An Assessment of the Nutritional Quality and Future Prospects of *Aplosonyx Chalybaeus* and *Aeolesthes Holosericea* (Coleoptera) in Nagaland, India

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Abstract: ***An Investigatory survey was conducted on the practice of entomophagy among the tribal people of Nagaland, and the nutritional potential of two types of beetles (Coleoptera) commonly used as food, namely Aplosonyx chalybaues (Hope,1831) and Aeolesthes holosericea (Fabricius, 1787) was assessed. About 5% of the people surveyed were found to be frequent consumers (FC) and 4% were infrequent consumers (IC) of A. chalybaues, while 41% were FC and 34% were IC of A. holosericea. Biochemical analysis revealed that both the coleopterans have significantly high protein and fat content. A. holosericea was found to contain lesser amount of fat, but higher amount of protein (49.84±0.01%) compared to A. chalybaeus which contained higher amount of fat (44.42±0.37%), and thereby could be suggested as a possible alternative source of fat in the future. Further analysis for trace elements (Fe, Ca, Cu, Mg, K, Na, K, and Zn) showed that Fe, Cu, K and Zn content were higher in A. chalybaues, while Ca and Mg were higher in A. holosericea. Significant difference was seen in the case of Ca, K and Mg. A. chalybaues and A. holosericea was found to contain 125.6±0.01 % and 227.2±0.07% Na respectively. Both the species are savoured for their rich content of fat, protein and flavour and it is felt that consumerism can further be encouraged with the knowledge of its food values. With their high protein, fat, Fe, Ca and Mg content, these insects could be one sustainable alternative to vertebrate animal food with less environmental pressures.***

Keywords: Coleoptera, consumer, entomophagy, nutrient, tribal

1. Introduction

Entomophagy is reported in many countries of the world with more research and literature works recorded from parts of Asia, Africa and Latin America (Van Huis et al. 2013[1]). He mentioned approximately 1400 insect species of the world to be known as edible. Recently, Jongema (2017[2]), listed about 2000 edible insect species from around 113 countries. Nutrient components of the edible insects that have been assessed have showed rich content of protein, amino acids, fats, carbohydrates, vitamins and trace elements (Xioming, 2010[3];Van Huis et al. 2013[1]).

Global food crisis has hit 124 million people across 51 countries in 2017 and the number of undernourished people, defined as unable to acquire enough food to meet the daily minimum dietary energy requirements over a period of one year, has arrived at 793 million (FAO, 2015[4]). Entomophagy maybe the answer to many of these countries where consumption of insects are already practised. Even the United Nations have suggested entomophagy as one of the probable solution to the shortage of world food supplies (FAO, 2012[5]).

As far as India is concerned, the full potential of insects as food is still far from being appreciated. There are scanty and fragmentary information about edible insects in India. Yet, as early as 1945, Das (1945[6]) analyzed the locust *Schistocerca gregaria* for use both as human food and fertilizer in India, and concluded that locusts were high in crude protein and fat content. Roy and Rao (1957[7]) investigated on the insect eating practice of Muria tribes in Madhya Pradesh and reported that they consume an insect larvae known as chin kara as well as some species of ants. Practice of entomophagy by Negrito tribes of the Indian Andaman Islands have been reported by Sharief (2007[8]), while Ayekbam et al. (2014[9]) documented 46 species of insects that are used as food among various tribes in Manipur. The practice of entomophagy by the tribes of Meghalaya and Mizoram have been documented. An edible pentatomid bug (*Ochrophora montana*) was mentioned by Sachan et al. (1987[10]) as a delicacy for inhabitants of the Mizo Hills in Northeast India. In 2005, Meyer-Rochow (2005[11]) mentioned some food insects of the Meeteis of Manipur and the Khasis of Meghalaya. In Arunachal Pradesh about 158 edible insects have been documented (Singh et al. 2008[12]; Chakravorty et al. 2011[13] & 2013[14]). In a noteworthy study, Meyer-Rochow and Changkija (1997[15]) documented and listed the vernacular names of 42 species of insects used as food by Ao-Nagas in Nagaland. The most recent documentation of edible insects mentions 82 species belonging to 28 families and 9 orders, that comprises of 8 species of Odonata, 17 species of Orthoptera, 2 species of Mantodea, 1 species of Isoptera, 19 species of Hemiptera, 9 species of Coleoptera, 20 species of Hymenoptera, 5 species of Lepidoptera and 1 species of Diptera (Mozhui et al. 2017[16]).

