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Nutritional potential of five selected insect meals for poultry diets

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***Target Audience** : Feedmillers, Poultry farmers, Animal nutritionist*

Abstract

Protein is the major quality indicator in poultry diets. Fish meal, the only animal protein source with relatively high biological value in poultry feed has limited use because of its high cost. Fish meal alternatives have not been realised in Nigeria. However, the scavenging behaviour of poultry indicated consideration for insects as alternative to fish meal. Therefore, this study investigated the nutritional potential of five insects for poultry diets. Grasshopper (Melanoplus spp.) were handpicked from a local farm, Cockroach (Periplaneta americana) from houses, Cricket (Acheta domestica) were harvested at night with insect net through white light, Black ants (Monomorium minimum) and Weaver ants (Oecophylla longinoda) collected using palm oil as bait. The insects were steam killed at 70°C and oven dried at 60°C. Samples were analysed for proximate, mineral, anti-nutritional and amino acids compositions. Except for the amino acid profile, the proximate content, anti-nutritional components and mineral composition were virtually significantly different in magnitude among the samples. Though not significant, Cricket, cockroach and grasshopper had the crude protein levels of 56.90±24.60%, 51.40±25.70% and 55.70±27.85% respectively. All year round availability of the insects suggests their availability as alternative protein source. However, in-depth studies are required to optimise their levels of inclusion.

***Keywords**: Insect meal, Nutrient composition, feed ingredient, protein source*

Description of Problem

The poultry industry is the most commercialized subsector of Nigerian agriculture (29; 1). Its contribution to the economic and nutritional survival of Nigerians cannot be overemphasised. Poultry industry contributed about 25% of the country's Agricultural Gross Domestic Product GDP (16). Nigeria produces above 550,000 metric tons of poultry meat per annum and 700,000 metric tons of eggs (16). To produce 1 kg of meat from a commercial broiler chicken only about 1.7 kg of feed is needed (11). In terms of size, poultry chickens are likely to contribute the least detrimental impact on the environment compared to other livestock. Semi-scavenging backyard indigenous poultry are extremely important in providing income and high-quality protein in the diets of rural people whose traditional foods are typically rich in carbohydrate but low in protein (11). In the Nigerian traditional poultry production system, poultry chickens are generally reared under free range. This system allows chickens to roam around fending for themselves items to meet their nutritional needs with little or no dietary supplements from the keepers. In the course of going about searching for food they naturally consume various selected items that come their ways as food. The commonly consumed items consist of plants, creeping and flying organisms that are principally earthworms, insects or their larvae. However, the advent of intensive management systems in farm animal production limited the direct access of chickens to all these natural feed resources. The animals are fed processed and various industrial and agricultural by-products but the high cost of some of these various feed ingredients, especially protein sources like fishmeal, soybean cake and groundnut cake limited the commercial development of poultry industry in most developing countries (3). This resulted in the high cost of production in the poultry industries (27). Therefore, alternative or complementary protein sources for poultry chickens are of necessity in achieving lower cost of production.

Feed constitutes approximately 75% of the variable costs in intensive poultry production (23) or 70% of the total production costs of broiler meat (25). The demand for low cost poultry feed is high, due to the rising cost and limited supply of commercial feeds (23). The growing number of poultry farms coupled with high demand for fish meal bring about competition for conventional feed ingredients; which often resort to high cost of finished feeds. Therefore, there is need for alternative feed ingredients. However, getting alternative protein sources for fish meal (most costly ingredient in poultry diets) have been an unaccomplished effort in Nigeria (25). Fortunately, insects are known natural food for many poultry species especially chickens. The most suitable insect species for large scale production are; black soldier fly, housefly and the yellow mealworm (9). (18) in their studies on insect meal reported high (42 to 63 %) crude protein contents, high digestibility and added that insect meal could completely replace soybean meal or fishmeal depending on the animal species. The potential of insects as feed ingredient could be investigated and harnessed as alternative feedstuff in feeding monogastrics.

