NUTRITIONAL AND ANTINUTRITIONAL PROPERTIES OF SOME EDIBLE INSECTS OF ASSAM

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By

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ASSAM AGRICULTURAL UNIVERSITY

Faculty of Agriculture

Department of Biochemistry and Agricultural Chemistry

CERTIFICATE – I

This is to certify that the thesis entitled **"Nutritional and antinutritinal properties of some edible insects of Assam"**submitted to the Faculty of Agriculture, Assam Agricultural University, in partial fulfillment for the degree of **Master of Science (Agriculture)** in **Agricultural Biochemistry** is a record of research work carried out by **Saihlupuii Sailo, Regd. No. 2016-AMJ-49** under my personal supervision and guidance.

All helps received by her have been duly acknowledged.

No part of this thesis has been reproduced elsewhere for any degree.

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CERTIFICATE – II

This is to certify that the thesis entitled **"Nutritional and antinutritional properties of some edible insects of Assam"**submitted by **Saihlupuii Sailo**, **Roll No. 2016-AMJ-49** to the Assam Agricultural University, in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture)** in the discipline of **Agricultural Biochemistry** has been examined and approved by the Student's Advisory Committee after viva-voce.

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ABSTRACT

Edible insects are considered as underutilized foods that offer significant potential to meet the 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. 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. Besides nutritional importance, the edible insects also possess an ample sources of antioxidant properties such as phenol, flavonoid as well as some antinutritional components.

In the present investigation, five different edible insects 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, 3.16-9.71 per cent, 7.20-16.84 per cent and 2.58-5.60 per cent respectively. Five different edible insect 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. All the five edible insect species exhibited a well-balance nutrient profile and therefore, these could be the potential source for human food and animal feed.

CONTENTS

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ABBREVIATIONS AND SYMBOLS USED

AOAC	Association of official Analytical Chemists
%	Percentage
µl	Micro liter
et al.	Et alia
rpm	Revolutions per minute
Fig.	Figure
gm	Gram
hr.	Hour
min	Minute
N	Normal
M	Molar
/	Per
mg	Milligram
ml	Millilitre
mM	Millimolar
nm	Nanometer
°C	Degree Celsius
mm	Millimeter
pH	-log [H+]
CRD	Completely Randomize Design
CD	Critical difference
S.Ed	Standard error of difference
i.e.	That is
Viz.	Videlicet (namely)
IC	Inhibition concentration
ppm	Parts per million

CHAPTER I
INTRODUCTION

Edible insects are considered as underutilized foods that offer significant potential to meet 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 (Durst *et al.*,2010) and plays an important role in the history of human nutrition in different parts of the world (Idolo and Henry, 2011). It is estimated that more than fifty insect species were consumed in South Asia (India, Pakistan and Sri Lanka), thirty nine species in Papua New Guinea and the Pacific Islands and one hundred fifty to three hundred species in Southeast Asia (Johnson,2010). It is expected that by 2050 the world will host around nine billion people for which efforts will also have to focus on increasing the production and consumption of currently underutilized and underappreciated foods.

Edible insects are important dietary components which are consumed as food in many developing countries. Insects are high quality food items that can provide substantial amount of nutrients essential for maintenance of health and protection from age related diseases. The ethnic people of India consumed different insects as food. Practice of entomophagy is quite common among the ethnic individuals ofNorth East India especially among the tribes of Arunachal Pradesh, Assam, Manipur and Nagaland andto a lesser degree by the tribes of Mizoram and Meghalaya (Rahman *et al.*, 2018).

Insects are important as items of aesthetic values and as food. *Bombyxmori* L. is an economically important edible insect in tropics. Arthropods have established intimate relationships with man and his valuables since time immemorial (Banjo *et al.*, 2006; Omotoso, 2007).

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. (Rumpold and Schluter, 2013, Makkar*et al.*, 2014). Besides nutritional importance, the edible insects also possess an ample sources of antioxidant properties such as phenol, flavonoid etc. (Shantibala*et al.*, 2014). The nutritional value of edible insects is highly variable because of the broad range of edible insect species. Even within the same group of species, nutritional value may vary depending on the metamorphic stage of the insect, the habitat in which it lives, and its diet. 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 (Christensen*et al.,* 2006), in view of the fact that the percentage of the world population at risk for these deficiencies is more than 17% for zinc and 25% for iron(McLean*et al.,* 2009).Therefore, insects as a food source can prevent under-nutrition particularly in the developing world and underdeveloped countries (Nadeau *et al.,* 2014). The edible insects have been prescribed as a severe choice to conventional meat production, both as animal feed and human food (Paoletti, 2005; Ramos-Elorduy, 1997; Huis*et al.*, 2013).

The North Eastern statesconsumed lot of insect as food and a very limited effort has been given to study on their nutritional aspect. The nutritional database of edible insects of Assam will definitely provide more ecologically sound food recommendations to consumers and policymakers with environmentally sustainable food system basis. The nutritional profiling of edible insects will act as a source of food and feed in both national and international food agencies. Proper documentation on nutritional composition of edible insects will raise awareness towards their contribution in improving global food security. The feasibility of insect derived proteins in human food and animal feed can be demonstrated through complete nutritional profiling. The nutritional profiling can also act as a tool to restrict the consumption and marketing of unhealthy edible insect species.

Eri silkworm is a traditional source of food in North East India, where it is grown primarily for silk and food production. Nutrient analysis showed that proximate composition of eri silkworm prepupae and pupae grown on either castor or tapioca were a good source of protein, fat and minerals (Longvah *et al*. 2011). The state of Assam, occupies an important position in the Sericulture map of India. Sericulture practice in this region is mostly confined to the Brahmaputra valley and its surrounding areas. The congenial atmosphere helps in the cultivation of the host plants and availability of the silk insects. The ‘Muga’ (*Antheraeassama*) culture originated in Assam, as this moth is not cultured in other parts of the world and it has now become a good source of silk for cottage industry (Mishra *et al*., 2003).

The possibility of silkworm and mulberry production for pharmaceutical and nutritional ends was already explored at the Conference on Sericulture for Multi Products-New Prospects for Development, organized by the Black, Caspian Seas and Central Asia Silk Association (BACSA, 2011). Similarly, other nutritionally superior edible insect species of Assam and Northeast India can be used for pharmaceutical and nutritional ends. There is enormous scope to promote "Insect Farming" or "Entomophagy" to improve the rural livelihood in this region. The nutritional profiling of edible insect species is very much helpful for multifaceted exploration of promising edible insect as bio-wealth and bioprospecting to improve both nutritional and the rural livelihood security in this region.

In North east India, around two hundred and twenty five different edible insect specieshas been found. The information on nutritional value of those edible insect species is very sporadic and scanty. Only a few researcher have attempted to study the nutritional composition of restricted numbers of edible insect species only from Northeast India (Deori*et al.,* 2014; Shantibala*et al*., 2014; Narzari and Sharma, 2015). 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. A perusal of literature reveals that a very limited volume of research work has been conducted on this aspects. Many of these edible insects from this particular region currently lack recognition and appreciation of their potential to contribute to food security. The biochemical profiling of edible insects of Assam will help toexplore nutritionally superior edible insects among the consumers.

Considering all these facts, the present investigation on nutritional and antinutritional aspects of edible insects of Assam has been formulated with the following objectives.

1. Study of proximate and elemental composition of certain edible insect species.
2. Study of antioxidant and antinuritional properties of certain edible insect species.

CHAPTER II

REVIEW OF LITERATURE

The study was aimed at the nutritional, antinutritional and antioxidant properties of some edible insect species of Assam. The biochemical profiling *viz.,* red ant, muga silkworm, honeybee, winged termite and eri silkwormwill help to explore nutritionally superior edible insects among the consumers. However, literature on evaluation of nutritional, antinutritional and antioxidant properties of edible insect species of Assamis scarce and hence brief reviews of literature related to the various aspects of the present investigation are presented as a whole here under selected subheads.

2.1. Moisture content

Adeduntan (2005) studied the nutritional and antinutritional characteristics of some edible insects of Akure Forest Reserve Ondo State, in Nigeria. He reported that the moisture content of ant, termite, winged termite, *Anaphe venata* and meal bug were to be (16.375%), (15.533%), (27.247%), (36.337%) and (7.333%) respectively.

Almeida-Muradian *et al*. (2005) studied the moisture content of Brazilian dried bee (*Apis mellifera* L.) and recorded 7.40 per cent of moisture content.

Igwe *et al*. (2011) observed moisture content of 10.78 per cent in a termite species (*M. nigeriensis*).

Longvah *et al*. (2011) found the moisture content of prepupae and pupae of eri silkworm (*Samia ricinii)* were to be 9.00 and 8.80 per cent respectively.

Siulapwa *et al*. (2012) observed the moisture content of 4.10 per cent in grasshopper (*Ruspolia differens*) and 9.20 per cent in winged termite (*Macrotermes falciger*).

2.2 Crude fat

Ying *et al*. (2017) reported that the fat content of few edible insects ranged from 4.00 to 30.00 per cent.

Teffo *et al*. (2007) reported that the stink-bug (*E. delegorguei*), which is traditionally used by the Venda people in South Africa contains 51.00 per cent of fat.

Xiaoming *et al*. (2010) reported the fat content of the diving beetle (*C. tripunctatus*) was 21.57 per cent and can contribute a significant source of oil in the diets.

Rompold and Schluter (2013) studied the nutritional composition of different edible insects in various parts of the world and recorded the fat content of honeybee (*Apis mellifera*) was 12.30 per cent in the wild of Nigeria. The termite (*M. bellicosus*) of different parts of Nigeria contained a range of 28.20 to 46.10 per cent of fat. The silkworm (*Bombyx mori*) pupae reared in India contained 30.10 per cent of fat. The eri silkworm (*Samia racinii*) prepupae grown on castor leaves in India contained 26.20 per cent of fat.

Kourimska and Adamkova (2016) found that silkworm (*Bombyx mori*) and western honey bee (*Apis melifera*)contained 29.00 per cent and 31.00 per cent of fat respectively.

2.3 Crude Protein

The stink-bug (*Encosternum delegorguei*) which was traditionally used by Venda people in South Africa's Limpopo province contained 35.00 per cent of protein (Teffo *et al.* 2007).

Womeni (2012) from Cameroon investigated the crude protein of palm weevil (*Rhynchophorus phoenicis*) and found the 67.09 per cent of protein content.

Ntukuyoh *et al*. (2012) studied the nutritional values of soldiers, workers and queen of the termite (*Macrotermes bellicosus*) in Niger Delta Region of Nigeria. They found that crude protein content among the soilders, workers and the queen varied from 25.38 per cent and 56.44 per cent and reported that the crude protein of the soldiers were higher than those of workers and the queen.

Jonathan (2012) reported that crude protein content of yam beetle and palm weevil from Nigeria were found to be 38.10 per cent and 50.01 per cent respectively.

Narzari and Sarmah (2015) studied the proximate analysis of twenty species of wild edible insects commonly consumed by the tribes of *'Bodo'*tribes of Assam and reported that the crude protein ranged from 30.25 to 84.56 per cent.

2.4 Total soluble protein

Hemalatha *et al*. (2015) recorded the soluble protein level of silkworm (*Bombyx mori L.)* during the 5^{th} instar development. The total soluble protein content of CNS, muscle, silk gland, fat body and hemolymph in silkworm of day1 to day7 ranges from (32.9 to 49.0%), (32.3 to 59.4%), (44.4 to 127.3%), (33.8 to 41.9%) and (11.6 to 33.8%).

