DISCUSSION

With an increasing human population and environmental degradation, the world faces a major problem in providing adequate animal based proteins. The basic challenge to improve food security by introducing novel ways of feeding world’s human population is to secure adequate nutrition. The nutritional value of food largely depends on the quality of protein and thus, amino acid composition it contains. Data on the nutrition information of insects are important; it informs consumers about the quality and quantity of their intake. For international comparison, a common yardstick to assess the nutritional value of food is the weight of food, along with its nutrient content (Grigg, 1995). They can easily be collected, are and taste good. Nutritional aspects, for instance whether they contain a lot of protein, minerals or vitamins are apparently not considered in decisions on which species to eat and which to avoid.

Insects that are taken as food are an integral part of culture and tradition for the tribes of Arunachal Pradesh. The choice of insects for food is mainly dependent on good taste, cheap and can easily be collected. Whether they contain a lot of protein, minerals or vitamins are apparently not considered in decisions on which species to eat and which to avoid. Therefore, to understand the nutritional potential of the edible insects, edible insects such as Hexacentrus sp., Mecopoda sp., Conocephalus sp., Schistocerca sp., Ducetia japonica, Phyllozetus sp., Oxya fuscovittata and assorted samples of grasshopper were considered to evaluate nutritional composition.

Grasshoppers are one of the main edible insects. They are eaten widely among the Adi tribe of Arunachal Pradesh. They are usually collected in crop fields or in the bush or hilly terrain. The woman enjoys collecting grasshoppers. Collecting grasshoppers requires work from early in the morning, as it is easy to collect them while they are wet from the morning dew. They enjoy collecting them, despite the early morning star.
The healthy grasshoppers are caught alive and processed immediately. The grasshoppers are kept alive for one night after they are collected to allow time for the feces to be expelled. The next day, they are suitable for eating. Usually the wings, hard exoskeletons and intestines are removed before cooking. They are cooked in various ways before being eaten: deep-fried, grilled over an open fire, parched and ground, or steamed in banana leaves. Some time, spices and herbs like garlic, chilies are also used to increase flavour and mask unpleasant insects’ smell. Though ethnic people collect this insect mostly for their personal consumption, sometimes they also sell or trade it for profit.

**MOISTURE**

The moisture content of the entire insects under study was generally high but observed to agree with the published data for various insects species. At 42% to 59% moisture content in *Hexacentrus sp.*, *Mecopoda sp.*, *Conocephalus sp.*, *Schistocerca sp.*, *Ducetia japonica*, *Phyllozela sp.*, *Oxya fuscovittata* and assorted sample of grasshopper was higher than the reported values: 0.96% to 1.13% for crickets, yam beetles, palm weevil, grasshopper (Ekop et al., 2010), 22.19% for army worms (Abulude et al., 2008), 10.85% for *Cirina forda* (Lepidoptera) (Omotoso, 2006), 16.73% for *Oryctes rhinoceros* larvae (Okaraonye and Ikewuchi (2009), 8.3% for pentatomid bugs (Mariod et al., 2011), 1.91% to 4.4% for various species of termite, grasshopper, beetles, honey bees and caterpillars (Banjo et al., 2006), 7.9% for larva of soldier fly *Hermetia illuceus* (Newton et al., 1977), 5.2% for house cricket *Acheta domesticus* (Nakagaki et al., 1987), 6.61% for *Anaphe venata* (Ashiru, 1988), 12.6% for *Macrotermes bellicosus*, 34.36% for *Imbrasia belina* larva (Ekpo et al., 2009) and comparable to (42% to 48%) moisture content in stink bug (*A. nepalensis*), short horned grasshopper (*C. rosea*), termite (*Odontotermes sp*) (Chakravorty et al 2014) and 69% to 72% in bush cricket (B. orientalis), weaver ant (*O. smaragdina*) (Chakravorty et al. 2016). However, moisture values of present studied insects are lower than the reported values e.g., Davis (1918) had earlier reported a moisture value (%) of 70.0 and 60.4 respectively

113
for the larva and adult beetle of *Lachnosterna species*. Bodine (1923) reported a moisture value of 79% for the larva of *Chortophaga viridifasciata*, while studies by Ludwig and Landsman (1937) gave the moisture content for the larva of *Popillia japonica* in the range 78-81%. Moisture values for some other insects include: 67.4% for the adult beetle of *Popillia japonica* (Fleming, 1968), 69% for newly emerged housefly (*Musca domestica*) (Teotia and Miller, 1974), 60.7% for *Bombyx mori* (Leung, 1972), 61.8% for *Rhynchophorus phoenicis* larva (Ekpo and Onigbinde, 2005), 62% for *Oryctes rhinoceros* larvae (Ekpo et al., 2009). Finke (2004) also reported 71.7% for *Rhynchophorous palmarum* larvae, 63.7 for *Tenebrio molitor* adult, 77.1% for *Acheta domesticus* nymph, 76.7% for *Cytacanthris tatarica*, 77.8% for *Cortaritermes silvestri*, 75.3% for *Nausitermes corniger*, 78.3% for *Oecophylla virescens*, 64% for *Pachili gigas*.

While compared to the conventional food sources of animal origin *i.e.*, pork, chicken, beef, egg and veal it has been found that the moisture content of the studied insects are comparable to pork and beef; however, much lower than that of other food of animal origin as well as vegetables like cabbage, cauliflower, mung beans, bamboo shoot (cf. Fig. 2a).

Moisture content of food is generally used as a measure of the stability and susceptibility to microbial contamination (Scott, 1980). The lower moisture content in food is known to improve the shelf life of food. Therefore, relatively high moisture value in the insects under study will not assist in keeping quality since they may prone to spoilage on careless keeping. Yet, high moisture content in the studied insects implies that the most of the essential nutrients in them will be in forms that will be easily available to the body after their consumption. Habitually, the ethnic tribes of Arunachal Pradesh consume these insects in fresh form, either as snacks after frying or as part of the meal in the form of “chutney” (grinding the fresh insects along with spicy ingredients) so that total moisture in the insects are ingested as such. However, when they catch the insects in large quantity they preserve them for future use as sun dried or smoke dried.
ENERGY (CALORIFIC VALUE)

Energy is required to maintain basal metabolism, to power physical activity (muscle movement) and to provide the thermic effect of food. The mean energy values (kcal/100g) of the studied insects i.e. in Schistocerca sp. (377.098 kcal), Conocephalus sp. (382.91 kcal), Mecopoda sp. (385.339 kcal), Phyllozelus sp. (394.402 kcal), assorted sample (408.275kcal), Ducetia japonica (409.261 kcal), Oxya fuscovittata sp. (421.184 kcal), Hexacentrus sp. (532.035 kcal) were within the range (293 to 762 kcal/100g) reported by Ramos-Elorduy et al. (1997) for seventy eight species of edible insects and Chakravorty et al. (2014, 2016) for C. rosea, B. orientalis Odontotermes sp. (373.23 to 385.26 kcal/100g) and for Odontotermes sp.(617.41 kcal/100g). The winged sexual forms of the African termite, Macrotermes falciger (Gerstacker),

Macrotermes subhyalinus (Rambur), were 613 kcal (-2575 kJ)/100g (dry weight) (Oliveira et al., 1976). Ashiru (1988) reported a calorific value of 611 kcal (-2566 kJ)/100g for the caterpillar Anaphe venata (Butler) (Notodontidae) in Nigeria. It was further revealed that twenty-three species of caterpillars in Zaire, (mostly Saturniidae), were found to average 457 kcal (-1919 kJ)/100g dry weight, ranging from 397 to 543 kcal (1667 to 2281 kJ) (Malaisse and Parent, 1980). High caloric values can be hypothesized as the fat content in the respective species of insects as it was observed in Hexacentrus sp, Ducetia japonica, Oxya fuscovittata and the assorted grass hopper sample, in which considerable amount of fat was detected compared to other insects in the present study. Additionally, the calorific value of the tested insects was higher than that reported calorific values for rice (345 kcal), wheat (345 kcal), whole grams (335 kcal), and egg (173 kcal) (cf. Srilakshmi, 2012). The recommended dietary allowances (RDA) of energy i.e., the average daily requirements corresponding to daily average energy expenditure for Indian man and woman doing heavy work are 3490 kcal and 2850 kcal per day, whereas, the requirement increases

115
for pregnant and lactating woman by 350 and 600 kcal more per day respectively (ICMR, 2009). Therefore, consumption of 100g tested insect species can meet up the RDA to 17.69% in case of Hexacentrus sp., in which the calorific content was found be highest and 10.70% in case of Conocephalus where the calorific content was the lowest. However, the calorific values for most of these insects seem to be considerable since these insects are mostly taken as a side dish and not as their staple of food. So all the species of grass hopper are better source of energy compared to other insects species in this study.