Therefore, this study was carried out to investigate the nutritional profile of five selected insect species as potential animal protein source in poultry diets.

Materials and Methods

Sample collection and preparation:

The insects were collected from unfumigated locations at Onila Community in Irepodun Local Government Area of Kwara State; located in the western part of Nigeria. The five different insect species used in this study were selected based on their availability within the study area. The insects were handpicked from a local farm; Grasshopper (*Melanoplus spp*.), houses; Cockroach (*Periplaneta americana*), Cricket (*Acheta domestica*) were harvested at night with insect net under light, Black ants (*Monomorium minimum*) and Weaver ants (*Oecophylla longinoda*) collection was based on indigenous knowledge with pieces of foam soaked in palm oil as attractant and placed on their path. The collected insects were then dropped in a bowl containing hot water at 70 ºC for 10 minutes and then sieved. The insects were then oven dried to constant weight at 65 ºC for 24 hours. Dried samples were sorted according to species. The average number of each insect species per 100 g of their meals were 50/100 g, 4/100 g, 377/100 g, 40,000/100 g and 2000/100 g for Grasshopper, Cockroach, Cricket, Black ants and Weaver ants respectively. The insects were ground into powder (to form the meal) with an electric grinder. Each ground sample was stored in labelled air-tight polyethene bag and kept for laboratory analysis. Each of the samples were analysed in triplicate. All the analysis were carried out at Gaji Laboratory Alakia, Ibadan. Oyo State.

Proximate Analysis

The insect meals were analysed for proximate compositions according to the method of (4) while the energy contents of the insect meals were calculated using the procedure of (24).

Table 1: Proximate and energy contents of the selected insects

Insects	%Moisture content	%Crude protein	% Crude fibre	%Fat	%Ash	%Nitrogen free extract	Energy kcal/100g
Cricket	4.20±0.17	56.90±24.60	5.30±2.65	23.90±11.95	3.10±1.55	6.60^{b}±3.30	1026.40±513.20
Cockroach	3.20±0.17	51.40±25.70	5.40±2.70	22.60±11.30	3.70±1.85	13.70^{ab}±6.85	1001.87±500.94
Black ant	3.10±0.11	36.70±18.35	5.20±2.60	21.00±10.50	4.30±2.15	29.70^{a}±4.85	989.76±494.88
Tailor ant	2.90±1.21	38.30±19.15	4.00±2.00	24.50±12.25	4.60±2.30	25.70^{ab}±12.85	1013.05±506.53
Grasshopper	3.80±1.65	55.70±27.85	4.20±2.10	19.90±9.95	3.20±1.60	13.20^{ab}±6.60	1102.16±551.08

Mean± Standard deviation

Means with different superscripts in the same column are significantly different ($P<0.05$).

Table 2: Anti-nutritional components of selected insects

Insects	%Phytate	%Tannin	%Saponin	%Oxalate	%Flavonoid	%Alkaloid	HCN (mg/kg)
Tailor ant	0.006^{b}±0.003	0.002^{b}±0.009	0.007^{c}±0.004	0.004^{b}±0.002	0.004±0.002	0.005^{b}±0.003	0.000^{c}±0.000
Black ant	0.009^{b}±0.004	0.003^{ab}±0.002	0.023^{ac}±0.012	0.005^{ab}±0.003	0.003±0.002	0.011^{ab}±0.006	0.170^{bc}±0.085
Cricket	0.024^{a}±0.012	0.006^{ab}±0.003	0.079^{a}±0.040	0.013^{a}±0.007	0.002±0.001	0.018^{a}±0.009	0.460^{a}±0.230
Cockroach	0.007^{b}±0.004	0.007^{a}±0.004	0.016^{c}±0.008	0.004^{b}±0.002	0.003±0.002	0.009^{ab}±0.005	0.130^{bc}±0.065
Grasshopper	0.018^{ab}±0.009	0.006^{ab}±0.003	0.062^{ab}±0.031	0.011^{ab}±0.006	0.002±0.010	0.014^{ab}±0.007	0.370^{ab}±0.185

Mean± Standard deviation

Means with different superscripts in the same column are significantly different ($P<0.05$).

