CRUDE PROTEIN DIGESTIBILITY OF CRICKET (*Acheta domesticus*) BY BROILER CHICKEN

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ABSTRACT

This research was conducted at the Faculty of Sustainable Agriculture, University Malaysia Sabah, Sandakan Campus to investigate the digestibility of crude protein of cricket and soybean by broiler. The objective of the study is to reduce the cost of importing raw materials such as fishmeal and soybean meal from other countries by replacing it with alternative insect that is cricket. Digestibility trial of these two samples were carried out to determine the percent of digestible protein and were then analysed using CHN Analyser. Dry matter in ileum, dry matter in samples, Protein in ileum, protein in samples and the digestibility of samples were evaluated as parameter. Based on this research the average amount of protein found in cricket was 50.44% whereas 44.36% for soybean. Total protein found in ileum for cricket was 32.84% and 26.96% for soybean. The percent of digestible protein in cricket was 84.39% and 84.4% for soybean. Dry matter content found in cricket was 84.02% and 81.18% for soybean. Dry matter found in ileum for cricket was 86% and 84.4% for soybean. This research was conducted using Complete Randomized Design (CRD) with a factorial combination arrangement of two treatments with 3 replications.

ABSTRAK

Kajian ini dijalankan di Fakulti Pertanian Lestari, Universiti Malaysia Sabah, Kampus Sandakan untuk menyiasat kadar penghadaman protein cengkerik dan kacang soya oleh ayam pedaging. Objektif kajian ini adalah untuk mengurangkan kos mengimport bahan-bahan mentah seperti sisa lebihan ikan dan kacang soya dari negara-negara lain dengan menggantikannya dengan serangga alternatif iaitu cenkerik. Ujian penghadaman menggunakan cengkerik dan kacang soya dijalankan bagi mengetahui kadar peratusan penghadaman protein dan kemudiannya dianalisis menggunakan mesin analisis CHN. Kandungan bahan kering didalam sampel dan usus kecil, Kandungan protein didalam sampel dan usus kecil serta kadar penghadaman sampel dijadikan sebagai parameter kajian. Berdasarkan kajian ini, jumlah purata protein yang tedapat dalam cengkerik adalah 50.44% manakala untuk kacang soya pula adalah 44.36%. Jumlah protein yang terdapat dalam usus kecil untuk cengkerik adalah 32.84% dan untuk kacang soya pula adalah 26.96%. Peratusan protein yang hadam bagi cengkerik adalah 84.39% manakala 84.4% bagi kacang soya. Kandungan bahan kering didalam cengkerik adalah 84.02% dan 81.18% bagi kacang soya. Kandungan bahan kering di dalam usus untuk cengkerik adalah 86% dan 84.4% bagi kacang soya. Kajian ini telah dijalankan menggunakan reka bentuk rawak lengkap dengan susunan kombinasi factorial dua rawatan dengan tiga replikasi.

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LIST OF SYMBOLS, UNITS AND ABBREVIATIONS

ADF	Acid Detergent Fiber
ADIN	Acid Detergent Insoluble Nitrogen
AIA	Acid Soluble Ash
ANOVA	Analysis of variance
CF	Crude Fat
CP	Crude Protein
DE	Digestible Energy
DM	Dry Matter
IU	International Units
ME	Metabolize Energy
MPB	Menadione Dimethylpyrimidol
MSB	Menadione Sodium Bisulfite
MSBC	Menadione Sodium Bisulfite Complex
NDF	Neutral Detergent Fiber
PKC	Palm Kernel Cake
SBM	Soybean Meal
USP	U.S. Pharmacopeia units

LIST OF FORMULAE

CHAPTER 1

INTRODUCTION

1.1 Background of study

The production of poultry meat, consisting almost entirely of broiler meat, was expected to grow at a moderate rate of 2% in 2014, with production at 1.44 million tons. This industry has been self-sufficient since 1984. The poultry sub-sector contributes RM 4.0 billion (poultry meat RM 2.9 billion and eggs RM 1.1 billion) or 76.8% of the ex-farm output value of the industry during the years 1998-2000, the broiler and egg industries increased their output at a rate of 8.9% and 3.3% per annum, respectively. Integrator is a major commercial player in the production of broilers and eggs, and presently contributes 75% of total output in Malaysia. The annual consumption per capita of broiler meat is 31 kg and for eggs, 16.6 kg. The income export from this industry was RM 440 million in 1999 (Ministry of Agriculture, 2001).

