AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTERPRENEURIAL DEVELOPMENT

ASANTE MAMPONG

EFFECT OF SHEA CATERPILLAR (*Cirina butyrospermi*) MEAL ON THE PRODUCTION AND REPRODUCTIVE PERFORMANCE OF PEARL GUINEA FOWL (*Numida meleagris*).

RUTH TAWIAH

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BY

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JULY, 2025

DECLARATION

STUDENT'S DECLARATION

I hereby declare that this thesis with the exception of quotations and references contained in published works which have been dully acknowledge; is the result of my own original work and that no part of it has been presented for another degree at this university or elsewhere.

Candidate's Name: Ruth Tawiah

Signature…………………………………..   Date: ……………………..

SUPERVISOR'S DECLARATION

We hereby declare that the preparation and presentation of the thesis were supervised and in accordance with the guidelines on supervision of thesis as laid down by the Akenten Appiah- Menka University of Skills Training and Entrepreneurial Development.

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May the Lord Almighty bless you all

DEDICATION

The thesis is dedicated to my parents Solomon Yaw Tawiah and Comfort Afia Nipaa of blessed memory. My husband and wonderful children Joesam, Ruth, Elinock and Eliben.

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DEFINITIONS OF ABBREVIATION

ABBREVIATION	DEFINITION
AH	Albumen height
CF	Crude fibre
CP	Crude protein
EE	Ether Extract
FCR	Feed conversion ratio
HB	Haemoglobin
HCT	Haematocrit
HDEP	Hen day egg production
MCH	Mean corpuscular haemoglobin
MCHC	Mean corpuscular haemoglobin concentration
MCV	Mean corpuscular volume
ME	Metabolisable energy
P	Probability
QAS	Quality assessment score
RBC	Red blood cell
SCM	Shea caterpillar meal
ST	Shell thickness
SW	Shell weight
WBC	White blood cell
YW	Yolk weight

ABSTRACT

A search for an alternative protein source as a replacement for fish meal continues to be vital for promotion of poultry production. This study was conducted to determine the impact of dietary shea caterpillar meal (SCM) as replacement for fish meal on production and reproductive performance of Guinea fowl. A total of 75 Guinea fowl of age 25 weeks old and comprising 60 Guinea hens and 15 Guinea cocks were used for the study. There were 5 treatments with 3 replicates each in a completely randomized design. Each replicate had 4 Guinea hens and 1 Guinea cock. Performance indicators measured included feed and water intake, hen-day egg production (HDEP), follicular development, fertility, hatchability, keet morphometric traits and haematology. Data collected were subjected to analysis of variance using the Genstat version 12. Results obtained showed that feed and water intake decreased as the dietary SCM was increased. HDEP was relatively better for the control and least production was observed with SCM 100% diet. Follicular development for SCM diets (75%-100% rate) was late maturing relative to the control and SCM 25% and 50%. Whereas fertility was significantly influenced by the dietary treatments, hatchability values recorded were comparable among dietary treatments. Morphometric traits on the keets were impacted by the dietary treatments. Haematological characteristics were not influenced by dietary treatments. It was concluded that higher levels of the SCM (>50%) may be counterproductive to the reproductive indicators measured. A higher nutrient content of SCM and observed reduced performance at higher level of SCM suggest a deficiency in nutrient content or an impaired digestibility of the SCM. It is recommended that the SCM is incorporated in the diets of Guinea fowl at a level not exceeding 50% replacement of the fish meal in order not to compromise production and reproduction performance. Further studies involving digestibility trial is suggested to elucidate nutritional challenges of SCM.

CHAPTER ONE: INTRODUCTION

1.1 Background to the Study

The poultry industry is considered an important contributor to agriculture, accounting for 34.5% of the total gross domestic product (GDP) of Ghana (Kusi et al., 2015). According to the Ministry of Food and Agriculture (MoFA, 2016), the industry offers prospects for wealth creation, income enhancement, financial security and improvement in rural livelihoods. The poultry sector is increasingly gaining high recognition as the demand for poultry products as a source of protein is on the ascendency. According to Abu et al. (2015), poultry meat and eggs account for about 10% of the total amount of meat and eggs produced in the world annually.

In developing countries such as Ghana, poultry rearing has been a practice for both rural and urban dwellers as a result of population growth, increased urbanization and rising income demands. Poultry birds commonly raised in Ghana are chicken (layers, broilers and cocks), Guinea fowl, turkeys and quails. The Guinea fowl (*Numida meleagris*) is a bird native to the African continent (Moreki and Radikara, 2013). It derives its name from the Coast of Guinea where it is believed to have originated (Bashir et al., 2015). The indigenous Guinea fowl is widely distributed in Africa where it has distinct popularity among smallholder farmers (Moreki and Radikara, 2013). It is believed that Guinea fowl were taken to Europe and America by the Portuguese. In these regions, the Guinea fowl have been systematically improved resulting in more rapid growth rate, better body size and enhanced egg laying ability (Brown et al., 2016). Guinea fowl production is beginning to become popular all over the world. It is one of the most common poultry species found in northern Ghana. It has different strains, which include Pearl, White and the Lavendar Guinea fowl (Naandam and Issah, 2012). According to

Musiba et al. (2014), the birds are usually kept in households in small numbers as a source of protein for the family.

Protein sources for intensive Guinea fowl, such as fish meal and soybean meal, are essential components of their diet to ensure optimal growth and health. Fish meal is a highly digestible and rich source of animal protein, supplying essential amino acids that promote muscle development and overall protein balance in Guinea fowl (Onyenweaku et al., 2020). Soybean meal, on the other hand, is a valuable plant-based protein source, providing a well-balanced amino acid profile and serving as a cost-effective alternative to animal-based proteins (Akhtar et al., 2022).

A search for a suitable alternative, non-conventional feedstuff especially protein sources is necessary and timely for saving the poultry industry from collapse. One possible alternative source of animal protein feed is the use of insects like the shea caterpillar (*Cirina butyrospermi*). The shea caterpillar is an edible insect from the family Saturniidae (Anankware, 2017). The shea caterpillars or silk moths arise seasonally on shea-nut trees (*Butyrospermum parkii* or *Vitellaria paradoxa*) around June each year (Bama et al., 2018) and feed exclusively on the leaves of the host tree. Shea caterpillars serve as a source of food, employment, income, and used as feed ingredient in the diet of animals (Payne et al., 2020). In addition, these insects are less expensive compared with other animal protein sources and provide a rich source of protein, iron, and amino acids (Payne et al., 2020). Amino acids are major constituents of structural and protective tissues, like skin, feathers, ligaments, soft tissues, organs, and muscles (Ren et al., 2013). Also, amino acids and small peptides may serve a variety of metabolic functions and as precursors of many important non-protein body constituents (Jahan et al., 2011). The iron in shea caterpillar can support the formation of red blood cells which enables the birds to perform different metabolic activities (Yabuda et al., 2019).

1.2 Problem Statement

Poultry production is constrained by the high cost of feed, the incidence of diseases, scarcity of day-old chicks, and the importation of frozen chicken (Aboah and Enahoro, 2022). Among the constraints provided, high cost of feed poses much frustration to many poultry farmers, which subsequently deters the farmers from venturing into large-scale production (Donkor et al., 2021). To ensure a sustainable supply of poultry feed, efforts have been directed toward lowering feeding costs by using alternative ingredients that are rich in both energy and protein but more affordable. The price of conventional protein feeds resources such as groundnut cake, fish meal and soybean meal, is on the higher side and cannot permit profit maximization in poultry ventures (Ayo et al., 2021).

Fish meal is widely acknowledged as the primary conventional animal-based protein source for poultry. However, it is becoming increasingly scarce and expensive, and more importantly, concerns about its quality have been growing in recent times (Ayo et al., 2021). As a result, poultry feed is adjudged as one of the greatest problems affecting the productivity and profitability of poultry production (Esiobu et al., 2014). The cost of feed constitutes the major proportion of between 60 -75% of the total cost of poultry production and protein cost account for over 15% of the total feed cost in poultry farming (Olawumi et al., 2012; Amao et al., 2015). Alternative protein sources have been studied intensively during the last few decades because of the declining availability and the increasing cost of fish meal (Olsen and Hasan, 2012). One potential source of nutrients and a good candidate for replacing fish meal in poultry diets is insect meal (Ankamah-

Yeboah et al., 2018). Lately, insects have received wide attention as a potential alternative source of protein (Makkar et al., 2014), due to their nutritional content which is comparable to fish. The crude protein content of insects ranges from 40 to 75% on dry weight basis, with beneficial amino acids profile and variable fat content (Anankware et al., 2021).

Anvo et al. (2016) reported that shea caterpillars are rich in protein, fat, and minerals, making them a valuable addition to animal feed for addressing nutritional deficiencies in poultry. Although shea caterpillars have shown promise as a nutritious protein source for both human consumption (Payne et al., 2020) and livestock feed, there is still limited research on the use of shea caterpillar meal (SCM) as an animal protein ingredient specifically for Guinea fowl that are predominantly located in the northern regions where the shea caterpillar is mainly harvested in Ghana. Given their nutritional value and affordability, shea caterpillars represent a viable alternative protein source in poultry diets, with the potential to reduce production costs and enhance profitability. Therefore, it is important to investigate the impact of SCM on the reproductive performance of Pearl Guinea fowl.

1.3 Objectives of the Study

1.3.1 Main objective

The main objective of this study was to determine the effect of shea caterpillar (*Cirina butyrospermi*) meal on the production and reproductive performance of the Pearl Guinea fowl (*Numida meleagris*).

1.3.2 Specific objectives

The specific objectives of this study were to determine the effect of shea caterpillar meal on:

- feed and water intake,
- folliculogenesis,
- egg production and egg characteristic (external and internal) of Pearl Guinea hen,
- fertility and hatchability of eggs of Pearl Guinea hen,
- morphometric characteristics and quality assessment of Guinea fowl keets,
- haematological indices of laying Pearl Guinea fowl hen.

1.4 Significance of the Study

The study on the effect of shea caterpillar (*Cirina butyrospermi*) meal on the reproductive performance of the Pearl Guinea fowl (*Numida meleagris*) is worth conducting because, understanding the nutrient profile of this alternative feed ingredient is crucial for formulating balanced diets for pearl Guinea fowl. It will help determine the suitability of shea caterpillar meal as a protein source and assess its potential as a cost-effective alternative to conventional feed ingredients.

This study will shed light on whether incorporating shea caterpillar meal in the diet positively influences egg production, fertility, hatchability, and overall reproductive success in pearl Guinea fowl. Investigating and subsequently obtaining alternative feed ingredients like shea caterpillar meal will contribute to sustainable poultry production. Utilizing non-conventional feed sources helps reduce dependence on traditional feed ingredients, such as soybean meal or fish meal, which often have associated environmental and ethical concerns. The study on shea caterpillar meal and its impact on reproductive performance in Pearl Guinea fowl if successful, will contribute to the existing body of knowledge in the field of poultry nutrition and management.

CHAPTER TWO: LITERATURE REVIEW

2.1 Poultry Production in Ghana

Poultry encompasses a collection of domesticated species, comprising turkeys, chicks, Guinea fowl, ducks, and game fowls such as pheasant, quails and ostriches (Ravindran, 2013). Fowls' meat and eggs offer not only superior protein but also significant vitamins and minerals. Poultry meat is solid healthy meat and is the cheapest of all livestock meats. Furthermore, there are certainly not many taboos on the consumption of poultry eggs and meat as human food in Ghana. In addition, poultry provides a meal for a normal household without the need for a freezer to store left-overs unlike meat from other livestock such as pigs and ruminants (Ravindran, 2013).

In addition, poultry especially broilers are unique, efficient and economic converters of vegetable food into animal protein and delivers a rapid income to farmers (Cartoni et al., 2018). According to Selaledi et al. (2020) poultry is kept to provide the required protein content as a substitute for red meat. Besides, poultry does not destroy agricultural lands through overgrazing as in the case of ruminants like cattle. Furthermore, poultry does not also destroy established farms like maize, rice, and yam farms. According to Cartoni et al. (2018), traditional poultry is raised for domestic usage and as a source of revenue generated through the sale of eggs and live birds. Cartoni et al. (2018), added that, these local birds are used to meet social commitments, perform rituals, and are used at festivities. Again, poultry keeping is not strenuous and many people including women, retired workers, differently-abled, or physically challenged individuals can conveniently take care of fowls.

2.2 Guinea Fowl Production

Guinea fowl are poultry birds reared by poultry farmers worldwide with the bird originating from Africa (Obese et al., 2018). Even though the birds originated from Africa, they can still be found in many other countries such as France, Belgium and China because of their traits and growing popularity among the people. The production of the bird by many poultry farmers in Africa is making Guinea fowl farming business successful, mainly for eggs, meat and profit (Kyere, 2017). The bird is also sometimes referred to as Guineas or gleanies. Many years ago, the birds were actually wild birds and the modern birds are the domesticated form of the helmeted Guinea fowl. Guinea fowl are related to other game birds such as the turkeys, partridges, pheasants and domestic chicken (Konlan and Avornyo, 2013).

The Guinea fowl is very aggressive, hardy, vigorous and largely disease-free bird. All over the world, the production of Guinea fowl is increasingly popular among the keepers of small, backyard and commercial poultry farmers. Among all the poultry birds, some people prefer Guinea fowl farming for obvious reasons. Some of the notable reasons for keeping Guinea fowl include the birds' ability to sound an alarm whenever anything unusual occurs on the farm, and the loud sound has also been shown to discourage rodents from invading the area (Konlan and Avormyo, 2013). Some people find this to be a nuisance, but others find it to be an effective tool for protecting the farm. Guinea fowl are also an effective means of pest control (Agbolosu et al., 2012). The flocks of Guinea fowl generally will kill and eat mice and small rats. The birds can also be used for controlling insects, without causing harm to vegetables or flowers. They are used for controlling wood ticks and insects such as crickets, grasshoppers and flies (Kyere, 2017).

2.3 Overview of Guinea fowl

Guinea fowls (*Numida meleagris*) are avian species that exhibit unique characteristics in terms of their biology, growth, and reproductive physiology.

2.3.1 Biology

Guinea fowl are medium-sized birds, typically measuring around 40-71 cm in length and weighing between 0.9-2.7 kg (Shoyombo et al., 2021). They have a compact body with a small head, short neck, and a rounded shape. Guinea fowl are known for their striking feather patterns. The plumage varies among different varieties and can include speckles, spots, and stripes in shades of black, gray, and white (Saran et al., 2019). Guinea fowl are highly social birds that typically form small flocks. They are terrestrial and spend most of their time foraging on the ground, where they exhibit strong scratching and pecking behaviours to search for food. According to Gosomji et al. (2015), Guinea fowl have an average lifespan of 10-12 years, although some individuals can live longer under favourable conditions.

2.3.2 Growth

Guinea fowl have a relatively fast growth rate compared to other avian species. They exhibit rapid growth during their early weeks and continue to grow until reaching maturity, which is typically around 24-28 weeks of age (Freeman et al., 2014). The body weight of adult Guinea fowl can vary depending on the variety and gender, but they generally range between 2- 4 kg for males and slightly less for females (Bhogoju et al., 2018). As Guinea fowl grow, their skeletal system undergoes development and maturation, enabling them to support their body weight and engage in various locomotor activities (Freeman et al., 2014).

2.3.3 Sexual maturity

Sexual maturity in Guinea fowl refers to the stage at which they become capable of reproducing. It's worth noting that the age at which Guinea fowl reach sexual maturity can also be influenced by the specific variety or breed of Guinea fowl. The timing of sexual maturity can vary depending on factors such as genetics, nutrition, environmental conditions, and the innate characteristics of the birds (Oke et al., 2015). In general, male Guinea fowl tend to reach sexual maturity earlier than females. Male Guinea fowl may reach sexual maturity between 6 and 9 months of age, although some individuals may mature slightly earlier or later (Adjetey, 2011). It's important to note that male Guinea fowl can exhibit signs of sexual maturity before they are physically capable of successfully mating with females. Female Guinea fowl typically reach sexual maturity slightly later than males, usually between 7 and 9 months of age, at which point they are capable of ovulating and laying eggs (Adjetey, 2011).

Furthermore, it is important to consider that while female Guinea fowl may be sexually mature, optimal fertility and successful reproduction may require additional factors such as appropriate nutrition, proper lighting conditions, and suitable mating opportunities (Oke et al., 2015). Proper identification of sexual maturity is important for effective breeding and reproduction management in Guinea fowl (Abdul-Rahman et al., 2016). It allows for appropriate pairing of sexually mature males and females and enables the timely initiation of breeding programmes to ensure optimal fertility and successful reproduction.

2.3.4 Seasonal breeding

According to Abdul-Rahman et al. (2016), Guinea fowl are considered seasonal breeders, meaning their reproductive activity is influenced by the changing seasons and day length. Seasonal breeding in Guinea fowl is primarily driven by photoperiodic cues, specifically the length of daylight hours (Atawalna et al., 2020). In their natural habitat, Guinea fowl typically exhibit peak breeding activity during the spring and summer months. As the days get longer and the amount of daylight increases, it triggers hormonal changes in the birds, stimulating their reproductive system and initiating breeding behaviour (Mohan et al., 2016). The specific timing of seasonal breeding can vary depending on the geographical location and climate. Generally, Guinea fowl start showing signs of increased reproductive activity as the days lengthen and reach their peak breeding activity during the longer daylight periods (Dharani et al., 2016).

During the breeding season, male Guinea fowl engage in courtship displays to attract female mates. These displays often involve puffing up their feathers, strutting, vocalizations, and various behavioural rituals. Females, on the other hand, become receptive to mating and may display submissive behaviour, such as crouching or allowing the male to mount (Dharani et al., 2016). It is important to note that the reproductive activity and breeding behaviour of Guinea fowl can be influenced by various factors beyond daylight length. Other factors such as temperature, availability of food resources, and social dynamics within the flock can also impact breeding behaviour and reproductive success (Hoffmann, 2010). For commercial production or breeding programmes, managing the photoperiod and providing appropriate lighting conditions can help simulate the natural breeding season and stimulate reproductive activity in Guinea fowl (Hoffmann, 2010). By manipulating the duration and intensity of light, it is possible to promote breeding behaviour and optimise fertility in these birds. Understanding the seasonal breeding patterns of Guinea fowl is important for successful reproduction management. It allows breeders and farmers to plan their breeding programmes, ensure the availability of suitable mates, and optimise breeding conditions to enhance fertility, hatchability, and overall reproductive success in Guinea fowl

2.3.5 Nesting and incubation

Nesting and incubation are crucial stages in the reproductive process of Guinea fowl. Female Guinea fowl are responsible for nest construction and they typically choose a secluded location on the ground, such as tall grass, shrubs, or under a protective structure, to build their nests (Paliy et al., 2018). The nests are often shallow depressions lined with leaves, grass, feathers, or other available materials. Guinea fowl typically lay eggs in clutches and the clutch size can vary but usually ranges from 8 to 20 eggs, depending on the individual and breed (Harris et al., 2014). Guinea fowl are capable of laying eggs throughout the breeding season. After mating, females typically lay one egg every one or two days until the clutch is complete. Once the clutch is complete, the female Guinea fowl initiates incubation (Harris et al., 2014).

During incubation, the hen becomes more protective of the nest and exhibits behaviours such as vocalizations and aggression towards potential threats. The incubation period for Guinea fowl eggs is approximately 26 to 28 days (Dulac and Kimchi, 2017). During this period, the female remains on the nest to provide the necessary warmth for the eggs to develop and hatch. The female Guinea fowl is primarily responsible for incubation, although in some cases, males may also assist in incubation duties (Sellier, 2016). The incubating bird will carefully position the eggs, rotating them periodically to ensure even heat distribution and proper development. As part of the incubation process, the female Guinea fowl will turn the eggs several times a day (Harris et al., 2014). This helps prevent the embryo from sticking to the shell and promotes proper development. During incubation, the incubating bird spends a significant amount of time on the nest, rarely leaving except for brief periods to feed, drink, or relieve itself. The female may rely on the male or other flock members to provide food and protect the nest during these short breaks (Dulac and Kimchi, 2017).

2.3.6 Fertility and hatchability

Fertility and hatchability are critical factors to consider in the reproductive success of Guinea fowl. Fertilization occurs when a mature male Guinea fowl mates with a receptive female, and the male's sperm fertilizes the female's eggs (Assersohn et al., 2021). Guinea fowl typically engage in mating behaviours during the breeding season, and successful mating results in fertilized eggs. The fertility rate represents the percentage of fertile eggs out of the total eggs laid by the female. Various factors can affect fertility rates, including the genetic quality of the birds, breeding management practices, nutritional status, and overall health of the flock (Schradin et al., 2014). Adequate nutrition, proper lighting conditions, and the presence of suitable mates play significant roles in achieving optimal fertility rates in Guinea fowl. Providing a balanced diet rich in essential nutrients, maintaining optimal body condition, and ensuring a favorable reproductive environment can enhance fertility (Neumann and Schneider, 2015). After a clutch of eggs is laid, the female Guinea fowl begins incubating them to provide the necessary heat for embryonic development. Hatchability refers to the percentage of eggs that successfully hatch out of the total number of fertile eggs incubated (Schradin et al., 2014). It is influenced by some other factors such as incubation conditions including temperature and humidity levels, egg turning, and the overall health and viability of the embryos. Maintaining proper incubation conditions as mentioned earlier including (temperature and humidity control, regular egg turning, and adequate ventilation), is crucial for maximizing hatchability (Neumann and Schneider, 2015). High-quality incubation equipment and regular monitoring of environmental parameters contribute to successful commercial egg hatching. Additionally, the quality and viability of the fertile eggs themselves, which can be influenced by factors such as egg storage conditions and handling, impact hatchability.

