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Research article

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Entomophagous response of albino rats to cockroach (*Periplaneta americana*) meal

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Abstract: An experiment was conducted to determine the nutrient composition and effects of cockroach (Periplaneta americana) meal on the growth performance, economics of production and the absolute and relative weights of some internal organs of albino rats. Twelve (12) male albino rats with an average weight of 67.5g were randomly allotted three dietary treatments: T0 with no cockroach meal, and T1 and T2 with 2% and 4% cockroach meal respectively in a Randomised Complete Block Design (RCBD). Each treatment had four rats and each rat served as a replicate. Feed and water were provided ad libitum. The rats were euthanized and their internal organs were weighed at the end of a 28-day feeding trial. Data obtained were analysed using the analysis of variance procedure of the GenStat Statistical Package version 11.1. There were no significant differences in feed intake (P = 0.633), average daily gain (ADG)(P = 0.670) and feed conversion ratio (FCR)(P = 0.326) for the various treatments. The FCR figures recorded for T0, T1 and T2 were 4.81, 4.37 and 4.17 respectively whilst the inclusion of cockroach meal reduced feed cost by 3% and 7% in dietary treatments T1 and T2 respectively. Most of the internal organs recorded no significant difference (P >0.05) but rats on the cockroach meal diets recorded significantly (P = 0.001) lower relative heart weights. Relative kidney weights were also smaller (P = 0.034) for rats on diets containing 4% cockroach meal. Feeding diets containing up to 4% cockroach meal had no negative effects on the feed intake, ADG and FCR of the rats, and can therefore be safely fed to monogastrics up to 4% of the diet.

Keywords: Cockroach, Albino rats, feeding, protein, entomophagy, low cost ingredient, monogastrics

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1 Introduction

Feeds and feed ingredients are at the heart of every successful animal production venture, contributing a great percentage to the total variable cost of production (Kekeocha 1984; Noblet 2007; Veldkamp et al. 2012). The farmer who can manage feeding costs efficiently without compromising the dietary requirements of his animals stands to reap the reward of great profits. Such an endeavour to manage feeding efficiently, among other things, includes using low cost yet nutritious feed ingredients. The farmer must also make sure that his products are affordable and that his venture has, as little impact on the environment as possible. This is necessary due to soaring food prices and increasing global concerns about environmental issues.

The most expensive category of feed ingredients is the source of protein, and they are a very important component of the diets of farm animals, especially monogastrics. Their high prices is due to the fact that most farm animal protein sources are suitable for humans, and are in high demand. A solution to solve this problem is to find alternative feed ingredients which are less expensive but equally nutritious and/or of better quality. These are likely to be ingredients which are yet unknown or unexploited. Insect-based feeds have been identified (Oonincx and Dierenfeld 2012; Pei Yee et al. 2015) as having great potential in solving the problem of high cost of feed ingredients while reducing associated environmental consequences without sacrificing quality nutrition.

The use of insects as feed is viable and eco-friendly since raising insects requires less resources like land, water and time. And they also emit little or no greenhouse gases as compared to poultry and livestock (Oonincx et al. 2010). According to Van Huis et al. (2013), available evidence suggests that insect-based feeds are comparable with fishmeal and soy-based feed formulae. Over 470 insect species are reported to be eaten in Africa (Kelemu et al. 2015). According to a 2014 survey done by Anankware et al. (2016) in Ghana, entomophagy is practised in all 10 regions of the country, with 9 insect species, including termites and palm weevil larvae, being the most popular.

Although insects are eaten in several parts of the world, most people consider cockroaches, as inedible or unpalatable (Beccaloni and Eades 2014). In Ghana, cockroaches are widely regarded as pests, however, Anankware et al. (2016) reported their medicinal use in some rural communities. The low patronage of cockroaches by Ghanaians make them a good choice as an animal feeding material. Various works have been published on the use of cockroaches as feed ingredient and they have revealed that the nutrient composition of cockroaches is comparable to fish meal and soya bean meal (Ayssiwede et al. 2011; Oonincx and Dierenfeld 2012; Pei Yee et al. 2015). This study was therefore carried out with the aim of ascertaining the proximate and mineral composition of cockroach (*Periplaneta Americana*) meal and its influence on the growth performance, economics of production and internal organ components of monogastrics, using the albino rat (*Rattus norvegicus*) as a model animal.

