Pak. j. sci. ind. res. Ser. B: biol. sci. 2023 **66B**(1) 38-44

# Analytical Evaluation of Fatty Acid, Phospholipid and Sterol Profiles of Five Species of Edible Insects

**Abdul Ademola Olaleye[a]*, Emmanuel Ilesanmi Adeyeye[b], Adeolu Jonathan Adesina[b] and Habibat Omolara Adubiaro[c]**

[a]Chemistry Department, Faculty of Science, Federal University Dutse, Jigawa State, Nigeria
[b]Chemistry Department, Ekiti State University, Ado-Ekiti, Nigeria
[c]Industrial Chemistry Department, Federal University Oyo-Ekiti, Ekiti State, Nigeria

(received January 24, 2020; revised April 23, 2021; accepted May 3, 2021)

**Abstract.** Lipid compositions of five species of edible insects: adult bee, bee brood, winged termite, soldier termite and mopane worm were investigated using standard analytical methods. The saturated fatty acids (SFAs): C2:0, C3:0, C4:0 and C5:0 were absent, C6:0, C8:0 and C10:0 had 0.00%, palmitic acid (C16:0) had the highest level of abundance among the SFAs with value range of 16.6-31.9%, C18:1 (*cis*-9) (26.2-39.8%) was the most abundant monounsaturated fatty acid (MUFA) whilst C24:1 (*cis*-15), C18:1 (*trans*-6) and C18:1 (*trans*-9) were found in trace amounts. The highest abundant polyunsaturated fatty acid (PUFA) was C18:2 (*n*-6) (11.9-23.0%). Levels of total saturated fatty acid (SFA) (21.7-39.9%) were less than total unsaturated fatty acid (TUFA) (60.2-78.4%). The levels of C18:2 (*n*-6)/C18:3 (*n*-3) (448-1480) were much above the recommended 5-10. Lecithin (285-349 mg/100 g) was the most abundant phospholipid followed by phosphatidyl ethanolamine (144-167 mg/100 g). The major sterol was cholesterol with values ranging from 153-269 mg/100 g.

**Keywords:** edible insects, fatty acids, phospholipids, sterols

## Introduction

Insects belong to the class of invertebrates, cold-blooded, produce rapidly and in some cases have little or no parental attention. Insects have been utilized as food in the past in most west African cultures. Insects eaten are mostly those obtained in large quantity, such as locust, termites, caterpillars and the big African cricket *Brachtrypes* (Adeyeye, 2008). Series of researches have revealed that edible insects contain huge levels of proteins of good quality with good digestibility. They are found to be rich sources of micro and macro nutrients, especially iron and zinc. Edible insects are excellent sources of iron. Bee brood and adults of majority of bee species are edible. Bee brood are often found in traditional diets and their demand is high in markets, as a result, they are costly (Chen *et al*., 1998). Winged termites will usually develop to become kings and queens. Some big termite soldier species are consumed in many conutries of Africa, mostly, they are consumed fried or pounded. Mopane caterpillars (*Imbrasia belina*) is one of the nutritionally viable species. Though, they are important sources of nutrients during food scarcity, they also form a common source of food (Stack *et al*., 2003). Series of researches have been conducted on the nutritional contents of insects. These include (Zabentungwa *et al*., 2020; Ademolu *et al*., 2010; Xiaoming *et al*., 2010; Bukkens, 2005). However, little or no attention had been given to their lipid profiles as a whole. The objective of this study is to critically examine the fatty acid, phospholipid and sterol in each of the insect samples. This is aimed at further revealing the nutritional compositions of the selected insects and promote their utilizations in food industry. It is also expected to add values to food composition Tables.

*Author for correspondence; E-mail: lebdul@fud.edu.ng

## Materials and Methods

**Collection of the samples.** The insect samples were procured in various farms and markets in Ekiti State. They were sorted to remove the bad ones, washed properly with distilled water. They were then oven dried at 45 °C and separately milled into powder, kept in a dry environment pending the time of use for the analyses as described below.

**Production of the extract.** 250 mg of each sample was weighed into a thimble followed by addition of 200 mL petroleum ether. The extraction went on for 6 h using Soxhlet extractor. The extract was removed when the solvent is almost dried-off. The extract was put in an oven at 105 °C for 55 min, cooled and weighed on an electric balance.

**Analysis of fatty acid methyl ester (FAME).** 50 mg of the extract was saponified for 5 min at 95 °C using 3.4 mL 0.5MKOH in dry methanol. The mixture was neutralized with 0.7 molar HCl. 3 mL of 14% boron trifluoride in methanol was added. Heat was supplied for 5 min at 90 °C. The FAMEs were extracted thrice using re-distilled *n*-hexane. The content was concentrated to 1 mL for (GC) analysis and 1 µL was introduced into the injection port of gas chromatograph.