2.5 Crude fibre

The edible larva of *Cirina forda* from Nigeria contributed 9.40 per cent of crude fibre, as reported by Akinnawo and Ketiku (2000).

Mishra *et al*. (2003) reported that the pupae of silkworm (*Antheraea assama*) collected from Sualkuchi of Assam contained 4.76 per cent of crude fibre.

Banjo *et al*. (2006) evaluated the nutrient composition of seventeen species of edible insects from South Western Nigeria. They observed that crude fibre of these insects varied from 1.01 to 3.40 per cent.

Shantibala *et al*. (2014) reported the crude fibre content of five aquatic edible insects from Manipur like, viz. *L. indicus* (11.71%), *H. olivaceous* (14.25%), *C. tripunctatus* (15.13%), *L. maculatus* (7.31 %) and *C. servillia* (9.62%).

The larva mealworm beetle (*Tenebrio molitor*) contained 2.10 per cent of crude fibre (Nowak *et al.*, 2016).

2.6 Total carbohydrate

Bhulaidok *et al*. (2010) determined the carbohydrate composition of ants (*Polyrhachis vicina*) cultivated in Zhejiang and Guizhou provinces in China which contained 12.40 per cent and 3.80 per cent of total carbohydrate respectively.

Paul and Dey (2011) evaluated the nutrient content of sexual and worker forms of subterranean termite (*Reticulitermessp*) and found that the total carbohydrate of sexual forms of termite and worker termite were found to be 2.73 per cent and 1.26 per cent respectively.

The carbohydrate content of twenty five edible Orthopteran insects varied from 0.001 to 22.64 per cent from Mexico (Blasquez *et al*. 2011).

2.7 Ash content

Mishra *et al*. (2003) reported that the ash content of 4.64 per cent in silkworm pupae (*Antheraea assama*) of Kamrup District, Assam.

The ash content of termite (*M. nigeriensis*) was 7.60 per cent as reported by Igwe *et al*. (2011).

Blasquez *et al*. (2012) studied the nutritive values of twenty five edible Orthopteran insects in Mexico and recorded a range of ash content from 0.34 to 16.50 per cent.

The ash content of prepupae and pupae of eri silkworm (*Samia ricinii*) were found to be 4.00 per cent and 1.10 per cent respectively, (Longvah *et al*., 2011).

Omotoso (2015) evaluated the nutrients and some anti-nutrients in silkworm (*Bombyx mori* L.) in Nigeria and found that the ash content was higher in the larva (6.34%) than in the pupal stage (5.50%).

2.8 Sodium

Akinnawo and Ketiku (2000) reported 210.00 mg/100g of Na in edible larva of *Cirina forda* from Nigeria.

Shen *et al*. (2006) registered 1433.30 mg/100 g of Na in edible Chinese black ant (*Polyrhachis vicina)*.

Teffo *et al*. (2007) reported that the insect stink-bug (*E. delegorguei*), from South Africa contained 55.30 mg/100g of Na.

Blasquez *et al.* (2011) reported the range of Na content of twenty five edible Orthopteran insects from Mexico were found to be 0.066 to 7.050 mg/100g.

Finke (2012) studied the nutritional value of four species of edible insects from Mexico*viz.*, larva of soldier fly, Turkestan cockroach nymphs, tebo worms and adult house flies. He observed a range of 198.00mg/100g to 1350.00 mg/100g of Na content among four species of edible insects.

Siulapwa *et al.* (2012)evaluated the nutritional value of four edible insect *viz.*, grasshopper (*Ruspolia differens*), winged termite (*Macroterm*es *falciger*) and two caterpillars (*Gonimbrasia belina* and *Gynanisa maja*). They recorded a range of 12.70 to 42.10 mg/100g of Na content among those species.

Na content of locust, cricket, grasshoppers and termites from Nigeria were determined by Ajai *et al.* (2013) and recorded a range of 156.25 to 290.00 mg/100g of Na content among those species.

Shantibala *et al*. (2014) studied the nutritional value of five species of aquatic edible insect *viz.*, *Lethocerus indicus*, *Laccotrephes maculatus*, *Hydrophilus olivaceous*, *Cybister tripunctatus* and *Crocothemis servilia* from Manipur. They observed a range of Na content from 305.00 to 1500.00 mg/100g among those species.

2.9 Potassium

Akinnawo and Ketiku (2000) found that the edible larva of *Cirina forda* from Nigeria contained 213.00 mg/100g of K.

Shen *et al*. (2006) found 4481.00 mg/100g of K in edible Chinese black ant (*Polyrhachis vicina)*.

Teffo *et al*. (2007) recorded 275.00 mg/100g of K in stink-bug (*Encosternum delegorguei*) from South Africa.

Kinyuru *et al*. (2010) found that the green and brown coloured grasshoppers (*Ruspolia differens*) of Kenya contained 370.60 mg/100g and 259.70 mg/100 g of K respectively.

Blasquez *et al.* (2011) reported the K content of twenty five edible Orthopteran insects from Mexico and the range were found to be 0.044 to 0.574 mg/100g.

Finke (2012) studied the nutritional value of four species of edible insects from Mexico*viz.*, larva of soldier fly, Turkestan cockroach nymphs, tebo worms and adult house flies. He observed a range of 2240.00 to 4530.00 mg/100g of K content among four species of edible insects.

Siulapwa *et al.* (2012)evaluated the nutritional value of four edible insect *viz.*, grasshopper (*Ruspolia differens*), winged termite (*Macroterm*es *falciger*) and two caterpillars (*Gonimbrasia belina* and *Gynanisa maja*). They recorded a range of 9.10 to 65.60mg/100g of K content among those species.

Potassium content of locust, cricket, grasshoppers and termites from Nigeria were determined by Ajai *et al.* (2013) and recorded the range of 225.25 to 480.12 mg/100g of K content among those species.

Shantibala *et al*. (2014) studied the nutritional value of five species of aquatic edible insect *viz*., *Lethocerus indicus*, *Laccotrephes maculatus*, *Hydrophilus olivaceous*, *Cybister tripunctatus* and *Crocothemis servilia* from Manipur. They registered a range of K content from 170.00 to 643.00 mg/100g among those species.

2.10 Calcium

Akinnawo and Ketiku (2000) reported that the edible larva of *Cirina forda* from Nigeria contained 7.00 mg/100g of Ca.

Shen *et al*. (2006) recorded 1754.00 mg/100 g of Ca in edible Chinese black ant (*Polyrhachis vicina)*.

Teffo *et al*. (2007) reported that stink-bug (*Encosternum delegorguei*) from South Africa contained 91.00 mg/100g of Ca.

Bhulaidok *et al.* (2010) observed 49.10 mg/100g of Ca in edible black ants (*Polyrhachis vicina*) from South Africa.

Kinyuru *et al*. (2010) reported that the green and brown coloured grasshoppers (*Ruspolia differens*) of Kenya contained 27.40 mg/100g and 24.50 mg/100 g of Ca respectively.

Blasquez *et al.* (2011) reported a range of 0.051 to 0.120 mg/100g of Ca content in twenty five edible Orthopteran insects from Mexico.

Finke (2012) estimated the nutritional value of four species of edible insects from Mexico*viz.*, larva of soldier fly, Turkestan cockroach nymphs, tebo worms and adult house flies. He observed a range of 125.00 to 9340.00 mg/100g of Ca content among four species of edible insects.

Siulapwa *et al.* (2012)evaluated the nutritional value of four edible insect *viz.*, grasshopper (*Ruspolia differens*), winged termites (*Macroterm*es *falciger*) and two caterpillars (*Gonimbrasia belina* and *Gynanisa maja*). They recorded a range of 78.00 to 166.40 mg/100g of Ca among those species.

Shantibala *et al*. (2014) studied the nutritional value of five species of aquatic edible insect *viz. Lethocerus indicus, Laccotrephes maculatus, Hydrophilus olivaceous, Cybister tripunctatus* and *Crocothemis servilia* from Manipur. They observed a range of Ca content from 24.30 to 96.00 mg/100g among those species.

2.11 Iron

Akinnawo and Ketiku (2000) registered 64.00 mg/100g of Fe in edible larva of *Cirina forda* from Nigeria.

Shen *et al*. (2006) observed 940.50 mg/100 g of Fe in edible Chinese black ant (*Polyrhachis vicina)*.

Teffo *et al*. (2007) observed 20.20 mg/100g of Fe in insect stink-bug (*Encosternum delegorguei*) from South Africa.

Bhulaidok *et al.* (2010) recorded 118.00mg/100g of Fe in edible black ants (*P. vicina*) from South Africa.

Kinyuru *et al*. (2010) found the green and brown coloured grasshoppers (*Ruspolia differens*) of Kenya contained 16.60 mg/100g and 13.00 mg/100 g of Fe respectively.

Blasquez *et al.* (2011) reported a range of 0.016 to 0.044 mg/100g of Fe content in twenty five edible Orthopteran insects from Mexico.

Finke (2012) studied the nutritional value of four species of edible insects from Mexico*viz.*, larva of soldier fly, Turkestan cockroach nymphs, tebo worms and adult house flies. He found a range of 14.00 to 125.00 mg/100g of Fe content among four species of edible insects.

Siulapwa *et al.* (2012)evaluated the nutritional value of four edible insect *viz.*, grasshopper (*Ruspolia differens*), winged termite (*Macroterm*es *falciger*) and two caterpillars (*Gonimbrasia belina* and *Gynanisa maja*). They recorded a range of 2.00 to 26.70mg/100g of Fe among those species.

Iron content of locust, cricket, grasshoppers and termites from Nigeria were determined by Ajai *et al.* (2013) and recorded a range of 205.30 to 574.75 mg/100g of Fe among those species.

Shantibala *et al*. (2014) studied the nutritional value of five species of aquatic edible insect *viz.*, *Lethocerus indicus*, *Laccotrephes maculatus*, *Hydrophilus olivaceous*, *Cybister tripunctatus* and *Crocothemis servilia* from Manipur. They recorded a range of Fe content from 7.30 to 461.00 mg/100g among those species.

2.12 Zinc

Akinnawo and Ketiku (2000) observed 8.60 mg/100g of Zn in edible larva of *Cirina forda* from Nigeria.

Shen *et al*. (2006) observed 227.00 mg/100 g of Zn in edible Chinese black ant (*Polyrhachis vicina)*.

Teffo *et al*. (2007) observed that stink-bug (*Encosternum delegorguei*) from South Africa contained 46.00 mg/100g of Zn.

Kinyuru *et al*. (2010) observed that the green and brown coloured grasshoppers (*Ruspolia differens*) of Kenya contained 17.30 mg/100g and 12.40 mg/100 g of Zn respectively.

Bhulaidok *et al.* (2010) observed 17.60 mg/100g of Zn in edible black ants (*Polyrhachis vicina*) from South Africa.

Blasquez *et al.* (2011) reported a range of 0.016 to 0.078 mg/100g of Zn content in twenty five edible Orthopteran insects from Mexico.

Finke (2012) analyzed the nutritional value of four species of edible insects from Mexico*viz.*, larva of soldier fly, Turkestan cockroach nymphs, tebo worms and adult house flies. He found a range of 32.70 to 85.80mg/100g of Zn content among four species of edible insects.

Zn content of locust, cricket, grasshoppers and termites from Nigeria were determined by Ajai *et al.* (2013) and recorded the range of 159.30 to 256.92 mg/100g of Zn among those species.

