

**AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND
ENTREPRENEURIAL DEVELOPMENT**

**EFFECT OF THE ADDITION OF CRYSTALLINE LYSINE AND METHIONINE
TO LOW PROTEIN DIETS ON THE GROWTH PERFORMANCE, BONE
TRAITS, CARCASS TRAITS AND HAEMATOLOGICAL PARAMETERS IN
GUINEA FOWLS (*Numida meleagris*)**

SAEED MAHAMA MOGTARI

2025

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ASANTE MAMPONG



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BY

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**A thesis in the Department of Animal Science Education,
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of the requirements for the award of the degree of
Master of Philosophy
(Animal Production and Management)**

AUGUST, 2025

DECLARATION

STUDENT'S DECLARATION

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

Saeed Mahama Mogtari

Signature.....

Date:/...../.....

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of thesis as laid down by the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development.

DR. Holy Kwabla Zanu

Signature.....

Date:/...../.....

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DEDICATION

To the memory of my late mother (Baratu Dasaah).

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LIST OF ABBREVIATIONS

ABBREVIATION	MEANING
ADG	Average daily gain
AOAC	Association of Official Analytical Chemists
BWG	Body weight Gain
CP	Crude Protein
CRD	Completely randomized design
DCP	Dicalcium Phosphate
DNFE	Digestible nitrogen free extract
FBW	Final body weight
FCR	Feed conversion ratio
FI	Feed intake
NRC	National Research Council
WG	Weight Gain

ABSTRACT

This study was undertaken to assess the effect of three levels of crude protein supplemented with crystalline lysine and methionine on the growth performance, bone traits, carcass traits, gastrointestinal pH, as well as haematological parameters in the pearl Guinea fowls. One hundred and thirty-nine (139) experimental keets were randomly assigned to three diets with varied crude protein, lysine and methionine levels in a completely randomised design. Treatment one (T1) was formulated to contain high crude protein levels of 20.08 % with the addition of 0 % crystalline lysine and methionine, respectively. Treatment two (T2) was formulated to contain medium crude protein levels of 17.33 % with the addition of 0.15 % and 0.4 % crystalline lysine and methionine, respectively and Treatment three (T3) was also formulated to contain low levels of crude protein of 13.69 % with the addition of 0.9 % and 0.25 % crystalline lysine and methionine, respectively. The Guinea fowls were offered feed and water *ad libitum* throughout the starter, grower, and finisher phases. Feed consumption, body weight, gain, feed conversion ratio (feed: gain) and livability were calculated weekly. Bone dimensions and breaking strength were measured on d 65 and 93, as well as the weight of the heart, gizzard, liver, breast and thigh were also measured and expressed as a percentage during the same period of the experiment. Gastrointestinal pH of the crop, proventriculus, gizzard, duodenum, ileum, jejunum and caeca were measured on d 93 and finally, the haematological parameters were also measured on d 93 of the experiment. Treatment 1 and 2 improved the body weight (BW) and body weight gain of Guinea fowls significantly ($p < 0.05$), compared to dietary treatment 1. Treatment 3 improved ($p < 0.05$) the weight of the gizzard compared to treatments 1 and 2, while all other carcass traits were non-responsive to the experimental diets on d 65 and 93. There was no significant ($p > 0.05$) effect of dietary treatment on all haematological indices studied and pH of the intestinal segments of the experimental Guinea fowls. It was concluded that the diet containing 17.33 % CP with 0.15 % and 0.4 % lysine and methionine, respectively, generally promoted better growth of the pearl Guinea fowls.

CHAPTER ONE: INTRODUCTION

1.1 Background to the Study

The Guinea fowls (*Numida meleagris*), which is believed to have originated in Africa, has grown in popularity over time and its production has increased globally (Rafiu *et al.*, 2021). This can be attributed to the higher protein content and leaner composition of Guinea fowl meat when compared to chicken (Moreki, 2009). Despite gaining global recognition and increased production, many farmers in developing countries, including Ghana continue to feed their Guinea fowls poor-quality feeds (Olayode *et al.*, 2014). According to Oluyemi and Roberts (2000), feed alone makes up between 60 and 80 percent of the total cost of raising chickens. For this reason, it is imperative to combine feed ingredients in the best way possible to guarantee optimal performance. According to Olayed *et al.* (2014), protein is the most crucial and costly feed ingredient when it comes to formulating a diet for chickens.

Dietary crude protein (CP) is an essential component of poultry nutrition that affects the growth, development of muscles, and general health of poultry (Bortoluzzi *et al.*, 2018). Carcass quality and bone health are key determinants of the market value and welfare of poultry respectively (Mir *et al.*, 2017). Therefore, maximising the economic value of producing Guinea fowls requires optimising dietary protein levels to achieve desired traits in the carcass and bone (Hounkpêvi *et al.*, 2024).

Poultry feeding programs have historically favored high dietary protein levels to maximize growth and muscle accretion, although evidence shows that precise amino acid supplementation can achieve comparable results with lower protein inputs (Tesseraud *et al.*, 2003). However, recent advancements in nutritional science have challenged this notion. Several reports have shown how feeding low-protein diets to poultry improves their welfare and performance while also reducing environmental pollution caused by the excess nitrogen

emitted into the atmosphere (Bregendahl *et al.*, 2001; Applegate, 2008; Greenhalgh *et al.*, 2020). However, studies using low-CP diets given to broilers have generally resulted in subpar performance when compared to broilers receiving adequate amino acid levels (Berres *et al.*, 2010). Conversely, studies using low-protein diets have also shown no effect on performance (Widyaratne and Drew, 2011). As a result, it is impossible to draw firm conclusions about how these diets affect actual Guinea fowls production due to the inconsistent findings from previous studies. In order to improve overall performance, there is a growing interest in optimising the nutritional requirements of Guinea fowls.