FIBER

Fibers affect lipid absorption by adsorbing fatty acids, cholesterol and/ or bile acids within the digestive tract. Fatty acid and cholesterol that are bound to fiber cannot form micelles, thus not absorbed in the small intestine and pass into the large intestine where they are to be excreted or degraded by intestinal bacteria. Thus, high fiber in the diet reduces cholesterol, and prevents coronary heart disease. Fiber is also important as it prevent constipation and has protective role against colon cancer (Srilakshmi, 2012).

The indigestible part of the insect or the non structural carbohydrates, expressed as crude fiber and it differed from each other accounting for about 3.272% to 11.840%. Crude fiber content in the edible insects under study was 11.840% Ducetia japonica, 10.923% for Schistocerca sp. 10.383% Mecopoda sp. 7 to 8 % in other species and comparatively very low in Hexacentrus sp. and Oxya fuscovittata (3.272 to 3.520 %) These values are appreciably high and could be attributed to amount of chitin found normally in insects. Chen and Feng (1999) and He et al. (1999) reported that the body and skin of edible insects are rich in chitin; different insects have different chitin content 5-15%. Oduor et al. (2008) have reported that chitin and chitosan yield differ with species. Bhulaidok et al. (2010) reported the fiber content of 25.4% and 26.4% for Polyrhachis vicina (hymenoptera) from two different geographical region of China. Ramos-Elorduy et al. (1997) has
reported the lowest value of fiber in the social insects from 1 to 6%, in bee and stingless bee M. beechei and the highest values in adult beetle
*Callipogon barbatus* (22.7%), the avocado tree hopper, *Holophorion monograma* (19.4%) the bugs *Euschistus eglestoni* (13.5%)
*Acanthocephala declivis* (18.4%) and *Edessa petersii* (18.0%) the beetle larvae of *Aplagiognathus spinosus* (15.0%) and the tree hopper
*Umbonia reclinata* (13.3%). Blasquez *et al.* (2012) reported 10 to 12% in some orthopteran species while Ekop *et al.* (2010) reported 3.30 for cricket, 3.0, 2.20 and 2.5 for yam beetle, palm weevil, and grasshopper respectively. Banjo *et al.*, (2006) and Igwe *et al.* (2011) reported
2.70% for *Macrotermes bellicosus*, 2.20% for *M. notalensis* and 5.71% for *M. nigeriensis*. It was noted that the fiber contents of the insects in
the present study fall in the range reported for fiber values within and between insect taxa (cf. Fig. 2f). Crude fiber content of the insects in the
present study was comparable to the dietary fiber content (g/100g) of rice (4.1), wheat (12.5), whole Bengal gram (28.3), lentil (15.8),
cabbage (2.8), green colacasia (6.6), yam (4.2) (Gopalan *et al.*, 2004).

RDA for dietary fiber has not been prescribed so far for most of the countries including India. However, Current recommendation for
dietary fiber intake are related to age, gender and energy intake, the general recommendation for adequate intake is 14g/1000 kcal (IOM,
2005). The physiological role of crude fiber in the body is to maintain an internal distention for proper peristaltic movement of the intestinal
tract (Oduor *et al.*, 2008). Food having high fiber content has nutritional advantage as it assists in reducing constipation and other attendant
problems. Moreover, diet with high fiber content have been used for weight control and fat reduction as they give a sense of satiety even
when small quantity of food is eaten. High fiber content in the studied insects may contribute all these physiological advantage when they are
being consumed.
NFE AS CARBOHYDRATE

Carbohydrates are important nutritive component in the human body. Besides providing C, H and O, carbohydrates are the main heat source, can combine with protein and fat and in turn their compounds have important physiological functions (Jin, 1987). Recent research has revealed that insects have considerable amount of polysaccharide that can enhance the immunity function of the human body (Sun et al., 2007).

All the insects in the present study contained 13 to 22% crude carbohydrate as Nitrogen free extract (NFE) but Hexacentrus sp. contained lesser amount of carbohydrate but still it was about 8.75%. NFE content (%) can be compared favorably with range 0.19 to 22.64 given for some orthopterans by Blasquez et al. (2012). Ekop et al. (2010) reported NFE content in other orthopteran species; 13.08% for Gymnogryllus lucens, 24.94% for Zonoceros variegates. While NFE content of the present study was comparable to , A. nepalensis (15.3%) Aspangobus viduatus (7%) and Agonoscelis pubescens (4.4%) reported by (Mariod et al., 2011; Chakravorty et al., 2011b). NFE content of coleopteran species, X. gideon and Anomala sp. 12.78% and 19.60% respectively which was comparable to coleopteran species e.g. Oryctes monoceros larvae (15.05), Heteroligus meles larvae (21.707%), Rhynchophorus phoenicus larva (22.759%) (Idolo and Henry, 2011; Ekop et al., 2010). Carbohydrate content of a novel food often received very little attention than protein or fat received. Though, under most circumstances there is no absolute need for carbohydrate as amino acids, glycerol component of fat, and some organic acids can be converted to carbohydrate. However, in the absence of dietary carbohydrates lipolysis of stored triglycerides and the oxidation of fatty acids increases and ketone bodies accumulate (Manninen, 2004; Recommended Dietary Allowances, 1989). A carbohydrate free diet is also generally associated with an accelerated breakdown of dietary and tissue protein, loss of cations especially sodium and results in dehydration. Calloway
(1971) suggested that the effects produced by low carbohydrate diets can be prevented by daily ingestion of 50 to 100g of carbohydrates. In general, the insects in the present study contained significant amount of NFE, especially *Oxya fuscovittata* *Schistocerca* sp.; *Phyllozelus* sp., *Conocephalus* sp. and *Ducetia japonica* which indicate that these insects have the potential to complement diet and assists in complete utilization of protein, thereby enhancing nutritional value of insects as food. Among the eight studied insects, the ratio of crude fiber to carbohydrate (2:1).Srilakshmi (2012) proposed that, the proportion of soluble to insoluble fiber should be 1:2 and the intake is preferred through diet made up of various sources of conventional food. However, for such type of non conventional food like insects this ratio is yet to be worked out. Nonetheless, high carbohydrate content of these insect makes it a good quality food.

**PROTEIN AND AMINO ACIDS**

**Protein:** Protein is the basis of many important components such as enzymes, hormones and haemoglobin. It is an important component of antibodies as it bolsters the immunity function of the body. It is the only material to produce nitrogen for maintaining acid and alkali balance, transforming genetic information and transporting important materials in the human body. As a nutritive element that produces heat, protein can supply energy. According to reports and analysis (Ramos-Elorduy and Pino, 1989; Mitsuhashi, 1992; DeFoliart, 1992; Yang, 1998; Banjo et al., 2006; Chakravorty et al. 2014, 2016) many edible insects are rich in protein ranging from 20 to 7%.

This study revealed that, all the edible insects, in general, are rich in protein, though these values vary among them. It was noted that the protein contents of the insects in the present study fall in the range reported for protein values other insect taxa (*cf.* Fig. 2b). It is worth mentioning that protein values varied from a low of about 53% to 67.8 % for already reported insects species from hemiptera, orthoptera,
hymenoptera, isopteran and coleoptera respectively reported from different parts of the world (de Conconi et al., 1984; Banjo et al., 2006; Bhulaidok et al., 2010; Blasquez et al., 2012). These variations may partly be due to differences in feed, seasons, insect stages and their geographical location. Bhulaidok et al. (2010) reported a significant difference in protein content of same species of black ant from two different localities. Protein content of Zonocerus variegates adult was reported 26.8% (Banjo et al., 2006) whereas Adedire and Aiyesanmi (1999) reported the value 50.39% for larvae and 53.1% for adult.

The protein content, with the values 53% to 67.8 % in the present study were higher than the amount reported for grasshopper, termites, bugs and ants (de Conconi et al., 1984; Banjo et al., 2006) and comparable to many grasshopper and cricket species (Blasquez et al., 2012). Similarly respective values 56.28% and 53.07% in Schistocerca sp. and Ducetia japonica were higher than that reported for other ant species like Atta sexdens, A. cephalotes, Liometopum apiculatum, adult and reproductive forms of L. luctuosum (Dufour, 1987; de Conconi et al., 1984; cf. Rastogi, 2011) and some coleopteran species like Rhynchosaurus phoenicus larvae, Oryctes rhinoceros, june beetle (Ekpo et al., 2009; Ramos-Elorduy, 1998) and witjuti grub (Meyer-Rochow, 1976) and thirteen species tested by Banjo et al. (2006). Moreover, these species, protein content was still higher than that of the protein content in cow’s milk (whole 3.22g/100g) or soy milk (3.27g/100g) (USDA).