Banjo *et al.* (2013) recorded 5.50 mg/Kg and 2.70 mg/Kg of Zn in *R. phoenicis* (grubs) and *Macrotermes bellicosus* (winged termite) respectively from Nigeria.

Shantibala *et al*. (2014) analyzed the nutritional value of five species of aquatic edible insect *viz.*, *Lethocerus indicus*, *Laccotrephes maculatus*, *Hydrophilus* *olivaceous*, *Cybister tripunctatus* and *Crocothemis servilia* from Manipur. They found a range of Zn content from 5.75 to 29.50 mg/100g among those species.

2.13 Tannin

Adeduntan (2005) studied the nutritional and antinutritional characteristics of some insects from Nigeria. He reported that the tannin content of ant (400.00 mg/100g), termite (948.33 mg/100g), winged termite (250.00 mg/100g), *Anaphe venata* (753.33 mg/100g) andmeal bug (1150.00 mg/100g) respectively.

Idolo and Henry (2011) studied that the larva of coconut beetle (*Oryctesmonoceros*) contained 14.30 mg/100g of tannin.

Tannin content of yam beetle (*Heteroligus meles*) and palm weevil (*R. phoenicis*) were determined by Jonathan (2012) from Nigeria. He reported that the yam beetle and palm weevil contained 0.421 mg/100g and 0.481 mg/100g of tannin respectively.

Shantibala *et al*. (2014) reported the tannin content of *Lethocerus indicus*, *Laccotrephes maculatus*, *Hydrophilus olivaceous*, *Cybister tripunctatus* and *Crocothemis servilia* were found to be 372.33 mg/100g, 350.43 mg/100g, 528.67 mg/100g, 301.67 mg/100g and 465.33 mg/100g respectively.

The evaluation of the nutrients and some anti-nutrients in silkworm (*Bombyx mori* L.) from Nigeria was studied by Omotoso (2015). He observed that the tannin content of silkworm (*Bombyx mori* L.) larva and pupae were found to be 1.93.00 mg/100g and 2.04 mg/100g respectively.

Chakravorty *et al*. (2016) reported that tannin content of *Oecophylla smaragdina* and *Odontotermes sp.* were found to be 496.66 mg/100g and 615.00 mg/100g respectively.

2.14 Phytic acid

Adeduntan (2005) reported that the phytate content of the insects viz., ant, termite, winged termite, *Anaphe venata* andmeal bug from Nigeria were found to be 2030.79 mg/100g, 2482.08 mg/100g, 1128.22 mg/100g, 1917.97 mg/100g and 2256.43 mg/100g respectively.

The larva of coconut beetle (*Oryctesmonoceros*) contained 178.00 mg/100g of phytate as reported by Idolo and Henry (2011).

Ajayi (2012) found that the phytate content in queen, worker, soldier and alate were found to be 0.0175 mg/100g, 0.130 mg/100g, 0.0286 mg/100g and 0.0156 mg/100g respectively.

Phytic acid content of yam beetle (*Heteroligus meles*) and palm weevil (*R. phoenicis*) were determined by Jonathan (2012) from Nigeria. He reported that the yam beetle and palm weevil contained 0.311 mg/100g and 0.276 mg/100g of phytic acid respectively.

Ntukuyoh *et al*. (2012) evaluated the nutritional value of termite (*M. bellicosus*) species viz., soldier, worker and queen of Nigeria. They reported the phytic acid content of those species were 1.037 mg/100g, 1.026 mg/100g and 1.015 mg/100g.

Chakravorty *et al*. (2016) reported that phytic acid content of *Oecophylla smaragdina* and *Odontotermes sp.* were found to be 171.00 mg/100g and 141.22 mg/100g respectively.

2.15 Oxalate

The larva of coconut beetle (*Oryctesmonoceros*) contained 2.10 mg/100g of oxalate as reported by Idolo and Henry (2011).

Oxalate content of yam beetle (*Heteroligus meles*) and palm weevil (*R. phoenicis*) were determined by Jonathan (2012) from Nigeria. He reported that the yam beetle and palm weevil contained 29.00 mg/100g and 21.72 mg/100g of oxalate respectively.

Ajayi (2012) found that the oxalate content in queen, worker, soldier and alate were found to be 0.68 mg/100g, 0.0117 mg/100g, 0.94 mg/100g and 0.54 mg/100g respectively.

Omotoso (2012) reported that the larva of *Cirina forda from* Nigeria contained 4.110 mg/100g of oxalate content.

2.16 Phenol

Deori *et al*. (2014) reported that the phenolic content of muga silkworm and eri silkworm pupae were found to be 12.2 mg catechol equivalent/100g and 17.69 mg catechol equivalent/100g.

Shantibala *et al*. (2014) reported the phenolic content of *Lethocerus indicus*, *Laccotrephes maculatus*, *Hydrophilus olivaceous*, *Cybister tripunctatus* and *Crocothemis servilia* were found to be 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.

2.17 Flavonoid

Deori *et al*. (2014) reported that 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.

2.18 Antioxidant activity (DPPH)

Shantibala *et al*. (2014) reported that the IC_{50} % of *C. tripunctatus* and *C. servilia* were found to be 110 µg/mL and 880 µg/mL respectively. The species, *C. tripunctatus* had lesser IC_{50}% values with the best antioxidant property.

Deori *et al*. (2014) states that the IC_{50} % of muga silkworm and eri silkworm pupae were 25.83 µg/mL and 18.71 µg/mL respectively.

Dutta *et al*. (2016) registered that the edible insect, *Vespa affinis L*. contained 3.75 µg/µL of antioxidant activity.

CHAPTER III
MATERIALS AND METHODS

3.1 Materials

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 (Table 3.1) were obtained from different locations of Assam during 2018-19. 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.

Table. List of the species and stages used for present study

Sl. No.	Species	Stages used for study
1.	Red ant (*Oecophylla smaragdina*)	Adult
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

3.2 Analytical Methods

The Nutritional, Antinutritional and Antioxidant properties of some edible insect species of Assam were determined by using the following standard methods.

3.2.1 Determination of moisture content

Moisture content was determined by following the methods of AOAC (1970). For this,10 g fresh powdered sample were accurately weighed in aluminum moisture box and dried in an oven at 100°C (± 2°C) for 16 hours, cooled in a desiccator and re-weighed. The process was continued till a constant weight was obtained. The estimation was done in triplicate. The mean of all the three estimations was recorded.

Moisture content (g/100g sample) = $\frac{\text{Initial weight (g)} - \text{final weight (g)}}{\text{weight of the sample (g)}}$ x 100

3.2.2 Determination of crude fat content

Crude fat was determined from oven dried sample using a Soxhlet apparatus (AOAC, 1970).

For this purpose, 5g moisture free powdered sample was extracted with petroleum ether (b.p. 40-60°C) in a Soxhlet apparatus for about 16 hrs till a clear solvent was obtained. After removal of ether by evaporation, the residue was dried in an oven at 80°C, cooled in a desiccator and weighed. The estimation was done in triplicate and the mean of the three estimations was recorded as percentage of crude fat on moisture free basis.

3.2.3 Determination of crude protein content

Total nitrogen was estimated as per Kjeldahl modified method by Scales and Harrison (1920) and converted to protein values by multiplying nitrogen percentage with the factor 6.25.

In determining the total nitrogen, the organic form of nitrogen in the sample was first converted into inorganic form (ammonium sulfate) by wet digestion with conc. sulphuric acid in the presence of catalysts, copper sulphate and potassium sulfate, and subsequent decomposition of ammonium sulfate by excess alkali (40% NaOH). The liberated ammonia was collected in 4% boric acid solution. It was then titrated with hydrochloric acid of known strength.

Total nitrogen (g/100 g sample) = $\frac{(a-b) \text{ x Normality x 14 x 100}}{\text{g of sample x 1000}}$

Where,

a = ml of standard acid for sample

b = ml of standard acid for blank

If total nitrogen value is X, protein content in 100 g = X x 6.25

The estimation was done in triplicate for each sample and the mean of the estimations was recorded for interpretation of results. The protein content was expressed as percentage on moisture free basis.

3.2.4 Determination of total soluble protein

Total soluble protein was estimated by method of Lowry's *et al.* (1951). 0.1 ml sample extract was taken in each test tube and volume was made up to 1ml with water. A tube with 1ml of water was taken as blank .Similarly different volumes of working standards, less than or equal to 1ml were taken in different test tubes. 5 ml of reagent C [prepared by mixing 50 ml of reagent A (2% Na_2CO_3 in 0.1 N NaOH) and 1ml of working solution of reagent B (a mixture of equal volume of 0.5% $CuSO_4.5H_2O$ and 1% potassium sodium tartarate) was added to each tube including the blank, mixed well and allowed to stand for 10 minutes. 0.5 ml of 1N Folin ciocalteau reagent was added to each tube, mixed well and incubated at room temperature in the dark for 30 minutes. Absorbance was measured at 660 nm and protein content in the sample was calculated from the standard graph.

3.2.5 Determination of crude fibre content

Crude fibre content was determined by oxidative hydrolytic degradation of the cellulose and considerable lignin which occurs during the acid (0.255 N H_2SO_4) and the alkali (0.313N NaOH) treatments of the residues. They were oven dried at 130°C for 2hrs in crucible. The weight of the crucibles before and after ignition of the residues was noted as fibre content of the sample (Anon., 2005).

$$\text{Crude fibre} = \frac{(W2-W1)-(W3-W1)}{\text{Weight of the sample}} \times 100$$

Where, W1= preweighed crucible

W2 = weight of the residue after drying

W3 = weight of the residue after ignition

The estimation was done in triplicate and the mean of all estimations was recorded as percentage of crude fibre in moisture free sample.

3.2.6 Determination of carbohydrate content

The carbohydrate content was determined by difference, i.e., by subtracting the sum of the values (per 100g) for moisture, crude fat, crude protein, total minerals and crude fibre from 100 (AOAC, 1999).

3.2.7 Determination of ash content

The ash content was determined as described in the AOAC (1970). For this, 5 g moisture free powdered sample was taken in a silica crucible, charred in low Bunsen flame and finally ignited at 600°C for 6 hours in the muffle furnace.

$$\text{Ash content (g/100g sample)} = \frac{\text{Weight of the ash (g)}}{\text{weight of the sample taken (g)}} \text{x } 100$$

3.3 Preparation of mineral solution

The mineral solution was prepared according to the method as described by AOAC (1970). Ash was dissolved in HCl (1:1) on a water bath at 100°C and the solution was evaporated to dryness. After that 4 ml HCl and 2 ml distilled water were added and warmed. After filtration, the volume of the acid soluble portion was made up to 100 ml using distilled water. This solution was used for the estimation of sodium (Na), potassium (K), calcium (Ca), iron (Fe) and zinc (Zn).

