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Nutritional and antinutritional properties of few common edible insect species of Assam

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Abstract
Five common edible insect species like red ant (*Oecophylla smaragdina*), muga silkworm (*Antherea assamensis*), honey bee (*Apis cerana*), winged termite (*Odontotermes obesus*) and eri silkworm (*Samia ricini*) were evaluated for biochemical constituents. The range of moisture, crude fat, crude protein, total soluble protein, crude fibre, carbohydrate and ash were between 6.30-16.04 per cent, 10.20-36.08 per cent, 23.31-52.35 per cent, 12.54-18.71 per cent, 3.16-9.78 per cent, 7.20-16.84 per cent and 2.58-5.60 per cent respectively. These species had sodium content ranging from 10.67-149.10 mg/100g, potassium from 9.68-710.49 mg/100g, calcium from 20.65-222.83 mg/100g, iron from 5.70-25.18 mg/100g and zinc from 5.40-35.18 mg/100g respectively. Antinutritional components like tannin, phytic acid and oxalate were recorded as of 97.82-236.31 mg tannic acid equivalent/100g, 8.55-97.91 mg/100g and 1.49-3.79 mg/100g respectively. The range of phenol content, flavonoid content and antioxidant activity (DPPH) were recorded between 25.78-210.06 mg catechol equivalent/100g, 4.96-44.68 mg quercetin equivalent/100g and 89.36-94.41 per cent respectively.

Keywords: Edible insect, entomophagy, nutritional, antinutritional, Assam

1. Introduction

Edible insects are considered as underutilized foods that offer significant potential to contribute to meeting future global food demands. Insects traditionally were an integral element of human diets in nearly 100 countries of the world, especially in Asia, Africa, and Latin America [1] and play an important role in the history of human nutrition in different parts of the world [2]. It is expected that by 2050 the world will host around 9 billion people; efforts will also have to focus on increasing the production and consumption of currently underutilized and underappreciated foods.

Edible insects provide satisfactory energy, protein, monounsaturated fatty acids, polyunsaturated fatty acids and rich in several minerals such as copper, iron, magnesium, manganese, phosphorous, selenium, zinc and vitamins such as riboflavin, pantothenic acid, biotin and folic acid etc. [3]. Besides nutritional importance, the edible insects also possess an ample sources of antioxidant properties such as phenol, flavonoid etc. [4]. The insects are also supposed to have higher proportion of quality protein, fat along with higher energy value than other animal protein like beef and fish. The practice "Entomophagy" has been proposed to warfare the deficiencies of these minerals in developing countries [5], in particular in view of the fact that the percentage of the world population at risk for these deficiencies is more than 17 % for zinc [6] and 25 % for iron [7] Therefore, insects as a food source can prevent under-nutrition particularly in the developing world and underdeveloped countries [8] Nadeau *et al.*, 2014. The edible insects have been prescribed as a severe choice to conventional meat production, both as animal feed and as human food [9], [10].

In North east India, around 225 different edible insect species has been found. Only a few researchers have attempted to study the nutritional composition of restricted numbers of edible insect species only from Northeast India [11], [4], [12]. In Assam, the entomophaghy is mainly practiced by the few tribal communities like *Bodo Mising, Karbi, Rabha* etc. with knowing or unknowingly their nutritional value. Even though it is being practiced all over the North-Eastern region of India, there is scantiness of information regarding assessment of nutritional and antinutritional composition of edible insects. Therefore, research is most needed on the nutritional aspects of wild, underused, indigenous and traditional edible insect species of Assam for further exploration as a healthy food source and data need to be compiled in accessible databases. The nutritional database of edible insects of Assam will definitely improve food and nutritional security and provide more ecologically sound food recommendations to consumers and policymakers with environmentally sustainable food system basis. The biochemical profiling of edible insects of Assam will help to explore nutritionally superior edible insects among the consumers.

