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# Nutritive evaluations of laboratory-reared edible field cricket *Coiblemmus compactus* Chopard, 1928 (Orthoptera: Gryllidae), for utilising them as an alternate protein source

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## Abstract

**Background:** The increasing world population has made researchers to explore and validate alternate food sources for the future; in that regard, due to the attractive nutritive profile, edible insects ensure the food and feed security in some developing countries. Crickets are orthopteran edible insects widely eaten around the world not as an emergency food but as a delicacy. This present study aims to stabilise a mass rearing technique of field cricket *Coiblemmus compactus* using cost-effective rearing medium and feed materials.

**Results:** The reared adult crickets were processed and analysed for its proximate, mineral, amino acid, fatty acid and energy contents. The cost-effective rearing methods were standardised for the cricket species, and the obtained nutritive values were comparatively higher than other edible meat sources. The cricket *Coiblemmus compactus* had  $50.2 \pm 0.37$ ,  $26.50 \pm 0.80$ ,  $8.20 \pm 1.61$ ,  $5.50 \pm 0.48$ ,  $10.93 \pm 0.19$  and  $5.40 \pm 0.16$  g/100 g of crude protein, crude fat, carbohydrate, crude fibre, moisture and ash contents, respectively. The cricket also possessed higher amounts of potassium ( $897.83 \pm 1.55$  mg/100 g) and phosphorous elements ( $604.66 \pm 4.11$  mg/100 g) with  $458.30 \pm 0.29$  kcal/100 g of energy content. The chromatography studies showed the abundance of amino acid and fatty acid contents in the reared edible cricket.

**Conclusions:** The attractive and high-protein nutritive profile of edible cricket *Coiblemmus compactus* makes itself an alternate food and feed material to elevate food crisis in developing countries.

**Keywords:** Entomophagy, Crickets, Gryllidae, Nutrition, Protein source

## Background

In recent years, most of the developing countries are facing a high global demand for food due to various reasons; among them rapid urbanisation and increase in economies are some major factors (Paul et al., 2016). Some of the natural factors like climate change, energy crisis, incidence of pests and plant diseases and disparity in food distribution may aggravate the demand for

food and cause food insecurity (Gahukar, 2009, 2011; Kumar, 2010). In order to satisfy the increased world population's food need, the total world's food production has to be almost doubled (Huis et al., 2013). As there is a great hike in consumer population, there is an urgent need to identify the alternative protein sources for the developing countries (Samuel et al., 2016). In that regard, insects are an untapped human food source and a radical food innovation to solve the anticipated global hunger. Insects can be potentially utilised as an alternative protein source, and also insect rearing could appear as one of the ways to enhance food and feed security (Huis

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et al., 2013). Utilisation of insects as food is termed as 'entomophagy,' and this term is gaining more attention in recent times due to the urgent need for an alternate food source. Entomophagy has been practised culturally in 113 countries all around the world (MacEvilly, 2000), and more than 2,000 insect species were reported to be edible (Jongema, 2012; Rumpold & Schluter, 2013). In several parts of the world, orthopteran insects are cultured for human consumption, and among them crickets are the most consumed insects (Magara et al., 2019; Oonincx et al., 2015; Orinda, 2018; Ramos-Elorduy, 2009). The most common species includes *Brachytrupes membranaceus*, *Gryllus similis*, *Gryllus bimaculatus*, *Gryllotalpa orientalis* and *Acheta domesticus* (Ayieko et al., 2016; Orinda, 2018).

India is a rich bio-diversified country inhabited with more ethnic groups distributed all around whose cultural practices differ in accordance with their geographical nature and resource availability. Most of the ethnic people of India consume crickets as their traditional food, and that has made clear that crickets are reliable and efficient alternate source of food. Edible crickets have become popular in the past few years, and one of the major advantages of eating crickets is their impressive nutritional composition (Magara et al., 2021), as they were found to be rich sources of proteins and other nutrients (Araujo et al., 2019).

In this world of ever-growing population, the search for alternate food source is of great concern and edible insects could be a remedy for that. In this present study, the field cricket *Coiblemmus compactus* were reared under laboratory conditions using green vegetable matter which is a low-cost and sustainable feed material; then, the obtained adult crickets were characteristically analysed to explore its nutritional profile.

## Methods

### Collection and rearing of crickets

The field crickets of *Coiblemmus compactus* species were collected from the grasslands of Madras Christian College campus (80°7' E & 12°55' N) located in Tambaram, Chennai, Tamil Nadu, which is a tropical dry evergreen forest with average temperatures of 21 °C (minimum) and 41 °C (maximum). It is located at 30 MSL elevations and receives 1300 mm of an average annual rain fall. Handpicking method and nets were used for the collection of orthopteran crickets from the study area having scrub jungle vegetation. A pair of the collected samples of both the species was preserved (Ghosh & Sengupta, 1982) and then submitted in Zoological Survey of India, Kolkata, for taxonomic identification and authentication. The remaining insects were taken for breeding by following the methods described by Magara et al. (2019)

and FAO (2020) with some modifications. The crickets were reared in rectangular plastic breeding containers (60 × 30 × 30 cm), in which egg cartons are arranged and covered with muslin cloth. The cricket colonies were fed with fresh cabbage on alternate days and supplied with sufficient quantities of water. A cup of moist sand was kept inside the culture box to act as an ovitrap for three days and then incubated in an empty container for 5–6 days at room conditions (30–35 °C temperature and 65–70% relative humidity) for hatching. The newly hatched pinheads were then transferred to spacious culture boxes and reared with sufficient supply of feed and water to produce mass colonies. Only during the nursing period (for the initial 3 days), the pinheads were fed with rice and wheat flour in addition to cabbage.