Based on dry weight, protein values, 75.3%, 75.3%, 77.13%, 77.13% and 77.13%, respectively, were reported for orthopteran species Melanoplus femurrubrum, red legged locusts, Melanoplus mexicanus, Boopedon flaviventris and Sphenarium sp. (de Conconi et al., 1984; Ramos-Elorduy, 1998). Brachytrupes sp., Brachytrupes membranaceus, Cytocanthacris aeruginosus unicolor, Zonocerus variegates, Sphenarium histrio contained 6.25%, 35.06%, 12.1%, 26.8% for adult and 50.39% for larvae, and 52.13% respectively (Banjo et al., 2006; Agbidye et al., 2009; de Conconi et al., 1984; Adedire and Aiyesanmi, 1999; Banjo et al., 2006). A study by Ekop et al. (2010) showed that
Heteroligus meles (yam beetle), Rhynchophorus phoenicus (palm weevil), Zonoceros variegates (grasshopper) contained 37.62%, 49.87% and 44.62% protein respectively. Banjo et al. (2006) reported the respective value of caterpillar Anaphe sp., A. venata and Cirina forda 18.9, 25.7 and 20.2%; termite Macrotermes bellicosus and M. notalensis 20.4 and 22.1%; honey bee Apis mellifera 21% for crude protein.

Compared to conventional food of animal and plant origin, grasshopper species in the present study were superior to some conventional food used as source of protein (chicken beef, pork egg, bamboo shoot soybean and mung beans etc.) (cf. Fig. 2c). The recommended dietary allowances (RDA) of protein for Indian man and woman are 60g and 55g per day and for pregnant and lactating woman are 82.2g and 77.9g per day respectively. For growing boys and girls in the age group of 16-17 years, protein requirements are 61.5g and 55.5g per day, (ICMR, 2009). Therefore, Daily consumption of 100g of the tested edible insects can satisfy to nearly 88.46% of RDA protein requirements for man.

Amino acid: Protein is composed of more than 20 types of amino acids. Protein quality, as related to human nutrition, is dependent upon the amino acid composition of the source. A cell can synthesize non-essential amino acids when they are unavailable from food, but essential amino acids can only be obtained from foods (Sizer and Whitney, 2000). In this regards, having high protein content in the studied edible insects, the information about the amino acid profile is of great value from a nutritional standpoint.

About 18 amino acids could be detected in these insects in the present study and the most predominant ones were Glu, Ala, and Asp as non-EAA and Leu, Lys, Val and Ile as EAA. They varied among the species in the present study and which may be attributable to differences in amino acid content in the feed of these insects. The total EAA in Conocephalus sp., Mecopoda sp., Hexacentrus sp., Schistocerca sp., Ducetia japonica, Phylozelsus sp., Oxya fuscovittata and assorted grasshopper sample were 38.267%, 40.459%, 36.432%, 39.008%,
42.057%, 40.606%, 39.042% and 33.868% respectively (cf. Fig. 3a). Most of the essential amino acids are obtained from diet and it maintains nitrogen balance in the body.

Among the EAA the branched-chain amino acids, Ile, Leu, and Val help in minimizing muscle wasting under conditions of increased protein breakdown, which is particularly beneficial for athletes. Leu is solely a ketogenic amino acid, giving rise to acetyl CoA or acetoacetate, neither of which can bring about net glucose production. In the present study, Leu, a predominant EAA ranged between 5.388% for *Hexacentrus sp.* to 8.834% for *Phyllozelsus sp.* This findings were in agreement with the Leu content for other edible insects like *Boopedon flaviventris* (Orthoptera), *Hoplihorion monograma* (Homoptera), *Parachartegus apicalis* (Hymenoptera), *Brachygastra azteca* (Hymenoptera) *Oryctes rhinoceros* larva (Coleoptera), *Rynchophorus phoenicis* larvae (Coleoptera), *Bombyx mori* (Lepidoptera), etc. (de Guevara *et al.*, 1995; Okaraonye and Ikewuchi, 2009; Ekpo and Onigbinde, 2005; Tomotake *et al.*, 2010; Idolo and Henry, 2011; Ghaly and Alkoai, 2010) except a few like *Ascalapha odorata* (Lepidoptera) in which Phe was found to be dominant (de Guevara *et al.*, 1995) and *Busseola fusca* (Lepidoptera) (Ghaly and Alkoai, 2010) in which His was dominant one. The next predominant amino acid found was Val. Val, a glucogenic amino acid, influences brain to uptake other precursors for neurotransmitter like Trp, Phe and Tyr. The proportion of Val ranged between 4.763% in *Oxya fuscovittata* to 6.833% in *Mecopoda*. Val content of tested insect was higher than that of other reported edible insects like *Busseola fusca, Heliothis armerigera, Boopedon flaviventris, Rynchophorus phoenicis* larva etc. (Ghaly and Alkoai, 2010; de Guevara *et al.*, 1995; Ekpo, 2010). Lys, another entirely ketogenic amino acid, has received attention as it is a limiting amino acid in cereals, especially wheat, rice, cassava and maize based diets which are prevalent in the developing world including India (Hill, 1970; Ozimek *et al.*, 1985). Lys synthesizes carnitine which is required for transportation of medium and long chain fatty acids into mitochondria
for β-oxidation. All the studied insects contained considerable amount of Lys and found to meet recommended values as proposed by FAO/WHO/UNU (2007) upto 82.4% to 158.9. Ile, Thr and Phe are both glucogenic and ketogenic amino acid. Thr is known to be the second rate limiting amino acid in the maintenance requirement for the body (Said and Hegsted, 1970; Hegsted, 1973; Fuller et al., 1989). Considerable amount of Thr are present in these insects ranged within 3.499% to 5.865%. His is a precursor of histamine, carnosine and arserine. Histamine, releases from the cells as a part of allergic reaction and also takes part in dilation and contraction of certain blood vessels. Among the amino acids in this study, though His content was comparatively lower, it was 2.753 to 5.228%. In *Schistocerca sp.*, it was 5.228%, the highest value and in rest of the insects it falls between 2.7 to 3.2%. However, the contents of all these EAA in these insects were much closer to the values for conventional meat like beef, pork chicken and conventional protein sources of plant origin like chickpeas, beans, lentils, soybean etc. (cf. Fig. 3b). Moreover, it was also noted that, in these seven insects as well as assorted sample, the values for Val, Leu, Ile, Lys, Phe, His, Thr surpassed (>100%) the values recommended by FAO/WHO/UNU (2007) for "chemical score" of amino acid as an index of accessing the protein quality (cf. Fig. 3d – 3f; Table 3c). However, Met content in these insects was comparatively lower (1.087% in *Conecephalus sp.* to 3.254% in *Phyllozetus sp.*) but at this lowest valu of it in *Conecephalus sp.*, could meet the requirement of recommended value upto 67.9% of chemical score (FAO/WHO/UNU, 2007), it was even comparable to conventional food of plant origin (cf. Fig. 3b). But among these insects, *Phyllozetus sp.*, *Oxya fuscovittata* and assorted sample contained good amount of Met and this is better than Met content in conventional protein sources of both plant and animal origin; it could meet about 190 to 203.4% of chemical score (*FAO/WHO/UNU, 2007*). It implies that the quality proteins in these insects are as good as conventional food of plant and animal origin. In
addition to the presence of these EAA, effective utilization of the dietary protein requires an appropriate balance between the EAA and non-EAA and other nitrogen containing compounds.

Among the non-EAA, the most predominant one is Gln+Glu. It was 7.774 in Schistocerca sp., 9.953 in Mecopoda sp., 10.8498% in Oxya fuscovittata, 10.058 in Ducetia japonica, 11.434 in Hexacentrus sp. 11.684% in Conocephalus sp., 12.006% in Phyllozels sp. and even 13.932% in assorted species of grasshopper sample. These values fall within the range as reported for other edible insects (Okaraonye and Ikewuchi, 2009; Ekpo, 2010; Idolo and Henry, 2011). The principle activity of Gln is to transport free ammonia, which is toxic to human body. Glu is a component of glutathione and a precursor of γ-amino butyric acid (GABA), a neurotransmitter and precursor for Pro and ornithine. Next to Gln+Glu, Ala is the next predominant non-EAA for these insects. Ala helps to convert blood glucose to energy and plays a role in muscle health and reduces muscle fatigue (Culbertson et al., 2010). Ala content of tested insects was comparatively higher than the Ala content reported for many insects like Oryctes rhinoceros, Rhynchophorus phoenicus, Oryctes moncoros, Bombyx mori (Okaraonye and Ikewuchi, 2009; Ekpo, 2010; Idolo and Henry, 2011; Tomotake et al., 2010). Besides Ala, Asn is important for proper functioning and chemical balance in various tissues including human brain (Gropper and Smith, 2013). With the values of 7.851% to 9.574 % Asp+Asn content in these five insects were much closer to the values reported for other insects (Okaraonye and Ikewuchi, 2009; Ekpo, 2010; Idolo and Henry, 2011; Tomotake et al., 2010). Similarly, Arg, one of the important components of enzyme of urea cycle, ranged between 4.69% for Oxya fuscovittata to 8.804% for Ducetia japonica. Arg is synthesized by mammalian tissues, but the rate is insufficient to meet the need of it during growth. It is essential for growing children but not essential in adults because Arg can be synthesized from Met and ornithine in them. In addition to all these amino acids, substantial amount of both Ser and Gly were also present in these insects. In the body, Ser is converted
reversibly to Gly in a reaction that requires pyridoxal phosphate and tetrahydrofolate and Gly is the precursor of glyoxalate, which can be transaminated back to glycine or oxidized to oxalate. Gly is one of two major inhibitory neurotransmitters that balance the excitation in the brain. Therefore, these insects can also serve as a source of non-EAA as and when it is required.