2.3.7 Parental care

Guinea fowl exhibit limited parental care, with females being responsible for incubation and early rearing of the chicks (Vleck, 2011). Once hatched, the chicks are precocial, capable of walking and feeding independently shortly after emergence. The chicks have a strong instinct for self-sufficiency and can navigate their environment quickly (Agboola et al., 2013). Guinea fowl exhibit shared incubation, where both the male and female may take turns incubating the eggs. The incubating bird(s) remain on the nest, providing warmth and turning the eggs to ensure proper development (Ospina et al., 2018). After hatching, the female Guinea fowl assumes the primary responsibility of brooding the chicks. She provides warmth, protection, and guidance to the young ones during their early stages. The brooding period can last for a few weeks, during which the mother keeps the chicks close to her, teaching them feeding behaviours and providing a secure environment (Archer and Mench, 2014). Parental Guinea fowls play a crucial role in teaching the chicks to find and consume appropriate food items. They guide the young birds in foraging behaviours, demonstrating what to eat and where to find food (Agboola et al., 2013). The adults protect the chicks from potential predators and help them learn essential survival skills. Parental Guinea fowl use vocalizations or calls to communicate with their offspring (Cooper et al., 2011). They may give warning calls to alert the chicks about potential dangers or signal them to gather or follow. Through vocal cues, they establish a bond and provide guidance to the young birds. Adult Guinea fowl offer series of protection to their young and actively defend them against potential threats (Archer and Mench, 2014). They may use aggressive displays, vocalizations, or physical intervention to deter predators or intruders to keep their offspring safe.

2.4 Challenges to Guinea Fowl Production

Despite the abundant number of Guinea fowl in Ghana and their numerous benefits, the production of Guinea fowl is still at a rudimentary level. The production of Guinea fowl, unlike the domestic chicken is plagued by numerous challenges. Moreki and Radikara (2013) noted that, poor housing poses a serious challenge to Guinea fowl rearing. Due to poor housing, predation rates are high. Moreki and Radikara (2013) further observed low egg productivity due to frequent change of laying spot in the bush which leads to egg being preyed upon. Presently in Ghana, there is no commercially compounded feed for Guinea fowl. Birds are allowed to scavenge for most of their feed around the village compounds (Lawal et al., 2014). Mwale et al. (2013), opined that, the lack of information about feed requirements contributed to high early keet mortality. Also, a large percentage of farmers are compelled to keep the birds on free range because they do not know their nutrient requirements. And even if known, the financial background of most farmers in Ghana makes it a challenge to purchase such feed to be given to the birds. This has, to a large extent, affected the pre-pubertal growth rate as well as reproductive performance of Guinea fowl in Ghana and Africa at large.

Though resistant to most poultry diseases, the Guinea fowl suffer from some diseases of poultry. Avornyo et al. (2016), reported that Guinea fowl are highly intolerant of internal and external parasites as a result of their scavenging behaviour under the free-range system of management. Boko et al. (2013), identified the diseases of Guinea fowl to include collibacilosis, salmonellosis and Newcastle disease. Ebegbulem and Asuquo (2018), reported that in Ghana, Guinea fowl though resistant to common avian diseases suffered from yolk sac infection, leg paralysis and worm infestation. Ebegbulem and Asuquo (2018), identified leg paralysis as a major cause of mortality and stunted growth, and attributed it to inadequate nutrition and absence of marek's disease vaccination. Ebegbulem and Asuquo (2018) noted that, leg paralysis between the ages of 2-5 weeks and the resultant inability of the affected birds to feed, led to loss of considerable number of keets. Moreki and Radikara (2013) observed that rural farmers often used ethno-veterinary medicine as a substitute for conventional veterinary support.

According to Boko et al. (2013), thermoregulation system in young Guinea fowl is not very efficient during the first month of life; as a result, young keets are very sensitive to the differences between day and night temperatures during the rainy season. Yakubu et al. (2014) asserted that, Guinea fowl although hardy and resistant, are susceptible to viral diseases such as Newcastle, bacterial infections (*E. coli*), protozoan diseases (Coccidiosis) and verminous infestations (round worms). Yakubu et al. (2014) noted that Newcastle disease infestation is usually observed in a large flock of birds kept in confinement. Administration of Newcastle disease vaccine to keets one week after hatching and repeating it at 8-10 weeks of age, may help in controlling the infection. Dahouda et al. (2015), also observed that Guinea fowl productivity is low because of high keet mortality. The mortality was attributed to the exposure of the keets to bad weather such as rain, cold or heavy dew and probably also due to parasites. Difficulty in sexing of Guinea fowl has been identified as one of the challenges to its production. According to Eltayeb et al. (2015), sex determination in Guinea fowl is extremely difficult especially in keets as males and females appear very similar to each other, thus making it difficult to distinguish them. The inability of the farmers to separate the sexes makes it difficult to raise a breeder or layers stock. Sex may be distinguished by the voice cry of the birds from about 8 weeks of age (Abdul-Rahman et al., 2016). The female makes sounds like “buck-wheat, buck-wheat” or “put-rock, put-rock” which is quite different from the “wheat” sound of the males. The wattles of the males have thicker edges at about 12-15 weeks of age (Abdul-Rahman et al., 2016).

2.5 Prospects of Guinea Fowl Production

The Guinea fowl, though originated from tropical West Africa, is adaptable to various climatic conditions, therefore it is reared even in temperate countries. Guinea fowl consume a large range of non-conventional feed not used in feeding chicken. It is also an ideal bird in an integrated crop-livestock farming system. The Guinea fowl egg and meat are good sources of protein and income (Moreki and Radikara, 2013). Konlan et al. (2011) reported that, in Ghana, Guinea fowl eggs and meat command premium prices because of their gamey flavour. Their eggs have better storage qualities than chicken eggs, as a result of their thicker shells therefore they do not crack easily. The Guinea fowl meat is reported by Moreki and Seabo (2012), to be high in protein and low in fat content, making it more desirable than chicken meat. Moreki and Seabo (2012), further asserted that Guinea fowl meat has a protein content of about 28 % as against 20 % in the domestic chicken. Rafiu et al. (2021) opined that meat of the Guinea fowl is tastier and firmer than that of the chicken and further added that, the yield of edible meat is also higher than that of the domestic chicken as a result of its slender skeleton. Guinea fowl play important socio-cultural roles in the lives of many tribes. They are used for religious sacrifices and to perform some funeral rites (Issaka and Yeboah, 2016). Their colourful feathers are used by local craftsmen for artworks and making of decorative articles. Guinea fowl, as reported by Moreki and Radikara, (2013) are tolerant to most poultry diseases. Lawal et al. (2014) also reported that Guinea fowl are resistant to most poultry diseases such as gumboro, Newcastle and salmonellosis.

2.6 Insects

The word insect was derived from insectum, which means "divided body" (Badkillaya et al., 2021). Insects are creatures within the arthropod with an external exoskeleton, jointed appendages, three paired legs, compound eyes, and two antennae (Badkillaya et al., 2021). Insects, comprised a diverse and ecological group within the animal kingdom that play a fundamental role in the functioning of terrestrial ecosystems. Their multifaceted significance encompasses aspects ranging from pollination and decomposition to serving as a vital food source for various organisms (Kohl, 2016). Furthermore, insects are of paramount importance in agriculture, where they can either be pests, causing substantial economic losses or beneficial allies in pest management strategies. Their susceptibility to environmental changes, such as climate fluctuations and habitat loss, underscores the urgency of comprehending their biology, behaviour, and ecological interactions to ensure the long-term stability of ecosystems and human well-being (Pacifici et al., 2015).

2.6.1 Economic importance of insects

Globally, the highest most consumed insects in descending order are beetles (31 %), caterpillars (18%), wasps, ants and bees (14 %), grasshoppers, locusts and crickets (13 %), plant hoppers, scale insects, and true bugs (10 %), termites (3 %), dragonflies (3 %), and flies (2 %) (Badkillaya et al., 2021). In Ghana, there are nine edible insects found to be consumed by at least 30 % of Ghanaians (Anankware et al., 2021). The termite (94.7 %) is the most accessible insect while the shea tree caterpillar is the least available with 37 % (Anankware et al., 2021). Edible insects can be used as a sustainable source of income and food to fight food shortages in the future and during periods of drought (Payne et al., 2020). Edible insects are used in traditional diets, as well as a source of protein in other Africa dishes (Hlongwane et al., 2020). In addition, insects serve as pollinators in plant reproduction. Insect rearing does not need too much land to commence production (Badkillaya et al., 2021). The economic importance of edible insects is gaining recognition as a sustainable and lucrative industry. Edible insects offer a cost-effective source of protein, essential nutrients, and healthy fats, making them a potential solution to global food security challenges. Their efficient conversion of feed into edible biomass, low greenhouse gas emissions, and reduced land and water requirements compared to traditional livestock make them environmentally friendly (Hlongwane et al., 2020). Additionally, the cultivation and processing of edible insects create employment opportunities in both rural and urban areas, fostering economic development.

2.7 Overview of Shea Caterpillar (*Cirina butyrospermi*)

Shea Caterpillar (*Cirina butyrospermi*) is an insect species belonging to the order Lepidoptera and the family Saturniidae (Khan, 2018). It is commonly found in sub-Saharan Africa, particularly in countries like Nigeria, Ghana, and Cameroon. According to Bougma et al. (2021), the shea caterpillar undergoes complete metamorphosis, progressing through four distinct stages: egg, larva (caterpillar), pupa, and adult. The adult shea caterpillar moth has a large wingspan of approximately 10-15 centimeters. The wings are usually brown or gray with intricate patterns, and the body is covered with dense hairs (Bougma et al., 2021). The larval stage, which is of primary interest in this thesis, is characterized by a cylindrical body with a smooth surface. The colouration of the larva varies, ranging from shades of green to brown or gray, with distinct markings. Shea caterpillars are commonly found in wooded areas and forests, where their primary food source, the shea tree (*Vitellaria paradoxa*), is abundant (Garba et al., 2020). The larvae of shea caterpillars feed voraciously on the leaves of shea trees, which are rich in nutrients and provide essential sustenance for their growth and development. Shea caterpillars are valued not only for their ecological role as decomposers but also for their nutritional composition. They are known to possess high protein content, essential fatty acids, vitamins, and minerals (Garba et al., 2020). In certain African communities, shea caterpillars have been traditionally consumed as a protein-rich food source (Mutungi et al., 2019). They are harvested during specific periods of the year when they are abundant. Local communities have developed various culinary methods to prepare and preserve shea caterpillars, including boiling, drying, smoking, and frying. The high protein content and nutritional profile of shea caterpillars make them a potential alternative feed ingredient for poultry and other farm animals (Dobermann et al., 2017). They offer a sustainable and cost-effective source of nutrients, particularly for indigenous poultry species like the Pearl Guinea fowl (*Numida meleagris*). A study by Dobermann et al. (2017) indicated that, incorporating shea caterpillar meal into poultry diets may have positive effects on growth, reproductive performance, and overall health.

2.7.1 Biology and life cycle of shea caterpillar

The shea caterpillar or 'Night' butterfly caterpillar (*Cirina butyrospermii*) is an important edible insect from the family Saturniidae and order Lepidoptera (Anankware et al., 2021).

The shea caterpillar is locally called Kantuli in Frafra (Anankware et al., 2021), 'chitoumou in Southwestern Burkina Faso (Payne, 2020), 'Taatul in Sissali, and Tantuni'or Ware Tantuni' in Dagaare/Wale. Shea caterpillars or silk moths occur seasonally due to their univoltine life cycle (Bama et al., 2018). The moth emerges from its pupal stage every year in June, after the maiden rainfall. Its life cycle encompasses distinct developmental stages, from the egg to the larval, pupal, and adult phases. The larval morphology is characterized by a cylindrical body covered in fine hairs, facilitating camouflage among shea leaves, while pupation occurs within a cocoon, leading to the transformation into an adult moth with distinctive wing patterns. The Silk moth or 'Night' butterfly lives for about three days during which it mates and lays eggs at night on the leaves of nearby shea-nut trees. The eggs hatch after an average period of 30 days (Rémy et al., 2017). After hatching, the larva prey exclusively on the leaves of the shea plants. The pupae burrow into the earth, preferably permeable soil, beneath the shea trees, and pupate and emerge the next season as adult night butterflies, and the cycle is continuous (Rémy et al., 2017). Moreover, shea caterpillars exhibit herbivorous feeding behaviour primarily on shea tree leaves and employ defensive mechanisms, such as regurgitating noxious fluids, when threatened. Reproductively, they engage in nocturnal mating behaviours, with females emitting pheromones to attract males and subsequently laying eggs on shea tree branches.

2.7.2 Nutritional composition of shea caterpillar

Shea caterpillars are a rich source of protein, (amino acids), fats, and both macro and micro minerals in human diets which can minimise protein deficiency in children (Anvo et al., 2016; Payne et al., 2020). According to Ahmad et al. (2018), proteins form muscles and tissues of the body, therefore, it is essential for the growth and development of the animal body. Proteins help in maintaining the loss of body tissues and muscles (Deutz et al., 2014). Furthermore, proteins help in the repair of body cells as well as in the production of new cells. Proteins also supply energy to the body and are essential for the formation of eggs and feathers of birds. The minerals in caterpillars generally serve as constituents of skeletal structure, help in regulating acid-base equilibrium, and act as components or activators of enzymes and other biological systems (Ahmad et al., 2018). Moreover, shea caterpillar (*Cirina butyrospermi*) boasts of a remarkable nutritional profile, making it a valuable food resource and potential feed ingredient. It is notably rich in protein, typically containing over 50 % protein content, which renders it a high-quality protein source, particularly in regions where protein deficiency is a concern (Ahmad et al., 2018). Additionally, Shea caterpillars are abundant in healthy fats, with substantial levels of unsaturated fatty acids, including oleic and linoleic acids, contributing to their dietary value (Deutz et al., 2014). These caterpillars also provide essential vitamins and minerals, such as vitamins A and B-complex, iron, and calcium. Furthermore, their consumption can contribute to a well-rounded diet, offering diverse nutrients that can aid in addressing malnutrition and supporting both human nutrition and livestock production.

2.7.3 Amino acid content of shea caterpillar

The amino acid content of shea caterpillar (*Cirina butyrospermi*) is a key aspect of its nutritional value, especially in regions where it is consumed as a protein source. These caterpillars are notable for their well-balanced amino acid profile, containing all essential amino acids in sufficient quantities (Anvo et al., 2016). Essential amino acids are those that the human body cannot synthesise on its own and must be obtained through dietary sources. Shea caterpillars are particularly rich in lysine and methionine, two essential amino acids that are often limited in plant-based diets (Kusia et al., 2021). Lysine is crucial for tissue growth and repair, while methionine plays a vital role in various metabolic processes. The presence of these essential amino acids makes shea caterpillars a valuable dietary component, especially in areas where access to animal protein is limited. The composition of the amino acid is required to assess the quality and how effectively that feed can meet the essential amino acid requirements of farm animals (Kusia et al., 2021), especially poultry. This is because, chicks require, all ten essential amino acids plus glycine for proper growth (Kusia et al., 2021). Shea caterpillars are very important in meeting the protein (amino acid) needs of humans and these insects contain both indispensable and dispensable amino acids (Dobermann et al., 2017). Amino acids acquired from dietary protein are used by poultry to carry out a diversity of functions. Amino acids are major constituents of structural and defensive tissues, like skin, feathers, bone matrix, ligaments, soft tissues, organs, and muscles. Moreover, amino acids and small peptides may serve a variety of metabolic functions and as precursors of many important non-protein body constituents (Rezaei et al., 2013). Additionally, the amino acid content of shea caterpillars makes them a complementary protein source when combined with other staple foods, such as cereals or legumes.

2.7.4 Sources of feed ingredients for poultry in Ghana

Poultry feed refers to a compounded combination of diverse edible ingredients which provide nourishment to birds (Lamsal et al., 2017). The conventional feed ingredients normally used in feeding fowls include maize, wheat, cassava, sorghum, cottonseed cake, copra cake, palm kernel cake, fish meal, meat meal, blood meal, soybean, groundnut cake, wheat bran, rice bran, and maize bran, premix, oyster shell, bone meal, and dicalcium phosphates (Lamsal et al., 2017). The modern intensive system of keeping poultry introduces the technique of compounding more nutritious feed for birds to meet their daily nutrient requirement. The ingredients used to formulate these compounded feeds perform various functions which include: protein in feed as source of energy to the body. Also, protein is essential for the formation of the egg, wool, and hairs of farm animals. Protein delivers the basic cellular matrix within which the bone mineral matter is deposited (Rezaei et al., 2013). The carbohydrates are a major source of energy and form the bulk of about 70% to 75% of poultry feed (Lamsal et al., 2017). Carbohydrates also are vital components of production, temperature control, and proper functioning of the different parts of the animal body (Rezaei et al., 2013). Fats help in the absorption of calcium and phosphorus. Fats in diet delays the sensation of hunger, as it needs a longer period to pass through the digestive tract than carbohydrate and protein. Besides, certain fat-soluble vitamins like vitamins, A, D, E, and K are absorbed in the blood in the presence of fat (Lamsal et al., 2017). Vitamins are essential for good health and play important role in the growth of the animal body. Additionally, vitamins provide resistance against diseases and increase the productivity potential of poultry. Furthermore, vitamins are essential constituents of certain enzyme systems, standardize body metabolism, and coagulation of blood (Rezaei et al., 2013). The minerals serve as components of the skeletal structure. Minerals help in regulating acid-base equilibrium and also act as a component or an activator of enzymes in biological organisms (Lamsal et al., 2017). These ingredients are obtained from different sources. The protein in feed comes from two main sources namely; plant and animal sources. The plant sources include soybean meal, cottonseed cake, copra cake and palm kernel cake while the animal sources are derived from fish meal and meals of certain insects.

2.7.5 Gathering, processing, and ingestion of shea caterpillar

The harvesting of shea caterpillars happens early in the morning just like how shea-nut fruits are collected in many communities. According to Payne et al. (2020) caterpillar collection commences early in the morning before sunrise by men, women, and children between July and August every year, shea caterpillars are manually picked in the night with flash light and a bucket from one shea tree to the other across all areas regardless of land ownership. (Payne et al., 2020). The harvested caterpillars are washed properly and then cooked in pots over a fire with some ash and salt to help preserve them. Shea caterpillars that are to be sun-dried for sale are spread out on a tarpaulin sheet for some days until the caterpillars are considered dried enough and ready for market. In Burkina Faso, the dried caterpillars are conveyed to market for sale using a large empty can (bowl) which also doubles as a measuring vessel (Payne et al., 2020). In Northern Ghana, the fresh caterpillars are processed in the same manner as in Burkina Faso and sold either in bulk or in smaller quantities in villages where these caterpillars are harvested. Treated caterpillar larvae are stored in sacks with transparent rubber lining to extend their shelf life by the market women and are then sold either to retailers or directly to consumers. In Wa in the Upper West region of Ghana, measuring container normally used to either purchase or sell shea caterpillar is called 'kokoolaa' (in the Wali/Dagaare language) which means porridge bowl and the content is equivalent to 1.53 kg. Harvesting of shea caterpillar and all the other processes are done manually and exclusive of chemicals.