### Processing of reared crickets for analyses

The reared healthy adult crickets were starved without food for 24 h prior to be killed to clear their gut contents. The insects were freeze-killed and then dried in hot air oven at 70 °C for 8 h. The dried insects were ground into fine powder using an electric blender, then packed in air-tight zip lock covers and stored in dry place at room temperature (30–35 °C) for laboratory analyses.

### Nutritional analyses of reared crickets

The processed cricket samples were subjected to proximate composition, mineral, amino acid, fatty acid and energy content analyses using standard methods.

### Proximate composition analyses

#### Determination of crude protein content (Bureau of Indian standards IS: 7874 [2014])

The crude protein content of the sample was determined by calculating the difference in percent by mass of total nitrogen, and that of ammoniacal nitrogen is multiplied by the conversion factor ( $f = 6.25$ ).

$$\text{Crude protein (g)} = 6.25(X - Y)$$

where  $X$  is the percent by mass of total nitrogen and  $Y$  the percent by mass of ammoniacal nitrogen.

**Estimation of total nitrogen** About 2 g of the sample is taken in the Kjeldahl flask, to which 10 g of potassium sulphate, 0.5 g of copper sulphate and 25 mL of concentrated sulphuric acid are added. The flask slightly heated in an inclined position until frothing ceases. The heat is increased until the acid boils vigorously and the mixture gets clear or until oxidation is complete (about 2 h). Cool the contents of the flask and transfer quantitatively to the round-bottomed flask with 200 mL of water, to which few pieces of pumice stone added to pre-

vent bumping. Sufficient quantity of sodium hydroxide solution is added to make the solution alkaline and to form an acid layer below. The apparatus is assembled taking care of the tip of the dip tube to extend below the surface of the standard sulphuric acid solution in the receiver. The contents of the flask were mixed by shaking and distilled until all ammonia passes over into the standard sulphuric acid solution. Now it is titrated with standard sodium hydroxide solution.

**Estimation of ammoniacal nitrogen** About 2 to 4 g of the sample is shaken and filtered with water. The filtrate is then transferred to the distillation flask and then diluted to about 200 mL with water. About 5 g of magnesium oxide is added to the solution and the flask connected to the condenser by means of the connecting bulb tube, and about 100 mL of liquid is distilled into the receiver containing standard sulphuric acid and methyl red indicator solution. The content in the receiver is titrated with standard sodium hydroxide solution.

**Determination of crude fat (Bureau of Indian standards IS: 7874 [2014])**

About 2.5 g of the sample is extracted with petroleum ether or hexane, in a Soxhlet, and the extract is dried on a steam bath for 30 min and cooled in a desiccator. Alternate drying and weighing at 30-min interval done until the difference between two successive weighing is less than one mg. The lowest mass is noted, and the fat content is calculated using the formula

$$\text{Crude fat (g)} = \frac{100(M_1 - M_2)}{m}$$

where  $M_1$  is the mass in 'g' of the extraction flask with dried extract;  $M_2$  the mass in 'g' of extraction flask;  $m$  the mass in 'g' of the dried sample.

**Determination of crude fibre (Bureau of Indian standards IS: 7874 [2014])**

The fat-free residues left over from the crude fat determination is taken in a one-litre conical flask, and respective methodologies (Bureau of Indian standards IS: 7874, 2014) were followed for determining the crude fibre content using the formula.

$$\text{Crude fibre (g)} = \frac{100(M_1 - M_2)}{m}$$

where  $M_1$  is the mass in 'g' of the Gooch crucible and contents before ashing;  $M_2$  the mass in 'g' of Gooch crucible containing asbestos and ash;  $m$  the mass in 'g' of the dried sample.

The moisture and ash contents in the sample were determined using the methods as described in Bureau of Indian standards IS: 7874 (2014). The carbohydrate content of the sample had been calculated by difference method (CTL, 2014), where the other nutrient constituents in the sample were determined individually, summed up and subtracted from the total weight of the food.

**Quantitative estimation of minerals**

The calcium and magnesium contents present in the test sample were estimated by following the methods recommended by the bureau of Indian Standards IS: 5949 (2010). The quantities of zinc and iron present in the sample were determined by dry ashing the test sample and subjecting that to flame atomic absorption spectroscopy (FAAS) (AOAC, 2016a, 2016b, 2016c). The phosphorous content in the test sample was determined using the NMKL-AOAC colorimetric method (AOAC, 2016a, 2016b, 2016c). The sodium and potassium contents in the test samples were determined using flame photometric methods (AOAC, 2016a, 2016b, 2016c).

**Determination of amino acid composition**

The amino acid quantifications for the test samples were done using HPLC by following the methods described in standard manual, USP30-NF25 pharmacopeial forum (2013). The mobile phase was prepared by dissolving about 15.2 g of trimethylamine in 800 mL of water and adjusted to pH 3.0 with phosphoric acid, then diluted to 1000 mL with water. 850 mL of the prepared solution was added to 150 mL of a mixture of 2 volumes of propanol and 3 volumes of acetonitrile. The test sample to be examined (processed and dried insect powder) was dissolved in the mobile phase to obtain a concentration of 1.0 mg/mL. In the stationary phase, octadecylsilyl silica gel for chromatography (3  $\mu$ m) was used. The mixed amino acids were dissolved to obtain a concentration of 1.0 mg/mL and used as a reference solution. 20  $\mu$ L of test solution and standard was injected, with the flow rate as 1.0–1.5 mL/min and detected at 220 nm in 90 min running time.