Although the industry has the capacity to grow further, rising costs of production are limiting growth. A reduction in fuel subsidies, depreciation of Malaysian ringgit, and implementation of minimum wages in 2013 are all factors that have led to higher production costs in 2014. Average cost of production has increased RM 1.45 per kg in 2012 to RM 1.60 per kg in 2013, to a forecasted RM 1.68 in 2014. (Ministry of Agriculture, 2001).

The expectations for relatively flat consumption growth reflect slow population growth. Poultry meat is the most important protein source for all ethnic groups in the population, and is the dominant meat offered in all food service outlets. This is because chicken is much cheaper than other meat offered in the market such as beef, pork and the prices have been more consistent.

In terms of the cost of production feed constitutes a large proportion in any livestock industry. Raw ingredients for animal feeds are not produced in Malaysia which cause increase in production cost. As such the intensive livestock industries particularly pig and poultry are dependent on imported feedstuffs. The imported ingredients range from vegetables, cereal grains, and animal proteins such as fish meal, bone meal, corn gluten meal, soybean meal, mineral sources and other various micro-ingredients such as minerals, vitamins and other additives used to improve feed efficiency and growth (Raghavan, 2000).

In contrast, the ruminant industry depends primarily on locally available feedstuffs, with only some supplementation provided by imported ingredients. The major local materials used are crop residues and other agro-industrial by-products such as rice bran, copra cake, palm kernel cake (PKC), oil palm frond, sago, tapioca and broken rice. There are 43 compound feed mills in West and East Malaysia ranging from small to medium to highly complex operations, which produced 3.9 million tonnes annually (DVS, 1999).

Whereas for non-ruminant (poultry and pig), most compound feeds are based on maize mixed with other ingredients and numerous additives to provide the necessary amino acids, vitamins and minerals. Most of the ingredients used in the rations are imported which increase the cost of production, although to some extent locally produced ingredients are also included (Chiew, 2001). However, the use of locally produced ingredient depends on supply, cost and also quality. The locally produced ingredients are tapioca and fishmeal. Unfortunately, the amount produced is not sufficient to meet the requirements of the local feed industry. The by-products of oil extraction and the milling factories that produce rice bran, soybean meal, wheat bran and pollard, are always available and usually included in pigs and poultry feeds. (Raghavan, 2000).

Most developing countries are facing difficulties of acute shortage of animal protein that adversely affects the protein intake level of the country's population resulting in malnutrition (Das *et al.*, 2009). As a result, insects are a good alternative as they are consumed all over the world (Melo *et al.*, 2011). Insects have played an important role in human nutrition as a source of protein since time immemorial. Protein is a very important nutrient source in poultry diets and is useful in maintaining and repairing tissues for organisms to enable proper growth and development (Bondari and Sheppard, 1981). Melo *et al.* (2011) noted that several species of Orthoptera order, grasshoppers form part of the diet of some ethnic groups in all continents.

Most edible insects are cheap, available and can provide a good source of protein and minerals needed to complement cereal-based foods consumed in the developing countries (Ifie *et al.*, 2011). In the Niger Delta region of Nigeria, the larva of *Oryctes monoceros* is one of the insects that are commonly consumed raw, boiled, smoked or fried. Similarly, Mophane worms (*Imbresia belina*) form an important source of protein in human nutrition and to a lesser extent animal nutrition in Botswana, Namibia, South Africa and Zimbabwe. According to Womeni *et al.* (2012), the high cost of animal protein has directed interest towards several insects as potential sources of proteins for humans.

The high cost and scarcity of feedstuffs particularly the protein sources such as soybean cake, groundnut cake and fish meal are the major factors militating against commercial poultry production (Adeniji, 2007). Feed constitutes approximately 75% of the variable costs in poultry production (Mupeta *et al.*, 2003) or 70% of the total production costs of broiler meat (Teguia and Beynen, 2005). The demand for low cost poultry feed is high, due to the rising cost and limited supply of commercial feeds (Mupeta *et al.*, 2003). Hassan *et al.* (2009) contended that the cost of feed ingredients has been steadily increasing due to growing number of poultry farms and feed compounding mills. In Nigeria, Ojewola *et al.* (2005) stated that the search for alternative protein sources of feed ingredients as a partial or complete substitute to fish meal, a conventional costly ingredient in poultry diets has been long and tortuous. Presently, the demand for feed grade fish and fish meal far exceeds availability. As a result, Gabriel *et al.* (2007) opined that locally produced feed using locally available ingredients will reduce the cost of production.