2. Methodology

2.1. Survey

A survey on edible insects was carried out in four districts of Nagaland, India viz; Dimapur, Kohima, Mokokchung and Zunheboto. To fulfill the investigation, printed photos of *Aplosonys chalybaeus* and *Aeolesthes holosericea* along with a questionnaire were used. The questionnaire was also prepared to garner information about seasonal occurrence, vernacular names, habit and habitat, stages of insects consumed, modes of preparation, presumed nutritive and therapeutic values, harvesting methods, seasonal availability, cleaned methods, cooked or dried and body parts consumed or discarded. The survey was carried out for over a year in 2006 as seasonal availability permitted. Local guides and informants were used for collecting the specimens from forest and from local markets. Information and required data was gathered from 309 respondents during insect gathering seasons and off season. The respondents consisted of 13-15 tribals with 2 to 3 elderly persons from selected villages with knowledge and experiences in the traditional use of insects. The interviewed persons consisted of three groups – frequent consumers, infrequent consumer and non consumers. The data collected were compiled then uploaded in Microsoft excel. The insect collected were preserved according to standard methods (Ghosh & Sengupta 1982[17]) and identified with the help of published keys (Hope, 1831[18]; Atkinman, 1974[19]; Kimoto, 2005[20] and Mitra et al. 2016[21]). Further confirmation was also done by referring published papers (Gahan, 1906[22]; Basu, 1985[23]; Gupta & Tara, 2013[24] and Gogoi et al. 2017[25]).

2.2 Nutrients analysis

For determination of proximate analysis and mineral compositions, the insects were washed with running tap water, dried at 55 ºC in a hot air oven for three days, appendages, wings and removable exoskeletal parts were removed, grounded to fine powder in a grinder, taken in air tight tupperware plastic container and then stored at -30 ºC in a deep freezer. All the solvents and chemicals used in this study were of analytical grade and care was taken that the glasswares were meticulously clean. Moisture content and ash determination was completed within ten days of collection of the insects.

Determination of proximate values: Standard AOAC procedures were followed for estimation of moisture, ash, crude protein, crude fibre and crude fat content (AOAC [26,27,28,29,30]).

Determination of total carbohydrate: The carbohydrate content was calculated by the difference method (James, 1995[31]) according to the following formula:
% Carbohydrate = 100 – [Moisture (%) + Ash (%) + Crude protein (%) + Crude fat (%)]

Determination of minerals: Minerals were determined using inductively coupled plasma optical emission spectrometry (ICP-OES) (Model: iCAP^{TM}.7600ICP-OES), at Sophisticated Analytical Instrumentation Facility (SAIF), North-Eastern Hill University, Shillong, India. Samples were digested using concentrated HNO_3 and the results obtained were converted to mg/100 g of dried sample.

Statistical analysis: The experimental results were expressed as mean of three replicates ± standard deviation (SD). Statistical calculations of the survey were carried out in Microsoft Excel and that of proximate analysis in OriginPro 8 software.

3. Results and Discussion

3.1 Survey

The corm borer of *Colocasia esculenta (*commonly known as *Yam)* is the grub of the beetle *A. chalybaeus*. The corm borer is a seasonal and endemic pest causing damage to the foliage and corms, resulting in great losses to the tribal farmers of the region. The grub hibernates in the corms during winter and emerges in the monsoon season with a build-up from July-August (Korada, 2012[32]). In India, *A. chalybaeus* was reported from the North Eastern states for the first time by Barwal (1988[33]). Later, the pest was also reported from several South Asian countries (Maddison, 1993[34]). During the build-up of the beetle (July-August), farmers collect and kill the corm-borer from the fields thus keeping a check on the rise of the insect population. This insect was never eaten by the Nagas in general but tribal migrants from neighbouring states have introduced its use as food in the hill villages. It has a distinct colocasia-scented smell and is considered a palatable insect food, and taken as an alternative source of proteins and fats. Many tribes of Meghalaya and indigenous tribes of Arunachal Pradesh in India consume the adults and grubs of *A. chalybaeus* as a seasonal diet. The adults and grubs are considered rich in proteins (Pathak & Rajasekhara, 2000[35]; Chakravorty, 2009[36]). It is consumed after drying above the fire or freshly roasted in a frying pan along with a chutney prepared with roasted green chillies and tomatoes (Table 1). No known therapeutic uses were reported during the survey.