2.8 Haematological Characteristics in Poultry

Haematology refers to the study of the numbers and morphology of cellular elements of blood namely the red blood cells, white blood cells, and platelets, and these results are used in the diagnosis and monitoring of diseases (Ayoola, 2011). Blood transports nutrients and materials to the entire body. Thus, whatever affects the blood (drugs, pathogenic organisms, or nutrients) will affect the whole body either positively or unfavourably in terms of growth, health, maintenance, and reproduction (Etim et al., 2014). A readily accessible and rapid means of assessing the clinical and nutritional well-being of livestock during feeding experiments may be the use of blood analysis since diet has effects on blood composition (Etim et al., 2014). Haematological indices are of environmental and physiological significance and could be beneficial in the selection of breeds that are genetically resistant to certain diseases and environmental conditions (Isaac et al., 2013). Isaac et al. (2013) revealed that animals with required blood composition variables are more probable to display good and better performance. Esonu et al. (2006) testified that haematological components reflect the physiological alertness of an animal to its core and peripheral environments which include food and nourishment. Blood parameters that are frequently measured under haematological profile are red blood cell and white blood cell. Packed cell volume (Haematocrit), mean cell volume, mean cell haemoglobin concentration, and mean cell haemoglobin. Red blood cells function as a carrier of haemoglobin. According to Isaac et al. (2013), RBCs are involved in the transport of oxygen and carbon dioxide in the body of animals. Hence, a small red blood cell count denotes a reduction in the level of oxygen that would be carried to the tissues and the level of carbon dioxide returned to the lungs (Isaac et al., 2013). White blood cells help to fight infections, defend the body against pathogens and produce as well as dispense antibodies in immune response (Etim et al. 2014). Therefore, animals with reduced white blood cells are exposed to a high risk of disease infection, while those with enough cells can resist diseases (Etim et al., 2014). Blood platelets are involved in blood clotting. Low platelet concentration recommends that the process of clot-formation will delay resulting in excessive loss of blood in the case of Injury to an animal. Isaac et al. (2013) reported that Packed Cell Volume is associated with the conveyance of oxygen as well as absorbed nutrients. Haemoglobin has the physiological role of conveying oxygen to tissues of the animal to release energy for other body functions as well as deliver carbon dioxide out of the body of animals (Isaac et al., 2013; Etim et al., 2014). According to Abu et al. (2021) haemoglobin, PCV, and MCH are major indices for evaluating circulatory erythrocytes and are important in the diagnosis of anaemia. High PCV interpretation showed a rise in the number of red blood cells (RBCs) or a reduction in circulating plasma volume (Abu et al., 2021), MCH and MCHC show blood level conditions and a low value is a sign of anaemia.

2.8.1 Effects of insect meal on haematological attributes

Various insects' meals have been fed to birds without any haematological and biochemical effects on performance (Shariat et al., 2020). Substituting a fish meal with maggot meal in broiler and layer diets did not display a significant effect (P>0.05) on blood profile (Biasato et al., 2017). Anankware et al. (2020) added that, insignificant changes were detected for a decrease in blood haematological indices such as platelets but saw an increase in packed cell volume, and red blood cells. It, therefore, suggests that the inclusion of insects in poultry diets may influence haematological parameters in various ways.

2.8.2 Effects of insect meal on reproductive performance of Guinea fowl

The effects of insect meal, like the shea caterpillar, on the reproductive performance of Guinea fowl have gained attention as researchers explore alternative protein sources in poultry diets. Insect meal is known for its high protein content and nutritional richness, which can contribute to improved reproductive outcomes in Guinea fowl (Anankware et al., 2015). Adequate protein intake is crucial for egg production, fertility, and the overall reproductive health of poultry. When incorporated into Guinea fowl diets, insect meal can provide essential amino acids, vitamins, and minerals that support the development of healthy eggs and successful reproduction (Anankware et al., 2015). Furthermore, insect meal has the potential to enhance the hatching rates of Guinea fowl eggs, leading to increased chick production. The high-quality protein and nutrient profile of insect meal can positively impact eggshell quality and egg fertility, both of which are vital factors for successful reproduction (Kenis et al., 2014). However, the optimal inclusion rates of insect meal in Guinea fowl diets may vary based on factors like the specific insect species used, the bird's age, breed, and the overall dietary composition.

2.9 Nutrition in Guinea Fowl

Guinea fowl nutrition plays a crucial role in their growth, health, and overall performance. Understanding their nutritional requirements and providing a balanced diet is essential for optimizing productivity and maintaining the well-being of these birds. Guinea fowl as any other farm animal require all the essential nutrients namely carbohydrates, proteins, fats, minerals, vitamins and water for various physiological functions including maintenance, growth and production (Kyere et al., 2021). These nutrients must be present in the diets of Guinea fowl in the right amounts and proportions to ensure physiological harmony. Guinea fowl are natural foragers and have the ability to obtain a portion of their nutritional needs from their environment (Ahaotu et al., 2019). They actively search for insects, seeds, greens, and other small organisms, supplementing their diet with natural sources of nutrients. Providing opportunities for foraging and access to pasture can contribute to their overall nutritional balance.

2.9.1 Energy requirements

Energy is typically provided through carbohydrates and fats in the diet. The energy requirements of Guinea fowl depend on factors such as age, activity level, and environmental conditions (Salgado et al., 2022). Energy is a vital component of Guinea fowl nutrition, providing the necessary fuel for metabolic processes, growth, and maintenance. The energy requirements of Guinea fowl vary based on factors such as age, activity level, environmental conditions, and production goals (Herring et al., 2021). Energy is typically supplied through dietary carbohydrates and fats. Carbohydrates are a significant source of energy for Guinea fowl and are converted into glucose, which is used for various metabolic functions (Ellerby et al., 2011). Common sources of carbohydrates in Guinea fowl diets include grains (such as corn, wheat, and barley), tubers, and root crops. These carbohydrates provide readily available energy for the birds. Dietary fats are a concentrated source of energy and provide more energy per gram compared to carbohydrates and proteins (Ellerby et al., 2011). Fats are essential for optimal growth and development, especially in young Guinea fowl. Good sources of dietary fats for Guinea fowl include vegetable oils, fish oil, and animal fats. It is important to ensure a balanced amount of dietary fats to prevent excessive fat deposition and other related health issues. The energy density of the diet is a crucial consideration to meet the energy requirements of Guinea fowl. The energy density is usually expressed in terms of kilocalories (kcal) per kilogram (kg) of feed. Formulating diets with appropriate energy density helps meet the energy demands of Guinea fowl while considering factors like feed intake capacity and nutrient balance. The energy requirements of Guinea fowl vary throughout their lifecycle (Herring et al., 2021). Young birds require higher energy intake for rapid growth, while adult birds require maintenance energy levels. During peak egg production, Guinea fowl hens have increased energy needs to support egg formation and laying. Adjustments can be made in the diet formulation to meet the changing energy requirements of Guinea fowl based on their growth stage, activity level, and environmental conditions (Ahiwe et al., 2018). According to Henry et al. (2010), feed conversion ratio (FCR) is another useful parameter to evaluate the efficiency of energy utilization. Balancing energy intake with other nutrient requirements is crucial for optimal performance and overall health of Guinea fowl.

2.9.2 Protein requirements

Protein is a critical component of Guinea fowl nutrition as it is essential for growth, muscle development, feather production, enzyme synthesis, and overall body maintenance (Salgado et al., 2022). Meeting the protein requirements of Guinea fowl is crucial for their optimal performance and health. Guinea fowl require a diet that contains an adequate amount of protein (Okyere et al., 2020). The protein content in the diet is usually expressed as a percentage of the total diet composition. The specific protein requirement depends on various factors such as age, sex, growth rate, activity level, and reproductive status of the birds (Adjetey, 2011). Proteins are composed of amino acids, and Guinea fowl have specific requirements for essential amino acids that cannot be synthesized by their bodies. These essential amino acids include lysine, methionine, cysteine, threonine, tryptophan, valine, isoleucine, leucine, phenylalanine, and histidine (Adeyeye and Adesina, 2014). Meeting the requirements for essential amino acids is crucial for optimal growth and development. Protein quality refers to the amino acid composition and bioavailability of protein in the diet. High-quality proteins contain a well-balanced profile of essential amino acids that are easily digestible and absorbed by the birds (Adeyeye and Adesina, 2014). The digestibility and bioavailability of protein sources can vary, and it is important to consider protein quality when formulating diets for Guinea fowl (Nahashon et al., 2012). Common sources of protein in Guinea fowl diets include animal-based proteins and plant-based proteins. Animal-based proteins include fish meal, poultry by-products, meat meal, and insect meal. Plant-based proteins include soybean meal, canola meal, sunflower meal, and legume-based meals. The selection and combination of protein sources depend on factors such as availability, cost, and nutritional composition (Wolfe et al., 2018). The protein requirements of Guinea fowl vary with age. Young birds have higher protein requirements to support their rapid growth and development. As they reach maturity, the protein requirements decrease to maintenance levels. During peak egg production, Guinea fowl hens may have increased protein needs to support egg formation (Nahashon et al., 2012). Amino acids are the building blocks of protein, and Guinea fowl have specific requirements for essential amino acids. Essential amino acids cannot be synthesized by the bird's body and must be obtained through the diet. Meeting the amino acid requirements is crucial for proper growth, feather quality, and overall health (Moyo et al., 2019).

2.9.3 Mineral and vitamin requirement

Guinea fowl require a balanced supply of vitamins and minerals for various metabolic functions and overall health (Moyo et al., 2019). Guinea fowl, like all poultry birds, have specific mineral and vitamin requirements to maintain good health and maximise their growth and productivity. Minerals are essential for various physiological processes, and Guinea fowl need a balanced supply of calcium, phosphorus, sodium, and potassium for proper bone development, muscle function, and overall health (Nahashon et al., 2012). Calcium is particularly important for eggshell formation in laying hens, so it's crucial to provide a calcium source such as oyster shell or crushed limestone for Guinea fowl during their egg-laying phase. Additionally, adequate phosphorus levels must be maintained to ensure optimal bone strength and energy metabolism. Vitamins are also critical for Guinea fowl nutrition. Vitamin A is essential for healthy eyesight and immune function, while vitamin D is necessary for calcium absorption and bone health (Moyo et al., 2019). Guinea fowl usually obtain vitamin D through exposure to sunlight, so it's important to ensure they have access to outdoor areas or provide supplemental vitamin D in their diet if they are kept indoors. B-vitamins, such as B12, riboflavin, and niacin, are vital for energy metabolism and the formation of feathers, among other functions (Nahashon et al., 2012). Ensuring a well-balanced diet that includes grains, greens, insects, and commercial poultry feeds can help meet the vitamin and mineral requirements of Guinea fowl, promoting their overall well-being and productivity

2.9.4 Water requirement

Guinea fowl, like all poultry, have specific water requirements for their overall health, digestion, and physiological functions. Water is essential for the transportation of nutrients, temperature regulation, and waste elimination in these birds (Gholipour et al., 2019). Guinea fowl need access to clean, fresh water at all times. Their water requirements can vary depending on factors such as environmental temperature, age, and activity level. In hot weather, Guinea fowl may drink more to stay cool and hydrated (Vineetha et al., 2017). As a general guideline, adult Guinea fowl may consume around 0.5 to 1 litre (or more) of water per bird per day. However, this can increase during periods of stress, high egg production, or hot weather. It is essential to provide water in a way that prevents contamination and ensures it remains free of debris and algae (Vineetha et al., 2017). Regularly cleaning and refilling water containers is crucial to meet the water requirements of Guinea fowl and maintain their health and productivity.

Dehydration can lead to reduced egg production, poor growth, and overall health issues in Guinea fowl, so constant access to clean water is vital (Kouame et al., 2021).

2.10 Folliculogenesis

Folliculogenesis refers to the process of development and maturation of ovarian follicles in the female reproductive system (Aerts and Bols, 2010). It is an essential part of the reproductive cycle and involves the formation and growth of follicles, which house the eggs (oocytes) within the ovaries. According to Silva et al. (2012), folliculogenesis begins during foetal development, where primordial follicles are formed. These primordial follicles contain immature oocytes surrounded by a single layer of flattened cells called granulosa cells. However, the majority of folliculogenesis occurs during the reproductive years of a female's life. Each month, a group of primordial follicles is stimulated to develop further by hormones released by the pituitary gland, primarily follicle-stimulating hormone (FSH) (Gifford, 2015).

The primordial follicles are often referred to as the "cohort." Within the cohort, usually only one follicle becomes dominant and continues to develop, while the others undergo atresia (degeneration) (Gifford, 2015). The dominant follicle, also known as the pre-ovulatory follicle, grows in size and undergoes several stages of development (Bonnet et al., 2013). The granulosa cells surrounding the oocyte proliferate and form multiple layers, forming a structure known as the cumulus oophorus. This structure is important for providing essential nutrients and support to the developing oocyte. As the dominant follicle continues to mature, a fluid-filled cavity called the antrum forms within it and the antrum contains a follicular fluid that plays a crucial role in nourishing the oocyte (Akhigbe et al., 2018). During the final stages of folliculogenesis, the dominant follicle reaches its maximum size and prepares for ovulation, which is the release of the mature oocyte from the follicle (Plate 2.1). Ovulation is triggered by a surge of luteinizing hormone (LH) from the pituitary gland. After ovulation, the remaining follicular cells in the ovary form a structure called the corpus luteum, which produces hormones such as progesterone to prepare the uterus for potential implantation of a fertilized egg (Khan and Kauffman, 2012). If fertilization does not occur, the corpus luteum regresses, and a new cohort of follicles starts developing in the subsequent cycle in mammals. This is different from the birds where a distinct hierarchical structure in laying hens allows for almost daily ovulation. Folliculogenesis is a tightly regulated process involving complex interactions between gonadotrophin hormones (LH and FSH) and growth factors such as IGF-1, EGF, and FGF (Webb et al., 2004). Any disruption in this process can lead to reproductive disorders or fertility issues (Gifford, 2015).

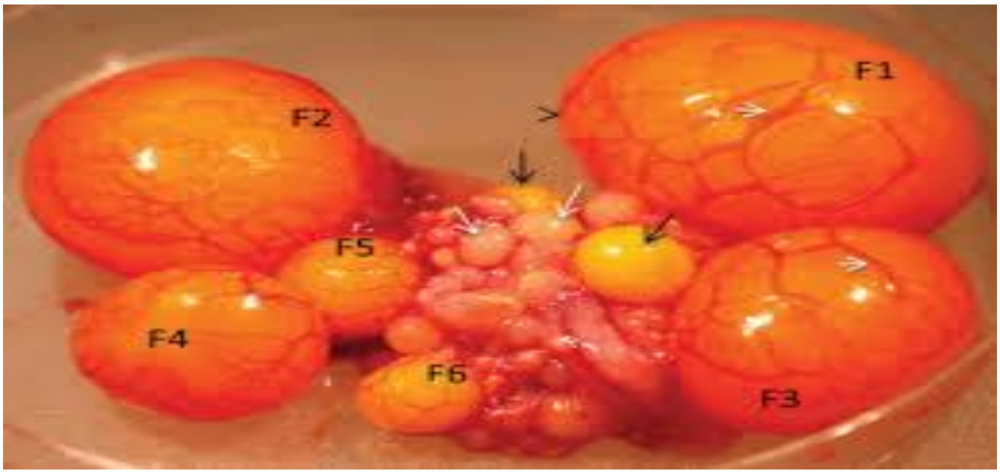

Plate 2.1: A normal follicular development of hen Source: Johnson (2015)

2.11 Effect of Protein on Folliculogenesis

Shea Caterpillar meal provides protein which is an essential macronutrient that plays a crucial role in various physiological processes, including folliculogenesis in poultry. Adequate protein intake is important for the overall health and function of the reproductive system, including the development and maturation of ovarian follicles (Agarwal et al., 2015). Protein provides the building blocks for the production of hormones, enzymes, and structural components within the body. During folliculogenesis, protein is needed for the growth and proliferation of granulosa cells, which surround the oocyte and support its development (Thomas and Vanderhyden, 2014). Research suggests that protein intake can influence follicle development and female fertility. According to Thomas and Vanderhyden (2014), protein intake can affect the function and health of granulosa cells, which can, in turn, impact follicle development. Adequate protein intake is essential to ensure proper granulosa cell function. Protein intake can influence the production and balance of hormones involved in folliculogenesis, such as follicle-stimulating hormone (FSH) and luteinizing hormone (LH) (Agarwal et al., 2015). These hormones regulate the growth and maturation of ovarian follicles. A protein-rich diet can help maintain optimal hormone levels, supporting follicle development. Adequate protein intake is important for overall reproductive health and fertility. Insufficient protein intake or imbalanced diets may lead to suboptimal folliculogenesis and compromised fertility. A study by Moslehi et al. (2017), revealed that higher protein intake was associated with a higher antral follicle count, which is a marker of ovarian reserve. The study suggested that protein intake may have a positive impact on the number of developing follicles in poultry. A study by Chavarro et al. (2015) found that a higher intake of animal protein was associated with better oocyte quality compared to a higher intake of carbohydrate-rich diets.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Location of the Experiment

The experiment was conducted at the poultry section of the Department of Animal Science Education Farm of the Faculty of Agriculture Education of the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (Asante Mampong Campus). The study lasted for a period of 28 weeks - beginning from 12th March, 2022 to 30th September 2022. Asante Mampong, the capital town of the Mampong Municipality, is located within longitudes $0^0$05''W and $1^0$30''W and latitudes $6^0$55''N and $7^0$30'' N. Asante Mampong experiences an average annual rainfall of 1,270 mm and two rainy seasons. The major rainy season starts in March and ends in August whilst the minor is between September and November. The remaining months span the harmattan dry season. The average annual temperature is 27 ^{0}C with variations in mean monthly temperature ranging between 22 ^{0}C – 30 ^{0}C (Meteorological Service Department, 2018).

Asante Mampong lies within the wet semi – equatorial forest zone. Due to human activities like charcoal production, lumbering and bush fires, the forest vegetation particularly in the north–eastern part, has been reduced to Savannah. Vegetation of primary origin can only be found within a reserve known as the Kogyae Natural Forest Reserve, which has a total land area of 115 square kilometers. The land is fairly low – lying in the south and steadily undulates towards the north. The highest point is about 2400 meters above mid-sea level whilst the lowest point is 135 meters above mid-sea level (Meteorological Service Department, 2018).

3.2 Sources of Feed Ingredients

The feed ingredients used in the experiment included shea caterpillar, soybean meal, wheat bran, maize, anchovy, vitamin premix, oyster shell, dicalcium phosphate, and salt. The ingredients (except for shea caterpillar) were bought from commercial feed suppliers in Kumasi and compounded in the feed unit of the Animal Science farm. The larvae of shea caterpillar were obtained from the principal markets in Tamale, in the Northern Region of Ghana.

3.3 Housing and Equipment

A deep litter house unit was used where the birds were confined in a room with a wall raised to about 1.2 m tall and wire mesh of about 2 m tall. The floor of the experimental house was made of concrete and spread with wood shavings. The roof was made of corrugated iron sheet. The pen was partitioned into 12 rooms (1×3.25 m^2) with wire mesh net and wood. The pen was cleaned with soapy water and all cobwebs were removed. A dried bedding material (wood shavings) was spread on the floor to a depth of 4.5 cm. The pen of each experimental unit was disinfected using omnicide at a dilution of 10 ml to 2 L of water. The pen was kept clean and dry to prevent infections to the birds.

3.4 Experimental Birds, Treatments and Design

3.4.1 Experimental birds

Sixty (60) Guinea hens at point of lay and fifteen (15) Guinea cocks at 25 weeks old were used for the experiment. The birds were obtained from the poultry unit of the Department of Animal Science, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Asante Mampong Campus and reared in separate pens. The birds were managed under the same housing and management conditions.

3.4.2 Experimental treatments and design

The birds were allocated to five dietary treatments with three replications each that had five birds (4 females:1 male) per replicate in a Completely Randomized Design (CRD). The various experimental pens were labeled in accordance with their experimental treatments and replicates. The treatments for the experiment comprised the control which had no shea caterpillar meal (SCM 0%). The remaining treatments had shea caterpillar meal replacing anchovy at varying levels of 25%, 50%, 75% and 100% designated as SCM 25%, SCM 50%, SCM 75% and SCM 100% respectively. The Composition of experimental diets and calculated analysis is shown in the Tables 3.1.

Table 3. 1: Composition of experimental diets and calculated analysis.

Ingredients	**SCM0%**	**SCM25%**	**SCM50 %**	**SCM75%**	**SCM100%**
Maize grain	58	58	58	58	58
Anchovy	6.5	4.875	3.25	1.625	0
Soybean meal	11.5	11.5	11.5	11.5	11.5
Wheat bran	18.5	18.5	18.5	18.5	18.5
Oyster shell	4.5	4.5	4.5	4.5	4.5
Dicalcium Phosphate	0.5	0.5	0.5	0.5	0.5
Vit/Min. Premix	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25
SCM	0	1.625	3.25	4.875	6.5
Total (kg)	100	100	100	100	100
Calculated analysis					
Crude protein (%)	17.16	17.16	17.13	17.12	17.11
Crude fibre (%)	4.18	4.29	4.41	4.52	4.63
Ether extract (%)	3.18	3.27	3.35	3.44	3.52
Lysine (%)	1.3	1.29	1.27	1.26	1.25
Methionine (%)	0.35	0.33	0.32	0.31	0.29
Ash (%)	10.36	10.16	9.96	9.76	9.56
Phosphorus (%)	0.61	0.57	0.54	0.51	0.48
ME (kcal/kg)	2677.25	2689.7	2700.9	2712.4	2724.4

Premix contains contained the following per kilogram of diet: Fe 100 mg, Mn 110 mg, Cu 20 mg, Zn 100 mg, Se 0.2 mg, Co 0.6 mg, Senoquin 0.6 mg, retinal 2000mg, cholecalciferol 25 mg, α-tocopherol 25 mg, menadione 1.33 mg, cobalamin 0.03 mg, thiamin 0.83 mg, riboflavin 2 mg, folic acid 0.33 mg, biotin 0.03 mg, pantothenic acid 3.75 mg, macin 23.3 mg, pyridoxine 1.33mg.