Studies on amino acid profile of these insects indicate that these insects are the sources of good quality protein or “complete protein” from a nutritional point of view and can supplement protein supply by complementing other animal protein sources.

FAT AND FATTY ACIDS

**Fat:** Fat is the most energy-dense macronutrient in food. It consists of triglycerides, which all have a glycerol molecule and three types of fatty acids in their molecular makeup. The importance of fat for the body is not unknown; it is one of the main constituents of cell membrane, helps in transportation and absorption of fat soluble vitamins and other nutrients, provides energy to the body etc. Nevertheless, fats are unpopular and avoidable for consumers, being considered as unhealthy. However, to meet the calorific deficiency, there is need of fat to combat malnutrition in developing countries. In general fats are commonly found in different food sources in varying proportions and their databases can be available from varied sources. However, until recent time, exploitation of insects as an alternative source of food in general and fat in particular has received little attention despite being in abundance and widely used by 3000 ethnic communities of 113 countries around the world (MacEvilly, 2000; Mitsushashi, 2008).

Energy is necessary for all biological processes and heterotrophic organisms obtain it through their food. Compare to other macronutrients, fat supplies the highest amount of energy. Edible insects vary widely in fat, and, thus, energy content. They are natural
renewable resource used as food by people around the world (Ramos-Elorduy and Conconi, 1994) and the quantity and quality of nutrients that insects contribute to human diets may be considerable as proposed by Dufour (1987). Besides supplying energy, fats play important roles in formation of cerebrosides, phospholipids, cephalins and sphingomyelins as well as in the elaboration of steroids. Fat is also precursors of prostaglandins, thromboxins and prostacyclins and involved in the formation of cholesterol (Krause and Mahan, 1984). Regarding malnutrition in developing countries, the problem of calorific deficiency reflects mainly the need of fat.

The fat content of edible insects varies widely. Not all edible species of insects contain high amount of fat. Ramos-Elorduy et al. (1997) reported in seventy eight species of insects and found it ranged from 4.0 to 77.2%. In the present study, fat content of Hexacentrus sp. was considerably higher than many reported insects (Ukhun and Osasona, 1985; Adeduntan, 2005; Agbidye et al., 2009; Banjo et al., 2006; Omotoso, 2006; Ekpo and Onigbinde, 2007; Ekpo et al., 2009; Okaraonye and Ikewuchi, 2009) and lesser than that reported for Rhophorus phoenicis larvae (coleoptera), Brachytrupes membranaceus (orthoptera) and winged termite (isoptera) (Ekpo et al., 2009; Adeduntan, 2005). Adeduntan (2005) and Leung (1972) reported fat content of winged termite and termite 53.063% and 55.24% dry weight basis respectively and most of the reported edible insects belonging to orders coleoptera, orthoptera, lepidoptera, hymenoptera except few like winged termites and Australian witjuti grab (39.8% of the dry weight basis) (Adeduntan, 2005; Banjo et al., 2006; Fast, 1970; Meyer-Rochow, 1982; Meyer-Rochow, 1976).

Fat content in other orthopteran species in this study was comparable to other reported for grasshopper, cricket, Brachytrupes sp., Cytacanthacris aeruginosus unicolor, Zonocerus variegates and lesser than that reported for cricket, Brachytrupes membranaceus among C.
rosea and Brachytrupes orientalis. Chondacris rosea orthopteran insects (Akeduntan, 2005; Banjo et al., 2006; Leung, 1972; Agbidye et al., 2009; Banjo et al., 2006; Chakravorty et al. 2014, 2016), however, Agbidye et al. (2009) reported considerably lesser value for Brachytrupes membranaceus (53.05%). It was noted that the fat contents of the insects in the present study fall in the range reported for the values fat, within and between insect taxa (cf. Fig. 2d).

High fat content is particularly relevant in the developing countries as much of energy is expended in doing works manually in contrast to developed countries where the work is done through machine. DeFoliart (1992) pointed out that calorific deficiency as that of protein deficiency is one of the reasons behind malnutrition in developing countries. Food containing high amount of fat is thus expected to play significant role to avoid malnutrition. In this regards, the Hexacentrus, Ducetia japonica and Oxya fuscovittata in the present study, can contribute to the fat requirement of the people who eats them. The intake of at least 50g dried Hexacentrus sp. can provide 15 g fats, which is near to the value of RDA as suggested by (RDA 2009 by ICMR). The recommended dietary allowance (RDA) of visible fat for Indian man and woman varies and depends on the nature of work a person used to perform. RDA for the Indian man and woman under heavy work category are 40g and 30g per day respectively, the requirement remains same for pregnant and lactating woman. For growing boys and girls in the age group of 16-17 years visible fat requirements are 50g and 35g per day respectively, higher than RDA for man and woman as reported by ICMR, (2009).

**Fatty acid:** Fat is a source of essential fatty acids. Fatty acid compositions determine the quality of fat. Fatty acids can be categorized into saturated fatty acid (SFA) and unsaturated fatty acids (UFA) and in turn UFA can be sub categorized into mono unsaturated fatty acids
(MUFA) and poly unsaturated fatty acids (PUFA). The consumption of proper quality and quantity of SAF, MUFA and PUFA in diets may benefit human health. Foods containing low levels of saturated fatty acids and/or high proportions of unsaturated fatty acids are considered the most suitable. There are two series of essential fatty acids which cannot be synthesized by mammals- (a) ω-6 series linoleic acid derivatives and (b) ω-3 series from α-linolenic acid and therefore must be supplied in the diet. Insects represent an alternative source of essential fatty acids polyunsaturated fatty acids that cannot be synthesized de novo in animals like minerals and vitamins (DeFoliart, 1989; Bukkens, 2005).

The most abundant SFA in all the seven species of edible insects and assorted edible grasshopper sample was, palmitic acid (16:0), which was similar in many edible insects, such as mole cricket, ground cricket, spur-throated grasshopper, giant water bug, true water beetle, water scavenger beetle, and winged reproductive of termite (Yang et al., 2006; Ekpo and Onigbinde, 2005; Bophimai and Siri, 2010, Chakravorty et al 2014, 2016). Among the detected MUFAs, oleic acid (18:1 ω-9) was the most abundant one. High concentrations of 18:1 oleic acid were detected in all species in this study which was also reported in some insects (Ghioni et al., 1996; Bophimai and Siri, 2010; Priyadarshini and Revanasiddaiah, 2013). Low concentrations of eicosenoic acid (20:1) were also detected in four species, Mecapoda sp., Hexacentrus sp. Phylozelus sp. and Oxia fuscovittata and assorted species of grasshopper. Among detected PUFAs, linoleic acid (18:2) was the most abundant in all the species. Besides linoleic acid, 18:3 ω-3 linolenic acid was detected in the present study ranged from 0.06g/100g in Mecopoda sp. to 1.07 g/100g in Ducetia japonica. 18:3 ω-6 linolenic acid as PUFAs were detected in all the species except Hexacentrus sp. However, long-chain fatty acids 20:4 ω-6 arachidonic acid was detected only in Hexacentrus sp. The content of PUFAs (7.111 to 43.155% of total fatty acids) in all these insects was low compared to the content of SFA (30.737 to 79.707% of total fatty acids) in species specific
manner. However, *Mecopoda sp.*, *Phyllozelus sp.*, *Oxya fuscovittata* and assorted sample showed higher percentage of PUFA than SFA compared to rest of the species in this study. While in *Schistocerca sp.*, percentage of MUFA was much higher than SFA. (cf Fig. 4a)