3.3.1 Determination of Na, K, Ca, Fe and Zn

The five minerals (Na, K, Ca, Fe and Zn) were estimated using atomic absorption spectrophotometer (Chemito, AA203D, Double beam atomic absorption spectrophotometer) and flame photometer. The working range for different minerals was prepared and those were listed below:

Minerals	**Working range**
Sodium (Na)	0.1 - 0.6 ppm
Potassium (K)	0.5 - 2.0 ppm
Calcium (Ca)	1 - 4.0 ppm
Iron (Fe)	2 – 10.0 ppm
Zinc (Zn)	0.2 - 1.0 ppm

3.4 Determination of antinutritional and antioxidant activity

3.4.1 Estimation of tannin content (Folin-Denis Method)

Reagents

1) Folin-Denis reagent

2) Sodium carbonate solution

3) Standard tannic acid solution

4) Working standard solution

Method

1. 0.5g of powdered samples were weighed and transferred to a 250 ml conical flask. 75 ml of water was added. The flask was heated gently and boiled for 30 min. Centrifuged at 2000 rpm for 20 min and the supernatant was collected in 100 ml volumetric flask and make up the volume.
2. 1 ml of sample extract was transferred to a 100 ml volumetric flask containing 75 ml water.
3. 5 ml of Folis-Denis reagent, 10ml of sodium carbonate solution was added and diluted to 100 ml with water.
4. The absorbance was read at 700 nm after 30 min.

3.4.2 Estimation of phytic acid content (Wheeler and Ferrel, 1971)

Reagents

1) 3% TCA

2) 3% Sodium sulfate in 3% TCA

3) 1.5N NaOH

4) 3.2N HNO_3

5) $FeCl_3$ solution

6) 1.5M potassium thiocyanate (KCSN)

Method

1. 2g of finely samples was weighed
2. Samples were extracted in 50 ml 3%TCA for 30 min with mechanical shaking or with occasional swirling by hand for 45 min.
3. The suspension was centrifuged and transferred a 10 ml aliquot of the supernatant to a 40 ml conical centrifuge tube.
4. 4 ml of $FeCl_3$ solution was added to the aliquot by blowing rapidly from the pipette.
5. The contents were heated in a boiling water bath for 45 min.

6. The clear supernatant was centrifuged (10-15) and carefully decant.
7. The precipitate was washed twice by dispersing well in 20-25 ml 3% TCA and was heated in boiling water for 5-10 min and centrifuged it again.
8. Repeated washing with water.
9. The precipitate was dispersed in a few ml of water and then 3 ml of 1.5N NaOH was added.
10. Brought the volume to 30 ml with water and heated in boiling water for 30 min.
11. Mixture was filtered by Whatman filter paper No.2.
12. The precipitate was washed with 60 ml hot water and the discard was filtrated
13. The precipitate was dissolved with 40 ml hot 3.2N HNO_3 into 100 ml volumetric flask.
14. The paper was washed with several portion of water, collecting the washings in the same flask.
15. The flask and contents were cooled to a room temperature and it was diluted to a volume with water.
16. 5 ml aliquot was transferred to another 100 ml volumetric flask and diluted to approximately 70 ml.
17. 20 ml of KSCN was added and the colour was read immediately at 480 nm.
18. A reagent blank was runned with each set of samples.

3.4.3 Determination of oxalic acid (Mohanraj *et al,* 1971)

Reagents

1) 4N H_2SO_4
2) 1N NaOH
3) Diethyl ether
4) Calcium chloride acetate buffer
5) 5% acetic acid saturated with calcium oxalate
6) Saturated 0.02N Potassium permanganate solution.

Sample Extraction

1. Oven dried the tissue to a constant weight in a hot-air oven at 80°C.
2. Grinded the tissue to a fine powder in a mortar and pestle. Then dried the powder again and took 500 mg from it.
3. Samples were mixed with 1g of asbestos and 1.5 ml of 4N H_2SO_4.
4. Extraction thimble was filled to a depth of 2 cm with clear ground glass. Two circular pieces of cheese cloth were placed.
5. The samples mixed with asbestos and H_2SO_4 were transferred to the thimble.
6. The thimble was placed with contents in soxlet extraction apparatus and extracted with 500 ml of pure diethyl ether for 48 hr.
7. 5 ml of 1N NaOH and 7 ml of water was added to the extract and shake it well.
8. The ether layer in a rotary evaporator was evaporated.
9. The water phase was transferred to a centrifuge tube and 4 ml of calcium chloride acetate buffer was added and kept it overnight.
10. Centrifuged at 3000g for 10 min
11. The supernatant was discarded and washed the pellet with 5 ml of 5% acetic acid saturated with calcium oxalate and centrifuged.
12. The residue was dissolved in 5 ml of 4N H_2SO_4 and was heated at 80-90°C on a water bath.
13. It was filtered and titrated against 0.02N potassium permanganate solution.
14. The amount of oxalic acid was calculated (mg/100g sample) present in the sample using the relationship:

    1 ml of 0.02N potassium permanganate = 1.2653 mg of oxalic acid.

3.4.4 Estimation of total phenol content (Malick and Singh, 1980)

Reagents

1) 80% ethanol

2) Folin-Ciocalteu reagent

3) 20% Na_2CO_3

4) Standard (100 mg catechol in 100 ml of water). Dilute 10 times for working standard.

Method

1. 1g of each sample was mixed with 10 times volume of 80% ethanol.
2. The homogenate were centrifuged at 10,000 rpm for 20 min and the supernatant were saved. The residue was re-extracted with five times the volume of 80% ethanol, the supernatants were centrifuged and pool.
3. The supernatant was evaporated to dryness.
4. The residue was dissolved in a known volume of distilled water (5 ml)
5. Different aliquot was pipetted out (0.2-2 ml) into test tubes.
6. The volume was made up to 3 ml of water.
7. 0.5 ml of Folin-Ciocalteu reagent was added.
8. After 3 min, 2 ml of 20% Na_2CO_3 was added.
9. Mixed thoroughly, the tubes were placed in a boiling water for exactly one min, cooled it and the absorbance was measured at 650 nm against a reagent blank.

3.4.5 Estimation of total flavonoid (Woisky and Salatino, 1998)

0.5g of each sample was taken and mixed with 5 ml of 80% ethanol in 100 ml of conical flask and placed on a shaker at 200 rpm for 24 hrs. After 24 hrs, the extracts were filtered through Whatman No.42 filter paper. The volume of the filtrate was adjusted to 5 ml with 80% ethanol and kept it for further analysis.

The total flavonoid was determined according to Woisky and Salatino (1998) with slight modification. 0.5 ml of extracts of each sample was taken in a test tube followed by addition of 1.5 ml 95% ethanol, 0.1 ml of aluminium chloride, 0.1 ml of 1M potassium acetate and 2.8 ml of distilled water. After incubation for 30 min at room temperature, the absorbance was measured at 415 nm in spectrophotometer.

3.4.6 Estimation of total antioxidant activity, DPPH (Vani *et al.*, 1997)

Method

1. 2g of samples was extracted with 20 ml of methanol (99.5%).
2. The extraction step was done twice each for 2 hrs in shaking machine.

3. The supernatant was filtered using Whatman No.1 filter paper after centrifuging the suspension at 10,000 rpm for 15 min, till analysis filtrated stored at -20°C.
4. 100 µl of aliquot of sample extract was taken in a test tube and 2.9 ml of DPPH solution was added, after that vortex the mixture.
5. The test tube was incubated for half and hour in dark.
6. The discolouration of DPPH was measured against blank at 517 nm.

Calculation:

$$\% \text{ inhibition} = \frac{(Ao - A)}{Ao} \times 100$$

where,

Ao = Absorbance of blank

A = Absorbance of sample

3.5 Statistical analysis

The mean values of the observations recorded on sampled genotypes were subjected to the following statistical and biometrical analyses.

3.5.1 Analysis of variance

The mean data for each of the physical and biochemical parameters were subjected to analysis of variance following randomized block design, in which, data recorded in different period were considered as replication .

The partitioning of the total variance assignable to different sources was done according to Fisher's method as follows:

Source of variance	Degree of freedom	Mean square	Expected mean square
Replication	(r-1)	---	---
Variance	(g-1)	MSg	$\sigma^2_e + r\sigma^2_g$
Error	(r-1)(g-1)	MSe	σ^2_e

Genotypic variances were tested against error variance by applying usual F-test of significance.

In order to test the difference of means of the genotypes, critical differences (CD) was calculated as follows:

CD = $SE_{d.}$ xt for error df at 0.05 and 0.01 level of probability.

$SE_{d.}$ is the standard error of the difference of genotypic means to be tested.

$SE_d = (2MSe/r)^{1/2}$

Where,

MSg = Genotype mean square

MSe = Error mean square

r = Number of replication

CHAPTER IV
EXPERIMENTAL FINDINGS

Results obtained in the present investigation are presented under different heads in this chapter. Based on ANOVA (Analysis of Variance), all the parameters studied here were found to be significant.

4.1 Proximate composition

4.1.1 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 4.1, Fig. 1). However, moisture content registered in case of honeybee (*A. cerana*)and muga silkworm, (*A. assamensis*)were found to be *at par* with each other.

4.1.2 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 4.1, Fig. 2). However, the fat content recorded in honeybee (*A. cerana*)and red ant (*O. smaragdina*) were found to be *at par* with each other.

4.1.3 Crude protein content

The highest crude protein content (52.35%) was recorded in species mugasilkworm (*A. assamensis*) and the lowest (23.31%) was observed in the species winged termite (*O.obesus*) (Table 4.1, Fig. 3).The crude protein content of red ant(*O. smaragdina*), honeybee(*Apis cerana*)and eri silkworm(*Samia ricini*)werealmost similar to each other.

Table: 1 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

4.1.4 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 4.1, Fig. 4). The soluble protein content were 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.

4.1.5 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%). The lowest crude fibre content (3.16%) was registered in the species eri silkworm (*Samia ricini*).

4.1.6 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%).The lowest carbohydrate content (7.20%) was recorded in the species eri silkworm (*S.ricini*).

4.1.7 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*) andhoney bee (*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 4.2, Fig. 7).

Table: 2 Elemental composition of five edible insects

Insect species	Ash (%)	Sodium (mg/100 g)	Potassium (mg/100 g)	Calcium (mg/100 g)	Iron (mg/100g)	Zinc (mg/100 g)
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

4.2. Mineral composition

In the present study,five minerals, namely sodium, potassium, calcium, iron and zinc were estimated and the results are presented in the Table 2.

4.2.1 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 2, Fig. 8)

4.2.2 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 2, Fig. 9). 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.

4.2.3 Calcium content

The calcium content (222.83 mg/100g) of honeybee (*A. cerana*)was found to be highest among the species (Table 2, Fig. 10). The species muga silkworm (*A.assamensis*) was recorded with lowest amount (20.65 mg/100g) of calcium content.

4.2.4 Iron content

The honeybee (*A. cerana*)was registered withthe 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 2, Fig. 11).

4.2.5 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 2, Fig. 12).

Table: 3 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

4.3 Antinutritional and antioxidant composition

4.3.1 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 3, Fig. 13)

4.3.2 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 3, Fig. 14).

4.3.3 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 3, Fig. 15).

4.3.4 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 3, Fig. 17).

4.3.5 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). 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*).

4.3.6 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 3, Fig. 18).