**GC setup for FAMEs determination.** GC: HP 6890 powered by HP Chem Station rev. A 09.01 (1206) software; splitratio = 20/1; injection type = split type; carrier gas = nitrogen; inlet temperature = 250 °C; column type = HPINNOWAX; oven programme = initial temperature = 60 °C; first ramp = 10 °C/min in 20 min; maintained for 4 min; second ramp = 15 °C/min for 4 min; maintained in 10 min; column dimensions and 30 m by 0.25 mm by 0.25 µm; which detector = FID; detector temperature = 320 °C; hydrogen pressure = 22 psi; compressed air = 35 psi.

**Phospholipid analysis.** 10 mg of the extract was weighed into the test tube. Solvent was totally eliminated by nitrogen gas. 0.40 mL chloroform added to the oil, then 0.10 mL of the chromogenic solution added. Heat was supplied to the resulting mixture at 100 °C in a water bath for 80 sec. It was cooled to the ambient temperature followed by adding 5 mL hexane. The content of the tube was shaken gently several times. There was separation into two layers. The layer containing hexane was recovered and concentrated to 1 mL for gas chromatography analysis.

**Chromatographic setup for phospholipid.** GC: HP 5890 powered by HP Chem Station Rev. A 09.01 (1206) software; injection temperature = split injection; split ratio = 20/1; carrier gas = nitrogen; inlet temperature = 250 °C; column = HP 5; column measurement = 30 m by 0.25 mm by 0.25 µm; oven programme = initial temperature = 50 °C; first ramp = 10 °C/min for 20 min; maintained in 4 min; second ramp = 15 °C/min for 4 min; maintained in and 5 min; temperature = 320 °C; hydrogen pressure = 20 psi; compressed air = 30 psi; detector = pulse flame photo-metric detector.

**Analysis of sterols.** Aliquots of the extract were introduced into the test tubes. The insect sample saponified at 95 °C in 30 min by 3 mL of 10% KOH in ethanol, to which 0.2 mL benzene was added and followed by adding 3 mL deionised water. The non-saponifiable content was extracted by 2 mL of hexane. Three extractions, using 2 mL hexane each, were done for 1 h and 30 min and only 30 min, respectively. The hexane was concentrated to 1 mL for gas chromatographic analysis and 1 µL was introduced into the port.

**GC conditions for analysis of sterol.** GC = HP 6890 powered by HP Chem Station rev. A 09.01 (1206) software; splitratio = 20/1; injection type m = split type; carrier gas = nitrogen; inlet temperature = 250 °C; column type = HPINNOWAX; oven programme = initial temp. was 60 °C; first ramp = 10 °C/min in 20 min; maintained for 4 min; second ramp = 15 °C/min for 4 min; maintained in 10 min; column dimensions = 30 m by 0.25 mm by 0.25 µm; detector = Pulse flame photometric; detector temp = 320 °C; hydrogen pressure = 22 psi; compressed air = 35 psi.

**Statistical studies.** The mean standard deviation and percent coefficient of variation were determined. The Chi-square at $\alpha = 0.05$ was also determined to confirm if there were significant difference among the samples.

## Results and Discussion

Table 1 shows the percentage values of different fatty acids in the insect samples. The most abundant fatty acids in this study were palmitic acid in adult bee (31.9%), bee brood (29.2%) and mopane worm (29.3%), oleic acid in winged termite (37.0%) and soldier termite (39.8%). The following saturated fatty acids (SFAs) were not found: C2:0, C3:0, C4:0 and C5:0. Also, hexanoic, octanoic and decanoic acids had 0.00% concentration; dodecanoic, myristic, palmitic, stearic, arachidic, behenic and lignoceric acids, all recorded various concentrations. The most abundant SFA in all the samples was palmitic acid with levels ranging from 16.6-31.9%. Palmitic acid has been observed to be the most concentrated SFA in nature.

Literature reports on palmitic acid are as follows: groundnut seeds (10.1-13.0%) cereals consumed in Nigeria (millet, maize, sorghum and rice) (10.9-21.0%) (Adeyeye and Ajewole, 1992), grains of treated sorghum bicolour (16.6-18.3%) (Adeyeye and Adesina, 2013) and melon seeds flour (9.54-10.8%) (Adeyeye and Olaleye, 2015). It has been reported that myristic and palmitic acids both raise low density lipo-proteins bonded cholesterol but that myristic acid was more effective (Adyeye and Olaleye, 2015). The levels of myristic acid (0.157-2.59%) were however, low in these samples. Saturated fatty acids increase serum cholesterol but stearic acid (18:0) may not pose much risk as other SFAs (due to its conversion to oleic acid).