**Saturated Fatty Acid (SFA):** SFA was higher than UFA in *Conocephalus sp.* (79.7% : 20.2% of total fatty acid) and to a lesser extent in *Hexacentrus sp.*(58.6% : 45.6% of total fatty acid) & *Ducetia japonica.(57.9% : 41.7% of total fatty acid)*. Bophimai and Siri, (2010) and Raksakantong et al. (2010) also reported higher SFA in edible *Heliocoris bucephalus* (Coleoptera) and *Meimuna opalifera* (Hemiptera). From a nutritional point of view, the SFA is important, since cholesterol is synthesized in the liver from saturated fats. Yet, too high an amount of saturated fats, as has been widely publicized, can result in excessively high levels of blood cholesterol and thereby increase the risk of cardiovascular disease from atherosclerosis. Moreover, high blood cholesterol is widely accepted to depress the immune system. In this context, it is important to mention that saturated fats in the liver do not all have the same effect on cholesterol synthesis. Only saturated fats of long chain lengths; e.g., 12, 14, and 16 (lauric, myristic, and palmitic acids) have been shown to elevate blood cholesterol. Of these, myristic acid elevates cholesterol the most (Mensink, 1993). Lauric acid level was either very low as in case of *Ducetia japonica*, (0.917%) and further lesser extent in *Conocephalus sp.*, *Hexacentrus sp.*, *Oxya fuscovittata* and assorted grass hopper sample (0.11 to 0.45%) or remained below the detection level in *Schistocerca sp.*, and *Phyllozelus sp.* Myristic acid content of these insects’ oils was low and even found lower than that reported for lamb, veal and beef except chicken (cf. Fig. 4f). But, Stearic acid (18 carbons, saturated) which was found in moderate amount, has been shown to lower cholesterol by 21% which is even more than the reported ability of oleic acid (18 carbons, monounsaturated) to lower low-density lipoprotein (LDL) by 15% (Bonanome and Grundy, 1988). Therefore, in spite of having predominant level of palmitic acid (16:0) and stearic acid (18:0) as SFA in all the species in general and *Conocephalus sp.* in particular in which SFA was highest (79.707%
of total fatty acids) along with very low level of myristic acid (1.674% of total fatty acids) and comparatively high level of stearic acid (31.59% of total fatty acids) may not pose any health problem. Moreover, the fat content of Concephalus sp. was high (30.3%), with this quantity of fat in it, the contribution of SFA for cholesterol enhancement can also be expected to be meager when it is consumed. On the contrary, Concephalus sp. with its high fat content (30.3%) and higher SFA 79.707% (of total fatty acids) than UFA may be expected to exert the ill effect of SFA. However, Concephalus sp contained high concentrations of oleic acid (9.623g/100g) as MUFA and considerable amount of both 18:2 linoleic (2.301g/100g), 18:3 ω-3 linolenic acid (3.14g/100g) as PUFA. Therefore, in spite of having high fat in Concephalus sp. it may not be considered as unsafe, rather it can exert health benefit through UFA and can be recommended as good source of fat. However, further study need to be done before coming to any such conclusion.

**Monounsaturaed Fatty Acid (MUFA) & Polyunsaturaed Fatty Acid (PUFA):** UFA was higher in Mecopoda sp., Schistocerca sp., Phyllozels sp. Oxya fucovittata and assorted grasshopper species than SFA. Similar trend was also reported for other edible insects (Womeni et al., 2009; Raksakantong et al., 2010; Ekpo et al., 2009; Bophimai and Siri, 2010; Yang et al., 2006; Okaraonye and Ikewuchi, 2009; Due et al., 2009; Fontaneto et al., 2011; Wang et al., 2006; Bukkens, 2005; Paoletti et al., 2003; Oyarzun et al., 1996). Unsaturated fat is safe for consumption by individuals predisposed to dyslipidemia, diabetes mellitus and cardiovascular disease. Reduction in the consumption of saturated fats and an increase in unsaturated fatty acid intake are likely to prevent (or at least reduce) the negative effects of lipid metabolism (Holub and Holub, 2004) because UFAs were shown to lower the serum cholesterol and triglyceride levels (Holub and Holub, 2004). This effect is increased when a part of the unsaturated fatty acids in question consists of the essential linoleic acid (Maimanee et al., 1999). The UFAs: eicosapentaenoic acid (EPA) and decasahexaenoic acid (DHA) is known for their health benefit (Nair, et al, 1997; Simopoulos, 1999).
Alpha linolenic acid is converted into eicosapentaenoic acid (EPA) and in turn docosahexaenoic acid (DHA) (Emken et al., 1994). DHA is particularly important in infant nutrition (Oski, 1997).

MUFA was predominant followed by SFA and PUFA in *Schistocerca* sp (53.44% of total fatty acid). Among MUFA, oleic acid (18:1) was the predominant one. Oleic acid is one of the necessary components in diet. Oleic acid is considered to be responsible for lowering levels of the low-density lipoprotein (LDL) cholesterol (Grundy, 1989). Current theory suggests that higher levels of LDL (the bad cholesterol) promote health problems and cardiovascular diseases as opposed to high-density lipoprotein (HDL), which are often called good cholesterol or healthy cholesterol (Peskin et al., 2008). However, it is to be noticed that, the desirable intake of monounsaturated fatty acid is more difficult to define. Some investigators suggest that higher intake of MUFA is desirable whereas others suggest lower intake of MUFA is favorable in case of higher consumption of carbohydrate (Grundy, 1997). A reduction in the consumption of saturated fatty acids prevents and/or reduces the impact of the lipid metabolism when some of the unsaturated fatty acid in question is represented by essential fatty acid, linoleic acid (Maimanee et al., 1999).

Like other common edible oils, *Conocephalus* sp, *Hexacentrus* sp, *Ducetia japonica* oil also contained stearic acid (cf. Fig. 4f). Oleic acid was rather less abundant in the studied insects than in olive oil and canola oils and other fat from animal origin (cf. Fig. 4f). Having substantial amount UFA (MUFA & PUFA) than SFA, the oils of these species are of similar nutritive value. However, one can avail the full nutritional potential of these insects through innovation culture system development for. From nutritional point of view, the species insects in this study have the potential for their recommendation as good source of fat.
The proportion of PUFAs of *Mecopoda sp.*, *Phyllozelsus sp.*, *Oxya fuscovittata* and assorted sample was higher than that reported for egg, veal, beef, chicken, pork and most of the conventional oil sources except wheat germ oil, even higher than other four studied insects in this study (*cf.* Fig. 4e). For other four insects, proportion of PUFA was comparable if not higher than that of coconut oil, cocoa butter, palm oil, veal, beef (*cf.* Fig. 4e). PUFA have beneficial effects for both maintenance of normal health and prevention of chronic diseases by regulating lipid levels (Lauritzen *et al.*, 2000; Mori *et al.*, 2000), cardiovascular (Kris-Etherton *et al.*, 2002) and immuno functions (Hwang, 2002). Animal studies suggest that α-linolenic acid-rich food has ability to prevent atherosclerosis and chemical-induced cancer, improves immune and mental function, decreased postprandial plasma lipids in male Sprague-dawley rats (Kurowska *et al.*, 2003; Kim and Choi, 2005). ω-3 fatty acid α-linolenic acid (C18:3) cannot be produced within the body and therefore, must be acquired from outside sources. α-linolenic acid is a precursor of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). The adequate intake of α-linolenic acid is 1.6g and 1.1g for adult male and female respectively. The recommended requirement for pregnant and lactating women is 1.4g and 1.3g respectively. In addition to ω-3 fatty acid α-linolenic; ω-6 linoleic acid (C18:2) was also detected in all the insect species in this study. This value is more than the foods of animal origin like lamb, veal and beef (*cf.* Fig. 4f). It is an essential fatty acid as it is known that mammals cannot convert oleate into linoleate or α-linolenate and is therefore required to be present in the diet. The adequate intake of linoleic acid is 17g and 12g per day for adult male and female (31 to 50 years) respectively, for the pregnant and lactating women, the requirement is 13g per day and the requirement is little less in the more aged condition (IOM, 2005). However, studies indicate that a high intake of ω-6 fatty acids shifts the physiologic state to one that is prothrombotic and proaggregatory, characterized by increases in blood viscosity, vasospasm, and vasoconstriction and decreases in bleeding time (Simopoulos, 1999). However role of linoleic acid is conflicting. Today, more than 85% of
the total dietary polyunsaturated fatty acid in developed country is \( \omega-6 \) polyunsaturated fatty acid, mainly linoleic acid, a precursor of arachidonic acid, whereas the consumption of \( \omega-3 \) polyunsaturated fatty acid has declined (Simopoulos, 2002). Since the consumption of \( \omega-6 \) polyunsaturated fatty acid has been associated with childhood obesity, concerns have been raised (Ailhaud et al., 2006). However, animal studies have yielded conflicting results, with some studies demonstrating that a diet enriched in \( \omega-6 \) polyunsaturated fatty acid decreases adipose tissue mass (Matsuo et al., 2002; Okuno et al., 1997) whereas others have showed that consumption of \( \omega-6 \) polyunsaturated fatty acid is associated with an increased propensity for obesity (Cleary et al., 1999; Massiera et al., 2003). FAO/WHO (1994) recommended that the ratio of linoleic acid to \( \alpha \)-linolenic acid or \( \omega-6/\omega-3 \) in the diet should be between 5:1 and 10:1. Excessive amounts of \( \omega-6 \) polyenoic acid and very high \( \omega-6/\omega-3 \) ratio promote the pathogenesis of many diseases, including cardiovascular disease, cancer and inflammatory and autoimmune diseases (Okuyama, 2001; Simopoulos, 2002; Griffin, 2008). However, several studies indicated that the optimal ratio may vary with the disease under consideration (Simopoulos, 2002). Except Mecopoda sp. and Phyllozelenus sp. ratio of \( \omega-6/\omega-3 \) of other insects species in this was comparable to insects reported for Agonoscelis pubescens (27.5), Onitis sp. (17.9), Onthophagus mouhouti (21.0) (Mariod et al., 2011; Bophimai and Siri, 2010) but higher than many other insects (Bhulaidok et al., 2010; Fontaneto et al., 2011). This result implies that there is a scope to fortify the insect oils with \( \omega-3 \) fatty acid in order to fulfill the recommendation of FAO/WHO (1994). Diet with excessive amounts of \( \omega-6 \) PUFA and a very high \( \omega-6/\omega-3 \) ratio, has been reported to promote the pathogenesis of many diseases, but, in Mecopoda sp. and Phyllozelenus sp fat content is very low (approx 8%) and in turn \( \omega-6 \) linoleic acid. However, edible insects are not the staple food for the ethnic people who eat them rather they take them as side dish. Therefore, the intake of these insects may not pose any health problem rather it may be considered as fat of good quality.
Elaidic acid (MUFA) which is a trans fatty acid (TFA) was found in all the insects in this study. TFA potentially increases coronary heart diseases (CHD) risk factors and CHD events by raising cholesterol concentration (Uauy et al., 2009). Elaidic acid increases cholesteryl ester transfer protein (CETP) activity, which in turn raises VLDL and lower HDL cholesterol (Abbey and Nestel, 1994). However, the TFA content of these insects occurs within the range of recommended intake of TFA which is <1% of total energy intake (FAO/WHO, 2008). Elaidic acid occurs in small amount in caprine and bovine milk (0.1% of the fatty acids) (Alonso et al., 1999).

