UNIVERSITY OF EDUCATION, WINNEBA

EFFECT OF SUPPLEMENTARY TERMITE MEAL ON GROWTH PERFORMANCE OF THE PEARL GUINEA FOWL (*Numida meleagris*)

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MASTER OF PHILOSOPHY (ANIMAL PRODUCTION AND MANAGEMENT)

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DECLARATION

STUDENTS DECLARATION

I, Hawa Mohammed, declare that this thesis, with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole for another degree elsewhere.

SIGNATURE: ……………………………

DATE: ……………………………………

SUPERVISORS' DECLARATION

We hereby declare that the preparation and presentation of this work or research was supervised in accordance with the guidelines for supervision of thesis as laid down by the University of Education, Winneba.

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DEDICATION

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LIST OF ABBREVIATION

EAA	**-**	Essential Amino Acid
FAO	**-**	Food and Agriculture Organization
PAP	**-**	Processed Animal Protein
PDIFF	**-**	Probability of Difference
AMP’s	-	Antimicrobial Peptides.
NRC	-	National Research Council
BSFL	-	Black Soldier Flies Larvae
IFIF	-	International Feed Industry Federation
EU	-	European Union
CRD	-	Completely Randomized Design
FEC	-	Faecal Egg Count
SAS	-	Statistical Analysis System
EC	-	European Commission
GLM	-	General Linear Model
DM	-	Dry Matter
EFSA	-	European Food Safety Authority
BSE	-	Bovine Spongiform Encephalopathy
FM	**-**	Fish Meal
TM	-	Termite Meal
EM	-	Earthworm Meal
MM	-	Maggot Meal

ABSTRACT

This study was undertaken to determine the effect of termite meal on the growth and survival of Guinea fowls (*Numida meleagris*). A 12-week experiment was divided into two phases, namely brooding and post-brooding phases. One hundred and thirty-five (135) day old keets were used for the experiment. Termites were harvested from the termitarium with soil. Samples of termites and soil were taken for laboratory analysis. A pre weighed 300g of termites only was given to the third group of keets and 3000g of termite plus soil was given to the birds the second group of keets early in the morning before the main feed was given and water was provided *ad libitum*. A Completely Randomized Design (CRD) was used for the experiment since the treatments used were more than two. Parameters measured included; average daily feed intake, total feed intake, final body weight body, weight gain and daily weight gain and feed conversion ratio. Data collected were analyzed using the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS for Windows, Version 11). The means were separated by using the probability of difference (PDIFF). Termites' meal-only inclusion in the diet had a significant ($P < 0.05$) effect on daily feed intake, total feed intake, final body weight, body weight gain, and daily weight gain. However, the feed conversion ratio was not significantly ($P > 0.05$) influenced by the termites plus soil meal used in this study. Daily feed intake, total feed intake, final body weight, body weight gain, and daily weight gain were significantly ($P < 0.05$) higher among local Guinea fowls fed with termites' meal only, followed by birds fed with a combination of termites' meal plus soil. However, the control treatment which did not include termites recorded the least daily feed intake and total feed intake throughout the study.

High mortality was recorded in the control group, followed by the termites and soil group and no mortality in the termite's only group in brooding period (0-6 week) while in the post brooding period (6-12 week) no mortality was recorded for the treatment groups. Faecal samples of the birds taken for laboratory analysis showed eggs of Hymenolepis, Trichostrogyloides, and Spirometra in the control group, Ascarids, Hymenolepis and Trichostrongylus in the termite and soil group as well as Trichostrongylus and Ascarids in the termite's only group. Post-mortem examination on birds proved the presence of tapeworms and roundworms in the intestinal tract. Termite only meal conferred better growth performance and improved feed intake and body weight as compared to birds on the control treatment and termite plus soil. It was concluded that, increased productivity of poultry particularly Guinea fowls could be achieved by feeding termite only meals which could reduce mortality significantly.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Insects are consumed as a supplementary source of protein by over two billion people in the world (Jongema, 2015; Moula and Detilleux, 2019). According to Pedigo (2002) and Akunne *et al. (*2013), insects form about 75 % of all organisms on earth. Some of which are grasshoppers, locust, crickets, black soldier fly, housefly mealworms earthworm, termites etc. Insects provide satisfactory sources of nutrients (proteins, fat, energy, vitamins and minerals). In this regard, a study by Agbidye *et al*. (2009) and Khan (2018) showed that, intake of 100 g of caterpillars fulfills about 76 % of the required quantity of proteins on daily basis and accomplishes about 100 % daily needs of the vitamins in humans. Similarly, the nutritive values of three silkworm pupae are considered to be same in nutrients for one chicken egg (Mitsuhashi, 2010).

Insects are suggested as an alternative protein source in poultry feed, due to similar fat (30–40 % dry matter; DM) and protein content (40–60 % DM) to that of Soyabean Meal or Fish Meal (Makkar *et al*., 2014). A shift from conventional protein sources such as Soyabean Meal and Fish Meal towards insect meals might result in a more efficient use of natural resources and lower emissions of greenhouse gases as well as limiting eutrophication (loss of nutrients) of water environments (Khan, 2018). Due to the reasons mentioned above, the potential of insect protein in poultry diets has attracted much attention. Therefore, it is an opportunity to consider the inclusion of insect proteins as raw material to be used in commercial feed manufacturing and to develop intensive farming systems for insects.

The FAO strongly recommends the use of insects as human food and animal feed as a tool for poverty alleviation (FAO, 2013). Termites are among the most nutritious insects and widely consumed by humans (Lavalette, 2013). Insects are natural food sources for many poultry (Bovera *et al.*, 2016). Insects such as termite are employed as feed in poultry and also used in the pet industry (EU, 2017; Boafo *et al.*, 2019). Chickens, for example, can be found picking worms and larvae from the topsoil and litter where they walk, which demonstrates that they are developmentally adjusted to insects as a characteristic piece of their diet (Bovera *et al*., 2016). The mass production and methods of collection without destruction have been problematic in West Africa, therefore used as supplementary feed for poultry (Kenis *et al.,* 2014). Termites serve as a good protein supplement in the diet of poultry at both starter and finisher level without any diverse effect on the carcass and the health quality (Shindi *et al.,* 2019). It is used as a substitute to fishmeal for birds.

Termites in poultry nutrition in west Africa plays an important role towards improvement of poultry production as it is widely given to domestic fowls and Guinea fowls (Sankara *et al.*, 2018; Dao *et al*., 2020). A study by Poissonnier *et al.* (2020) indicates that, the amount of food ingested is enough for termites to attain nutritional balances. This makes it be of nutritional value when consumed by their prey (poultry). However, farmers consider termites as very important because they are an easily available protein for birds not withstanding its variation with seasons (Boafo *et al*., 2019). In poultry nutrition, the supply of essential amino acids (EAAs) to grow rapidly in a short period of time is a key factor.

In recent years, the increasing price of soybean has become a critical aspect for the economic sustainability of the poultry meat industry, particularly in some developing countries (Khan, 2018). Due to problems with over-fishing and environmental pollution, marine fish can be regarded as a limited resource. This is reflected by a drastic increase of the market price for Fish Meal during the last ten years, which has given rise to the demand for a new and more sustainable protein source (Veldkamp and Bosch 2015; Gasco *et al.*, 2020). Alternative protein sources of comparable value are therefore urgently needed in order to make poultry production a sustainable production form in the future. Moreover, the International Feed Industry Federation (IFIF 2019); Hunter *et al*., 2017) predicted that, livestock production will have doubled by 2050. Hence, to meet the future requirement for protein, new protein sources may be explored.

1.2 Problem Statement

Several farmers in the three northern regions, parts of Ashanti and Volta regions feed Guinea fowl keets (0-6 weeks) with termites during brooding (Sankara *et al.,* 2018). Termites are believed to be intermediate hosts of tapeworm (Padgett *et al.,* 2007). It is believed that, when Guinea fowls feed on termites there is an infestation of tapeworms.

After brooding, the Guinea keets become loaded with adult tapeworm resulting in high mortality of the keets which could even be 100 % (Teye and Adam, 2000; Atawalna *et al.,* 2020). This has become a drawback to the use of insects as a potential protein source. Despite the potential of the termite's meal as a protein supplement in the poultry diet, there is limited literature to support it use. Additionally, the claim that tapeworms are transmitted to Guinea fowl from feeding termites has not been scientifically substantiated.

There was therefore the need to research to determine the feeding value of termites, growth performance and intestinal worm count of Guinea fowls fed termites meal as well as establish scientifically whether termites are the intermediate host of tapeworms.

1.3 Research Objective

The main objective of this study was to determine the supplemental feeding value of termite meal on the growth performance of Guinea fowls.

1.3.1 Specific objectives

The specific objectives include:

(i) To evaluate the nutrient content of termite meal.

(ii) To evaluate the growth performance of Guinea fowls fed diets containing termite meal.

(iii) To determine if termites are the intermediate host of tapeworms

(iv) To determine tapeworm counts of Guinea fowls fed diets containing termites.

1.4 Research hypothesis

Given the problem of the study, the hypotheses tested in this study are the following:

i. H_0: There is nutrient content in termite meal.

H_1: There is no nutrient content in termite meal.

ii. H_0: Termite meal improves growth performance in Guinea fowls.

H_1: Termite meal does not increase the growth performance of Guinea fowls.

iii. H_0: Termites are the intermediate host of tapeworms.

H_1: Termites are not an intermediate host of tapeworms.

iv. H_0: There were tapeworms in Guinea fowls fed termite's diet.

H_1: There were no tapeworms in Guinea fowls fed termite's diet.

1.5 Significance of the study

The study will assist farmers in the use of termites to improve the nutritional value of poultry and to take advantage of the opportunities emanating from the ever-changing agri-business environment. The work is useful to the government to enact policies about farm practices that need to inculcate into the teaching of poultry at both high school and tertiary levels. This ensures food security for the ever-increasing population and improves GDP growth. This research is significant from an academic perspective not only to reveal the major challenges affecting the use of termites as supplementary feed for Guinea fowls but eventually present a study that will provide a relevant contribution to the empirical literature on the use of insects as a feed meal for poultry. This will help to compare the impact of termite only, termites plus soil, and no termites (control diet) in terms of the growth performance of Guinea fowls.

1.6 Delimitations

This research should have used termites to feed humans and poultry. Due to time constraints, it is limited to poultry which is the common traditional feed for birds in Ghanaian local settings. There are also a lot of poultry birds such as broilers, layers, etc. but attention was given to Guinea fowl because the researcher focuses on feeding termites to Guinea fowls.

1.7 Organization of the study

The thesis is divided into six chapters. The first chapter takes care of the general introduction. It covers the background of the study, problem statement, research objectives and the significance of the study, delimitation, and organization of the study. Chapter two concentrates on the review of related literature. Chapter three focuses on materials and methods. Chapter four is devoted to results. Chapter five is a discussion of empirical results. The final chapter concentrates on a summary of the major findings of the study, a conclusion, and recommendations for policy consideration.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Guinea Fowl Production in Ghana

The Guinea fowl is a promising genetic resource for evolving a low-input poultry venture generally in developing countries, and has the potential for reducing poverty (Atawalna *et al*., 2020). The Guinea fowl has proven to be adaptable to any place it has been taken to ranging from the tropics to Siberia although its natural habitat is woodland savannah with ground-level cover for its nest and trees for roosting at night time. Guinea fowls are raised on commercial basis in India, Belgium, France, Italy, and South Africa (Atawalna *et al*., 2020). However, in West Africa where the Guinea fowl originates, it is still raised on a small-scale basis under the traditional system of management with a local chicken hen or a Guinea hen brooding on the eggs to hatch and take care of the keets (Dougnon *et al*., 2012). It is an integral part of the rural family system providing a sustainable family income for small marginal and landless farmers (Annor *et al.,* 2012).

Authors such as Annor *et al.* (2013) and Adjetey (2011) reported that, the Guinea fowl is a poultry species suitable for use in meat production to grow and expand the diversify poultry industry due to its consumer acceptance, resistance to common poultry diseases and tolerance to poor management conditions. In Ghana, Guinea fowls are found mainly in the Northern area, especially in the Northern, Upper East, and Upper West districts, where the production over the years has assumed socio-social, economic and nutritional significance (Ahiagbe *et al*., 2021). Annor et al., (2013) reported that, the Guinea fowl is an important bird in the Upper East area. However, the number in each household ranges from 115 to 200 birds with an average around 20 (Kim *et al.*, 2022).

In most households, males and females as well as children rear these birds (Abdul-Rahman *et al.,* 2019). The birds are an integral part of the lives of individuals of Northern Ghana and serve different functions, including use for ceremonies, courtship and dowry, gifts as well as sacrifice. (Abdul-Rahman and Adu, 2017). In a free range, the domesticated birds lay between 90-120 eggs for each season (Farrell, 2010). Guinea fowls are traditionally reared just like the local chicken. The eggs are regularly incubated by the local chicken, ducks and turkeys (Dahouda *et al.,* 2008). Guinea fowl eggs are typically given to the homegrown chicken to hatch with or without a combination of chicken eggs, whereas the local chicken is raised close by the Guinea fowl (Abdul-Rahman *et al*., 2019). Guinea fowl eggs take between 26 to 28 days to incubate with the keets weighing around 24 to 25 g (Farrell, 2010).

It is normal to see a local chicken hen with a combination of chicks and keets in most households. These chicks and keets are raised till the chickens are prepared to lay and brood over new eggs (Abdul-Rahman *et al*., 2019). The sub-humid tropical pearl Guinea fowls are monogamous and seasonal breeders. Thus, there are periods within the year when their eggs are in abundant and other periods when they are scarce. The seasonality in reproduction has been perceived as one of the serious issues that might impede the large-scale commercial Guinea fowl production (Annor *et al.,* 2012). The periods of shortage address a serious impediment and militate against the development of the industry in the country in general and Northern Ghana specifically (Abdul-Rahman *et al*., 2019).

As reported by Abdul-Rahman *et al*. (2019), the factors responsible for this seasonality are however not yet clearly known (Avornyo *et al*., 2013).

Free-roaming trained Guinea fowls can lay up to 50-60 eggs for every season with each egg weighing moderately between 37 to 40g (Annor *et al*., 2012). Guinea fowl eggs are smaller than chicken eggs however with thicker egg shells than that chicken (Farrell, 2010). Guinea fowls are left to scavenge around farmsteads, open fields, and compounds for food like scraps, worms, insects, seeds, leaves, and organic products. Under containment, good feeding and watering, improved housing and sanitation as well as medical care, the birds can lay between 150-220 eggs each year and weigh around 1.1125 kg at 18 weeks (Kim *et al*., 2022). Guinea fowl farmers procure their stock by buying eggs from different farmers or the market. The eggs are set for the fowl (a hen) to incubate for brooding around 24 - 28 days (Annor *et al*., 2012).

The management and production of Guinea fowls in Ghana are most partly extensive (free-roaming) and in most cases some farmers provide the birds with poorly ventilated accommodation, during the night. The birds roost on trees around houses (Annor *et al*., 2012). Annor *et al.* (2012) reported that, Guinea fowls are fed with a variety of supplementary feed such as grains (maize, millet and sorghum, termites and other agro-industrial by-products such as pito mash, corn chaff, rice bran, and leftover feed from around the household in the mornings and evenings as a means of taming the birds so that birds always return to the house. Inbreeding is a major concern of Guinea fowl breeding in rural communities of Ghana as the birds are hatched together from the same parents and live together and interbreed among themselves.

The consequence of this in most communities is reduction in growth rate and size of birds, poor reproductive performance, genetic defects and unexpected high mortality (Annor *et al.,* 2012). The productivity of the Ghanaian local Guinea fowl is far below that of the European breeds. Annor *et al.* (2012) attributed the lower productivity of the indigenous breed of the Guinea fowl to the extensive production system with its accompanying poor feeding, poor health care and management in addition to the use of unimproved breeds of birds.

2.1.1 Importance of Guinea fowl production

The importance of Guinea fowl production cannot be overemphasized especially considering its benefits including employment generation, income generation and as a source of protein nutrition (Annor *et al.,* 2012). In addition, Guinea fowls act as watch dogs on plantations, homes and in the control of insects on fruits and vegetable farms (Baimbill *et al.,* 2021). Karbo *et al.* (2002) and Abdul- Rahman *et al.* (2017) noted that, Guinea fowl production plays an important role as a means of individual and social wealth generation and socio-culturally, Guinea fowls are used for payment of dowries. Other authors have also noted that, the meat and eggs of Guinea fowls are delicacies and a source of quality protein and contain less cholesterol and fats (Annor *et al.,* 2012,). Guinea fowls are also used for different cultural purposes including funerals, sacrifices, courtship and as a token for settling disputes (Annor *et al.,* 2012; Abdul- Rahman *et al.,* 2017). In northern Ghana, Guinea fowls play an important role during courtship and marriage ceremonies particularly among the Mamprusis, Frafras and the Kusasis while the Gonjas celebrate an annual Guinea fowl festival (Annor *et al.,* 2012).

