Short communication

Nutritional Profililinge of German Cockroach Meal (*Blattela germanica*) as a Poultry Feed in Kenya

Comment [S1]: As such the insect was not fed to the broiler birds. So the title need to be revised. Only nutrient profiling of the insect was made, it's a choice for broiler. Be specific in using the terms.

Abstract

Evaluation of animal feed stuff is a very important aspect in animal nutrition and feeding. Physical and chemical evaluation is a preliminary analysis done on novel feeds before further *in vivo* studies. A study was conducted to evaluate the nutritional value of cockroaches based on their chemical values. Sample of adults and sub-adults of *B. germanica* were ~~analysed~~analyzed for dry matter content, crude protein, ether extracts, minerals and crude fibre. Samples of sub-adult *B. germanica* were further analysed for profilinges of amino acids, ~~and~~ fatty acids and mineral composition. The chemical composition was compared to that documented for of anchovy-fishmeal by calculating parameters such as essential amino acid index, chemical score, and ideal amino acid ratios. The parameters were also compared to those recommended by NRC and GRRS. The dry natter, crude protein, crude fibre, ash per cent were ~~was~~ 91.40, 56.64, 7.94, 6.05, 4.11 and 89.12, 58.28, 15.03, 5.21, 3.45 for adult and sub-adult, respectively. The crude fat (15.03 %) in nymph was significantly different from adults (p<0.05). Unsaturated fatty acid accounted for 70% of crude fat dominated with oleic acid (35.90 %). All the essential amino acids were present ~~with~~ in which leucine (3.14 mg/g) and methionine (0.65 mg/g) being the highest and the lowest, respectively. The essential amino acid index was 1.73 for cockroach meal and 1.86 for fishmeal. *B. germanica* had higher number of essential amino acid exceeding the IAAR values as prescribed by NRC and GRRS. Although the nutritional value of *B. germanica* is lower than of fishmeal, it is sufficient to be used as an alternative chicken feed.

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Keywords : cockroach ,chicken ,feed

Introduction

Consumption of edible insects for the purposes of human and animal nourishment has been practiced for centuries, but it is now being promoted to ameliorate pangs of food insecurity globally (Govorushko, 2019). It is estimated that over 3000 million families consider edible insects as a part of their diets. More than 2300 species of edible insects have been documented(Van Huis, 2020). Availability of insects depends on the ecological zones and therefore the type of edible insects in a given place tend to varry depending on local habitats and region in the world (Van Huis, 2013). Insect species within the order coleopteran are the dominates in the global list of edible insects (Hanboonsong *et al.*, 2013). Other factors that determine species of insects consumed are indigenous knowledge, skills of harvesting ~~skills~~ , processing method and seasons they are available (Kelemu *et al.*, 2015; Raheem *et al.*, 2018). Wild harvesting is the main method by which edible insects are obtained (Dao *et al.*, 2020; Govorushko, 2019), however this method is not sustainable to carter for ever increasing demand. Some edible insects such as termites are seasonal and therefore only available during some part of the year (Dao *et al.*, 2020). Seasonable edible insects may be harvested during peak periods, processed, and preserved for later consumptions. Method of processing may be in the form of drying, frying, milling, blanching or simple steaming (Mutungi *et al.*, 2019). It has also been noted that processing may alter the quality of the products while prolonged storage also affects the chemical composition and final nutritional value (Ekpo, 2011). Parameters that have been used to evaluate ~~asses~~ the nutrient~~s~~ contents include simple proximate composition, profiling for amino acids, fatty acids, salts ~~profiles,~~ and mineral ~~salts~~. During preliminary investigation, the results of chemical composition have been used in calculation of parameters such as chemical score, essential amino acid index, and ideal amino acid ratio. Computed values are compared, documented for reputable feeds such as fishmeal and soybean(Veldkamp & Bosch, 2015). Using these parameters aforementioned parameters has made it easier to establish suitability of some novel feeds before in vitro studies (Wecke, Pastor, & Liebert, 2016).