Among the mono-unsaturated fatty acids (MUFAs), C18:1 (*cis*-9) was most concentrated in each of the samples with values range of 26.2-39.8%. People having high insulin may benefit from a high mono-unsaturated fatty acid diet (Kris-Etherton, 1999). The following MUFAs: myristoleic acid, nervonic acid, *trans* petroselinic acid, elaidic acid and vaccenic acid had either zero or trace levels.

The most abundant poly-unsaturated fatty acid (PUFA) was linoleic acid with values ranging between 11.9-23.0% in each of the samples. The levels of linoleic acid in this study were comparatively lower than 58.9-60.7% in three varieties of melon seeds (Adeyeye and Olaleye, 2015), 40.8-50.2% of pumpkin (*Cucurbate moschata*) seeds (Petkova and Antova, 2015) and 67.7% in edible ant eggs (Virginia *et al*., 2013). The present C18:2 (*n*-6) fatty acid levels were higher than 7.52-9.07% reported by Olaleye *et al*. (2014) for fresh water fishes and 8.1% in the larva of *Cirinia forda* (Akinnawo and Ketiku, 2000) but comparabe to 13.9-20.9% in *Vigna subterranea* seed parts (Adeyeye *et al*., 2015). The levels of eicosapentaenoic acid (EPA) in the insect samples (0.037-0.399%) were generally low whereas, docosahexaenoic acid (DHA) levels were moderately high at 4.27% in adult bee, 5.05% in bee brood and 4.36% in mopane worm but low in winged and soldier

**Table 1.** Percentage fatty acid composition of the insect samples

| Fatty acid | ADB | BBR | WTM | STM | MWM | Mean | SD | CV% | $\chi^2$ | Rem |
|---|---|---|---|---|---|---|---|---|---|---|
| Hexanoic | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | NS |
| Octanoic | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | NS |
| Decanoic | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | NS |
| Dodecanoic | 0.124 | 0.205 | 0.326 | 0.232 | 0.325 | 0.242 | 0.086 | 35.5 | 0.121 | NS |
| Myristic | 0.157 | 0.226 | 2.59 | 2.02 | 0.336 | 1.07 | 1.15 | 107 | 5.04 | NS |
| Palmitic | 31.9 | 29.2 | 16.6 | 16.9 | 29.3 | 24.8 | 7.41 | 29.9 | 8.86 | NS |
| Stearic | 7.30 | 8.36 | 4.50 | 2.46 | 9.88 | 6.50 | 2.99 | 46.0 | 5.51 | NS |
| Arachidic | 0.017 | 0.016 | 0.016 | 0.020 | 0.031 | 0.020 | 0.006 | 30.0 | 0.008 | NS |
| Behenic | 0.016 | 0.015 | 0.015 | 0.019 | 0.029 | 0.019 | 0.006 | 31.6 | 0.007 | NS |
| Lignoceric | 0.002 | 0.002 | 0.002 | 0.002 | 0.004 | 0.002 | 0.001 | 50.0 | 0.002 | NS |
| Myristoleic | 0.002 | 0.002 | 0.002 | 0.003 | 0.004 | 0.003 | 0.001 | 33.3 | 0.001 | NS |
| Palmitoleic | 4.62 | 4.77 | 6.41 | 5.95 | 5.53 | 5.46 | 0.763 | 14.0 | 0.427 | NS |
| Petroselinic | 5.18 | 5.41 | 5.69 | 5.60 | 4.61 | 5.30 | 0.431 | 8.13 | 0.141 | NS |
| Oleic | 27.3 | 26.9 | 37.0 | 39.8 | 26.2 | 31.4 | 6.44 | 20.5 | 5.29 | NS |
| Cis-II Gondoic | 1.34 | 1.32 | 1.42 | 1.41 | 1.09 | 1.32 | 0.134 | 10.2 | 0.054 | NS |
| Erucic | 0.442 | 0.915 | 1.04 | 0.939 | 0.738 | 0.815 | 0.235 | 28.8 | 0.271 | NS |
| Nervonic | 0.002 | 0.002 | 0.002 | 0.002 | 0.004 | 0.002 | 0.001 | 50.0 | 0.002 | NS |
| Trans-Petroselinic | 0.006 | 0.006 | 0.006 | 0.007 | 0.011 | 0.007 | 0.002 | 28.6 | 0.003 | NS |
| Elaidic | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.00 | 0.00 | 0.00 | NS |
| Trans-II Vaccenic | 0.013 | 0.012 | 0.00 | 0.00 | 0.024 | 0.010 | 0.010 | 100 | 0.041 | NS |
| Linoleic | 12.7 | 11.9 | 22.2 | 23.0 | 13.0 | 16.6 | 5.54 | 33.4 | 7.38 | NS |
| Eicosadienoic | 0.002 | 0.002 | 0.002 | 0.003 | 0.004 | 0.003 | 0.001 | 33.3 | 0.001 | NS |
| Docosadienoic | 0.028 | 0.174 | 0.138 | 0.276 | 0.205 | 0.164 | 0.092 | 56.1 | 0.204 | NS |
| Rumenic | 0.007 | 0.010 | 0.007 | 0.009 | 0.013 | 0.009 | 0.002 | 22.2 | 0.003 | NS |
| Gamma-Linolenic | 0.020 | 0.019 | 0.019 | 0.024 | 0.037 | 0.024 | 0.008 | 33.3 | 0.010 | NS |
| DGLA | 0.115 | 0.225 | 0.280 | 0.265 | 0.223 | 0.228 | 0.066 | 28.9 | 0.077 | NS |
| α-Linolenic | 0.016 | 0.015 | 0.015 | 0.019 | 0.029 | 0.019 | 0.006 | 31.6 | 0.007 | NS |
| Eicosatrienoic | 0.010 | 0.010 | 0.010 | 0.012 | 0.019 | 0.012 | 0.004 | 33.3 | 0.005 | NS |
| Arachidonic | 4.40 | 5.14 | 0.502 | 0.532 | 3.92 | 2.90 | 2.22 | 76.6 | 6.78 | NS |
| Timmodonic | 0.037 | 0.212 | 0.399 | 0.148 | 0.142 | 0.188 | 0.134 | 71.3 | 0.381 | NS |
| DHA | 4.27 | 5.05 | 0.762 | 0.399 | 4.36 | 2.99 | 2.20 | 74.1 | 7.72 | NS |
| **Total** | 100 | 100 | 100 | 100 | 100 | 100 | 0.00 | 0.00 | 0.00 | NS |