Insects such as grasshoppers fly lava, corn crickets, field crickets and mophane worms (also locally known as phane) occur in good numbers in most parts of Botswana and could be easily harvested and utilized as protein sources in poultry diets. Of these, only phane has recently been utilized as a protein source in livestock feeds, indicating that there is limited information on the use of insects as alternative sources of protein in livestock diets in Botswana. Therefore, this work endeavours to draw attention to the nutritional value of insects as constituents of poultry diets in smallholder poultry production.

Furthermore, the local fishmeal production that depends on the supply of fish waste, and the fish industry is not large enough to support production for fishmeal as well as for human consumption. This may cause the supply to be irregular and as a consequence, the local feed millers prefer to import rather than use locally produced fishmeal. (Gracey, 1981). Soybean meal is produced in small quantities and is obtained after extraction of oil from soybean and after the production of soybean curd and soybean drinks. It is estimated that locally produced soybean meal provides 50% of the total requirement (Griffiths *et al.*, 1977)

1.2 Justification

In a population the need for these protein and energy sources which came from imported ingredients such as maize and soybean has increased. As a result, these industries are growing day by day. But they demand fast-growing animals and good quality of feed with high levels of energy, protein, vitamins and essential minerals to support maximum growth of these animals before they can be sold. At present the major conventional protein and energy source that is used to formulate various livestock feed were imported and has been over-exploited and consequently has a very high price. As a result the cost of conventional feed incurs about 50-65% of the total cost of livestock production (Banerjee, 1992; Sharma and Kishan, 2006). Hence, various investigations are being carried out to find alternative way to reduce the cost for importing feedstuff. Such alternatives may include insects. Thus, this study was carried out because majority of feedstuffs used in rations for monogastric livestock (i.e. pig and poultry) are imported. Maize and soybean meal are the major imported ingredients. Locally available raw materials make up about 30 percent of the total feed ingredients in Malaysia.

1.3 Objective

The objective of this study was:

a) To reduce the cost of importing raw materials from outside countries such as maize and soybean by replacing it with alternative insect that is cricket.

b) To evaluate the dry matter and crude protein content of cricket and soybean meal

c) To evaluate and compare the digestibility of crude protein between cricket and soybean meal.

1.4 Hypothesis

Ho : The digestibility of crude protein of cricket is not within normal range found in contemporary protein feed (80% digestibility)

Ha : The digestibility of crude protein of cricket is within normal range found in contemporary protein feed (80% digestibility)

Ho : The profile of protein is not similar to soybean meal

Ha : The profile of protein is similar to soybean meal

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

The poultry production in Malaysia is too dependent on imported feedstuffs especially protein feed ingredients. Presently, local production of soybean and other beans to be used as protein feed ingredients are not economically feasible. The current supply of local fish meal is small and future production is expected to decrease due to limited availability of trash fish. Therefore, alternative protein sources for livestock in the country should be explored and studied so that they could replace some of the imported protein feed ingredients (Ismasyahir *et al.*, 2012).

Among potential protein sources that could replace soybean meal and fish meal is insect protein. Insects can be used to produce cheaper proteins from non-food animals. Insects are rich in protein, with reported protein contents ranging from 44-70% (Ramos and Elorduy, 1987). One of the local insects that have potential to be used as protein source for poultry diets is house cricket. House crickets are being sold in most pet shops and tropical fish shops as fishing bait and food for birds, reptiles and aquarium fish. The house cricket is easily adapted to domestic rearing and has not been seriously studied as a potential source of nutrients for non-ruminants in the country (Ismasyahir *et al.*, 2012).

Suitability of cricket as source of protein feed for poultry has been much proven. This study will focus on the use of cricket as the source of protein for poultry feed

2.2 House Cricket

Crickets are a group of insects related to grasshoppers and katydids (Hahn, 2008). The house cricket, *Acheta domesticus*, is commonly encountered in Florida in only two contexts: bait for fish and food for pets. This is because it does not survive very well in the wild in United States. House crickets that are sold in bait and pet stores are reared in large commercial cricket factories or by local entrepreneurs (Walker, 2014).

While crickets are common outdoors, they may accidently enter homes.. They enter buildings through open doors and windows, cracks around poorly fitted windows, in foundations, in siding, and spaces under doors, so it may be difficult to find the exact point of entry. In Minnesota, the most common crickets found in homes are the field cricket, the camel cricket, and the house cricket (Hahn, 2008).

