worm the most commonly used insects.

**MATERIALS AND METHODS**

**Field survey:**

The present study was carried out in the five villages (Gohaingaon, Bakal gaon, Naharani, Kechukhana and Deogharia) of Dhemaji district of Assam in the year 2013 to 2016. Extensive field survey was carried out to document the edible silkworm species, their mode of consumption, seasonal availability, mode of preparation, therapeutic value if any, folklore related to insects and anything else important in connection with the sericigenous insects at Dhemaji district. The villages were selected on random basis. The surveys were based on interviews during which a total of 30 persons aged between 45 and 70 years of age (20 male and 10 female) were interviewed with semi structured questionnaire.