Globalization and cultural interaction has transformed the trend and behavior of consuming insects globally. For instance, there is a similarity in consumption pattern of edible insects in places where diversity existed before ; this is attributed to the adoption of new species of edible insects (Govorushko, 2019). Besides, the consumption of termites and grasshopper was domiciled in Eastern Africa but has now spread to western Africa and Europe (Moreki & Tiroesele, 2012). Similarly, consumption of cockroach was a common practice in South America and Far East (China) but has spread to South Korea and Eastern Africa. Despite being used as food and feed in Tanzania (unpublished), cockroaches are now being produced at Maishahai Farm on industrial scale for export to Korea for biomedical exploration (Kulma *et al.*, 2016). Traditionally humans associated cockroach with dirtiness and that hindered there advancement as food and feed.

Comment [S3]: Repetition of ideas as that of the initial introductory paragraph.

Production of cockroach for feed and food in Eastern Africa is lagging behind compared to commercial scales operations in China due to several factors including attitude, scarce information on best technology on how to optimize production, and also limited information on its nutritional value (Feng *et al.*, 2018). Reliable information on its nutritional value is vital for stakeholders to make an informed decision for the development of policy and legal framework for up scaling this trade.

Materials and Methods

Study Site

The insects (*B. germanica*) for nutritional analysis were obtained by rearing them for six months at Kenya Agricultural and Livestock Research Organization –Non Ruminant Institute, Kakamega, Kenya. The *B. germanica* were fed on a composite diets consisting of locally available organic wastes that included brewers waste, fishmeal and wheat bran. The insects were reared in four 60-litres capacity container in a dark room. They were provided with accessible water and feed throughout the research period. Stacked carton trays were used to provide hiding place while 6 inches from the brim of each container was laced with petroleum jelly to deter cockroaches from escaping.

Analysis of Samples for Chemical Composition

At the end of six months, samples of cockroach from each container were harvested using an insect net. They were then sacrificed by cold shock through placing them in a refrigerator (-5 ^{o}C) for 24 hours before being removed, washed in water and strained to remove any impurities and then dried in oven at 60^{o} C for 24 hours. Dry *B. germanica* were sorted into adults and nymphs; nymph possess wings while adults do not, and then milled to 1mm particle and stored under (-5 ^{o}C) for proximate analysis, amino acid profiling, fatty acid profiling and mineral content determination. The proximate analysis, amino acid profile and fatty acid profile was determined according to standard procedures and guidelines (Association Of Analytical Chemistry (AOAC), 1990).

Figure 1. Nymph, adult, and ground sample of *B. germanica*
Source: Author

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Determination of Dry Matter and Moisture Content

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Dry matter was determined using AOAC Method 0934.02. In principle, dry empty porcelain crucibles were dried overnight at 105 ^{0} C and then placed in desiccator to cool to room temperature and then weighed. Into ~~of the~~ three crucibles, 2g of sample was added (W_0), and placed in an oven at 105^0 C for 12 hours. The crucibles+ samples were then placed in a desiccator and allowed to cool to room temperature (W_t). The moisture content and dry matter was calculated using the following formulae:

(a) Moisture (%) = ((W_0- W_t)/W_0)100)
(b) Dry matter(%) =((W_t/W_0)*100) .

Determination of Ash

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Total ash was determined by AOAC method 0942.05. The samples were oven dried at 105^{0}C for 12 hours to get the dry matter. Into a dry empty porcelain crucible (W_c), 2g of the dry matter was added (W_a). The dry matter samples was ignited overnight in a muffle furnace at 550 ^{0} C, then cooled in desiccator to room temperature and weighed (W_b). The ash was calculated as;

Ash (%) =((Wb-Wc)/Wa-Wc)*100

Determination of Organic Dry Matter

Organic Dry Matter (%) = 100- Ash (%)

Determination of Crude Protein

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Crude Protein was determined by Kjeldahl Method, where 1g of sample was digested in sulfuric acid using K_4SO_4 as a catalyst, Nitrogen was converted into NH_3 and then distilled in boric acid .The solution was then titrated with 0.1142 N H_2S0_4 until colour turned purple. (Zaklouta, Hilali, Nefzaoui, ~~&~~ and Haylani, 2011). The following formulae was used to calculate crude protein.