1.2 Problem Statement

Protein is a vital yet costly component in poultry diets, crucial for growth and muscle development (Barszcz *et al.*, 2024). For species like Guinea fowls with unique nutrient needs, balancing crude protein levels is essential to ensure optimal performance while avoiding high feed costs and environmental issues from nitrogen waste (Abbasi *et al.*, 2018; Chojnacka *et al.*, 2021). With lysine and methionine being limiting amino acids in poultry diets (Kidd *et al.*, 2021), the traditional practice has been to increase dietary crude protein so as to meet these amino acid requirements. However, higher crude protein levels in diets often result in excess non-essential amino acids without proportionally increasing lysine and methionine, leading to inefficiencies and possible deficiencies (Ayub *et al.*, 2021).

To overcome this, nutritionists have adopted the strategy of reducing crude protein while supplementing diets with crystalline lysine and methionine (Paschal, 2021). This approach precisely meets the amino acid requirements of birds, reduces nitrogen excretion, lowers feed costs, and improves overall performance. Empirical studies indicate that reducing dietary crude protein by 2–3%, with balanced lysine and methionine supplementation, can

lower feed costs by about 5–8% and decrease nitrogen excretion by 10–20%, without affecting growth or feed efficiency (Aletor et al., 2000; Namroud et al., 2008; Belloir et al., 2017). Despite these benefits, limited research has examined how guinea fowls specifically respond to such dietary adjustments. Previous studies have evaluated the effects of varying crude protein levels on the growth, carcass, and bone traits of guinea fowls (Alabi et al., 2023; Hounkpêvi et al., 2024), yet the interaction between reduced protein and targeted lysine and methionine supplementation remains underexplored. This study therefore seeks to address this gap by assessing the effects of three dietary protein levels supplemented with crystalline lysine and methionine on the performance of guinea fowls in Ghana.

1.3 Main Objective

The main objective of the study was to investigate the effect of three levels of dietary crude protein supplemented with crystalline lysine and methionine on the general performance of the pearl Guinea fowls

1.3.1 Specific objective

The specific objectives were to:

1. evaluate the growth performance of Guinea fowls fed three (3) levels of dietary crude protein supplemented with crystalline lysine and methionine
2. examine the carcass traits of Guinea fowls fed different levels of dietary crude protein supplemented with crystalline lysine and methionine
3. assess the bone dimension and breaking strength of Guinea fowls fed different levels of dietary crude protein supplemented with crystalline lysine and methionine
4. analyse gastrointestinal pH of Guinea fowls fed different levels of dietary crude protein supplemented with crystalline lysine and methionine

5. determine the Haematological parameters of Guinea fowls fed different levels of dietary crude protein supplemented with crystalline lysine and methionine

1.4 Significance of the Study

This study holds considerable significance as it evaluates the potential of crystalline lysine and methionine supplementation in low-protein diets to sustain or enhance growth performance, bone characteristics, carcass quality, and haematological parameters in Guinea fowls (*Numida meleagris*). Given the rising cost of conventional protein-rich feed ingredients, identifying alternative strategies to maintain productivity while reducing dietary protein levels is crucial for improving economic efficiency in poultry production. The supplementation of limiting amino acids may allow for more precise nutrient formulations, reducing feed costs without compromising animal performance.

Moreover, the study contributes to the relatively limited body of research on nutrient requirements and dietary optimization in Guinea fowls, a species with increasing agricultural relevance. By assessing physiological and haematological responses to dietary manipulation, the research provides important insights into the health and metabolic status of birds under varied nutritional regimes. The outcomes of this study have the potential to inform feed formulation practices, enhance production sustainability, and support the development of more cost-effective and environmentally responsible poultry production systems.

CHAPTER TWO: LITERATURE REVIEW

2.1 Guinea Fowl Production in Ghana

Guinea fowls (*Numida meleagris*) is a domesticated poultry which is native to Africa and gets its name from the Coast of Guinea, specifically in the West Coast of Africa (Teye and Gyawu, 2002). Prior to its recent introduction to other regions of the country, such as the Volta, Brong Ahafo, Ashanti, and Greater Accra regions, Guinea fowls were traditionally raised in the northern regions of Ghana (Adu-aboagye, 2020).

The production of Guinea keets in Ghana has over the years demonstrated financial viability. This is because the birds are more resilient to unfavourable management conditions than exotic chickens (Embury, 2001; Agbolosu *et al.*, 2012). Subsistence farmers mostly from rural areas in the Upper West, Upper East, and Northern regions of Ghana raise the majority of Guinea fowls produced in the country (Fig. 1). According to Issaka and Yeboah, 2016, the Guinea fowls population in the northern regions makes up 81% of all Guinea fowls and 7.1% of all poultry produced in Ghana. In addition to providing income for the household, the birds are significant to the sociocultural lives of the people in Northern Ghana (Teye and Adam, 2000). The Pearl helmeted Guinea fowls is the most common variety raised in Ghana (FAO, 2014).

Despite the economic and nutritional importance of raising Guinea fowls in the country, the provision of sufficient feed has remained a significant obstacle to raising Guinea fowls to reach their maximum growth and reproductive potential. This is because there is a dearth of empirical research on optimising the nutritional needs of Guinea fowls, especially with regards to dietary protein levels (Jacob & Pestacore, 2022; Araújo *et al.*, 2023). Hatchability

and fertility are two other significant issues with Guinea fowls production. According to Teye and Adam (2000), both traits peak three months after the breeding season starts but are low at the onset of the breeding season. According to Yamak *et al.* (2016a), the larger size and thicker egg shells of Guinea hens result in lower hatchability than those of chickens.