Annor *et al., (*2012) asserts that, the sale of Guinea fowls forms the first line for meeting immediate cash needs followed by sheep and goats and therefore, Guinea fowls play a central role in ensuring food security for people in the North. Annor *et al.,* (2012) further noted that the production of Guinea fowl is very lucrative business because apart from the meat, there is a high demand for their eggs. Annor *et al.,* (2012) noted that, poultry production including the rearing of Guinea fowls, if given the necessary boost can act as an income generating activity for most rural poor women in the Northern part of Ghana.

2.1.2 Challenges of Guinea fowl Production in Ghana

2.1.2.1 Breeding (Stock acquisition)

The seasonality of breeding has been recognized as one of the major drawbacks to large-scale Guinea fowl production (Abdul- Rahman *et al.,* 2019). Under the traditional system, breeding stocks are obtained from the farmers own stocks thus, fertile eggs are not available for year-round production. This makes it not easy to go into large commercial production in Ghana.

2.1.2.2 Availability of feed

Scavenging is the main feeding system under free-range Guinea fowl production in rural areas where the birds feed mainly on insects, leaves, grass seeds, tubers and sedges Kyere *et al.,* (2017), with ground millet, Guinea corn and maize as supplements provided by poultry owners. These feed resources are quite abundant during the rainy season but are scarce during the dry season. According to Malapela *et al., (*2016) feed supply is one of the main constraints to rural poultry production in Zimbabwe which is contrary to Ghana.

Guinea fowls have a unique ability to utilize a wide range of flora and fauna as feed resource base. Guinea fowls consume non-conventional feeds that are not used in chicken feeding. Therefore, the Guinea fowl has a competitive advantage over chicken as a ranging bird (Adei *et al.,* 2012). In addition, Guinea fowls digest nitrogen-free-extract and lignin 13 components of feed better than the chicken but have a disadvantage of poor utilization of crude protein (Malapela *et al*., 2016).

2.2 Feeding and Nutritional Requirement of Guinea Fowls

The Guinea fowl is known to have higher adaptability to poor nutritional conditions (Khairunnesa *et al*., 2016). Scavenging has been the most widely means of feeding in the Guinea fowl (Adjetey, 2011). The Guinea fowl make good use of insects as a source of nutrition and hence is used to control insect in gardens since it does not scratch the soil for feed to cause harm to growing crops unlike the local chicken (Moreki, 2009). The Guinea fowl is omnivorous and feeds on varied feed resources including plants and animals (Tiroesele and Moreki, 2012; AU-IBAR, 2012; Moreki & Radikara, 2013).

In most situations, the Guinea fowl is fed with kitchen waste and cereal grains (Moreki *et al*., 2013). Guinea fowls are at times fed with commercial broiler and layer diets; starter diets are fed to the Guinea keets for about 4 weeks which is then followed up by a grower diet to the matured age (Moreki *et al*., 2012). Guinea fowl in the northern part of Ghana are fed with grain: such as maize and millet (Avornyo *et al*., 2019). Guinea fowl is reported to have the capability to cover wide range of distance in search for feed (Musundire, 2016). Konlan *et al*. (2013) reported that, most farmers provide supplementary feed grains to their Guinea fowl.

Nesa *et al*. (2018) argued that, there is no recommended standard of feeding of formulated diets in the Guinea fowl. Guinea fowls feed on most non-conventional feed which might not be useful for the local chicken (Kusina *et al*., 2012). Commercial feed millers have successfully formulated diets for the Guinea fowl (Tiroesele & Moreki, 2012). Considerable amounts of feeds are wasted when Guinea fowls scoop with their beaks during feeding (Nsoso *et al*., 2003). Guinea fowl should be fed by supplying the feed to them in their pens since this train the birds to return to their pens in the evenings when reared in semi-intensive system (Downes, 1999). The birds have been observed to consume less supplementary feed when given enough feed to eat on their own (Atawalna *et al.*, 2020).

2.2.1 Protein and energy requirement of Guinea fowl

The protein utilization of the Guinea fowl would be less when fed diets containing less amount of protein (Seabo *et al*., 2011). Early keet mortality and leg paralysis can be reduced in the Guinea keets when considerable amounts of proteins are fed to the birds (Amoah *et al*., 2018). The protein requirement of Guinea fowl is higher from the 5th to 10th weeks of life (Iddrisu, 2014, Amoah *et al*., 2018). Oke *et al*. (2003) recommended a diet containing 18% CP and 2750 kcaI/kg ME for optimum egg production. In formulating diets for Guinea fowls, it is necessary to consider the protein: energy content but not necessarily on the protein content alone (Avornyo *et al*., 2013). In Guinea fowl a recommended protein level of 16% to improve production and reproductive performance has been reported (Adjetey, 2011). A crude protein and energy levels of 24% CP and 12.5 ME/kg respectively is ideal to improve performance in the Guinea fowl (Amoah *et al*., 2018).

Studies conducted by Avornyo *et al.* (2013) revealed that with l8% protein and 2750 kcal/kg ME energy the performance of Guinea fowl could be advanced. Studies on the performance of Guinea fowl in the three northern regions of Ghana utter feeding the birds with 20% crude protein and 2800 KcaI/Kg metabolizable energy resulted in improved performance in the Guinea fowl from the upper east region (Avornyo *et al*., 20l3). Starter (0-8 weeks old) Guinea keet diet contains 26% crude protein and 3000 kcal/kg metabolizable energy while grower (above 8 weeks) diets contain 20% crude protein and 2800 kcal/kg metabolizable energy also enhanced performance of the birds (Alli *et al*., 20l6). To Improve Guinea fowl performance, a dietary crude protein of 16% should be fed to the Guinea fowl (Korankye *et al.*, 2018). The productivity of poultry and Guinea fowls for that matter is adversely affected as a result of poor efficiency in converting feed into a desired product which translates to high cost of production and consequently the cost of the product particularly under situations where the commodity is scarce (Nahashon *et al*., 2007; Avornyo *et al.*, 2015).

The poor productivity often recorded is attributed to the nutritional value of the feed that is fed to the bird's vis a vis the nutritional requirement of the birds. Generally, the energy requirements (metabolizable energy) of farm animals and for that matter poultry have however been known to be influenced by a number of factors. These include the species of animal, breed and the stage of growth or developmental phase and the feed ingredients or the type of feed fed to the birds. It has been well-documented that adult broilers for instance generally utilize the energy of feedstuffs to a greater degree with less variation than growing broilers (Barzegar *et al*., 2020).

Similarly, a number of studies that have evaluated the energy requirements Guinea fowls have even confirmed different metabolizable energies for different sexes of Guinea fowls as well as their stage of growth (Nahason *et al*., 2005; Amoah *et al*., 2018). Although considerations for feed and for that matter the nutrient requirements for Guinea fowls for instance have often been assumed to be the same for the chicken, there is substantial evidence that differences however, exist in the utilization of some of the nutrients (Vogt & Stute, 1974). Adjetey (2011) have also established that Guinea fowls need a higher protein feed than chickens. The function of dietary protein is to supply amino acids for maintenance, muscle growth and synthesis of egg protein (Maurice *et al*., 1982). The synthesis of muscle and egg proteins requires a supply of amino acids, all of which are physiological requirements (Jacquie, 2018).

2.3 Insects in Poultry Production

Plant derived protein is a key ingredient of farm animal feed around the world. However, in many cases it contains low amounts of lysine, tryptophan, threonine and methionine (Bukkens, 2005; Leinonen *et al*., 2019). Some insect species provide high amino acids concentrations, for example the caterpillars of Saturniidae, have a lysine content higher than 100 mg/100 g of CP (Bukkens, 2005; Hatab *et al*., 2020). Most of the experiments published to date have been carried out with broiler chickens fed housefly larvae meal.

The results showed that housefly larvae may be added at approximate dietary levels of 25% DM, without any negative effects on weight gain (BWG), feed intake (FI) and feed efficiency (Sarica *et al*., 2020). It suggests that maggot meal may efficiently replace other protein sources, such as soybean meal, fishmeal and groundnut cake.

Additional experiments by Schiavone *et al.* (2014) showed that, mealworm meal can be included at maximum dietary concentrations of 25 % without causing growth depression. The above-mentioned results and high digestibility of nutrients reported by Bovera *et al.* (2015) showed that, mealworms are an alternative protein source for soybean meal and fishmeal. Although chickens have been shown to produce chitinase in the proventriculus and hepatocytes Suzuki *et al.* (2002), the digestibility of chitin seems to be limited (Hossain and Blair, 2007). Chitin as a polysaccharide may be a substrate for microbial fermentation in the gastrointestinal tract of the chickens and could serve as a substrate for production of chitosan which can have immunomodulatory, antioxidative, antimicrobial, and hypocholesterolemic effects when used as feed additive for poultry (Świątkiewicz *et al.*, 2015).

As discussed earlier, another interesting aspect of insects considered for poultry feed is their content of antimicrobial peptides (AMPs). These are highly abundant in several species and when used as a feed ingredient, these may reduce the growth of indigenous and potentially pathogenic intestinal bacteria similar to antibiotic growth promoters.
However, poultry feeding with fresh insect larvae includes potential risks primarily with regard to feed hygiene, in particular when organic waste products or even manure is used as the medium for larvae growth. In line with this, the "on top" supplementation of living maggots to a balanced diet for young pullets significantly reduced the fearfulness of the birds (Engberg *et al.*, 2015).

2.4 Termite Feeding

Termites are highly nutritious insects (Ntukuyoh *et al.,* 2012). Throughout West Africa, termites are collected in the bush to feed poultry (Biasato *et al.,* 2018). For example, 72% of the farmers in South-Western Burkina use termites to feed poultry (Diawara, 2013). Chippings of termite mounds or underground nests are collected and given to poultry on-farm, particularly to chicks and keets (Figueirêdo *et al.,* 2015). This activity is often done by children who sometimes also sell the chippings to other users. Termites are not equally available in all regions and seasons, and in many cases, collectors have to walk long distances to find sufficient amounts of termites to feed the farm animals. The difficulty of finding termites sometimes forces farmers to abandon this ancestral technique (Diawara, 2013).

According to farmers, not all termites are appropriate for poultry feed (Diawara, 2013). For example, in Burkina Faso, some species of Cubitermes are reported as toxic to chicks, but not to Guinea fowls and ducks (Diawara, 2013). In a feeding trial with chicks and keets in Benin, Kenis *et al*. (2014) showed that, a humivorous species of the genus *Noditermes* was toxic to both poultry species, in contrast to *Trinervitermes sp*., confirming farmers' knowledge. Feeding keets and chicks with the non - toxic species resulted in similar growth and survival as compared to conventional feed. Termites cannot be easily produced and moreover, rearing produces high amounts of methane, an important greenhouse gas Goux *et al*., (2023). However simple methods have been developed to increase the number of termites available on farm (Amoah *et al*., 2018).

2.4.1 Cultivation and harvesting of termites

Singh, (2020) described in detail methods used in Togo and Benin, to harvest termites which is based on fibrous and humidified waste or crop residues placed in clay pots or baskets, which are then inverted and placed on small termite nests. The pots are moistened regularly and protected from excess heating. Termites are collected in the pots after three to four weeks. Chrysostome *et al.* (2009) described a similar technique used in Benin for collecting termites for keets. Maize or sorghum straws are placed in empty palmyra palm nuts (*Borassus spp.*), which are then put in moistened pots filled with bark pieces of locust bean (*Parkia biglobosa*) and sorghum straw. The pots as placed on nontoxic termite nests. The day after, termites are collected in the nuts and given to keets, preferably with grains. Other, similar techniques used in Burkina Faso are described by Diawara (2013).

Diawara, substituted fish meal by fresh termites of the genus Macrotermes in chick diets without affecting the daily weight gain, although the feed conversion ratio was significantly higher with termites as compared to fish meal. Similarly, Munyuli Bin Mushambanyi & Balezi (2002) and Kenis *et al.* (2014) showed, in the Democratic Republic of the Congo, that chick fed portions containing 12% of termite (*Kalotermes flavicollis*) meal gave satisfactory result in terms of mean weight gain and were economically much more profitable than conventional meat meal. Termites are also used occasionally by smallholder fish farmers, although it is not clear to what extent this practice occurs in West Africa. In Uganda, about five per cent of fish farmers use termites as supplementary feed (Rutaisire, 2007).

The quantity available depends on, among other things, the season, the availability of termite mounds and the termite species. On average, a termite mound provides about 50 kg of termites per year (Rutaisire, 2007; Boafo *et al*., 2019). Reproductive winged termites swarm in very high numbers at the onset of the rainy season or after heavy rainfall. Sogbesan &Ugwumba (2008) suggested that, termites could be used to prepare termite meal as a replacement to fish meal. Sogbesan *et al*. (2008) tested termite meal from oven-dried reproductive adults of *Macrotermes sub hyalinus* and obtained excellent results on fingerlings of *Heterobranchus longifilis*, a commonly cultured catfish in Nigeria. The best results, in terms of growth rate and cost-benefit ratio, were obtained when combining 50 % termite meal with 50% fish meal.

2.5 Nutritional composition of feeding termites

Nutritional composition of termites as reported in literature is shown in Table 2.1.

Table 2.1: Proximate mineral content and energy composition (% dry matter) of termites

Composition	Sogbesan and Ugwumba 2006a	Oyarzun *et al.*, 2006	Banjo *et al.*,2006
Crude protein (%)	46.3	58.20 ± 3.67	21.25
Crude lipid (%)	30.1	15.04 ± 8.6	-
Crude fibre	7.3%	-	2.45
Lignin	-	17.25 ± 3.19%	-
Cellulose	-	9.77 ± 1.71%	-
Ash (%)	3.6	4.11 ± 0.23	2.90
Dry matter (%)	96.4	92.36 ± 4.32	90.05
Sodium	0.20 (g)/100g)	0.17 ± 0.04%	-
Calcium	0.23(g/100g)	0.26 ± 0.04%	-
Potassium	0.38 (g/100g)	0.54 ± 0.06%	-
Phosphorus	0.38 (g/100g)	0.38 ± 0.04%	-
Magnesium	0.15 (g/100g)	0.14 ± 0.01%	-
Gross energy	2457.61 (kJ/100g)	6.01 ±0.46 (kcal/g)	-
Metabolizable Energy	1843.21 (kJ/100g)	-	-
Digestible energy	3040 (kJ/100g)	-	-

Termites are often included in human diet in many parts of Africa, Latin America, Asia and Australia Raheem et al., (2015). The study of Chagwena *et al,* (2019) showed that, insects are highly nutritious and present the cheapest source of animal protein. The nutrient analysis of *Odontotermes formosanus* has revealed a high percentage of protein, lipids and carbohydrates. According to Solavan *et al*, *(2006)*, termites are among the insects with the highest fat content. Phelps *et al*. (2001) found that the winged sexual forms of the African termites (*Macrotermes falciger)* had about 3196 KJ/100 g (dry weight basis) caloric value while *Macrotermes. sub hyalinus* had about 2575 KJ/100 g (dry weight basis). According to Hickin (1971) and (Tiroesele and Moreki, 2012) termites provide 560 calories per 100 g. The findings from the previous investigations show that termites can be used as a protein source in poultry diets.

Termites are a valuable source of protein, fats and essential amino acids in the diet for both primates and humans. Termites have crude protein of 81.66% and 87.33% for workers and sexual forms, respectively (Banjo *et al.,* 2006). These crude protein values suggest that termites can be used as a source of protein in poultry diets to support growth and maintenance of the birds. Furthermore, Sogbesan and Ugwumb (2005) reported crude protein content of 46.3% in termites. On the other hand, Banjo *et al.* (2006) reported crude protein values of 20.4% and 22.1% in *Macrotermes bellicosus* and *Macrotermes notalensis,* respectively. The carbohydrate content was also found to be 1.26% for workers and 2.73% for sexual forms.

2.5.1 Essential amino acids (EAA) content (% dry matter) of fish meal and animal proteins sources

Fish meal, a principal ingredient used in the manufacture of fish food, is not essential; it is the nutrient it contains that is important (Médale *et al*., 2013).

Rich in proteins (65 to 72 %), fish meal is highly digestible and balanced in amino acids (essential and non-essential), it also contains also lipids (5 to 12 %) which are not completely eliminated during its manufacture and minerals coming from the skeleton and the scales (Médale *et al.*, 2013). The animal sources of protein such as maggot, earthworm and termite have a lightly low protein rate as compared to that of the fish meal except from chicken viscera with comparable rates in crude fats (10.7 to 18.7 %).