Table 3: Mineral content (mg/kg) of the selected insects

Insects	Ca (mg/kg)	Mg (mg/kg)	Na (mg/kg)	K (mg/kg)	P (mg/kg)	Mn (mg/kg)	Fe mg/kg)	Cu (mg/kg)	Zn (mg/kg)
Tailor ant	71.00^{b}±35.50	2200.00±1100.00	6480.00^{ab}±3240	5624.00^{ab}±2812.00	4300.73.00±2150.37	648.00^{b}±324.00	1270.00^{ab}±635.00	15.00^{b}±7.50	256.00±128.00
Black ant	482.00^{b}±241.00	1985.00±992.50	9128.00^{b}±4564.00	8415.00^{b}±4207.50	3759.50±1879.75	85.00^{a}±42.50	842.00^{ab}±421.00	24.00^{b}±12.00	149.00±74.50
Cricket	365.00^{b}±182.50	2348.00±1174.00	7963.00^{ab}±3981.50	6873.00^{ab}±3436.50	5238.15±2619.08	67.00^{a}±33.50	965.00^{ab}±482.50	42.00^{b}±21.00	186.00±93.00
Cockroach	2200.00^{a}±1100.00	3000.00±1500.00	11988.00^{a}±599.00	1021.00^{a}±510.50	4783.25±2391.63	32.00^{a}±16.00	1780.00^{b}±890.00	34.00^{b}±17.00	161.00±80.50
Grasshopper	612.00^{b}±306.00	2250.00±1125.00	8829.00^{b}±4414.50	7622.00^{b}±3811.00	3035.17±1517.59	25.00^{a}±12.50	213.00^{a}±106.50	112.00^{a} ±56.00	160.00±80.00

Mean± Standard deviation

Means with different superscripts in the same column are significantly different (P<0.05).

Determination of the Anti-Nutrient contents

The insect meals were screened for the presence of anti-nutritional factors such as phytate, oxalate, saponin, tannin, flavonoid, alkaloid and hydrocyanic acid (HCN). The estimation of Phytate-phosphorus (Phytate-P) was by the colorimetric procedure of (30). Phytate was calculated by multiplying phytate-P by a factor of 3.55 (13). Oxalate, saponin and flavonoid were determined according to the procedure of (12). Tannin content was determined by the method of (19) as modified by (14). For hydrocyanic acid (HCN) determination, alkaline sample solution was titrated with standard 0.02N $AgNO_3$ indicator end point (4).

Mineral composition

The mineral compositions were determined in each sample of the insect meals using Atomic Absorption Spectrophotometer (AAS) and the flame photometer for potassium and sodium. Phosphorus was determined using tehnicon auto-analyser (4).

Amino acid Analysis

Amino acid analysis of 0.1 mg sample, hydrolyzed with 1 ml 6 N HCl for 24 hours was made with an Eppendorf Biotronik LC 3000 microprocessor controlled amino acid analyser.

Results

Table 1 presents the proximate composition of the selected insects. The proximate values and the energy were not significantly (P>0.05) different among the selected insects except for the nitrogen free extract (NFE). Black ant had the highest NFE value (29.70±4.85%) significantly (P<0.05) different from cricket (6.60±3.30%) but not significantly (P>0.05) different from the remaining insect samples with similar values.

