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Proximate and mineral compositions of *Samia cynthia ricini* and *Dytiscus marginalis*, commonly consumed by the Bodo tribe in Assam, India

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Abstract

Background: Entomophagy, the consumption of insects, is a common practice among various tribal communities across the globe. Various factors such as flavour, nutrient content, availability and claimed medicinal values have contributed to the increased consumption of insects. Two commonly consumed insects among the Bodo tribe in Assam, namely, *Samia cynthia ricini* Boisduval, 1854 (Lepidoptera: Saturniidae) and *Dytiscus marginalis* Linnaeus, 1758 (Coleoptera: Dytiscidae), were procured from local markets in Kokrajhar and evaluated for their proximate and mineral contents using Association of Official Analytical Chemists (AOAC) guidelines and inductively coupled plasma-optical emission spectroscopy (ICP-OES). Both the insects are available throughout the year and are consumed on a large scale.

Results: *S. cynthia ricini* showed higher contents of moisture (7.89 ± 0.020%), ash (4.10 ± 0.077%), fat (22.23 ± 0.209%) and carbohydrate (7.78 ± 0.057%) whereas higher contents of crude fibre (14.28 ± 0.102%), protein (56.37 ± 0.366%) and nitrogen (9.02 ± 0.058%) were observed in *D. marginalis*. The calorific value of *S. cynthia ricini* was higher with 430.19 ± 2.241 kcal whereas *D. marginalis* showed a lower value of 382.58 ± 1.527 kcal. *D. marginalis* showed the presence of arsenic (As) (0.014 ppm), and sodium (Na) was not detected. *S. cynthia ricini* did not show the presence of As and magnesium (Mg). Lead (Pb) showed a value of 0.026 and 0.044 ppm, and cadmium (Cd) showed a value of 0.005 and 0.005 ppm in *S. cynthia ricini* and *D. marginalis* respectively.

Conclusions: Both the studied insects showed high protein and fat contents and a high calorific value. Although the insects show the presence of several essential minerals in considerable amounts, they showed the presence of toxic heavy metals in trace amounts. Hence, their consumption must be done in a controlled manner owing to the presence of As, Pb and Cd which are capable of causing adverse reactions in its consumers.

Keywords: Bodo tribe, *Dytiscus marginalis*, Entomophagy, Heavy metals, *Samia cynthia ricini*

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Background

Insects are consumed in various countries across the world (Van Huis et al. 2013). About 2.5 billion people across the world supplement their food with insects (Van Huis 2016). With the rapid increase in population, there is a fear of food scarcity. Entomophagy may serve as an alternative solution to food scarcity (Kim et al. 2019). Insects are found to be rich sources of vitamins, proteins, carbohydrates, fats and minerals (DeFoliart 1989; Zielinska et al. 2018). Entomophagy has been reported from various parts of the world such as Sub-Saharan Africa, where about 250 insect species are consumed (Van Huis 2003) and in Thailand about 164 different species of insects are sold as food in open markets (Yhoung-aree 2010). They can be used as emergency food in case of food scarcity, high cost of food grains, crop failure and seasonal disturbances (Gahukar 2018). The consumption of these insects depends on various factors such as their taste, availability, palatability, nutritional value and local and religious beliefs (Chakravorty et al. 2011).

In India, entomophagy is mainly practiced in the northeastern states predominantly by tribal population. In addition to these states, tribal communities in other states of India such as Kerala, Odisha, Jharkhand, Karnataka, Tamil Nadu, Chhatisgarh and Madhya Pradesh also practice entomophagy (Chakravorty 2014; Gahukar 2018). About 158 different species of insects are consumed in Arunachal Pradesh alone and about 40 are consumed by ethnic tribes in Assam (Ronghang and Ahmed 2010). The tribals in Mizoram consume about 60 species of insects (Meyer-Rochow 2005). About 42 species of insects are consumed in Nagaland (Meyer-Rochow and Changkija 1997) and about 41 insect species are consumed in Manipur (Shantibala et al. 2012).