House crickets are often associated with the new year and good luck. Although some (including the Audubon field guide) say that crickets are a nuisance because of their continuous chirping, others value them for that very characteristic. Indeed, unlike most other insects, cricket songs are characterized by almost pure tones of constant frequency (Simmons and Ritchie, 1996). In China and Japan, crickets have been brought indoors to delight inhabitants for almost 1000 years. Valued for their song, crickets were kept in small cages of bamboo or other materials. Crickets were also valued for sport, with cricket fighting coming into vogue during the Sung Dynasty (960-1279 A.D.). Books detailing the collection, care and feeding of crickets were written, as well as techniques for conducting a proper cricket fight. Special diets of rice mixed with delicacies such as cucumbers, lotus seeds or mosquitoes were fed to the little warriors (Walker and Masaki, 1989). Incidentally, Hack (1977) found fighting to be highly demanding in terms of energy costs for crickets, and also found that acoustic signalling was the most efficient of the seven measured antagonistic response tactics measured.

2.3 Distribution

The house cricket is probably native to southwestern Asia, but has been widely distributed by man. In the United States it occurs wherever it is sold, but it survives in feral populations only in the eastern United States (except peninsular Florida), and southern California. Why it fails to survive in peninsular Florida is not known (Walker, 2014).

2.4 Life Cycle

House crickets take two to three months to complete their life cycle when reared at 28-35° C The female is capable to produce as many as 200-1,500 eggs/female for three weeks. Fertile eggs will hatch after 10-12 days of oviposition. Eggs are deposited in whatever damp substrate is provided for example, sand or peat moss. Juveniles resemble the adults except for being smaller and wingless (Bennett, 2003). Each female will lay between 50 to 100 eggs that hatch in about two to three weeks (Incomplete metamorphism). Newly hatched nymphs are the same size as the eggs, and blend in with their surroundings (Bennett, 2003).

Adult crickets will eat their own young (cannibalism). Also, it is normal for some adults to die naturally after mating. The remaining eggs will continue to hatch for 10 to 15 days. As is the case with other orthopterans, when crickets first hatch they already look much like adults (nymphs), except that their wings and genital organs are not yet developed. It takes these tiny crickets eight to twelve weeks to reach full maturity. Adult crickets generally live two to three months (Bennett, 2003)

2.5 Identification

The house cricket is a 16 to 21 mm long, light yellowish-brown cricket, with wings that cover the abdomen. It has three dark transverse bands on the top of the head and between the eyes. All house crickets have long hind wings when they become adult, but they sometimes shed them later (Walker, 2014).

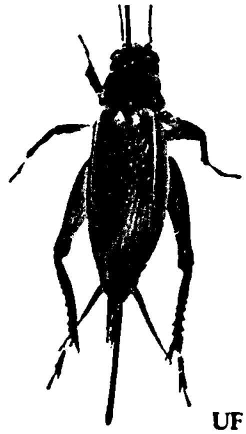

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Figure 2.1 An adult female house cricket, *Acheta domesticus* (Linnaeus), with hindwings intact. Photograph by Paul M. Choate, University of Florida.

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Figure 2.2 An adult female house cricket, *Acheta domesticus* (Linnaeus). Forewings extended, revealing intact right hindwing. Left hindwing has been shed. Photograph by Paul M. Choate, University of Florida.

2.6 Habits and Habitat

House crickets can spend their whole lives inside buildings. They are usually found in warm areas where they can get enough moisture and food. Inside the safety of a building they can lay many eggs. In the winter they are often found near fireplaces, kitchens, water heaters, and furnace areas, but they may be found anywhere inside a structure. House crickets are common outdoors and are particularly common around garbage dumps. Like field crickets, house crickets are strongly attract to light. They feed on plant material and dead or weakened insects. House crickets can feed on fabrics, such as silk and wool, and can cause severe damage, especially if they are numerous. (Walker, 2014).

2.7 Nutritional Value of crickets

Previous studies indicate that crickets (Orthoptera: Gryllidae) play a role in human nutrition. In West Africa, some children dig the brown crickets (*Brachytrypes membranaceus L.*) from their holes in the fields, roast and eat them. Crickets come out of their holes at night when they can be picked life. DeFoliart *et al.* (1982) reported that corn cricket (*Anabrus simplex Haldeman*) had a mean dry weight (males and females combined) of 1.08 g and CP content of 58%. Furthermore, the crude protein (CP) content of *B. membranaceus L* was 25.8% and 32.4% for females and males, respectively. Additionally, the carbohydrate for males was lower (489 g/kg) than that of females (548 g/kg). The fat content for males and females were 32 and 53 g/kg, respectively and fibre content for males and females 85 and 80 g/kg, respectively (Adeyeye and Awokunmi, 2010). According to Mayhew and Macmillan (1998), the protein and fat contents of locusts are 490 to 610 and 100 to 180 g/kg, respectively.