2. Materials and methods

The present investigation was designed to evaluate nutritional, antinutritional and antioxidant properties of some edible insect species of Assam. Five numbers of edible insect species of different stages were obtained from different locations of Assam during 2018-19 (Table 1). Out of the five species, wings of the winged termites were removed with the help of scissors. Finally, all insect species were oven dried at 100°C (± 2°C) and converted into fine powder and kept in a desiccator for analytical works.

For analysis of proximate composition, moisture, crude fat, crude fibre, Protein content and ash contents were assayed by the Association of the Official Analytical Chemists methods [13]. Total soluble protein was estimated by Lowry method [14] with some modification. Carbohydrate was obtained by difference (100- sum of moisture, protein, fat, crude fibre and ash). Mineral estimation was carried out by dry-ashing the sample according to the AOAC [13] procedure. Sodium, potassium, calcium, iron, and zinc were estimated using atomic absorption spectrophotometer (AAS) and flame photometer. To study anti-nutrient and antioxidant analysis, tannin content was carried out by AOAC method [15], phytic acid content by Wheeler and Ferrel (1971) [16] and oxalic acid content by Mohanraj *et al*. (1971) [17]. The total phenol content was assayed by Malick and Singh (1980) [18], flavonoid content by Woisky and Salatino (1998) [19] and antioxidant activity by DPPH method [20].

Table 1: List of the species and stages used for present study

S. No.	Species	Stages used for study
1.	Red ant (*Oecophylla smaragdina*)	Egg
2.	Muga silk worm (*Antherea assamensis*)	Pupa
3.	Honey bee (*Apis cerana*)	Pupa
4.	Winged termite (*Odontotermes obesus*)	Adult
5.	Eri silk worm (*Samia ricini*)	Pupa

3. Results and discussion

Proximate composition

Moisture content

Highest moisture content (16.04%) was recorded in red ant (*O. smaragdina*) and lowest (6.30%) was found in the species winged termite (*O. obesus*) (Table 2). However, moisture content registered in case of honeybee (*A. cerana*) and muga silkworm, (*A. assamensis*) were found to be *at par* with each other. It was evident from the present investigations that the moisture content of five different edible insect ranged from 6.30 to 16.04 per cent and it was similar to the findings of Adeduntan (2005) [21] who reported that range of moisture content of the eight different insect species was 7.33 to 36.33 per cent. The edible insects with lower moisture content have the ability to reduces the risk of microbial attack and thus increase the preservation period. In present investigation, the muga silkworm (*A. assamensis*) was recorded with 7.54 per cent of moisture content and similar with the result of Omotoso (2015) [22] who recorded a range of 7.92 to 8.26 per cent of moisture in muga silkworm. Present findings showed 7.90 per cent of moisture in Honeybee (*A. cerana*) and it was found to be slightly similar with the result (7.40%) of Almeida-Muradian *et al.* (2005) [23]. The value (6.30 %) of winged termite (*O. obesus*) of present study was comparable with Kinyuru *et al*. (2013) [24]. The value of present findings (8.4%) in eri silkworm was almost similar with the result of Longvah *et al*. (2011) [25] who recorded 8.2 per cent in eri silkworm.

Crude fat content

Out of five insects, the highest (36.08%) crude fat content was registered in winged termite (*O. obesus*) and lowest (10.20%) was found in the species red ant (*O. smaragdina*) (Table 2). However, the fat content recorded in honeybee (*A. cerana*) and red ant (*O. smaragdina*) was found to be *at par* with each other. The fat content of five different edible insects in present investigation ranged from 10.20 to 36.08 per cent. Among these insects, winged termite (*O. obesus*) contributed the highest crude fat whereas, the minimum per cent of fat was registered in red ant (*O. smaragdina*). Present findings corroborate the results of Chakravorty *et al*. (2016) [26], who showed the crude fat content of red ant (*O. smaragdina*) was 14.99 per cent. Siulapwa *et al.* (2012) [27] observed high fat content in four different edible insect species *viz*., *G. belina*, *Gynanisa maja*, *Ruspolia differens* and *M. falciger* with a range of 10.0 to 49.0 per cent. Longvah *et al*. (2011) [25] registered 8.20 to 26.20 per cent of crude fat in pupae and prepupae of eri silkworm, which was similar to the present findings (20.51%). Omotoso (2015) [22] reported that silkworm contained a range of 17.57 to 19.90 per cent of fat which was slightly higher than the present findings (12.66%). In case of honeybee, similar finding was also noticed by Ghosh *et al*. (2016) [28] who reported fat content within the range of 6.90 to 14.50 per cent.