**Determination of fatty acid composition**

The dried insect samples were processed, and their respective methyl esters were subjected to fatty acid analyses using the GC-FID (gas chromatography flame ionisation detection) technique by following the standard methods as described in the International Organization for Standardization ISO 5509 (2000) and Wang et al. (2015). The fat material in the test sample was extracted with petroleum ether using the Soxhlet apparatus, and the obtained extract was taken for the analyses. 1  $\mu$ L of the processed sample was injected at 200 °C as initial

**Table 1** Growth parameters of reared adult *Coiblemmus compactus*

Male			Female		
Length (cm)	Width (cm)	Weight (g)	Length (cm)	Width (cm)	Weight (g)
1.90 ± 0.13	0.60 ± 0.04	0.49 ± 0.10	1.98 ± 0.13	0.67 ± 0.07	0.88 ± 0.13

**Table 2** Proximate compositions of *Coiblemmus compactus*

S. No	Parameter	<i>Coiblemmus compactus</i> (g/100 g)
1	Carbohydrate	8.20 ± 1.61
2	Total fat	26.50 ± 0.80
3	Crude protein	50.20 ± 0.37
4	Crude fibre	5.50 ± 0.48
5	Moisture	10.93 ± 0.19
6	Ash	5.40 ± 0.16

oven temperature for 1 min and subsequently increased to 230 °C at 1.5 °C/min and then held at that constant temperature for 1 min. The injector was set at 250 °C and the detector at 280 °C. Nitrogen was used as the carrier gas at a flow rate of 1 mL/min.

#### Determination of energy content

The quantities of all nutritive components were converted to food energy using the standard factor that expressed the amount of available energy per unit of

weight. The food energies of all components are added together to determine the total nutritional energy content of the food sample (FAO, 2003).

## Results

### Rearing of crickets

The rearing technique was successful for the crickets *Coiblemmus compactus*. The eggs collected through the ovitraps were incubated in room condition, which took 3 to 4 days for hatching. The hatched pinheads reared in fresh culture boxes emerged as adults in 43 ± 2 days. The length, width and height of the reared adult crickets were recorded and tabulated.

The male *Coiblemmus compactus* attained 1.90 ± 0.13 cm and 0.60 ± 0.04 cm of average length and width, and also weighed about 0.49 ± 0.10 g. The same of female had 1.98 ± 0.13 cm length, 0.67 ± 0.07 cm width and 0.88 ± 0.13 g of body weight (Table 1).

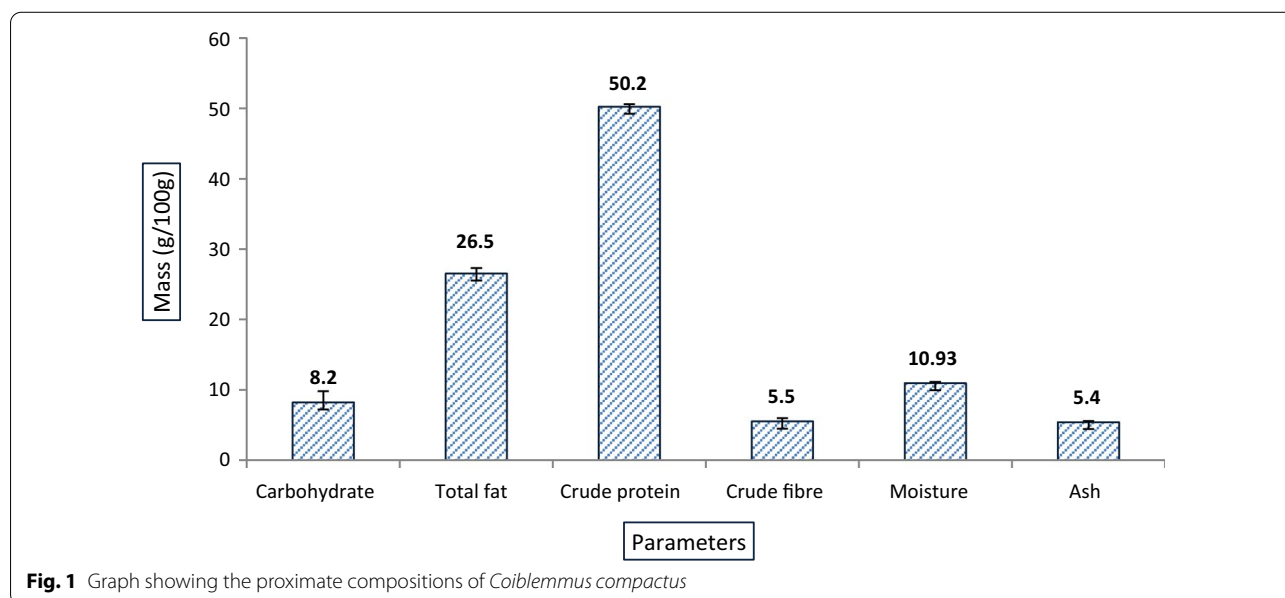
### Nutritional analyses of crickets

#### Proximate composition of *Coiblemmus compactus*

The nutrient composition of reared *Coiblemmus compactus* is presented in Table 2). The crude protein level was found to be 50.2 ± 0.37 g/100 g, which comprises of half of the total body weight of the insect species. Appreciable amounts of fat content (26.50 ± 0.80 g/100 g) with comparatively lower levels of carbohydrates (8.20 ± 1.61 mg/100 g) were determined (Fig. 1).

#### Mineral composition of *Coiblemmus compactus*

Potassium (897. 83 ± 1.55 mg/100 g) and phosphorous elements (604.66 ± 4.11 mg/100 g)

**Fig. 1** Graph showing the proximate compositions of *Coiblemmus compactus*

**Table 3** Mineral composition of *Coiblemmus compactus*

S. No	Mineral	<i>Coiblemmus compactus</i> (mg/100 g)
1	Calcium (Ca)	213.66 ± 3.86
2	Magnesium (Mg)	109 ± 0.82
3	Phosphorous (P)	604.66 ± 4.11
4	Sodium (Na)	246.66 ± 2.62
5	Potassium (K)	897.83 ± 1.55
6	Iron (Fe)	5.51 ± 0.45
7	Zinc (Zn)	8.24 ± 0.047

were found to be abundantly available, whereas the sodium ( $246.66 \pm 2.62$  mg/100 g), calcium ( $213.66 \pm 3.86$  mg/100 g) and magnesium ( $109 \pm 0.82$  mg/100 g) elements were determined to be present in moderate levels. Iron ( $5.51 \pm 0.45$  mg/100 g) and zinc ( $8.24 \pm 0.047$  mg/100 g) compounds were detected in lower levels (Table 3 and Fig. 2).