Also, the high digestibility of the animal protein sources NRC (2011), their availability or the possibility of making the animal protein source available at low cost makes, a serious potential protein sources in fish feeding as well as for poultry. In addition, the sources of proteins must bring the 10 amino acids essential for fish, which are identical for the other animals (Médale and Kaushik, 2009; NRC, 2011). As a whole, the sources of identified proteins contain variable proportions of EAA. Apart from the termite meal, the large majority of the animal protein sources have good EAA contents except for methionine and the tryptophan in the earthworm meal as compared to fish meal. Médale and Kaushik (2009) and Djissou *et al*. (2016) asserted that in the animal protein sources used in fish feeding, the Sulphur amino acids (Methionine and Cysteine) are limited.

2.6 Effects of Termite Meal on Growth Performance

A study on the effect of a termite diet on poultry growth in West Africa is that of Diawara (2013) in Burkina Faso. Diawara substituted fish meal by fresh termites of the genus. Macrotermes in chick diets without affecting the daily weight gain, although the feed conversion ratio was significantly higher with termites as compared to fish meal.

Similarly, Munyuli Bin Mushambanyi & Balezi (2002) showed, in the Democratic Republic of the Congo, that chick feed portions containing 12 % of termite (*Kalotermes flavicollis*) meal gave satisfactory result in terms of mean weight gain and were economically much more profitable than conventional meat meal. Termites are also used occasionally by smallholder fish farmers, although it is not clear to what extent this practice occurs in West Africa. In Uganda, about five per cent of fish farmers use termites as supplementary feed (Rutaisire, 2007).

Fishes are often observed consuming winged termites when fell into ponds. Sogbesan &Ugwumba (2008) suggested that termites could be used to prepare termite meal as a replacement to fish meal. Termite meal from oven-dried reproductive adults of *Macrotermes subhyalinus* and obtained excellent results on fingerlings of *Heterobranchus longifilis*, a commonly cultured catfish in Nigeria. The best results, in terms of growth rate and benefit-cost ratio, were obtained when combining 50% termite meal with 50% fish meal. House Termite has been appraised in the diet of chickens to be very palatable and a suitable replacement for soybean, fish meal and vitamin premix without any reduction in growth performance (Men *et al.*, 2005).

The fact that weight gain was recorded in all experimental diets was an indication that the fish was able to convert the protein fed to muscles. The higher growth performance observed in combined feeding can be explained by the synergetic effect of combining two biological compounds to have a single and superior effect than when applied individually.

This observation is in agreement with suggestions by previous authors that combined protein source is better than single protein source for fish diets (Sogbesan and Ugwumba, 2008). Previous studies already suggested that immune response stimulating agents could improve broiler chicken growth due to an improved health status (Sigolo *et al.*, 2019). This hypothesis was confirmed in the study by Lee *et al.* (2018). The BSFL-fed broiler chicken showed enhanced weight gain and reached the target body weight of 1.3kg two days earlier than the broiler chicken fed with the control diet (30 days instead of 32 days).

2.7 Effect of Termite Meal on Survival of Guinea Fowls

In a recent study by Lee *et al.* (2018) the effects of Black Soldier Flies Larvae (BSFL) meal inclusion on the immune response of broiler chickens to (*Salmonella. gallinarum)* was investigated. *Salmonella. gallinarum,* a Gram-negative bacterium, causes fowl typhoid that often leads to anorexia, diarrhoea, dehydration, but also anaemia, hepatosplenomegaly (enlarged liver and spleen) and bleeding of the intestinal tract of chicken, and high mortality rates in flocks (Lee *et al.*, 2018).

Overall, fowl typhoid represents a major problem for the poultry industry in Asian countries, such as Korea and India (Barbour *et al.*, 2015). The inclusion of Black Soldier Flies Larvae (BSFL) meal even in relatively small amounts in the diet resulted in enhanced immune responses in broiler chicken, as well as reduced mortality and improved pathogen clearance when broiler chicken were challenged with *S. gallinarum.* This was, furthermore, accompanied by increased gain in body weight.

The inclusion of 3 % BSFL resulted in especially high survival rate with 85 %. In the literature, mortality rates of up to 100% have been reported, and two to three weeks old animals seem to be particularly affected and susceptible (Liu *et al.*, 2022; Manyara, 2018). These results show that even relatively low amounts of BSFL meal in the diet leads to increased survivability of broiler chicken that are artificially infected by *Salmonella gallinarum.*

2.8 Barriers to the Inclusion of Insect Protein in Poultry Feed

There is no doubt that insect meals from a nutritional perspective are suitable for the feeding of poultry. However, a barrier to the inclusion of insects in feed for livestock is the present European Union (EU) legislation (Regulation (European Commission C) No. 1069/2009), where insect meals are defined as Processed Animal Protein (PAP). As such, they are suitable as feed for livestock in particular for fish, poultry and pigs.

However, Regulation European commission (EC) No. 1069/2009, Regulation (EC) No. 999/2020 ("Bovine Spongiform Encephalopathy" (BSE) regulation prohibits the feeding of farmed animals with Processed Animal Proteins, with the exception of hydrolysed proteins. The feeding of insect meals to aquaculture species is going to be allowed and a re-authorization of these PAPs for pig and poultry feed is expected in the near future.

A risk profile related to the production and consumption of insects as food and feed has been published by EFSA Scientific committee (2022). At the moment, a significant obstacle for the use of insects in animal feed is the limited quantity of produced insects, which does not guarantee a constant supply. The prices for insects and insect meals are presently very high, and cannot compete with other protein sources in this respect. To overcome this problem, the most suitable insect species should be identified which has effective protein in terms of production costs on an industrial scale.

For mass production, it is necessary to develop automated process technologies for the rearing, harvest and post-harvest procedures, which certainly include the monitoring of product safety and quality (Rumpold and Schlüter, 2013). The general acceptance of the inclusion of insects in animal feed has been frequently discussed to be a barrier. However, in a recent study from Belgium, cross-sectional data were collected among farmers, agriculture sector stakeholders and citizens (Sogari *et al.*, 2019). The results of this study indicate a broad acceptance.

The perceived benefits such as improved sustainability of livestock production, lower dependence on imported protein sources and lower environmental impact, outweighed the perceived risks, such as microbiological contamination, chemical residues in the food chain and lower consumer acceptance of animal products.

Currently, there are significant knowledge gaps in the field of insect production, particularly in Europe, where insects are not considered a traditional food item (Veldkamp and Bosch, 2015; Van Huis, 2020). However, it seems that there is nothing stopping Africa from using insect meals as feed material, so the need to get to work to reduce the costs of insect productions and to remove other limitations in their use in poultry nutrition.

2.9 Worms

Parasitism is an association in which the parasite is metabolically dependent to a greater or lesser extent to the host. Gastro- intestinal parasites are however the most prevalent and most devastating parasites affecting chicken productivity (Swaton *et al*., 2003; Subedi *et al.,* 2018). Village chicken are raised mainly under the free range (scavenging) product system, with partial or no housing and this predisposes the chicken to disease and parasites especially helminths ((Swaton *et al*., 2003; Muchadeyi *et al.,* 2004; Mwale and Masika, 2009) and different types of helminth parasites infect the chicken flocks.

Worms find moist places to stay in the crop, gizzard, intestine, caecum, windpipe and even the eyelids (Gauthier and Ludlow, 2013). On the basis of their site of location helminths are of different types, the worm which are found in caecum of large intestine are called caecal worms (*Heterakis* spp.), worms which are found in eye are called eye worm (*Oxyspirura mansoni*) while gape worms (*Syngamus trachea*) are found in trachea (Gauthier and Ludlow, 2013). These worms are also called “red- worm” or “forked-worm” and birds infected with gape worm show “open mouth breathing characteristics”.

Round worm (*Ascaridia*) and tape worms (*Raillietina*) are found in intestine while thread worm (*Capillaria*) is found in crop or oesophagus (Janquera, 2017). The eggs and immature stages of many parasitic worms can live outside of the chicken host for a long time, possibly several years, whereas some parasitic worms spend part of their life cycle in other creatures such as earthworms, insects, slugs or snails. Chicken picks up worms by eating dirt or litter contaminated with worms' eggs or by eating small creatures carrying immature stages of worm (Janquera, 2017).

2.10 Faecal Sample Analysis for Poultry and Worm Load

Much as like other livestock species worms can infest the animals even under commercial production, birds are rarely troubled by worm parasites on commercial farms (Othman *et al*,.2017). The very few registered occurrences have been attributed to the use of poorly managed built-up litter (which fosters the propagation of intermediate hosts and the accumulation of infective eggs) and resistance of the parasites to therapeutic drugs Precup *et al.*, (2022).

Considering the adverse effect worms can have on a flock especially when the appropriate measures are not implemented it becomes essential to periodically test birds via their droppings to establish the number of either worms, their eggs or larvae in other livestock species like sheep and goats, it is easier for them to develop clinical signs such as apathy or diarrhea but not poultry (Van *et al.*, 2020). Faecal egg count (FEC) or the analysis for faecal worm load to get an approximation of the parasite load in a living organism (poultry) has been widely used in assessing or establishing parasite burden and to prompt the necessary veterinary intervention.

Faecal egg count using the modified McMaster method is a well-recognized procedure for diagnosing and interpreting parasite burdens in a number of farm animals of which poultry is not an exception Oladosu *et al*. (2023).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area and Period of the Study

The study was carried out at the Poultry Section of the Department of Animal Science Akenten Appiah- Menka University of Skill Training and Entrepreneurial Development Mampong-Ashanti. The experiment commenced in February, 2019 and ended in May, 2019. Mampong-Ashanti lies in a transitional zone between the Guinea savanna zone of the north and the tropical rain forest of the south of Ghana. Essentially, Mampong-Ashanti lies between latitude $07^{o}04'$ north and longitude 01^{o} 24' west with an altitude of 457 metres above sea level. Maximum and minimum annual temperatures recorded during the study period were $30.6^{o}C$ and $21.2^{o}C$, respectively (Meteorological Service Department 2019). Rainfall in the district is bimodal, occurring from April to July (major season) and again August to November (minor season) with about 1224 mm per annum. The dry season occurs from December to March. The vegetation is transitional savanna woodland, which guarantees poultry keeping.

3.2 Procurement of Experimental Birds and Design

The work was divided into two parts; the laboratory work and field work. For the laboratory work, termites were harvested from the mounds where the termites inhabit. A sample of the termite and soil from the mound were taken from the upper, lower and inner or middle part of the mound to the laboratory for proximate analysis. The Determination of the chemical composition was done according to the procedure outlined by Association of Official Analytic Chemists (AOAC, 2000).

Analyzing the proximate composition of termites involves determining the relative amounts of moisture, ash, crude protein, crude fat, and carbohydrates in the insect. This procedure typically follows established methods used for proximate analysis of other biological samples. Here's a detailed procedure: Materials Needed:

1. Termites (collected samples)
2. Analytical balance
3. Drying oven
4. Muffle furnace
5. Soxhlet extractor or solvent extraction setup
6. Proximate analysis dishes or crucibles
7. Mortar and pestle
8. Desiccator
9. Distilled water
10. Laboratory glassware (flasks, beakers, etc.)
11. Filter paper
12. Weighing boats
13. Bunsen burner or hot plate
14. Thermometers
15. Chemicals: petroleum ether (for fat extraction), hydrochloric acid (HCl), sulfuric acid (H_2SO_4), sodium hydroxide (NaOH), etc.
16. Safety gear: lab coat, gloves, safety goggles

Procedure: Collect a representative sample of termites from the desired location. Ensure that the sample is large enough to provide accurate results. Weigh an empty proximate analysis dish (D1) and record its weight. Place a known amount of the collected termites in the dish and record the combined weight (W1).

Dry the sample in an oven at around 105°C (221°F) until a constant weight is achieved (usually 16-24 hours). d. Weigh the dish with the dried sample (D2) and record its weight (W2).

Moisture Content (%) = [(W1 - W2) / (W1 - D1)] * 100

Ignite a clean and empty crucible in a muffle furnace at around 550-600°C (1022-1112°F) for a few hours. Allow it to cool in a desiccator. Weigh the cooled crucible (D3) and record its weight. Place a known amount of the dried termite sample in the crucible and record the combined weight (W3). Heat the crucible with the sample in the muffle furnace at around 550-600°C until the sample turns into ash (usually a few hours). Allow the crucible to cool in a desiccator and then weigh it with the ash (D4).

Ash Content (%) = [(W3 - D4) / (W3 - D3)] * 100 a. Grind the dried termite sample into a fine powder using a mortar and pestle. Weigh a portion of the powdered sample (W4) and record the weight. Perform Kjeldahl digestion on the sample, using concentrated sulfuric acid and a catalyst. Distill the digested sample to collect the ammonia generated. Titrate the distilled ammonia with a standardized acid solution. Crude Protein (%) = (N content of ammonia in sample * 6.25) / W4

Weigh another portion of the powdered sample (W5) and record the weight. Perform solvent extraction using a Soxhlet apparatus and petroleum ether as the solvent. Extract the fat from the sample using the Soxhlet extractor. Evaporate the solvent from the extracted fat using a rotary evaporator or a hot plate. Weigh the extracted fat residue and calculate the fat content. Crude Fat (%) = (Weight of extracted fat / W5) *

100Carbohydrate content can be estimated by subtracting the sum of moisture, ash, protein, and fat percentages from 100.

Carbohydrates (%) = 100 - (Moisture + Ash + Protein + Fat)

Compile the results of the moisture, ash, protein, fat, and carbohydrate content determinations.

Note:

Always follow safety guidelines and wear appropriate protective gear when working with chemicals and high temperatures. It's essential to calibrate and verify the accuracy of your equipment before starting the analysis. Ensure that you're using appropriate standards and methods approved by relevant authorities or organizations for accurate results. The metabolizable energy was calculated according to the formular derived by Pauzenga (1985),

ME(Kcal/g) = (37×%CP) + (81.8×%EE) +(35×%NFE).

The termite and soil samples taken to the lab were also checked if tapeworm eggs or larvae could be identified in the termites as well as in the soil. This was to help determine whether the Guinea fowls take the tapeworm eggs or larvae from the soil or from the termites. 135 unsexed Guinea fowl keets were obtained from Akate Farms in Kumasi and used for the experiment. The keets were randomly allocated to three dietary treatments of 45 keets in each treatment with 3 replicates made up of 15 keets each in Completely Randomized Design (CRD). The dietary treatments are;

- Diet one contained no termite's supplementation (control)
- Diet two contained the termites and soil supplementation
- Diet three contained isolated termites from the soil and used for supplementation.

3.3 Sources of Experimental Feed Ingredients and Drugs

The raw ingredients used for the formulation of the experimental diets were yellow maize grain, fishmeal, wheat bran, Soya bean meal, dicalcium phosphate, oyster shells, vitamin- mineral premix and sodium chloride (common salt). The ingredients were purchased mainly from Kumasi, Ashanti Region. Drugs and medications used during the experimental period include Antibiotics, Coccidiostat etc. These drugs were also purchased from the regional veterinary office.

3.4 Management of Experimental Birds

3.4.1 Housing

The deep litter cages were cleaned, disinfected and fresh wood shavings (litter material) spread on the floor to depth of 4-5cm before the arrival of the guinea fowl keets. Wet litter was removed and replaced with fresh ones during the experimental period to ensure good litter environment.

3.4.2 Feeding

The keets were fed on starter basal diet from day old to week four and changed to grower basal diet from week five to week twelve (Table 3.1). The treatment groups were given a daily measurement of 300 g isolated termites only as against the termites and soil of 3000 g. Traditionally farmers will harvest the termites from the termitarium by breaking it into chippings and give it to birds without any measurement. However, the researcher decided to take the measurement of the quantity that farmers locally give to the birds. The measurement of the isolated termites only (300 g) and termites and soil ((3000 g) were given to the keets early in the morning daily.

Each treatment was provided with same feed as required according to the treatment. The birds were fed per treatment at a time. In addition to the basal diet treatments were given supplemental diet (termite's meal).

Table 3.1: Composition of experimental basal diets

Ingredients	Starter Diet (kg)	Grower Diet(kg)
Maize	57.5	58
Wheat bran	11	21
Soybean	14.5	5
Fish meal	18	13
Oyster shell	1.5	1.5
Dicalcium phosphate	0.5	0.5
Vitamin premix	0.5	0.5
Salt	0.5	0.5
TOTAL	**100**	**100**

3.4.3 Watering

The plastic watering troughs were washed thoroughly with soap and water every morning and fresh, clean water provided *ad libitum* for the birds.