Adeyeye and Awokunmi (2010) also worked on the proximate compositions of field cricket (*B. membranaceus L.*) and found the CP to be 324 and 258 g/kg for males and females, respectively while carbohydrate was 489 and 548 g/kg for females and males, respectively. The energy content of cricket meal ranged from 15 MJ (male) to 16 MJ (female) which compared favourably with the cereal value of 13-16 MJ/kg. Also, the Fe content is 31-100 mg/kg. *B. membranaceus* is a good source of Zn (515-1032 mg/kg), K (746-1122 mg/kg), Na (1037-2226 mg/kg) and P (10880 - 10936 mg/kg).The authors concluded that *B. membranaceus* was a good source of protein carbohydrate and energy, and minerals (major and trace).

Finke *et al.* (1985) evaluated the protein quality of Mormon crickets (*Anabrus simplex Haldeman*) in broiler chick diets and found that the corn cricket diet compared favourably with a corn-soybean meal diet with no significant differences in weight gain or feed/gain ratios. Previously, DeFoliart *et al.* (1982) fed corn-cricket to broilers and found that corn cricket-based diets produced significantly better growth of broiler chicks than was produced by a conventional corn-soybean based diet. Similarly, Nakagaki *et al.* (1987) incorporated dried house cricket meal into practical diets replacing soybean meal as the major protein source and reported no significant differences in weight gain between chicks fed corn-soybean meal diet and those fed cricket diets. However, feed ratios improved significantly when diets were supplemented with methionine and arginine, indicating that these were probably limiting.

The study by Wang *et al.* (2005) on the nutritional value of field cricket as poultry feed. Table 2 also shows that field crickets also have 58.3% CP on a dry basis. Also, fat and, thus energy content was higher in field crickets compared to soybean meal, meat and bone meal, and fishmeal. The chitin content of this insect was 8.7%. Ifie *et al.* (2011) found that larva of *O. monoceros* had 36.45% CP (dry weight), 34% crude fat, 10.5% CF and 4.0% ash contents. The ash contained 440.0 mg/100 g, 175.0 mg/100 g, 85.00 mg/100 g and 38.40 mg/100 g of Na, Mg, Fe and K, respectively. The protein digestibility was found to be 58.05%. These values indicate that insect larva could serve as an alternative source of protein and other nutrients supplement in human and animal diets. *Wang et al.* (2005) compared the total amino acid profiles for field cricket to fishmeal and found that amino acids percentages of field cricket were higher than those of fishmeal. Lysine, methionine and cysteine were 4.79%, 1.93% and 1.01%, respectively in field cricket compared to 4.51%, 1.59% and 0.49% respectively in fishmeal. These values indicate that field crickets could be excellent source of protein in poultry diets. The authors also found that field crickets had good amounts of digestible amino acid for poultry. The average total amino acid digestibility coefficient of field cricket was higher (92.9%) than that of fish meal (91.3%) showing that in addition to high protein content, it also has good amounts of digestible amino acids. The amino acid composition of *B. membranaceus* samples also showed that total essential amino acids were comparable to those of milk, beef and eggs (Adeyeye and Awokunmi, 2010). Furthermore, the total essential amino acid was reported to be higher in all the cricket samples ranging from 288.5 to 339.7 mg/g protein (with histidine) and 267.9-316.8 mg/g protein (without histidine). These results compare favourably with the total essential amino acid values found in cow's milk, beef and eggs, indicating that *B. membranaceus* is a good source of protein, carbohydrate, energy and minerals.

REFERENCES

Adeniji, A.A. 2007. Effect of Replacing Groundnut Cake with Maggot Meal in the Diet of Broilers. *Int. J. Poult. Sci.*, 6 (11): 822-825.

Adeyeye, E.I., and Awokunmi, E.E. 2010. Chemical Composition of Female and Male Giant African Crickets, Brachytrypes membranaceus L. *Int. J. Pharma Bio Sci.*, 1(1): 125-136

AOAC. 1990. Official Method of Analysis, 15th Edition. Association of Analytical Chemists. Washington D.C.

Applegate, T.J., Powers, W.J., Angel, R., and Hoehler, D. 2008. Effect of Amino Acid Formulation and Acid Supplementation on Performance and Nitrogen Excretion in Turkey Toms. *Poult. Sci.* 87:514-520

Balnave, H.S. 1970. Nutrient Requirements of Poultry: Ninth Revised Edition, 1994 Subcommittee on Poultry Nutrition, National Research ISBN: 0-309-59632-7, 176 pages.