Calculations %N = [1.4007×(Vc–Vd)×N]/W

Vc = volume of acid used for sample titration, Vd = volume of acid used for the blank N= Normality of acid, ~~while~~ W= sample weight in grams, 1.4007: conversion factor milliequivalent weight of nitrogen and N percent

Calculation:

Crude protein (%) = % N*6.25.

Determination of Crude Fat

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Ether Extracts was determined by adding 5g dry matter of ground *B. germanica* (W_F) in petroleum ether and then filtering the mixture. Petroleum ether was then evaporated in the

Soxtherm Apparatus from Gerhardt GmbH to obtain weight of crude fat as residue (W_P) (Zaklouta *et al.*, 2011).

Calculation

Crude Fat (%) = ((W_P/W_F)*100)

Determination of Crude Fibre

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The organic residue left after sequential extraction of fat with ether was used to determine the crude fibre using the following formulae.

$$Crude\ Fibre(\%) = \frac{(Dry\ weight\ of\ Fat\ free\ sample)}{Dry\ Weight\ of\ sample\ with\ fat\ before\ Ashing} \times 100$$

Calculation of Metabolizable Energy

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The metabolizable energy was estimated by calculation using the following formulae (Pauzenga, 1985)

$$ME\left(\frac{Kcal}{Kg}\right) = (g\ of\ crude\ protein \times 4) + (g\ of\ crude\ Fat \times 9) + (g\ of\ nitrogen\ free\ extract\ \times 4)$$

Determination of Nitrogen free extract

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Nitrogen Free Extract (NFE) was calculated by determining the difference according to procedure of Pauzenga (1985) as;

$$Nitrogen\ Free\ Extract(\%) = (Dry\ Matter(\%) - (Crude\ Fibre + Crude\ Protein + Crude\ Fat + Ash\%)$$

Determination of Macro and Trace Minerals

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Concentration of specific mineral was determined using specific methods as outlined as follows; method 0968.08 atomic absorption method; in principle the ash was dissolved in 10% hydrochloric acid (HCL), water was added up to 100 ml mark in a standard flask. Magnesium, Calcium, Iron, Phosphorus, Manganese, Zinc, and Copper were analyzed by alpha 4 Atomic Absorption Spectrophotometer. Sodium and Potassium was determined using official method 0965.17; using Flame Photometer (Corning 405) (AOAC 1990).

Determination of Fatty Acid Profiles

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A 10 gm~~rammes~~ sample of the dry cockroach was used for crude fat extraction that was used in fatty acid profiling as per the description Official method 996.06. Fats were extracted by hydrolytic method and then methylated into fatty acid methylated esters (FAMES) and ~~subsequently~~ quantitatively measured in a gas chromatography and recorded (AOAC, 1990).

Determination of Amino Acid Profiles

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~~Ten grammes~~10gm of dry sample of *Blattela germanica* was obtained for the purposes of extracting proteins for amino acid profiling as outlined in the AOAC 1990 Official Method 994.12; Performic Acid Oxidation with Acid Hydrolysis–Sodium Metabisulfite. In principle performic~~,~~ acid oxidation was performed prior to hydrolysis to oxidize cysteine and methionine to cysteic acid and methionine sulfone, respectively. Sodium metabisulfite was added to decompose performic acid. Amino acids were liberated from protein by hydrolysis with 6M HCl. Hydrolysates were diluted with sodium citrate buffer, pH was adjusted to 2.20, and individual amino acid components were separated on ion-exchange chromatograph.