Crude protein content

The highest crude protein content (52.35%) was recorded in species muga silkworm (*A. assamensis*) and the lowest (23.31%) was observed in the species winged termite (*O. obesus*) (Table 2).The crude protein content of red ant (*O. smaragdina*), honeybee (*Apis cerana*) and eri silkworm (*Samia ricini*) were almost similar to each other. In the present investigation, high levels of crude protein (23.31-52.35%) was recorded in all the species and results were comparable with earlier report of Narzari and Sarmah (2015) [12] who recorded 30.00 to 84.56 per cent of protein in twenty species of wild edible insects of Assam. A high value of crude protein in different species of insect were also reported by Blasquez *et al*. (2011) [29] and Siulapwa (2012) [27]. In present study, the highest amount of crude protein was registered in muga silkworm (*A. assamensis*) followed by eri silkworm (*S. ricini*), red ant (*O. smaragdina*), honeybee (*A. cerana*) and winged termite (*O. obesus*). The crude protein content (23.31%) of winged termite (*O. obesus*) was found to be slightly lower than the earlier report of Ntukuyoh *et al*. 2012 [30], who recorded 25.38 to 29.75 per cent of crude protein in worker termites (*M. bellicosus*). The crude protein content (45.22%) of red ant was slightly higher than the results of Kinyuru *et al.* (2012) [24] who recorded 39.79 to 44.64 per cent. The crude protein content (52.35%) in muga silkworm was found to be lower than results of Deori *et al.* (2004) [11] who recorded 54.20 per cent in muga silkworm. Similarly, the results (54.00-54.80%) of crude protein in eri silk worm registered by Longvah *et al*. (2011) [25] was found to be higher than the present investigation (48.17%). Ramos-Elorduy *et al.* (1997) [10] recorded the crude protein content of larval stage (42.00%) and pupal stage (49.00%) of honeybee, whereas 42.09 per cent of crude protein in honeybee pupa was recorded in present investigation.

Total soluble protein content

The highest soluble protein content (18.71%) was registered in species honeybee (*Apis cerana*) and lowest (12.54%) was found in the species winged termite (*O. obesus*) (Table 2). The soluble protein content was found to be 12.60 per cent and 12.54 per cent in muga silkworm (*A. assamensis*) and winged termite (*O. obesus*) respectively and both were found to be *at par* with each other. The highest (18.71%) and lowest amount (12.54%) of soluble protein in five different edible insects were found in honeybee (*Apis cerana*) and winged termite (*O. obesus*) respectively. The total soluble protein content in five different edible insects in present investigation ranged from 12.54 to 18.71 per cent.

Crude fibre content

The highest crude fibre content (9.71%) was observed in species red ant (*O. smaragdina*) which was followed by winged termite (8.09%), honeybee (7.35%) and muga silkworm (6.19%) (Table 2). The lowest crude fibre content (3.16%) was registered in the species eri silkworm (*Samia ricini*). The crude fibre present in muga silkworm (6.19%) was compared to the results of Omotoso (2015) [22] who recorded 6.30 to 6.46 per cent of crude fibre in muga silkworm. Similar results were also observed by Agbidye *et al.* (2009) [31] in some forest insects in Benue State, Nigeria. They reported crude fibre content ranging from 5.55 to 7.85 per cent in those insects. For honeybee, the results of crude fibre content (7.35%) was found to be lower than the crude fibre content in honeybee from Colombia as reported by Fuenmayor *et al.* (2014) [32]. The value of the crude fibre of eri silk pupa of present study was found to be 3.16 per cent and can be compared with the range of 1.18 to 3.62 per cent in pupae and prepupae of eri silkworm from the earlier report of Longvah *et al*. (2011) [25].