Several workers have documented the use of insects as food by the Bodos; however, studies on their proximate and nutritional contents are lacking, or these studies portray the proximate contents only and not the mineral contents and vice versa (Narzari and Sarmah 2015a; Narzari and Sarmah 2015b; Ghosh et al. 2017a; Ghosh et al. 2017b; Hazarika 2018). Also, studies describing the presence of toxic heavy metals in edible insects are lacking. Toxic heavy metals such as lead (Pb), cadmium (Cd), arsenic (As) and mercury (Hg) are known to cause severe health complications in individuals exposed to them (Imathiu 2020). These heavy metals have been detected in some edible insects (Zhang et al. 2009). Consequently, this study was designed to evaluate the proximate, mineral and toxic heavy metal contents of *S. cynthia ricini* and *D. marginalis* commonly consumed by the Bodo tribe in Assam.

Methods

Study area and the people

The Bodo tribe is of Tibeto-Burman origin and belongs to the Tibeto-Chinese linguistic stock. They are the largest group among the Plains Tribal population in Assam today. They racially belong to the Mongoloid stock (Census of India 2011). According to the 2011 census, they number about 1,416,125 persons in the state of Assam (Census of India 2011). The Bodo-dominated areas fall under the Bodoland Territorial Autonomous Districts (BTAD), namely, Kokrajhar, Chirang, Baksa and Udalguri.

Experimental procedure

Fresh insects were procured from local markets in Kokrajhar, Assam, from August to November 2019. They were degutted, weighed and sun-dried. They were identified using literature and taxonomic keys. The samples were then made into powder using a kitchen blender. The powdered samples were subjected to proximate, mineral and heavy metal content analyses.

Studied insects

A preliminary survey across the markets and villages was performed. The data collected is depicted in Table 1. It was found that these insects are usually eaten due to their taste which is usually from their fat content. They are very commonly available, and *Samia cynthia ricini* is reared at home by several families.

Samia cynthia ricini Boisduval, 1854

Samia cynthia ricini (Family: Saturniidae) is commonly called as the Indian eri silkworm. It belongs to the order Lepidoptera and is a commercial silk-producing insect (Vijayan et al. 2006). It is believed to have originated in

Table 1 Information of the studied insects

Sl. No	Scientific name	Order	Family	English name	Vernacular name	Seasonal availability	Preparation
1	*Samia cynthia ricini*	Lepidoptera	Saturniidae	Eri silkworm	Endi amphow	Available throughout the year but usually abundant during summer March to May	Prepupae are fried in oil or cooked with spices
2	*Dytiscus marginalis*	Coleoptera	Dytiscidae	Diving beetle	Singkhaori	Available throughout the year but abundant during summer, March to May	Mature insect is fried in oil, mashed and eaten

the Brahmaputra valley (Jolly et al. 1979). Although it feeds on several other plant species, its preferred host plant is the castor plant (Naika et al. 2003). It is found in tropical and temperate eastern Asia (Naumann and Peigler 2001; Peigler and Naumann 2003). It is abundant in northeastern India, particularly in the states of Assam and Meghalaya (Renuka and Shamitha 2014). The collected worms (prepupae) were bulky and measured about 3.5 to 4 cm in length with a bright yellow texture (Fig. 1).

Dytiscus marginalis Linnaeus, 1758

Dytiscus marginalis (Family: Dytiscidae) is commonly called as the great diving beetle. They belong to the adephagous order Coleoptera. They are predatory aquatic insects inhabiting stagnant freshwater bodies (Lundkvist et al. 2003). They are commonly found in Asia and Europe (Nilsson 2003). They can be serious pests at commercial fisheries (Frelik 2014). Characteristics include threadlike antennae with 11 segments; long, flattened hind legs with five-segmented, tapering tarsi bearing swimming hairs; and hind coxae with rounded, pointed or truncate processes (Foster and Friday 2011). The collected beetles showed a shiny black texture and measured about 3 cm in length (Fig. 2).