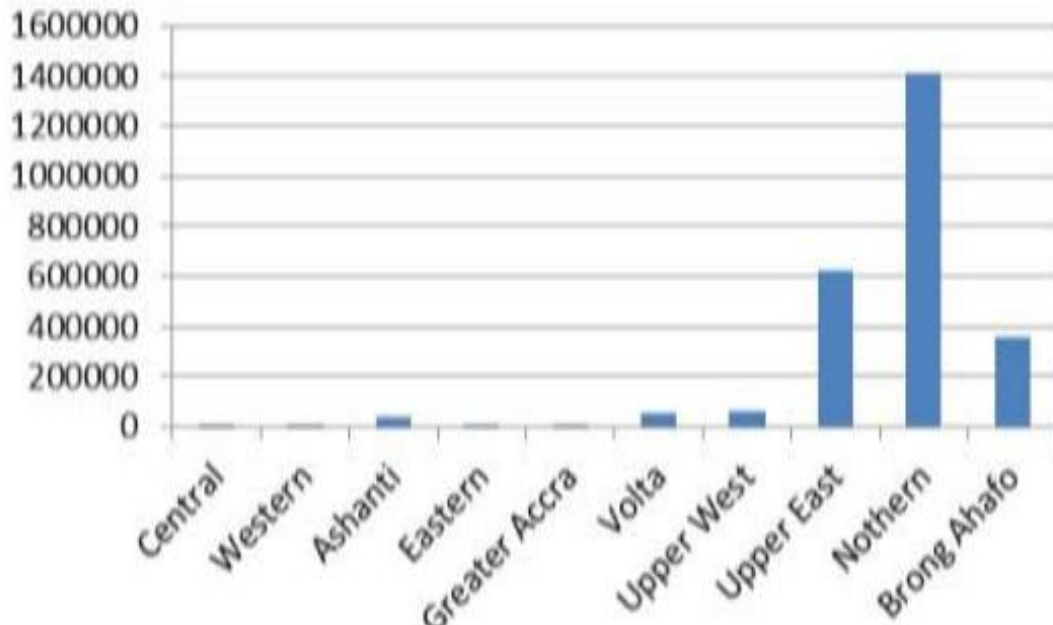


Figure 2.1: Regional Distribution of Guinea Fowls in Ghana

Source : (Issaka & Yeboah, 2016).

2.2 Species and Breeds of Guinea Fowls

The most numerous and widely distributed species is the helmeted Guinea fowls *Numida meleagris* (John, 2024). There are three well-known types of helmeted Guinea fowls, namely, pearl, lavender and the white and the less popular black breed (Payne, 1990; Annor *et al.*, 2012;). The pearl is the most abundant and it possesses a purplish-grey plumage dotted or “pearled” with white (Plate 2.1). It is also characterized by shanks of slate grey colour and more or less dark grey-blue plumage with many rounded small white spots (Table 2.1). The lavender type has paled purple colour with black shanks, pink slate or mixture of pink and black shanks (Plate 2.3). The white type has the ordinary white colour with pink shanks

or slate shanks white or pink wattles (Plate 2.2) (Baimbill-Johnson 2021; Prabakaran & Valavan, 2020; Annor *et al.*, 2012).

Table 2.1: Common Species of Guinea Fowls

Genus	Species	Description
Agelastes	<i>Agelastes meleagrides</i>	White breasted guinea fowls
	<i>Agelastes niger</i>	Black breasted guinea fowls
Numida	<i>Numida meleagris</i>	Helmeted guinea fowls
Guttera	<i>Guttera plumifera</i>	Plumed guinea fowls
	<i>Guttera pucherani</i>	Crested guinea fowls
Acryllium	<i>Acryllium vulturinum</i>	Vulturine guinea fowls

Source: Annor *et al.*, (2012)

2.3 Guinea Fowls Rearing Systems in Ghana

Guinea fowls are reared mainly under extensive (free-range or traditional) and semi-intensive systems and the free-range system is the predominant rearing method common in Africa (Yamak, 2015). A study by Moreki and Radikara (2013) in Ghana showed that 98 % of farmers housed their Guinea fowls in the night and offered them few handfuls of grains and allowed them to scavenge the whole day. Free-range Guinea fowls constitutes an important resource for under-resource poor farmers in developing countries.

In the extensive system, birds depend mainly on scavenging with no or very little inputs committed resulting in low productivity (Sankhyan *et al.*, 2013). Additionally, housing is rudimentary, indicating that losses due to predation are high. Also, health management practices are based mainly on ethno veterinary medicine probably due to its availability in the villages. The belief that Guinea fowls are resistant to diseases could be a contributing factor to why farmers do not adopt preventative measures against diseases which devastates



Plate 2.1: Peal Guinea fowl



Plate 2.2: White Guinea fowl



Plate 2.3: Lavender

Source: Adu-aboagye, 2020



Plate 2.4: Black Guinea fowl

flocks (Wagari, 2021). Jajere *et al.* (2018) also reported that, there are three systems of rearing Guinea fowls namely, free-range, semi-intensive and intensive systems. Under the free-range system, Guinea fowls are left free to search for food on their own in a boundless area and return in the evening to sleep in a stall or roost on trees or roofs. In the semi-intensive system, there is minimum or a reasonable control of the birds. Guinea fowls are confined but allowed to roam in a fenced area, feed and water may be provided within the area. Fairly spaced shrubs are incorporated in the area to provide hiding places for laying and mating (Kvarnemo, 2018).

2.4 Management of Guinea Fowls

Management practices such as feeding, watering, housing, health-care and general sanitation contributes very immensely to the productivity of rural poultry. However, management in the rural areas is very poor and so reduces productivity greatly (Molden *et al.*, 2010). Management systems such as suitable housing, adequate quality feeding, provision of clean drinking water, maintaining high level of sanitation are carried out haphazardly in the rural set up, which leads to poor output (Kusina *et al.*, 2012). Domestic Guinea fowls are nervous and noisy birds, and are therefore not widely raised commercially (Molden *et al.*, 2010). Through lack of good management, many farmers who keep small flocks of Guinea fowls obtain only a few young birds from each hen. Guinea fowls are much more active than chickens and are not as easily tamed (Aminu *et al.*, 2017). In most parts of sub-Saharan Africa, they are basically semi-domesticated birds which are timid and roost in trees at night. Majority of rural Guinea fowls farmers (80.6 %) raise their birds on purely extensive system, with few of them (16.7 %) practicing the semi-intensive system in the northern regions of Ghana (Takyi-Mensah, 2012).