Calculation of Essential Amino Acid Index (EAAI)

The following formula was used ……….(Veldkamp & Bosch, 2015)

$$EAAI = n\sqrt{\frac{aa_1}{AA_1} \times \frac{aa_2}{AA_2} \times \frac{\dots}{\dots} \times \frac{aa_n}{AA_n}}$$

Where EAAI= essential amino acid index, *aa* = amount of amino acid in protein source in percent of crude protein, *AA* = ~~the~~ requirement of the target animal for amino acids in percent of crude protein and *n* = ~~the~~ total number of amino acids used in the calculation. This parameter takes in account of the level of amino acid in the target species and those in studied protein.

Calculation of Chemical Score (CS)

Chemical score (CS) was calculated for each amino acid present in protein under study. It was calculated by dividing the quantity of amino acid in *B. germanica* by the quantity in target animal (broiler grower chicken) and then multiplyed~~ing~~ by 100. Lowest CS represented the first limiting amino acid and subsequent~~ly~~ scores ranked the rest of amino acids.

Calculation of Ideal Amino Acid Ratios (IAAR)

This value relates other essential amino acids to the concentration of lysine in the protein under analysis; in this case, the sample was nymph *B. germanica*. It was calculated by dividing each quantity of essential amino acid by quantity of lysine and then multiplying by 100.

Data Analysis

Essential amino acid index (EAAI), chemical score (CS), ideal amino acid ratios (IAAR) of *B. germanica* in reference to the requirement of broiler growers were calculated and compared with that of fishmeal.

Results and Discussion

Proximate Composition of *Blattela germanica* Meal (BGM)

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Proximate results of *Blattela germanica* meal for adults and nymphs are as recorded in **Error! Reference source not found.**~~Table 1~~ where the percent dry matter was 91.40 ± 0.84 % and 89.12 ± 0.03% for adults and nymphs, respectively. There was no significant difference in the values of ~~in composition of~~ dry matter between the adults, nymphs, and fishmeal. The percent dry matter composition is similar to that reported by Boate *et al.*, (2020) for american cockroach (*Periplaneta americana*).

The crude protein is 56.64±0.93 and 58.28±0.01 for adults and nymphs of *B. germanica*, respectively. These~~is~~ figures are lower than the documented literature value of 78% for this species (Zielińska *et al.*, 2019). Crude protein in fishmeal ~~varry~~vary with species but generally ranges from 50-70%, for instance omena-fishmeal (55%) which is lower than those for anchovy-fishmeal (64%). Crude protein in *B. germanica* is lower than that of *Blattodea* species (60.2- 67.8 %) as reported by Kulma *et al.*, (2016). Insect in the order *Blattodea*, where all cockroach species belong) are documented to have an average crude protein of 53 % (Amza & Tamiru, (2017). Based on the finding of these~~is~~ results, it can be concluded that the cockroach meal can be used as an alternative complement or supplement to fishmeal in livestock diets (Karimi, 2006).

The research also recorded a crude fat content of 9.94 and 15.03 % for adult and nymph *Blattella germanica*, respectively, ~~this imply~~indicating that the nymph accumulates more crude fat than adult ~~does~~. The results are similar to those of Kulma *et al.*, (2016) who reported a crude fat of 23.6 - 36.3% for sub-adults and 14.5-21.4% for adult in blattodea species. Fats are a requisite in broiler nutrition; they are used to provide energy especially during starvation. The total ash is an indicator of minerals; and in this study, the nymph and adult *Blattela germanica* had 3.87 and 4.5 %, respectively as indicated in **Error! Reference source not found.**~~Table 1~~.

Table 1. Proximate composition of adult and nymph *Blattela germanica*

Proximate Component (%)	**Nymph *B.germanica***		**Fishmeal**	**Requirement in growers diet**
	Adult	**Nymph**		
Dry Matter (%)	91.40±0.84	89.12±0.03	92	90
Organic Dry Matter	95.89	96.55	89	
Crude Protein	56.64±0.93	58.28±0.01	64.2	16
Crude Fat	7.94±0.11	15.03±0.25	9.2	<7
Crude Fibre	6.05±0.22	5.21±0.45	1	<8
Ash	4.11±0.03	3.45±0.03	11	
NFE	16.66	7.01	6.6	
ME(Kcal/Kg)	3639.56	3964.3	3420	2900
Reference			NRC,1994	NRC,1994