Proximate analysis

Proximate analysis was performed following AOAC methods (AOAC, 1995, 2006).

i. Moisture content: After drying the samples in an incubator for 4 h at 105 °C, the samples were cooled in desiccators and then weighed. The moisture content was obtained from the difference between wet weight and dry weight using the following formula:

$$\text{Moisture}\% = \frac{\text{weight of fresh sample} - \text{weight of dried sample}}{\text{weight of fresh sample}} \times 100$$

ii. Ash content: After moisture content analysis, the samples were placed on porcelain dishes and then placed in a furnace at 550 °C for 4 h. The ash content was calculated using the following formula:

$$\text{Ash}\% = \frac{\text{weight of ash}}{\text{weight of dried sample}} \times 100$$

iii. Crude fibre content: The dried samples were digested with 1.25% sulphuric acid, filtered and washed and then digested with 1.25% sodium hydroxide, filtered, washed and dried. This dried sample was then ignited. The crude fibre content was calculated using the following formula:

$$\text{Crude fibre}\% = \frac{\text{weight of sample after ignition}}{\text{weight of sample}} \times 100$$

iv. Fat content: The samples were kept in diethyl ether for 2 h at 90 °C. After extraction, the samples were then kept at 70 °C in an incubator for 30 min, cooled in desiccators and weights were taken. The fat content was calculated using the following formula:

$$\text{Crude fat}\% = \frac{\text{original weight of the sample} - \text{weight of the sample after extraction}}{\text{original weight of the sample}} \times 100$$

v. Protein content: The nitrogen content was evaluated by Kjeldahl method. The crude protein content was calculated by multiplying the crude nitrogen content by a factor of 6.25.

Fig. 1 *Samia cynthia ricini* Boisduval, 1854 (prepupae)

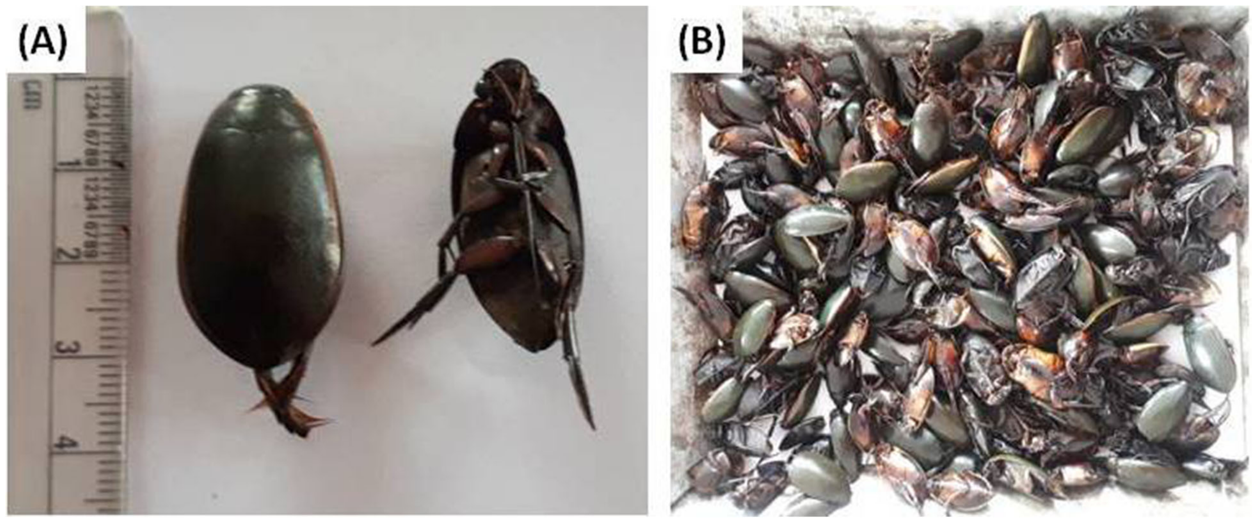

Fig. 2 *Dytiscus marginalis* Linnaeus, 1758

vi. Carbohydrate content: The total carbohydrate content was determined by the following formula.