Under the extensive system, the birds are exposed to a lot of dangers that impede on their performance in terms of growth and laying. Housing made of wooden coops or mud pens, if any, are provided only at night (Seidu *et al.*, 2017). Avornyo, *et al.* (2016), also attested that, the scavenging farming system is the basis of Guinea fowls breeding with overnight housing in overcrowded coops and natural feeding / watering conditions. Avornyo, *et al.* (2016) observed that the scavenging system is predisposed to the onset and spread of microbial and parasitic diseases. With the free-range system, houses for birds are improperly constructed. Houses are small in sizes, roofed with thatch, poorly ventilated, inadequate space with narrow entrance causing overcrowding which leads to easily spread out of diseases in the

houses (Moreki and Radikara, 2013). Farmers do not pay attention to sanitation measures such as cleaning of the coops, provision of clean water and clearing around the coops. Water is provided in locally made clay pot with small holes around which makes it difficult for young birds to reach and drink water (Moreki &Radikara, 2013).

2.4.1 Brooding of Guinea fowls keets

Temperature regulation is essential for the survival and growth of guinea fowls keets, as they are more sensitive to temperature fluctuations compared to other poultry. According to Adewale *et al.* (2018), maintaining temperatures between 35°C and 37°C during the first week and gradually decreasing by 2-3°C per week until reaching ambient temperature is crucial. This gradual decrease mimics the keets' natural adaptation process and prevents stress-related mortality. Kebe *et al.* (2020) observed that keets brooded under infrared heating systems had improved growth rates and lower mortality compared to those under conventional lighting, as infrared provides uniform warmth and reduces chilling effects. Ventilation is another critical factor. Poorly ventilated brooders can accumulate harmful gases such as ammonia, which affects respiratory health and increases mortality rates. As noted by Otieno *et al.* (2019), adequate ventilation helps control humidity and reduces the risk of respiratory diseases, common in keets kept in humid and poorly ventilated environments.

Lighting significantly affects the behaviour and development of keets. Continuous lighting during the first week encourages feed intake and prevents piling, a behaviour where keets cluster, which can lead to suffocation and increased mortality. A study by Yeboah *et al.* (2021) indicated that a 24-hour lighting regime during the initial brooding period enhanced feed intake and body weight gain in keets. After the first week, reducing the light exposure

gradually to a 16-hour light, 8-hour dark cycle helps regulate activity levels and improves keet welfare (Mensah & Azza, 2017).

Proper nutrition is fundamental to successful brooding. Guinea fowls keets require diets rich in protein, energy, vitamins, and minerals to support rapid growth and immune development. For optimal growth, keets benefit from starter feeds with at least 24% protein and 2900 kcal/kg of metabolisable energy (Yeboah *et al.*, 2019). Diets supplemented with essential vitamins, particularly vitamins A, D, and E, and minerals such as calcium and phosphorus are essential to prevent deficiencies and promote skeletal health (Oladejo *et al.*, 2022). According to Asare and Owusu (2023), adding probiotics to keet diets improved growth performance and reduced early mortality by promoting a balanced gut microbiota, which aids nutrient absorption and enhances immunity.

Keets are highly susceptible to diseases during the brooding stage, making biosecurity and vaccination critical aspects of brooding management. Common diseases affecting keets include coccidiosis and Newcastle disease, both of which can lead to high mortality if left unchecked. Preventive measures, such as regular cleaning, use of disinfectants, and vaccination protocols, are recommended to minimize disease outbreaks. Studies by Ali *et al.* (2020) emphasize that vaccinating keets against Newcastle disease at day 10 and again at 21 days reduces mortality rates and enhances long-term flock health. In addition to vaccinations, antibiotics are sometimes administered to prevent bacterial infections; however, the trend is shifting towards natural alternatives. A study by Zongo *et al.* (2019) found that natural additives, such as garlic and ginger extracts, have antibacterial properties that help control bacterial pathogens without adverse effects on keet health. These

alternatives are increasingly preferred in line with the rising demand for antibiotic-free poultry products.

The design of the brooder can significantly impact keet comfort and accessibility to feed and water. Circular brooders are recommended over rectangular ones to reduce cornering behavior, which often leads to piling and suffocation (Tunde *et al.*, 2021). Furthermore, brooder spacing is crucial; overcrowded brooders can lead to aggressive behaviors and restricted access to feed and water, which ultimately impacts growth. Keets should have a minimum of 0.2 square feet per bird in the first two weeks, increasing to 0.5 square feet as they grow (Nkrumah & Adusei, 2018).

2.5 Nutritional Requirements of Guinea Fowls

The nutrient requirement of Guinea fowls is increasingly an important aspect of profitable guinea fowls production. The ability to meet the nutritional needs of Guinea fowls (*Numida meleagris*) keets is a key determinant of their survivability and this in turn is a function of feed quantity and quality available to the keets (Alabi, *et al.*, 2023). According to Lamot (2017) and Ross *et al.* (2019), young birds, such as the Guinea fowls keet, require access to vital components of feed such as energy, protein, vitamins, minerals, and antioxidants to maintain a healthy metabolism of energy and protein for essential body functions. These elements are absent from the diet of the local keet, hence reduces the number of keets that are capable of surviving to reach maturity (Ahiagbe *et al.* 2021). The lack of commercial feeds and established guidelines for Guinea fowls production in developing countries (Rafiu *et al.*, 2021) has hampered the development of native Guinea fowls in a significant way. Most rural farmers allow the Guinea fowls to roam freely for feed and provide little or no extra feed. This results in starvation, stunted growth, and keet mortality as the birds must

expend more energy searching for food, which may not be sufficient or of sufficient quality to support the growth and development of the very young keets (Baruwa and Sofoluwe 2016; Nanette *et al.* 2021).