The larva/grub of *A. holosericea* is found inside the trunks of oak tree (*Quercus serrata* and other species), alder tree (*Alnus nepalensis* and other species) and other hardwood trees. *A. holosericea* has been reported in Nagaland by Mitra et al. (2016[19]). The grub is considered as a rich source of fats and usually fed to young children to make them healthy. They are collected opportunistically when people find a rotten trunk or fallen tree trunk during their visits to the field or from infested firewood while chopping it. It is also sold in the local market during summer from July-October. The larva is packaged in banana leaves that weighs approximately about 600-700 g and commands a price of Rs. 200. They are either fried in a little oil as it contains high amount of fats or consumed after roasting in a Kadai. It is used therapeutically for mouth ulcers – freshly boiled or dried larva are sucked for relief from pain and subsequent healing. They are also collected to be used as feed for their poultry and fish farms.

Table 1: Data Collected During Survey in 2016

S.No	Scientific Name	Common Name	Order	Family	Availability	Edible Stages
1.	*A. chalybaeus*	Cormborer Beetle	Coleoptera	Chrysomelidae	May- August	Larvae
2.	*A. holosericea*	Woodborer Beetle	Coleoptera	Cerambycidae	July-October	Larvae, Pupae

S.No	Mode of Consumption	Vernacular Name		
		Ao	Angami	Sumi
1.	Dried, Fried	Milong tuo	Tzununo Khu	Akhala
2.	Roasted, Fried	Tsüka	Jeviseno ali	Aphisu kulho

Table 2: Data on Consumption by the Tribals in 4 districts of Nagaland

Insects	FC	IC	NC	FM	C
A. chalybaeus	15 (4.85%)	12 (3.88%)	282 (91%)	114 (36.89%)	27 (8.74%)
A. holosericea	127 (41.10%)	105 (33.98%)	77 (24.92%)	287 (92.88%)	232 (77.08%)

Legend: FC: Frequent Consumers**, IC**: Infrequent Consumers**, NC:** Non Consumers, **FM:** People aware of the Insect being used as Food or having medicinal value **C**: Percentage who consume Insects (Both **FC** & **IC**),

The study revealed that, only 8.74% of the consumers consume *A. chalybaeus* whereas, the percentage of NC is significantly large with 91% (Table 2). It is also noteworthy to mention that though the consumer percentage is very low, tribals aware of its use as food (FM) altogether constituted 37%. Hence, this percentage of tribals can still be motivated into the practice of enthomophagy for this particular insect as a good supplement of fat and proteins. The reasons for non consumption of these insect as food by the tribals include: it is not a traditional food for them but its consumption was imitated from the tribals of the neighbouring states; its seasonal availability (Table 1); their unavailability in the market; they are collected from their habitats for personal consumption only and due to its distinct colocasia-scented smell.

A high popularity for consumption of larvae of *A. holosericea* was observed with 77% of the respondents preferring it (Table 2). The FM% also eclipse the percentage of C indicating again the NC are also familiar with this insect being use as food or medicine and apparently there seem to be no innate aversion for these insects. The high rate of consumption is credited to its high content of fat, consideration as a good food supplement for growing children and their rich flavor. Therapeutically it is considered to cure mouth ulcer. Other coleopterans have also been utilized since ages in folk medicines for wound healing, ulcers, respiratory disorders, urinogenital problems, burns, skin disorders and kidney problems (Meyer & Changkija, 1997[15] ; Ronghang & Ahmed, 2010[37]). Senthilkumar et al. (2008[38]) have recorded 11 species of coleoptera being use as medicines for several ailments by tribals in India. They reported the larvae and adult forms to be used as feeds for chicken and fish. In 2011, combined world feed production was estimated at 870 million tones and FAO estimates this production will increase by 70% in 2050. Recent high demand and consequent rise in prices for these feeds and elevating pressure of production on aquaculture has led to research into the development of insect feeds for aquaculture and livestock (Huis et al. 2013[39]). Insect feed could be the alternative, sustainable protein and eventually become a successful meal replacement for conventional fish and animal meals.