Carbohydrate (%) = 100 − [moisture (%) + ash (%) + crude protein (%) + crude fat (%) + crude fibre (%)]

vii. Calorific value: Calorific value or the total energy value of insects in kcal/100 g was calculated using the following equation (FAO 2003).

Calorific value (kcal/100 g) = [4 × protein (%)] + [9 × fat (%)] + [4 × carbohydrate (%)].

Mineral analysis

The samples were processed using acid digestion method, cooled, filtered with distilled water, final volume made to 50 ml and the filtrate was used for the analysis of mineral contents. Mineral contents were determined by inductively coupled plasma-optical emission spectroscopy (ICP-OES) (Thermo Fisher iCAP 7600).

Statistical analysis

Each experiment was performed thrice, and data was analysed using OriginPro v8. All data are represented as mean ± standard error of mean (SEM).

Results

Proximate compositions

D. marginalis showed higher crude fibre, protein and nitrogen contents, whereas *S. cynthia ricini* showed higher moisture, ash, fat and carbohydrate contents. The calorific value of *S. cynthia ricini* was higher with 430.19 ± 2.241 kcal whereas *D. marginalis* showed a lower value of 382.58 ± 1.527 kcal (Table 2).

Mineral contents

D. marginalis showed higher contents of potassium (K), calcium (Ca), copper (Cu), iron (Fe) and zinc (Zn) than *S. cynthia ricini*. High level of Mg of 54.323 ppm was observed in *D. marginalis*. *S. cynthia ricini* showed higher levels of manganese (Mn) and boron (B). It, however, did not show the presence of Mg. A high level of 80.400 ppm Na was observed in *S. cynthia ricini*. Pd, Cd, and As were detected in *D. marginalis* whereas, *S. cynthia ricini* showed the presence of Pb and Cd only, and As was found to be absent (Table 3).

Discussion

Since these insects are consumed as food, knowledge on their mineral contents is essential. Earlier studies on various insects do not possess information on their mineral contents (Narzari and Sarmah 2015b; Narzari et al. 2017). Proximate compositions of 20 insects consumed by the Bodo tribe were analysed by Narzari and Sarmah (2015b). The study revealed moisture content of the insects ranging from 1.72 to 8.59%, nitrogen content

Table 2 Proximate composition of the studied insects

Parameters	*Samia cynthia ricini*	*Dytiscus marginalis*
Moisture (%)	7.89 ± 0.020	5.46 ± 0.207
Ash (%)	4.10 ± 0.077	3.40 ± 0.227
Crude fibre (%)	8.24 ± 0.382	14.28 ± 0.102
Fat (%)	22.23 ± 0.209	15.04 ± 0.156
Protein (%)	49.74 ± 0.189	56.37 ± 0.366
Nitrogen (%)	7.95 ± 0.028	9.02 ± 0.058
Carbohydrate (%)	7.78 ± 0.057	5.43 ± 0.063
Calorific value (kcal)	430.19 ± 2.241	382.58 ± 1.527

Data are mentioned as mean ± SEM

Table 3 Mineral contents of the studied insects (ppm)

	Samia cynthia ricini	*Dytiscus marginalis*
Potassium	0.012	0.735
Sodium	80.400	0.000
Calcium	0.224	2.888
Manganese	0.071	0.016
Copper	0.023	0.030
Iron	0.716	1.411
Zinc	1.980	2.052
Boron	0.060	0.039
Magnesium	0.000	54.323
Lead	0.026	0.044
Cadmium	0.005	0.005
Arsenic	0.000	0.014