2 Materials and methods

2.1 Location and duration of experiment

The experiment was conducted at the Livestock Section of the Department of Animal Science, KNUST, Kumasi, Ghana and it lasted a period of 28 days.

2.2 Source and processing of feed ingredients

American cockroaches (*Periplaneta americana*) were collected from crevices and hideouts in and around KNUST and kept alive until sufficient quantities were obtained. The cockroaches were immobilised by freezing after which they were put into a sealed aluminium container and kept in an oven at a temperature of 105°C for 30 minutes. The dead cockroaches were then dried at the same temperature for 5 hours, milled, put in an air-tight containers and stored until needed. The other feed ingredients; i.e. maize, wheat bran, fish meal, soya bean meal, oyster shells, dicalcium phosphate, vitamin/trace mineral premix, and common salt were obtained from the open markets in Kumasi. All ingredients were ground to pass through a 2 mm sieve.

2.3 Nutrient composition of feed ingredients

Proximate analysis was done on the cockroach meal at the Nutrition Laboratory of the Department of Animal Science, KNUST, Kumasi, Ghana whilst the nutrient compositions of the other ingredients were obtained from the National Research Council (1998). The metabolizable energy (ME) of the cockroach meal was calculated using Pauzenga (1985) equation i.e.:

$$\text{ME (kcalkg}^{-1}\text{)} = 37 \times\% \text{ CP} + 81.8 \times\% \text{ EE} + 35 \times \% \text{ NFE}$$

Where CP, EE and NFE represented crude protein, ether extract and nitrogen free extracts respectively.

2.4 Experimental animals, design and diets

Twelve (12) male albino rats with an average weight of 67.5g were randomly allotted to three isonitrogenous (18% CP) dietary treatments (Table 1): T0 with no cockroach meal, T1 with 2% cockroach meal and T2 with 4% cockroach meal in a Randomised Complete Block Design (RCBD). Each treatment had four rats and each rat served as a replicate. Blocking was assigned on the basis of weight of rats. All the rats were obtained from the Faculty of Pharmacy and Pharmaceutical Sciences, KNUST, Kumasi, Ghana.

2.5 Care and Management of Experimental Animals

The rats were housed separately in plastic containers measuring 25 × 20.5 × 15 cm. Feed was supplied with a metal trough whilst water was supplied with the aid of overhead nipple drinkers. The plastic containers were tightly covered with a 2.5 cm gauge wire mesh to prevent rats from escaping. Feed and water were supplied *ad libitum*.

2.6 Parameters Measured

2.6.1 Growth Performance and Economics of Production

Weekly feed intake and weekly weight gain were measured and used to calculate the daily feed intake, daily weight gain and feed conversion ratio (FCR). The feed cost index was calculated as:

$$\text{Feed cost index} = \frac{\text{Cost of diet}}{\text{Cost of control diet}} \times 100$$

Table 1: Composition of experimental diets (%, as-fed basis)

	Dietary Treatments		
Ingredients	**T0 (Control)**	**T1 (2%)**	**T2 (4%)**
Maize	55	55	55
Wheat bran	24	24	24
Soya bean meal	13	13	13
Fish meal	6	4	2
Cockroach meal	0	2	4
Dicalcium phosphate	0.5	0.5	0.5
Oyster shells	1	1	1
Vitamin/trace mineral premix[α]	0.25	0.25	0.25
Common salt	0.25	0.25	0.25
Total	100	100	100
Nutrient composition (%) (Calculated)			
Crude protein	18.36	18.17	17.98
Crude fibre	4.16	4.36	4.55
Calcium	0.63	0.62	0.61
Phosphorus	0.70	0.68	0.67
Metabolizable energy (kcal/kg)	3047	3071.8	3094.5

[α]Vitamin-trace mineral premix provided the following per kg of diet: Vitamin A (8000 I.U); Vitamin D3 (150I.U); Vitamin E (2.5mg); Vitamin K (1mg); Vitamin B2 (2mg); Vitamin B12 (5×10-3mg); Folic Acid (0.5mg); Nicotimic Acid (8mg); Calcium Panthotenate (2mg); Choline Cloruro (50mg), Trace Elements: Mg (50mg); Zn (40mg); Co (0.1mg); Cu (4.5mg); Se (0.1mg). Antioxidants: Butylated Hydroxytoluene (10mg). Carrier: Calcium carbonate q.s.p.