#### Determination of the energy contents of *Coiblemmus compactus*

Table 4 reveals the energy contents in the test sample, where 100 g of processed powder of *Coiblemmus compactus* yielded  $458.30 \pm 0.29$  kcal of energy.

#### Quantification of amino acids from *Coiblemmus compactus* using high-pressure liquid chromatography (HPLC) technique

The HPLC peak graph of the analysed test sample is presented in Fig. 3, and the values were interpreted accordingly. The levels of amino acids in *Coiblemmus compactus* were quantified, and the values are

**Table 4** Energy contents of *Coiblemmus compactus*

Energy content	<i>Coiblemmus compactus</i> (kcal /100 g)
Energy calories	$458.30 \pm 0.29$

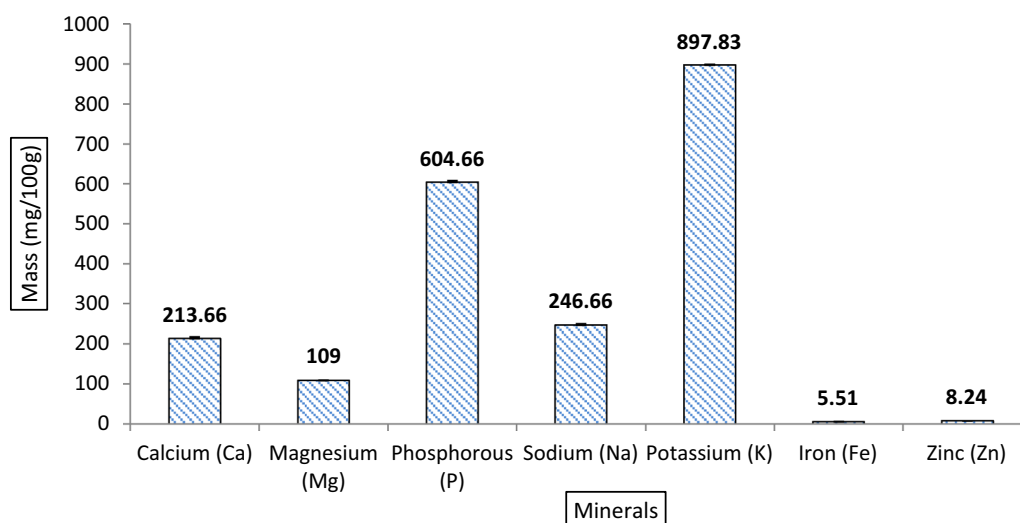
presented in Table 5, which depicts the maximum quantities of asparagine ( $1.38 \pm 0.04$  mg/100 g), methionine ( $1.07 \pm 0.02$  mg/100 g) and threonine ( $0.93 \pm 0.00$  mg/100 g) among them. Other amino acids were present in minimal quantities (Fig. 4).

#### Quantification of fatty acid levels using gas chromatography flame ionisation detection (GC-FID) techniques

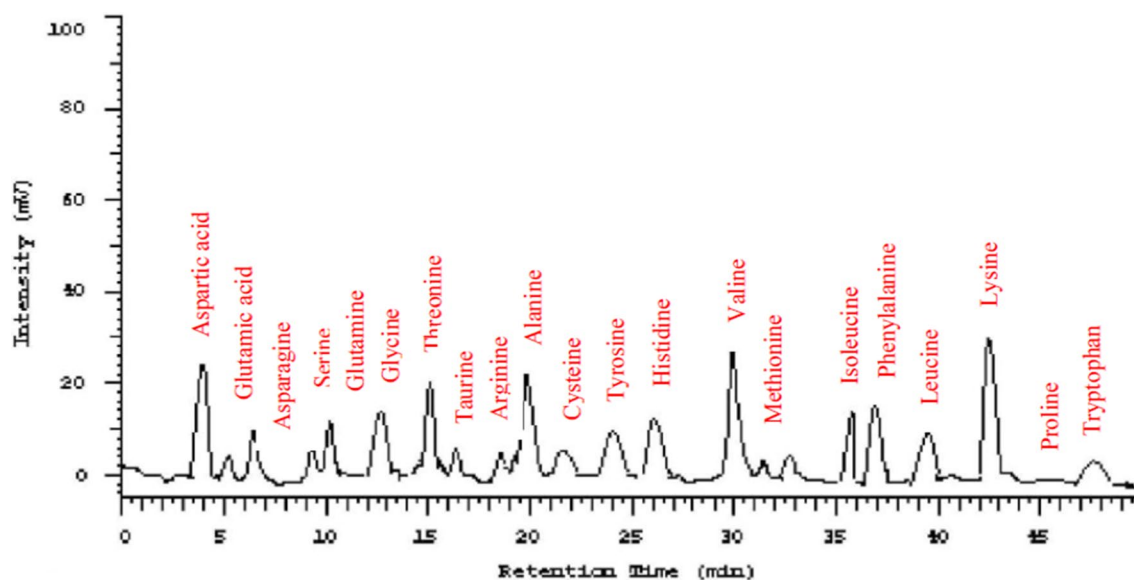
The test sample was analysed for the fatty acid content using the GC-FID studies, and from the obtained peak graph (Fig. 5), the fatty acid levels were estimated. It is inferred that the test sample contained higher amounts of methyl linoleate ( $32.79 \pm 0.43$  mg/100 g), methyl palmitate ( $30.21 \pm 0.23$  mg/100 g) and cis 9 oleic acid methyl ester ( $28.70 \pm 0.60$  mg/100 g) along with moderate detectable quantities of methyl octadecanoate ( $6.72 \pm 0.09$  mg/100 g) (Table 6 and Fig. 6).