Table 2 presents the anti-nutritional content of the selected insects. Except for flavonoid, the anti-nutritional components were significantly (P<0.05) different among the selected insects. Result revealed that the phytate content ranged from 0.006±0.003 to 0.024±0.012%; with tailor ant, black ant, cockroach and grasshopper were not significantly (P>0.05) different but they were significantly (P<0.05) different from cricket (0.024±0.012%) of similar phytate level with grasshopper (0.018±0.009%). The tannin level of the selected insects ranged from 0.002±0.009 to 0.007±0.004%; tailor ant had the least value (0.002±0.009%) that was not significantly (P>0.05) different from black ant, cricket and grasshopper but significantly (P<0.05) different from cockroach (0.007±0.004%) of the highest tannin level. However, the tannin level of cockroach was similar to that of black ant, cricket and grasshopper. The saponin value ranged from 0.007±0.004 to 0.079±0.040% in the selected insects. Within this range, cricket had the highest level (0.079±0.040%) similar to grasshopper (0.062±0.031%) and black ant (0.023±0.012%) but significantly (P< 0.05) different from others. However, cockroach (0.016±0.008%) had similar saponin level with black ant and tailor ant (0.007±0.004%). The oxalate level in the selected insects ranged between 0.004±0.002 and 0.013±0.007 %. Cricket (0.013±0.007%) with the highest oxalate level was significantly (P<0.05) different from cockroach (0.004±0.002 %) and tailor ant (0.004±0.002 %) but not significantly (P>0.05) different from black ant (0.005±0.003 %) and grasshopper (0.011±0.006 %) that were similar to tailor ant and cockroach. The alkaloid level in the selected insects ranged from 0.005±0.003 to 0.018±0.009 %. The level of alkaloid in the cricket was the highest (0.018±0.009%) and significantly (P<0.05) different from tailor ant (0.005±0.003 %) but similar to grasshopper, black ant and cockroach. Similarly, the tailor ant had similar level of alkaloid with black ant, cockroach and grasshopper. The level of hydrogen cyanide (HCN) of each selected insect samples ranged between 0.000±0.000 and 0.460±0.230 mg/kg. The level of HCN in cricket (0.460±0.230 mg/kg) was the highest and significantly (P<0.05) different from tailor ant (0.000±0.000 mg/kg), black ant (0.170±0.085 mg/kg) and cockroach (0.130±0.065mg/kg) but similar to grasshopper (0.370±0.185mg/kg). However, grasshopper was not significantly (P>0.05) different from cockroach and black ant which were similar to tailor ant.

The result of the mineral contents of the selected insects (Table 3) shows that three (Ca, Na and K) minerals out of the five macro minerals (Ca, Mg, Na, K and P) identified were significantly (P<0.05) different among the insects. Similarly, three (Mn, Fe and Cu) out of the identified four (Mn, Fe and Cu and Zn) micro minerals were significantly (P<0.05) different among the insects. Calcium (Ca), with values between the range of 71.00±35.50 and 2200±1100.00 mg/kg was significantly (P<0.05) higher in cockroach than other insects. The values of Sodium (Na) in the sampled insects ranged between 6480.00±3240.00 and 11988.00±599.00 mg/kg; with cockroach having the highest value (P<0.05) and different from black ant and grasshopper but similar to tailor ant and cricket. Likewise, black ant and grasshopper were similar in their calcium (Ca) levels. The potassium (K) value ranged from 5624.00±2812.00 to 8415.00±4207.50 mg/kg. The black ant (8415.00±4207.50 mg/kg) with the highest value was significantly (P<0.05) different from cockroach (1021.00±510.50 mg/kg) but similar to tailor ant, cricket and grasshopper. However, cockroach, cricket and tailor ant were also similar in their potassium levels. For the manganese (Mn), tailor ants had the highest value; 648.00±324.00 mg/kg significantly (P<0.05) different from other insects while the grasshopper with the least value; 25.00-12.00mg/kg was not (P>0.05) different from cockroach, cricket and black ant. Cockroach had the highest iron (Fe) value (1780.00±890.00mg/kg) significantly (P<0.05) different from grasshopper (213.00±106.50 mg/kg) of the least value; but similar to cricket, black ant and tailor ant. However, the grasshopper was not significantly (P>0.05) different from cricket, black ant and tailor ant. Among the insects, grasshopper had the highest value of copper (Cu) (112.00±56.00mg/kg) which was significantly (P<0.05) different from the others. Table 4 shows the eighteen (18) amino acids contents of the selected insects. All the amino acids were not significantly (P>0.05) different among the insects. Table 5 shows the availability of insects during the year. All the insects were almost available throughout the year except for cricket and grasshopper with isolated scarcity in few months within the year.