ADB = adult bee; BBR = bee brood; WTM = winged termite; STM = soldier termite; MWM = mopane worm; DGLA = Dihomo-γ-Linolenic acid; DHA = Docosahexaenoic acid; SD = standard deviation; CV% = percentage coefficient of variation; $\chi^2$ = Chi-square ($\alpha_{0.5}$); NS = not significant; Rem = remark.

termites (0.762 and 0.399%, respectively). Eicosapentaenoic acid (EPA) has also been reported in trace amounts in many food sources (%): beef (0.02) (Sun *et al*., 2006), *Vigna subterranean* seed parts (0.01-0.15) (Adeyeye *et al*., 2015), larva of *Cirinia forda* (<0.1) (Akinnawo and Ketiku, 2000), melon seed samples (0.026-0.038) (Adeyeye and Olaleye, 2015). They have been studied for health benefits. EPA lowers serum triglyceride acids and cholesterol levels, increase membrane fluidity and reduce thrombosis (Simopoulos and Cleland, 2003). Intake of long chain ω-3 (omega-3) EPA and DHA is vety important in human nutrition, health and disease prevention.

The levels of alpha linolenic acid (ALA) in the samples ranged from 0.019-0.037%. These values were low when compared with the following food sources: melon seed flour (1.64-1.81%) (Adeyeye and Olaleye, 2015), fresh water fish samples (1.17-1.30%) (Olaleye *et al*., 2014), edible ant eggs (2.61%) (Melo *et al*., 2013). Omega-3 (3*n*-3) linolenic acid is necessary for oxidation of cell and shortage has been linked with asthma, heart disease and poor learning ability (Okuyama *et al*., 1997).

Table 2 depicts the summary of the fatty acids into saturated, mono-unsaturated, poly-unsaturated. Also, the following ratios: MUFA/SFA, PUFA/SFA and 2n-6/3*n*-3 are contained in Table 2.