3.5 Shea Caterpillar Meal Preparation

The larvae of shea caterpillars (*Cirina butyrospermi*) (Plate 3.1A) were washed and cooked at 100°C in boiling water for 10 minutes. The precooked shea caterpillar was dried in the sun for a period of seven (7) days to reduce the moisture content. The dried larvae were ground first with hammer mill of sieve size 2 mm (Plate 3.1 B) and second with corn mill to further reduce the particle sizes (Plate 3.1 C) of the SCM. The resulting meal was stored for analysis and used in ration formulation.

A- Shea caterpillar (SC) B- Hammer milled SC C-Milled SC in corn mill

Plate 3.1: Shea caterpillar before milling and after milling

3.6 Parameters Measured

Parameters measured were feed intake, water intake, body weight, body weight gain and feed conversion ratio; Egg Production and egg characteristics (Hen-day egg production, weight of egg, length of egg and width of egg); and reproductive traits (folliculogenesis, fertility, and hatchability).

3.6.1 Mean weekly feed intake

A weighed quantity of feed was given to birds daily. The leftover feed was measured and feed intake was determined by subtracting the leftover feeds from the quantity of feed given and the resulting value divided by the number of birds. The daily feed intakes were summed up for a week to give weekly feed intake. This is expressed mathematically as:

$$\text{Daily Feed intake (g / bird)} = \frac{\text{feed given (g)} - \text{leftover feed(g)}}{\text{number of birds}}$$

3.6.2 Water intake

A measured quantity of fresh water was supplied to the birds every morning. Leftover water collected the following morning at the time the water was placed in the rooms of the respective replicates and measured. The leftover water was then subtracted from the initial amount to obtain the daily water intake. The resulting figure was divided by the number of birds per replicate to obtain daily water intake per bird. The summation of daily water consumption for seven days gave the weekly water intake per bird.

3.6.3 Body weight and body weight gain

The initial body weight of birds was taken, before putting them in the experimental pens. Birds were weighed at the end of the experiment to determine the final body weight. Total weight gained was determined by subtracting the initial body weight from the final body weight. This can be expressed mathematically as:

Total weight gain (g) = final body weight (g) – initial body weight (g).

3.6.3.1 Feed conversion ratio (FCR)

Feed conversion ratio in animal husbandry is an animal’s efficiency in converting feed into desirable products (usually meat, milk, or eggs). In this experiment, feed conversion ratio is the mathematical relationship between the input of the feed that has been consumed and the weight of eggs produced by the bird. The conversion ratio was calculated according to the formula;

$$\mathbf{FCR} = \frac{\mathbf{Feed\ intake}}{\mathbf{Egg\ Mass}}$$

3.6.4 Egg production

3.6.4.1 Hen-day egg production (HDEP)

Hen-day egg production was calculated as the percentage of the number of eggs laid to the number of hen days.

$$\text{HDEP} = \frac{\text{number of eggs laid}}{\text{number of hen on the day}} \times 100$$

3.6.5 Hen-house egg production

Hen-house egg production was calculated as the percentage of the total number of eggs laid to the number of Guinea fowl housed at the start of the laying period.

$$\text{(HHEP)} = \frac{\text{total number of eggs laid}}{\text{number of pullets housed at the start of the laying season}} \times 100$$

3.6.6 Egg characteristics

3.6.6.1 Weight of eggs

A digital Weiheng portable HF electronic balance, China, was used to take the weight of each egg accordingly. The eggs were placed on it and the weight of the eggs was measured in grams.

3.6.6.2 Length of the eggs

The length of the eggs was measured using a digital inside vernier caliper, which provided a high degree of accuracy of 0.01 – 0.0005 mm (Plate 3.2). Each egg was carefully placed on a flat surface, and the rule was gently used to measure the length from the pointed tip to the opposite end.

Plate 3.2: Vernier caliper used for measurement of egg length

3.6.6.3 Width of the eggs

The eggs were cleaned to remove any dirt. Then, the inside measuring jaws of digital vernier caliper were carefully placed from the perpendicular to the widest part of the egg, which is typically at the equatorial region. The caliper was closed until it lightly touched the eggshell without applying excessive force, and the width was recorded in millimeters (Plate 3.2).

3.6.6.4 Yolk colour

The yolk colour of Guinea fowl eggs was measured using a specialized instrument called the Roche Yolk colour fan chart (Figure 3.1). The yolk colour was expressed in terms of a numerical value on the Roche Yolk Colour Fan.

Figure 3.1: Yolk colour chart

3.6.6.5 Albumen height

The eggs were cracked open, and the egg white (albumen) was separated from the yolk. The egg white was gently poured into the petri dish, ensuring that it formed a uniform layer. A ruler was used to measure the height of the albumen from the base of the container to its highest point. The albumen height was measured in millimeters.

3.6.6.6 Eggshell weight

The eggs of the Guinea fowl were cracked open and the eggshell was separated from the egg white and yolk. The wet eggshell free of any residual membrane was weighed using a digital Weiheng portable HF electronic balance, China. The wet eggshells were subjected to sun drying to reduce the moisture content. The dried eggshells were then weighed using digital Weiheng portable HF electronic balance, China, and the weights recorded.

3.6.6.7 Shell thickness

The egg shells were cleaned of residual egg white and membrane. A digital vernier caliper (Plate 3.2) was used to measure the eggshell thickness at 3 different planes and the average recorded as the eggshell thickness.

3.7 Reproductive Parameters Measured

3.7.1 Percentage fertility

The female and male experimental Guinea fowl were paired for mating at the ratio of 4:1 for each replicate. Fertilized eggs were determined by candling at 14 days after incubation. Percentage fertility was calculated by expressing the total number of fertile eggs as a percentage of the total number of eggs set. Arithmetically,

$$\% \text{ Fertility} = \frac{\text{Total number of fertile eggs}}{\text{Total number of eggs set}} \times 100$$

3.7.2 Percentage hatchability

Percentage hatchability was determined as the total number of eggs hatched as a percentage of total number of fertile eggs. Mathematically,

$$\% \text{ hatchability} = \frac{\text{Total number keets hatched}}{\text{Total number of fertile eggs}} \times 100$$

3.7.3 Folliculogenesis

Three experimental birds from each treatment (each from a replicate) were selected randomly, sacrificed, dressed and eviscerated for follicular counts. Both mature and immature follicles were counted. The assessment was done by comparing the follicles to the chart (Figure 3.2; Plate 2.1) and scoring the number of eggs at the various stages of development according to the procedure outlined by Nie et al. (2022).

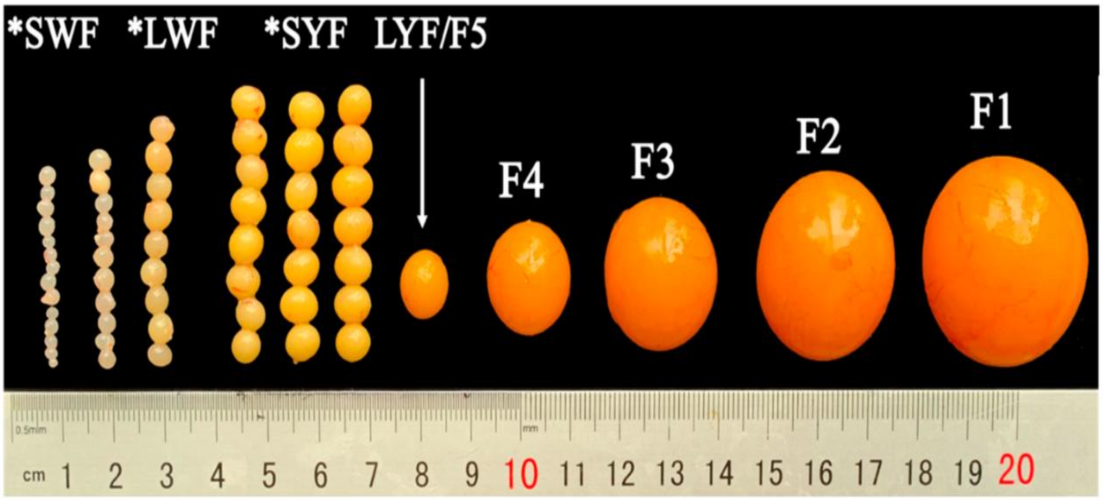

Figure 3.2: Ovarian follicles of laying hens (Nie et al., 2022)

Key: Asterisks show pre-hierarchal follicles; SWF: small white follicles; LWF: large white follicles; SYF: small yellow follicle; F5-F1 represent hierarchal follicles, which are sorted from smallest to largest in diameter. F5 represents the most recently selected follicle (LYF: large yellow follicle).

3.7.4 Keet quality and morphometric characteristics

Keets hatched were observed for the presence or absence of yolk sac infection. Keets that were hatched had their body condition inspected and scored. Quality assessment score (QAS) or body condition scoring was done by ranking on a scale of 1-5, where 1=poor (yolk sac presence, paralysis, not active); 2=fair (partial paralysis, active); 3=moderate (no deformity but poor feathers); 4=good (no deformity but little active); 5=very good (no deformity, active, good feathers).

Keets were individually weighed with an electronic balance scale and weights recorded. Keet body length and shank length were also measured with a 30 cm length ruler.

3.8 Haematological Assessment

Blood samples were taken from three (3) birds (one from each replicate). The blood collection was done through wing vein puncture using a 5 ml syringe and needle. A 2 ml each of the blood collected was released into EDTA tubes and identified accordingly for haematological analysis. A clean dry cotton was placed over the venipuncture site and wing closed to maintain pressure to stop the accumulation of blood under the vein. The tubes were labelled, placed in an ice chest and transported to the ABC Medical diagnosis laboratory at Agona in the Ashanti Region of Ghana for analysis.

The haematological profile of individual Guinea fowl was done using a Rayto haematology auto-analyser manufactured by Rayto Life Analytical Sciences Company Limited, China. The parameters measured included Red Blood Cell count (RBC), Haemoglobin (Hb), Mean Corpuscular Volume (MCV), Mean Corpuscular Haemoglobin (MCH), Mean Corpuscular Haemoglobin Concentration (MCHC), and platelets, Packed Cell Volume (PCV) or haematocrit. Leucocyte parameters measured included White Blood Cell (WBC) count and lymphocyte counts.

3.9 Statistical Analysis

Data collected were subjected to Analysis of Variance (ANOVA), using Genstat Statistical package (12th edition, 2008) and treatment means compared using Fisher's Least Significance Difference (LSD) test at the 5% significance level.

CHAPTER FOUR: RESULTS

4.1 Proximate Composition of Shea Caterpillar and Experimental Diets

Results on the proximate composition of the shea caterpillar meal and the experimental layer diets are presented in Table 4.1.

Table 4.1: Proximate composition of shea caterpillar and the layer diets

Fraction	SCM	SCM 0%	SCM 25%	SCM 50%	SCM 75%	SCM 100%
MC %	11.08	12.9	12.89	12.65	12.56	12.41
CP %	57.8	17.02	16.98	16.88	16.80	16.68
CF %	8.4	4.19	4.21	4.29	4.36	4.38
EE %	9.84	3.21	3.28	3.33	3.41	3.48
Ash %	4.7	6.78	7.12	7.65	7.98	8.04
NFE %	8.18	55.9	55.52	55.2	54.89	55.01
*ME $Kcalkg^{-1}$	3229.8	2848.8	2839.8	2829.05	2821.7	2827.2

** Metabolisable energy (ME kcal/kg) was calculated according to the formula derived by Pauzenga (1985); ME kcal/kg = (37 x % CP) + (81.8 x % EE) + (35 x % NFE)*
MC=moisture content, CP = crude protein, CF= crude fibre, EE =ether extract, NFE=nitrogen free extract, ME=Metabolizable energy, DM=dry matter, SCM= shea caterpillar meal

The shea caterpillar meal had appreciable level of crude protein (CP) (57.8 %) that is comparable to that of CP of fish meal (60.0%). The metabolizable energy (ME) was considerably high. The ether extractive was quite high and could influence the relatively high ME obtained although the nitrogen free extractive was lower (8.18%). The result of proximate composition on the dietary treatments showed minor reduction from the calculated analysis (Table 3.1). However, the control (SCM 0%) met the requirement of 17% CP while the other dietary treatments slightly missed the 17% CP mark ranging from 16.68% to 16.98%. Metabolisable energy values appreciated from the calculated analysis values but were lower than 2850 kcal/kg recommended value. The crude fibre content ranged from 4.19% to 4.36% and the value obtained increased as the level of the SCM increased in the diet.

4.2 Effect of Shea Caterpillar Meal on Feed and Water Intake

The effect of dietary shea caterpillar meal on feed intake is presented in Table 4.2.

Table 4.2: Effect of dietary shea caterpillar meal on weekly feed intake by Guinea fowl in grams

Week	Dietary Treatments					SEM	P- Value
	SCM 0%	SCM 25%	SCM 50%	SCM 75%	SCM 100%		
1.	537^{a}	534^{a}	397^{b}	439^{b}	402^{b}	25.3	0.005
2.	672^{ab}	720^{a}	601^{bc}	571^{cd}	505^{d}	25.1	<.001
3.	659^{ab}	733^{a}	671^{ab}	567^{b}	557^{b}	36.9	0.031
4.	670	678	661	610	566	34.1	0.180
5.	668	703	682	653	589	27.8	0.117
6.	730.3	699.7	680.0	709.3	647.0	20.77	0.129
7.	728.3^{a}	721.7^{a}	713.3^{a}	709.3^{a}	642.7^{b}	8.45	<.001
8.	558.0	558.7	559.3	553.0	550.7	2.27	0.078
9.	626.7	563.3	572.7	575.7	565.0	16.99	0.121
10.	626.7	581.3	587.0	575.0	569.0	14.00	0.098
11.	624.0	617.7	575.3	581.0	602.7	13.72	0.111
12.	653.7	627.3	592.7	603.0	612.0	13.90	0.077

ABCD: Means with different superscripts in the same row are significantly different (P<0.05)

Feed intake for week one (1) was significantly higher (p=0.005) for Guinea fowls fed the control diet and the diet that had 25% shea caterpillar meal (SCM 25%) as compared to the other dietary treatments (SCM 50%, SCM 75% and SCM 100%) which had similar feed consumption values. Feed intake in the second week was higher (p<.001) for birds fed the SCM 25% diet as compared to the other shea caterpillar meal treatments but not the control. Guinea fowls fed the diet that had 100% fish replacement recorded the least (p<.001) intake (505g). The third week had a similar intake pattern as week 2 for birds fed the SCM 25% diet which recorded higher feed intake as compared to Guinea fowl fed the SCM 75% and SCM 100% diet but similar to the control and SCM 50%. Week seven (7) had similar feed intake for all dietary treatments except Guinea fowl fed the diet that had no fish meal (SCM 100%) which recorded the least value (p<.001). There was no significant difference among dietary treatments in the other weeks (4, 5, 6, 8, 9, 10, 11, and 12).

Table 4.3: Effect of dietary shea caterpillar meal on water intake by Guinea fowl (Litres)

Week	Dietary Treatments					SEM	P- Value
	SCM 0%	**SCM 25%**	**SCM 50%**	**SCM 75%**	**SCM 100%**		
1.	0.953^{a}	0.870^{ab}	0.660^{c}	0.673^{c}	0.750^{bc}	0.053	0.016
2.	1.353	1.227	1.107	1.387	0.950	0.171	0.361
3.	1.427^{a}	1.433^{a}	1.253^{ab}	1.400^{a}	1.023^{b}	0.085	0.030
4.	1.533	1.38	1.287	1.300	1.240	0.091	0.249
5.	1.580	1.427	1.187	1.253	1.027	0.118	0.057
6.	1.443	1.573	1.253	1.373	1.207	0.089	0.090
7.	1.487	1.733	1.293	1.400	1.327	0.099	0.065
8.	1.567^{ab}	1.737^{a}	1.347^{b}	1.443^{b}	1.367^{b}	0.082	0.037
9.	1.637	1.667	1.387	1.473	1.400	0.921	0.165
10.	1.603^{ab}	1.743^{a}	1.490^{b}	1.507^{b}	1.437^{b}	0.057	0.025
11.	1.600^{ab}	1.733^{a}	1.480^{b}	1.517^{b}	1.450^{b}	0.049	0.013
12.	1.600	1.707	1.551	1.543	1.450	0.074	0.252

ABC: Means with different superscripts in the same row are significantly different (P<0.05)

Water consumption for week one was similar for the Guinea fowl fed the control diet and the SCM 25% diet but was higher ($p<0.016$) as compared to the birds fed on the other diets except diet SCM 100% which also had similar consumption value as that of birds fed SCM 25% diet. Dietary treatments had no significant effect on water intake in Week 2. The third week observed similar consumption for the birds on control diet, SCM 25%, SCM 50% and SCM 75% but not SCM 100% which recorded lower ($p<0.03$) value, although it was similar to the consumption of birds fed the SCM 50% diet. Weeks 2, 4, 5, 6, 7, 9 and 12 had consumption values that did not differ ($p>0.05$) among dietary treatments. Water consumption for weeks 8,10 and 11 followed a similar pattern where significantly ($p< 0.05$) higher consumption was observed for Guinea fowl fed the SCM 25% diet as compared to the other dietary treatments but not the control diet which was also similar to the other dietary treatments (SCM 50%, SCM 75% and SCM 100%).

4.3 Effect of Dietary Shea Caterpillar Meal on Egg Production

The effect of dietary shea caterpillar meal on hen- day egg production is presented in Table 4.4.

Table 4.4: Effect of dietary shea caterpillar on hen-day egg production by Guinea fowl (%)

Week	Dietary Treatments					SEM	P- Value
	SCM 0%	SCM 25%	SCM 50%	SCM 75%	SCM 100%		
1.	17.86[a]	16.67[ab]	14.62[abc]	13.76[bc]	11.06[c]	1.252	0.025
2.	27.38[a]	12.52[b]	10.10[bc]	9.430[bc]	7.810[c]	1.584	<.001
3.	31.00[a]	20.50[b]	20.20[b]	16.70[b]	16.00[b]	3.180	0.048
4.	34.50[a]	18.00[b]	15.50[b]	15.20[b]	12.30[b]	3.490	0.008
5.	32.90[a]	20.20[b]	20.20[b]	19.50[b]	18.80[b]	2.470	0.011
6.	34.30[a]	14.30[b]	15.50[b]	11.90[b]	11.70[b]	2.63	<.001
7.	20.62[a]	10.29[b]	10.71[b]	9.050[b]	8.620[b]	1.170	<.001
8.	15.38[a]	6.430[b]	6.860[b]	8.000[b]	5.240[b]	1.308	0.002
9.	28.16[a]	13.26[b]	10.48[b]	11.43[b]	5.950[c]	1.055	<.001
10.	36.81[a]	25.33[b]	20.33[bc]	20.00[c]	19.05[c]	1.681	<.001
11.	39.94[a]	25.41[b]	22.14[bc]	21.57[bc]	18.62[c]	1.743	<.001
12.	45.70[a]	32.28[b]	30.17[b]	28.05[bc]	25.19[c]	1.347	<.001

ABC: Means with different superscripts in the some row are significantly different (P<0.05)

Weekly hen-day egg production (HDEP) was significantly (p<0.05) influenced by the dietary treatments throughout the duration of the study. The laying performance was generally low with HDEP figures that were less than 46% across the dietary treatments. Guinea fowl fed the control diet, SCM 25%, and SCM 50% had HDEP values that were similar (p>0.05) whereas birds fed SCM 50% and SCM 100% diets also had similar HDEP values in week 1. Guinea fowl fed the control diet and SCM 25% had higher (p=0.025) HDEP as compared to those fed SCM 75% and SCM 100% but not SCM 50% diet. In week 2, HDEP was higher (p<.001) for birds fed the control diet as compared to the shea caterpillar diets. Birds fed SCM 25% diet had significantly higher HDEP than the SCM 100% but not SCM 50% and SCM 75% diets. HDEP was higher (p= 0.048) for birds fed the control as compared to the SCM diets which recorded similar values during week 3. The pattern in week 3 was repeated for weeks 4 to 8. Week 9 recorded significantly ($p<.001$) higher HDEP for the control diet relative to the SCM diets. However, birds fed SCM 25%, SCM 50% and SCM 75% had values that were significantly higher than the SCM 100%. Weeks 10 to 12 had similar pattern as that of week 9. The control diet recorded significantly ($p<0.05$) higher HDEP as compared to the SCM diets. The Hens fed the SCM 100% consistently recorded the least HDEP value comparatively.

4.4 Effect of Dietary Shea Caterpillar Meal on General Performance

The initial body weights of birds were similar for all dietary treatments. Total feed intake for the study period was significantly higher ($p=0.003$) for Guinea fowl fed the control diet as compared to the other dietary treatments except birds fed the SCM 25% diet which recorded values similar to those on the control diet (Table 4.5). Birds fed SCM 25% had feed intake that was similar to that of birds fed SCM 50% but was significantly higher than the values recorded for birds fed SCM 75% and SCM 100% diets. Guinea fowl fed SCM 50% and SCM 75% diets also had similar total feed intake but were significantly higher than that of birds fed SCM 100%. Birds fed the SCM 100% had the least ($p=0.003$) total feed intake (6809 g) as compared to the other dietary treatments. The total feed intake result shows a trend that feed intake decreases as the replacement level of the fish meal by the shea caterpillar meal increased.