2.5.1 Protein requirements of Guinea fowls

Guinea fowls have a protein requirement that are impacted by a number of variables, such as age, sex, physiological state, and environmental circumstances. It is crucial to provide Guinea fowls with adequate protein to support their growth, reproduction, and general health (Molnar *et al.* 2015). Understanding the protein requirements of Guinea fowls is critical for formulating balanced diets and optimizing production efficiency. In a study designed to determine the crude protein needs of Guinea fowls keets in tropical climates, Rafiu *et al.* (1984) found that the body weight of keets fed diets containing 24% and 26% crude protein (CP) was significantly higher than that of their counterparts, and that the feed conversion ratio was better in keets fed 24 % of CP. These findings suggest that, in order to achieve maximum productivity in tropical climates, Guinea fowls keets could be fed diets containing not less than 24% CP. Furthermore, a much more recent study found that Guinea fowls keets fed 24% crude protein and 2650 kcal/ kg had higher growth performance indices, such as average daily gain (ADG), final body weight (FBW), and also digestible nitrogen free extract (DNFE), and digestible crude fibre (Alabi *et al.*, 2023). Moreover, Avornyo *et al.* (2013) assessed the impact of dietary protein on the performance of native Guinea keets in the northern region of Ghana. It was found that feeding keets 24 % dietary protein improved the daily mean weight, survivability, and mean cost of feed per kilogram weight.

Despite the successes recorded in feeding a high crude protein diet to Guinea fowls, there has been welfare issues and concerns of environmental pollution associated with feeding

high protein diets to poultry due to the emission of excess nitrogen. In poultry nutrition, there is great interest in the use of low crude protein (CP) diets for economic and environmental advantages that may lead to a reduction of feed cost and total nitrogen (N) output to the environment (Sigolo *et al.*, 2017).

2.5.2 Consequences of high crude protein diet in poultry production

Crude protein is a fundamental component of poultry diets, providing essential amino acids necessary for various physiological functions. However, feeding high levels of crude protein in poultry diets can have both immediate and long-term consequences on the health of birds, welfare, and environmental impacts (Hilliar *et al.*, 2006). When a bird consumes more protein than it needs for metabolism, the liver turns it into uric acid, which is then expelled by the kidneys (Boykin, 1995). The breakdown of uric acid in the intestines releases nitrogen in the form of ammonia (NH₃), a compound with a pungent odor (Swelum *et al.*, 2021)

It is established that, concentrations of gaseous ammonia above 10 ppm in poultry houses have a detrimental effect on worker health as well as the productivity, welfare, and general health of the birds (Kristensen and Wathes, 2000; Miles *et al.*, 2004). Ammonia contributes to eutrophication, acidification, and decreased biodiversity in natural ecosystems after it is released from poultry houses (Lekkerkerk *et al.*, 1995). However, according to several studies (Bregendahl *et al.*, 2001; Applegate, 2008; Greenhalgh *et al.*, 2020), feeding low-protein diets to poultry reduces environmental pollution caused by the excess nitrogen emitted into the atmosphere while also improving the welfare and performance of the birds.

2.5.3 Low protein diet (reduced CP) and its benefits in poultry production

Amino acids are widely recognised as being important for poultry nutrition. Now, instead of focusing solely on crude protein, poultry diets are designed to meet the needs of essential

dietary amino acids. According to Hayat *et al.* (2014), it is crucial to supply all the amino acids needed for upkeep, growth, production, and reproduction. Commercially available amino acids, such as methionine, lysine, and threonine, are added to feeds to meet the modern broiler chicken's requirements for amino acids (Kidd *et al.*, 2013). Unbound methionine, lysine, and threonine that are added to poultry diets have in fact made it much easier and more affordable to formulate nutrient-dense, modern broiler diets that meet current requirements for amino acids while reducing excess crude protein and improving amino acid balance (Greenhalgh *et al.*, 2020). In an effort to lower the levels of crude protein in poultry diets, the addition of synthetic amino acids has produced a number of encouraging outcomes.

Reduced nitrogen (N) excretion and ammonia (NH₃) emissions into the environment have been reported when synthetic amino acids are added to diets to lower the concentration of CP (Nahm, 2007). In a study to determine the effect of dietary crude protein on growth, ammonia concentration, and litter composition in broilers, Ferguson *et al.* (1998) discovered that a 2% decrease in dietary crude protein was equal to a 13% decrease in nitrogen intake. Following the excretion of N in the litter, bacterial fermentation transforms the N into NH₃, which volatilizes and diffuses into the atmosphere (Brink *et al.*, 1998; Ospina-Rojas *et al.*, 2012). N excretion can be decreased by up to 40% by reducing the amount of crude protein in the diet and maximising the addition of unbound amino acids (Nahm 2007). According to some studies (Powers *et al.*, 2006; Hernandez *et al.*, 2013), reducing CP by 60 g/kg (220 to 160 g/kg) reduced nitrogen excretion by an average of 35%.

The complicated problem of poor litter quality and its related issues has grown to be a welfare concern (Dunlop *et al.*, 2016). However, Van Harn *et al.* (2019) have reported that,

reductions in dietary crude protein improve litter quality and lower the frequency of footpad and other lesions. It has been demonstrated in some series of studies that dietary CP reductions cause a daily water intake reduction of 23.2% and a decrease in litter moisture of 28.1% (Huang *et al.*, 2011; Hernandez *et al.*, 2013; van Harn *et al.*, 2017). This leads to the body no longer needing to eliminate the excess protein in the form of uric acid. In addition, a lower water intake raises the DM content of the litter, which lowers the likelihood of skin dermatitis-related conditions like footpad lesions, hock burns, and breast blisters (van Harn *et al.*, 2017). Furthermore, with amino acid supplementation, a 19 g/kg reduction in dietary CP (from 215 to 196 g/kg), decreased N in the litter by 16.5% and atmospheric NH₃ concentrations by 31.0% (Ferguson *et al.*, 1998), highlighting the possibility of reduced-CP diets improving bird welfare. The findings of the research conducted by Shao *et al.* (2018), Lemme *et al.* (2019), and Van Harn *et al.* (2019) suggest that a 59 % improvement in footpad scores could be achieved by reducing dietary CP by 29 g/kg, or from 198 to 169 g/kg. In recent times, a decline in the use of antibiotic growth promoters (AGPs) has increased the risk of necrotic enteritis (Broom, 2017), a serious health issue that causes outbreaks to cost the poultry industry about US \$6 billion annually (Wade and Keyburn 2015). Reduced-CP diets have the ability to lessen the quantity of undigested protein that enters the large intestine, assisting in the inhibition of possible pathogen growth. A clinical example is *Clostridium perfringens*, the etiological agent of necrotic enteritis (NE), whose populations in broiler chickens have been demonstrated to be influenced by undigested dietary protein and amino acids. According to Drew *et al.* (2014), birds would be predisposed to NE by a 170 g/kg increment in CP diets based on fishmeal, as this would result in a 1.65 (7.55 versus 4.57 cfu/g) increase in the *C. perfringens* population in the caecum. Hence, the risk of NE is