Discussion

The low moisture content of the selected insects indicates that they can all be preserved for a reasonable period of time without the risk of microbial deterioration and spoilage (5). The shelf-life of the selected insects is an added advantage over other conventional sources of protein like fish meal which is easily prone to spoilage. The moisture contents of the selected insects (2.1 to 4.2%), particularly that of cricket (4.2%) obtained in this study was slightly higher than the 3.4 % reported by (10). The disparity could be due to the size, age and location (habitat) of the sample collected for analysis (5).

The ash contents of the selected insects, particularly the tailor ant is similar to the 4.92 % reported for palm weevil (5). The values (3.1 to 4.6 %) reported in this study were lower than values (5.39 to 17.9 %) reported by (8); (20) for termites (*Trinervitermes germinatus*) and *Chrysichthys* species but falls within the range (4.30 to 6.40 %) reported by (15) for grasshopper (*Melanoplus spp*.).

The ether extract or crude fat contents of the selected insects were similar to the values reported by (6) for grasshopper, crickets, and red ants (17.65 to 22.93 %). Fats are essential in the diets as they increase the palatability of feeds by absorbing and retaining their flavour (7). The ether extract values revealed that the insects under study can provide supplementary dietary fat in the feed for poultry.

Table 4: Amino acid profile of selected insects

Parameter (%)	Tailor ant	Black ant	Cricket	Cockroach	Grasshopper
Aspartic Acid	6.26±3.13	6.67±3.34	7.21±3.60	8.37±4.19	6.48±3.24
Alanine	3.24±1.62	3.43±1.72	3.68±1.84	4.81±2.41	3.32±1.66
Cysteine	3.07±1.55	3.29±1.65	3.41±1.71	3.65±1.83	3.18±1.59
Glutamic Acid	11.04±5.49	11.23±5.62	11.49±5.75	12.08±6.04	11.15±5.58
Glycine	2.92±1.46	3.31±1.66	3.26±1.63	3.43±1.72	3.06±1.53
Histidine	1.89±0.95	2.13±1.07	2.21±1.11	2.35±1.18	2.04±1.02
Isoleucine	3.48±1.74	3.74±1.87	3.85±1.93	4.01±2.01	3.61±1.81
Leucine	6.33±3.17	6.68±3.34	6.92±3.46	7.86±3.93	6.49±3.25
Lysine	6.89±3.45	7.22±3.61	7.35±3.68	8.21±4.11	7.08±3.54
Methionine	1.92±0.96	2.11±1.06	2.18±1.09	2.37±1.19	2.04±1.02
Arginine	4.41±2.21	4.76±2.38	4.87±2.43	5.36±2.68	4.58±2.29
Phenylalanine	2.69±1.35	3.05±1.53	3.18±1.59	3.47±1.74	2.87±1.44
Proline	2.05±1.03	2.29±1.15	2.36±1.18	2.48±1.24	2.13±1.07
Serine	2.78±1.39	3.04±1.52	3.15±1.58	3.29±1.65	2.91±1.46
Threonine	3.05±1.53	3.31±1.66	3.43±1.72	3.52±1.76	3.22±1.61
Tyrosine	2.66±1.33	3.03±1.52	3.15±1.58	3.31±1.66	2.84±1.42
Tryptophan	1.21±0.61	1.43±0.72	1.52±0.76	1.64±0.82	1.33±0.35
Valine	3.58±1.79	3.88±1.94	4.06±2.03	4.21±2.11	3.73±1.87