The total SFA in adult bee (39.5%), bee brood (38.0%) and mopane worm (39.9%) were higher than 24.0% in winged termite and 21.7% in soldier termite. The first three values compared well with 35.0-38.1% reported by Olaleye *et al.* (2014) for three fresh water fishes. The total MUFA for the insect samples 38.2-53.7% were higher than those reported for skin (24.0%) and muscle (24.3%) of *Oreochromis niloticus* (Adeyeye, 2011), fresh water fish samples (38.3-39.4%) (Olaleye *et al*., 2014). The levels of MUFA/SFA were greater than 1.00 in three of the samples (1.03-3.45) showing that total mono-unsaturated fatty acid (MUFA) was more than the total saturated fatty acid (SFA). The relative proportion of SFA to MUFA is an important aspect of phospholipid compositions and abnormal changes to this ratio have been claimed to have effects on diseases states such as cardiovascular disease, obesity, diabetes, neuropathological condition and cancer (Christie, 2011). In the present study, two out of the five samples: winged termite (1.01) and soldier termite (1.14) had their PUFA/SFA values greater than 1.00. PUFA/SFA ratios from other food sources are, *Vigna subterranea* seed parts (1.65-2.50) (Adeyeye *et al*., 2015); melon seed flour (2.76-4.25) (Adeyeye and Olaleye, 2015), fresh water fish samples (0.59-0.75) (Olaleye *et al*., 2014). The PUFA/SFA ratio is important in determining the detrimental effects of dietary fats. The higher the PUFA/SFA ratio, the more nutritional usefulness of the dietary oil. The PUFA/SFA ratios in the present study are good enough to discourage atherosclerosis tendency.

Linoleic acid and alpha linolenic acid ratios (2*n*-6/3*n*-3) in the samples were high at 448-1480. These two acids are the essential fatty acids (EFAs) that must be consumed in the diets. The two EFAs compete for similar metabolic enzymes and have different biological roles, the balance between them in the diets can be of considerable importance. The ratio of 2*n*-6 to 3*n*-3 should be between 5:1 and 10:1 (WHO/FAO, 1994). The present reports of 2*n*-6:3*n*-3 ratios showed that the

**Table 2.** Composition of SFA, MUFA, PUFA and 2*n*-6/3*n*-3 (% total fatty acid)

| Fatty acid | ADB | BBR | WTM | STM | MWM | Mean | SD | CV% | $\chi^2$ | Rem |
|---|---|---|---|---|---|---|---|---|---|---|
| SFA | 39.5 | 38.0 | 24.0 | 21.7 | 39.9 | 32.6 | 8.98 | 27.5 | 9.90 | NS |
| MUFA- *cis* | 38.9 | 39.3 | 51.6 | 53.7 | 38.2 | 44.3 | 7.63 | 17.2 | 5.26 | NS |
| *-trans* | 0.020 | 0.019 | 0.007 | 0.008 | 0.036 | 0.018 | 0.012 | 66.7 | 0.031 | NS |
| **Total** | 38.9 | 39.3 | 51.7 | 53.7 | 38.2 | 44.4 | 7.66 | 17.3 | 5.28 | NS |
| PUFA- *cis* | 21.6 | 22.8 | 24.3 | 24.7 | 21.9 | 23.1 | 1.39 | 6.02 | 0.337 | NS |
| *-trans* | 0.007 | 0.010 | 0.007 | 0.009 | 0.013 | 0.009 | 0.002 | 22.2 | 0.003 | NS |
| **Total** | 21.6 | 22.8 | 24.3 | 24.7 | 22.0 | 23.1 | 1.37 | 5.93 | 0.327 | NS |
| MUFA/SFA | 0.985 | 1.03 | 2.15 | 2.47 | 0.957 | 1.52 | 0.732 | 48.2 | 1.41 | NS |
| PUFA/SFA | 0.547 | 0.600 | 1.01 | 1.14 | 0.551 | 0.770 | 0.283 | 36.8 | 0.417 | NS |
| 2*n*-6/3*n*-3 | 794 | 793 | 1480 | 121 | 448 | 945 | 403 | 42.6 | 688 | S |

SFA = saturated fatty acid; MUFA = mono-unsaturated fatty acid; PUFA = poly-unsaturated fatty acid; S = significant.

insect samples contained too much more omega-6 than omega-3. Hence, diets higher in omega-3 essential fatty acid should be consumed in conjunction with the insect samples to bring the 2*n*-6/3*n*-3 to normal healthy ratio.

Table 3 presents the energy contributions by various fatty acid groups and their percentages. The contributions by SFA were 33.3-689 KJ/100 g (21.6-40.2%), MUFA range was 49.9-713 KJ/100g (38.1-53.7%), PUFA ranged between 28.6-412 KJ/100g (21.4-24.8%). The % SFA levels: 24.1% (winged termite) and 21.6% (soldier termite) were less than 30% of total caloric value.