Bennett-Clark, H.C. 1989. Songs and the Physics of Sound Production. In: Cricket Behavior and Neurobiology. (ed. F. Hubrer, T.E. Moore and W. Loher), pp. 227-261. Ithaca, New York: Cornell University Press.

Boisen, S. 1998. A New Protein Evaluation System for Pig Feeds and Its Practical Application. Acta Agriculturae Scandinavica. Section A, Animal Science 48, 1–11.

Bondari, K., and Sheppard, D.C. 1981. Soldier Fly Larvae as Feed in Commercial Fish Production. Aqua-Culture,24: 103-109.

Bryden, W.L., Angkanaporn, K., Ravindran, V., Imbeah, M. and Annison, E.F. 1996. Use of Homoarginine Technique to Determine Endogenous Amino Acid Losses in Poultry and Pigs. In: Protein Metabolism and Nutrition, (editors A.F. Nunes, A.V. Portugal, J.P. Costa and J.R. Ribeiro) Estacao Zootecnica Nacional: Vale de Santarem, Portugal, pp. 319- 323

Das, M., Ganguly, A., and Haldar, P., 2009. Space Requirement for Mass Rearing of Two Common Indian Acridid Adults (Orthoptera: Acrididae) in Laboratory Condition. *American Eurasian J. Agric. and Environ. Sci.*, 6 (3): 313-316.

DeFoliart, G.R., Finke, M.D., and Sunde, M.L. 1982. Potential Value of the Mormon Cricket (Orthoptera: Tettigoniidae) Harvested as a High-Protein Feed for Poultry. J. Econ.Entomol., 75(5): 848-852.

Dufour, D.L. 1987 Insects as Food a Case Study from the Northwest Amazon. Am. Anthropol. 89: 383-397.

DVS. 1999. Department of Veterinary Services, Ministry of Agriculture, Malaysia.

Ensminger, M.E., Oldfield, J.E., and Heinemann, W.W. 1990. Feeds & Nutrition. Clovis, California, Usa, Ensminger Publishing company

Finke, M.D., Sunde, M.L., and DeFoliart, G.R. 1985. An Evaluation of the Protein quality of Mormon Crickets (Anabrus simplex Haldeman) When Used as a High Protein Feedstuff for Poultry. Poult. Sci.,64(4): 708-712.

Fox, D.G., Nutrient Requirements of Poultry: Ninth Revised Edition, 1994 Subcommittee on Poultry Nutrition, National Research ISBN: 0-309-59632-7, 176 pages.

Gabriel, U.U., Akinrotimi, O.A., Bekibele, D.O., Onunkwo, D.N., and Anyanwu, P.E. 2007. Locally Produced Fish Feed: Potentials for Aquaculture Development in Sub-Saharan Africa. *Afr. J. Agr. Res.*, 2(7): 287-295

Gurnsey, M.P. and James, K.A.C. 1985. An Improved Method of Ileal Cannulation of Adult Cockerels. Res. Vet. Sci. 39:390-391.

Hack, M.A. 1997. The Energetic Costs of Fighting in The House Cricket Acheta domesticus L. Behavioral Ecology, 8(1): 28-36'

Hassan, A.A., Sani, I., Maiangwa, M.W., and Rahman, S.A. 2009. The Effect of Replacing Graded Levels of Fishmeal with Grasshopper Meal in Broiler Starter Diet. PAT, 5(1): 30- 38. www.patnsukljournal.net/currentissue. Access on 25 June 2016. Verified on 5 September 2016

Hirs, C. W. H. 1967. Performic Acid Oxidation. Methods Enzymol. 11: 197-199.

Ifie, I., and Emeruwa, C.H. 2011. Nutritional and Anti-Nutritional Characteristics of the Larva of Oryctes Monoceros. *Agric. Biol. J. N. Am.*, 2(1):42-46.

Ismasyahir, A .R., Yusof, H.A., and Azahan, E.A., 2012. Nutritional Evaluation of House Cricket (Brachytrupes Portentosus) Meal for Poultry 14-18

Koltho, I.M., Sandell, E. B., and Meehan, E. J. 1969. Quantitative Chemical Analysis (4 Ed). Lon-don: The Macmillan Company, pp 793-1075. (Chinese edition)

Kratzer, F.H. 1985. Nutrient Requirements of Poultry: Ninth Revised Edition, 1994 Subcommittee on Poultry Nutrition, National Research ISBN: 0-309-59632-7, 176 pages.