The study revealed that the most abundant SFA is Palmitic acid. Palmitic acid content of the insect’s oil was superior to most commonly used edible oil like safflower oil (4.86%), sunflower oil (5.40%), walnut oil (7.60%) etc. (USDA). These insect’s oils may be used as a source of palmitic acid, industrially needed for margarine production, production of hard soap. In these insects oils palmitic acid was followed by stearic acid and the proportion of stearic acid is also found higher than that reported for most of the commonly used oil (cf. Fig. 4f). As insect fats contain substantial saturated fatty acid, they may be used in the paint industry as truly suggested by Due et al. (2009).

The PUFA/SFA ratio is one of the major parameters currently used to assess the nutritional quality of the fat fraction of foods. Nutritional guidelines recommended for PUFA/SFA ratio is above 0.4 (FAO/WHO, 2003). PUFA/SFA was 0.0892 in Conocephalus sp. 0.115 in Hexacentrus sp. 0.327 in Ducetia Japonica. However, rest of the species are having PUFA/SFA ratio: 1.119 in Mecopoda sp.; 0.746 in Schistocerca sp.; 1.357 in Phyllozelenus sp.; 1.124 in Oxya fuscovittata and 1.346 in assorted grasshopper sample.

Therefore, fatty acid compositions of orthopteran insects in general reinforce the utilization of these insects as promising sources of fat from nutritional point of view as well as have their industrial implication too.
ASH AND MINERALS

Ash: Ash content of the studied insects ranged 1.40 to 6.23%. Among them, Schistocerca sp. possessed highest level (6.23%) of ash content followed by Ducetia japonica, Conocephalus sp Oxya fuscovittata, Mecopoda sp., Phyllozestus sp., Assorted grasshoppers (4.586% to 3.235%) and lowest in Hexacentrus sp. (1.40%). These values of ash were also comparable to the ash content of larvae and adult beetle of Lachnosterna sp. with values of 2.0% and 1.6% respectively (Davis, 1918), lepidopteran Popillia japonica, 1.5% (Flemming, 1968). Anaphe venata, 3.21% (Ashiru, 1988), Bombyx mori, 3.8% (Leung, 1972) and reported by Banjo et al. (2006) for other insects species like Analeptes trifasciata (4.21%), Macrotermes bellicosus (2.90%), Cytcanthis aruginosa unicolor (2.1%), Brachytrupes sp. (1.82%), Zonoceros variegates (1.20%) as well as 0.34 to 5.05% for orthopteran species (Blasquez et al., 2012), Imbrasia belina (Lepidoptera) (6.2%) (Onigbinde and Adamolekun, 1998), Rhynchophorus phoenicis larva (Coleoptera) (5.79%) (Ekpo, 2010). Higher values were also reported for Hermetia illucens 14.6% (Newton et al., 1977), Macrotermes bellicosus 10.2% (Ukhun and Osasona, 1985), Cirina forda larva 10.26% (Omotoso, 2006), Arphia falax, Sphenarium histrio and S. purpurancens (16.5% each) (Blasquez et al., 2012). There is a consensus among researchers that ash content of a given sample correlates the mineral contents of the sample. It indicates that the eight insects studied here can give a fair source of mineral elements as earlier suggested by Ene (1963).

Minerals: Minerals play an important role in the nutritional value of food. Micronutrient deficiencies, which are commonplace in many developing countries, can have major adverse health consequences, contributing to impairments in growth, immune function, mental and physical development and reproductive outcomes that cannot always be reversed by nutrition interventions (FAO, 2011). In insects,
metamorphic stage and diet highly influence nutritional value, making all-encompassing statements on the micronutrient content of insect species of little value. Consumption of the entire insect body generally elevates nutritional content. Moreover, the mineral and vitamin contents of edible insects described in the literature are highly variable across species and orders. The insect in general is phytophagous, so, its mineral composition would be greatly influenced by the mineral composition of its host plant. This is analogous to the observation that the trace element content of plants vary widely and is dependent on the composition of the soil on which the plant grow (Nye and Tinker, 1977; Bremner and Mills, 1981; Tinker, 1981; West, 1981). Minerals play an important part in biological processes. The recommended dietary allowance (RDA) and adequate intake are generally used to quantify suggested daily intake of minerals. To evaluate the status of mineral content of the insects in the present study with that of other edible insects it is observed that:

**Macro-minerals:**

**Sodium (Na):** With regard to sodium content, with the value 92.74 to 150 mg/100g DM in *Hexacentrus sp.*, *Conocephalus sp.*, *Schistocerca sp.*, *Ducetta japonica*, *Phyllozelus sp.*, *Oxya fuscovittata* and assorted grasshopper was higher than lepidopteran species, *Heliothis armigera* larva (70mg/100g), *Cirina forda* larva (45.26mg/100g) and orthopteran species, *Anacridium melanorhodon* (6.32 and 3.43mg/100g for boiled and fried) (Ghaly and Alkoai, 2010; Omotoso, 2006; Hassan *et al.*, 2008). Though *Mecopoda sp.* had the least amount of Na among the studied insects in this study as well as other orthopteran species reported by Blasquez *et al.*, (2012) however, this value was much higher than *Anacridium melanorhodon* (Orthoptera) (6.32 and 3.43mg/100g for boiled and fried) (Hassan *et al.*, 2008). Sodium content in the analysed sample was much lower than egg, chicken, veal but coparable to beef and pork but generally higher than the
conventional food of plant origin (cf. Fig. 5a) but none of the species in the present study could meet the RDA proposed by ICMR (2009) (cf. Table 5i) or as per recommendation by Linus Pauling Institute Micronutrient Centre (2012, http://lpi.oregonstate.edu/infocentre/).

**Potassium (K):** Potassium content, at value 185.3 to 710 mg/100g DM for *Hexacentrus sp.*, *Mecopoda sp.*, *Conocephalus sp.*, *Schistocerca sp.*, *Ducetia japonica*, *Phyllozela sp.*, *Oxya fuscovittata* and assorted grasshopper species was comparable to Potassium content of other orthopteran species (Blasquez et al., 2012; Rumold and Schluter, 2013), *Asponobus viduatus* (Hemiptera) (200.08mg/100g) and lower than that reported for *Agonoscelis pubescens* (412.52mg/100g) as reported by Mariod et al., (2011) and were higher than *Rhynchophorus phoenicus* larva (Coleoptera) (26.65mg/100g); *Oryctes monaceros* larva (Coleoptera) (38.40mg/100g), *Cirina forda* larva (Lepidoptera) (64.02mg/100g) (Ekpo, 2010; Idolo and Henry, 2011, Omotoso, 2006). However potassium content in the studied insects were much lower than the conventional food of both plant and animal origin also could not meet the RDA (cf. Table 5i & Fig. 5a).