Table 4.5: Effect of dietary shea caterpillar meal on general production performance of Guinea fowl

Parameter	Dietary Treatments					SEM	P-Value
	SCM 0%	SCM 25%	SCM 50%	SCM 75%	SCM 100%		
Initial BW (g)	1410.6	1448.4	1442.1	1417.5	1411.0	12.61	0.166
Total FI (g)	7754^{a}	7738^{ab}	7298^{bc}	7146^{cd}	6809^{d}	139.8	0.003
Total WI (L)	17.82^{ab}	17.90^{a}	15.57^{bc}	16.37^{b}	14.63^{c}	0.497	0.003
Final BW (g)	1490^{a}	1433^{b}	1518^{a}	1434^{b}	1401^{b}	23.3	0.030
Total WG (g)	81.00	51.60	59.10	49.40	19.70	20.61	0.391
Average HDEP (%)	30.37^{a}	17.94^{b}	16.40^{bc}	15.38^{bc}	13.36^{c}	1.257	<.001
Total EM (g)	3365^{a}	1735^{b}	1741^{b}	889^{b}	699^{b}	502.5	0.026
Average FCR	2.70^{c}	4.66^{bc}	4.63^{bc}	9.04^{ab}	10.16^{a}	1.451	0.017

ABCD: *Means with different superscripts in the same row are significantly different (P<0.05)****)***

BW- Body Weight, FI- Feed Intake, WI- Water Intake, HDEP- Hen-Day Egg Production, WG - Weight Gain, EM- Egg Mass, FCR- Feed Conversion Ratio

Total water consumption was significantly higher (p=0.003) for Guinea fowl fed SCM 25% diet as compared to the other dietary treatments but not the control diet which had similar consumption as that of the SCM 25% diet. Similar to the total feed intake, birds fed SCM 100% recorded the least total water intake.

Final body weights of the Guinea fowl were significantly influenced by dietary treatments with birds fed SCM 50% diet and the control diet recording the highest (p=0.03) weight (1,518 g and 1490 g respectively) as compared to weight recorded for birds fed SCM 25%, SCM 75% and SCM 100% diets which had similar values.

Total body weight gain at the end of the study showed no significant differences among the dietary treatments irrespective of the variation in feed intake.

The average hen-day egg production was significantly (p<.001) higher for the birds fed the control diet as compared to the SCM diets. Guinea hens fed the SCM 25% diet also had higher (p<.001) HDEP relative to those birds fed the SCM 100% diet but not SCM 50% and SCM 75% diets which recorded similar values. Total egg mass which is the total weight of eggs laid showed significant (p=0.026) variation among dietary treatments. Guinea fowl fed the control diet had a significantly higher egg mass as compared to the diets that had fish meal partially to fully replaced by shea caterpillar meal which recorded similar values for egg mass.

The average feed conversion ratio was better for Guinea fowls fed the control diet (2.70) as compared to birds fed SCM 75% (9.04) and SCM 100% (10.16) diets but not SCM 25% (4.66) and SCM 50% (4.63) diets. Birds fed SCM 25%, and SCM 50% had relatively better FCR values as compared to SCM 100% but not those on SCM 75% diet. FCR values for SCM 75% and SCM 100% diets were similar.

4.5 Effect of Shea Caterpillar Meal on Egg Characteristics

The effect of dietary shea caterpillar meal on egg characteristics is presented in Table 4.6.

Table 4.6: Effect of dietary shea caterpillar meal on egg characteristics of Guinea fowl

Parameter	Dietary Treatments					SEM	P- Value
	SCM 0%	SCM 25%	SCM 50%	SCM 75%	SCM 100%		
Egg Weight (g)	40.76[a]	41.68[a]	41.53[a]	16.11[b]	14.46[b]	1.769	<.001
Egg Length (mm)	49.42	50.56	51.38	51.24	50.73	1.047	0.704
Egg Width (mm)	38.42	38.65	37.97	38.41	39.15	0.892	0.915
Egg ST (mm)	0.583	0.647	0.677	0.703	0.730	0.018	0.828
Egg AH (mm)	6.34	4.32	5.25	4.34	4.91	0.817	0.436
Wet SW (g)	5.95	7.06	7.16	7.36	7.46	0.505	0.288
Dry SW (g)	4.73	5.49	5.67	5.64	5.86	0.593	0.708
Wet YW (g)	14.99	15.00	14.67	14.82	14.27	0.784	0.960
Dry YW (g)	12.58	12.65	12.50	12.08	12.01	0.598	0.906

AB: Means with different superscripts in the same row are significantly different (P<0.05)
ST- Shell Thickness, AH- Albumen Height, SW- Shell Weight, YW- Yolk Weight, SCM- Shea Caterpillar Meal

Weight of eggs laid by the birds differed (p<.001) among treatment diets. Guinea fowl fed SCM 25%, SCM 50% and the control diets recorded heavier (p<0.05) egg weight as

(Table 4.6) compared to weight of eggs recorded for birds fed SCM 75% and SCM 100% which had similar egg weights.

Eggshell thickness was not significantly different (P=0.828) among the dietary treatments. Values of shell thickness obtained tended to follow a pattern. The shell thickness obtained for eggs from Guinea hens fed the shea caterpillar diets increased in thickness as the level of inclusion was increased from 25% to 100%. Dry yolk weight, egg length, egg width, egg albumen height, wet shell weight, dry shell weight and wet yolk weight were all not significantly influenced (p>0.05) by the SCM among the dietary treatments.

4.6 Effect of Dietary Shea Caterpillar Meal on Reproductive Traits

4.6.1 Effect of dietary shea caterpillar meal on folliculogenesis

Effect of dietary shea caterpillar meal on the development of egg follicles is presented in Plate 4.1.

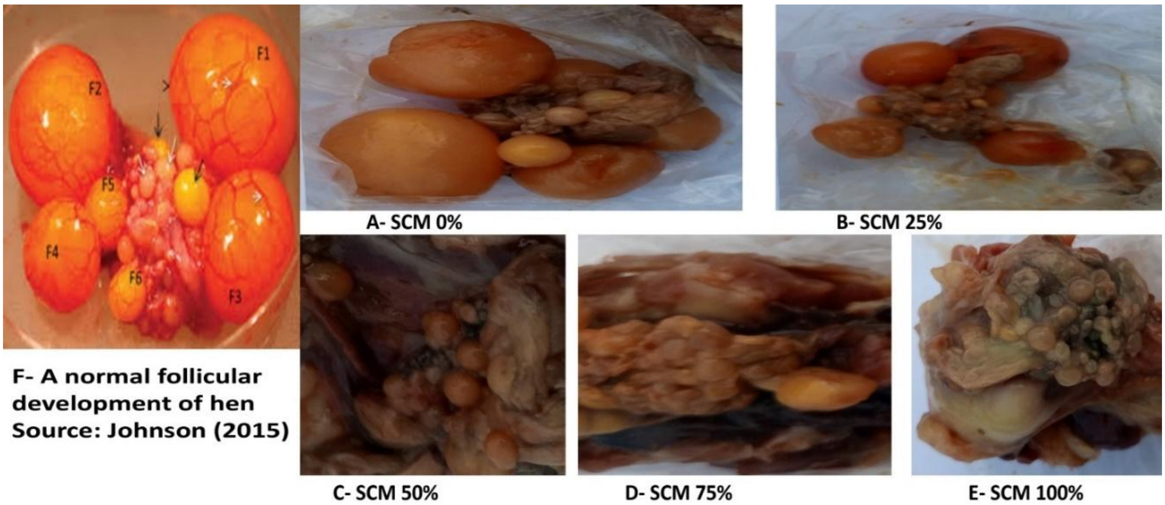

Plate 4.1: Folliculogenesis of Guinea fowls as influenced by dietary shea caterpillar meal

Nutrition has marked effect on poultry reproduction as it affects age at sexual maturity and development of egg follicles. The developmental stage of the follicles from the dietary treatments shown in photographs A and B of Plate 4.1, indicates that Guinea fowl fed the control and SCM 25% diets had their egg follicular development similar to the normal follicular development of hen (photograph F of Plate 4.1) and was ahead of the follicular development of the other dietary treatments (photographs C, D, and E). Guinea fowl fed the SCM 100% diet had its follicular development late as compared to the birds fed the other diets which is evidenced by presence of no F5 - F1 follicles (Table 4.7), an indication that Guinea hens fed the SCM diet were not ready to lay eggs at the time when the respective hens were sacrificed for determination of folliculogenesis. The number of large white follicles (2) were similar across the dietary treatments except SCM 100% which recorded one (1). Guinea hens fed SCM 50% and SCM 25% recorded relatively higher numbers of small yellow follicles than the other treatment diets, whereas Guinea hens fed SCM 25% and control diet had higher number of large yellow follicles (LYF/F5) than those hens fed SCM 50%, SCM 75% and SCM 100% diets. Hens fed on SCM 100% diet recorded no LYF/F5 (Table 4.7). Guinea hens fed on the control and SCM 25% diets had F1 follicles and indicated that there was a matured follicle ready to be laid whereas the other dietary treatments had no F1 follicle.

Table 4.7: Effect of dietary shea caterpillar meal on folliculogenesis of Guinea fowl

Parameter	SCM 0%	SCM 25%	SCM 50%	SCM 75%	SCM 100%
SWF	4	4	4	4	7
LWF	2	2	2	2	1
SYF	2	3	4	3	1
LYF/F5	3	4	1	1	0
F4	1	1	1	1	0
F3	1	1	1	0	0
F2	1	1	1	0	0
F1	1	1	0	0	0

SWF: small white follicles; LWF: large white follicles; SYF: small yellow follicle; F5-F1 represent hierarchal follicles, which are sorted from smallest to largest in diameter. F5 represents the most recently selected follicle (LYF: large yellow follicle).

4.6.2 Effect of dietary shea caterpillar meal on fertility and hatchability

The effect of dietary shea caterpillar meal on reproductive traits (fertility and hatchability) of Guinea fowl is presented in Table 4.8.

Table 4.8: Effect of dietary shea caterpillar meal on reproductive traits of Guinea fowls

Parameter	Dietary Treatments					SEM	P-Value
	SCM 0%	SCM 25%	SCM 50%	SCM 75%	SCM 100%		
Total AE	84.70[a]	53.70[b]	50.00[b]c	48.00[b]c	41.00[c]	3.33	<.001
Fertility (%)	58.60[a]	48.70[b]	41.40[bc]	36.20[c]	35.50[c]	2.450	<.001
Hatchability (%)	61.80	56.50	58.5	51.40	53.8	3.350	0.286

ABC: *Means with different superscripts in the same row are significantly different (P<0.05)****)***

AE- Average number of eggs laid.

Total number of eggs produced differed among the dietary treatments as was observed from the weekly hen-day egg production (Table 4.4). The highest (p<.001) number of eggs was laid by the Guinea hens fed the control diet as compared to the SCM diets. Guinea hens fed the SCM 25% diet recorded similar egg numbers as that of hens fed SCM 50% and SCM 75% diets but not SCM 100% diet. These eggs were set into the incubator after taking out those eggs that were misshaped and cracked. Fertility was significantly higher for eggs of the Guinea hens that were fed the control diet (58.60%) (Table 4.8) as compared to the other treatments. Eggs of Guinea hens fed SCM 25% diet also had a higher (p<.001) fertility as compared to that of the eggs incubated from birds fed SCM 75% and SCM 100% diets but not SCM 50% diet. Fertility of eggs for hens fed SCM 50% was however, similar to that of eggs from hens fed SCM 75% and SCM 100% diets. Fertility of eggs recorded was generally low.

Hatchability, regardless of the variability in fertility was not significantly different (P=0.286) among the dietary treatments. Hatchability values recorded for dietary treatments was considerably low ranging from 61.80% in the control to 51.40% in those hens fed SCM 75% diet (Table 4.8). Hatchability values of 58.50%, 56.50% and 53.80% respectively were recorded for eggs of Guinea hens fed SCM 50%, SCM 25% and SCM 100% diets.

4.7 Effect of Shea Caterpillar Meal on Keet Quality and Morphometric Characteristics

The effect of dietary shea caterpillar meal on the characteristics of keets of Guinea fowl is presented in Table 4.9.

Table 4.9: Effect of dietary shea caterpillar on keets characteristics of Guinea fowls

Parameter	Dietary Treatments					SEM	P- Value
	SCM 0%	SCM 25%	SCM 50%	SCM 75%	SCM 100%		
Keet BW (g)	30.53^{a}	29.37^{a}	30.03^{a}	29.53^{a}	25.87^{b}	0.670	0.004
Keet BL (cm)	16.00^{a}	15.27^{ab}	14.27^{bc}	15.27^{ab}	13.87^{c}	0.326	0.006
Keet SL (cm)	2.667^{a}	2.567^{a}	2.433^{ab}	2.433^{ab}	2.367^{b}	0.056	0.021
Keets QA	4.67	5.00	4.33	4.33	3.67	0.298	0.089

ABC: *Means with different superscripts in the same row are significantly different (P<0.05)***)**

BW- Body weight, BL- Body Length, SL- Shank Length, QA- Quality Assessment

Dietary treatments had significant (p<0.05) influence on keets characteristics (keets body weight, body length and shank length) except the keets quality assessment. Body weight was heavier (p<0.004) for keets hatched from Guinea hens that were fed the control and SCM diets except birds fed SCM 100% diet which recorded the lowest body weight (25.87 g) (Table 4.9). Body length was longer (p<0.006) for keets (16.0 cm) hatched from Guinea hens fed the control diet as compared to those hens fed SCM 50% (14.27 cm) and SCM 100% (13.87 cm) diets but not SCM 25% and SCM 75% diets which recorded similar values. Similar body length was also recorded for keets from hens fed SCM 25%, SCM 50% and SCM 75%, however, SCM 50% and SCM 100% had similar values for the keets body length. Shank length of keets was significantly (P=0.021) influenced by dietary treatments. Keets from Guinea hens fed the control and SCM 25% diets had longer keet shank length (2.67 cm and 2.57 cm respectively) as compared to those from hens fed SCM 100% diet but not SCM 50% and SCM 75% diets which also had shank values similar to that of SCM 100% diet. Quality of keets hatched was generally good as no significant differences (P=0.089) was observed among the dietary treatments. There were some keets which had their vent wet with white patches of droppings as shown in Plate 4.2. Keets from Guinea hens fed SCM 25% diet had the highest quality with a score of 5 (no deformity, active, good feathers).

Plate 4.2: Guinea keet with wet vent and white discharge

4.8 Effect of Shea Caterpillar Meal on Haematological Characteristics

Effect of dietary shea caterpillar meal on haematological characteristics is presented in Table 4.10.

Table 4.10: Effect of dietary shea caterpillar meal on haematological characteristics of Guinea fowl

Parameter	Dietary Treatments					SEM	P-Value
	SCM 0%	SCM 25%	SCM 50%	SCM 75%	SCM 100%		
HB (g/dl)	13.20	12.80	12.57	12.83	13.53	0.590	0.794
WBC(10^9/L	24.02	25.64	26.37	26.85	26.81	1.685	0.745
RBC(10^12/L)	2.240	2.177	2.127	1.950	1.987	0.108	0.331
MCV(FL)	131.5	132.0	132.2	133.4	128.6	3.09	0.843
MCH(pg.)2	41.40	43.10	44.20	40.20	38.73	1.678	0.225
MCHC(g/Dl	32.80	32.63	32.20	31.07	30.37	0.911	0.321
Lymph(10^9/L)	62.6	57.2	64.5	69.3	62.7	5.630	0.677
PLT(10^9/L)	20.0	24.7	27.70	27.70	35.7	3.79	0.134
HCT%/PCV	23.40	26.43	26.97	24.80	25.30	1.388	0.441

HB- Haemoglobin, WBC- White Blood Cells, RBC- Red Blood Cells, MCV- Mean Corpuscular Volume, MCH- Mean Corpuscular Haemoglobin, MCHC- Mean Corpuscular Haemaglobin Concentration, Lymph- Lymphocytes, PLT- Platelets, HCT- Haematocrit

All the haematological characteristics measured were not significantly (P>0.05) affected by the dietary treatments.

CHAPTER FIVE: DISCUSSION

5.1 Proximate Composition of Shea Caterpillar Meal and Experimental Diets

The appreciable level of crude protein (CP) obtained for the SCM which is comparable to the CP of fish meal gives an indication that the SC could replace fish meal in the diet of Guinea fowl. The CP obtained conforms to the CP levels of insects of the order Lepidoptera (Xiaoming et al., 2010) and was also similar to the 55.41% reported by Yapo et al. (2017). However, the CP level of SC obtained in this study was marginally lower than the 62% and 63% reported by Anvo et al. (2016a) and Anankware (2017) respectively. This could be attributed to the variations in the processing and storage methods (Womeni et al., 2012).

The metabolizable energy (ME) of 3229.8 kcal/kg of the SCM is considerably higher than 2580 kcal/kg of the fish meal as reported by NRC (1994). The ME obtained in this study is similar to that of Seidu et al. (2024). The ether extractive value of SCM is quite higher compared to 5.0% in fish meal (NRC, 1994) and could have influenced the relatively higher ME obtained in SCM than fish meal.

The CP levels of the dietary treatments ranged between 16.68 and 17% whilst the ME levels also ranged between 2750 and 2900 kcal/kg which conforms to the CP and energy required for optimum performance of laying Guinea hens (NRC, 1994; Nahashon et al., 2007). The crude fibre content increased as the level of SCM also increased and it ranged between 4.19% (control) and 4.36% (SCM 100%). The differences in the CF values could be attributed to the fibre levels of the dried SCM. This could explain why the CF levels increased with the increasing levels of SCM in the diets. The values of the proximate composition of the diets obtained give indication that the formula for the dietary treatments might have met the nutrient requirements of the laying Guinea fowl.

5.2 Effect of Shea Caterpillar Meal on Feed and Water Intake

Feed intake for week one (1) was influenced by the dietary treatments. Animals fed the control (0% SCM) and 25% SCM diets consumed similar amounts of the diets but consumed much higher feed than their counterparts offered diets containing higher inclusion levels of SCM (50%, 75%, 100%). This suggests that moderate substitution of fish meal with SCM (up to 25%) does not affect feed consumption, while higher levels reduce intake within the first week of consumption by Guinea fowl which corroborates the work by Seidu et al. (2024).

In week 2, feed intake recorded for birds that were fed the 25% SCM diet consumed more feed compared to other SCM treatment diets, though intake did not differ from the control diet (0% SCM). The group that had 100% replacement of fish meal with SCM recorded the least feed intake (505 g). Feed intake patterns similar to that of week 2 were noted in week 3. Laying Guinea fowl fed 0% to 50% SCM inclusion diets recorded a higher feed intake compared to their counterparts fed higher (75% and 100%) inclusion levels. Feed intake is highly influenced by dietary energy level (Classen, 2017). The diets used in this study had similar CP and energy levels for the SCM diets, therefore the differences in feed intake could possibly be the negative effect of texture and colour on consumption (Moula and Detilleux, 2019) of diets that had higher than 50% to full replacement of fish meal. The ether extract levels of the diets increased with increasing inclusion of the SCM which might have negatively influenced the texture of the diets. This corroborates the work by Parsons et al. (2009) that feed texture influenced feed intake of broiler chicken.

The work by Ham and Osono (2007) also revealed that feed consumption could be influenced by feed colour to extent that broilers fed with feed coloured with high wave length such as yellow and green consumed more than their counterparts with lower wave length (Goldsmith, 2006; Khosravinia, 2007). In this current study, the diets with higher levels of SCM (≥ 50%) appeared darker due to the dark nature of the SCM meal. The variations in feed intake could also be attributed to palatability of the diets fed. Feed intake was observed to decrease with increasing levels of SCM in the diets; the lower feed intake could be as a result of reduced palatability as the level of the SCM increased (≥ 50%). This might have accounted for the reduced feed intake observed in the diets that have higher SCM inclusion.

In week 7, feed intake was similar across all treatments except for the 100% SCM group, which again had relatively lower feed intake, underscoring potential limits to SCM when fully incorporated in a diet of laying Guinea fowl. In subsequent weeks, it was observed that feed intake was not remarkably influenced by the dietary treatments, suggesting that over time the laying Guinea hens adjusted to the diets which irradicated the variations in feed consumption that was attributed to palatability, texture, and colour in the early stages of introduction of the diets.

Ad libitum supply of water to avians is prerequisite for a successful eggs and meat production (Van Der Klis and de Lange, 2013) because freedom from thirst is one of the undeniable welfare requirements (Rault et al., 2016). The water consumption by laying Guinea fowl hens fed varying inclusion levels of SCM in their diets revealed interesting patterns which were to a larger extent could be influenced by some key production factors such as quantity of feed consumed, period of laying and quantity of eggs being laid.