Feed cost per weight gain index was also calculated as:

$$\text{Feed Cost per Weight Gain} = \frac{\text{cost per 100g gain of dietary treatment}}{\text{cost of 100g weight gain of control}} \times 100$$

2.7 Internal organ components

At the end of the 28 days, the rats were euthanized for subsequent carcass analysis. The weights of the viscera, lungs, heart, kidneys, spleen, liver, and empty and full gastrointestinal tract (GIT) were measured using an electronic scale (KERN & Sohn GmbH, Balingen, Germany). The relative weights of these organs were expressed as a percentage of the weight of the organ to the final live weight of the rats.

2.8 Statistical Analysis

Data collected were analysed using the Analysis of Variance (ANOVA) procedure of GenStat Statistical Package version 11.1 (VSN International Limited 2008) and differences between means were separated using Fisher's protected LSD. Differences were deemed significant at an alpha level of $P < 0.05$.

Ethical approval: Due to the absence of ethical policy document on the use of live animals for research at the Kwame Nkrumah University of Science & Technology at the time of this research, the authors adopted the Massey University Code of Ethical Conduct for the use of live animals for research, testing and teaching. MUAEC Code 2014-18 (Amended 2018) Feb.pdf (202 KB)

3 Results

3.1 Nutrient composition of cockroach meal

Proximate analyses revealed that cockroach meal contained 53.04%, 26.93%, 12.22%, 4.91%, 2.5% and 0.4% crude protein, ether extract, crude fibre, ash, moisture and nitrogen free extract respectively (Table 2). Furthermore, the cockroach meal contained 0.464%, 0.174%, 0.301%, 0.812% and 0.285% phosphorus, calcium, magnesium, potassium and sodium respectively. The meal also contained 10.80 and 9.80 mg/kg iron and zinc respectively.

3.2 Growth performance and economics of production

It can be observed from Table 3 that, feed intake, average daily gain and feed conversion ratio (FCR) were not significantly different ($P>0.05$) for rats on the various

Table 2: Nutrient Composition of Cockroach Meal

Nutrient	Composition (%)
Moisture	2.5
Crude Protein	53.04
Crude Fibre	12.22
Ether Extract	26.93
Ash	4.91
Nitrogen free extract	0.4
Metabolizable Energy (kcal/kg)$^{\beta}$	4179.6
Minerals	
Potasium	0.812
Phosphorus	0.464
Magnesium	0.301
Sodium	0.285
Calcium	0.174
Iron (mg/Kg)	10.80
Zinc (mg/Kg)	9.80

$^{\beta}$*Metabolizable energy for the cockroach meal was calculated using Pauzenga (1985) equation (ME = 37 × % CP + 81.8 × % EE + 35 × % NFE)*

Table 3: Growth Performance of Rats and Economics of Production

Parameter	TREATMENT			
	T0 (Control)	T1 (2%)	T2 (4%)	F pr.
Initial weight, g	67.5	67.5	67.5	1.000
Final weight, g	135.5	147.8	141.8	0.817
Daily feed intake, g	11.58	12.14	10.71	0.633
Total feed intake, g	324	340	300	0.633
Daily weight gain, g	2.43	2.87	2.65	0.670
Total weight gain, g	68.0	80.2	74.2	0.670
FCR (intake/gain)	4.81	4.37	4.17	0.326
Feed cost index	100	97	93	-
Feed cost/wt. gain index	100	88	81	-

dietary treatments. The FCR values showed slight improvements with increasing inclusion levels of the cockroach meal. Treatments T1 and T2 containing 2% and 4% cockroach meal were 3% and 7% respectively cheaper than the control diet (T0) which contained no cockroach meal. Also, it cost 12% and 19% less to produce a unit weight in rats fed T1 and T2 respectively when compared to the Control diet.