Latshaw, J.D. 1994. Nutrient Requirements of Poultry: Ninth Revised Edition, 1994 Subcommittee on Poultry Nutrition, National Research ISBN: 0-309-59632-7,176 pages

Landry, S.V., DeFoliart, G., and Sundae, M.L. 1986. Larval Protein Quality of Six Species of Lepidoptera (Saturniidae, Sphingidae, Noctuidae). J Econ Ent 79(3):600-604.

Lawrence, L.M. 1994. Nutrient Requirements of Poultry: Ninth Revised Edition, 1994 Subcommittee on Poultry Nutrition, National Research ISBN: 0-309-59632-7, 176 pages

Lemme, A., Ravindran, V., and Bryden, W.L. 2004. Ileal Digestibility of Amino Acids in Feed Ingredients for Broilers. Wld's.Poul. Sci. J. 60:421-435.

Mayhew, S., and Macmillan, A. 1998. Tropical and Sub-Tropical Foods, Macmillan, London, UK, (1988) In: Tropical Science, 38:233–237.

McNab, J.M. 1994. Amino Acid Digestibility and Availability Studies With Poultry. In Amino Acids in Farm Animal Nutrition (editor J.P.F.D'Mello), CAB International, Wallingford, U.K. pp. 63-98.

Medway, S.C., Kare, C.T. 1959. Nutrient Requirements of Poultry: Ninth Revised Edition, 1994 Subcommittee on Poultry Nutrition, National Research ISBN: 0-309-59632-7, 176 pages.

Melo, V., Garcia, M., Sandoval, H., Jiménez, H.D., and Calvo, C. 2011. Quality Proteins From Edible Indigenous Insect Food of Latin America and Asia. *Emir. J. Food Agric.*, 23 (3): 283-289.

Miligan, L.P. 1994. Nutrient Requirements of Poultry: Ninth Revised Edition, 1994 Subcommittee on Poultry Nutrition, National Research ISBN: 0-309-59632-7,176 pages

Moran, E.T., Nutrient Requirements of Poultry: Ninth Revised Edition, 1994 Subcommittee on Poultry Nutrition, National Research ISBN: 0-309-59632-7, 176 pages.

Moughan, P.J., Darragh, A.J., Smith, W.C. and Butts, C.A. 1990. Perchloric and Trichloaacetic Acids as Precipitants of Protein in Endogenous Ileal Digesta From the Rat. J. Sci. Food Agric. 52:13- 21.

Mupeta, B., Coker, R., and Zaranyika, E. 2003. The Added Value of Sunflower Performance of Indigenous Chickens Fed A Reduce-Fibre Sunflower Cake Diet in Pens and on Free- Range.www.dfid.gov.uk/r4d/PDF/outputs/R7524e.pdf. Access on 13 August 2016.Verified on 20 October 2016

Nakagaki, B.J., Sunde, M.L., and DeFoliart, G.R. 1987. Protein Quality of the House Cricket, Acheta domesticus, When Fed to Broiler Chicks. *Poult. Sci.*, 66(8): 1367-1371.

NAP. 1998. Third National Agriculture Policy (1998-2010).

NRC, 1988. Quality Protein Maize. National Academy Press, Washington D.C. USA., pp: 41-54.

Parsons, C.M. 1994. Nutrient Requirements of Poultry: Ninth Revised Edition, 1994 Subcommittee on Poultry Nutrition, National Research ISBN: 0-309- 59632-7, 176 pages.

Parsons, C.M. 2002. Digestibility and Bioavailability of Protein and Amino Acids. In: Poultry Feedstuffs: Supply, Composition and Nutritive Value (editors J.M. McNab and K. N. Booman). CABI Publishing, England. pp115-135.

Parsons, C. M., Potter, L. M., Brown, R. D. JR., Wilkins, T. D. and Bliss, B. A. 1982. Microbial Contribution to Dry Matter and Amino Acid Content of Poultry Excreta. *Poult. Sci.* 61:925-932.

Payne, W.L., Combs, G.F., Kifer, R.R. and Snider, D.G. 1968. Investigation of Protein Quality –Ileal Recovery of Amino Acids. Fed. Proc. 27: 1199-1203.

Raghavan, V. 2000. Managing Risks by the Feed Industry for Safe Food. 22nd MSAP Annual. Conference., p. 27-48.