Table 4, depicts the various phospholipids levels of the insect samples and their percentage distributions. Phospholipids are present in almost all food in human nutrients. They accumulate in cell membranes, therefore, foods with cell membranes contain phospholipids. The levels of phospholipids in this study ranged as follows (mg/100 g), phosphatidylethanolamine (PE) (144-167), phosphatidylcholine (PC) (285-349), phosphatidylserine (PS) (15.1-31.6), lysophosphatidylcholine (LPC) (18.8-51.2), sphingomyelin (SGM) (2.63-33.9), phosphatidylinositol (PI) (8.12-41.3). Phosphatidylcholine (lecithin) had the highest concentration in all. Lecithin is usually the hughest phospholipid in plants and animals, mostly taking 50% of the total and therefore, it is the major part of membrane bilayers (Adeyeye and Olaleye, 2015). There is close agreement between the present results and those reported by Adeyeye *et al*. (2011), where lecithin formed 66.8% (muscle) and 46.7% (skin) in Tongue sole fish. In the percentage distribution, lecithin had the highest percentage (51.0-58.0%). These values were comparable with 55.0-57.4% reported for three samples of melon seeds flour (Adeyeye and Olaleye, 2015). The least percentages were recorded as follows: phosphatidyl-ethanolamine in adult bee (1.42%), bee brood (1.51%) and mopane worm (2.02%), sphingomyelin in winged termite (1.23%) and soldier termite (0.512%).

The levels of sterols in the insect samples are shown in Table 5. The following sterols were reported in trace amounts (mg/100 g), cholestanol (4.30e-5 to 8.10e-4), ergosterol (5.50e-5 to 6.62e-4), campesterol (2.72e-3 to 2.88e-3), stigmasterol (4.48e-6 to 7.41e-5), 5-Avenasterol (1.37e-5-1.37e-3), sitosterol (1.67e-6 to 5.55e-3). Cholesterol occupied the highest position in terms of concentration in the insect samples, this being typical of animal sterols. Cholesterol is present in trace levels in plants especially vegetable oils. Sitosterol was relatively low in concentrations in the samples. Sitosterol is a plant sterol that reduces the levels of cholesterol in the blood and is applied in Europe for the treatment of breast cancer and prostatic carcinoma (Kockar, 1983).

**Table 3.** Energy (κJ/100 g) contributed by the different fatty acid fractions and their percentages

| Fatty acid | ADB | BBR | WTM | STM | MWM | Mean | SD | CV% | $\chi^2$ | Rem |
|---|---|---|---|---|---|---|---|---|---|---|
| SFA(%) | 80.4(40.2) | 689(38.0) | 33.3(24.1) | 94.3(21.6) | 52.1(39.8) | 190 | 280 | 147 | 1651 | S |
| MUFA(%) | 77.0(38.5) | 713(39.3) | 71.4(51.7) | 234(53.7) | 49.9(38.1) | 229 | 280 | 122 | 1372 | S |
| PUFA(%) | 42.8(21.4) | 412(22.7) | 33.6(24.3) | 108(24.8) | 28.6(21.8) | 125 | 164 | 131 | 856 | S |
| **Total(%)** | 200 (100) | 1841(100) | 138(100) | 436(100) | 131(100) | 544 | 721 | 133 | 3820 | S |

**Table 4.** Phospholipids (mg/100 g) level in the insects and their percentages

| Phospholipids | ADB | BBR | WTM | STM | MWM | Mean | SD | CV% | $\chi^2$ | Rem |
|---|---|---|---|---|---|---|---|---|---|---|
| PE | 164(28.7) | 159(29.6) | 158(25.6) | 144(28.0) | 167(29.9) | 158 | 8.85 | 5.60 | 1.99 | NS |
| PC | 306(53.6) | 298(55.4) | 349(56.7) | 298(58.0) | 285(51.0) | 307 | 24.5 | 7.98 | 7.85 | NS |
| PS | 16.8(2.99) | 18.3(3.40) | 15.1(2.45) | 31.6(6.15) | 15.2(2.72) | 19.4 | 6.95 | 35.8 | 9.95 | S |
| LPC | 42.4(7.43) | 29.9(5.56) | 45.3(7.35) | 18.8(3.66) | 51.2(9.16) | 37.5 | 13.0 | 34.7 | 18.1 | S |
| SGM | 33.9(5.94) | 24.4(4.54) | 7.59(1.23) | 2.63(0.512) | 29.5(5.28) | 19.6 | 13.8 | 70.4 | 38.7 | S |
| PI | 8.12(1.42) | 8.13(1.51) | 41.3(6.70) | 19.2(3.74) | 11.3(2.02) | 17.6 | 14.0 | 79.5 | 44.5 | S |
| **Total** | 571(100) | 538(100) | 616(100) | 514(100) | 559(100) | 560 | 38.3 | 6.84 | 10.5 | S |

PE = Phosphatidylethanolamine; PC = Phosphatidylcholine; PS = Phosphatidylserine; LPC = Lysophosphatidylcholine; SGM = Sphingomyelin; PI = Phosphatidylinositol.