3.4.4 Health, Medication, Mortality and Culling

The Guinea fowl keets were given glucose as fast energy supplier to reduce travelling stress on arrival. Appropriate medications were given as the need arise thereafter throughout the experimental period. Birds were observed for signs of ill-health and the right medication given to curtail the situation. Dead birds were taken from the post mortem examinations to determine the cause and appropriate management practice to check and the medication to use to curtail the problem. Mortality was recorded as and when they occurred. The details of medication and vaccination schedules were as followed;

Table: 3.2 Health, medication, mortality and culling

Age(days)	Medication
1	Glucose
2,3	Antibiotic plus Vit
4	Coccidiostat
8 (week 1)	1st Newcastle
14	Gumboro
24- 26	Antibiotic Vitamin
29 (week 4)	2nd Newcastle (Lasota)
34-37	Vitamins
45-47	Glucose
52- 54	Antibiotics Vitamin
56 (week 8	1st Fowl pox
59-61	Glucose
70 (week 10)	3rd Newcastle (Lasota)
72, 73, 74 (week 11)	Coccidiostat
78-80	Coccidiostat
82	Dewormed
84 (week 12)	2nd fowl pox

3.5 Parameters Measured

3.5.1 Examination of termites for worm eggs

Fifteen (15) termites were dissected to bring out the abdominal contents or intestines. The intestines and its contents were spread on glass slide and a drop of Zinc Sulphate solution added. A glass cover slip was placed over it and examined under a microscope using a low objective (×10) for larvae or eggs of cestodes according to miller *et al*. (1998).

3.5.2 Examination of soil sample for worm eggs

A 3g of soil sample picked from termite mound was mixed with 45 ml of Zinc Sulphate solution. 15ml of the solution was poured into a test tube and centrifuged at a speed of 2500rpm for 5 mins. The test tube was removed and Super Natant topped up with more Zinc Sulphate solution until a convex shape was formed at the brim. A cover slip was carefully placed on the test tube containing the solution, avoiding spillage. After 5 mins, the cover slip was gently removed, placed on the microscope slide and examined under low power objective (×10) according miller *et al*. (1998).

3.5.3 Egg count from faecal sample analysis

Faecal sample was collected from the rectum of three randomly selected birds from each replicate of 15 birds and put in a sterilized swap tubes to the lab for analysis to check for parasites and also number of eggs in the faecal sample. Using the floatation method as used by Permin *et al. (*2016) for parasites assay. 2g of faecal sample was weighed accurately using digital weighing scale and placed in a beaker. 60 ml of saturated sodium chloride solution was added to the faecal sample in the beaker.

The content of the beaker was stirred thoroughly to allow the faecal material break down and also form a suspension. The resulting suspension was strained through a fine sieve and the residue pressed out. The filtrate was stirred using a Pasteur pipette to obtain a complete homogenous distribution of the eggs in the liquid. A sub-sample of the filtrate was taken using a Pasteur pipette to fill one compartment of the chamber.

The filtrate was then stirred again and another sub-sample was taken to fill the second compartment of the chamber.

The McMaster was allowed to stand for 5 minutes for eggs to float to the surface and the debris also sinks in the chamber. The sub-sample of the filtrate was examined under the compound microscope under low power magnification (x10). Helminths' ova and coccidian oocyst within the engraved area of the chamber were identified according to keys provided by Soulsby (1982). The number of eggs per gram of faeces (EPG) was counted, recorded in grams.

3.5.4 Worm Load

Two birds were randomly picked and sacrificed from each replicate for the determination of worm load. The intestinal tract was taken out and dissected to check for worm, worm types and also the number of worms or eggs. Cleaned worms were isolated and identified using miller et al., (1998) keys and recorded accordingly.

3.5.5 Feed Intake

Feed was measured and given to the birds and the left over the next day was weighed and subtracted from what was given to obtain the amount the birds consumed. Data on feed intake were taken on birds daily for three months.

3.5.6 Body Weight and Body weight gain

The initial weight gain was taken at the start of the experiment when the birds were day old. The final body weight was also taken at the end of the brooding. This also served as the initial weight for the post brooding phase.

Final body weight of the post brooding phase as also recorded. Body weight gains for both phases were calculated as the difference between the final body weight and the initial body weight. Arithmetically;

Body Weight Gain (g) = Final Weight Gain (g) – Initial Weight Gain (g).

3.5.7 Feed Conversion Ratio

Feed conversion ratio is the ratio of the total feed intake in grams throughout the experimental period to total weight gain in grams. It was expressed as gain to feed ratio.

That is:

$$\mathbf{FCR} = \frac{\text{Total feed intake(g)}}{\text{Total weight gain(g)}}$$

3.6 Data Collection and Analysis

The data obtained were subjected to one-way analysis of variance (ANOVA) using the General Linear Model (GenStat statistical package version 11.1(2008)) and means separated by the Least Significant Difference (LSD) test at 5% (P< 0.05) significant level.

CHAPTER FOUR

4.0 RESULTS

4.1 The Proximate Composition of Termite Meal

The proximate composition of termite meal is presented in Table 4.1.

Table 4.1: Proximate composition of Termite meal

Nutrients	**Composition (%)**
Moisture	4.00
Crude Protein	49.70
Crude Fibre	7.96
Ether Extract	31.50
Ash	2.50
Nitrogen Free Extract	4.34
*Metabolized energy	4567.5(kcal/kg)

**Estimated*

From the above table (Table 4.1) the results of the proximate analysis indicate that crude protein was the highest source of nutrient components found in termites (49.70 %), followed by ether extract (31.50 %), then crude fiber at (7.96 %), and followed by ash (2.5 %) respectively. The moisture content of the termite is quite low (4.00 %) given a dry matter content of 91.66 %. The crude protein content is quite high accounting for 54.22 % of the dry matter. However, crude fiber is low (7.9 %) constituting 8.68 % of the dry matter. The mineral content (ash) is 2.50 % which is normal for the kind of insect used. The ether extract (fats) also was quite high (31.50 %) expressed as a percentage of the dry matter. The metabolizable energy calculated for this sample was 4567.5 Kcal/g.

4.2 Examination of Soil and Termite Samples for Worm Eggs

The results of soil and termites for worm eggs are presented in Plate 4.1 and 4.2.

Plate 4.1: Image of *Ascaris* eggs viewed under microscope

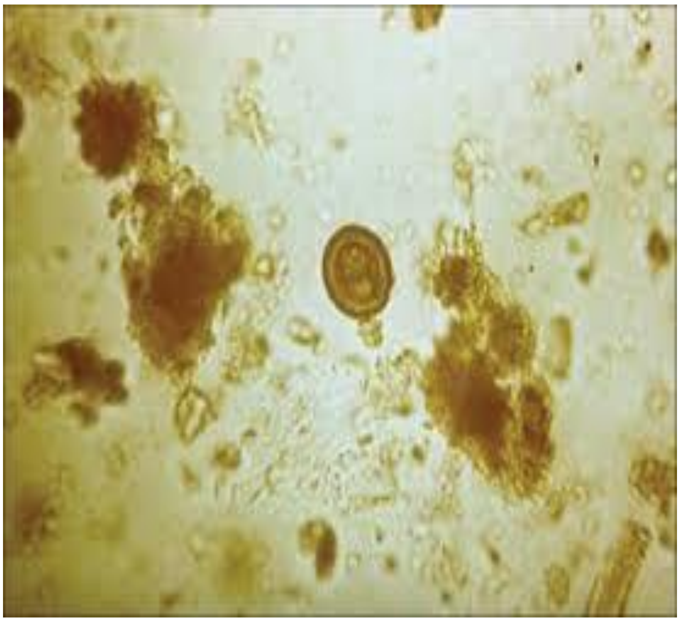

Plate 4.2 Image of *Raillientina* eggs viewed under microscope

A careful and critical examination of both soil and termites showed the presence of worm eggs which are in oval shape on Plate 4.1 and round shape in Plate 4.2. Worm eggs were found in both soil and termites but that of the soil was phenomenal in *Ascaris* and *Raillientina.* Termites on the other hand had more *Ascaris* (9) and *Raillientina* (2) while the soil had more *Raillientina* (11) than the *Ascaris* (4).

4.3 Effect of Termite Meal on Growth performance of Guinea Keets

The effects of termite meal on the growth performance of Guinea keets are presented in Table 4.2

Table 4.2: Effect of termite meal on growth performance of Guinea fowl keets (0-6 weeks)

PARAMETER	CONTROL	TERMITE AND SOIL	TERMITE ONLY	SEM	P VALUE
INBWT(g)	49.2	51.9	48.4	2.78	0.8878
DFI(g)	14.2^{b}	15.8^{a}	14.5^{b}	0.36	0.1265
TFI(g)	510.9^{b}	569.2^{a}	522.3^{b}	12.95	0.1257
FBWT(g)	235.8^{b}	252.0^{a}	251.9^{a}	7.43	0.5659
DWTG(g)	5.2^{b}	5.6^{a}	5.7^{a}	0.16	0.4098
BWTG(g)	186.5^{b}	200.6^{a}	203.5^{a}	5.72	0.3974
FCR	2.7^{ab}	2.8^{a}	2.6^{b}	0.07	0.2394

Means with different superscripts in a row vary significantly

DFI=*Daily Feed Intake* ***TFI=*** *Total Feed Intake* ***INBWT=*** *Initial Body Weight* ***FBWT=****Final Body weight* ***BWTG=*** *Body Weight Gain* ***DWTG*** *=Daily Weight Gain* ***FCR=*** *Feed Conversion Ratio.*

The initial body weight was similar among the dietary treatments and did not differ significantly with variations of not more than 3.5 g. The daily feed intake, total feed intake and final body weight were highest amongst the termites and soil treatment (569.2 g and 252.0 g) followed by termite only (522.3 g and 251.9 g) and control respectively. Also, daily weight gain and body weight gain were highest amongst the termite-only treatment representing (5.7g and 203 g), followed by the termite and soil (5.6 g and 200.6 g) and control respectively. FCR was highest amongst termites and soil representing (2.8), followed by the control (2.7) and finally by the termite only (2.6) respectively (Table 4.2). In all, termite meal had no significant effect (P >0.05) on all the parameters considered under brooding stage of keets.

4.3.1 Effects of Termite Meal on Post-Brooding Growth Performance (6-12 weeks)

Effect of termite meal on post-brooding growth performance is presented in Table 4.3

Table 4.3: Effect of termite meal on post-brooding growth performance

PARAMETER	CONTROL	TERMITE AND SOIL	TERMITE ONLY	SEM	P VALUE
INBWT(g)	235.8	252.0	251.9	7.43	0.5659
DFI(g)	37.6	47.7	46.1	1.70	0.0654
TFI(g)	1579.6	2001.3	1934.4	71.37	0.0655
FBWT(g)	578.4^{b}	638.4^{a}	661.4^{a}	12.99	**0.0501**
DWTG(g)	8.7^{b}	9.2^{a}	9.8^{a}	0.25	**0.0451**
BWTG(g)	242^{b}	385.8^{a}	409.5^{a}	10.31	**0.0451**
FCR	4.6^{c}	5.2^{a}	4.7^{b}	0.07	**0.0080**

Means with different superscripts in a row vary significantly.

DFI= *Daily Feed Intake,* ***TFI=*** *Total Feed Intake,* ***INBWT =*** *Initial Body Weight,* ***FBWT=*** *Final Body weight, BWTG=Body Weight Gain,* ***DWTG=****Daily weight Gain,* ***FCR=****Feed Conversion Ratio.*

There was no significant difference in the initial body weight. Termite meal had no effect (P> 0.05) on daily feed intake and total feed intake. However, final body weight and total body weight gain were influenced by termite meal such that termite meal without soil had the highest ($P \leq 0.05$) total body weight gain and final body weight followed by termite with soil and control in descending order. Termite meal had a significant effect ($P \leq 0.05$) on daily body weight gain (Table 4.3).

Keets given termite meal without soil had the highest ($P \leq 0.05$) daily body weight gain, whereas birds fed termite with soil, followed by control in that order respectively. Birds-fed termites with soil had the highest (P< 0.01) feed conversion ratio followed by termite only and control in descending order.

4.4 Effect of Termite Meal on Survival of Guinea Fowls

Effect of termite meal on the mortality rate of Guinea keets at brooding and post-brooding stages is presented in Table 4.4.

Table 4.4: Effect of termite meal on mortality (%) at brooding stages of the Guinea keets

PARAMETER	CONTROL	TERMITE + SOIL	TERMITE ONLY	SEM	P-VALUE	LSD
Brooding	22.2^{a}	11.1^{ab}	0.00^{b}	6.02	**0.029**	12.04
Post Brooding	0.00	0.00	0.00	0.00	0.00	0.00

Values with different superscripts in a row vary significantly.

The control treatment had more mortality (22.2 %), followed by those that were fed termite and soil (11.1 %), and finally, those that were fed a diet that had termite only (0.00 %) in that order during the brooding stage (0-6 wks) but there was no mortality during post brooding period among the treatments (Table 4.4). Percentage mortality varied between the control and termite only with the control having the highest percentage mortality rate (P<0.05). However, percentage mortality did not vary significantly between termite plus soil and termite only (P>0.05).

4.5 Faecal Egg Count. (FEC)

Effects of termite meal on FEC from faeces of birds are presented in Table 4. 5

Table 4.5: Effects of termite's meal on faecal egg count (epg)

TREATMENT	Wk 4	Wk 6	Wk 8	Wk 10	Wk 12
Control	$1.67^{\mathbf{a}}$	0.67	0.33	0.00	7.7
Termites + soil	ND	1.33	0.33	1.00	3.7
Termites only	1.33^{b}	2.67	1.00	0.00	2.0
SEM	0.471	1.106	0.430	0.571	2.73
LSD	0.942	3.826	1.489	1.998	8.21
P-VALUE	**0.011**	0.474	0.492	0.422	0.295

Means with superscript letters in a column vary significantly.

The control treatment had the highest faecal egg count (7.7 %), followed by termites and soil (3.7 %) and the lowest by termites only accounted for 2.00 % respectively in week 12 however they were not significantly different. The control treatment had the highest faecal egg count (1.67 %), which was significantly different compared with that of termites only and termites with soil only (1.33 %) and the lowest by termite and soil (0.00 %) respectively in week 4 (Table 4.5).

In week 6, birds given termites only had the highest faecal egg count (2.67 %), followed by termites and soil (1.33 %), and lastly by the control treatment (0.67 %). However, in week 8, those that were fed termites only had the highest faecal egg count (1.00 %), followed by termite and soil as well as the control treatment both of which represent 0.33 % in each treatment. Also, in week 10, those with termite and soil had the highest faecal egg count constituting 1.00 % and the remaining treatments (0.00 %) respectively. There was a significant difference (P= 0.01) in the faecal egg count in week 4.

4.6 Parasite Identification in Birds

Parasite egg identification in birds is presented in Table 4.6

Table 4.6: Parasite egg identification in Guinea fowls

Treatment	Parasite Identification
Control	Spirometra
	Hymenolepis
	Trichostrongylus
Termites and soil	
	Hymenolepis
	Trichostrongylus
	Ascaris
Termites only	
	Trichostrongylus
	Ascaris

The parasites eggs identified from faecal samples collected from the control group and the treatment groups were as follows as viewed under the microscope (Plate 4.3).

For the control treatment which was not fed with termites, it was observed to have Spirometra, Hymenolepis and Trichostrongylus respectively.

It was also observed in Termites and soil Hymenolepis, Trichostrongylus and ascaris. However, in the termites, only Trichostrongylus and Ascaris were found. It could be seen that the Trichostrongylus runs through the control group and the treatment groups as well. The Hymenolepis was also be found in the control as well as the termite plus soil group. Ascaris was also found in the treatment groups and not in the control.