Carbohydrate content

The highest carbohydrate content (16.84%) was recorded in winged termite (*O. obesus*) followed by muga silkworm (12.85%) and honeybee (9.17%) (Table 2). The lowest carbohydrate content (7.20%) was recorded in the species eri silkworm (*S. ricini*). In the present investigation, highest content (16.84 %) of carbohydrate was recorded in winged termite followed by muga silkworm (12.85%) and honeybee (9.22%). Remaining two species namely red ant (*O. smaragdina*) and eri silkworm (*S. ricini*) were recorded with slightly low amount of carbohydrate. Similar findings were reported by Bhulaidok *et al.* (2010) [33] in edible black ant (*P. vicina*) and recorded a range of 3.80 to 12.40 per cent of carbohydrate. The species winged termite (*O. obesus*) was registered with 16.84 per cent of carbohydrate and the value was found to be lower than the values reported by Ntukuyoh *et al*. (2012) [30] who recorded a relatively higher amount of carbohydrate in all the castes of *Macrotermes bellicosus* (34.84-67.09%).

Ash content

The highest amount (5.60%) of ash content was registered in winged termite (*O. smaragdina*). However, muga silkworm (*A. assamensis*), eri silkworm (*S. ricini*) and honeybee (*A. cerana*) registered 4.71 per cent, 4.50 per cent and 4.10 per cent of ash respectively and those were found to be *at par* with each other. The lowest ash (2.58%) content was observed in the species red ant (*O. smaragdina*) (Table 2). The present investigation showed that the ash content of five edible insects ranged from 2.58 to 5.60 per cent. These findings are similar with Chakravorty *et al*. (2016) [26] who also reported 2.58 per cent of ash in red ant (*O. smaragdina*). The ash content of muga silkworm from present investigation was 4.71 per cent and it is comparable with the reports of Omotoso (2015) [22], who recorded a range of 5.50 to 6.34 per cent of ash content in muga silkworm. More or less similar value of ash (3.80%-4.10%) were also recorded by Ghosh *et al*. (2016) [28] in honeybee and shared the exact amount of ash (4.10%) in muga silkworm of present investigation. From the present study, the ash content recorded in the species winged termite (5.60%) lies within the range of ash content (4.58%-7.58%) recorded by Kinyuru *et al*. (2013) [24] in four species of winged termite. However, the ash content in eri silkworm recorded by Longvah *et al.* (2011) [25] was in a range of 1.10 to 4.20 per cent which was slightly lower than ash value (4.50%) of present investigation.

Table 2: Proximate composition of five edible insects

Insect species	Moisture (%)	Crude fat (%)	Crude protein (%)	Total soluble protein (%)	Crude fibre (%)	Carbohydrate (%)
Red ant (*O. smaragdina*)	16.04	10.20	45.22	17.36	9.78	8.04
Muga silkworm (*A. assamensis*)	7.54	12.66	52.35	12.60	6.19	12.85
Honeybee (*A. cerana*)	7.90	10.74	42.09	18.71	7.38	9.22
Winged termite (*O. obesus*)	6.30	36.08	23.31	12.54	8.10	16.84
Eri silkworm (*S. ricini*)	8.40	20.51	48.17	16.46	3.16	7.20
SE(d)±	0.581	0.530	0.588	0.261	0.379	0.148
C.D. 5%	1.294	1.181	1.310	0.582	0.844	0.329
C.D. 1%	1.841	1.680	1.863	0.827	1.201	0.469