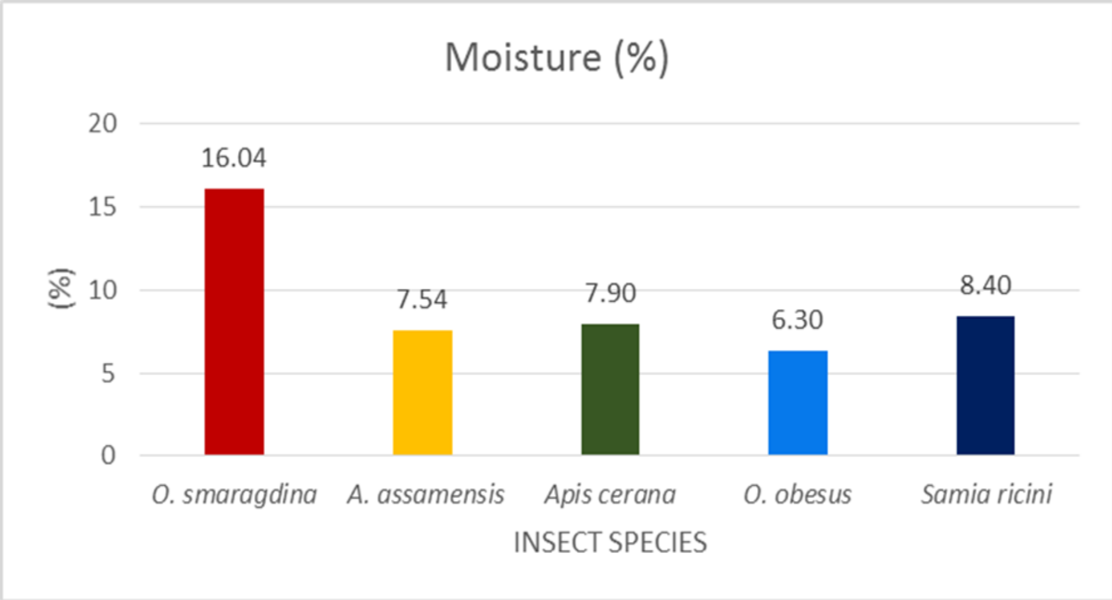

Fig.1. Moisture content of five edible insects

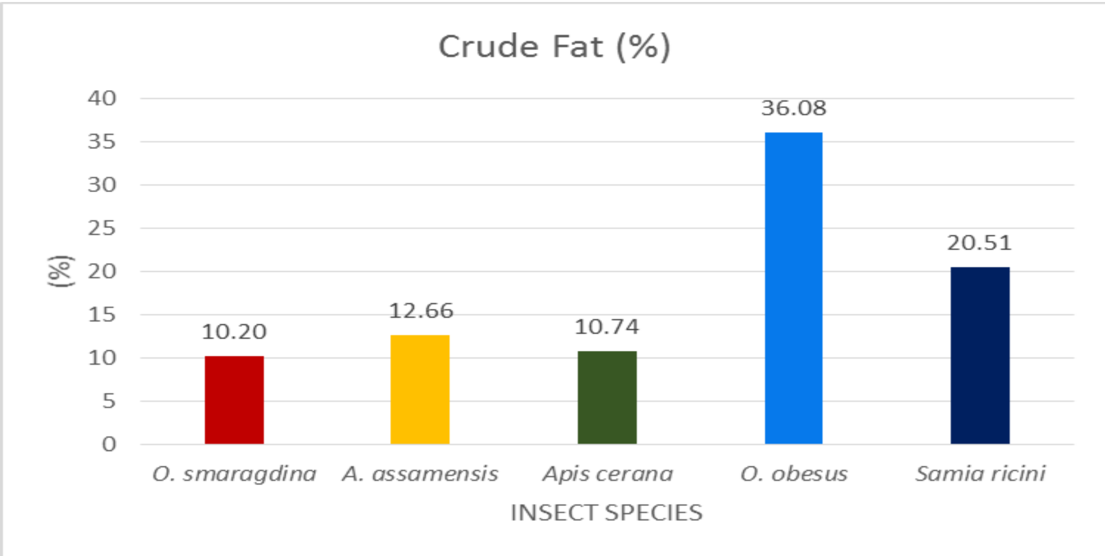

Fig.2. Crude fat content of five edible insects

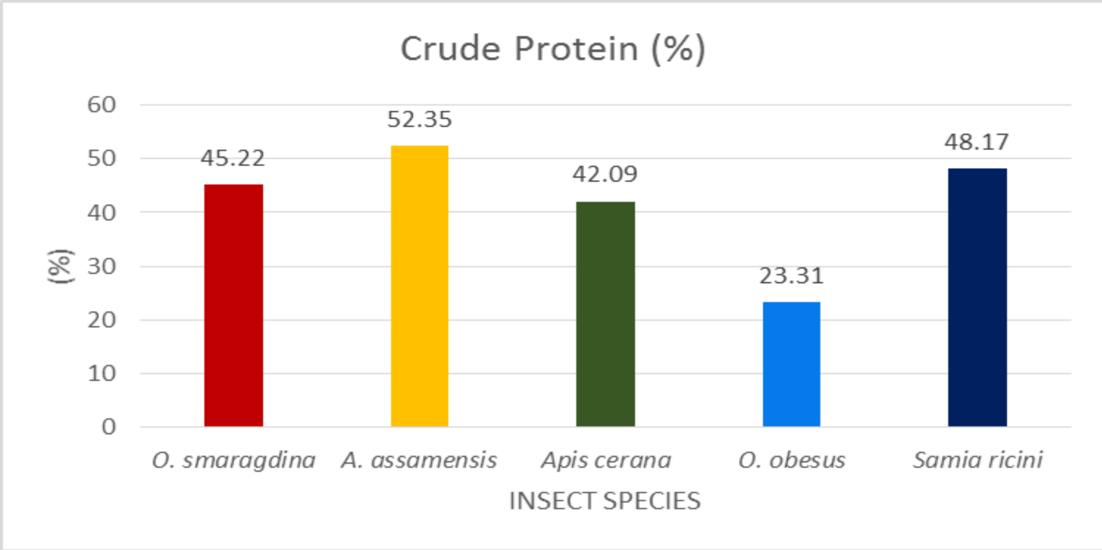

Fig.3. Crude protein content of five edible insects

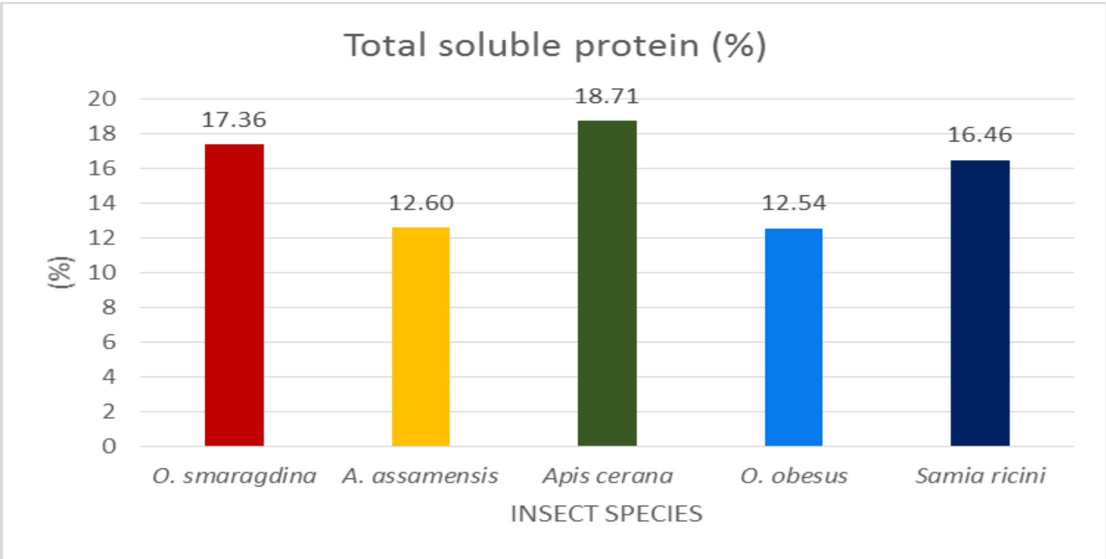

Fig.4. Total soluble protein content of five edible insects

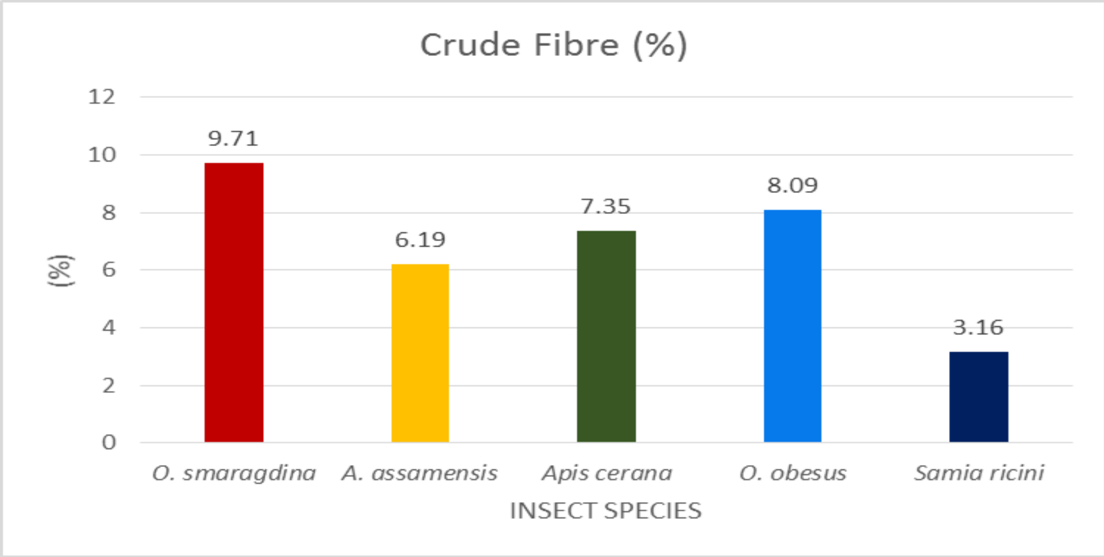

Fig.5. Crude fibre content of five edible insects

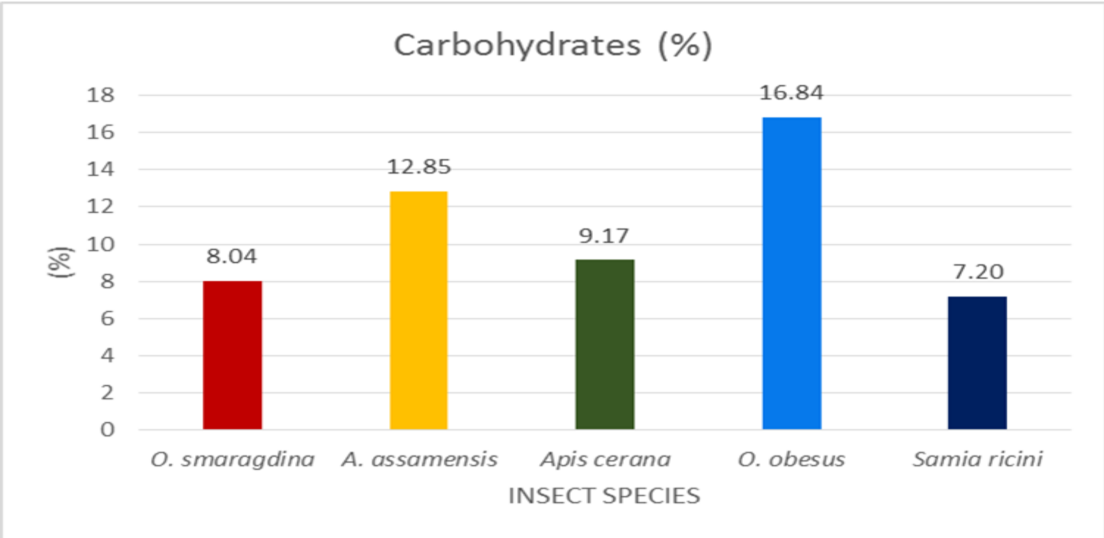

Fig.6. Carbohydrate content of five edible insects

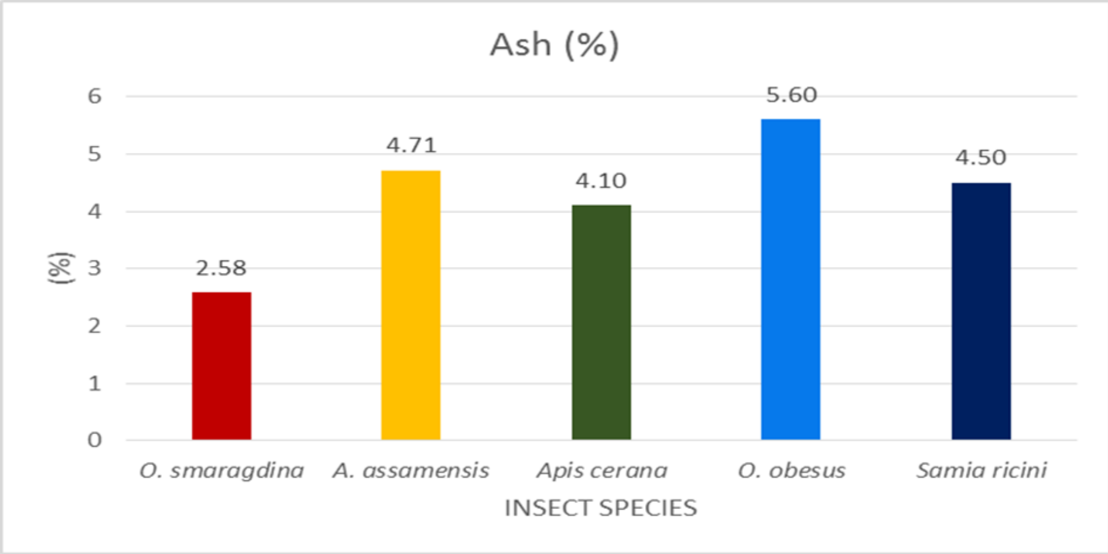

Fig.7. Ash content of five edible insects

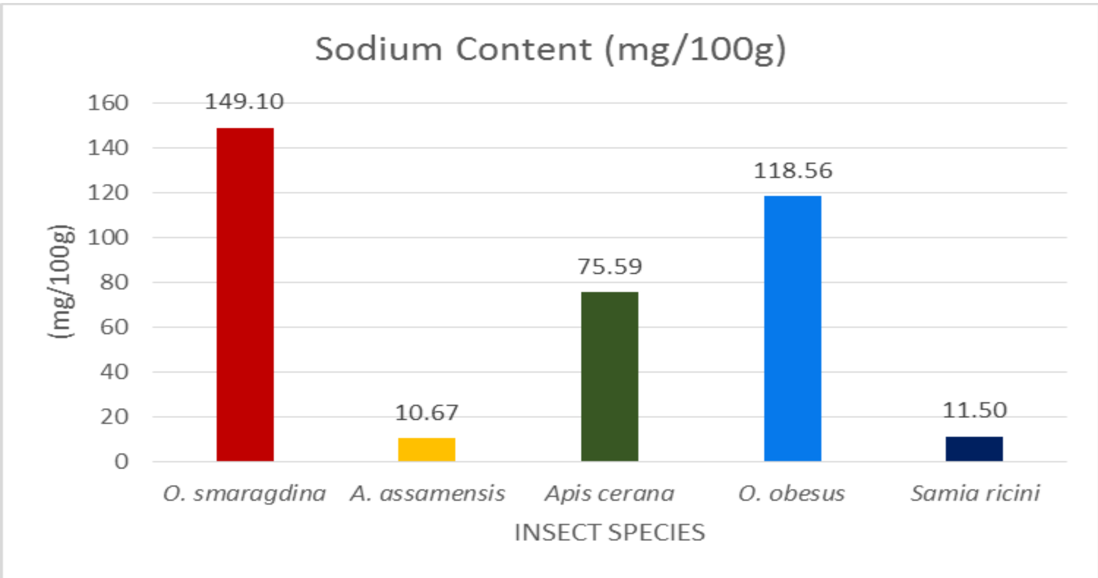

Fig.8. Sodium content of five edible insects

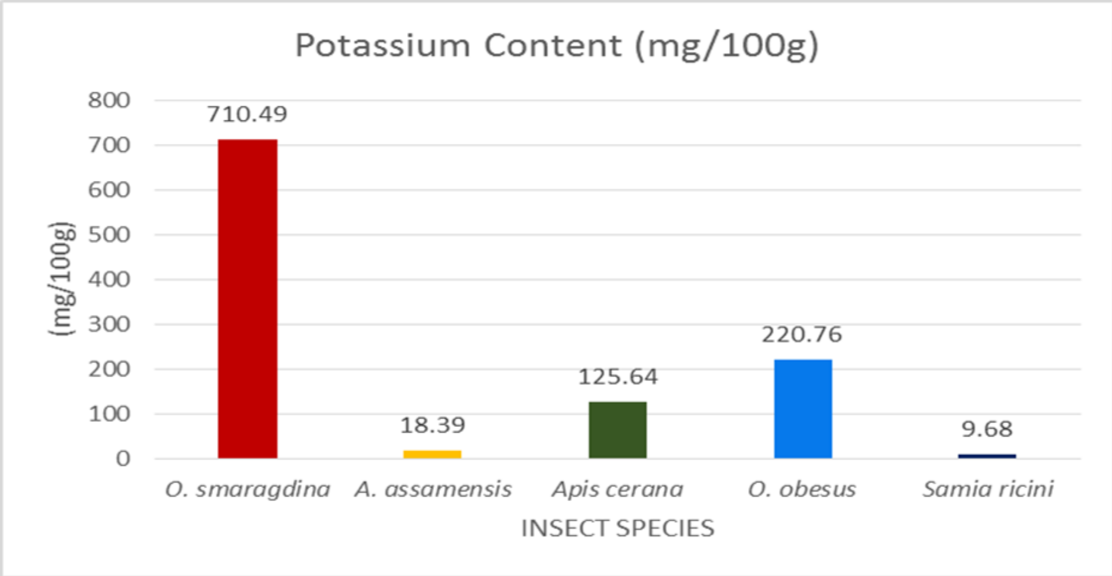

Fig.9. Potassium content of five edible insects

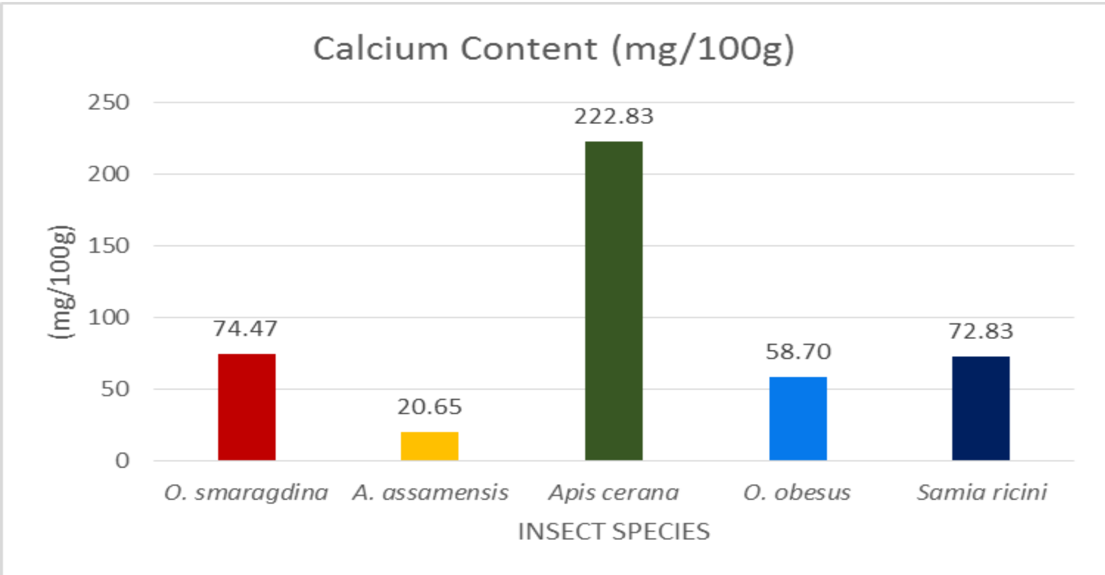

Fig.10. Calcium content of five edible insects

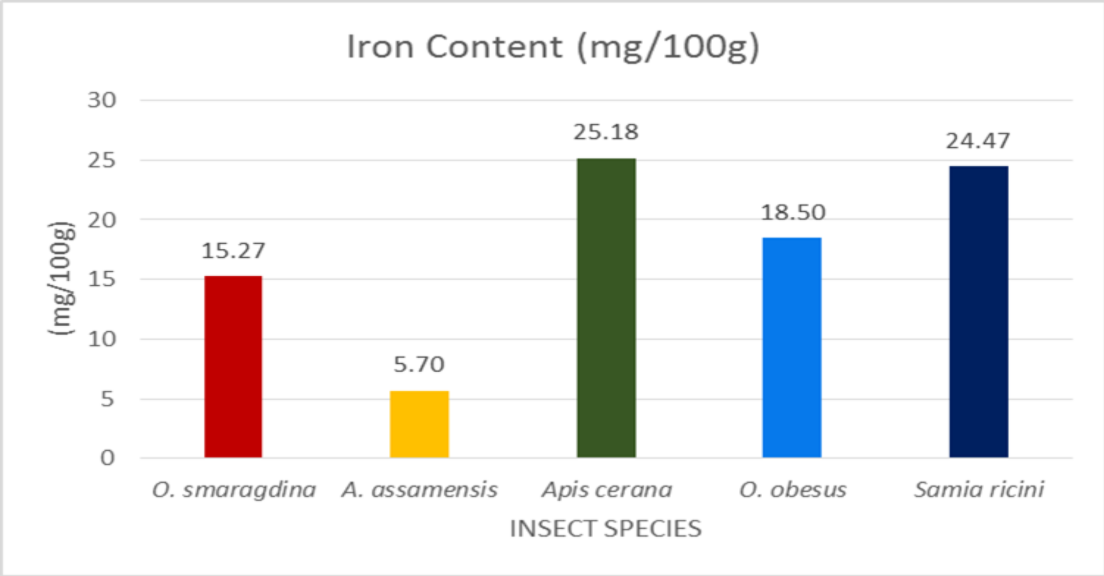

Fig.11. Iron content of five edible insects

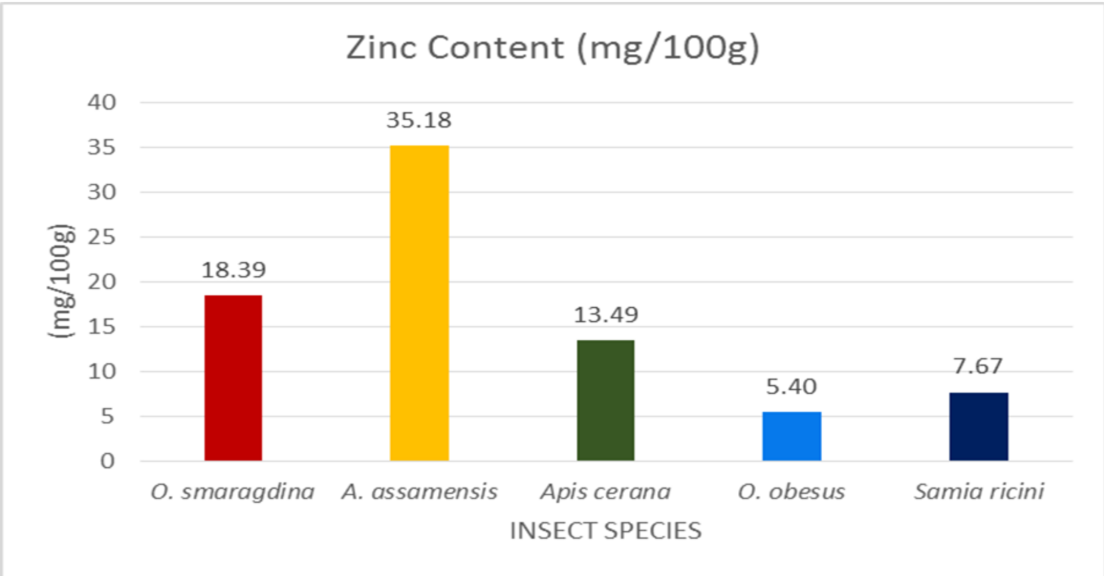

Fig.12. Zinc content of five edible insect

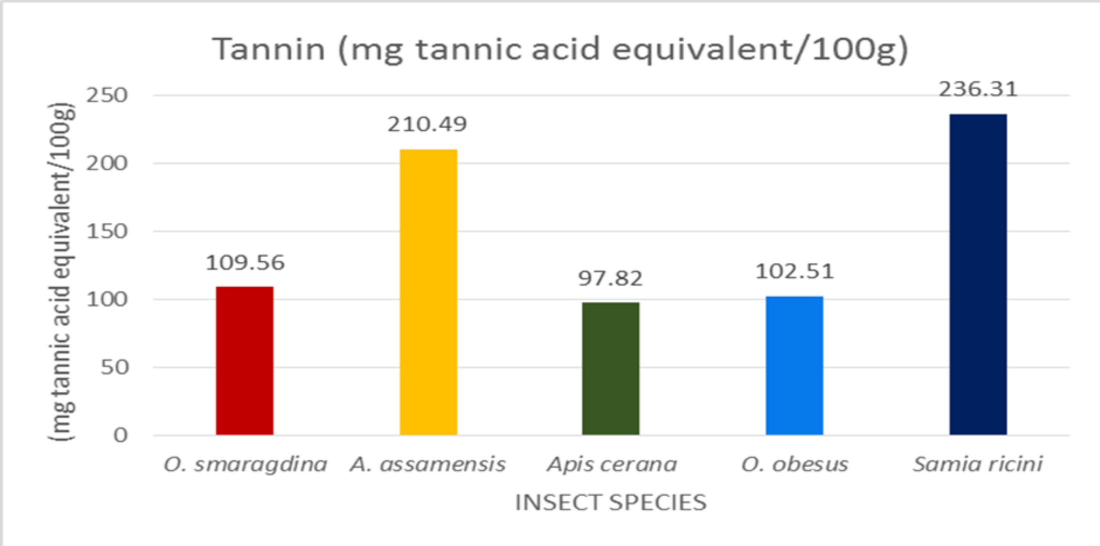

Fig.13. Tannin content of five edible insects

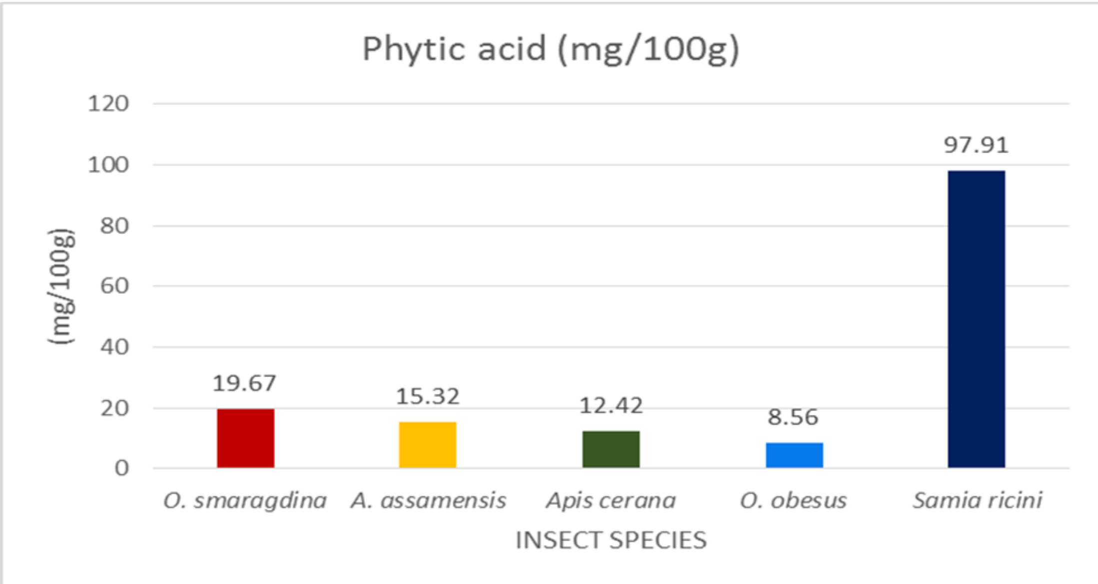

Fig.14. Phytic acid content of five edible insects

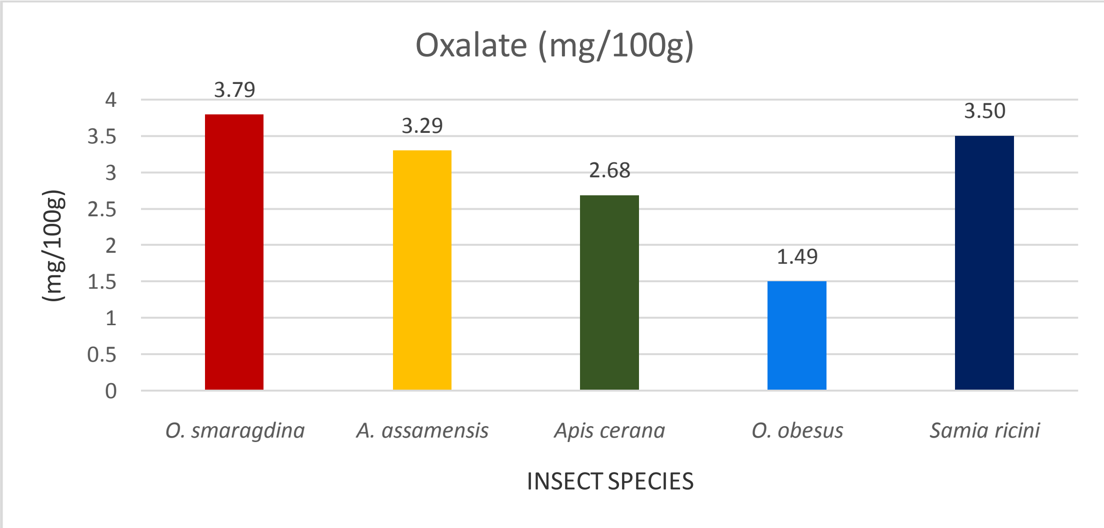

Fig.15. Oxalate content of five edible insects

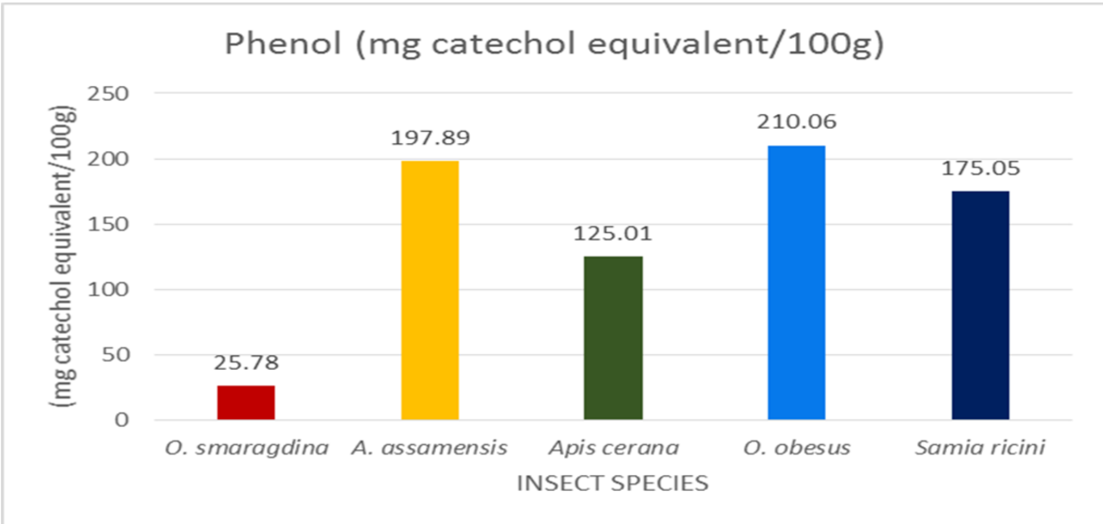

Fig.16. Phenol content of five edible insects

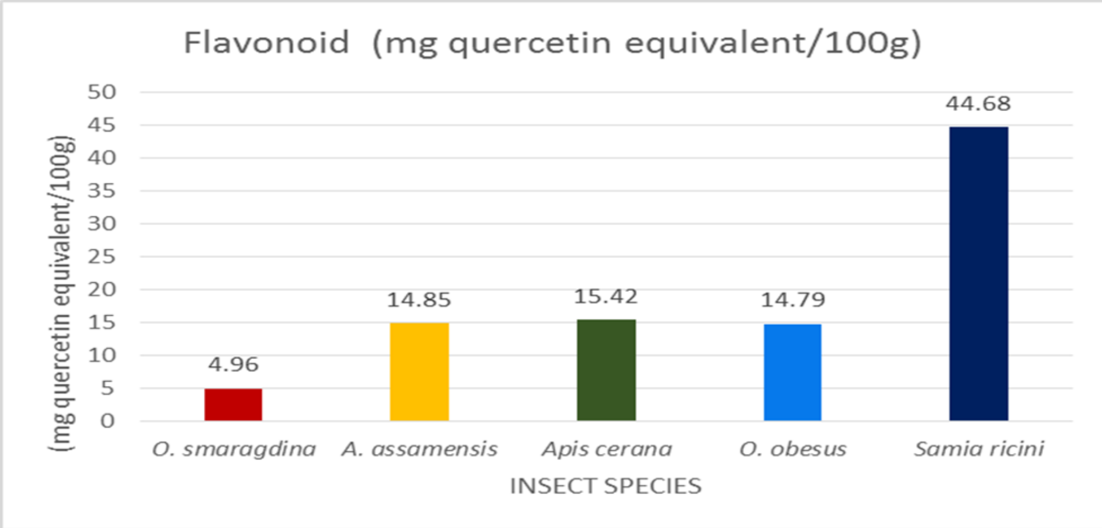

Fig.17. Flavonoid content of five edible insects

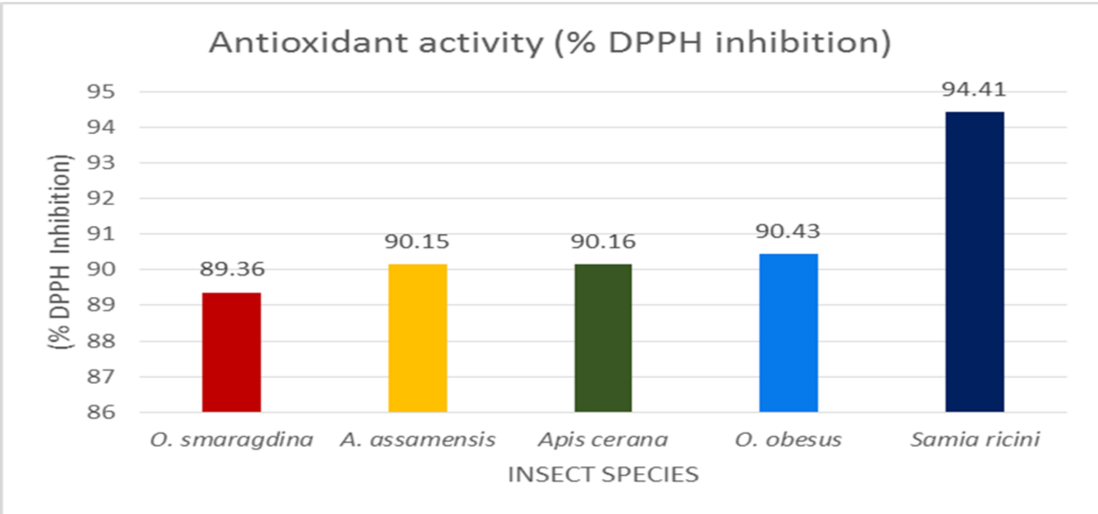

Fig.18. Antioxidant activity (DPPH) of five edible insec

CHAPTER V
DISCUSSION

The results obtained from the five different edible insects of Assam are discussed in this chapter.

5.1 Proximate contents of five different edible insects

5.1.1 Moisture

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) 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) 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). The value (6.30 %) of winged termite (*O.obesus*) of present study was comparable with Kinyuru *et al*. (2013) who found a range of 5.13 to 8.76 per cent moisture in winged termite species (*M. nigeriensis*). The value of present findings (8.4%) in eri silkworm was almost similar with the result of Longvah *et al*. (2011) who recorded 8.2 per cent in eri silkworm.

5.1.2 Crude fat

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), who showed the crude fat content of red ant (*O. smaragdina*) was 14.99 per cent. Siulapwa *et al.* (2012)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) 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) 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) who reported fat content within the range of 6.90 to 14.50 per cent.

5.1.3 Crude protein

Protein content is high in insects, therefore edible insects helps to increase dietary quality. The protein content of insects also depends on the metamorphosis stage, adults usually have higher protein content than instars.

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) 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) and Siulapwa (2012). 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 edible insect species studied in present investigation contained higher amounts of protein than other plants and animals food such as beef, chicken, fish, soybeans and maize.

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, 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) 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) 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) was found to be higher than the present investigation (48.17%). Ramos-Elorduy *et al.* (1997) 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.