#### Discussion

The main aim of our present study was to utilise market waste vegetables (organics) as cricket feed and to raise protein rich crickets using sustainable methods. This cricket species, *Coiblemmus compactus*, was found to be suitable for sustainable rearing and could be produced in mass number. Throughout the study, no major disease or infection has been observed attacking the colonies, as the culture was maintained dry always with minimal

**Fig. 2** Graph showing the mineral compositions of *Coiblemmus compactus*





**Fig. 3** Peak graphs denoting the amino acids quantified using the HPLC technique

**Table 5** Amino acid contents of *Coiblemmus compactus*

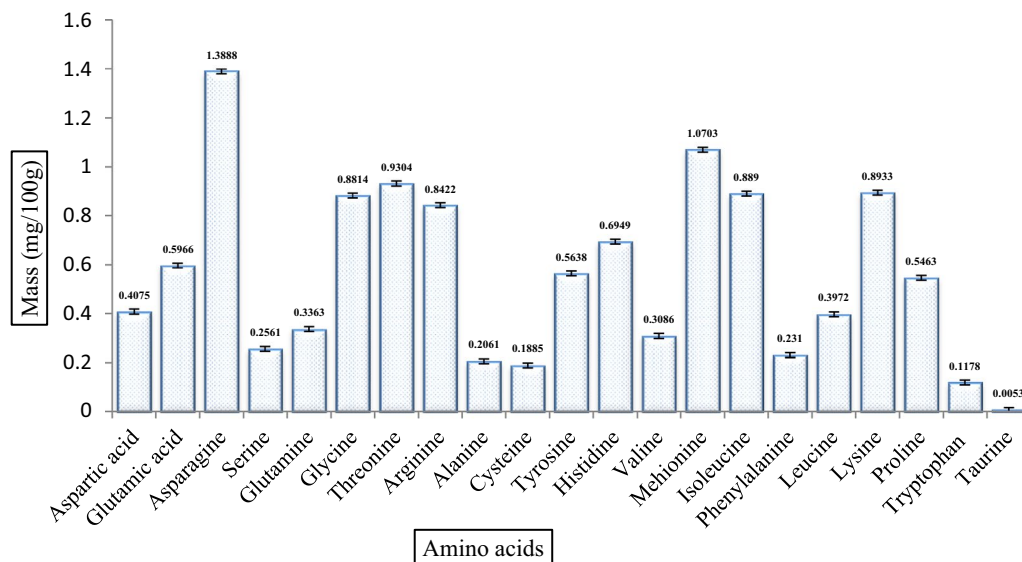
S. No	Amino acids	Mean and SD (mg/100 g)
1	Aspartic acid	6.0787 ± 0.04
2	Glutamic acid	0.3372 ± 0.02
3	Asparagine	0.4378 ± 0.01
4	Serine	1.5247 ± 0.06
5	Glutamine	0.3289 ± 0.01
6	Glycine	0.4978 ± 0.00
7	Threonine	0.9090 ± 0.00
8	Arginine	0.4615 ± 0.02
9	Alanine	0.1190 ± 0.00
10	Cysteine	0.1077 ± 0.00
11	Tyrosine	0.5058 ± 0.00
12	Histidine	0.5260 ± 0.00
13	Valine	0.1078 ± 0.00
14	Methionine	1.3036 ± 0.06
15	Isoleucine	0.9727 ± 0.02
16	Phenylalanine	0.2233 ± 0.01
17	Leucine	0.3042 ± 0.01
18	Lysine	0.2174 ± 0.00
19	Proline	0.9382 ± 0.00
20	Tryptophan	0.0979 ± 0.00
21	Taurine	0.0530 ± 0.02

supply of water for drinking. But still, the reared edible insect has to be subjected for detection of microbial load in them. Such quality and sensory studies are required in future to stabilise this cricket *Coiblemmus compactus* as

a standard edible cricket. In addition to this, several post-harvest processing, preserving and shelf life determination studies are required for standardisation of this edible cricket.

Many researchers who have explored the nutritional and food security assuring potentials of crickets have recommended them for human food and animal feed source (EFSA, 2015; Frigerio et al., 2020; Sun-Waterhouse et al., 2016). The nutritional contents of the crickets were found to vary among the same species which are influenced by their habitat, food habits, climate and sex (Finke & Oonincx, 2014; Musundire et al., 2016). The evaluated proximate values of *Coiblemmus compactus* were compared with that of other food sources (Fig. 7), and it was inferred that our test insect had higher quantities ( $50.20 \pm 0.37$  g/100 g) of protein which was more than that of spirulina (referred as 'single cell protein'). These crickets could be used to eradicate protein deficiency diseases, especially among infants as crickets possess higher protein levels than the recommended dietary protein allowance for Indian man (55–60 g/day) (National Institute of Nutrition- ICMR, 2011). Researches were made on evaluating the efficacy of crickets as supplementary diet for school children and found to fight protein deficiency diseases, such as Marasmus and Kwashiorkor. It showed better growth and learning among them (Homann et al., 2017; Kipkoech et al., 2017).