decreased by utilising reduced-CP diets and having less undigested protein enter the large intestine as a substrate for gut microflora (Timbermont *et al.*, 2011).

Nevertheless, even though cutting back on crude protein in poultry diets has advantages, there seems to be a point at which broiler chickens can no longer tolerate dietary CP reductions (Greenhalgh *et al.*, 2020). This is due to the fact that the precise requirements for amino acids in reduced-CP diets are still unknown, and it is improbable that the bioequivalence of an amino acid that is bound to protein and its unbound counterpart is the same (Wu *et al.*, 2013). Studies have shown that while more drastic reductions in the order of 50 g/kg CP typically result in inferior performance of birds, moderate reductions in dietary CP of about 20 to 30 g/kg are feasible as they do not compromise the growth of birds (Aftab *et al.*, 2006; Belloir *et al.*, 2017).

2.5.4 Energy requirements of Guinea fowls

Energy is essential for supporting various physiological functions in Guinea fowls, including growth, maintenance, reproduction, and thermoregulation. To meet their energy needs, Guinea fowls require diets with appropriate levels of metabolizable energy (ME) derived from carbohydrates, fats, and proteins (Ofori *et al.*, 2019).

According to Adebawale *et al.* (2019), dietary energy regulates feed consumption, which affects how nutrients are used. Hence, before utilising any dietary energy for growth, newly hatched keets must first tend to their maintenance needs. According to Alabi *et al.* (2023), this implies that the amount of feed that growing birds consume is inversely related to the amount of energy in their diet. At different stages of lives, Guinea fowls show different energy requirements. While adult birds require less energy for maintenance, young chicks require more energy for rapid growth (Smith *et al.*, 1993; Idrissu, 2014). Guinea fowls need

more ME to support growth and development as they develop from the starter to grower, and finisher phases (Ikani and Dafwang, 2004).

ME levels and animal weight gain have been shown to be strongly positively correlated in numerous studies (Oke *et al.*, 2004; Nahasho *et al.*, 2005; Iddrisu, 2014). Faster growth rates are a consistent outcome of higher ME diets, and this is especially significant when considering meat production. According to Sadeghi and Tabiedian (2005), broiler chickens fed diets high in ME demonstrated a notable increase in body weight gain and a quicker time to market when compared to those fed diets low in ME. Nahashon *et al.* (2005) asserted that, French Guinea broilers were more productive when fed diets containing 3,100 kcal of ME/kg and 23% CP, or 3,150 kcal of ME/kg and 21% CP at 0 to 4 weeks of age and 5 to 8 weeks of age, respectively. The results of an experiment conducted in the southern region of Ghana to ascertain the energy and protein requirements of Guinea fowls revealed that the amounts of protein and energy needed by Guinea keets during their first eight weeks of growth could be estimated to be 24 % CP and 12.5 MJ ME /kg, respectively (Amoah *et al.*, 2017)

2.5.4.1 Energy to protein ratio

Energy to crude protein ratio is a critical aspect of nutrition for poultry, as it directly impacts their growth, development, and overall health (Sadeghi & Tabiedian, 2005) . Guinea fowls, like other poultry species, require a balanced diet consisting of adequate protein and energy sources to support their physiological needs, particularly during periods of rapid growth, egg production, or maintenance.

The impact of dietary composition on growth performance and carcass characteristics has attracted increasing scientific interest in recent years. Given the escalating cost of feed ingredients, optimising nutrient utilisation efficiency and carcass composition has become a

primary concern, often taking precedence over growth rate alone. This consideration is particularly critical during the early stages of development, as early nutritional strategies exert a lasting influence on subsequent performance in broiler chickens (Firman and Boling, 1998).

During ontogenetic growth, young birds initially accrete lean, lipid-free tissue before progressing toward a physiological state characterised by increased adiposity. The rate of fat deposition during this transition is largely governed by the balance and absolute levels of metabolizable energy (ME) and crude protein (CP) in the diet. Diets with elevated ME-to-CP ratios have been shown to enhance lipid retention, as surplus dietary energy relative to protein is preferentially stored as body fat (Sell *et al.*, 1985; Kamran *et al.*, 2008). Consequently, precise regulation of the ME: CP ratio during early growth is essential to optimise nutrient partitioning, improve feed efficiency, and achieve desirable carcass composition. The protein efficiency ratio and energy efficiency ratio in broiler chicken production were found to be decreased ($P < 0.05$) when low-CP and low-ME diets were used throughout the trial phases. Implying that the growth performance of broiler chickens has been negatively impacted by feeding them low-CP diets with a constant ME: CP ratio (Kamran *et al.*, 2008). In two experiments with varying energy to protein ratios, Reginatto *et al.* (2000) showed that protein utilisation improved with higher dietary energy levels and lower dietary CP levels. In another experiment, Kamran *et al.* (2008) asserted that a diet with 22% CP and 2,904 kcal/kg ME produced the best results for broiler chicken performance.