**Calcium (Ca):** At value 120 to 224mg/100g DM, calcium content of all the studied insect species was higher than that reported for 25 orthopteran species of Mexico (50-120mg/100g), *Zonocerus variegatus* (orthoptera) (42.16mg/100g), *Analepsitrisfaciata* larva (Coleoptera) (61.28mg/100g), *Oryctes boas* larva (coleoptera) (45.68mg/100g), *Rhynchophorus phoenicus* larva (coleoptera) (39.58mg/100g) etc. (Blasquez et al., 2012; Banjo et al., 2006; Adeduntan, 2005; Siririmungkararat et al., 2010). *Brachytripes sp.* (orthoptera) (9.21mg/100g), *Cirina forda* larva (lepidoptera) (33.16mg/100g), *Anacridium melanorhodon* (orthoptera) (19.23mg/100g and 19.41mg/100g for boiled and fried) *Macrotermes bellicosus* (21mg/100g) and *Macrotermes natalensis* (18mg/100g) (Banjo et al., 2006; Omotoso, 2006; Hassan et al., 2008) and lower than that reported for *Acheta domesticus* (juvenile cricket, orthoptera:1290 mg/100) *Asponobus viduatus* (hemiptera).
(1021.21mg/100g) and *Agonoscelis pubescens* (hemiptera) (759.51mg/100g) (Mariod *et al.*, 2011 Banjo *et al.*, 2006; Rumpold and Schluter, 2013).

The richest dietary source of calcium among conventional food of animal origin is milk and dairy products. Skim milk powder and whole milk powder contain 1370mg and 950mg calcium per 100g. Buffalo milk contains 210mg Ca/100g (cf. Srilakshmi, 2012). However, it is often inaccessible to a large population because of poverty. Calcium is an essential nutrient, playing vital roles (to name but a few) by virtue of its phosphate salts in neuromuscular function, in many enzyme-mediated processes and blood clotting, and in bone and tooth formation. Compared with other minerals, calcium is economically relatively inefficient. Following most intakes, only about 25 – 30% of dietary Ca is effectively absorbed and obligatory Ca losses are relatively large. On the other hand Na administration raises Ca excretion, presumably because Na competes with Ca for reabsorption in the renal tubules. All the species in this study contained 75 to 224.34 mg/100g of calcium on a dry weight basis. This amount is higher than that found in conventional meats (cf. Fig. 5b) but still much lower than the RDA (ICMR 2009) (cf Table 5i) and recommended daily intake of 1300 mg/ day for adult (FAO 2004).

**Magnesium (Mg):** *Schistocerca sp.* (160 mg/100g) and assorted sample (189.45 mg/100g) contained the highest amount of magnesium followed by other insect species in this study, ranging from 75 to 120 mg/100g DM. as well as higher than reported values for many edible insects like *Anacridium melanorhodon* (orthoptera) (0.83mg/100g and 0.56mg/100g for boiled and fried), *Cirina forda* larva (lepidoptera) (62.31 mg/100g), *Polyrhachis vicina* (hymenoptera) (65.3 and 67.6mg/100g for two different location) (Hassan *et al.*, 2008; Omotoso, 2006; Bhulaidok *et al.* 2010) and lower than that reported for *Busseola fusca* larva (lepidoptera) (470mg/100g), *Heliothis armigera* larva.
(lepidoptera) (450mg/100g); *Gonimbrasia belina* larva (lepidoptera) (410mg/100g); *Oryctes monoceros* larva (coleoptera) (175mg/100g), *Aspogobus viduaetus* (hemiptera) (301.10mg/100g), *Agonoscelis pubescens* (hemiptera) (309.2mg/100g) (Ghaly and Alkoai, 2010; Ghaly, 2009; Mariod et al., 2011). Dietary deficiency of magnesium of a severity sufficient to provoke pathological change is rare. Mg is widely distributed in plant and animal foods. Most green vegetables, legume seeds, beans, and nuts are rich in Mg, as are some shellfish, spices, and soy flour, all of which usually contain more than 500 mg/kg fresh weight. Magnesium content in the analysed sample was generally higher than food of animal origin but lower than the food of plant origin (cf Fig. 5b). Only *Scistocerca sp.* and *Oxys fuscovittata* and assorted grasshopper sample could meet 61 to 47% RDA (ICMR 2009) and with the value 189.45 to 160 mg/100g in these three species were near to the recommendation of daily intake given by FAO (2004) as 220 – 260.

Finally, all these insects also contained moderate amount of macro nutrient (Na, K, Ca and Mg). Cereal based diet provide only meager amount of these essential elements. The small amounts of these micronutrients are found in the aleurone layer cells associated with bran and germ which are removed during milling, therefore cereal-based foods tend to be deficient in trace elements (Salunkhe and Deshpande, 1991). The possible inclusion of these insects in their diet may can take care only to a minimal extent except for magnesium.

**Micro-minerals:**

**Copper (Cu):** With the value 0.850 to 2.62 mg/100g DM, copper content of the studied orthopteran species was higher than or comparable to *Polyrhachis vicina* (hymenoptera) (1.9 and 2.4mg/100g in two different geographical location), *Rhychophorus phoenicis* larva (coleoptera)
(1.26mg/100g), *Oryctes monoceros* larva (coleoptera) (1mg/100g) (Bhulaidok *et al.*, 2010; Ekpo, 2010; Idolo and Henry, 2011; Bhulaidok *et al.*, 2010; Ekpo, 2010; Idolo and Henry, 2011).

**Iron (Fe):** At the value 10.76 mg/100g to 28.664 DM, iron content of *Hexacentrus sp.*, *Mecopoda sp.*, *Conecephalus sp.*, *Schistocerca sp.*, *Ducetia japonica*, *Phyllozelus sp.*, *Oxya fuscovittata* and assorted grasshopper species were higher than or comparable to that reported for *Cirina forda* larva (Lepidoptera) (5.34mg/100g), *Anacridium melanorhodon* (orthoptera) (12.31 and 12.20mg/100g for boiled and fried), *Sphenarium histrio*, *S. purpurascens*, *Melanoplus ferrubrum* (orthoptera) (16mg/100g) (Omotoso, 2006; Hassan *et al.*, 2008; Blasquez *et al.*, 2012 Rumpold and Schluter, 2013). In general, iron content of the insects of present study was relatively lower than that reported for *Polyrhachis vicina* (hymenoptera) (53.7 and 118mg/100g in two different geographical region), *Rhynchophorus phoenicus* larva (coleoptera) (65.23mg/100g), *Busseola fusca* (lepidoptera) (280mg/100g), *Heliothis armigera* (lepidoptera) (170mg/100g) and *Oryctes monoceros* larva (coleoptera) (85 mg/100g) (Bhulaidok *et al.*, 2010; Ekpo, 2010; Ghaly and Alkoaik, 2010; Idolo and Henry, 2011).

The sections of a population most at risk for iron deficiency are infants, children, adolescents, and women of childbearing age, especially when pregnant. The situation with regard to iron supplies is much less critical in developed countries compared with developing countries. In the latter there are still many groups, especially infants in the weaning stage, who do not obtain sufficient iron from their diet. The iron content of *Hexacentrus sp.*, *Mecopoda sp.*, *Conecephalus sp.*, *Schistocerca sp.*, *Ducetia japonica*, *Phyllozelus sp.*, *Oxya fuscovittata* and assorted grasshopper showed that they are higher than conventional meats and food of plant origin (cf. Fig. 5d). However, a bioavailability study to examine the nutritional potential of the Fe content in these insects, in order to avoid iron deficiency symptoms in the local population is still to be carried out. *Conecephalus sp* can be one of the good sources of iron. Consumption of 100g of dry *Conecephalus*
sp. can meet 168.61% to 136.50% of RDA (for male/ Female) for iron, the highest, among the seven studied insects. Similarly, other species in the present study also can meet the requirement iron to more than 100% by consumption of 100g of other analysed insects species. Since the requirement of iron is much higher for woman C. sp may serve the requirement of iron in women.