5.1.4 Total soluble protein

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.

Present investigation corroborate with the results of Hemalatha *et al*. (2015) who recorded the soluble protein level of silkworm (*Bombyx mori* L.)during the 5^{th} instar development. The total soluble protein content of CNS, muscle, silk gland, fat body and hemolymph of silkworm of day1 to day7 ranged from (32.90 to 49.00%), (32.30 to 59.40%), (44.40 to 127.30%), (33.80 to 41.90%) and (11.60 to 33.80%) respectively.

5.1.5 Crude fibre

Crude fibre is a measure of the quantity of indigestible cellulose, pentosans, lignin and other components present in foods. These components have little food value but provide the bulk, necessary for proper peristaltic action in the intestinal tract. Insects contain significant amounts of fibre, as measured by crude fibre, acid detergent fibre and neutral detergent fibre.

The crude fibre present in muga silkworm (6.19%) was compared to the results of Omotoso (2015) 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) 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). 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).

5.1.6 Carbohydrates

Carbohydrates are necessary for optimum growth, development, reproductive activity, and survival of individual species. For most insect species, glucose, fructose, and sucrose are nutritionally adequate sugars.

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) in edible black ant (*P. vicina*)andrecorded 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) who recorded a relatively higher amount of carbohydrate in all the castes of *Macrotermes bellicosus* (34.84-67.09%).

5.1.7 Ash

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) 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), 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) 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) in four species of winged termite. However, the ash content in eri silkworm recorded by Longvah *et al.* (2011) was in a range of 1.10 to 4.20 per cent which was slightly lower than ash value (4.50%) of present investigation.

5.2 Elemental contents of five different edible insects

5.2.1 Sodium

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 (150.00mg/100g) of Chakravorty *et al*. (2016). 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), 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). Present findings of Na (118.70 mg/100g) can be compared with the results of Chulu (2015) who found 118.70 mg/100g of Na in species winged termite.

5.2.2 Potassium

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 (710.00mg/100g) of Chakravorty *et al*. (2016). 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), who observed a range of 18.65 to 22.45 mg/100g of K in muga silk worm. Igwe *et al*. (2011) 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) recorded a higher range (170 to 643 mg/100g) of K content in aquatic edible insect from Manipur.

5.2.3 Calcium

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). 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), 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 valueis 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).

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). 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).

5.2.4 Iron