Elemental composition

Sodium content

The highest (149.10 mg/100g) amount of Na content was registered in red ant (*O. smaragdina*) and followed by winged termite (118.56 mg/100g) and honeybee (75.59 mg/100g).The lowest amount (10.67 mg/100g) of Na content was recorded in the species muga silkworm (*A. assamensis*) (Table 3). In the present investigation, highest Na content (149.10 mg/100g) was registered inred ant (*O. smaragdina*) followed by winged termite (118.56 mg/100g and honeybee (75.59 mg/100g). However, the remaining two species *viz*., eri silkworm (*S. ricini*) and muga silkworm (*A. assamensis*) recorded were to be 11.50 mg/100g and 10.67 mg/100g respectively. The Na content of species *O. smaragdina* was found to be 149.10mg/100g, which was slightly similar with the report (150.00 mg/100g) of Chakravorty *et al.* (2016) [26]. The muga silkworm in present investigation was recorded with 10.67 mg/100g and it was found to be similar with the report of Omotoso (2015) [22], who recorded a range of 10.52 to 11.66 mg/100g of Na. Similarly, the Na content of honeybee (75.59 mg/100g) from present studies lied within the range of 59.40 to 75.60 mg/100g as recorded by Ghosh *et al.* (2016) [28]. Present findings of Na (118.70 mg/100g) can be compared with the results of Chulu (2015) [34] who found 118.70 mg/100g of Na in species winged termite.

Potassium content

The highest (710.49 mg/100g) amount of K content was recorded in red ant (*O. smaragdina*) followed by winged termite (220.76 mg/100g), honeybee (125.64 mg/100g) and muga silkworm (18.39 mg/100g) (Table 3). The species eri silkworm (*S. ricini*) was registered with very low amount of potassium content (9.68 mg/100g) as compared to other four species. The highest K content (710.49 mg/100g) was registered in species red ant (*O. smaragdina*) and the value was found similar with the results (710.00 mg/100g) of Chakravorty *et al.* (2016) [26]. In present investigation, the K content was found to be 18.39 mg/100g in muga silkworm and it was found to be slightly similar with the results of Omotoso (2015) [22], who observed a range of 18.65 to 22.45 mg/100g of K in muga silk worm. Igwe *et al.* (2011) [35] recorded K content (336.00 mg/100g) in edible African termite, which was higher than the K content recorded in present findings (220.76 mg/100g). However, Shantibala *et al.* (2014) [4] recorded a higher range (170 to 643 mg/100g) of K content in aquatic edible insect from Manipur.

Calcium content

The calcium content (222.83 mg/100g) of honeybee (*A. cerana*) was found to be highest among the species (Table 3). The species muga silkworm (*A. assamensis*) was recorded with lowest amount (20.65 mg/100g) of calcium content. In the present studies, Ca content was highest in honeybee (222.83 mg/100g) followed by red ant (74.47 mg/100g). In the present investigation, the result of Ca content (74.47 mg/100g) of red ant was observed similar with the result (74.67 mg/100g) recorded by Chakravorty *et al.* (2016) [26]. Similarly, the Ca content (72.83 mg/100g) of eri silkworm of present investigation was also found similar with the report of Longvah *et al.* (2011) [25], who recorded similar value (24.00 to 76.80 mg/100g) of Ca content in eri silkworm. A high value of Ca (222.83 mg/100g) was recorded in the species honey bee and the value is comparable with the range of Ca content (84.90 to 222.90 mg/100g) in different honey bee species as reported by Ghosh *et al.* (2016) [28]. The lowest amount of Ca was recorded in muga silkworm (20.65 mg/100g) and this result was observed to be similar with the result (20.31 to 26.65 mg/100g) of Omotoso (2015) [22]. The Ca (58.70 mg/100g) recorded in winged termite of present investigation was found to be similar with the result (42.89 to 63.6 mg/100g) of Kinyuru *et al.* (2013) [24].