The cricket *Coiblemmus compactus* was found to possess  $26.50 \pm 0.80$  g/100 g of fat, which is comparatively higher than the red meats (beef and pork) (Fig. 7). For treating some ailments, high-fat diets are prescribed

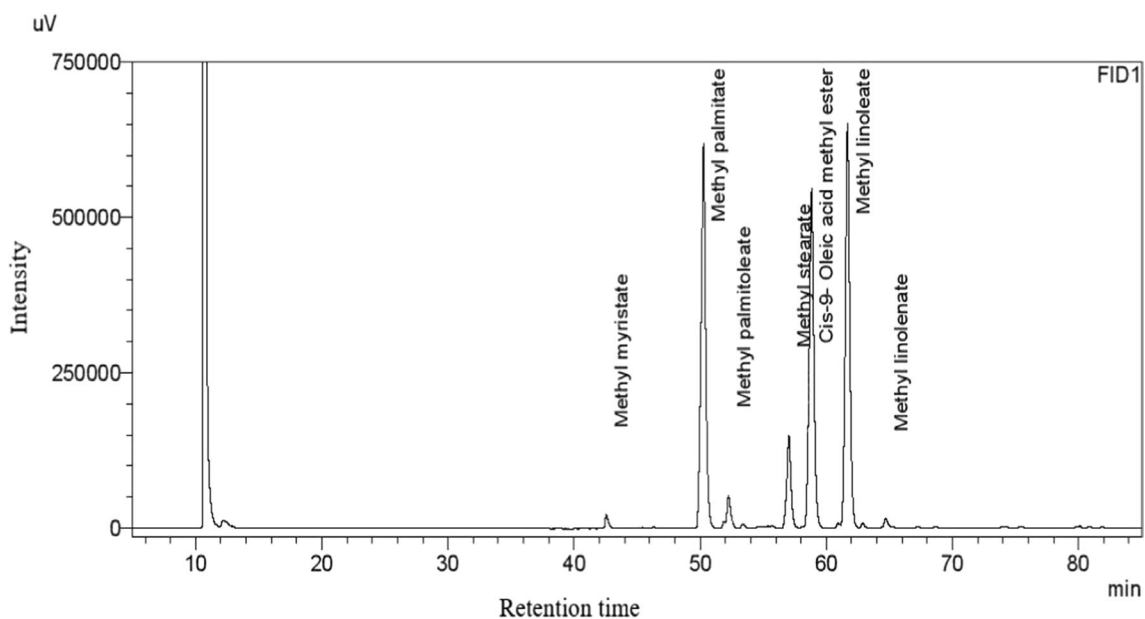


**Fig. 4** Graph showing the amino acid composition of *Coiblemmus compactus*

by dieticians, and in that regard, crickets could make a great contribution to satisfy lipid requirements. It was reported that generally *Gryllus bimaculatus* and *Acheta domestica* represents higher lipid contents in two different forms as phospholipids and triglycerols which are then utilised to derive the energy content for its physical activities (Ekpo et al., 2009; Tzompa-Sosa et al., 2014). The higher the ash content, the higher the value of the

mineral elements for human health. Crickets have a higher content of ash (2.96 to 20.50 g/100 g dry weight) when compared to goat, broiler and pork meat (Magara et al., 2021). The cricket of the present study contained considerable amounts of ashes even when fed with simple and inexpensive diet.

The reared *Coiblemmus compactus* possessed higher amounts of potassium, which is an essential mineral



**Fig. 5** Peak graphs denoting the fatty acids determined using the GC-FID technique

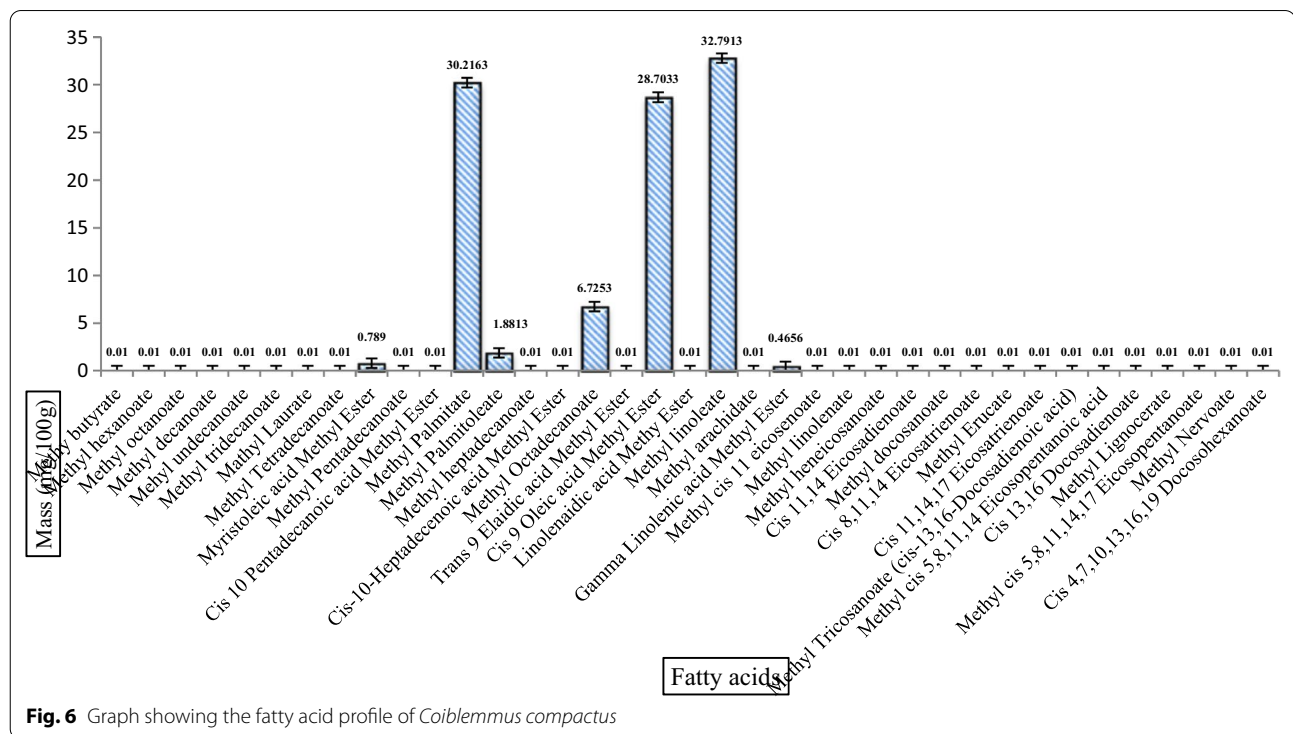
**Table 6** Fatty acid contents of *Coiblemmus compactus*