The records of water consumption pattern for weeks 1, 8, 10, and 11 in this study show a similar consumption pattern. Thus, Guinea hens offered the control diet and 25% SCM diet drank more water than their counterparts fed the other diets. Water intake, to a great extent, is influenced by dietary compositions (Van Der Klis and de Lange, 2013) and dietary factors such as nutrient concentration, texture (granular or pelleted) and dietary fibre (Van Der Klis and de Lange, 2013). In this study, it was noted that the rate of water consumption was inversely proportional to the rate of replacement of fish meal by SCM in the diets. Thus, as the fish meal replacement by the SCM increased, water consumption decreased. This might be due to the fact that as the SCM inclusion increased feed intake decreased which most likely was due to the texture, colour and palatability associated with high percentage SCM-based diets (50%, 75%, and 100%) as was observed with the feed intake. This might suggest a lower preference or physiological need for water when laying Guinea hens were fed relatively higher SCM levels as a result of a corresponding reduction in feed intake.

Generally, the recurring increase in water consumption as the weeks go by suggests potential increase in metabolic and physiological processes which could be linked to increase in feed intake, aging effect and / or increasing rate in egg laying that demanded for more water. For instance, laying hens deprived of water for 6 hours led to an increase in frustration-induced aggression (Haskell et al., 2000).

The observed pattern in water intake highlights the importance of monitoring water consumption alongside dietary formulations involving SCM inclusions to ensure optimal hydration in Guinea hens.

5.3 Effect of Shea Caterpillar Meal on Egg Production

The weekly hen-day egg production (HDEP) of Guinea fowl studied was significantly influenced by the inclusion levels of shea caterpillar meal (SCM) across all the dietary treatments. Across most of the weeks, the control diet (0% SCM) produced significantly higher HDEP than any SCM-containing diet, a trend that persisted from week 2 to week 12.

The intermediate inclusion levels (25% and 50% SCM) diets sometimes produced HDEP values similar to the control diet, particularly in the early weeks (week 1), but diminished over time. Notably, birds on the 100% SCM diet consistently had the lowest HDEP.
The poor laying performance of Guinea hens fed higher levels of SCM could be due to limitations in their nutritional profile. While SCM offers a considerable protein and amino acid content and has been suggested as a viable alternative protein in poultry feed (Seidu et al., 2024), full replacement (SCM 100%) is likely to be insufficient to meet the precise nutrient and amino acid needs for sustained egg production in Guinea fowl.
Secondly, lower feed intake recorded for the animals fed higher levels of SCM could account for the poor laying performance. Reduced feed intake might have led to reduced uptake of essential nutrients such as CP, minerals and vitamins needed for the formation and development of eggs, consequently, lower egg production. According to Li et al. (2011), there is positive correlation between daily feed intake and HDEP to the extent that reduction in feed intake negatively impact on egg production.

Meanwhile, the effect of larvae of other insects (Black soldier fly) on egg production of Guinea hens shows that while moderate insect meal inclusion can maintain or even boost production, full replacement often results in reduced egg yield and efficiency (Kere et al., 2023; Veldkamp et al., 2024). This observation is consistent with the patterns observed in this present study but contrary to the work by Wamai et al. (2024) where laying hens fed 75% fly larvae included in a diet accelerated the onset of laying and increased total egg number, whereas lower or no inclusion of the insect larvae yielded lower outputs.

However, the overall laying performance obtained in this study (<46% HDEP) was low throughout the study period. The HDEP figures being under 46% across all the dietary treatments suggest that the laying performance was suboptimal, which could be due to disease infestation encountered within the 7^{th} and 8^{th} weeks of the experiment. The disease infestation caused a reduction in both feed and water intake which consequently impacted on HEDP.

This study has established a clear performance hierarchy for the five dietary treatments on HEDP of Guinea hens: Control > SCM 25% ≈ SCM 50% > SCM 75% > SCM 100%. This supports the principle that while partial replacement of conventional protein sources is feasible, total replacement with SCM may negatively affect laying performance.

5.4 Effect of Shea Caterpillar Meal on Egg Characteristics

The observed differences in egg weight among Guinea fowl fed varied levels of shea caterpillar meal (SCM) diets, with heavier eggs recorded for SCM 25%, SCM 50%, and control diets compared to SCM 75% and SCM 100% could be attributed to the nutritional uptake of the diets fed which influenced nutrients available for follicular development. Similar responses have been observed in other studies involving insect-based feed inclusion levels in poultry diets. A substantial variation in egg weight observed indicates that moderate inclusion levels of SCM in the diet of laying Guinea hens support better egg weight outcomes, while higher inclusion levels (75-100%) may reduce this benefit, possibly due to nutrient imbalance or anti-nutritional factors at high inclusion levels. Comparable research on insect-based proteins (such as fly larvae or other larvae meals) in Guinea fowl and other birds' diets supports that moderate inclusions can maintain or enhance egg production characteristics, but higher inclusion levels may reduce performance metrics (Kere et al., 2023).

Eggshell thickness did not significantly differ among treatments but showed a tendency to increase with higher SCM inclusion levels. This pattern suggests that while the quality parameter of shell thickness is not statistically impacted by SCM inclusion, there may be a physiological response to the diet composition affecting shell deposition. Majority of the eggshell composition is calcium, so a diet with higher level of Ca is more likely to increase eggshell thickness (Yapo et al., 2017). It is estimated that cuticles of the shea caterpillar which is rich in Ca might have increased the Ca levels of the diet and thus the eggshell. This could be evidenced by the high ash contents of the diets which ranged between 4.7% and 8.0% as the fish meal was replaced by the SCM at 0% to 100%.

Other egg quality traits such as dry yolk weight, egg length, egg width, albumen height, wet and dry shell weights, and wet yolk weight were not significantly influenced by SCM diet variations, suggesting that these parameters were not clearly influenced by the varied inclusion levels of dietary SCM.

5.5 Effect of Shea Caterpillar Meal on Reproductive Traits

5.5.1 Effect of dietary shea caterpillar meal on folliculogenesis

The developmental stage of the follicles shown in Plate 4.1 indicates that Guinea fowl fed the control and SCM 25% diets had their egg follicles developed ahead of the other dietary treatments. The maintenance of a small cohort of viable, undifferentiated (pre-hierarchical) follicles ensures sequence (clutch) of egg production. One follicle is selected from the cohort usually on daily routine to start fast growth and final differentiation before ovulation (Johnson, 2015).

Guinea fowl fed the SCM 100% diet had their follicular development late as compared to the birds fed the other diets which is evidenced by the absence of F5 - F1 follicles, an indication that Guinea hens fed the SCM diet were not ready to lay eggs at the time when the respective hens were sacrificed for determination of folliculogenesis. The presence of good number of small white follicles (SWF) gives an indication of developing follicles for future egg laying. Guinea hens fed on the control and SCM 25% diets had F1 follicles and indicated that there was a matured follicle ready to be laid whereas the other dietary treatments had no F1 follicle. The follicular development of Guinea hens fed the control and SCM 25% diets was similar to that reported by Johnson (2015). The variations in the number of the respective follicles are attributed mainly to nutrition and individual differences. Nutrition plays a role in the attainment of sexual maturity and follicle development (Seol et al., 2006), release of gonadotropin hormones (LH and FSH) (Saleh et al., 2021) and the development of the egg follicles (Novero and Asem, 1993; Johnson, 2014). Whereas good plane of nutrition promotes early sexual maturity and egg follicle development, poor nutrition delays the development. It was generally observed that the follicular development of the Guinea hens fed the dietary shea caterpillar meal delayed as the level of replacement of the fish meal increased from 25% to 100 % of the SCM. Several growth factors are produced in the avian ovary which play diverse roles in the development of the ovary and in its efficient functioning. These factors (Insulin-like growth factor family (IGF), the epidermal growth factor family (EGF), the Transforming growth factor-β family (TGF-β), Fibroblast growth factors (FGF), the Tumour necrosis factor-α (TNF-α)) are identified either in the granulosa and/or theca compartments of ovarian follicle and in the embryonic and juvenile ovary (Onagbesan et al., 2009). The intra-ovarian roles reported for the different growth factors include regulation of cell proliferation, steroidogenesis, follicle selection, modulation of gonadotrophin action, control of ovulation rate, cell differentiation, and production of growth factors (Onagbesan et al., 2009).

Although the nutrient contents of the diets were similar (Table 4.1), it appears as though the dietary shea caterpillar meal was not fully digested into nutrients and made available to the Guinea fowl for utilisation, probably due to strong bond with other constituents in the diet or antinutritional factors which might have accounted for the delay in ovarian follicular development. This observation gives strong reason for digestibility trial to be conducted on the shea caterpillar meal to elucidate the potential setback in digestibility and nutrient availability.

5.5.2 Effect of dietary shea caterpillar meal on fertility and hatchability

The variation in the total number of eggs laid by the Guinea hens fed the control diet as compared to the SCM diets could be attributed to dietary influence of the SCM. As observed from section 5.5.1, Guinea hens fed the SCM diets had their follicular development delayed and this is assigned as the reason for the relatively lower total eggs recorded for those birds, although, the birds had started laying not for long period and optimum performance was yet to be realized.

Fertility in Guinea fowl is controlled by a number of factors including acceptability of the Guinea hen by the Guinea cock for marriage, mating ratio and the production system employed. The mating ratio of 4 Guinea hens: 1 Guinea cock was the recommended ratio for mating (Giri et al., 2014; Atawalna et al., 2022), however, within the few hens available, some of them were not accepted by the cock for marriage and mating and such hens will lay eggs that are not fertile as observed by Annor et al. (2012). The significantly higher fertility of eggs of the Guinea hens that were fed the control diet (58.60%) was similar to 56.9% and 58.46% reported by Adu-Aboagye et al. (2020) and Yamak et al. (2015) but lower as compared to best value (48%) recorded for birds fed the SCM diets. Araujo et al. (2023) reported relatively higher fertility values of 75.6% and 65.6% for eggs that were stored for 7 and 14 days respectively before incubation.

Hatchability, was not significantly different among the dietary treatments regardless of the variability in values of fertility obtained. Hatchability values recorded for dietary treatments was considerably low ranging from 61.80% in the control group to 51.40% in those hens fed SCM 75% diet (Table 4.8). Hatchability values of 58.50%, 56.50% and 53.80% was respectively recorded for eggs of Guinea hens fed SCM 50%, SCM 25% and SCM 100% diets. Values of hatchability obtained in this study are lower than 78.4% and 68.1% reported by Araujo et al. (2023) for Guinea fowl eggs stored for 7 and 14 days respectively, and also 80% and 82.2% reported by Yamak et al. (2015) and Adu-Aboagye et al. (2020) respectively. Fertility and hatchability are influenced by hormonal levels (progesterone, FSH and LH) (Natsir et al., 2021) and could account for variations.

The lower hatchability particularly in Guinea hens fed the SCM diets is attributed partly to the increased egg shell thickness arising from increased calcium deposit from the shea caterpillar which affected the pipping ability of the keets to the outside. This resulted in a number of dead in shell of the keets. Future work may factor the calcium level of the shea caterpillar in the overall diet in order not to increase the eggshell thickness unnecessarily to disadvantage the hatchability.

5.6 Effect of Shea Caterpillar Meal on Keet Quality and Morphometric Characteristics

Keet quality score was not negatively impacted by the dietary treatments as keets hatched were generally active and healthy. Few keets hatched from SCM 100% diet, had white faeces "pasty butt" (Plate 4.2) which is a condition usually attributed to poorly digested feed, stress and/or infections (Berhanu & Fulasa, 2020; Greenacre, 2021; Morishita & Porter Jr, 2021). Since keets had not started feeding, the cause could be attributed to infections or stress from pipping through the hard eggshell which also makes keets exhausted and less active post-hatch.

5.7 Effect of Shea Caterpillar Meal on Haematological Characteristics

Haematological indices (either wholly or in isolation) define an organism's health or physiological state (Etim et al., 2014). Among the major external determinants or influencers of these indices are stage of development, breed, dietary compositions and other management systems (Etim et al., 2014; Obese et al., 2018; Drobot et al., 2019). For instance, haemoglobin (HB) and white blood cells (WBC) levels were found to increase with age in helmeted Guinea fowl (Obese et al., 2018). In this study, the (HB) levels were similar and this could be attributed to the similar age group of the Guinea fowl used. The CP levels in the five diets fed to the animals were also similar (16.68 – 17.02% CP). The similar CP levels might have also influenced the similar HB levels observed in the laying Guinea fowl because according to Tateishi et al. (2023), HB levels increase with increasing dietary CP, suggesting that diets with similar CP levels are more likely to yield similar HB levels. The HB levels obtained in the laying Guinea fowl from each of the dietary treatments is comparable to the reference range (7.6 – 13.5 g/dL) for Guinea fowl (Etim et al., 2014).

The red blood cell (RBC) levels were also similar and were all within the reference range (2.0 – 3.0 $x10^6/\mu L$) for Guinea fowl except for the 75% SCM and 100% SCM that dipped just below the minimum value of 2.0×10^6 µL. RBCs are derived from haemopoietic stem cells in bone marrow which undergoes series of maturation to be able to transport oxygen from the lungs to all parts of the body and carbon dioxide (CO_2) back from the peripheral parts of the body to the lungs to be excreted (Klinken, 2002). This is made possible through the presence of haemoglobin contained in the cells.

Leucocytes or white blood cells (WBC) form the body's defense system against possible invasion of pathogens and are further classified as granulocytes and agranulocytes depending on mechanism of attack against pathogens (Glenn and Armstrong, 2019). The WBC numbers observed in this study were similar irrespective of the diet fed and were comparable to the reference range (15 – 35 $x10^9/L$) for Guinea fowl.

The mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC) and packed cell volume (PCV) were all similar across the dietary treatments and fell within the reference ranges for Guinea fowl (Etim et al., 2014). The implications are that the red cells were of normal size, healthy haemoglobin per cell, and normal haemoglobin concentrations and that the animals were free from anaemia.

Lymphocytes (T and B cells) are popularly referred to as the killer cells due to their fundamental role in immune response of fighting and destroying infectious microorganisms and other foreign materials that enter the body (Orakpoghenor et al., 2019). The lymphocyte percentages observed in this study showed no significant variation across treatment groups and remained within the established reference range of 50–70% for Guinea fowl (Etim et al., 2014). This suggested that the immune cells of the Guinea fowl fed varied inclusion levels of SCM were all normal.

Platelets (also known as thrombocytes) are small colourless cell fragments which prevent bleeding whenever there is a cut on the body. The normal platelet counts in Guinea fowl ranges from 20 – 40 $x10^9$/L (Etim et al., 2014). Juxtaposing the platelets reference range with the values obtained in this study (20.0 – 35.7 $x10^9$/L), it could be concluded that no clotting issues were suspected since adequate supply of platelets in circulation is essential in order to maintain vascular integrity and also facilitate thrombus formation at sites of vascular injury to curtail excessive loss of blood (Daly, 2011). A constant balance between thrombopoiesis, platelet use and senescence is essential to maintain sufficient levels of platelets in the blood.

CHAPTER SIX: SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary

6.1.1 Effect of SCM inclusion levels on feed and water intake of laying Guinea hens

Feed intake in laying Guinea fowl was influenced by dietary levels of shea caterpillar meal (SCM), especially in the early weeks. Birds fed 0% and 25% SCM consumed more feed than those on higher inclusion levels (≥50%), likely due to changes in diet texture, colour, and energy density. By week 7, feed intake differences diminished, with only the 100% SCM group consistently showing lower intake. Over time, birds appeared to adapt to the diets, possibly driven by increased energy demands for egg production.

Water consumption in laying Guinea fowl was generally higher in birds fed 0% and 25% shea caterpillar meal (SCM) diets compared to those on higher inclusion levels (≥50%). This inverse relationship between SCM levels and water intake is likely due to reduced feed consumption and higher dietary energy content in high-SCM diets. Water intake patterns also increased over time, possibly due to rising metabolic demands and egg production. These findings emphasize the need to monitor water intake when using SCM in diets to ensure proper hydration and bird welfare.

6.1.2 Effect of SCM inclusion levels on HEDP of laying Guinea hens

Hen-day egg production (HDEP) in Guinea fowl was significantly affected by the level of shea caterpillar meal (SCM) in the diet. Birds on the control (0% SCM) diet consistently had the highest HDEP, while those on 100% SCM had the lowest. Birds on moderate inclusion levels (25–50%) showed comparable performance to the control in early weeks but declined over time. Reduced feed intake and possible nutrient imbalances in high-SCM diets probably contributed to the poor laying performance. A disease outbreak in weeks 7–8 also negatively impacted overall productivity, which remained below 46% HDEP across all treatments. The performance trend followed: Control > 25% ≈ 50% > 75% > 100% SCM, indicating that full SCM replacement may impair egg production.

6.1.3 Effect of SCM inclusion levels on egg characteristics of laying Guinea hens

The egg weight varied significantly with different levels of shea caterpillar meal (SCM) in the diet. Moderate inclusion levels (25% and 50%) and the control diet (0%) yielded heavier eggs compared to higher inclusion levels (75% and 100%), likely due to better nutrient balance at moderate levels. This aligns with findings from similar studies on insect-based feeds. Although eggshell thickness did not differ significantly, it tended to increase with higher SCM levels, possibly due to increased dietary calcium from the calcium-rich cuticles of the shea caterpillar. Other egg quality traits—including yolk weight, egg dimensions, albumen height, and shell weights—were not significantly affected by SCM inclusion, indicating minimal influence of the diet on these parameters.

6.1.4 Effect of SCM inclusion levels on folliculogenesis of laying Guinea hens

Guinea fowl fed 0% and 25% SCM diets showed advanced follicular development, indicating readiness for egg laying, while higher SCM levels (75–100%) delayed follicular development, likely due to nutritional inadequacies as a result of reduced feed intake. Good nutrition supports early sexual maturity and follicle growth, influenced by intra-ovarian growth factors regulating key reproductive processes.

6.1.5 Effect of SCM inclusion levels on fertility, hatchability and keet quality of laying Guinea hens

Guinea hens on the control diet laid more eggs with higher fertility due to better follicular development and mating success. SCM diets delayed follicle development and reduced fertility. Hatchability was low across all diets, with SCM diets showing poorer outcomes, likely due to increased eggshell thickness from excess calcium, hindering keet hatching. Keet characteristics such as body weight, body length, and shank length were influenced by the inclusion levels of the SCM. The keets from birds fed SCM 100% diet had poorer body weight compared to their counterparts offered SCM 0% to 75% inclusion levels. Keets body and shank lengths were relatively lower for birds fed SCM 100% compared to those fed the control diet but similar to the other SCM diets. Keet quality assessment score was generally similar for all the dietary treatments; although few keets from SCM 100% diet had white pasty feaces at their vent.

6.1.6 Effect of SCM inclusion levels on haematological indices of laying Guinea hens

Haematological indices in Guinea fowl fed varying levels of shea caterpillar meal (SCM) diets remained largely within normal reference ranges, indicating good health. Haemoglobin, RBC, WBC, and other red cell indices (MCV, MCH, MCHC, PCV) showed no significant differences, likely due to similar age and dietary protein levels. Lymphocyte and platelet counts were also normal across treatments, suggesting unaffected immune function and blood clotting capacity. Slight RBC reduction in 75% and 100% SCM diets may indicate marginal effects at higher inclusion levels.

6.2 Conclusions

6.2.1 Effect of SCM inclusion levels on feed and water intake of laying Guinea hens

- SCM inclusion affects feed intake early on: Higher levels (≥50%) of shea caterpillar meal in the diet initially reduce feed intake in laying Guinea fowl, probably due to sensory changes (texture, colour) and energy density.
- Lower SCM levels (0–25%) are more preferably consumed than their counterparts, suggesting better acceptance or preference for these formulations.
- Adaptation to SCM diets occurs over time: Feed intake differences lessen by week 7, indicating birds adjust to the diets, except in the 100% SCM group, which continues to show reduced intake.
- High SCM levels may limit feed intake long-term: Persistent lower intake in the 100% SCM group may affect overall performance, pointing to a possible upper limit for SCM inclusion.
- Energy demands may drive dietary adaptation: As laying progresses, birds may overcome initial aversions to meet their nutritional and energy needs for egg production.
- The study demonstrates that increasing levels of shea caterpillar meal (SCM) in the diets of laying Guinea fowl tend to reduce water consumption, likely due to associated reductions in feed intake and increased dietary energy density.
- Additionally, water intake naturally rises over time, possibly reflecting increased metabolic activity and egg production.

- These results highlight the importance of closely monitoring water consumption in birds to ensure adequate hydration and support optimal health and productivity.