Table 3: Proximate Analysis of Two species of Coleoptera in g /100g Dry Weight

Scientific Name	Ash (%)	Protein (%)	Fat (%)	Moisture (%) Dry & Fresh*	Carbohydrate (%)	Fibre (%)
A. chalybaeus	3.68±0.026	39.81±0.11	44.42±0.37	6 .60±0.52 55.34±0.45*	5.49±0.26	7.4±0.34
A. holosericea	1.37±0.090	49.84±0.01	19.80±0.44	2.32±0.35 63.36±0.39*	26.67±0.22	9.7±0.22

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

3.2. Analysis

The content of crude protein was found to be, 39.81±0.11% and 49.8 4±0.01% in *A. chalybaeus* and *A. holosericea* respectively (Table 3), and therefore consumption of these insects as food can boost dietary value when including animal source proteins. The protein content of these insects are much higher in comparison to protein content of beef (raw) and fishes (raw) shown by FAO (2012[40]). Xiaoming et al. (2010[41]) recorded the protein content of some species of coleoptera (adult and larvae stages) ranging from 23-66% of dry matter. Both fresh (wet) and dry protein content of several insects species was evaluated by Bukkens (1997[42]). The results revealed that the protein content was found to be higher when fried or smoked and showed lower content when raw. The difference was due to the varying water content in the two different forms. The crude fat value in *A. chalybaeus* was recorded to be 44.42±0.37% and 19.80±0.44% in *A. holosericea*. Fat content and randomly selected fatty acids of several edible insect species consumed in Cameroon (Womeni et al. 2009[43]) have shown a wide range of fat content from 9-67%. Many recent researches have shown that these fatty acids differ and depend on many factors such as species reproduction stages, season, life stages and types of host plant (Stanley-Samuel et al. 1988[44] ; Pennino, 1991[45] ; Bukkens , 2005[46]). The nutritional inputs of two essential fatty acids present in the fat of insects ie., omega-3 (e.g. α-linolenic acid) and omega-6 fatty acids (e.g. linoleic acid) is emphasized for the healthy development of children and infants (Michaelsen et al. 2009[47]). Consuming diverse types of fat will allow incorporation of different types of fats into the cell membrane, modifying the response to a number of metabolic processes including inflammation, controlling gene expression in the cell, and cellular protein production (Mogensen, 2017[48]). Insects could play an important role, by supplying these essential fatty acids to local diets and fight potential deficient consequences. Moreover, they can be used to substitute animal proteins such as beef and other products.

The carbohydrates value of *A. chalybaeus* was found to be 5.49 ±0.26% and in *A. holosericea*, 26.67±0.22%. Carbohydrates are important nutritive elements and main energy source in the human body, thereby lowers consumption of proteins, and aid detoxification (Alamu et al. 2013[49]). With carbohydrate content ranging from 6.71% in sting bug to 15.98% in cicada (Raksakantong et al. 2010[50]), edible insects can be a good source of carbohydrates. Carbohydrates in insects are formed mainly by chitin. This chitin reduces serum cholesterol (Burton & Zaccone, 2007[51]) and boost immune functioning of human body (Sun et al. 2007[52]). The crude fibre content in *A. chalybaeus* was found to be 7.4±0.34% and 9.7±0.22% in *A. holosericea*. In insects the most common fibre is chitin, a derivative of the exoskeleton and is insoluble. Chitin is largely considered undigestible by humans but chitin has also been associated with defence against parasitic infections and some allergic conditions and arguably a dietetic fibre (Muzzarelli et al. 2001[53]), thus inferring a high-fibre content in edible insects, mostly in species with hard exoskeletons (Bukkens, 2005[46]).