**Zinc (Zn):** Zinc is an essential component of a large number (>300) of enzymes participating in the synthesis and degradation of carbohydrates, lipids, proteins, and nucleic acids as well as in the metabolism of other micronutrients. Furthermore, it has an essential role in polynucleotide transcription and thus in the process of genetic expression (Sandstrom, 1989). Lean red meat, whole grain cereals, pulses, and legumes provide the highest concentration of zinc in the range of 25 – 50mg/kg (380 – 760μmol/kg) raw weight. Processed cereals with low extraction rates, polished rice, chicken, pork, or meat with high fat content contain moderate amounts of zinc, typically between 10 – 25mg/kg (150 – 380μmol/kg). Fish, roots and tubers, green leafy vegetables, and fruits are only modest sources of zinc, having concentrations of <10mg/kg (<150 μmol/kg); and saturated fats and oils, sugar, and alcoholic beverages have very low Zn content (Sandstrom, 1989).

The zinc contents, at the value 2.8 to 5.6 mg/100g DM, for *Phyllozetus sp.*, *Oxya fuscovittata* and assorted grasshopper sample ; 7.1mg/100g and 10.5mg/100g for *Schistocerca sp.* and *C. sp.* respectively and 13.8mg/100g, and 15.9 mg/100g DM, for *Mecopoda sp.* and *Hexacentrus sp.* respectively, were comparable to *Rynchophorus phoenicus* larva (coleoptera) (10.57mg/100g), *Busseola fusca* larva (lepidoptera) (10mg/100g), *Anacidium melanorhodon* (orthoptera) (2.80 and 2.95mg/100g for boiled and fried), *Oryctes monoceros* larva (Coleoptera) (7mg/100g) and black ant (7.6mg/100g) *Polyrhachis vicina* (black ant7.6mg/100g) *Cirina forda* larva (3.81mg/100g) and lower than *Anthoera zambezina* larva (lepidoptera) (250mg/100g), *Gonimbrasia belina* (lepidoptera) (190mg/100g) and
many orthopteran species (Ekpo, 2010; Ghaly and Alkoai, 2010; Hassan et al., 2008; Idolo and Henry, 2011; Omotoso, 2006; Ghaly, 2009; Bhulaidok et al., 2010 Blasquez et al., 2012).

High values of Zn are usually obtained from high-protein foodstuff, whereas low levels are obtained from food rich in carbohydrates. High protein content in the analysed insects was observed. Zn content in Conocephalus sp. (4.98 mg/100g), Hexacentrus sp (8.35mg/100g), Mecopoda sp 2.76 .mg/100g and assorted sample 3.96 mg/100g are higher than the conventional food of both plant and animal origin. Moreover, the Zn content with the value 1 to 1.69 mg/100g for the insect in this study are higher than the amounts present in most conventional food of animal origin (cf. Fig. 5c) and most of the analysed insects could meet the RDA substantially (cf. table 5i) and 1.8 to 2.6 mg/day requirement by adult as per recommendation by Linus pauling institute Micronutrient Centre (2012, http://lpi.oregonstate.edu/infocentre/).

**Manganese (Mn):** Manganese activates numerous enzymes such as hydrolases, transferases, kinases, and decarboxylases and is a constituent of some enzymes like pyruvate carboxylase, arginase and superoxide dismutase (SOD) (Scrutton et al., 1966). Mn also activates enzymes associated with fatty acid metabolism and protein synthesis and is also involved in neurological functions (Wilson et al., 1979).

Except for Schistocerca sp., manganese content of all insects of the present study was higher than that reported for Rhynchophorus phoenicis larva (coleoptera) (1.16 mg/100g), Oryctes monaceros larva (coleoptera) (1.21mg/100g), Cirina forda larva (lepidoptera) (1.14mg/100g) (Ekpo, 2010; Idolo and Henry, 2011; Omotoso, 2006) and for all studied insects. However, they were lower than Anthoaea zambezina larva (lepidoptera) (60mg/100g), and Gonimbrasia belina larva (lepidoptera) (40mg/100g) (Ghaly, 2009). Mn content in
Hexacentrus sp. was much higher than food animal origin and generally comparable to food of plant origin. Particularly, Hexacentrus sp., Conocephalus sp., Mecopoda sp. and assorted sample contained much higher manganese compared to both food of even plant origin (cf. Fig 5c). Furthermore, all the analysed insects can act as a source of manganese as per RDA ICMR (2009) and as per recommendation (1.8 to 2.6 mg/day) by Linus pauling institute Micronutrient Centre (2012, http://ipi.oregonstate.edu/infocentre).

Therefore, based on these minerals composition in all these species, the rank of micro- nutrients is better than macro-nutrients as per requirement proposed by ICMR 2009. Consequently, Conocephalus sp. followed by Oxya fuscovittata to Schistocerca sp. can be recommended for iron (Fe), Mecopoda sp. and Ducetia japonica, Hexacentrus sp. for zinc (Zn); Mecapoda sp., Schistocerca sp. for copper (Cu) and all the species for manganese (Mn).

It can be observed that all the insects analysed are low in calcium and do not meet the required amount for adults. A 100 g of dried insects also does not fulfil the requirements for the daily uptake of 4700 mg/day for potassium. Of the 8 insects sample analysed for their magnesium content only Oxya fuscovittata, Schistocerca sp., Mecopoda sp. as well as assorted grasshopper sample sufficiently supply with magnesium.

It was also suggested that the consumption of insects could decrease iron and zinc deficiency in developing countries (Christensen et.al. (2006). Although this could not not be confirmed regarding iron supply, most edible insects show high zinc content could function as zinc supplementing food (ingredients). Further more, these insects contain in most cases sufficient amount of manganese and copper. Therefore it can be concluded that, although a 100 g of the studied insects generally lack sufficient amount of calcium, potassium but theses
insects have the potential to provide with specific microminerals such as iron, zinc, Manganese and Copper. It is further assumed that the content of micromineral in these can be controlled via feed. In addition, these insects can be utilized in low-sodium diets.

CONCLUSION

The results of this study confirm the fact that analyzed Grasshoppers samples are not just a traditional food; potentially represent an excellent alternative food source with reasonable levels of protein, fat, fiber and calorific value. The results also indicate that these insects are rich in essential amino acids like lysine, threonine, valine, leucine, and may well meet the criteria to satisfy protein criteria (FAO/WHO/UNU, 2007). This is particularly important as there is a need for novel protein sources owing to the increasing cost of conventional sources of protein in the third world. In addition, the cereal based diets common in developing countries could receive a boost with the inclusion of these insects in their diet. The fat contents in these are of good quality having reasonable level of essential saturated and unsaturated fatty acid to substantiate high energy requirement in their physical work and at various physiological situation where need arises for quality saturated fatty acids and unsaturated fatty acids. As far as mineral contents are concerned, they are also good source of zinc, iron, copper and manganese. However, further research is required to asses the quality of protein and to understand the bioavailability of nutrients and minerals through edible insects in order to fully asses their value in comparison to plant protein as well as other animal proteins and more data, on fatty acids fatty acid composition, vitamin content are necessary for a more profound statement on their nutritional value.

Yet in order to make recommendations regarding the use of analysed grasshoppers as food enrichments in diets, it is important to look at traditional diets in their entirety, and in particular at staple foods, and to compare their nutritional quality against that of edible insects locally available in the region. In the Democratic Republic of the Congo, for example, lysine-rich caterpillars complement lysine-poor staple
proteins. Likewise, people in Papua New Guinea eat tubers that are poor in lysine and leucine but compensate for this nutritional gap by eating palm weevil larvae. Additionally, the presence of harmful ingredients such as toxin, anti-nutrients, allergens and microbial load should be investigated.

Therefore, their continued consumption is advocated and encouraged in solving the problem of malnutrition among the less privileged in parts of Arunachal Pradesh and world at large where need arises. However, the insect food will become better known when both the private and public sectors provide long term promotional support. Food processing sector should take up projects to develop high valued product from insects as there are several scopes to fortify them with lacking nutrients. Insect food should be quickly and widely promoted through consumer publicity campaigns. In this way, the potential of these food insects can be realized to support government food security policies and broaden the availability of edible insects as commodities in Arunachal Pradesh. Protection and sustainable utilization must be considered in the exploitation of these insects.

Culture system should be developed in order to avail nutritional benefits of edible insects. Food security can be enhanced, where necessity arises, by development and implementation of the protocol for sustainable production system of insects. As livestock in most cases are integrated part of inclusive agriculture growth and also augment income for farmers, likewise edible insect production system may be a good source of income for the ethnic people of the state. Beside the indigenous eaters, edible insects may occupy the attraction as ethnic/exotic food for foreign tourists, as occurs in Thailand and Laos. To encourage the use of insects as food it is reasonable to develop policies to include insects as part of livestock production system. It will also help to reduce adverse environmental effect of animal protein production.
The decline in entomophagy in the ethnic communities is a real cause for concern and has to be taken seriously. Scientific documentation or database preparation of the edible insects and its associated knowledge is required before complete disappearance of the traditional knowledge. The revival of entomophagy may help the tribal communities of Arunachal Pradesh and India as whole.