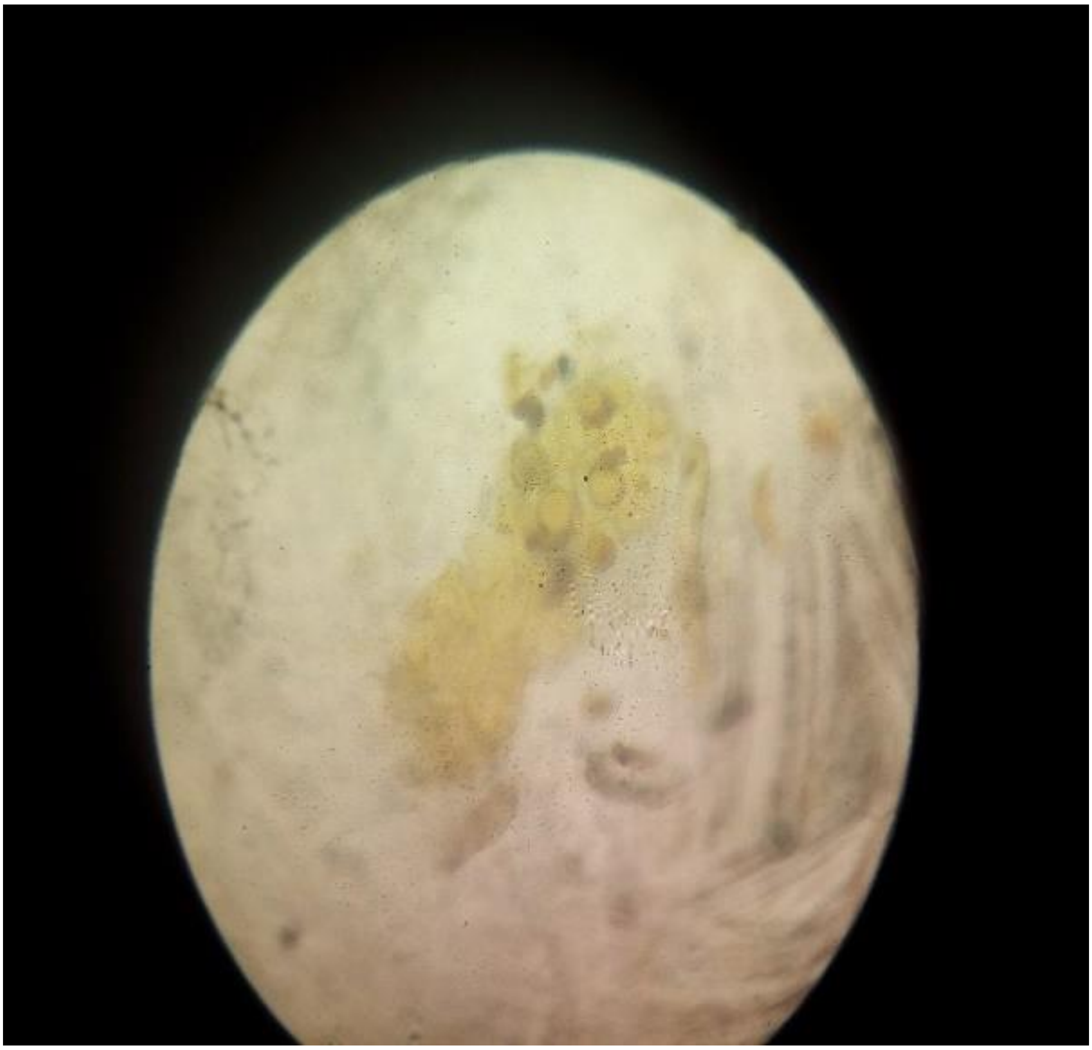

Plate 4.3: Eggs of Parasite viewed under microscope

4.7 Effect of Termite Meal on Worm Burden of Guinea Fowls

The effect of termite meal on the worm burden of Guinea fowls is presented in Table 4.7

Table 4.7: Effect of termite's meal on the worm burden of Guinea fowl (week 6)

Treatment	**Number of birds slaughtered**	**Number of worms found in each treatment/ bird/g**	**Worm types**
Control	3	1.00	Roundworms
Termites and soil	3	5.67	Roundworms
Termites only	3	1.00	Roundworms
SEM		2.725	
LSD		5.45	
P- VALUE		**0.13**	

The worm burden in termites and soil was higher than the control and termites only. It could also be seen (Table 4.7) that; roundworms were the only worms found in both the control and treatment groups. The number of worms isolated in this study did not vary significantly between the control group and the treatment groups ($P>0.05$).

4.7.1 Effect of termite meal on the worm burden of Guinea fowls.

The effect of termite meal on the worm burden of guinea fowls is presented in Table**.** 4.8

Table 4.8: Effect of termite's meal on the worm burden of Guinea fowl (week 12)

Treatment	**Number of birds slaughtered**	**Number of worms found in each treatment/ bird**	**Worm types**
Control	3	150^{a}	Roundworm
Termites and soil	3	5^{b}	Roundworm
Termites only	3	52^{ab}	Roundworm
SEM		56.55	
LSD		113.1	
P- VALUE		**0.051**	

***Means with superscript letters in a column vary significantly*.**

Table 4.7.1 shows, the population of roundworms observed varied significantly (P<0.05) among the dietary treatments. Guinea fowls fed the diet that had no termites (control) supplementation had a higher roundworm population (150) as compared with Guinea fowls fed supplemental termites and soil (5). Guinea fowls given supplemental termite meal only recorded a roundworm population of 52 which was not significantly different (P>0.05) from Guinea fowls fed the control diet and those given the supplemental termite and soil meal.

4.7.2 Effect of termite meal on the worm burden of Guinea fowls

The effect of termite meal on the worm burden of Guinea fowls is presented in Table 4.9

Table 4.9: Effect of termite's meal on the worm burden of Guinea fowl (week 12)

Treatment	Number of birds slaughtered	Number of tapeworms found in each treatment/ bird	Worm types
Control	3	0.00	-
Termites and soil	3	11.00	Tapeworm
Termites only	3	0.00	-

The postmortem examination of Guinea fowls sacrificed at the end of the work in week 12 showed that only eleven (11) tapeworms were collected from the treatment that fed termite plus soil and not in the control group and the treatment group that ate termites only (Plate 4.6).

Plate 4.4: A picture of round worms as expelled from the intestinal tract of Guinea fowl


Plate 4.5: A picture of roundworm as expelled from the intestinal tract of Guinea fowls.


Plate 4.6: A Picture of tape worm as found in the intestinal tract

CHAPTER FIVE

5.0 DISCUSSION

5.1 Proximate Composition of Termite Meal

The proximate analysis for the termite meal indicated a higher crude protein percentage (49.7%) than the rest of the nutrients. The value of the protein recorded is similar to fish meal and soyabean meal which indicates that termite meal could be a substitute protein source for poultry production if produced on large quantities. On the other hand, 48% as reported by Fadiyimu *et al*. (2003) for *Macrotermites* species but higher than the result (46.30%) obtained by Tiroesele and Moreki (2012). This is in agreement with a study by Adeyemo et al., 2014 who reported that, termites are rich source of protein and fat while providing moderate levels of ash, fibre and carbohydrates. These nutritional attributes make termite potentially valuable feed supplement for Guinea fowls.

The higher value obtained could be as a result of the extraction of oil which contributes to the increase in protein. The fat value obtained in the study was 31.5% which adds up to the energy content of the diet which improves growth. The only reason which an animal will eat is to meet its energy requirement. Generally, the fat content of insects is higher than that in fish meal and soyabean (Barroso *et al*., 2014). The crude fiber content of 7.9% indicates the presence of indigestible plant material in the termites.

While Guinea fowls do not have high fiber requirements, some dietary fiber can promote gut health and aid in digestion. However, the relatively low fiber content suggests that termites are more easily digestible compared to fibrous plant-based feeds. The ash content of 2.50% represents the inorganic mineral content of the termites.

Minerals are essential for various physiological functions, including bone formation, enzyme activation, and nerve signaling. The ash content suggests that Macrotermes bellicosus termites can contribute valuable minerals to the guinea fowl's diet. The low moisture content of 4% indicates that the termites have been dried or processed, making them more stable for storage and less prone to spoilage. This allows for a longer shelf life and easier incorporation into feed formulations.

The NFE content represents the portion of the termites that is neither protein, fat, crude fiber, nor ash. It primarily consists of carbohydrates, including sugars, starches, and other digestible carbohydrates. The NFE content of 4.34% suggests a moderate carbohydrate content in the termites. The high metabolizable energy of 4567.5 kcal/kg indicates the termites' potential to provide a concentrated source of energy for guinea fowls. This energy can be utilized for various metabolic processes, including growth, movement, and maintenance.

5.2 Examination of Soil and Termite Samples for Worm Eggs

The worm eggs and larvae obtained from the examination of the soil and termites indicate that, there were more Ascaris eggs (round worm) obtain than the Raillientina eggs (tapeworm). This means that, when the guinea fowls feed on the termites and soil supplementation or termites only the eggs will give rise to a more advanced developmental stage of the parasite. This has been proven that there have been more roundworms in the intestinal tract of the Guinea fowl at the post mortem examination. Yang *et al*.,2017 also reported identifying roundworm eggs in the digestive tract of birds.

The life cycle of a helminth of one of these species, like the life cycle of all other parasitic helminths, is initiated by the eggs or microscopic larvae produced by the mature female or hermaphroditic individual. But depending on its specific identity, its eggs or larvae are infectious only to an insect or a mite or perhaps a tick. If ingested by a suitable insect, for example, each egg or larva gives rise to a more advanced developmental stage of the parasite, which takes up its abode in some part of the insect's body. However, the development of the worm stops at a stage far short of reproductive maturity.

5.3 Effect of Termite Meal on Growth Performance of Guinea Keets (0-6weeks)

There was no significant difference amongst the treatment groups given termite supplementation and control group in the brooding phase (0-6week) based on all the parameters measured. Nsoso *et al.* (2006) observed a similar trend of no difference in growth rate of Guinea keets during the first 4 weeks of age when they compared growth and morphological parameters of guinea fowl (*Numida meleagris*) raised on concrete floors in Botswana. Differences in weight gains were observed from week 6. Contrary to research conducted by Zivar *et al.* (2015) on broiler chicken reported significant differences in daily feed intake across the period of study as a result of termites and soil meal inclusion in the diet.

A study conducted on the layer Guinea fowl from the three northern regions of Ghana revealed an average daily gain per bird to be 7.5g with higher gains observed in Guinea fowl from the upper west Agbolosu *et al*. (2012). The average daily gain per bird reported by Agbolosu *et al*. (2012) on the growing performance of local Guinea fowls from the three northern regions of Ghana is 6.7g.

Duodu (2019) compared effect of different variety of Guinea fowl on production performance reported an average pre-brooding (0-8 weeks) daily gain of 6.3g/bird and a post-brooding (8-16, 16-24 and 24-32 weeks) daily gain per bird to be 6.7g, 12.5g and 3.3g respectively.

5.3.1 Effect of termite's meal on feed intake of local Guinea fowls (Post brooding)

The effect of termite meal on post brooding growth performance of Guinea fowls had no significance difference observed in the initial body weight, daily feed intake and total feed intake. Contrary to a study conducted by Olaniyi et al., 2016, termite meal had the best performance in terms of feed intake, weight gain and feed conversion ratio which replaced fish meal without any adverse effect.

This could be attributed to the inclusion of termite's meal only in the diet. This could be explaining that, the addition of termites only, termites and soil meal in the diet improves digestibility and nutrient absorption. This could also be explained that, the inclusion of termites only meal in the diet reduces microbial load thereby reducing worm infestation (Prayogi, 2011). This result is in agreement with Rezaeipour *et al.* (2014) who reported that inclusion of termites and earthworm meal in the diet of the broilers significantly ($P<0.05$) enhanced daily feed intake and body weight gain as compared with the control treatment. Similar findings were reported by Prayogi (2011).

Another research conducted by Zivar *et al.* (2015) on broiler chicken reported significant differences in daily feed intake across the period of study as a result of termites and soil meal inclusion in the diet.

5.3.2 Effect of termite's meal on body weight of local Guinea fowls

The effect of post brooding growth performance had significant difference ($P<0.05$) on final body weight, body weight gain and daily weight gain among the dietary treatment groups as compared with the control treatment could be explained that, intensive rearing of the Guinea fowl leads to higher growth performance (Nesa *et al*., 2018).

Growth of the Guinea fowl is expected to increase when birds are fed diets containing considerable amounts of protein (Adjetey, 200). Growth occurs in the Guinea fowl mainly through nutrition of fowl (Moreki *et al.*, 2011). Termite's meal only supplementation in the diet enhance nutrient digestion and absorption on daily basis which significantly ($P< 0.05$) enhances body weight throughout the period of study in the post brooding phase. Body weight gain has been of major importance in any poultry and livestock industry. The growth performance observed in any livestock specie depends on the environment (Kerketta *et al*., 2016). The environment comes in the form of feeding and watering, housing, stocking rate, photoperiod, geographical location, and others.

Similar findings were reported by Zivar *et al.* (2015) in an experiment on the effect of earthworm (*Eisenia fetida*) and termites' meal in diet for broiler chicken efficiency and carcass components. The authors reported significant ($P<0.01$) differences on final body weight and body weight gain. In a study of the effect of earthworm meal supplementation in the diet on quail's growth performance in attempt to replace the usage of fish meal, Prayogi (2011) showed that, birds fed with the combination of termites and soil meal inclusion in the diet significantly ($P < 0.05$) improved water intake, body weight, feed conversion and liveability on the overall performance.

It has been established from the studies from Annor *et al*. (2012) who reported weekly body gains of 41g in local breeds and 108g in the European Guinea fowl breeds. The average weekly body gains of the Guinea fowl of three different genotypes reported from the study of Ebegbulem, (2018) is 66g.

5.3.3 Effect of termite's meal on a feed conversion ratio of local Guinea fowls

The effect of termite's meal on the feed conversion on the post brooding growth performance of the Guinea fowls was significantly (P>0.01) observed among termites and soil meal in this study. This could be attributed to the use of termites and soil meal throughout the period of study and proper utilization of the protein supplementation which boost the immunity of the birds and convert to muscle.

However, this finding is in line with the observation made by Zivar *et al.* (2015) in an experiment on the effect of earthworm (*Eisenia fetida*) and termites' meal in the diet of broiler chicken efficiency and carcass components and reported significant (P < 0.05) improvement on feed conversion ratio.

This is contrary to the findings by Khajavi *et al.* (2015) who observed that different levels of dietary termites and soil meal to broiler chicken had no significant (P>0.05) effect on feed conversion ratio. The average FCR observed from the studies on Black and Pearl Guinea fowl is 5.23 (Ebegbulem *et al*., 2018). Management practices, age of birds, type of feed fed to the birds and other environmental factors affect the FCR of Guinea fowls (Khairunnesa *et al*., 2016). Under intensive rearing of Guinea fowl for 20 weeks, an FCR of 4.1 was recorded (Nesa *et al*., 2018).

However, Tjetjoo *et al*. (2013) reported an average FCR of 13.5 when birds were fed with varying diets for 6 to 13 weeks under intensive rearing which is expensive for any farmer to get one kilo by feeding 13.5. Comparing the performance of Guinea fowls raised in cages and deep litter, Alli *et al.* (2016) reported mean FCR of 6.62 and 8.61 respectively. The average FCR from the raising of Guinea fowl from pullet to laying period under different lighting regime was reported to be 2.23 (Korankye *et al*., 2019) while an average FCR of 2.06 was recorded for a period of 6 weeks from birds hatched from large, medium and smaller eggs (Kyere *et al.*, 2017).

5.4 Mortality

Termite as a diet is good for feeding Guinea fowls as mortality reduced significantly at brooding stage. That notwithstanding, termite meal only is the best form of protein for Guinea fowls since it recorded zero mortality. The higher mortality in the control could also be attributed to low protein in the diet compared to those that had access to the protein supplement which was the termite meal.

The major constraint of Guinea fowl production reported by farmers in the northern part of Ghana is keet mortality (Teye & Adam, 2000). Mortality range of 40-100 % has been recorded in Ghana (Iddrisu, 2014). The major causes of death at this stage had been attributed to worm infestation and poor nutrition (Annor *et al.*, 2012). Numerous studies have reported that there is high mortality rate in the Guinea fowl usually from day one of hatch to about the sixth week of life (Araújo *et al*., 2023). A pre-brooding survival rate of 70.8% and a post-brooding survival of 94.6% has been reported in Ghana by Salgado *et al.*, (2022) while Khairunnesa *et al*. (2016) reported a pre-brooding survival of 90%.

Guinea fowl survival is highly essential for the successful operation of the Guinea fowl enterprise (Saina, 2005; Khairunnesa *et al*., 2016). Poor feeding and worm infestation and poor housing facilities have also been found to contribute to high rate of mortality in Guinea keets (Kusina *et al.*, 2012). Comparatively, the Guinea fowl has higher survival potential than the local chicken (Adedibu *et al.*, 2014). Improved management practices are essential to improving the survival rate of Guinea keets (Kusina *et al.*, 2018).

5.5 Faecal Sample Egg Count from Birds

The week four, the effect of termite meal on faecal egg count proved to be significant among the control group and treatment groups but more pronounced in the control. The eggs found it difficult to live in the Guinea fowls as they age, this is a proof that more deaths occurred in the brooding stage.