Mineral Profile of nymph *B. germanica*

The results of macro and trace elements are as indicated in Table 2. Potassium was the highest (0.54) while magnesium (0.12) was the least macro mineral. Iron was the highest trace mineral while copper was the least. Mineral content in cockroach meal was lower than that in fishmeal but is adequate to meet the daily minimum requirement for grower chicken. The~~se~~ trend in ~~this results are~~present study is similar to those reported in Sule *et al*., 2020 but contrary to those in (Boate *et al*., 2020) although both studied the *P.americana*. Minerals are the important component of animal diets as they are utilized as structural components of organs and tissues, activators in enzyme and hormone systems, constituents of body fluids and tissues and as regulators of cell membrane activity thus vital for animal health. Macronutrients elements are required in large quantities and can easily be supplied in diets from other feedstuffs but trace mineral daily targets can easily be attained through daily diets.

Table 1~~2~~. Composition of macro and micro mineral of nymph *Blattela germanica* ~~nymph~~

Minerals			
Macro Mineral	Composition (%) *B.germanica*	Anchovy Fishmeal	Daily Requirement in broilers (%)
Calcium	0.23±0.02	3.73	0.80
Phosphorous	0.35±0.07	2.43	0.30
Magnesium	0.12±0.01	0.24	0.400
Potassium	0.54±0.02	0.69	0.25
Sodium	0.22±0.02	0.65	0.15
Trace Minerals	Composition(ppm)		
Iron	481.00±19	220	60
Zinc	156.00±9	103	35
Manganese	67.00±7	10	30
Copper	49.00±5	9	40

Ppm = parts per million

Essential Amino Acids

Proximate composition is a crude way of assessing the quality of feedstuffs; better evaluation is achieved when proteins are profiled for their essential amino acids. The highest percentage of amino acid was leucine (3.14±0.63) while the least was methionine (0.65 ± 0.01) as indicated in **Error! Reference source not found.**~~Table 3~~.

Table 2~~3~~. Composition of Essential amino acid index, chemical score of Blattela germanica and daily essential amino acid requirements of broiler grower chicken

Amino Acid(AA)	**Anchovy Fishmeal**	**AAC in Nymph *B. germanica*(g/100g CP)**	**DAAR(g/100g Crude Protein)**	**AAC /DAAR**	**Chemical Score (%)**
Leucine	7.74	3.14±0.63	0.93	3.38	337.63
Lysine	7.91	2.81±0.02	0.85	3.31	330.59
Arginine	5.70	2.46±0.08	1	2.46	246.00
Valine	5.43	2.23±0.03	0.7	3.19	318.57

Phenylalanine	4.12	1.95±0.21	0.56	3.48	348.21
Isoleucine	4.74	1.71±0.34	0.62	2.76	275.81
Threonine	4.37	1.67±0.04	0.68	2.46	245.81
Histidine	2.41	1.28±0.11	0.27	4.74	474.07
Methionine	3.02	0.65±0.01	0.32	2.03	203.13
EAAI				1.73	

EAAI = essential amino acid index, AAC=amino acid composition, DAAR= daily amino acid requirement

Essential Amino Acid Index (EAAI)

The Essential Amino Acid Index (EAAI) for nymph *B.germanica* meal was 1.73 as indicated in **Error! Reference source not found.**~~Table~~ 3. This is higher than that of *Blattodea* species < 0.7 and other insects such as black soldier fly larvae (1.24), black soldier fly prepupae (1.43), housefly larvae (1.25), housefly prepupae (1.19) and almost similar to meal worm larvae 1.72 (Kulma et al., 2016; Veldkamp & Bosch, 2015). EAAI summarizes the concentration and distribution of amino acids in a given feedstuff to the consuming animal; higher EAAI tend to have better protein quality and are more beneficial. The physiology of most animals allows for the synthesis of protein depending on the supply of essential amino acids provided in diets because their body does not have a mechanism of producing them. When the distribution of essential amino acids is proportional in the diet, their utilization will be with reference to the first limiting amino acids while the rest is downgraded. In this study, the EAAI in the nymph *B. germanica* is 1.73 that is lower than that of fishmeal (1.86). Based on these findings, anchovy fishmeal is still superior to cockroach meal. As a chicken feed, fishmeal still has a better concentration and distribution of amino acids ~~in~~ than cockroach meal.