2.6 Limitations of Guinea Fowls Production in Ghana

2.6.1 Breeding stock acquisition

The seasonality of breeding has been recognized as one of the major drawbacks to large-scale Guinea fowls production when using the indigenous breed (Soara et al., 2020; Orounladji et al., 2022; Abdallah & Oyebamiji, 2024). Under the traditional system, breeding stocks are obtained from the farmers own stocks thus, fertile eggs are not available for year-round production which only leads to small-scale farming.

2.6.2 Availability of feed

According to Abdallah and Oyebamiji (2024), scavenging is the main feeding system under free-range Guinea fowls production in rural areas where the birds feed mainly on insects, leaves, grass seeds, tubers and sedges with ground millet, Guinea corn and maize as supplements provided by their owners. These feed resources are quite abundant during the rainy season but are scarce during the dry season. Feed supply is one of the main constraints to rural poultry production in Ghana. Notwithstanding this constraint, Guinea fowls have a unique ability to utilize a wide range of flora and fauna as feed resource base.

2.6.3 Growth traits and productivity

The productivity of the Ghanaian local Guinea fowls is far below that observed in European breeds (Table 2.2). Indigenous Guinea fowls breeds generally have slow growth rate and utilize feed less efficiently than chickens (Annor *et al.*, 2012; Iddrisu, 2014). The slow growth rate of Guinea fowls is associated with the use of unimproved breeds, extensive production system, poor feeding, poor health care and poor management and selection (Annor *et al.*, 2012; Iddrisu, 2014; Arije, 2021; Wahab *et al.*, 2022). Guinea fowls reared under the intensive management system have superior production performance than those

reared under both semi-intensive and extensive management system (Saina, 2005; Iddrisu, 2014).

Table 2.2: Productivity of Ghanaian and European Guinea fowls

Parameter	Productivity in Ghana	Productivity in Europe
Annual egg production	100	180
Laying period (week)	20	40
Egg size (g)	32	60
Fertility rate (%)	42	88
Hatchability (%)	45	83
Mortality (%)	40-100	3-4
6 weeks weight (g)	245	650
12 weeks weight (g)	500	1600
24 weeks weight (g)	1200	2500

Source: Annor *et al.* (2012)

2.6.4 Research in genetic improvement

A lot of genetic research has been carried out on the Guinea fowls in order to identify genes of economic importance and breeders have achieved excellent improvement of stock. In France, Italy and India where considerable amounts of work have been done to improve performance, Guinea fowls production has become commercially viable (Araújo *et al.*,

2023). According to Islam and Kabir (2021), the keets and eggs that were imported from France and Belgium to the Poultry section of the Pong-Tamale Animal Production Unit were from exotic breeds that were fast growing and bigger, weighing between 1.8 kg and 2.0 kg at 20 weeks of age. The exotic Guinea fowls have been used for cross breeding to improve the local breeds for both eggs and meat quality but there are still some challenges in the acquisition of these improved breeds by rural farmers (Iddrisu, 2014).

2.6.5 Breeding season of Guinea fowls

Most wild Guinea fowls birds breed during a restricted period of the year irrespective of the latitude at which they are found (Akarikiya, 2021). The restriction is usually imposed by the seasonal availability of the appropriate food resources required for feeding and fledging the young (Howard, 2024). The sub-humid tropical pearl female Guinea fowls are monogamous (Oke *et al.*, 2003) and seasonal breeders (Howard, 2024). The seasonality in reproduction has been recognized as one of the major problems that may hinder large-scale commercial Guinea fowls production. Factors responsible for this seasonality are not yet clearly known (Oke *et al.*, 2003).

2.7 Lysine and Methionine Requirement in Guinea Fowls

Lysine and methionine are the first and second essential amino acids, which are limiting in the traditional diet for poultry (Harms and Russel, 2003). However, it has been cited earlier that there is a lack of information on the optimum requirement of these two essential amino acids that would support optimum growth and minimize production cost of Guinea fowls. Except for soybean, which contains relatively higher amount of lysine, all other plant protein sources contain low amount of lysine (Garcia *et al.*, 2005). Similarly, methionine contained in all plant sources is very low as required by chicken (Gill, 2003). Understanding the

methionine and lysine requirements of Guinea fowls is essential in guiding formulation of least cost diets that effectively meet the nutritional needs of individual birds (Biswas, 1999; Koney, 1993).

Researchers have proved that lysine and methionine function as precursors of L-carnitine which can play important roles in lipid and energy metabolism in poultry (Harmeyer, 2002). L-carnitine is a natural, vitamin-like substance that acts in the cells as a receptor molecule for activated fatty acids. The major metabolic role of it appears to be the transport of long-chain fatty acids into the mitochondria for B-oxidation (Harmeyer, 2002). A shortage of this substance results primarily in impaired energy metabolism and membrane function. The presence of lysine and methionine in their right proportions in poultry diet facilitate fatty acid oxidation and reduce the amount of long-chain fatty acids available for storage in adipose tissue and thus ensuring the production of lean meat (Golzar *et al.*, 2006).

According to Nkwanyana (2020) and Forsan (2024) the percentages of methionine and lysine are higher for the Guinea fowls than the chicken for fast growth. The requirements of methionine and lysine as the first two limiting amino acids in practical corn-soybean based diets for poultry has been evaluated by some researchers. Some studies that have been conducted to evaluate the effects of these amino acids over Wall (2023) recommendations on laying hens' performance, confirmed its effect on egg production, feed conversion ratio, egg weight, egg mass and livability especially in low protein diets of traditional poultry. However, it can be argued that such valuable information of high levels of lysine and methionine requirement is lacking on the production of the indigenous Guinea fowls.

2.7.1 Effect of lysine supplementation on growth performance of Guinea fowls

Lysine is an essential amino acid that plays a crucial role in the growth and development of poultry, including Guinea fowls. Numerous studies have highlighted the importance of lysine in optimizing growth performance, as it is vital for protein synthesis, muscle development, and overall metabolic functions. For instance, research by Costa (2023) demonstrated that lysine supplementation significantly improved body weight gain and feed conversion ratio (FCR) in broiler chickens, indicating its potential benefits for other poultry species. In Guinea fowls, similar trends have been observed, with studies indicating that appropriate lysine levels in the diet can enhance growth performance, improve muscle mass, and support efficient feed utilization. This is particularly important for Guinea fowls, which are known for their relatively slower growth rates compared to other poultry species.