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) who recorded the Fe content (15.66 mg/100g) in red ant (*O. smaragdina*)andthis 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) 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). The result of Fe content 25.18 mg/100g) in honeybee was found to be similar with the earlier result (25.20 mg/100g) of Banjo *et al.*(2006). Chulu (2015) 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).

5.2.5 Zinc

Zinc content recorded in muga silkworm (*A. assamensis*), red ant(*O. smaragdina*), honeybee(*A. cerana*), eri silkworm (*S. ricini*)andwinged 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) who recorded Zn content in red ant (18.97 mg/100g). This result was found to besimilar 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). 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). 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), 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) in eri silkworm.

5.3 Antinutritional and antioxidant contents of five edible insects

5.3.1 Tannin

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 (210.49mg 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). 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.

5.3.2 Phytic acid

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*)andwinged 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 were found to be lower than the earlier report of Adeduntan (2005). He reported that the phytic acid content of ant, termite, winged termite from Nigeria were found to be 2030.79 mg/100g, 2482.08 mg/100g, 1128.22 mg/100g respectively.

5.3.3 Oxalate

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) who registered 2.10 mg/100g of oxalate in the larva of coconut beetle (*O.monoceros*). Similarly,Omotoso (2012) reported that the larva of *Cirina forda* fromNigeria contained 4.11 mg/100g of oxalate.

5.3.4 Phenol

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) 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.

5.3.5 Flavonoid

The flavonoid (44.68 mg quercetin equivalent/100g) content of eri silkworm (*S. ricini*) was found to be superior than 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) 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.

5.3.6 Antioxidant activity (DPPH)

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) reported that the IC_{50} % of species *C. tripunctatus* and *C. servilia* were found to be 110 µg/mL and 880 µg/mL respectively.

The different biochemical parameters studied under present investigation showed a considerable variation among the different edible species. The nutritional value of different edible insect species studied here were found to be highly variable because of the wide range of edible insect species. The variation in nutritional value of different edible insect species from present investigation is mainly due to different metamorphic stage of the insect species, habitat in which they live and their diet.

CHAPTER VI

SUMMARY AND CONCLUSION

The present investigation wasconducted to evaluate the nutritional, antinutritional and antioxidant properties of five edible insects of Assam. Significant findings of these experiments are summarized below.

- Proximate analysis showed that highest moisture content was recorded in red ant (*O. smaragdina*) 16.04% and lowest in winged termite (*O. obesus*) 6.30%. The moisture content registered in muga silkworm (*A. assamensis*) and honeybee (*A. cerana*) and eri silkworm (*S.ricini*) were 7.54 per cent, 7.90 per cent and 8.40 per cent respectively.
- Highest fat content (36.08%) was recorded in species winged termite (*O. obesus*) and it was found to be superior over the remaining four species. The lowest (10.20%) crude fat content was recorded in red ant(*O. smaragdina*).