Sharma *et al. (2018*a) also suggest the impact of *Ascaris. galli* infection can be influenced by various aspects of hen husbandry. Other factors influencing the potential impacts of *A. galli* infection include the condition of birds when infected. Higher infection intensity and worm burdens have been observed in lighter as compared to heavier birds, possibly through different mechanisms acting on allocation of available nutrients towards immune system function versus production (Daş and Gauly, 2014).

Also, more stressed and fearful hens are known to have higher parasite excreta egg counts (EEC) suggesting that stress can impact on immune system function influencing infection intensity (Sherwin *et al.*, 2013).

Naturally infected hens were found to have higher intestinal worm burden compared to artificially infected hens (Sharma *et al.,* 2018a). Lower worm burden observed in the artificially infected hens might be due to increased worm expulsion after initial experimental inoculation (Stehr *et al.,* 2019). Whereas re-infection of hens from the infected ranges might have contributed to higher worm burden in natural infection studies (Sharma *et al.,* 2018b).

Therefore, it is evident that allowing bird's access to ranges, can lead to high intensity infections, an important consideration when implementing control strategies on farm. Different studies have highlighted the variable impacts of *A. galli* infection on various performance parameters. *A. galli* infection can also reduce the ability of infected birds to absorb and utilize nutrients, subsequently suppressing growth rates (Daş *et al.,* 2010).

5.6 Parasite Egg Identification

Hymenolepis was found to be present in both the control and termite and soil group. This might have caused the deaths in Guinea fowls in the brooding stage more especially the Spirometra which was not common to the treatment groups but only to the control and could be the reason for more deaths. This is in line with study by Fontaine *et al*. (2021), Spirometra have been found in the subcutaneous tissue, producing local tissue damage, paralysis, blindness, and death. This is implying that, if not the termites that were acting as protein and therefore immune booster for birds more deaths would have occurred in the termite and soil group than the control since all the birds are fed the same ration. Insect-borne worms of livestock and poultry include representatives of all four of the major groups of helminths:

Roundworms (Nematoda), tapeworms (Cestoda), thorny-headed worms (Acanthocephala), and flukes (Trematoda). The eggs ingested by the insects contain well-developed embryos at the time of oviposition. On hatching in the insect's gut, the larvae first enter the abdominal cavity of the intermediate host and finally come to rest in the walls of the Malpighian tubules or musculature, where they become encysted. Completely formed cysts are usually found free in the abdominal part of the body cavity. The larvae become infective in the intermediate host in a month or so. One of the commonest species of tapeworms, Hymenolepis carioca, found in the domestic fowl, Guinea fowls are also susceptible to infection with this tapeworm.

5.7 Effects of Termite Meal on Worm Burden of Guinea Fowls

In the sixth week, though the control group had lesser burden of worm load, higher mortality was recorded during the brooding phase. This is an indication that, termites act as immune booster hence reduced mortality in the termite and soil which had more worm load (Abiola *et al.*, 2018). Again, in week 12 (post brooding) phase, worm burden in the control and termite only were higher than termites and soil. At this period, the survival rate was high and no death was recorded.

This is evident that, any time after the first six weeks the birds may be able to withstand a considerable number of worms. However, the termites and soil group had tapeworms in them alongside round worms but were able to survive during the post brooding stage.

A study reported by Park *et al*. (2021) shows that, insects have micro compounds which can reduce growth of large number of harmful microorganisms.

The chickens pick up the parasite eggs directly by ingesting contaminated feed, water, or litter or by eating snails, earthworms, or other insects (intermediate hosts) or eating small creatures carrying immature stages of worm (Janquera, 2017).

The susceptible birds get infection by ingestion of these eggs. These worms have significant economic impact on the poultry farming due to the reduced feed conversion efficiency, decreased growth rate and mortality in the worm infected birds (Abdo et *al.*, 2022). Round worm (Ascaridia) and tape worms (Raillietina) are found in intestine while thread worm (Capillaria) is found in crop or esophagus (Janquera, 2017).

Tapeworms parasitize the intestinal tract and they debilitate the birds. Some of the clinical manifestations of chicken tapeworm infections include decline in production, retarded growth, emaciation, weight loss, ruffled and dry plumage, slow movement (weakness), rapid breathing, paralysis and diarrhea. Catarrhal enteritis, hemorrhage, intestinal blockage (large worms) and nodular growths can also be seen in heavy infestations. Other poultry diseases may have similar symptoms and effects like tapeworm infections. Hence, definitive diagnosis should be done in the laboratory and at post-mortem examination.

The use of drugs for removal of tapeworms is usually not effective if the intermediate hosts are still present as sources of infection. Therefore, treatment should be associated with control measures directed against intermediate hosts. Prevention of birds from contact with the intermediate hosts is the most important step that should be taken in the control of tapeworm infection.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

- ❖ Protein was the major nutrient found in the termite as feed, followed by ether extract and others which were the basic nutrients.
- ❖ There was an improvement in the growth performance of the Guinea fowl groups fed with supplementary termite meal compared to the control group.
- ❖ Mortality rate was low in the groups that were fed termites meal.
- ❖ Feeding termites to the Guinea fowls recorded roundworms for all the treatment groups in week 6. However, at week 12 both tapeworms and roundworms were recorded in the termite and soil supplementation.
- ❖ Therefore, this can be concluded that termites are not the intermediate host of tapeworms; rather it is the soil that transmits the tapeworms to the Guinea fowls.

6.2 Recommendations

It can be recommended that,

- ➢ The farmers should use Termite Only (without the soil) in feeding their poultry, especially Guinea fowls.
- ➢ Extensive studies on termite culture on a commercial scale and its use as an alternative protein source for poultry feed would go a long way in solving nutritional challenges.
- ➢ Farmers should do routine deworming of Guinea fowls if termites will be fed to them.

REFERENCES

Abdo, S., Zakir, S., & Nair, S. K. P. (2022). The Study of the Prevalence of Gastrointestinal Helminths in Chicken, A Study from Bale Zone, South East Ethiopia. *Vet Sci,* 1, 1-9.

Abdul-Rahman, I. I. & Adu, Y. E. (2017). The role of the rural farmer in guinea fowl *Numida meleagris* value chain, a case study of the Tolon district. *Livestock Research for Rural Development. 29(72).* Retrieved February 18, 2022, from http://www.lrrd.org/lrrd29/4/iddr29072.html

Abdul-Rahman, I. I., Angsongna, C. B & Baba, H. (2019). *Guinea Fowl (Numida Meleagris) Value Chain: Preferences and Constraints of Consumers. African Journal Food, Agriculture, Nutrition and Development, 19*(2), 14393-14414. DOI: 10.18697/ajfand.85.17335

Abiola, S.S., Oladele, S.B., Ayo-Ajasa, O.Y., Raji, A.O., Oluokun, J.A., & Amao, S.R. (2018). Termite meal (Macrotermes subhyalinus) improved the immune response of guinea fowl (Numida meleagris) challenged with Newcastle disease virus. International Journal of Poultry Science, 17(9), 445-452.

Adedibu, I., Ayorinde, K. L. & Musa, A. A. (2014). Multifactorial Analyses of Morphological Traits of Extensively Reared Helmeted Guinea Fowls Numidia meleagris in Kaduna and Katsina States of Nigeria. *Current Journal of Applied Science and Technology*, *4*(25), 3644-3652

Adei, D. & Asante, B. K. (2012). The Challenges and Prospects of the Poultry Industry in Dormaa District. *Journal of Science and Technology, 32*(1), 104-116

Adjetey, A. N. A. (2011). *Protein requirements for growing and laying indigenous guinea fowls (Numida meleagris) in the humid tropical zone of Ghana* (Doctoral dissertation).

Adjetey. N. A., Atuahene, C. C. & Adjei, M. B. (2014) Protein requirements for growing and laying indigenous Guinea fowls (Numida meleagris) in the humid tropical zone of Ghana. *Journal of Animal Science Advances 4*(2), 722-731 http://www.ejmanager .com/ mnstemps/72/72-1402302341.pdf

Agbidye, F. S, Ofuya, T. I., & Akindele, S. O. (2009). Marketability and nutritional qualities of some edible forest insects in Benue State, Nigeria. Pakistan Journal of Nutrition, 8(7), 917-9

Agbolosu, A. A., Teye, G. A., Adjetey, A. N. A., Addah, W., & Naandam, J. (2012). Performance characteristics of growing indigenous guinea fowls from upper east, upper west and northern regions of Ghana.

Aguilar - Miranda E.D., López M.G., Escamilla - Santana C., & Barba DeLa Rosa A.P. (2002). *Characteristics of maize flour tortilla supplemented with ground Tenebrio molitor larvae.*

Ahiagbe, K. M. J., Amuzu-Aweh, E. N., Bonney, P., Nyameasem, J. K., Avornyo, F. K., Adenyo, C., Amoah, K. O., Naazie, A. & Kayang, B. B. (2021). Comparison of early growth and survivability in indigenous guinea fowls from Northern Ghana. *Tropical Animal Health and Production, 53*(89), 1-17

Akunne, C. E., Ononye, B. U. & Mogbo, T. C. (2013). INSECTS: FRIENDS OR ENEMIES? Global Journal of Biology, Agriculture and Health Sciences, *2*(3), 134-140

Alli, O. I., & Ayorinde, K. L. (2016). Effect of different protein and energy levels on reproductive performance of Guinea hens. *Bullecting of Environmental Pharmacology Life Science, 2*(4), 17-20.

Al-Qazzaz, M. F. A., Ismail, D., Akit, H., Idris, L.H. (2016). Effect of using insect larvae meal as a complete protein source on quality and productivity characteristics of laying hens. *Turkish Journal of Fisheries and Aquatic Sciences 8*, 149-157.

Ameen, S. A., Adedeji O. S., Ojedapo L. O., Salihu T., & Fabusuyi C. O. (2010). Anthelmintic potency of pawpaw (Carica papaya) seeds in West African Dwarf sheep. Global Veterinaria 5(1), 30–34.

Amoah, K. O., Nyameasem, J. K., Asiedu, P., Adu-Aboagye, G. A., Wallace, P., Ahiagbe, K. M. J., & Rhule, S. W. A. (2018). Protein and energy requirements for indigenous guinea keets (Numida meleagris) in southern Ghana. Ghana Journal of Agricultural Science, 52, 105-111.

Annor, S. Y., Apiiga, S. & Ahiaba, J. A. (2012). Handbook on Guinea Fowl Production in Ghana. 1st Edition, Quality Type Limited, Accra, Ghana.

Annor, S.Y, Ahiaba, J.W and Apiiga, S.Y. (2013). *Guinea Fowl Production: A Handbook*. Owali type Limited, Accra, Ghana Pg.1- 2.

AOAC (2000). Official methods of analysis of AOAC. International 17th edition; Gaithersburg MD, USA Association of analytical communities.

Araújo, I. C. S., Guato Guamán, C., Sousa, L. S., Santos, H. J. B., Lopes, T. S. B., Costa, B. T. A., & Lara, L. J. C. (2023). Guinea fowl production in the world. World's Poultry Science Journal, 79(2), 379-390.

Association of official analytical chemists (AOAC,1990). Methods of analysis of the Association of Official Analytic Chemists 18th Ed. Association of official analysis of official analytic chemists, Washington, DC.

Atawalna, J., Agbehadzi, R. K., Essel, D. C. J. & Amponsah, P. (2020) Guinea Fowl Fertility, Hatchability and Embryonic Mortality in An Intensively Managed Farm in Ashanti Region of Ghana. *Animal Research International*, *17*(3), 3863 – 3868

Avornyo, F. K., Munkaila, L., Allegye-Cudjoe, E., Karbo, N. & Atosona, B. S. A (2015). Comparison of Six Treatments for Controlling Mortality of Keets in the Wet Season of the Northern Region of Ghana. *Ghana Journal Agricultural Science, 55*, 15 – 25

Avornyo, F. K., Salifu, S., Moomen, A. & Agbolosu, A. A. (2013). Effect of Dietary Protein on the Performance of Local Guinea Keets in the Northern Region of Ghana. *Greener Journal of Agricultural Sciences*, *3*(7), 585-591

Avornyo, F.K., Partey, S.T., Zougmore, R.B., S. Asare, A. A. Agbolosu, N. M. Akufo, N.A. Sowah & S. P. Konlan (2019). Correction to: In vivo digestibility of six selected fodder species by goats in northern Ghana. *Tropical Animal Health and Production*, *52***,** 481 (2020). https://doi.org/10.1007/s11250-020-02198-6

Baimbill-Johnson, N., Kwabena, A. A., & Ditchfield, A. (2021). Evaluation of the resource efficiency of guinea fowl production in the Savelegu-Nanton District of the Northern Region of Ghana. *Journal of Development and Agricultural Economics*, *13*(2), 142-155.

Banjo, A. D, Lawal, O. A, & Sogbesan, E. A. (2006). The nutritive value of fourteen species of edible insects in southwest Nigeria. African *Journal of Biotech*, *5*, 298-301

Barbour, E. K., Ayyash, D. B., Alturkistni, W., Alyahiby, A., Yaghmoor, S., Iyer, A., Yousef, J., Kumosani, T., & Harakeh, S. (2015). Impact of sporadic reporting of poultry Salmonella serovars from selected developing countries. *Journal of infection in developing countries*, *9*(1), 1–7. https://doi.org/10.3855/jidc.5065

Barbour, M. A. Rodriguez-Cabal, M. A., Wu, E. T., Julkunen-Tiitto, R., Ritland, C. E., Miscampbell, A. E., Jules, E. S., Crutsinger, G. M. (2015). Multiple plant traits shape the genetic basis of herbivore community assembly. *Functional Ecology*, *29*, 995–1006

Barroso, F.G., de Haro, C., Sanchez-Muros, M.-J., Venegas, E., Martinez-Sanchez, A. & Perez-Bañon, C. (2014). The potential of various insect species for use as food for fish. *Aquaculture 422/423*, 193–201.

Barzegar, S., Wu, S. B., Choct, M., & Swick, R. A. (2020). Factors affecting energy metabolism and evaluating net energy of poultry feed. *Poultry science*, *99*(1), 487-498.

Batkowska, J., Drabik, K., Karwowska, M., Ahsan, U., Raza, I., Adamczuk, A., & Horecka, B. (2021). Growth performance and meat quality of meat-type guinea fowl fed different commercial diets. *Archives animal breeding*, *64*(2), 325–334. https://doi.org/10.5194/aab-64-325-2021

Biasato, I., Gasco, L., De Marco, M., Renna, M., Rotolo, L., Dabbou, S., Capucchio, M. T., Biasibetti, E., Tarantola, M., Sterpone, L., Cavallarin, L., Gai, F., Pozzo, L., Bergagna, S., Dezzutto, D., Zoccarato, I., & Schiavone, A. (2018). Yellow mealworm larvae (Tenebrio molitor) inclusion in diets for male broiler chickens: effects on growth performance, gut morphology, and histological findings. *Poultry science*, *97*(2), 540–548. https://doi.org/10.3382/ps/pex308

Biswas, E.R.I. (1999). *Guinea fowl*. In: R. Ewbank, F. Kim Madlien and G.B. Hart. (Eds). *Management and Welfare of Farm Animals, 4th Edition*. Halstan

Boafo, H. A., Affedzie-Obresi, S., Gbemavo, D. S. J. C., Attuquaye, C. V., Nkegbe, E., Adu-Aboagye, G. & Kenis, M. (2019). Use of Termites by Farmers as Poultry Feed in Ghana. *Insects, 10*(69), 1-13 doi:10.3390/insects10030069

Bovera F., loponter., marono S., piccolo G., parisig., Iaconisi V., gacoL., nizza A. (2015*)*. Use Of Tenebrio Molitor Larvae Meal as Protein Source in Broiler Diet: *Effect on Growth Performance, Nutrient Digestibility, And Carcass and Meat Traits*. J. Anim. Sci., 94: 639–647.

Bovera, F., Loponte, R., Marono, S., Piccolo, G., Parisi, G., Iaconisi, V., Gasco, L., & Nizza, A. (2016). Use of *Tenebrio molitor* larvae meal as protein source in broiler diet: effect on growth performance, nutrient digestibility, and carcass and meat traits. *Journal of Animal Science, 94*, 639-647

Bovera, F., Piccolo, G., Gasco, L., Marono, S., Loponte, R., Vassalotti, G., ... & Nizza, A. (2015). Yellow mealworm larvae (Tenebrio molitor, L.) as a possible alternative to soybean meal in broiler diets. British poultry science, 56(5), 569-575.

Bovera, Fulvia, Rosa Loponte, Stefania Marono, Giovanni Piccolo, Giuliana Parisi, Valeria Iaconisi, Laura Gasco, and Antonino Nizza. "Use of Tenebrio molitor larvae meal as protein source in broiler diet: Effect on growth performance, nutrient digestibility, and carcass and meat traits." Journal of Animal Science 94, no. 2 (2016): 639-647.