**Table 5.** Concentrations of sterol (mg/100 g) in the insect samples

| Sterol | ADB | BBR | WTM | STM | MWM | Mean | SD | CV% | $\chi^2$ | Rem |
|---|---|---|---|---|---|---|---|---|---|---|
| Cholesterol | 239 | 221 | 269 | 153 | 235 | 223 | 43.1 | 19.3 | 33.3 | S |
| Cholestanol | 7.04e-4 | 3.12e-4 | 8.10e-4 | 4.30e-5 | 3.44e-4 | 4.43e-4 | 3.12e-4 | 70.4 | 8.80e-4 | NS |
| Ergosterol | 5.77e-4 | 6.31e-5 | 6.62e-4 | 5.50e-5 | 4.10e-4 | 3.53e-4 | 2.84e-4 | 80.5 | 9.11e-4 | NS |
| Campesterol | 2.88e-3 | 2.73e-3 | 2.79e-3 | 2.72e-3 | 2.78e-3 | 2.78e-3 | 6.36e-5 | 2.29 | 5.8 e-9 | NS |
| Stigmasterol | 5.96e-5 | 7.11e-6 | 7.41e-5 | 4.48e-6 | 5.31e-5 | 3.97e-5 | 3.19e-5 | 80.4 | 1.02e-4 | NS |
| 5-Avenasterol | 1.37e-3 | 1.36e-3 | 1.37e-5 | 1.36e-3 | 1.37e-3 | 1.09e-3 | 6.04e-4 | 60.4 | 1.34e-3 | NS |
| Sitosterol | 5.54e-3 | 1.10e-3 | 5.55e-3 | 1.67e-6 | 3.70e-3 | 3.51e-3 | 2.09e-3 | 59.5 | 7.53e-3 | NS |
| **Total** | 239 | 221 | 269 | 153 | 235 | 223 | 43.1 | 19.3 | 33.3 | S |

## Conclusion

This research has shown that the insects had high levels of omega-6 fatty acid and low in omega-3 fatty acid and therefore should be supplemented with foods rich in omega-3. Palmitic acid and oleic acid were the major SFA and MUFA respectively. The major PUFA was linoleic acid. The insect samples are good sources of unsaturated fatty acids, especially monounsaturated fatty acids which are nutritionally useful to the body. All the samples were high in lecithin and phophatidylethanolamine. Cholesterol was the major sterol present in the samples, other sterols were found in low concentrations. Generally, the samples are good sources of fatty acids and phospholipids and their consumption should be encouraged.

**Conflict of Interest.** The authors have no conflict of interest.

## References


Ademolu, K.O., Idowu, A.B., Olatunde, G.O. 2010. Nutritional value assessment of varietgated grasshopper, *Zonocerus variegatus* (L.) (Acridoidea: Pygomorphidae), during post-embryonic development. *African Entomology*, **18:** 360-364.

Adeyeye, E.I. 2008. Proximate composition, nutritionally valuable minerals and the effects of some salts on the functional properties of silkworm (*Anaphe infracta)* larvae. *Pakistan Journal of Scientific and Industrial Research*, **51:** 77-85.

Adeyeye, E.I. 2011. Levels of fatty acids, phospholipids and sterols in the skin and muscle of Tilapia (*Oreochromis niloticus*) fish. *La Rivista Italiana Delle Sostanze Grasse*, **88:** 46-55.

Adeyeye, E.I., Ajewole, K. 1992. Chemical composition and fatty acid profiles of cereals in Nigeria. *Food Chemistry*, **44:** 41-44.

Adeyeye, E.I., Adesina, A.J. 2013. Enhancement of lipid quality of raw guineas corn (*Sorghum bicolor*) grains through germination and steeping. *Open Journal of Analytical Chemistry Research*, **1:** 5-17.

Adeyeye, E.I., Olaleye, A.A. 2015. Lipid compositions of three varieties of melon seeds flour: Dietary and health implications. *Journal of Chemical, Biological and Physical Sciences*, **5:** 3828-3841.

Adeyeye, E.I., Olaleye, A.A., Adesina, A.J. 2015. Lipid composition of testa, dehulled and whole seed of bambara groundnut (*Vigna subterranean* L. Verdc). *Current Advances in Plant Sciences Research*, **2:** 1-9.