Comment [S7]: Sentence needs consideration. Major revision is required.

Chemical Score

Leucine and methionine had the highest and lowest chemical score at 337.63 and 203.13, respectively as shown in **Error! Reference source not found.**~~Table~~ 3. Similar results were reported ~~in~~ by Sule *et al.*, (2020) who studied the american cockroach (*Periplaneta americana*). The protein quality and quantity in *B. germanica* is better than ~~for~~ that of other insects species such as meal worm, black soldier fly and house fly (Veldkamp & Bosch, 2015). Although the CS ~~are~~ is lower than those of fishmeal, leucine and methionine are usually deficient in most plant proteins, thus necessitating inclusion of animal proteins such as insects in the diets of chicken for effective growth.

Comment [S8]: Only for growth? Not for other parameters?? Include reference for the statement.

Ideal Amino Acid Ratio

The use of ideal amino acid ratio to evaluate the quality of protein is being adopted in modern poultry nutrition as highlighted earlier in the literature review. The ideal amino acid ratio (IAAR) for various amino acid content in nymph *B. germanica* was determined and recorded as shown in **Error! Reference source not found.**~~Table~~ 4. Leucine had the highest IAAR (144) while methionine (23) had the least score. With reference to IAAR for broiler diet as outlined in NRC (1994) only leucine, phenylalanine and histidine amino acids had ratios above the recommended values. The three amino acids translates to about 33 % of essential amino acids, and the percent is higher than that of fishmeal that is 22%. In this case, cockroach meal was is better than fishmeal.

Regional difference has led to slight variation in IAAR value in the USA and that in Europe as indicated in Table 4. Further comparison was done for IAAR in nymph *B. germanica* with reference to similar values in as prescribe in German Recommended Ratios Standards (GRRS). It was realized that the percentage of amino acids with IAAR values was above to those prescribed by GRRS, which were was 33% and 11% for *B. germanica* meal and fishmeal, respectively. For both comparison, cockroach meal had higher percentage thus which is better than fishmeal.

Table 34. Calculated Ideal amino acid ratios (IAAR) related to lysine (Lys = 100) in nymph *B. germanica* compared with literature data (NRC, GRRS)

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Type of Amino Acid	**IAAR (USA)**	**IAAR(Germany)**	**Fishmeal**	***B. germanica***
Lysine	100	100	100	100(2.81)
Leucine	109	112	81	144(3.14)
Arginine	110	108	102	88(2.46)
Valine	82	-	72	79(2.23)
Phenylalanine	65	65	85	69(1.95)
Isoleucine	73	69	47	61(1.71)
Threonine	74	67	47	59(1.67)
Histidine	32	32	25	46(1.28)
Methionine	42	37	34	23(0.65)
Average	**64**	**74**	**66**	**74**

NRC =National research council, GRRS= German recommended ratio standards

Lysine has been widely being used as the reference amino acid in calculation of IAAR because it has been demonstrated that chicken exhaustively utilize it during digestion. Reputable organization such as British Agricultural Research Council (BARC) have advocated for the utilization of this concept in modern nutritional studies so as to increase the efficiency of nitrogen absorption in chicken (Wecke *et al.*, 2016).

Table 45. Non-Essential Amino Acid Profile of nymph *Blattela germanica*

Type of Amino Acid	**Composition (%)**	
	B. germanica	Anchovy Fishmeal
Glutamate	4.22±0.21	3.35±0.04
Aspartate	3.39±0.14	2.89±0.01
Alanine	2.52±0.09	1.76±0.02
Proline	2.22±0.06	0.99±0.01
Glycine	1.94±0.01	1.05±0.01
Serine	1.69±0.01	1.19±0.03

Concentration of non-essential amino acids in nymph *B. germanica* is recorded in Table 5. From the table, it can be noted that glutamine was the highest while serine was the lowest.