- Out of all the five edible insects, the highest crude protein (52.35%) content was recorded in muga silkworm (*A. assamensis*)and the lowest (23.31%) was found in winged termite (*O. obesus*). However, the remaining three species *viz.* red ant (*O. smaragdina*),honeybee (*A. cerana*) and eri silkworm (*S. ricini*) registered 45.22 per cent, 42.09 per cent and 48.17 per cent of crude protein respectively.
- The highest soluble protein content (18.71%) was recorded in honeybee (*Apis cerana*), which was found to be significant over rest of the species. The species winged termite (*O. obesus*)was recorded with lowest amount (12.54%) of soluble protein.
- Highest crude fibre content (9.78 %) was recorded in red ant (*O. smaragdina*)followed by winged termite (8.10%) and honeybee (7.38%). However, the species eri silkworm (*Samia ricini*) was registered with lowest amount (3.16%) of crude fibre.

- The highest carbohydrate content (16.84%) was recorded in winged termite followed by muga silkworm (12.85%), honeybee(9.22%), red ant (8.04%) and eri silkworm (7.20%).
- The range of ash content among the five different species were between 2.58 to 5.60 per cent and differed significantly from each other.
- Among the five different species,the highest sodium content (149.10 mg/100g) was registered in red ant (*O. smaragdina*) while the lowest (10.67 mg/100g) was recorded in muga silkworm (*A.assamensis*).
- The highest (710.49 mg/100g) K was recorded in red ant (*O. smaragdina*) followed by winged termit*e* (220.76 mg/100g) and honeybee (125.64 mg/100g).
- The highest Ca content (222.83 mg/100g) was found in honeybe*e* (*A. cerana*)and lowest(20.65%) was found in muga silk worm.
- The range of Fe content among the five insect species ranged between 5.00 to 25.87 mg/100g
- The highest (35.18 mg/100g) zinc content was registered in muga silkworm (*A. assamensis*) and lowest (5.40 mg/100g) was in the species winged termite (*O. obesus*)
- As for antinutritional factors, the range of tannin content among the five insect species ranged between 97.82 to 236.31 mg tannic acid equivalent/100g.
- The range of phytic acid content among the five insect species ranged between 97.82 to 97.91 mg tannic acid equivalent/100g.
- The range of oxalate content among the five insect species ranged between 1.49 to 3.75 mg/100g.
- The highest flavonoid content (44.68 mg quercetin equivalent/100g) in eri silkworm(*S. ricini*) and among the five insects, red ant (*O. smaragdina*) contained the lowest flavonoid content (4.96 mg quercetin equivalent/100g).
- The highest phenolic content (210.06 mg catechol equivalent/100g) was recorded in winged termite (*O. obesus*) whereas, red ant (*O. smaragdina*) contained lowest flavonoid (25.78 mg quercetin equivalent/100g).

- The antioxidant activity (DPPH) among the species were recorded in between 89.36 to 94.41 per cent DPPH inhibition.
- Not a single insect species was found superior over the others for all the biochemical parameters studied. All the species studied contain a high amount protein, fat and soluble protein and however, a 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 a potential source for human food and animal feed.
- 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 further study for complete mineral profiling, amino acid profiling, fatty acid profiling, vitamin composition and protein digestibility.
- The present study also suggest to carry out research on innovative issues such as insect nutrition and food safety, use of insects as animal feed, the processing and preservation of insects and their products to support livelihoods in both developing and developed countries.

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