S. No	Formula	Fatty acid	Mean and SD (mg/100 g)
1	C4:0	Methyl butyrate	< 0.01 ± 0.00
2	C6:0	Methyl hexanoate	< 0.01 ± 0.00
3	C8:0	Methyl octanoate	< 0.01 ± 0.00
4	C10:0	Methyl decanoate	< 0.01 ± 0.00
5	C11:0	Methyl undecanoate	< 0.01 ± 0.00
6	C13:0	Methyl tridecanoate	< 0.01 ± 0.00
7	C12:0	Methyl laurate	< 0.01 ± 0.00
8	C14:0	Methyl tetradecanoate	< 0.01 ± 0.00
9	C14:1	Myristoleic acid methyl ester	0.789 ± 0.05
10	C15:0	Methyl pentadecanoate	< 0.01 ± 0.00
11	C15:1	Cis 10 pentadecanoic acid methyl ester	< 0.01 ± 0.00
12	C16:0	Methyl palmitate	30.2163 ± 0.23
13	C16:1	Methyl palmitoleate	1.8813 ± 0.09
14	C17:0	Methyl heptadecanoate	< 0.01 ± 0.00
15	C17:1	Cis-10-Heptadecenoic acid methyl ester	< 0.01 ± 0.00
16	C18:0	Methyl octadecanoate	6.7253 ± 0.09
17	C18:1n9+	Trans 9 elaidic acid methyl ester	< 0.01 ± 0.00
18	C18:1n9C	Cis 9 oleic acid methyl ester	28.7033 ± 0.60
19	C18:2n6+	Linolenic acid methyl ester	< 0.01 ± 0.00
20	C18:2n6	Methyl linoleate	32.7913 ± 0.43
21	C20:0	Methyl arachidate	< 0.01 ± 0.00
22	C18:3n6	Gamma Linolenic acid methyl ester	0.4656 ± 0.04
23	C20:1	Methyl cis 11 eicosenoate	< 0.01 ± 0.00
24	C18:3n3	Methyl linolenate	< 0.01 ± 0.00
25	C21:0	Methyl heneicosanoate	< 0.01 ± 0.00
26	C20:2	Cis 11,14 eicosadienoate	< 0.01 ± 0.00
27	C22:0	Methyl docosanoate	< 0.01 ± 0.00
28	C20:3	Cis 8,11,14 eicosatrienoate	< 0.01 ± 0.00
29	C22:1n9	Methyl erucate	< 0.01 ± 0.00
30	C20:3n3	Cis 11,14,17 eicosatrienoate	< 0.01 ± 0.00
31	C23:3	Methyl tricosanoate (cis-13,16-Docosadienoic acid)	< 0.01 ± 0.00
32	C22:4n3	Methyl cis 5,8,11,14 eicosopentanoic acid	< 0.01 ± 0.00
33	C22:2	Cis 13,16 docosadienoate	< 0.01 ± 0.00
34	C24:0	Methyl lignocerate	< 0.01 ± 0.00
35	C22:5n3	Methyl cis 5,8,11,14,17 eicosopentanoate	< 0.01 ± 0.00
36	C24:1	Methyl nervoate	< 0.01 ± 0.00
37	C22:6n3	Cis 4,7,10,13,16,19 docosohexanoate	< 0.01 ± 0.00

for the good health of human. Potassium, which is supposed to be obtained from our regular diet, has more health benefits like lowering the blood pressure, prevents renal diseases, reduces osteoporosis, prevents heart disease and lowers the risks of hypercalciuria and kidney stones (He & MacGregor, 2008). Also, it is needed for maintenance of total body fluid volume, acid and electrolyte balance and normal cell function (Young, 2001). Phosphorous is the second abundant element estimated in both the test crickets,

which has much health benefits including the osteoporosis treatment (Heaney, 2004). Calcium is the bone and teeth supporting mineral, which are moderately present in both the crickets. The calcium levels in the cricket were found to be lesser than that of drumstick leaves ( $314 \pm 71.0$  mg/100 g) but higher than that in betel leaves ( $207 \pm 14.9$  mg/100 g), mint leaves ( $205 \pm 31.8$  mg/100 g) and the whole milk of cow ( $118 \pm 2.9$  mg/100 g) & buffalo ( $121 \pm 3.0$  mg/100 g) (USDA, <https://fdc.nal.usda.gov/index.html>). Adding





**Fig. 6** Graph showing the fatty acid profile of *Coiblemmus compactus*

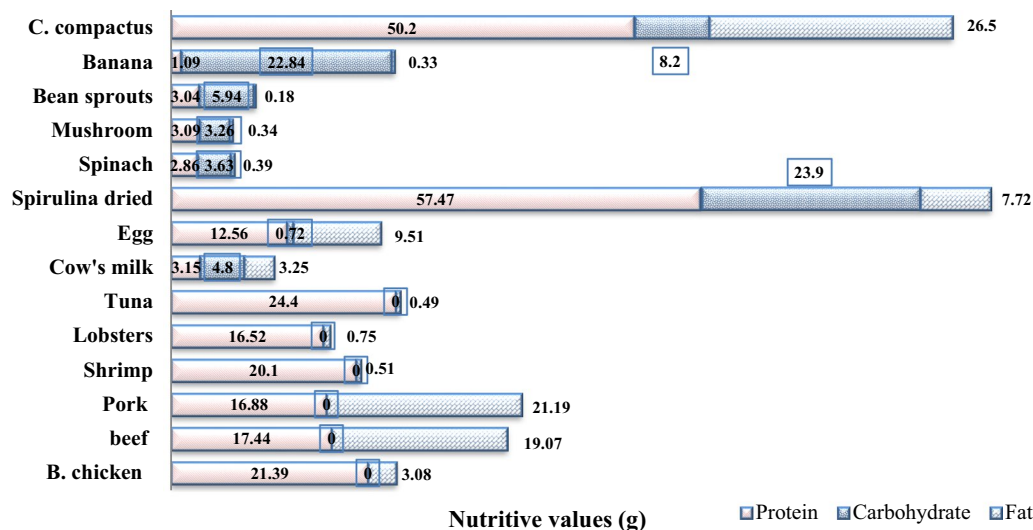
cricket meal to diet improves the nutritive quality of the food and also helps to overcome micronutrient deficiencies.