3.3 Internal Organ Components

There were no significant differences (P>0.05) in the absolute weights of the internal organs. However, the relative weights of the kidneys and the hearts were significantly different (P < 0.05). The relative weight of the heart for T1 and T2 were smaller than that of T0 (P=0.001) whilst relative weight of kidney for rats on the treatment containing 4% cockroach (T2) was smaller (P = 0.034) than rats on the other treatments.

Table 4: Absolute and relative weights of internal organs of rats feed diets containing cockroach meal

Absolute Weight (g)	**TREATMENT**			**F pr.**
	T0	**T1**	**T2**	
Viscera	28.2	28.0	27.1	0.960
Lungs	1.117	1.507	1.550	0.157
Heart	0.540	0.535	0.495	0.741
Liver	6.64	7.20	6.69	0.818
Kidneys	1.263	1.433	1.143	0.339
Spleen	0.575	0.593	0.708	0.635
Full GIT	17.2	16.2	16.2	0.933
Empty GIT	9.82	10.27	10.20	0.898
Relative Weight (%)				
Viscera	20.61	19.15	19.32	0.419
Lungs	0.82	1.02	1.09	0.062
Heart	0.40^{b}	0.36^{a}	0.35^{a}	0.001
Liver	4.93	4.89	4.75	0.920
Kidneys	0.94^{b}	0.97^{b}	0.81^{a}	0.034
Spleen	0.424	0.415	0.509	0.565
Full GIT	12.40	11.17	11.57	0.499
Empty GIT	7.27	7.06	7.28	0.830

ab different superscripts across a row are significantly different (P<0.05)

4 Discussion

The high amount of crude protein found in the cockroach meal is an indication that it is a potential protein source in the diet of non-ruminant livestock. The protein and metabolizable energy contents of the cockroach meal used in this study again compares favourably with proteinaceous ingredients like brewer's spent grains, copra cake, cotton seed meal and soya bean meal (National Research Council 1998). Moreover, the results of the proximate and mineral analyses are consistent with those of Bernard et al. (1997) when they investigated alternative feed materials for insectivorous species of animals. The nutrient composition of cockroach meal further supports the assertion made by Sánchez-Muros et al. (2014) that most insects are a rich source of nutrients and that entomophagy should be embraced as a chance towards attaining food security and obtaining a renewable source of feed.

Being able to give animals the right nutrition at an affordable cost is highly essential in today's animal production operations. The low feed cost index and the feed cost per weight gain index recorded in this study indicates that the cockroach meal is a potential suitable feed that can reduce cost of production and maximize profits. The improvements seen in the FCR as the level of cockroach meal increased also buttresses this point. These results corroborate earlier reports by Ravindran and Blair (1993) when they hinted that protein sources like insect meal can be a cheaper alternative to conventional animal and plant protein sources. Although the FCR improvements are not statistically significant, the authors speculate that significant improvements can be achieved if the level of inclusion of the cockroach meal is increased.

In general, the health of the rats was satisfactory and no mortalities were recorded. This suggests that cockroach meal had no detrimental effect on the health of the rats. This result was expected since *Periplaneta americana* has a tall history of being used medicinally. According to Jiang et al. (2012), various research works have reported *Periplaneta americana* to have a variety of pharmacological attributes such as being analgesic, anti-viral, anti-tumour, anti-inflammatory, improving immunity and promoting tissue repair. The authors (Jiang et al. 2012) further stated that the American cockroach contains 7 essential amino acids.

Some statistical differences were recorded between the relative weights of the hearts and kidneys, however, according to the Japanese National BioResource Project for the Rat (NBRP 2017), those values were all within normal range for the breed of rats used in the experiment.

The study concludes that cockroach meal has a nutrient composition that is comparable to many conventional feed ingredients but promises to be a cheaper alternative feed. Additionally, feeding cockroach meal obtained from *Periplaneta americana* at 2% and 4% inclusion levels have no adverse effects on rats and hence can be fed at such levels to monogastrics. In future studies, it is recommended that cockroach meal be included in diets at higher levels to ascertain their effects on animals.

Conflict of interest: Authors state no conflict of interest.

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