Bukkens, S.G.F. (2005*). Insects in the human diet: nutritional aspects*, in: PAOLETTI, MG (ed.) cake for poultry in Burkina Faso: availability and amino acid digestibility. International Journal of Poultry Science 6: 666-672.

Chagwena, D. T., Matanhire, G. T., Jombo, T. Z. & Maponga, C. C. (2019). Protein Quality of Commonly Consumed Edible Insects in Zimbabwe. *African Journal Food, Agriculture, Nutrition and Development*, *19*(3), 14674-14689 Chicken health for dummies. *Journal of Agriculture and Food Chemistry*, *50*, 192–195.

Chrysostome C.A.A.M., (1997) - *Utilisation des termites pour le démarrage des pintadeaux ; essaid'alimentationen milieu réel.* - pp 117-124 in : Proceedings Atelier RADAR, 9-13 Décember 1997. M'Bour, Sénégal.

Chrysostome, C. A. A. M., Coubéou, P. T., Dakpogan, H. & Mensah, G. A., (2009). *Comment collecter des termites avec des noix de rônier pour l'alimentation des pintadeaux ? Référentiel technicoéconomique pour la production avicole.* Vol. 1. PADAV/CASPA/ OADSA, Cotonou, Bénin

Dao, A.N.C., Sankara, F., Pousga, Coulibaly, S. K. Nacoulma, J. P. Ouedraogo, S., Kenis, M. & Somda, I. (2020). Traditional methods of harvesting termites used as poultry feed in Burkina Faso. *International Journal of Tropical*

Insect Science, 40, 109–118 (2020). https://doi.org/10.1007/s42690-019-00059-w

Daş, G., Kaufmann, F., Abel, H., & Gauly, M. (2010). Effect of extra dietary lysine in Ascaridia galli-infected grower layers. Veterinary Parasitology, 170(3-4), 238-243.

Delgado, L., Garino, C., Moreno, F. J., Zagon, J., & Broll, H. (2022). Sustainable food systems: EU regulatory framework and contribution of insects to the Farm-To-Fork strategy. Food Reviews International, 1-22.

Diawara, M., (2013). Impact the l'utilisation des termites en aviculture traditionnelle au Burkina Faso. Mémoire de Fin de Cycle. Université Polytechnique de Bobo-Dioulasso, Burkina Faso, 43 pp.

Djissou, A. S. M., Adjahouinou, D. C., Koshio, S., Fiogbe, E. D. (2016). Complete replacement of fish meal by other animal protein sources on growth performance of *Clarias gariepinus* fingerlings. *International Aquatic Research, 8,* 333–341 (2016). https://doi.org/10.1007/s40071-016-0146-x

Dougnon, T. J., Tobada, P., Djossa, B. A., Davito, F. E. & Youssao, I. (2012). Effects of powdered peanut (Arachis /zypogea) on the sex reversing in Guinea fowl and the parameters of production and reproduction in the fowl "Numida meleagris". *International Journal of Advanced Biological Research. 2*(2), 209-214.

Duodu, A., Twumasi, G., Dapaah, P. K., Kyere, C. G., Okyere, K., & Jnr, P. A. P. (2021). Effect of light on Guinea fowl (Numida meleagris) production: A review. *World Journal of Advanced Research and Reviews*, 9(3), 337-345.

E. M. & DeSouza, O., Cancello, (2010). Termites and ecosystem function. International Commission on Tropical Biology and Natural Resources, in Encyclopedia of Life Support Systems (EOLSS), Developed under the Auspices of the UNESCO, Eolss Publishers, Oxford, UK.

Ebegbulem, V. N. & Asuquo, B. O. (2018). Growth Performance and Carcass Characteristics of the Black and Pearl Guinea Fowl (Numida Meleagris) and their Crosses. *Global Journal of Pure and Applied Sciences, 24*, 11-16.

EFSA Panel on Biological Hazards (BIOHAZ), Koutsoumanis, K., Allende, A., Bolton, D. J., Bover-Cid, S., Chemaly, M., ... & Alvarez-Ordóñez, A. (2020). Potential BSE risk posed by the use of ruminant collagen and gelatine in feed for non-ruminant farmed animals. *EFSA Journal,* 18(10), e06267.

EFSA Scientific Committee (2022). Risk profile related to production and consumption of insects as food and feed. *EFSA Journal, 13*(10), 4257, 60 doi: 10.2903/j.efsa.2015.4257

Engberg, R. M & Józefiak, D., (2015, August). Insects as poultry feed. In 20th European Symposium on poultry nutrition (Vol. 24, p. 27).

Fadiyimu, A. A., Ayodele, A.O., Olowu, P.A. & Folorunso, O.R. (2003). Performance of finishing broilers fed graded levels of termite's meal as replacement for fish meal. Proceeding of the 28th Annual Conference of Nigeran society for Animal Production, 28, 211 -212.

FAO (2013). Edible insects. Future prospects for food and feed security. FAO Forestry Paper 171. Rome, FAO. pp. 201. (Also available at http://www.fao .org/3/i3253e/i3253e .pdf)

Farina, L., Demey, F. & Hardouin, J., (1991). Production de termites pour l'aviculture villageoise au Togo. Tropicultura 9: 181-187.

Farrell, D. (2010). Guinea Fowl Production. http://www.poultryhub.org/species/game-birds/guinea-fow11. 18/1 0/20 15. Gauthier, J. & Ludlow, R. (2013).

Ferdushy, T., Hasan, M. T., & Golam Kadir, A. K. (2016). Cross sectional epidemiological investigation on the prevalence of gastrointestinal helminths in free range chickens in Narsingdi district, Bangladesh. *Journal of parasitic diseases: official organ of the Indian Society for Parasitology*, *40*(3), 818–822.

Figueirêdo, R. E. C. R., Vasconcellos, A., Policarpo, I. S. & Alves, R. R. N. (2015). Edible and medicinal termites: a global overview. *Journal of Ethnobiology and Ethnomedicine, 11***(**29), 1-7 https://doi.org/10.1186/s13002-015-0016-4

Fontaine, A. M., de Paz, V. C., Bordao, J. P., Eom, K., & de Armas Rodríguez, Y. (2021). First molecular detection of Spirometra spp. in Cuba. *Revista Cubana de Investigaciones Biomédicas*, *40*(2).

Garcia, L. S., Arrowood, M., Kokoskin, E., Paltridge, G. P., Pillai, D. R., Procop, G. W., Ryan, N., Shimizu, R. Y., & Visvesvara, G. (2017). Practical Guidance for Clinical Microbiology Laboratories: Laboratory Diagnosis of Parasites from the Gastrointestinal Tract. *Clinical microbiology reviews*, *31*(1), 25-17. https://doi.org/10.1128/CMR.00025-17

Gasco, L., Acuti, G., Bani P., Zotte, A. D., Danieli, P. P., De Angelis, A., Fortina, R., Marino, R., Parisi, G., Piccolo, G., Pinotti, L., Prandini, A., Schiavone, A., Terova, G., Tulli, F. & Roncarati, A. (2020). Insect and fish by-products as sustainable alternatives to conventional animal proteins in animal nutrition, *Italian Journal of Animal Science, 19*(1), 360-372, DOI: 10.1080/1828051X.2020.1743209

Gauly, M., Duss, C., (2012). (Erhardt Influence of *Ascaridia galli* infections and anthelmintic treatments on the behaviour and social ranks of laying hens (*Gallus gallus domesticus*) #24. 23-25 May, MEKARN-CTU, Vietnam. August 10, 2012.

Gauthier, J. & Ludlow, R. (2013). Chicken health for dummies. 1st ed. pp. 336. Journal of Agriculture and Food Chemistry, *50*, 192–195.

Gope B, Prasad B. (2005). Preliminary observation on the nutritional value of some edible insects of Manipur. J Adv Zool 1983; 4:55-61. Manipur university India.

Goux, Xavier, Tong Liu, Maria Westerholm, And Magdalena Calusinska. "Microbial Degradation of Lignocellulose in Natural and Engineered Systems–From the Smallest to The Biggest Bioreactor." Microbial Fermentations in Nature and as Designed Processes 5 (2023): 167.

Hatab, M. H, Ibrahim N. S, Sayed, W. A, Sabic, E. M. (2020). Potential Value of Using Insect Meal as an Alternative Protein Source for Japanese Quail Diet. *Brazilian Journal of Poultry Science, 22*(1), 1-10

Hickin NE. (1971). Control of dry wood termites: In termites - A world problem. Hutchinson and Co. Ltd., London. ;169-186

Hossain, S. M., & Blair, R. (2007). Chitin utilisation by broilers and its effect on body composition and blood metabolites. *British poultry science*, 48(1), 33-38. https://doi.org/10.1186/s40104-017-0191-3

Hunter, M. C., Smith, R. G., Schipanski, M. E., Atwood, L. W. & Mortensen, D. A. (2017). Agriculture in 2050: Recalibrating Targets for Sustainable Intensification, *BioScience*, *67*(4), 386–391, https://doi.org/10.1093/biosci/bix010

Iddrisu, A. (2014). Growth response of Guinea fowl fed diets containing Bovine blood blended with cassava. (Master's Thesis. Kwame Nkrumah University of Science and Technology. Ghana)

IFIF. (2019). International Feed Industry Federation Annual report, 2018–2019. http://annualreport.ifif.org/#start

Jacquie, J. (2018). Basic poultry nutrition articles.extension.org. /Basic-poultry-nutrition.pp.109-112.

Janquera, P. (2017). Parasites of dogs, cats, horses and livestock: Biology and control. Parasitipedia.net.

Jongema, Y. (2015). World list of edible insects. Wageningen University, 75.

Józefiak, D. & Engberg, R. M. (2015). INSECTS AS POULTRY FEED. 20th European Symposium on Poultry Nutrition, 24–27 August 2015 Prague, Czech Republic

Karbo, N., Avornyo, F.K. & Apiiga, S.Y. (2002). Preliminary studies on the pattern and causes of Guinea fowl *(Numida meleagris*) keet losses in Garu, Bawku East District. The Savanna Farmer (July), 1: 15 – 17.

Kenis, M., Koné, N., Chrysostome, C. A. A. M., Devic, E., Koko, G.K.D., Clottey, V. A., Nacambo, S. & Mensah, G. A., (2014). Insects used for animal feed in West Africa. *Entomologia 2*, 107-114.

Khairunnesa, M., Das, S C. & Khatun, A. (2016). Hatching and growth performances of guinea fowl under intensive management system. *Progressive Agriculture 27*, 70-77

Khajavi, H.R., Karimi, T. M.A. & Ahmadi, H. (2015). Effect of Feeding Different Levels of Dietary Termites and Sand Meal on Growth Performance and Meat Quality in Broiler Chickens. *Journal of Animal Production*, 16(2)

Khan, S. H. (2018). Recent advances in role of insects as alternative protein source in poultry nutrition. *Journal of Applied Animal Research, 46*(1), 1144-1157, DOI: 10.1080/09712119.2018.1474743

Kim, Y.-B., Lee, S.-H., Kim, D.-H., Lee, H.-G., Choi, Y., Lee, S.-D., Lee, K.-W. (2022). Effects of Dietary Organic and Inorganic Sulfur on Laying Performance, Egg Quality, Ileal Morphology, and Antioxidant Capacity in Laying Hens. Animals, 2022, 12, 87. https://doi.org/10.3390/ani12010087

Konlan, S. P & Avornyo, F. K. (2013). The effect of wetland on Guinea fowl (Numida meleagris) egg productivity and fertility during the dry season in the Guinea savannah ecological zone of Ghana. *Sky Journal of Agricultural Research Vol. 2*(9), pp. 126 - 131

Korankye, O., Kagya-Agyemang, J. K., Annor, S. Y., Asabere-Ameyaw, A., Kyere, C. G., Fiashide, N. & Setsiwah, W. (2019). Effects of Graded Dietary Protein on Growth and Laying Performance of Pearl Guinea Fowl (Numida meleagris). *Journal of Applied Life Sciences International, 23*(6): 23-29, Kusina, N. T., Saina, H., Kusina, J. F. & Lebel, S. (2018). An insight into guinea fowl rearing practices and productivity by guinea fowl keepers in Zimbabwe. *African Journal of Agricultural Research, 7*(25), 3621-3625

Kyere, C. G. Annor, S. Y., Kagya-Agyemang, J. K. & Korankye, O. (2017). Effect of egg size and day length on reproductive and growth performance, egg characteristics and blood profile of the Guinea fowl. *Journal of Livestock Research for Rural Development*, 29(9)

Lamidi, W. A. (2014). Evaluation of Performances of Broilers Raised Under Different Floor Space Geometries in South Western Nigeria. *Journal of Tropical Agriculture, Food, Environment and Extension, 13*(1), 8 - 17

Lavalette, M., (2013). Les insectes : une nouvelle resource enprotéines pour l'alimentation humaine. Université de Lorraine, Nancy, France, 72 pp.

Lee, J., Kim, Y. M., Park, Y. K., Yang, Y. C., Jung, B. G., Lee, B. J. (2018). Black soldier fly (Hermetia illucens) larvae enhance immune activities and increases survivability of broiler chicks against experimental infection of Salmonella Gallinarum. *Journal of Vetenary and Medical Science, 80*(5), 736-740.

Leinonen, I., Iannetta, P. P. M., Rees, R. M., Russell, W., Watson, C., Barnes, A. P. (2019). Lysine Supply Is a Critical Factor in Achieving Sustainable Global Protein Economy. *Frontiers in Sustainable Food Systems, 3*(27), 1-11

Liu, T., Klammsteiner, T., Dregulo, A. M., Kumar, V., Zhou, Y., Zhang, Z., & Awasthi, M. K. (2022). Black soldier fly larvae for organic manure recycling and its potential for a circular bioeconomy: A review. *Science of the Total Environment*, 833, 155122.

Longvah, T., Mangthya, K., & Ramulu, P. J. F. C. (2011). Nutrient composition and protein quality evaluation of eri silkworm (Samia ricinii) prepupae and pupae. Food chemistry, 128(2), 400-403.

López-López, J. A., Marín-Martínez, F., Sánchez-Meca, J., Van den Noortgate, W., & Viechtbauer, W. (2014). Estimation of the predictive power of the model in mixed-e ects meta-regression: A simulation study. *British Journal of Mathematics, Statistics and Psychology, 67,* 30–48.

Makkar, H. P. S., Tran, G., Heuzé, V., & Ankers, P. (2014). State-of-the-art on use of insects as animal feed. *Animal, Feed and Science Technology, 197,* 1–33.

Malapela, T., Chisita, C. T. & Chinyemba, F. (2016). Challenges and Opportunities in providing for Animal Agricultural information services in Zimbabwe: The case of poultry farmers in Harare. Rome, Italy: Organization of the United Nations

Manyara, N. E. (2018). Optimization of Production of Black Soldier Fly Larvae (Hermetia Illucens, L) for Fish Feed Formulation. (Doctoral Thesis, Jaramogi Oginga Odinga University of Science and Technology)

Medale, F., & Kaushik, S. (2009). Protein sources in feed for farmed fish. Cahiers Agricultures, 18(2), 103-111.

Médale, F., Le Boucher, R., Dupont-Nivet, M., Quillet, E., Aubin, J., & Anserat, J. (2013). Des aliments à base de végétaux pour les poissons d’élevage. *INRA Production Animale, 26*(4), 303-316

Men BX, Ogle B, Preston TR. Production and evaluation of Black Soldier fly larvae and termites as protein supplements for chickens. Workshop-seminar "Making better use of local feed resources" (Editors: TR Preston and B Ogle) MEKARN-CTU, Cantho, 23-25 May, 2005. Article

Meteorological Service Department 2019 Mampong; Rainfall patterns at Mampong in the Ashanti Region of Ghana. Pauzenga, U. (1985). Feeding parent stock. Zootecnica international, 17, 22-24.

Mevo, S. I. U., Ashrafudoulla, M., Furkanur Rahaman Mizan, M., Park, S. H., & Ha, S. D. (2021). Promising strategies to control persistent enemies: Some new technologies to combat biofilm in the food industry—A review. Comprehensive Reviews in Food Science and Food Safety, 20(6), 5938-5964.

Miller, J. E. M., Bahirathan, L. S., Lamarie, G. F., Hembry, T. M., & Barras, R. S. (1998). Epidemiology of gastrointestinal nematode parasitism in Suffolk and Gulf Coast native sheep with special emphasis on relative susceptibility to Haemonchus concortus infection. *Veterinary parasitology,* 74, 55-74.