Asparagine, methionine and threonine are the amino acids detected from the cricket among which methionine is an essential amino acid. The nutrients composition also depends upon the processing methods like drying, smoking, cooking, roasting, deep-frying and toasting) (Huis et al., 2013; Musundire et al., 2014). The heat drying for the processing of crickets would have been a reason for reduced projection of amino acids. In the view of large-scale processing, freeze drying wouldn't be a suitable way to market insects at low cost (as our actual aim is to make insects as cheaper protein source). Therefore, heat drying is a possible way for processing crickets in larger scale quantities.

Methyl palmitate and methyl linoleate were the two fatty acids detected at higher levels in the cricket tested. Some studies have proved the anti-inflammatory (Saeed et al., 2012) and phagocytosis inhibitory effect (Cai et al., 2005) of methyl palmitate; therefore, it is reported to be safe for vertebrates and widely used in cosmetics, pharmaceuticals and industrial applications (Pearson, 2007). Methyl linoleate has showed anti-proliferative activity (Lampronti et al., 2003) and also found to possess good antifungal and antioxidant activity (Pinto et al., 2017). As a traditional medicine, Nigerians apply the intestinal content of mole crickets (*Grylotalpa africana*) over the

surface of patients to treat athlete's foot (Fosaranti, 1997; Rajkhowa & Rokozeno, 2016). Methyl linoleate possessed anti-melanogenic activity and could be widely utilised in cosmetics industry as whitening agent to treat hyperpigmentation conditions (Ko et al., 2018). Further studies on cricket extracts would help us to determine the bioactive compounds to evaluate their pharmaceutical bioactivity. Besides promoting them as food, highlighting their pharmaceutical activity and making people to understand its application on cosmetics would be easier.

Edible insects possess some benefits like attractive nutrient quality, less environmental impact and easy to farm capacity to prove their potentials, but the real challenge lies in the consumer acceptance part (Huis et al., 2013; Rumpold and Schlüter 2013). Some of the socio-cultural barriers like food taboo remain an obstacle among people for granting space for edible insects on their plates. Insects are often assumed as emergency foods to be consumed only during starvation, sometimes the wriggling larvae are seen with disgust and aversion from various reportings (De Folliart, 1999; MacEvilly, 2000), it was understood that the physical outlook of insect makes it to be rejected for food purpose, and many different studies confirmed that people are more ready to accept or eat products containing the less visible or invisible (more processed) insect ingredients (Schosler et al., 2012; Pascucci and de-Magistris 2013; de-Magistris et al., 2015; Tan et al., 2015; Gmuer et al., 2016; Caparros



**Fig. 7** Graph showing comparison of the proximate composition of *Coiblemmus compactus* and other food sources (Source: USDA Food data central database)

Megido et al., 2016). The processed (dried and milled) insect powder resembles the edible cereal flour which is used for cooking. Therefore, proportional mixing of the cricket flour with other ingredients makes them completely concealed with their full nutrient potentials. This study proves that crickets has higher nutritive values and also can be farmed like other meat animals for mass production. Further, the protein contents of the crickets have to be studied in detail so that they can be isolated and their exact use can be explored. Cricket farming could be widely practiced as the developing countries are in much need of alternate protein sources, and thereby, it may support the livelihood of some farmers.

## Conclusions

The evaluation on the nutritive composition of laboratory-reared *Coiblemmus compactus* has made it clear that it is a high protein edible insect along with appreciable quantities of fat and allied minerals in that. The feasible feature of raising them over vegetable wastes is another matter of significance, as that method doesn't require much of the capital investment. On comparing with other food sources, this species of cricket has been proved to nutritionally effective to be used as food and feed source. Further scientific investigations on the therapeutic nature of these edible insects may draw the interest of consumers over them. Thereby, edible insects could be effectively used as an alternate food and feed source to overcome the pressure exerted on food and feed production in many developing countries.

## Abbreviations

HPLC: High-Pressure Liquid Chromatography; GC-FID: Gas Chromatography Flame Ionisation Detection; MSL: Mean Sea Level; FAO: The Food and Agriculture Organization; CTL: Chennai Testing Laboratory; IS: Indian Standards; FAAS: Flame Atomic Absorption Spectroscopy; AOAC: Association of Official Analytical Collaboration; ISO: International Organization for Standardization; NIN: National Institute of Nutrition.

## Acknowledgements

The first author is thankful to the Managing trustee, Living In Fine Environment (LIFE) Trust—India—for their valuable support rendered to carry out this research work.

## Author contributions

BAD designed the outline of this research work and supervised the entire study. VL carried out insect collection, rearing, processing and other laboratory analyses. JJ helped with the chromatography techniques. MGR supervised the article writing and helped with manuscript correction. All the authors read and approved the final manuscript.

## Funding

Not applicable.

## Availability of data and materials

The dataset of the present study is available with the corresponding author on reasonable request.

## Declarations

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

Not applicable.

### Competing interests

The authors declare no competing interests among them.

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Received: 18 May 2021 Accepted: 16 April 2022  
Published online: 08 May 2022

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