Adeyeye, E.I., Owokoniran, S., Popoola, S.E., Akinyeye, R.O. 2011. Fatty acids, phospholipids and sterols levels in the skin and muscle of Tongue sole fish. *Pakistan Journal of Scientific and Industrial Research*, **54:** 140-148.

Akinnawo, O., Ketiku, A.O. 2000. Chemical composition and fattyacid profile of edible larva of *Cirina forda* (westwood). *African Journal of Biomedical Research*, **3:** 93-96.

Bukkens, S.G.F. 2005. Insects in the human diet: nutritional aspects. In: *Ecological Implications of Minilivestock; Role of Rodents, Frogs, Snails and Insects for Sustainable Development*, Paoletti, M.G. (eds), pp. 545-577, Science Publishers, New Hampshire.

Chen, P.P., Wongsiri, S., Jamyanya, T., Rinderer, T.E., Vongsamanode, S., MAtsuka, M., Sylvester, H.A., Oldroyd, B.P. 1998. Honey bees and other edible insects used as human food in Thailand. *American Entomologist*, **44:** 24-28.

Christie, W.W. 2011. *Fatty Acids: Straight-chain Monoenoic Structures, Occurrence and Biochemistry*, Crop Research Institute (and MRS lipid analysis unit), Invsgowire Dundee (DD25DA), Scotland.

Honatra, G. 1974. Dietary fats and arterial thrombosis. *Haemostasis*, **2:** 21-52.

Kochar, S.P. 1983. Influence of processing on sterols of edible vegetable oils. *Progress in Lipid Research*, **22:** 161-188.

Kris-Etherton, P.M. 1999. Mono-unsaturated fatty acids and risk of cardiovascular disease. *Circulation*, **100:** 1253-1258.

Melo, R.V., Sanchez, H.K., Sandoval, T.H., Quirino, B.T., Calvo, C.C. 2013. Lipids data composition of edible ant eggs (*Liometopum apiculatum* M.) Escamoles. *Journal of Life Sciences*, **7:** 547-552.

Okuyama, H., Kabayeshi, J., Watanabe, S. 1997. Dietary fatty acids: the *n*-6/*n*-3 balance and chronic disease. *Progress in Lipid Research*, **35:** 217-244.

Olaleye, A.A., Ogungbenle, H.N., Ayeni, K.E. 2014. Mineral and fatty acid compositions of three fresh water fish samples commonly consumed in south western states of Nigeria. *Elixir Food Science*, **74:** 26719-26723.

Petkova, Z.Y., Antova, G.A. 2015. Changes in the composition of pumpkin seeds (*Cucurbita moschata*) during development and maturation. *Grasas Aceites*, **66:** 058.

Simopoulos, A.P., Cleland, G.L. 2003. *Omega-6/Omega-3 Essential Fatty Acid Ratio: The Scientific Evidence*, World Review of Nutrition and Diabetics, Basel, Switzerland: Karger.

Stack, J., Dorward, A., Gondo, T., Frost, P., Taylor, F., Kurebgaseka, N. 2003. Mopane worm utilization and rural livelihoods in southern Africa. *Paper Presented at the International Conference on Rural Livelihoods*, Forests and Biodiversity, Bonn, Germany, 19-23 May 2003.

Sun, T., Xu, X., Prinyawiwatku, W. 2006. Fatty acid composition of the oil extracted from farmed atlantic salmon (*Salmon salar* L.) viscera. *Journal of American Oil Chemists' Society*, **82:** 615-619.

Watkins, B.A., Shen, C.L., Allen, K.G.D., Seifert, M.F. 1996. Dietary (*n*-3) and (*n*-6) poly-unsaturated and acetylasalicylic acid alter *ex vivo* PGE2 biosynthesis, tissue 1GF-1 levels and bone morphometry in chicks. *Journal of Bone and Mineral Research*, **1:** 1321-1332.

WHO/FAO, 1994. Fats and oils in human nutrition (Report of a joint expert consultation FAO food and nutrition). Paper 57, WHO/FAO, Rome, Italy.

Xiaoming. C., Ying, F., Hong, Z., Zhiyong, C. 2010. Review of the nutritive value of edible insects. In: *Forest Insects as Food: Humans Bite Back, Proceedings of a Workshop on Asia-Pacific Resources and their Potential for Development*, Durst, P.B., Johnson, D.V., Leslie, R.L., Shono, K. eds., Bangkok, FAO Regional Office for Asia and the pacific.

Zabentungwa, T.H., Rob, S., Thinandavha, C.M. 2020. Nutritional composition of edible insects consumed in Africa: A systematic review. *Nutrients*, **12:** 2786-2813. https://doi.org/10.3390/nu12092786.