Iron content

The honeybee (*A. cerana*) was registered with the highest amount of iron content (25.18 mg/100g) and was found to be *at par* with eri silkworm (24.47 mg/100g). The lowest amount (5.70mg/100g) of Fe content was registered with the species muga silkworm (*A. assamensis*) (Table 3). In the present investigation, Fe content of five edible insects ranged from 5.70 to 25.18 mg/100g. Among the five species, honeybee (*A. cerana*) contained the highest (25.18 mg/100g) amount of Fe content. Present findings can be compared to the results of Chakravorty *et al.* (2016) [26] who recorded the Fe content (15.66 mg/100g) in red ant (*O. smaragdina*) and this result was found to be almost similar with the result (15.27 mg/100g) of present investigation The Fe content of muga silkworm recorded by Omotoso (2015) [22] was in a range of 5.30 to 6.33 mg/100g and it was observed as similar with the present investigation (5.70 mg/100g). Chulu (2015) [34] recorded the Fe content (8.50 mg/100g) in winged termite, which showed a similar result with present investigation (8.50 mg/100g). The Fe (24.47 mg/100g) recorded in eri silk worm was found to be similar with the findings (7.00-25.40 mg/100g) of Longvah *et al.* (2011) [25].

Zinc content

The zinc content in muga silkworm (*A. assamensis*) was found to be highest (35.18 mg/100g) and the species winged termite (*O. obesus*) was recorded with lowest amount (5.40 mg/100g) (Table 3). Zinc content recorded in muga silkworm (*A. assamensis*), red ant (*O. smaragdina*), honeybee (*A. cerana*), eri silkworm (*S. ricini*) and winged termite (*O. obesus*) were found to be 35.18 mg/100g, 18.39 mg/100g, 13.49 mg/100g, 7.67 mg/100g and 5.40 mg/100g respectively. Present findings corroborate with the results of Chakravorty *et al.* (2016) [26] who recorded Zn content in red ant (18.97 mg/100g). This result was found to be similar with present findings (18.39 mg/100g) of Zn in species red ant. The Zn content of muga silkworm recorded in present investigation was 35.18 mg/100g and compared with a range of Zn content (35.63-37.50 mg/100g) in muga silk recorded by Omotoso (2015) [22]. The Zn content (13.49 mg/100g) of honeybee was found to be similar with the report (11.60-14.00 mg/100g) of Ghosh *et al.* (2016) [28]. A lower value (7.10-12.86 mg/100g) of Zn was recorded in species winged termite than the record of Kinyuru *et al.* (2013) [24], who recorded a range (7.10-12.86 mg/100g) of Zn content in winged termite. A slightly higher value of Zn (7.67 mg/100g) was recorded in the species eri silk worm than the values (2.02-7.24 mg/100g) reported by Longvah *et al*. (2011) [25] in eri silkworm.

Table 3: Elemental compositions of five edible insects

Insect species	Ash (%)	Sodium (mg/100g)	Potassium (mg/100g)	Calcium (mg/100g)	Iron (mg/100g)	Zinc (mg/100g)
Red ant (*O. smaragdina*)	2.58	149.10	710.49	74.47	15.27	18.39
Muga silkworm (*A. assamensis*)	4.71	10.67	18.39	20.65	5.70	35.18
Honeybee (*A. cerana*)	4.10	75.59	125.64	222.83	25.18	13.49
Winged termite (*O. obesus*)	5.60	118.56	220.76	58.70	18.50	5.40
Eri silkworm (*S. ricini*)	4.50	11.50	9.68	72.83	24.47	7.67
SE(d)±	0.768	0.216	0.556	0.495	0.367	0.221
C.D. 5%	1.710	0.485	1.249	1.103	0.817	0.492
C.D. 1%		0.689	1.777	1.569	1.162	0.700

Antinutritional and antioxidant contents

Tannin content

The highest (236.51mg tannic acid equivalent/100g) tannin content was registered in the species eri silkworm (*S. ricini*) which was followed by *A. assamensis* (210.49 mg tannic acid equivalent/100g). The lowest (97.82 mg tannic acid equivalent/100g) tannin content was found in the species honeybee (*A. cerana*) (Table 4). The present investigation shows that the eri silkworm (*S. ricini*) contained the highest tannin content (236.31 mg tannic acid equivalent/100g) followed by muga silkworm (210.49 mg tannic acid equivalent/100g), red ant (109.56 mg tannic acid equivalent/100g), winged termite (102.51 mg tannic acid equivalent/100g) and honeybee (97.82 mg tannic acid equivalent/100g). This result is comparable with the earlier report of Shantibala *et al*. (2014) [4]. They reported the tannin content of *L. indicus*, *L. maculatus*, *H. olivaceous*, *Cybister tripunctatus* and *Crocothemis servilia* were to be 372.33 mg/100g, 350.43 mg/100g, 528.67 mg/100g, 301.67 mg/100g and 465.33 mg/100g respectively.