varied from 5.28 to 13.53%, protein content varied from 30.25 to 84.56%, fat content varied from as low as 4.01 to 40.65%, carbohydrate content varied from 1.58 to 47.98% and calorific values ranged from 392.41 to 580.25 kcal. Similarly, the proximate contents of both the studied insects ranged within the values described in the above study and showed high contents of fat and protein and a high calorific value of 430.19 kcal (*S. cynthia ricini*) and 382.58 kcal (*D. marginalis*) indicating that these insects could act as alternatives to other foods which are usually costlier, particularly in rural areas (Patel et al. 2019). Consumable food items should be examined for the presence of essential elements. Rumpold and Schlüter (2013) analyzed 236 different edible insects and found that most edible insects contain considerable amounts of energy, protein, unsaturated fatty acid and nutrients such as Cu, Fe, Mg, Mn, biotin and pantothenic acid in trace amounts. Another similar study by Kim et al. (2017) on 5 edible insects consumed in Korea revealed that Ca concentration ranged from 349.2 to 2282, phosphorus ranged from 5105 to 8875.1, Mg ranged from 502.2 to 2522.9, Zn ranged from 75.6 to 189.1, Fe ranged from 49.5 to 99.7, Cu ranged from 9.4 to 27.3, Mn ranged from 7 to 48.2, B ranged from 14.6 to 22.3 and molybdenum (Mo) ranged from 0.2 to 1.5 mg/kg dry weight. The results of this study revealed that the studied insects possess considerable amounts of Na, K, Ca, Mg, Zn, Fe, Cu, Mn and B.

Toxic elements could also be present in insects, and their ingestion can cause mental retardation and damage to the central nervous system. They also alter blood parameters and cause damage of vital organs such as the liver, kidneys and lungs (Hajeb et al. 2014). Several studies on mineral content of insects have not evaluated the content of toxic elements (Shantibala et al. 2014; Ghosh et al. 2017a). A study by Kweon et al. (2012) on elemental analysis of *Bombyx mori* analysed the contents of both essential and toxic metals. The study detected the presence of elements such as Zn and Cu and although toxic heavy metals such as Pd, Cd and As were absent, mercury (Hg) was found in trace amounts. This undertaken study revealed the presence of toxic heavy metals Pb and Cd in both the studied insects in trace amounts. Earlier, Narzari and Sarmah (2015b) had estimated the proximate contents of *D. marginalis*, but mineral contents including toxic heavy metal were lacking. *D. marginalis* showed the presence of As, whereas it was not detected in *S. cynthia ricini*. The highest risk of As exposure takes place through ingestion (Cooper et al. 2020) leading to bioaccumulation in the consumers which ultimately results in adverse health conditions.

Conclusions

Edible insects can be sources of nutrients such as proteins, fats, carbohydrates and minerals. Although insects have high nutrition value, the current status of edible insect is still insufficient to replace other traditional foods worldwide (Kim et al. 2019); hence, more studies to evaluate their nutrient contents needs to be carried out. Heavy metal accumulation in edible insects depends on many factors such as insect species, growth phase and feed substrate (EFSA 2015). Hence, every edible insect must undergo proper studies to evaluate their mineral contents involving toxic elements as well. Such studies will help in avoiding future health complexities due to their consumption or can act as food supplements during food shortage.

Abbreviations

AOAC: Association of Official Analytical Chemists; ICP-OES: Inductively coupled plasma-optical emission spectroscopy; SEM: Standard error of mean

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Authors' contributions

KC supervised the work, collected the insects and edited the manuscript. DS carried out investigation of the samples and performed the calculations. PJS carried out investigation of the samples and performed the calculations. ADS conceptualised the study, carried out the statistical analysis and wrote the original draft. The final draft was verified, read and approved by all the authors.

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All the authors declare that they have no competing interests that could influence the work reported.