Mitsuhashi, J. (2010). The future use of insects as human food. In: Durst PB, Johnson DV, Leslie RN, Shono K, editors. Forest insects as food: humans bite back. Proceedings of a workshop on Asia-Pacific resources and their potential for development, Thailand: Chiang Mai

Moreki, J. C. & Radikara, M. V. (2013). Challenges to Commercialization of Guinea Fowl in Africa. *International Journal of Science and Research (IJSR), 2*(11), 437-400

Moreki, J. C. (2009). Guinea fowl production. Reach.

Moreki, J. C., & Radikara, M. V. (2013). Challenges to commercialization of guinea fowl in Africa. International Journal of Science and Research, 2(11), 436-440.

Moreki, J. C., & Tiroesele, B. (2012). Termites and earthworms as potential alternative sources of protein for poultry. Intern J Agro Veter Med Sci, 6, 368-76.

Moreki, J. C., Tiroesele, B., & Chiripasi, S. C. (2012). Prospects of utilizing insects as alternative sources of protein in poultry diets in Botswana: a review. J. Anim. Sci. Adv, 2(8), 649-658.

Moula, N., & Detilleux, J. (2019). A Meta-Analysis of the Effects of Insects in Feed on Poultry Growth Performances. *Animals: an open access journal from MDPI*, *9*(5), 201. https://doi.org/10.3390/ani9050201

Moula, N., Scippo, M. L., Douny, C., Degand, G., Dawans, E., Cabaraux, J.F., Hornick, J. L., Medigo, R. C., Leroy, P., Francis, F., et al. (2017). Performances of local poultry breed fed black soldier fly larvae reared on horse manure. *Animal Nutritional*, *4*, 73–78.

Muchadeyi, F.C., Sibanda, S., Kusina, N.T., Kusina, J. & Makuza, S. (2004). The village chicken production system in Rushinga District of Zimbabwe, **16**(6): 154-158.

Mushambanyi, T. M. B., & Balezi, N. (2002). Utilisation des blattes et des termites comme substituts potentiels de la farine de viande dans l'alimentation des poulets de chair au Sud-Kivu, République Démocratique du Congo. Tropicultura, 20(1), 10-16.

Musundire, M. T. (2016). Influence of age and sex on carcass and meat quality traits of scavenging guinea fowls. (Doctoral Thesis, University of KwaZulu-Natal)

Mwale, M. & Masika, P.J. (2009). Ethno-veterinary control of parasites, management and role of village chicken in rural household of Centage district in the Eastern Cape, South Africa. 41: 1685-1693.

Nahashon, S. N., Adefope, N., Amenyenu, A., & Wright, D. (2005). Effects of dietary metabolizable energy and crude protein concentrations on growth performance and carcass characteristics of French guinea broilers. *Poultry Science*, *84*(2), 337-344.

National Research Council (NRC, 2011). Nutrient requirements of poultry, 9th revised edition. National Academy Press, Washington, D.C; USA, pp.405

Nsoso, S. J., Mareko, M. H. D. & Molelekwa, C. (2006). Comparison of growth and morphological parameters of guinea fowl (*Numida meleagris*) raised on concrete and earth floor finishes in Botswana. *Livestock Research for Rural Development 18*(12)

Nsoso, S. J., Seabo, G. M., Kgosiemang, J., Molatlhegi, S. G., Mokobela, M., Chabo, R. G., & Mine, O. M. (2003). Performance of progeny of wild and domesticated Guinea fowl (Numida meleagris) in Southern Botswana. *South African Journal of Animal Science*, 4(1), 46-51.

Ntukuyoh, A. I., Udiong, D. S., Ikpe, E., Akpakpan, A. E. (2012). Evaluation of nutritional value of termites (*Macrotermes bellicosus*): soldiers, workers, and queen in the Niger Delta region of Nigeria. *Internal Journal Food Nutrition Safety 1*, 60-65

Oke, U. K., Herbert, U. & Nwuchukwu, E. N. (2004). Association between body weight and some egg production traits in the Guinea fowl Numida meleagris gafeata Pallas). Livestock Research for Rural Development. 16(9):6

Oladosu, O. J., Hennies, M., Stehr, M., Metges, C. C., Gauly, M., & Daş, G. (2023). Pattern and repeatability of ascarid-specific antigen excretion through chicken faeces, and the diagnostic accuracy of coproantigen measurements as compared with McMaster egg counts and plasma and egg yolk antibody measurements in laying hens. *Parasites & Vectors,* 16(1), 1-14.

Olaniyi, C. O, Olabomi, F. T, & Ajayi, O. M. (2016). Performance Characteristics and Nutrients Utilization of African Cat Fish Fed Termite Based Diets. *International Journal of Science, Environment and Technology, 5*(5), 2679 – 2688

Othman, R., & Abdallah, J. (2017). Effect of Poultry Production System on Infection with Internal Parasites in "Baladi" Layer Hens of Northern West Bank, Palestine. *Annual Research & Review in Biology*, 1-7.

Padgett, K. A. & Boyce, W. M. (2007). Ants as first intermediate hosts of Mesocestoideson San Miguel Island, USA. *Journal of Helminthology 79,* 67–73.

Park, S.I, Chang, B.S., Yoe, S.M. (2014). Detection of antimicrobial substances from larvae of the black soldier fly, *Hermetiaillucens* (Diptera**: *stratiomyidae*)** *Entomol Res*, 44, pp. 58-64

Pauzenga, U. (1985). Feeding parent stock. Zootech International, December. Pp 22-24

Permin, A. & Hansen, J. (2016). (Epidemiology, diagnosis and control of poultry parasites. Simple floatation p. 83-84. FAO Animal Health Manual.

Phelps R.J., Struthers J.K, & Moyo S.J.L. (1975). Investigations into the nutritive value of Macrotermes falciger, (Isoptera: Termitidae). Zool Afr : 10 :123-132.

Poissonnier, L. A., Simpson, J., Dussutour, A. & Buhl, J. (2020). Regulation of macronutrient intake in termites: A dietary self-selection experiment. *Journal of Insect Physiology*, *120*(10)

Prayogi, H. S. (2011). The Effect of Earthworm Meal Supplementation in the Diet on Quail's Growth Performance in Attempt to Replace the Usage of Fish Meal. *International Journal of Poultry Science 10*(10), 804-806

Precup, G., Ververis, E., Azzollini, D., Rivero-Pino, F., Zakidou, P., & Germini, A. (2022). The Safety Assessment of Insects and Products Thereof as Novel Foods in the European Union. Novel Foods and Edible Insects in the European Union, 123.

Raheem, D., Carrascosa, C., Oluwole, O. B., Nieuwland, M., Saraiva, A., Millán, R., & Raposo, A. (2019). Traditional consumption of and rearing edible insects in Africa, Asia and Europe. *Critical reviews in food science and nutrition,* 59(14), 2169-2188.

Ramos - Elorduy J., Pino J.M. (2002). Edible insects of Chiapas, Mexico. Ecol. Food Nutrition., 41: 271–299.

Renna, M., Schiavone, A., Gai, F. S. Dabbou, C. Lussiana, V. Malfatto, M. Prearo, M. T. Capucchio, I. Biasato, E. Biasibetti, M. De Marco, A. Brugiapaglia, I. Zoccarato & L. Gasco (2017). Evaluation of the suitability of a partially defatted black soldier fly (*Hermetia illucens* L.) larvae meal as ingredient for rainbow trout (*Oncorhynchus mykiss* Walbaum) diets. *Journal of Animal Science and Biotechnology*, 8, 57 https://doi.org/10.1186/s40104-017-0191-3

Rezaeipour, V., & Gazani, S. (2014). Effects of feed form and feed particle size with dietary L- threonine supplementation on performance, carcass characteristics and blood biochemical parameters of broiler chickens. *Journal of animal science and technology*, *56*, 20.

Rumpold, B.A. & Schlüter, O.K., (2013). Potential and challenges of insects as an innovative source for food and feed production. Innovative Food Science and Emerging Technologies 17:1-

Rutaisire, J. (2007). Analysis of feeds and fertilizers for sustainable aquaculture development in Uganda. - In: Hasan M. R., Hecht T., De Silva S. S., Tacon A.G., (eds). Study and analysis of feeds and fertilizers for sustainable aquaculture development. FAO Fisheries Technical Paper. No. 497. Rome, FAO: pp 471-487.

Saina, H., Kusina, N. T., Kusina, J. F., Bhebhe, E. & Lebel, S. (2005). Guinea fowl production by indigenous farmers in Zimbabwe. *Livestock Research for Rural Development*, *17*.

Salgado, R. P., Ortega, J. B., Canul, A. J. C., Casanova, R. E. S., Correa, J. S., & Vázquez, F. A. C. (2022). Factors affecting productive performance of guinea fowl: a review. *Tropical and Subtropical Agroecosystems*, 25(2).

Sankara, F, Pousga, S, Dao, N. C. A, Gbemavo, D. S. J. C, Clottey, V. A, Coulibaly, K, Nacoulma, J. P., Ouedraogo, S., Kenis, M. (2018) Indigenous knowledge and potential use of termites as poultry feed in Burkina Faso. *Journal of Insects Food and Feed 4,* 211–218

Sarica, S., Kanoglu, B. & Yildirim, U. (2020). Defatted yellow mealworm larvae (Tenebrio molitor l.) meal as possible alternative to fish meal in quail diets. *South African Journal of Animal Science, 50*(3), 482-491

Schiavone, A., DeMarco, M., Rotolo, L., Belforti, M., Mirò, M. S., Madrid, S. J., Hernandez, R. F., Bianchi C., Sterpone, L., Malfatto, V., Katz, H., Zoccarato, I., Gai, F., Gasco L. (2014). Nutrient digestibility of Hermetiaillucens and Tenebrio molitor meal in broiler chickens. Proc. Conference Insects to Feed. The World, Abstract Book, The Netherlands.

Seabo, D., Moreki, J. C., Bagwasi, N., & Nthoiwa, G. P. (2011). Performance of guinea fowl (Numida meleagris) fed varying protein levels. *Online Journal of Animal and Feed Research*, 1(6), 255-258.

Sharma, N., Hunt, P. W., Hine, B. C, Sharma, N. K., Chung, A., & Ruhnke I. (2018). Performance, egg quality and liver lipid reserves of free-range laying hens naturally infected with *Ascaridia galli Poultry Science*, 97, 1914-1921 Article Download PDF Cross Ref View Record in Scopus Google Scholar Sharma *et al.*, 2018c

Sherwin, C. M., Nasr, M. A., Gale, E., Petek, M., Stafford, K., Turp, M., & Coles, G. C. (2013). Prevalence of nematode infection and faecal egg counts in free-range laying hens: relations to housing and husbandry. *British poultry science*, *54*(1), 12–23. https://doi.org/10.1080/00071668.2012.757577

Shindi, H. A., Bandiya, H. M., Yahaya, M. M. & Aminu, A. (2019). Effect of Dietary Supplementation of Termites (Macrotermes bellicosus) on the Performance of Broiler Chickens. *Asian Journal of Research in Animal and Veterinary Sciences, 4*(1), 1-6, Sigolo, S. Deldar, E. Seidavi, A., Bouyeh, M., Gallo, A. & Prandini, A. (2019). Effects of dietary surpluses of methionine and lysine on growth performance, blood serum parameters, immune responses, and carcass traits of broilers. *Journal of Applied Animal Research, 47*(1), 146-153, DOI: 10.1080/09712119.2019.1583571

Singh, S. (2020). Entomophagy: insects as human food. Agriculture & Food, 56, 76.

Sogari, G, Amato, M, Biasato, I, Chiesa, S, Gasco, L. (2019). The Potential Role of Insects as Feed: A Multi-Perspective Review. *Animals*, *9*(4), 119. https://doi.org/10.3390/ani9040119

Sogbesan, A. O. & Ugwumba, A. A. A. (2008). Nutritional Evaluation of Termite (Macrotermes subhyalinus) Meal as Animal Protein Supplements in the Diets of Heterobranchus longifilis (Valenciennes, 1840) Fingerlings. *Turkish Journal of Fisheries and Aquatic Sciences 8*, 149-157.

Sogbesan, A. O., & Ugwumba, A. A. A. (2008). Nutritional evaluation of termite (Macrotermes subhyalinus) meal as animal protein supplements in the diets of Heterobranchus longifilis (Valenciennes, 1840) fingerlings. *Turkish journal of fisheries and aquatic Sciences,* 8(1), 149-158.

Solavan, A, Paulmurugan, R., & Wilsanand, V. (2006). Effect of the subterranean termite used in the South India folk medicine. *Indian Journal of Traditional Knowledge, 5*(6), 376-379

Soulsby, E. J. L. (1982). Helminthes. Arthropoda and Protozoa of Domesticated Animals, 6th Edition (Baillier, Tindall and Casell, London).

Stehr, M., Grashorn, M., Dannenberger, D., Tuchscherer, A., Gauly, M., Metges, C. C., & Daş, G. (2019). Resistance and tolerance to mixed nematode infections in relation to performance level in laying hens. Veterinary parasitology, 275, 108925.

Subedi, J. R., Mujahid, T. & Cheetri, B. (2018). Prevalence of Intestinal Helminth Parasites of Chicken (Gallus gallus domesticus Linnaeus, 1758) In Lalitpur District, Nepal. *Tribhuvan University Journal, 32*(2), 19-28

Suzuki, M., Fujimoto, W., Goto, M., Morimatsu, M., Syuto, B., & Iwanaga, T. (2002). Cellular expression of gut chitinase mRNA in the gastrointestinal tract of mice and chickens. Journal of Histochemistry & Cytochemistry, 50(8), 1081-1089.

Swaton, H.K., Tshovhote, J., Nesamvumi, E., Ranwedzi, N.N. & Fouric, C. (2003). Characterization of indigenous free ranging poultry production system under traditional management conditions in the Vhembe district of the Limpopo Province, South AfricaŚwiątkiewicz S., Świątkiewicz M., Arczewska - Włosek A., Józefiak D. (2015)

Swiatkiewicz, S, Swiatkiewicz, M, Arczewska-Wlosek, A, Jozefiak, D. (2015). Chitosan and its oligosaccharide derivatives (chito-oligosaccharides) as feed supplements in poultry and swine nutrition. *Journal of Animal Physiology and Animal Nutrition (Berl), 99*(1), 1-12. doi: 10.1111/jpn.12222.

Tay, L. K., Emikpe, B. O., Ockling S., Folitse, R. D. & Jarikre, T. A (2017). Point prevalence and pathology associated with gastrointestinal parasites in local chickens and Guinea fowls in Kumasi. Ghana. *Nigerian Journal of Parasitology, 38*(1), 93-99

Teye, G. A. & Adam, M. (2000) Constraints to Guinea fowl production in Northern Ghana: A case study of the Damongo Area. *Ghana Journal of Agricultural Science* 33,153– 157.

Tiroesele B. & Moreki J.C. (2012). Termites and Earthworms as potential alternative. *Tropical Animal Health and Production 35*, 563574

Van Huis, A. (2020). Insects as food and feed, a new emerging agricultural sector: a review. *Journal of Insects as Food and Feed*, *6*, 27–44.

Van, N. T., Cuong, N. V., Yen, N. T., Nhi, N. T., Kiet, B. T., Hoang, N. V., ... & Ribas, A. (2020). Characterizations of gastrointestinal helminths and their impact in commercial small-scale chicken flocks in the Mekong Delta of Vietnam. *Tropical animal health and production*, *52*(1), 53-62.

Veldkamp, T. & Bosch, G. (2015). Insects: a protein-rich feed ingredient in pig and poultry diets, *Animal Frontiers*, *5*(2), 45–50, https://doi.org/10.2527/af.2015-0019

Verbeke, W., Sans, P., & Van Loo, E. J. (2015). Challenges and prospects for consumer acceptance of cultured meat. Journal of Integrative Agriculture, 14(2), 285-294.

Vogt, H., & Stute, A. (1974). Digestibility of some carbohydrate fractions in hens and guinea fowls. *Archiv fur Geflügelkunde und Geikunde*, *38*, 117-118.

Vorsters A., Aminou T., Demey, F., 1994 - Récolte de termites pour l'aviculture à Songhai (Bénin). - Cahiers Agr. 3: 265-266.

Wang, Z., Wu, L., Chen, M., & Zhou, S. (2009). Facile synthesis of superparamagnetic fluorescent Fe3O4/ZnS hollow nanospheres. *Journal of the American Chemical Society*, *131*(32), 11276–11277. https://doi.org/10.1021/ja903246e

Zivar, B., Ladan, E. & Mohammad, A. K. T. (2015). The Effect of Earthworm (*Eiseniafetida*) And Termites Meal In Diet On Broilers Chicken Efficiency And Carcass Components. *Biological Forum – An International Journal*. *7*(1), 998-1005. https://doi.org/10.1186/2055-0391-56-20