In *A. chalybaeus* and *A. holosericea* the ash value was found to be 3.68±0.02% and 1.37±0.09% respectively. This gives an indication of the mineral levels of the insects. Akullo (2018[54]) estimated the ash content of insect species between 4.19±0.12 to 4.88±0.23% which are higher than the ash values estimated in this work. Reports of total ash in the insects of other works (Shantibala et al. 2014[55]) have shown a minimum of 1.34±0.24% and a maximum of 3.82±0.42% that closely agrees with the range of ash values obtained from this work. The variation noticed could be due to variations in age, sex, and environment (Huss, 1995[56]). Ash contents of fresh foods rarely exceed 5%, although some processed foods can have ash contents as high as 12%, e.g., dried beef. Moisture content of 6.60±0.52% and 2.32±0.35% from *A. chalybaeus* and *A. holosericea* respectively generally agree with those reported by other authors investigating different insects (Banjo et al. 2006[57]). Insects with low moisture content would be advantageous for its storage.

Table 4: Mineral contents of two Coleoptera species in mg/100g of dry weight compared with recommended intake of essential minerals per day

S.no	Scientific Name	ELEMENTS						
		Fe	Ca	Cu	Mg	K	Na	Zn
1.	*A. chalybaeus*	14.90±0.04	154.90±0.232	0.34±0.007	143.5±0.017	955.2±0.112	125.6±0.014	17.73±0.007
2.	*A.holosericea*	11.96±0.025	186.79±0.115	1.72±0.005	84.01±0.069	646.60±0.172	227.2±0.065	10.76±0.014
3.	Intake recommended for 25 year old males (mg per day)**	8	1000	0.9	400	4700	1500	11

Data expressed as mean of 3 replicates ± standard deviation. ** DRIs (Dietary reference intakes): recommended dietary allowances and adequate intakes, minerals, Food and Nutrition Board, Institute of Medicine, National Academies. Source: Bukkens, 2005.

Minerals are essential elements that play an important role in the physiological processes of an organism. It is observed that the studied species of coleoptera are good source of iron (Table 4). Bukkens (2005[46]) recorded most edible insects with higher amount of iron than beef (6mg/100g). The highest amount of iron recommended based on varying dietary iron bio-availabilities are found in a weaning mother (FAO/WHO 2001[58]).

A notable amount of Ca, Mg and K are shown for both species and apparently serve as good source of food to fulfil the recommended dietary allowances of minerals. Children from puberty to adulthood, women in menopause and male who are above 65 years of age are recommended to have higher Ca intake of 1300 mg/day (FAO/WHO, 2001[58]). Magnesium is essential for the activity of the enzymes of glycolysis. Intolerant amount of Mg has been known to cause hypermagnesemia, nausea, hypotension and diarrhoea (FAO/WHO, 2001[58]). Potassium is important for heart function and in skeleton and muscle contraction. Diets with low potassium lead to hypertension. Clinical deficiency of zinc includes thymic atrophy and high frequency of bacterial, viral and fungal infections (Wellinghausen et al. 1997[59]; Rink et al. 2001[60]). Copper plays an important role cellular respiration, neurotransmitter biosynthesis and strengthening of connective tissue, however, in excess it becomes toxic. Sodium functions to maintain the amount of intracellular and intercellular fluid of the body's cells and regulate the electrolyte flow in the body.

4. Conclusion

The world population is predicted to reach 9 billion by 2050 and the task to feed the escalating population is enormous, given the limited agricultural resources of water and land in climate-change era (FAO, 2009[61]). Thus, promoting sustainability has become the most relevant challenge of today. In this context, insect must be viewed as an alternative source of animal protein. With substantial proximate values and minerals too, the studied species have the potential to be considered as micro-livestock as well as animal feed. *A. holosericea* which are also use as feeds to chickens and fishes could have a promising future prospect with mass rearing in insects farms as various researches have shown the rearing of the stem borer from grubs to adult stage successfully using artificial diet (Gundappa, 2015[62] ; Gupta & Sharma, 2015[63]; Gichuhi et al. 2017[64]). The therapeutic use of *A. holosericea* to heal mouth ulcer is a matter of traditional medicine, which requires validation with evidence-based research using modern scientific techniques with the cooperation of tribal communities that could eventually lead to the discovery of a medicine from the bug.

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