Mean± Standard deviation

Table 5: Availability of selected insects during the year

Sample	Jan	Feb	March	April	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Cricket	-+	-+	++	++	++	++	++	++	++	--	--	--
Cockroach	++	++	++	++	++	++	++	++	++	++	++	++
Black ant	++	++	++	++	++	++	++	++	++	++	++	++
Tailor ant	++	++	++	++	++	++	++	++	++	++	++	++
Grasshopper	++	++	++	++	-+	- +	- -	-+	++	++	++	++

Source: Local farmers, 2014

Key

-- Not available

- + Available in Trace Amount

++ Available in Abundance

The similar values obtained for the crude protein contents of selected insects could be as a result of non-significant difference in amino acids contents among the insects. However, the values revealed that the insects were fairly rich in protein and amino acids. The amino acid profile suggests that the selected insects were rich in the two amino acids (methionine and lysine) commonly limited in the major feed ingredients in poultry diets. Other essential amino acids; isoleucine, leucine phenylalanine, valine, tryptophan, threonine, arginine and histidine were as well present in the insects. The relatively high protein content is an indication that these insects can be of value in poultry diet, particularly in developing countries where the cost of conventional protein sources is expensive. Similar values (50.39 to 53.10 %) were reported by (6) in their studies on grasshopper. However, the crude protein contents of grasshopper and cricket were lower than the 65 % crude protein content of fish meal reported by (2) but higher than the 44 % crude protein content of soybean meal (2). In most of the commercial feed producers and other on-farm formulation of poultry diets, soybean meal is commonly used in place of fish meal because of its relative cheaper price and closer biological value compared to other protein source of plant origin. However, this preliminary investigation into the nutritional potential of the insects in poultry diets is suggestive of performance study that would provide empirical inclusion levels of any of the insect meals in poultry diets.

The amount of nitrogen free extract (NFE) for the insects under study, although low but were slightly higher than the values (2.1 to 5.1 %) reported by (6). Insects have been reported not to be a good source of carbohydrates (5). The high crude fibre reported could be attributed to the little amount of chitin normally found in insects (26). The physiological role of crude fibre in the body is to maintain an internal distention for proper peristaltic movement of the intestinal tract (26). The appreciable level of fibre in the insects under study, suggest their potential as sources of feed ingredient in poultry diet. The similar energy contents of the various insects under study could be attributed to their similar fat contents.

The anti-nutritional values reported for the various insects studied were generally low. Considering the trace values of the various anti-nutritional components in the selected insects, it could mean that they can be consumed without any deleterious effects on poultry. The low anti-nutritional contents and high protein suggest that the nutritive value of the insects studied would not be impaired.

The mineral contents of the insects under study suggest their potential as possible sources of feed ingredients in poultry diets. The high content of iron and copper is of particular interest, as these will help against the fear of anaemic condition in poultry. Magnesium is needed for more than 300 biochemical reactions in the body, as it helps maintain normal muscle and nerve functions, keeps heart rhythm steady, supports a healthy immune blood and regulate blood sugar levels (28).

However, the study showed that the insects were available almost all year round with most of them during the rainy season but some exhibit changes in their biotic and abiotic environments (21). The relative availability of these insects during the rainy season possibly favoured their reproduction and survival on vegetation flush.

Conclusion and Applications

1. Cricket, cockroach and grasshopper had high crude protein content that can make them serve as alternative sources of animal protein.
2. The sampled insects were available almost all year round. This suggested the availability of the insects as animal protein source.
3. The samples were low in anti-nutritional contents. This suggested that the nutritive value of the insect meal would not be impaired.
4. The insect samples were rich in essential minerals and amino acids.
5. The samples have the potential to serve as sources of animal protein in monogastrics especially poultry diets. However, more in-depth studies are required to optimise their levels of inclusion. Also, collaborations of animal nutritionist and livestock industry with entomologists could enhance sustainable insect meal

availability as ingredient for feed milling.

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