Raharjo, Y., and Farrell, D.J. 1984. A New Biological Method for Determining Amino Acid Digestibility in Poultry Feedstuffs Using a Simple Cannula, and the Influence of Dietary Fibre Onendogenous Amino Acid Output. Anim. Feed Sci. Technol. 12: 29-45.

Ramos-Elorduy, J. 1987. Are insects edible? Man's attitudes Toward eating Insect. Food Def Stud Persp 20: 78-83

Ravindran, V. & Bryden, W.L. 1999. Amino Acid Availability in Poultry – in Vitro and in Vivo Measurements. Australian Journal of Agricultural Research, 50: 889–908.

Ravindran, V. 2007. Standardized Ileal Digestibility. The Poultry Site. www. the poultrysite. com/articles /317 /standardised-ileal-digestibility

Ravindran, V., Hew, L.I., Ravindran, G. and Bryden, W.L. 2004. Endogenous Amino Acid Flow In the Avian Ileum: Quantification Using Three Methods. Br. J. Nutr. 92:217-223.

Robert, W. 1999. Pemberton Insects and Other Arthropods Used as Drugs in Korean TraditionaL Medicine. J. Ethnopharmacol. 65: 207-216.

Roos, N., Pfeuffer, M., and Hagemeister, H. 1994. Labelling with 15N as Compared with Homoarginine Suggests a Lower Prececal Digestibility of Casein in Pigs. J. Nutr. 124: 2404-2409

Rostagno, H.S., Pupa, J.M.R. And Pack, M. 1995. Diet Formulation for Broilers Based on Total Versus Digestible Amino Acids. Journal Applied Poultry Research 4: 293-299.

Sauer, W.C., Dugan, M., de Lange, C.F.K., Imbeah, M. and Mosenthin, R. 1989. Considerations in Methodology for the Determination of Amino Acid Digestibilities in Feedstuffs for Pigs. In Absorption and Utilisation of Amino Acids (editor M. Friendman). Vol. III. CRC Press, Boca Raton, Florida, pp. 217-230.

Schutte, J.B., De Jong, J. 1999. Ideal amino acid profile for poultry. pg. 259-263 (Cahiers Options Méditerranéennes; n. 37)

Sibbald, I.R. 1987. Estimation of Bioavailable Amino Acids in Feed Stuffs for Poultry and Pigs: Overview With Emphasis on Balance Experiments. Can. J. Anim. Sci. 67: 221-300.

Simmons, L.W., and Ritchie, M.G. 1996. Symmetry in the songs of crickets. Proceedings of the Royal Society of London, B26: 1305-1311.

Siriwan, P., Bryden, W.L., and Annison, E.F. 1994. Use of Guanidinated Dietary Protein to Measure Losses of Endogenous Amino Acid in Poultry. Br. J. Nutr. 71: 515-529.

Teguia, A., and Beynen, A.C. 2005. Alternative Feedstuffs for Broilers in Cameroon.Livestock Research for Rural Development. http://lrrd.cipav.org.co/lrrd17/3/tegu17034.htm. Access on 15 October 2016. Verified on 15 November 2016

Walker, T.J., and Masaki. 1989. Cricket Natural History. In: Cricket Behavior and Neurobiology.(ed. F. Hubrer, T.E. Moore and W. Loher). Ithaca, New York: Cornell University Press.

Walker, T.J., 2014. House cricket, Acheta domesticus (Linnaeus 1758). Singing Insects of North America. (11 April 2014).

Wang, D., Zhai, S.W., Zhang, C.X., Bai, Y.Y., An, S.H., and Xu, Y.N. 2005. Evaluation on Nutritional Value of Field Crickets as a Poultry Feedstuff. Asian-Aust. J. Anim. Sci., 18: 667-670.

Wedekind, T., Baker, B.L. 1990. Nutrient Requirements of Poultry: Ninth Revised Edition, 1994 Subcommittee on Poultry Nutrition, National Research ISBN: 0-309-59632-7, 176 pages.

Wilson,R.P. 1994. Nutrient Requirements of Poultry: Ninth Revised Edition, 1994 Subcommittee on Poultry Nutrition, National Research ISBN: 0-309-59632-7, 176 pages.

Womeni, H.M., Tiencheu, B., Linder, M., Nabayo, E.M.C, Tenyang, N.M., biapo, F. T., Villieneuve, P., Fann, J., and Parmentier, M. 2012. Nutritional Value and Effect of Cooking, Drying and Storage Process on Some Functional Properties of Rhynchophorus phoenicis. Int. J. Life Sci. Pharm. Res., 2(3): 203-219.