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References

AOAC (Association of Official Analytical Chemists). Official method of analysis (16th ed). AOAC International, Arlington Virginia. 1995.
AOAC (Association of Official Analytical Chemists). Official methods of analysis (18th ed [revised]). AOAC International, Washington, DC. 2006.
Census of India. Paper 1 of 2018. Language. India, stated and union territories. Office of the Registrar General, New Delhi. 2011.
Chakravorty J (2014) Diversity of edible insects and practices of entomophagy in India: an overview. J Biodivers Biopros Dev 1(3):124
Chakravorty J, Ghosh S, Meyer-Rochow VB (2011) Practices of entomophagy and entomotherapy by members of the Nyishi and Galo tribes, two ethnic groups of the state of Arunachal Pradesh (North East India). J Ethnobiol Ethnomed 7:5
Cooper AM, Felix D, Alcantara F, Zaslavsky I, Work A, Watson PL, Pezzoli K, Yu Q, Zhu D, Scavo AJ, Zarabi Y, Schroeder JI (2020) Monitoring and mitigation of toxic heavy metals and arsenic accumulation in food crops: a case study of an urban community garden. Plant Direct 4(1):e00198
DeFoliart GR (1989) The human use of insects as food and as animal feed. Bull Entomol Soc Am 35(1):22–36
EFSA (2015) Risk profile of insects as food and feed. EFSA J 13:4257
FAO (Food and Agriculture Organization). Food energy-methods of analysis and conversion factors. FAO Food and Nutrition paper 77. Rome, Italy. 2003.
Foster GN, Friday LE. Keys to the adults of the water beetles of Britain and Ireland (Part 1). Handbooks for the identification of British insects. Vol.4 Part 5 (2nd Edition). Published for the Royal Entomological Society by the Field Studies Council. 2011.
Frelik A (2014) Predation of adult large diving beetles Dytiscus marginalis (Linnaeus, 1758), Dytiscus circumcinctus (Ahrens, 1811) and Cybister lateralimarginalis (De Geer, 1774) (Coleoptera: Dytiscidae) on fish fry. Oceanol Hydrobiol Stud 43:360–365
Gahukar RT (2018) Entomophagy for nutritional security in India: potential and promotion. Curr Sci 115(6):1078–1084
Ghosh S, Lee SM, Jung C, Meyer-Rochow VB (2017a) Nutritional composition of five commercial edible insects in South Korea. J Asia Pac Entomol 20(2):686–694
Ghosh SS, Bhagabati B, Chatterjee S, Deka P (2017b) Practice of entomophagy by the Bodo community residing in rani area of Kamrup district, Assam. Int J Appl Res 3(6):387–389
Hajeb P, Sloth JJ, Shakibazadeh S, Mahyudin NA, Afsah-Hejri L (2014) Toxic elements in food: occurrence, binding, and reduction approaches. Compr Rev Food Sci Food Saf 13(4):457–472
Hazarika HN (2018) Entomophagy with special reference to Assam. Int J Res Eng Appl Manag 4(4):458–462
Imathiu S (2020) Benefits and food safety concerns associated with consumption of edible insects. NFS Journal 18:1–11
Jolly MS, Sen SK, Sonwalker TN, Prasad GK (1979) Non-mulberry silks. In: Rangaswami G, Narasimhanna MN, Kashivishwanathan K, Sastri CR, Jolly MS (eds) Manual on sericulture. Food and Agriculture Organization of the United Nations, Rome., pp 1–178
Kim S-K, Weaver CM, Choi M-K (2017) Proximate composition and mineral content of five edible insects consumed in Korea. CyTA - J Food 15(1):143–146
Kim TK, Yong HI, Kim YB, Kim HW, Choi YS (2019) Edible insects as a protein source: a review of public perception, processing technology, and research trends. Food Sci Anim Resour 39(4):521–540
Kweon HY, Jo YY, Lee HS, Lee KG, Sung GB, Kim KY, Ji SD (2012) Determination of heavy metals and residual agricultural chemicals in Bombyx mori silkworm cocoon. J Seric Entomol Sci 50(2):48–52
Lundkvist E, Landin J, Jackson M, Svensson C (2003) Diving beetles (Dytiscidae) as predators of mosquito larvae (Culicidae) in field experiments and in laboratory tests of prey preference. Bull Entomol Res 93(3):219–226