Phytic acid content

The highest (97.91 mg/100g) phytic acid content was registered in eri silkworm (*S. ricini)* and lowest was found in the species winged termite (8.55 mg/100g) (Table 4). In the present investigation, the phytic acid content recorded in eri silkworm (97.91 mg/100g) was found to be highest than the remaining species. The phytic acid content of red ant (*O. smaragdina*), muga silkworm (*A. assamensis*), honeybee (*A. cerana*) and winged termite (*O. obesus*) were found to be 19.67 mg/100g, 15.32 mg/100g, 12.42 mg /100g and 8.55 mg /100g respectively. The result of the phytic acid content of the present findings was found to be lower than the earlier report of Adeduntan (2005) [21] who reported that the phytic acid content of ant, termite, and winged termite from Nigeria were found to be 2030.79 mg/100g and 2482.08 mg/100g, 1128.22 mg/100g respectively.

Oxalate content

The species red ant (*O. smaragdina)* was recorded with highest (3.79 mg/100g) oxalate content and it was found to be *at par* with eri silkworm (3.50 mg/100g) However, the oxalate content of honeybee (*A. cerana*) and winged termite (*O. obesus*) were found to be 2.68 mg/100g and 1.49 mg/100g respectively (Table 4). Oxalate content registered in red ant (*O. smaragdina*), muga silkworm (*A. assamensis*) and eri silkworm (*S. ricini*) were to be 3.79 mg/100g, 3.29 mg/100g and 3.50 mg/100g. The remaining two species honeybee (*A. cerana*) and winged termite (*O. obesus*) contained 2.68 mg/100g and 1.49 mg/100g respectively. Present findings corroborate the results of Idolo and Henry (2011) [2] who registered 2.10 mg/100g of oxalate in the larva of coconut beetle (*O.monoceros*). Similarly, Omotoso (2015) [22] reported that the larva of *Cirina forda* from Nigeria contained 4.11 mg/100g of oxalate.

Phenol content

The highest (210.06 mg catechol equivalent/100g) amount of phenol content was found in the species winged termite (*O. obesus*) followed by muga silkworm (197.89 mg catechol equivalent/100g), eri silkworm (175.05 mg catechol equivalent/100g) and honeybee (125.01 mg catechol equivalent /100g). The phenol content in case of red ant (*O. smaragdina*) was found to be the lowest (25.78 mg catechol equivalent/100g) (Table 4). The highest (210.06 mg catechol equivalent/100g) phenol content was found in winged termite (*O. obesus*). The remaining four species *viz.* muga silkworm (*A. assamensis*), eri silkworm (*S. ricini*), honeybee (*A. cerana*) and red ant (*O. smaragdina*) contained 197.89 mg catechol equivalent/100g, 175.05 mg catechol equivalent/100g, 125.01 mg catechol equivalent/100g and 25.78 mg catechol equivalent/100g respectively. Phenol content from present study was found almost similar with the results of Shantibala *et al*. (2014) [4], where they recorded the phenol content of *Lethocerus indicus*, *Laccotrephes maculatus*, *Hydrophilus olivaceous*, *Cybister tripunctatus* and *Crocothemis servilia* were 160.00 mg catechol equivalent/100g, 141.00 mg catechol equivalent/100g, 202.66 mg catechol equivalent/100g, 268.67 mg catechol equivalent/100g and 18.00 mg catechol equivalent/100g respectively.