6.2.2 Effect of SCM inclusion levels on HDEP of laying Guinea hens

- It can be concluded that complete replacement of conventional fishmeal with shea caterpillar meal (SCM) negatively affects hen-day egg production (HDEP) in laying Guinea fowl.
- Partial replacement (up to 25%) of conventional protein with SCM may be viable, but full substitution is not recommended for sustaining optimal laying performance.
- Moderate SCM inclusion levels (25–50%) can maintain egg production comparable to 0% SCM inclusion diets in the short term, their long-term use results in a decline in performance.
- The observed reduction in egg laying at higher inclusion levels (75–100%) is likely caused by lower feed intake and potential nutrient imbalances.
- Additionally, external factors such as disease outbreaks can further compromise egg production.

6.2.3 Effect of SCM inclusion levels on egg characteristics of laying Guinea hens

- Egg weight was significantly influenced by SCM levels, with the heaviest eggs produced on the 0%, 25%, and 50% inclusion diets, suggesting better nutrient balance at moderate SCM levels.
- Higher SCM levels (75% and 100%) resulted in lighter eggs, indicating that excessive inclusion may compromise egg quality.

- Eggshell thickness tended to increase with higher SCM inclusion, likely due to the calcium-rich cuticles of the shea caterpillar, although differences were not statistically significant.
- Other egg quality parameters—such as yolk weight, egg dimensions, albumen height, and shell weight—were not significantly affected by SCM, suggesting these traits are relatively stable across inclusion levels.
- Moderate SCM inclusion appears optimal for maintaining good egg weight without negatively affecting other quality traits.

6.2.4 Effect of SCM inclusion levels on folliculogenesis of laying Guinea hens

- Good nutrition supports early sexual maturity and follicular growth.
- Guinea fowl fed 0% and 25% SCM diets showed advanced follicular development.
- Higher SCM levels (75–100%) delayed follicular development, likely due to nutritional inadequacies resulting from reduced feed intake.

6.2.5 Effect of SCM inclusion levels on fertility, hatchability and keets quality of laying Guinea hens

- Control diet (0% SCM) resulted in the highest egg production and fertility, likely due to improved follicular development and effective mating.
- SCM inclusion negatively affected reproductive performance by delaying follicle development and reducing fertility rates.
- Hatchability was generally low across all treatments, with the poorest results observed in high-SCM diets.

- Increased eggshell thickness in SCM-fed birds may have contributed to lower hatchability by physically impeding keet emergence.
- High levels of dietary calcium from SCM may have unintended negative effects on embryonic development and hatching success.
- Whereas SCM levels of ≤50% may not have detrimental effect on keet quality characteristics, SCM levels ≥75% should be used with caution to avoid negative impacts on keets.

6.2.6 Effect of SCM inclusion levels on haematological indices of laying Guinea hens

- Haematological indices (haemoglobin, RBC, WBC, MCV, MCH, MCHC, PCV) mostly remained within normal reference ranges across all SCM diets, indicating overall good health of the birds.
- No significant differences were observed in most blood parameters, likely due to similarities in bird age and dietary protein content across treatments.
- Lymphocyte and platelet counts stayed within normal limits, suggesting that immune function and blood clotting ability were not compromised by SCM inclusion.
- Slight reductions in RBC counts at 75% and 100% SCM levels may point to marginal adverse effects at higher inclusion rates.

6.3 Recommendations

6.3.1 Effect of SCM inclusion levels on feed and water intake of laying Guinea hens

- Limit SCM inclusion to ≤50% in laying Guinea fowl diets to avoid reduced feed and water intake and ensure adequate nutrient consumption, especially during early laying periods.
- Lower inclusion levels (0–25%) of SCM should be adopted to possibly improve palatability, feed acceptance and water intake, particularly when introducing SCM into the diet for the first time.
- Higher inclusion levels (≥ 50%) of SCM diets should be discouraged, as persistent low feed and water intake at this level can negatively impact bird performance and productivity (egg laying and hatchability).

6.3.2 Effect of SCM inclusion levels on HDEP of laying Guinea hens

- SCM inclusion for the diets of laying Guinea fowl should be limited to 25% to avoid adverse effects on hen-day egg production (HDEP).
- Full replacement (100%) of fish meal with SCM should be discouraged, as it significantly reduces egg production.
- Use moderate inclusion levels (25–50%) with caution, and only for short-term feeding, as prolonged use may lead to performance decline.
- Energy levels in diets with SCM inclusion should be well considered, as excess energy in diets of laying Guinea hen reduces feed and water intake
- Implement health management practices to mitigate the impact of disease outbreaks, which can further compromise productivity, especially laying and hatchability.

6.3.3 Effect of SCM inclusion levels on egg characteristics of laying Guinea hens

- Incorporate SCM at moderate levels (25%–50%) to maintain optimal egg weight and overall egg quality.
- Avoid high SCM inclusion (75%–100%), as it can lead to reduced egg weight, indicating a potential nutrient imbalance.
- The cuticle of shea caterpillar is rich in Ca; therefore, its inclusion in the diets of laying hens should be closely monitored to properly regulate eggshell thickness

6.3.4 Effect of SCM inclusion levels on folliculogenesis of laying Guinea hens

- Use SCM at low inclusion levels (up to 25%) to support healthy follicular growth
- Avoid high SCM inclusion levels (75%–100%), as they may delay follicular development due to possible deficiencies in essential nutrients.

6.3.5 Effect of SCM inclusion levels on fertility, hatchability and keet quality of laying Guinea hens

- Lower SCM inclusion levels (≤25%) should be used to support optimal egg production, fertility, and hatchability.
- The use of SCM inclusion (≥75%) for laying Guinea hens should be discouraged, as it may impair reproductive performance and significantly reduce fertility and hatchability.

- Dietary calcium levels for laying Guinea hens should carefully be considered, especially when using SCM, to prevent excessive eggshell thickness that could hinder keet emergence and affect keet quality.

6.3.6 Effect of SCM inclusion levels on haematological indices of laying Guinea hens

- Continue to monitor blood parameters to ensure birds maintain good health across different dietary treatments.
- Low to moderate levels (≤50%) SCM is encouraged, as these did not significantly affect haematological indices or compromise immune and clotting functions.
- Due to a slight reduction in RBC counts observed in the laying Guinea hens fed high SCM (≥75%), their inclusion should be keenly observed to prevent subclinical deficiencies.
- Further research should explore the long-term haematological and biochemical effects of high SCM inclusion to confirm safety thresholds for Guinea fowls.

REFERENCES

Abdul-Rahman, I. I., Obese, F. Y., & Jeffcoate, I. A. (2016). Developmental changes in the histological structure of the testes, and testosterone profiles in male guinea fowls (Numida meleagris). *Theriogenology*, 101, 114-122.

Aboah, J., & Enahoro, D. (2022). A systems thinking approach to understand the drivers of change in backyard poultry farming system. *Agricultural Systems*, 202, 103475.

Abu, F., Jabar, J., & Yunus, A. R. (2015). Modified of UTAUT theory in adoption of technology for Malaysia small medium enterprises (SMEs) in food industry. *Australian Journal of Basic and Applied Sciences*, 9(4), 104-109.

Abu, O. D., Olude, O. M., & Obayuwana, H. O. (2021). Effect of methanol extract of Citrullus lanatus seed on hematological profile and tissue histology of normal Wistar rats. *Advanced Research Journal of Medical and Clinical Science*, 7(07), 608-615.

Adeyeye, E. I., & Adesina, A. J. (2014). Proximate, mineral compositions and mineral safety index of eight organs of guinea-fowl (Numidia meleagris). *Frontiers in Food Science and Technology*, 1(1), 7-13.

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).

Adu-Aboagye, G., Nyameasem, J. K., Ahiagbe, K. M. J., Ansah, K. O., Zagbede, G. A., & Agbe, K. K. (2020). Reproductive traits of the indigenous Guinea fowl under tropical humid conditions; the effect of egg size. *Livestock Research for Rural Development, 32, 4.*

Aerts, J. M. J., & Bols, P. E. J. (2010). Ovarian follicular dynamics: a review with emphasis on the bovine species. Part I: Folliculogenesis and pre-antral follicle development. *Reproduction in Domestic Animals*, 45(1), 171-179.

Agarwal, A., Gupta, S., & Sharma, R. K. (2015). Role of oxidative stress in female reproduction. *Reproductive Biology and Endocrinology*, 3, 1-21.

Agbolosu, A. A., Teye, G. A., Jebuni, S. N., Ansah, T., & Naandam, J. (2012). Comparative Study of Growth and Laying Performance of Indigenous Layer Guinea Fowls (Numinda Meleagris) From Upper East, Upper West and Northern Regions of Ghana.

Agboola, A. K., Olaniyi, O. M., Aliyu, S., & Ayanwale, B. A. (2013). Increasing livestock production in Nigeria: development of cost-effective models for bird-egg incubator.

Ahaotu, E. O., Nwafor, C., Onyebuchukwu, P. A., & Okpara, O. (2019). Carcass, organ weights and egg quality characteristics of guinea fowl layers fed varying levels of butterfly pea leaf (Centrosema Pubescens) meal. *Sustainability, Agri, Food and Environmental Research*, 7(1), 37-51.

Ahiwe, E. U., Omede, A. A., Abdallh, M. B., & Iji, P. A. (2018). Managing dietary energy intake by broiler chickens to reduce production costs and improve product quality. *Animal Husbandry and Nutrition*, 115, 145.

Ahmad, R. S., Imran, A., & Hussain, M. B. (2018). Nutritional composition of meat. *Meat Science and Nutrition*, 61(10.5772), 61-75.

Akhigbe, R. E., Ebiwonjumi, O. S., Ajayi, L. O., & Ajayi, A. F. (2018). Codeine alters female reproductive function by targeting ovarian steroidogenesis and folliculogenesis via the induction of oxidative stress, inflammation, and apoptosis. *Reproductive Toxicology*, 109, 1-9.

Akhtar, S., Ismail, T., Layla, A., Hussain, M., & Qamar, M. (2022). An overview of plant-based protein rich products. *Plant Protein Foods*, 27-60.

Amao, S. R., Ojedapo, L. O., Oso, O. E., Salah, M., Boudiche, S., Ameur, M. & Bornaz, S. (2015). Evaluation of two commercial broiler strains differing in efficiency of feed utilization. *Journal of New Sciences*, 14.

Anankware, J. P. (2017). Neglected and underutilised insects of Ghana: identification, spatial distribution and utilisation for food, feed and nutrition (Doctoral dissertation).

Anankware, J. P., Roberts, B. J., Cheseto, X., Osuga, I., Savolainen, V., & Collins, C. M. (2021). The nutritional profiles of five important edible insect species from West Africa—An analytical and literature synthesis. *Frontiers in Nutrition*, 8, 792941.

Anankware, P. J., Fening, K. O., Osekre, E., & Obeng-Ofori, D. (2015). Insects as food and feed: A review. *International Journal of Agricultural Research and Review*, 3(1), 143-151.

Ankamah-Yeboah, I., Jacobsen, J. B., & Olsen, S. B. (2018). Innovating out of the fishmeal trap: The role of insect-based fish feed in consumers' preferences for fish attributes. *British Food Journal*, 120(10), 2395-2410.

Annor, S.Y., Apiiga, Y. & Ahiaba, J. (2012). *A Handbook on Guinea fowl Production in Ghana*, 1st Edition. Qualitype Limited. Accra. Pp 1 – 91.

Anvo, M. P. M., Toguyéni, A., Otchoumou, A. K., Zoungrana-Kaboré, C. Y., & Kouamelan, E. P. (2016). Nutritional qualities of edible caterpillars Cirina butyrospermi in southwestern of Burkina Faso. *International Journal of Innovation and Applied Studies*, 18(2), 639.

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.

Archer, G. S., & Mench, J. A. (2014). Natural incubation patterns and the effects of exposing eggs to light at various times during incubation on post-hatch fear and stress responses in broiler (meat) chickens. *Applied Animal Behaviour Science*, 152, 44-51.

Assersohn, K., Brekke, P., & Hemmings, N. (2021). Physiological factors influencing female fertility in birds. *Royal Society Open Science*, 8(7), 202274.

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., Salifu, S., Panyan, E. K., Al-Hassan, B. I., Ahiagbe, M., & Yeboah, F. (2016). Characteristics of guinea fowl production systems in northern Ghana. A baseline study of 20 districts in northern Ghana. *Livestock Research for Rural Development*, 28(8), 1-12.

Ayo, O. Y., Abiona, J., Egbeyale, L., Fafiolu, A., Bamidele, L., & Fatola, O. (2021). Effect of dietary supplementation of Moringa oleifera leaf meal on blood profile, haemagglutination potential and testicular activities of rabbits. *Pol. J. Nat. Sci*, 36(1), 95-106.

Ayoola, S. O. (2011). Haematological characteristics of Clarias gariepinus (Buchell, 1822) Juveniles fed with poultry hatchery waste. *Iranica Journal of Energy and Environment*, 2(1), 18-23.

Badkillaya, R. R., Tippana, A., Basivi, P. K., & Pasupuleti, V. R. (2021). Importance and Application of Biotechnology in Insects. In Introduction to Insect Biotechnology (pp. 45-64). Cham: Springer International Publishing.

Bama, H. B., Dabire, R. A., Ouattara, D., Niassy, S., Ba, M. N., & Dakouo, D. (2018). Diapause disruption in Cirina butyrospermi Vuillet (Lepidoptera, Attacidae), the shea caterpillar, in Burkina Faso. *Journal of Insects as Food and Feed*, 4(4), 239-245.

Bashir, L., Ossai, P. C., Shittu, O. K., Abubakar, A. N., & Caleb, T. (2015). Comparison of the nutritional value of egg yolk and egg albumin from domestic chicken, guinea fowl and hybrid chicken. *American Journal of Experimental Agriculture,* 6(5), 310.

Berhanu, G., & Fulasa, A. (2020). Pullorum disease and fowl typhoid in poultry: a review. *Br J. Poult Sci*, *9,* 48-56.

Bhogoju, S., Nahashon, S., Wang, X., Darris, C., & Kilonzo-Nthenge, A. (2018). A comparative analysis of microbial profile of Guinea fowl and chicken using metagenomic approach. PloS one, 13(3), e0191029.

Biasato, I., Gasco, L., De Marco, M., Renna, M., Rotolo, L., Dabbou, S. & Schiavone, A. (2017). Effects of yellow mealworm larvae (Tenebrio molitor) inclusion in diets for female broiler chickens: implications for animal health and gut histology. *Animal Feed Science and Technology*, 234, 253-263.

Boko, C. K., Kpodekon, T. M., Duprez, J. N., Imberechts, H., Taminiau, B., Bertrand, S., & Mainil, J. G. (2013). Identification and typing of Salmonella enterica serotypes isolated from guinea fowl (Numida meleagris) farms in Benin during four laying seasons (2007 to 2010). *Avian Pathology*, 42(1), 1-8.

Bonnet, A., Cabau, C., Bouchez, O., Sarry, J., Marsaud, N., Foissac, S., & Mandon-Pepin, B. (2013). An overview of gene expression dynamics during early ovarian folliculogenesis: specificity of follicular compartments and bi-directional dialog. *BMC Genomics*, 14, 1-19.

Bougma, A., Bazié, B. S. R., Traoré, E., Parkouda, C., Gnankiné, O., & Bassolé, I. H. N. (2021). Chemical composition, energy and nutritional values, digestibility and functional properties of defatted flour, protein concentrates and isolates from Carbula marginella (Hemiptera: Pentatomidae) and Cirina butyrospermi (Lepidoptera: Saturniidae). *BMC Chemistry*, 15(1), 46.

Brown, P. A., Touzain, F., Briand, F. X., Gouilh, A. M., Courtillon, C., Allée, C. & Eterradossi, N. (2016). First complete genome sequence of European turkey coronavirus suggests complex recombination history related with US turkey and guinea fowl coronaviruses. *The Journal of General Virology*, 97(Pt 1), 110.

Cartoni, A., Dal Bosco, A., Mattioli, S., Ranucci, D., & Castellini, C. (2018). Mobile poultry processing unit as a resource for small poultry farms: planning and economic efficiency, animal welfare, meat quality and sanitary implications. *Animals*, 8(12), 229.

Chavarro, J. E., Rich-Edwards, J. W., Rosner, B. A., & Willett, W. C. (2015). A prospective study of dietary carbohydrate quantity and quality in relation to risk of ovulatory infertility. *European Journal of Clinical Nutrition*, 63(1), 78-86.

Classen, H. L. (2017). Diet energy and feed intake in chickens. *Animal Feed Science and Technology*, 233, 13-21.

Cooper, C. B., Voss, M. A., Ardia, D. R., Austin, S. H., & Robinson, W. D. (2011). Light increases the rate of embryonic development: implications for latitudinal trends in incubation period. *Functional Ecology*, 25(4), 769-776.

Council, N. R. (1994). Nutrient Requirement of Poultry. 9th revised editionNational Academic Press. *Washington, DC, USA*.

Dahouda, M., Toleba, S. S., Youssao, A. K. I., Kogui, S. B., Aboubakari, S. Y., & Hornick, J. L. (2015). Guinea fowl rearing constraints and flock composition under traditional management in Borgou Department, Benin. *Family Poultry*, 17(1&2), 3-14.

Daly, M. E. (2011). Determinants of platelet count in humans. *Haematologica*, *96*(1), 10.

Deutz, N. E., Bauer, J. M., Barazzoni, R., Biolo, G., Boirie, Y., Bosy-Westphal, A., & Calder, P. C. (2014). Protein intake and exercise for optimal muscle function with aging: recommendations from the ESPEN Expert Group. *Clinical Nutrition*, 33(6), 929-936.

Dharani, P., Ushakumary, S., Sundaram, V., Joseph, C., & Ramesh, G. (2016). Morphological Analysis of Testis of the Guinea Fowl (Numida meleagris) Under Tropical Savannah Climate of India. *International Journal of Morphology*, 36(3).

Dobermann, D., Swift, J. A., & Field, L. M. (2017). Opportunities and hurdles of edible insects for food and feed. *Nutrition Bulletin*, 42(4), 293-308.

Donkor, M. N., Mosobil, R., Abaah, E. A., Kanati, C., Akabanda, F., & Donkor, A. M. (2021). Potential of shea fruit-based ingredients for the feed industry. *Agriculture & Food Security*, 10, 1-10.

Drobot, G.P., Trubacheva, V.S., Zabiyakin, V.A., Popova, O.V. & Yu Smolentsev, S. (2019). Comparative analysis of haematological parameters of guinea fowls of different breeds and populations. IOP Conference series: *Earth and Environmental Science*, 315 (4).

Dulac, C., & Kimchi, T. (2017). Neural mechanisms underlying sex-specific behaviors in vertebrates. *Current Opinion in Neurobiology*, 17(6), 675-683.

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(1), 11-16.

Ellerby, D. J., Henry, H. T., Carr, J. A., Buchanan, C. I., & Marsh, R. L. (2011). Blood flow in guinea fowl Numida meleagris as an indicator of energy expenditure by individual muscles during walking and running. *The Journal of Physiology*, 564(2), 631-648.

Eltayeb, N. M., Yousif, I. A., Elamin, K. M., & Hamid, M. A. (2015). Determination of growth performance and carcass characteristics of Sudanese guinea fowl (Numida Meleagris) in different location. *Journal of Animal Science Advances*, 5(11), 1473-1479.

Esiobu, N. S., Onubuogu, G. C., & Okoli, V. B. N. (2014). Determinants of income from poultry egg production in Imo State, Nigeria: an econometric model approach. *Global Advanced Research Journal of Agricultural Science*, 3(7), 186-199.

Esonu, B. O., Opara, M. N., Okoli, I. C., Obikaonu, H. O., Udedibie, C., & Iheshiulor, O. O. M. (2006). Physiological response of laying birds to Neem (Azadirachta indica) leaf meal-based diets: body weight organ characteristics and haematology. *Life Science Journal*, 4(2), 37-41.

Etim, N. N., Williams, M. E., Akpabio, U., & Offiong, E. E. (2014). Haematological parameters and factors affecting their values. *Agricultural Science*, 2(1), 37-47.

Freeman, B. G., & Class Freeman, A. M. (2014). Rapid upslope shifts in New Guinean birds illustrate strong distributional responses of tropical montane species to global warming. Proceedings of the National Academy of Sciences, 111(12), 4490-4494.

Garba, I. D., & Muhammad-Lawal, A. (2020). The Economic and Constraints to Shea Tree Conservation Among the Shea Value Chain Actors in the North-Central, Nigeria.

Gholipour, V., Chamani, M., Aghdam Shahryar, H., Sadeghi, A., & Aminafshar, M. (2019). Effects of dietary L-glutamine supplement on performance, characteristics of the carcase and intestinal morphometry in guinea fowl chickens (Numida meleagris). *Italian Journal of Animal Science*, 18(1), 513-521.

Gifford, J. H. (2015). The role of WNT signaling in adult ovarian folliculogenesis. Reproduction (Cambridge, England), 150(4), R137.

Glenn, A., & Armstrong, C. E. (2019). Physiology of red and white blood cells. *Anaesthesia & Intensive Care Medicine*, 20(3), 170-174.

Goldsmith, T. H. (2006). What birds see. *Scientific American*, *295*(1), 68-75.