Quantities of non-essential amino acids in nymph *B. germanica* were higher than that of fishmeal. Kulma *et al*., (2016) and Sule *et al.* (2020) reported similar trend for nonessential amino acid. In practical feed formulation, these amino acids are given little attention because they can easily be synthesized from nitrogen by animals.

Fatty Acid profile nymph *Blattela germanica*

Adult and subadults cockroaches have been demonstrated to have crude fat of 7 and 15 %, respectively. Subadults are rich in fats compared to adult; this may be attributed intense feeding habits and inactive sexual habits. Fats extracted from the subadults were further profiled for fatty acids concentration. Oleic acid (35.90±0.16) and lauric acid (0.67±0.02) was the highest and lowest fatty acid, respectively (Table 6). As shown in the same table, oleic and palmitoleic were the highest and lowest unsaturated fatty acids while stearic and lauric were highest and lowest saturated fatty acids, respectively.

Table ~~5~~6. Type of fatty acids and percent composition of nymph *Blattela germanica*

Type of Fatty Acid	Fatty Acid Chain	Composition (%)	Fishmeal (%)
SFA			
Lauric	12:0	0.67±0.02	0.079±0.002
Myristic	14:0	4.10±0.04	5.394±0.010
Palmitic	16:0	7.54±0.02	20.296±0.031
Stearic	18:0	11.81±0.05	4.211±0.026
Arachidic	20:0	1.66±0.04	0.147±0.002
Behenic	22:0	2.38±0.26	0.129±0.074
Sub Total		**28.16**	**30.256**
UNFA			
Palmitoleic	16:1(n-7)	01.19±0.00	5.047±0.009
Oleic	18:1(n-9)	35.90±0.16	12.285±0.09
Myristoleic	14:1(n-7)	01.86±0.01	0.208±0.008
Linoleic	18:2(n-6)	11.51±0.07	1.710±0.011
Linolenic	18:3(n-3)	09.61±0.17	1.053±0.008
Gadoleic	20:1(n-11)	01.20±0.03	1.367±0.016
Arachidonic	20:4(n-6)	09.12±1.01	1.343±0.026
SubTotal		**70.39**	**23.013**

The trend in composition of fatty acids are in tandem ~~those~~ to that reported by (Kulma *et al*., 2016) who studied *blattodea* species. Percentage of saturated fatty acids (SFA) was almost similar at 28.16 % and 30.26% for nymph *B. germanica* and fishmeal, respectively. Great variation was recorded in percent proportion of unsaturated fatty acids; 70 % was recorded in fats from nymph *B. germanica* compared to 23 % was recorded for fats from anchovy fishmeal. Cockroach meal could be having high level of unsaturated fatty acids that may limit their shelf life. Similar challenge was experienced in storage of termites ~~that also have~~having high fat content. In nutrition studies, fats supplement the energy sources in feed especially when carbohydrates are limited. During feed digestion and absorption, excess fats are stored

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as abdominal fat pad in chicken. Higher deposition of abdominal fat pad negatively affects fertility in breeding hen and may alter the carcass quality and increases cooking loss.

For appropriate nutrition, chicken requires daily supply of 1% linoleic fatty acid in their daily diet, but nymph *B. germanica* meal can provide 11%, that is sufficient to sustain a chicken. However, unsaturated fatty acids have reactive points that can undergo oxidation and rancidification when exposed to air or other active compounds. Higher level of UNFA (70%) in cockroach meal may be a challenge in durability of compounded feeds unless appropriate antioxidants are added into feeds during formulation.

Conclusion

The values of proximate composition of nymph and adult *B. germanica* is not significantly different but lower than that of anchovy-fishmeal. Quality of protein in *B. germanica* is better than that of fishmeal. *B. germanica* should be considered as a supplement, complement, or alternative source of protein in broiler chicken feeds.

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