Flavonoid content

The highest (44.60 mg quercetin equivalent/100g) flavonoid content was found in eri silkworm (*S. ricini*) which is followed by honeybee (15.42 mg quercetin equivalent/100g) (Table 4). The species muga silkworm (*A. assamensis*) and winged termite (*O. obesus*) recorded 14.85 mg quercetin equivalent/100g and 14.79 mg quercetin equivalent/100g respectively and both were found to be *at par* with each other. The lowest (4.96 mg quercetin equivalent/100g) amount of flavonoid registered in the species red ant (*O. smaragdina*). The flavonoid (44.68 mg quercetin equivalent/100g) content of eri silkworm (*S. ricini*) was found to be superior to the remaining four insect species. The two species muga silkworm (*A. assamensis*) and winged termite (*O. obesus*) were found to be *at par* with eachother. Honeybee (*A. cerana*) contained 15.42 mg quercetin equivalent/100g whereas; red ant (*O. smaragdina*) showed the lowest flavonoid (4.96 mg quercetin equivalent/100g) among the species. Present findings corroborate the results of Deori *et al*. (2014) [11] who recorded the flavonoid content of muga silkworm and eri silkworm pupae were 5.45 mg quercetin equivalent/100g and 3.49 mg quercetin equivalent/100g respectively

Antioxidant activity (DPPH)

The eri silkworm (*S. ricini*) was recorded the highest (94.41% DPPH inhibition) antioxidant activity as compared to the rest of the species. The lowest (89.36% DPPH inhibition) was recorded in the species red ant. The three species viz., winged termite (90.42% DPPH inhibition), honeybee (90.16% DPPH inhibition) and muga silkworm (90.15% DPPH inhibition) were found to be *at par* with each other (Table 4). The eri silkworm (*S. ricini*) was recorded with highest antioxidant activity (94.41% DPPH inhibition) whereas, the winged termite (*O. obesus*), honeybee (*A. cerana*), muga silkworm (*A. assamensis*) and red ant showed 90.43 per cent DPPH inhibition, 90.16 per cent DPPH inhibition, 90.15 per cent DPPH inhibition and 89.36 per cent DPPH inhibition antioxidant activity respectively. Present findings corroborate the results of Shantibala *et al*. (2014) [4] reported that the IC_{50} % of species *C. tripunctatus* and *C. servilia* were found to be 110 µg/mL and 880 µg/mL respectively.

Table 4: Antinutritional and antioxidant properties of five edible insects

Insect species	Tannin (mg tannic acid equivalent/100g)	Phytate (mg/100g)	Oxalate (mg/100g)	Phenol (mg catechol equivalent/100g)	Flavonoid (mg quercetin equivalent/100g)	Antioxidant activity (% DPPH inhibition)
Red ant (*O. smaragdina*)	109.56	19.67	3.79	25.78	4.96	89.36
Muga silkworm (*A. assamensis*)	210.49	15.32	3.29	197.89	14.85	90.15
Honeybee (*A. cerana*)	97.82	12.42	2.68	125.01	15.42	90.16
Winged termite (*O. obesus*)	102.51	8.55	1.49	210.06	14.79	90.43
Eri silkworm (*S. ricini*)	236.31	97.91	3.50	175.05	44.68	94.41
SE(d)±	0.611	0.225	0.206	0.144	0.256	0.181
C.D. 5%	1.358	0.502	0.460	0.324	0.571	0.402
C.D. 1%	1.931	0.714	0.654	0.460	0.813	0.572

4. Conclusion

In the present investigation, all the species studied contain a high amount protein, fat and soluble protein and however, the relative differences in those parameters were found among the species studied. The edible insect species studied here possess good and considerable quantity of antioxidant properties. All the species contain a trace amount of antinutritional parameters and can be accepted for edible purpose. The edible insect species could therefore be potential source for human food and animal feed since they exhibited a well-balanced nutrient profile. In addition to their nutritional benefits, edible insects need to be examined for their functional properties and further potential application as texturizing food ingredients as well as ingredients of protein-rich meat replacing products. The present findings suggest to further study the complete mineral profiling, amino acid profiling, fatty acid profiling, vitamin composition of those edible insect species from Assam.

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