Gosomji, I. J., Salami, S. O., Nzalak, J. O., Kawu, M. U., Omirinde, J. O., Wanmi, N., & Bukar, P. D. (2015). Morphological Development of the Gastrointestinal Tract of Helmeted Guinea Fowl (Numida meleagris) at Pre-Hatch and Post-Hatch. *Journal of Veterinary Anatomy*, 8(2), 17-27.

Greenacre, C. B. (2021). Physical examination. Backyard Poultry medicine and surgery. A guide for veterinary practitioners, 159-172.

Ham, A. D., & Osorio, D. (2007). Colour preferences and colour vision in poultry chicks. *Proceedings of the Royal Society B: Biological Sciences*, *274*(1621), 1941-1948.

Harris, R. B., Birks, S. M., & Leaché, A. D. (2014). Incubator birds: biogeographical origins and evolution of underground nesting in megapodes (Galliformes: Megapodiidae). *Journal of Biogeography,* 41(11), 2045-2056.

Haskell, M., Coerse, N.C.A., Forkman, B. (2000). Frustration-induced aggression in the domestic hen: The effect of thwarting access to food and water on aggressive responses and subsequent approach tendencies. *Bahaviour, 137(2000)*, 531 – 546.

Henry, H. T., Ellerby, D. J., & Marsh, R. L. (2010). Performance of guinea fowl Numida meleagris during jumping requires storage and release of elastic energy. *Journal of Experimental Biology,* 208(17), 3293-3302.

Herring, C. M., Bazer, F. W., & Wu, G. (2021). Amino acid nutrition for optimum growth, development, reproduction, and health of zoo animals. Amino Acids in Nutrition and Health: Amino Acids in the Nutrition of Companion, Zoo and Farm Animals, 233-253.

Hlongwane, Z. T., Slotow, R., & Munyai, T. C. (2020). Indigenous knowledge about consumption of edible insects in South Africa. *Insects*, 12(1), 22.

Hoffmann, I. (2010). Climate change and the characterization, breeding and conservation of animal genetic resources. *Animal Genetics*, 41, 32-46.

Isaac, R. S., Sakthivel, G., & Murthy, C. H. (2013). Green synthesis of gold and silver nanoparticles using Averrhoa bilimbi fruit extract. *Journal of Nanotechnology*, 2013.

Issaka, B. Y., & Yeboah, R. N. (2016). Socio-economic attributes of guinea fowl production in two districts in Northern Ghana. *African Journal of Agricultural Research,* 11(14), 1209-1217.

Jahan, A., Luhovyy, B. L., Khoury, D. E., & Anderson, G. H. (2011). Dietary proteins as determinants of metabolic and physiologic functions of the gastrointestinal tract. *Nutrients*, 3(5), 574-603.

Johnson, A. L. (2014). The avian ovary and follicle development: some comparative and practical insights. *Turkish Journal of Veterinary & Animal Sciences*, 38(6), 660-669.

Johnson, A. L. (2015). Ovarian follicle selection and granulosa cell differentiation. *Poultry Science*, 94(4), 781-785.

Kere, B.A., Pousga, S., Some, S., Nianogo, A.J., Anderson, A.K. & Kisaalita, W.S. (2023). Insect-based protein feed for Guinea fowl; Growth and egg laying performance under different feed regimes. *African Journal of Food and Agriculture, Nutrition and Development. 23(9),* 24626 – 24643.

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

Khan, A. R., & Kauffman, A. S. (2012). The role of kisspeptin and RFamide-related peptide-3 neurones in the circadian-timed preovulatory luteinising hormone surge. *Journal of Neuroendocrinology*, 24(1), 131-143.

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.

Klinken, S. P. (2002). Red blood cells. *The international Journal of Biochemistry & Cell Biology*, 34(12), 1513-1518.

Kohl, A. (2016). Business Potential of Insect Food: Studying the attitudes towards edible insects among young adults.

Khosravinia, H. (2007). Preference of broiler chicks for color of lighting and feed. *The Journal of Poultry Science*, *44*(2), 213-219.

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*, 2(9), 126-131.

Konlan, S. P., Avornyo, F. K., Karbo, N., & Sulleyman, A. (2011). Increasing guinea fowl eggs availability and hatchability in the dry season. *Journal of World's Poultry Research*, 1(1), 1-3.

Kouame, Y. A. E., Voemesse, K., Lin, H., Onagbesan, O. M., & Tona, K. (2021). Effects of egg storage duration on egg quality, metabolic rate, hematological parameters during embryonic and post-hatch development of guinea fowl broilers. *Poultry Science*, 100(11), 101428.

Kusi, L. Y., Asabre, P., Kosi, I., & Nyarku, K. M. (2015). The challenges and prospects of poultry farmers: The case of Dormaa Ahenkro municipal area. *Studies in Social Sciences and Humanities*, 2(4), 214-224.

Kusia, E. S., Borgemeister, C., Khamis, F. M., Copeland, R. S., Tanga, C. M., Ombura, F. L., & Subramanian, S. (2021). Diversity, host plants and potential distribution of edible Saturniid caterpillars in Kenya. *Insects*, 12(7), 600.

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. *Livestock Research for Rural Development*, 29(9).

Kyere, C. G., Okyere, K., Duodu, A., Twumasi, G., Dapaah, P. 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.

Lamsal, B., Wang, H., Pinsirodom, P., & Dossey, A. T. (2019). Applications of insect-derived protein ingredients in food and feed industry. *Journal of the American Oil Chemists' Society,* 96(2), 105-123.

Lawal, A. K., Rotter, T., Kinsman, L., Sari, N., Harrison, L., Jeffery, C., & Flynn, R. (2014). Lean management in health care: definition, concepts, methodology and effects reported (systematic review protocol). *Systematic Reviews*, 3(1), 1-6.

Li, F., Xu, L. M., Shan, A. S., Hu, J. W., Zhang, Y. Y., & Li, Y. H. (2011). Effect of daily feed intake in laying period on laying performance, egg quality and egg composition of genetically fat and lean lines of chickens. *British poultry science*, *52*(2), 163-168.

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

Ministry of Food and Agriculture. (2016). Agriculture in Ghana: Facts and figures. Tech. rep. Ministry of Food and Agriculture.

Mohan, J., Sharma, S. K., Kolluri, G., Singh, R. P., Tyagi, J. S., & Kataria, J. M. (2016). Semen quality characteristics and seasonality in different varieties of male guinea fowl. *Advances in Animal and Veterinary Sciences*, 4(6), 320-326.

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., & Seabo, D. (2012). Guinea fowl production in Botswana. *Journal of World's Poultry Research*, 2(1), 1-4.

Morishita, T.Y. & Porter Jr. R.E. (2021). Gastrointestinal and hepatic diseases. Backyard Poultry medicine and surgery. A guide for veterinary practitioners, 289-316.

Moslehi, N., Mirmiran, P., Tehrani, F. R., & Azizi, F. (2017). Current evidence on associations of nutritional factors with ovarian reserve and timing of menopause: a systematic review. *Advances in Nutrition*, 8(4), 597-612.

Moula, N., & Detilleux, J. (2019). A meta-analysis of the effects of insects in feed on poultry growth performances. *Animals*, *9*(5), 201.

Moyo, S., Masika, P. J., & Muchenje, V. (2019). The potential of Imbrasia belina worm as a poultry and fish feed. A review. *Journal of Animal and Feed Sciences*, 28(3), 209-219.

Musiba, M. J., Ngupula, G. W., Kashindye, B. B., Elison, M., Shoko, A. P., Ndikumana, J., & Katunzi, E. F. B. (2014). Performance of locally formulated feeds for rearing of Guinea fowl in Tanzania. *African Crop Science Journal*, 22, 979-986.

Mutungi, C., Irungu, F. G., Nduko, J., Mutua, F., Affognon, H., Nakimbugwe, D., & Fiaboe, K. K. M. (2019). Postharvest processes of edible insects in Africa: A review of processing methods, and the implications for nutrition, safety and new products development. *Critical Reviews in Food Science and Nutrition*, 59(2), 276-298.

Mwale, M., Mupangwa, J. F., Mapiye, C., Saina, H., & Chimvuramahwe, J. (2013). Growth performance of guinea fowl keets fed graded levels of baobab seed cake diets. *International Journal of Poultry Science*, 7(5), 429-432.

Naandam, J., & Issah, G. B. (2012). Hatchability of guinea fowls eggs and performance of keets under the traditional extensive system in Tolon-Kumbungu District of Ghana. *Online Journal of Animal Feed Research*, 2(3), 253-257.

Nahashon, S. N., Adefope, N. A., Amenyenu, A., & Wright, D. (2007). Effect of varying concentrations of dietary crude protein and metabolizable energy on laying performance of pearl grey guinea fowl hens. *Poultry Science*, *86*(8), 1793-1799.

Nahashon, S. N., Adefope, N., Amenyenu, A., & Wright, D. (2012). 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.

Natsir, M. H., Ciptadi, G., & Susilawati, T. (2021). Egg Production, Fertility, Hatchability and Luteinizing Hormone Profile of Progesterone Hormone Injected to Arabic Gold Chicken (Gallus turcicus). *Journal of World's Poultry Research*, 11(1), 73-82.

Neumann, R., & Schneider, J. M. (2015). Differential investment and size-related mating strategies facilitate extreme size variation in contesting male spiders. *Animal Behaviour*, 101, 107-115.

Nie, R., Zheng, X., Zhang, W., Zhang, B., Ling, Y., Zhang, H., & Wu, C. (2022). Morphological characteristics and transcriptome landscapes of chicken follicles during selective development. *Animals*, *12*(6), 713.

Novero, R. P., & Asem, E. K. (1993). Follicle-stimulating hormone-enhanced fibronectin production by chicken granulosa cells is influenced by follicular development. *Poultry Science*, 72(4), 709-721.

Obese, F. Y., Ali, Z. S., Naazie, A., & Ayizanga, R. A. (2018). Effect of age, breed and sex on haematological and blood biochemical parameters in helmeted guinea fowl (Numida meleagris). *Comparative Clinical Pathology*, 27, 901-909.

Oke, O. E., Adejuyigbe, A. E., Idowu, O. P., Sogunle, O. M., Ladokun, A. O., Oso, A. O., & Njoku, C. P. (2015). Effects of housing systems on reproductive and physiological response of guinea fowl (Numida Meleagris). *Journal of Applied Animal Science*, 8(1), 47-55.

Okyere, K., Agyemang, J. K. K., Annor, S. Y., Ameyaw, A. A., Kyere, C. G., Fiashide, N., & Setsiwah, W. (2020). 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.

Olawumi, S., Ogunlade, T., & Falemilehin, S. (2012). Production traits of broiler chicken strains fed ad libitum and raised on deep litter system in the humid tropics. *Animal Research International*, 9(1).

Olsen, R. L., & Hasan, M. R. (2012). A limited supply of fishmeal: Impact on future increases in global aquaculture production. *Trends in Food Science & Technology,* 27(2), 120-128.

Onagbesan, O., Bruggeman, V., & Decuypere, E. (2009). Intra-ovarian growth factors regulating ovarian function in avian species: a review. *Animal Reproduction Science,* 111(2-4), 121-140.

Onyenweaku, E. O., Akah, L. U., Kesa, H., Alawa, D. A., Ebai, P. A., Kalu, U. U., & Owan, V. J. (2020). Protein Quality Evaluation of Some Commonly Consumed Bird Egg Varieties Using Amino Acid Scores. Biochemistry research international, 2020.

Orakpoghenor, O., Avazi, D. O., Markus, T. P., & Olaolu, O. S. (2019). Lymphocytes: a brief review. *Sci. J. Immunol. Immunother*, *3*(1), 4-8.

Ospina, E. A., Merrill, L., & Benson, T. J. (2018). Incubation temperature impacts nestling growth and survival in an open-cup nesting passerine. *Ecology and Evolution*, 8(6), 3270-3279.

Pacifici, M., Foden, W. B., Visconti, P., Watson, J. E., Butchart, S. H., Kovacs, K. M., & Rondinini, C. (2015). Assessing species vulnerability to climate change. *Nature Climate Change*, 5(3), 215-224.

Paliy, A. P., Mashkey, A. M., & Sumakova, N. V. (2018). Distribution of poultry ectoparasites in industrial farms, farms, and private plots with different rearing technologies. *Biosystems Diversity*, 26(2), 153-159.

Parsons, A. S., Buchanan, N. P., Blemings, K. P., Wilson, M. E., & Moritz, J. S. (2006). Effect of corn particle size and pellet texture on broiler performance in the growing phase. *Journal of Applied Poultry Research*, *15*(2), 245-255.

Pauzenga, U. (1985). Feeding parent stock. *Zootecnica international*, *17*, 22-24.

Payne, C., Badolo, A., Sagnon, B., Cox, S., Pearson, S., Sanon, A. & Balmford, A. (2020). Effects of defoliation by the edible caterpillar “chitoumou” (Cirina butyrospermi) on harvests of shea (Vitellaria paradoxa) and growth of maize (Zea mays). *Agroforestry Systems*, 94, 231-240.

Rafiu, T. A., Adetutu, O. I., Adesoye, F. A., Adeniji, O. J., & Oluwafemi, E. O. (2021). Performance characteristics and meat quality assessment of guinea fowl fed varied levels of dietary protein. *Nigerian Journal of Animal Production,* 48(5), 135-142.

Rault, J. L., Cree, S., & Hemsworth, P. (2016). The effects of water deprivation on the behavior of laying hens. *Poultry Science*, *95*(3), 473-481.

Ravindran, V. (2013). Poultry feed availability and nutrition in developing countries. *Poultry Development Review*, 2, 60-63.

Rémy, S., Veira, A., Paugam, R., Sofiev, M., Kaiser, J. W., Marenco, F. & Hair, J. W. (2017). Two global data sets of daily fire emission injection heights since 2003. *Atmospheric Chemistry and Physics*, 17(4), 2921-2942.

Ren, W., Li, Y., Yin, Y., & Blachier, F. (2013). Structure, metabolism and functions of amino acids: an overview. Nutritional and physiological functions of amino acids in pigs, 91-108.

Rezaei, R., Wang, W., Wu, Z., Dai, Z., Wang, J., & Wu, G. (2013). Biochemical and physiological bases for utilization of dietary amino acids by young pigs. *Journal of Animal Science and Biotechnology*, 4, 1-12.

Saleh, A. A., Hamed, S., Hassan, A. M., Amber, K., Awad, W., Alzawqari, M. H., & Shukry, M. (2021). Productive performance, ovarian follicular development, lipid peroxidation, antioxidative status, and egg quality in laying hens fed diets supplemented with Salvia officinalis and Origanum majorana powder levels. *Animals*, 11(12), 3513.

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).

Saran, D., Meshram, B., Joshi, H., Singh, G., & Kumar, S. (2019). Gross morphological studies on the digestive system of guinea fowl (Numida meleagris). *International Journal of Livestock Research*, 9(02), 266-273.

Schradin, C., Kinahan, A. A., & Pillay, N. (2014). Cooperative breeding in groups of synchronously mating females and evolution of large testes to avoid sperm depletion in African striped mice. *Biology of Reproduction*, 81(1), 111-117.

Seidu, B., Bonsu, F. R. K., Kwenin, W. K. J., Tawiah, R., & Daniel, O. L. (2024). Utilization of shea caterpillar (Cirina butyrospermi) larvae meal as organic feed resource for broiler chicken. *Journal of Experimental Agriculture International*, *46*, 35-47.

Selaledi, L., Mbajiorgu, C. A., & Mabelebele, M. (2020). The use of yellow mealworm (T. molitor) as alternative source of protein in poultry diets: a review. *Tropical Animal Health and Production,* 52, 7-16.

Sellier, N., Brillard, J. P., Dupuy, V., & Bakst, M. R. (2016). Comparative staging of embryo development in chicken, turkey, duck, goose, guinea fowl, and Japanese quail assessed from five hours after fertilization through seventy-two hours of incubation. *Journal of Applied Poultry Research*, 15(2), 219-228.

Seol, H. S., Sato, K., Murakami, H., Toyomizu, M., & Akiba, Y. (2006). Changes in gene expression involved in energy utilization during chicken follicle development. *Animal Reproduction Science*, 95(3-4), 283-294.

Shariat, Z., Kheiri, F., & Faghani, M. (2020). Productive performance, egg-related indices, blood profiles, and interferon-Ɣ gene expression of laying Japanese quails fed on Tenebrio molitor larva meal as a replacement for fish meal. *Italian Journal of Animal Science,* 19(1), 274-281.

Shoyombo, A. J., Yakubu, A., Adebambo, A. O., Popoola, M. A., Olafadehan, O. A., Wheto, M., & Adebambo, O. A. (2021). Characterisation of indigenous helmeted guinea fowls in Nigeria for meat and egg production. *World's Poultry Science Journal,* 77(4), 1037-1058.

Silva, J. R. V., Figueiredo, J. R., & Van den Hurk, R. (2012). Involvement of growth hormone (GH) and insulin-like growth factor (IGF) system in ovarian folliculogenesis. *Theriogenology*, 71(8), 1193-1208.

Tateishi, Y., Ichikawa, R., Suzuki, K., Kitahara, Y., Someya, Y., & Tamura, Y. (2023). Effect of imbalance in dietary macronutrients on blood hemoglobin levels: a cross-sectional study in young underweight Japanese women. *Frontiers in Nutrition*, *10*, 1121717.

Thomas, F. H., & Vanderhyden, B. C. (2014). Oocyte-granulosa cell interactions during mouse follicular development: regulation of kit ligand expression and its role in oocyte growth. *Reproductive Biology and Endocrinology,* 4(1), 1-8.

Van Der Klis, J.D. & de Lange, L.O.E.K. (2013). Water intake in poultry. In Proc. 19th European *Poultry Nutrition Symposium, Postdam, Germany*. Pp. 102 – 107.

Veldkamp, T., Far, A. R., Caimi, C., Gasco, L., Lima, R. C., & Cunha, L. M. (2024). Partial or complete replacement of soybean meal with black soldier fly larvae meal improves feed efficiency in laying hens between 22 to 30 weeks of age. *Journal of Insects as Food and Feed*, *11*(17), 73-88.

Vineetha, P. G., Tomar, S., Saxena, V. K., Kapgate, M., Suvarna, A., & Adil, K. (2017). Effect of laboratory-isolated Lactobacillus plantarum LGFCP 4 from gastrointestinal tract of guinea fowl on growth performance, carcass traits, intestinal histomorphometry and gastrointestinal microflora population in broiler chicken. *Journal of Animal Physiology and Animal Nutrition*, 101(5), e362-e370.

Vleck, D. (2011). Hormones and regulation of parental behavior in birds. In Hormones and reproduction of vertebrates (pp. 181-203). Academic Press.

Webb, R. P. C. G., Garnsworthy, P. C., Gong, J. G., & Armstrong, D. G. (2004). Control of follicular growth: local interactions and nutritional influences. *Journal of Animal Science*, *82*(suppl_13), E63-E74.

Wamai, L. K., Munga, L. M., Osuga, I. M., Munguti, J. M., Subramanian, S., Kidoido, M. K., ... & Tanga, C. M. (2024). Big opportunities for tiny bugs: rush to boost laying hen performance using black soldier fly larvae meal. *Journal of Economic Entomology*, *117*(1), 58-72.

Wolfe, R. R., Baum, J. I., Starck, C., & Moughan, P. J. (2018). Factors contributing to the selection of dietary protein food sources. *Clinical Nutrition*, 37(1), 130-138.

Womeni, H. M., Tiencheu, B., Linder, M., Chouatcho Nabayo, E. M., Tenyang, N., Tchouanguep Mbiapo, F. & Parmentier, M. (2012). Nutritional value and effect of cooking, drying and storage process on some functional properties of Rhynchophorus phoenicis.

Yabuda, K. H., Mbembo, B. M., Bongo, G. N., Gbendo, T. G., Tshil, F. M., Kogba, L. S., & Ngbolua, K. (2019). Contribution to the ecological study of edible caterpillars in GbadoLite city and its surroundings, Nord-Ubangi, Democratic Republic of the Congo. *Plants and Environment*, 1(2), 109-114.

Yakubu, A., Musa-Azara, I. S., & Haruna, H. S. (2014). Village guinea fowl (Numidia meleagris) production systems in Nasarawa State, north central Nigeria: flock characteristics, husbandry and productivity. *Livestock Research for Rural Development*, 26(3).

Yamak, U. S., Boz, M. A., & Sarica, M. (2015). Changes in guinea fowl fertility and hatching traits over a 4-month laying season with long-term egg storage conditions. *Indian Journal of Animal Research*, *49*(4), 532-536.

Yapo, M. L., Amara, M. F., & Tuo, Y. (2017). Nutritional value of shea caterpillar (Cirina butyspermii Vuillet) sold at the market of Korhogo (Côte d'Ivoire). *International Journal of Agronomy and Agricultural Research*, *10*(5), 35-44.

Xiaoming, C., Ying, F., Hong, Z., & Zhiyong, C. (2010). Review of the nutritive value of edible insects. *Forest insects as food: humans bite back*, *85*.

APPENDIX

Appendix 1: Determination of hatchability of dietary treatments