Meyer-Rochow VB (2005) Traditional food insects and spiders in several ethnic groups of Northeast India, Papua New Guinea, Australia, and New Zealand. In: Paoletti MG (ed) Ecological implications of mini-livestock: rodents, frogs, snails, and insects for sustainable development. Science Publishers Inc., USA., pp 385–409
Meyer-Rochow VB, Changkija S (1997) Uses of insects as human food in Papua New Guinea, Australia and North-East India: cross-cultural consideration and cautious conclusions. Ecol Food Nutr 36(2-4):159–185
Naika R, Sannappa B, Govindan R (2003) Influence of castor varieties on rearing and grainage performances of different breeds of eri silkworm, Samia cynthia ricini. J Ecobiol 15:279–286
Narzari S, Sarmah J (2015a) A study on the prevalence of entomophagy among the Bodos of Assam. J Entomol Zool Stud 3(2):315–320
Narzari S, Sarmah J (2015b) Proximate composition of wild edible insects consumed by the Bodo tribe of Assam, India. Int J Bioassays 4(7):4050–4054
Narzari S, Sarmah J, Gupta P (2017) Nutritional aspects of an aquatic edible insect Sympetrum sp. (Odonata: Libellulidae) of Assam, northeast India. Int J Food Sci Nutr 2(4):38–42
Naumann S, Peigler RS (2001) Four new species of the silkmoth genus Samia (Lepidoptera: Saturniidae). Nachr Entomol Ver Apollo N F 22(2):75–83
Nilsson AN (2003) Dytiscidae. In: Löbl I, Smetana A (eds) Catalogue of Palaearctic Coleoptera, vol 1. Apollo Books, Stenstrup., pp 35–78
Patel S, Suleria HAR, Rauf A (2019) Edible insects as innovative foods: nutritional and functional assessments. Trends Food Sci Technol 86:352–359
Peigler RS, Naumann S (2003) A revision of the silkmoth genus Samia. University of Incarnate Word, San Antonio, Texas. 227–228.
Renuka G, Shamitha G (2014) Studies on the economic traits of Eri silkworm, Samia cynthia ricini, in relation to seasonal variations. Int J Adv Res 2(2):315–322
Ronghang R, Ahmed R (2010) Edible insects and their conservation strategy in Karbi Anglong district of Assam, North East India. The Bioscan 2:515–521
Rumpold BA, Schlüter OK (2013) Nutritional composition and safety aspects of edible insects. Mol Nutr Food Res 57:802–823
Shantibala T, Lokeshwari RK, Sharma HD (2012) Entomophagy practices among the ethnic communities of Manipur, North East India. Int J Int sci Inn Tech Sec A 1(5):13–20
Shantibala T, Lokeshwari RK, Debaraj H (2014) Nutritional and antinutritional composition of the five species of aquatic edible insects consumed in Manipur, India. J Insect Sci 14(1):14
Van Huis A (2003) Insects as food in Sub-Saharan Africa. Insect Sci Applic 23(3): 163–185
Van Huis A (2016) Edible insects are the future? Proc Nutr Soc 75(3):294–305
Van Huis A, Itterbeeck JV, Klunder H, Mertens E, Halloran A, Muir G, Vantomme P (2013) Edible insects: future prospects for food and feed security. Food and Agricultural organization of the United Nation (FAO forestry paper 171)., pp 89–97
Vijayan K, Anuradha HJ, Nair CV, Pradeep AR, Awasthi AK, Saratchandra B, Rahman SA, Singh KC, Chakraborti R, Urs SR (2006) Genetic diversity and differentiation among populations of the Indian eri silkworm, Samia cynthia ricini, revealed by ISSR markers. J Insect Sci 6:1–11
Yhoung-aree J (2010) Edible insects in Thailand: nutritional values and health concerns. In: Durst PB, Johnson DV, Leslie RN, Shono K (eds) Forest insects as

food: humans bite back. Food and Agriculture Organization of the United Nations; Bankok, Thailand., pp 201–216
Zhang ZS, Lu XG, Wang QC, Zheng DM (2009) Mercury, cadmium and lead biogeochemistry in the soil–plant–insect system in Huludao city. Bull Environ Contam Toxicol 83:255–259
Zielinska E, Karas M, Baraniak B (2018) Comparison of functional properties of edible insects and protein preparations thereof. LWT 91:168–174

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