Moreover, the role of lysine in promoting optimal health and immune function in poultry further underscores its importance. Lysine deficiency has been linked to poor growth rates, reduced feed efficiency, and increased susceptibility to diseases, as evidenced by studies on various poultry species. For Guinea fowls, which are increasingly being reared for meat production, maintaining optimal lysine levels is crucial to achieving desirable production outcomes. A study by Khwatenge *et al.* (2020) indicated that Guinea fowls fed diets supplemented with lysine showed improved growth metrics and enhanced carcass quality compared to those on lysine-deficient diets. These findings suggest that lysine supplementation is a key factor in maximizing the growth performance and overall health of Guinea fowls, thereby supporting their economic viability in commercial poultry production.

2.7.2 Effect of methionine supplementation on growth performance of Guinea fowls

Methionine is an essential sulfur-containing amino acid that plays a significant role in poultry nutrition, influencing growth performance, feather development, and overall health (Alagawany *et al.*, 2021). The importance of methionine in poultry diets has been extensively studied, with research consistently demonstrating its critical role in enhancing growth rates and feed efficiency. For instance, methionine supplementation has been shown to improve body weight gain and feed conversion ratio (FCR) in broiler chickens, laying hens, and turkeys. In Guinea fowls, similar benefits have been observed. Methionine is crucial for protein synthesis and various metabolic functions, including the synthesis of other sulfur-containing compounds like cysteine and taurine. A study by Waguespack *et al.* (2009) highlighted that methionine supplementation significantly improved growth performance in Guinea fowls, leading to better weight gain and feed efficiency compared to those on methionine-deficient diets.

Furthermore, methionine's role extends beyond growth performance to include immune function and antioxidative properties, which are vital for maintaining the health and productivity of Guinea fowls. Methionine deficiency can result in poor growth, feathering issues, and increased vulnerability to diseases due to compromised immune responses. For instance, research by Rostagno *et al.* (2007) indicated that adequate methionine levels are essential for optimal immune function and overall health in poultry. In Guinea fowls, methionine supplementation has been associated with improved carcass quality and meat yield, making it a crucial component of commercial Guinea fowls production. A study by Narváez-Solarte *et al.* (2005) demonstrated that methionine-supplemented diets significantly

enhanced the growth performance and carcass traits of Guinea fowls, supporting the economic benefits of this supplementation. These findings underscore the importance of methionine in the diet of Guinea fowls to achieve optimal growth performance and health.

2.8 Egg Production and Reproductive Performance of Guinea Fowls

Guinea fowls are seasonal breeders and this seasonality has been recognized as one of the major drawbacks to large-scale Guinea fowls production (Mallam, 2019). In the wild, production starts at 28-42 weeks with 15-20 eggs being laid each season but in captivity, production starts at 28-32 weeks with 50-100 eggs being produced in the first year and more eggs (180) are laid in the second year of production (Onunkwo and Okoro, 2015). Laying may continue for 7 or more years. In developed countries, where Guinea fowls production is well established, the use of light control programmes and selection have resulted in making Guinea fowls an all-year round breeder. Egg production can be increased by artificial lighting, a practice common with the domestic fowls. The ovary of the adult Guinea hen is smaller (25.29 g) than that of the domestic fowls (40-60 g). The smaller testicular size (1-9g) may place the Guinea fowls at a disadvantage when compared with the 14-16g commonly reported for the male of domestic fowls (Alders *et al.*, 2018). In Ghana, the season of lowest relative humidity, rainfall and high temperature corresponds with the period of low semen volume, low spermatozoa concentration, low percentage mortality, high percentage abnormality and high dead to live spermatozoa ratio (Yakubu *et al.*, 2019). Saeed *et al.* (2019) reported that heat stress reduces feed intake and induces testicular resting. Most eggs (80-90 %) are laid during the rainy months of April to September, although improved strains of Guinea fowls lay as early as February although under captive conditions breeding has been reported to be delayed. A 3-year study of the laying characteristics and productive

performance of the indigenous helmeted variety of Guinea fowls revealed that eggs could be obtained over a period of about 9 months each year (Onunkwo and Okoro, 2015).

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study Location and Duration

This experiment was carried out at the Poultry Unit of the Department of Animal Science Education, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED). Asante Mampong is in the forest-savanna transition agro-ecological zone of Ghana. The area has a bimodal rainfall pattern with the major rainy season occurring from early April to July and the minor rainy season from September to November (Pabi *et al.*, 2019). There is a harmattan (dry season) from December to February, and daily temperatures range from 25°C to 30°C, and the relative humidity of the area is 70 % (MSD, 2015). The experiment was conducted from June, 2023 to August, 2023.

3.2 Dietary Treatments and Experimental Design

The Concept 5 feed formulation program (Creative Formulation Concepts, LLC, Annapolis, MD) was used to formulate three experimental diets with varied crude protein (CP) levels, each supplemented with crystalline amino acids (lysine and methionine). Treatment one (T1)

was formulated to contain a high CP level (20.08%) with no lysine or methionine supplementation. Treatment two (T2) was formulated to contain a medium CP level (17.33%) supplemented with 0.15% lysine and 0.40% methionine, while Treatment three (T3) contained a low CP level (13.69%) supplemented with 0.90% lysine and 0.25% methionine (Table 3.1).

The classification of CP levels in this study was based on previous reports indicating that dietary crude protein levels between 16–18% are considered adequate for optimal growth and nutrient utilization in Guinea fowls (Ayeni et al., 1983; Nahashon et al., 2006; Hounkpêvi et al., 2024). Hence, the 17.33% CP diet was classified as medium and considered to meet the protein and lysine requirements of growing Guinea fowls. The formulation of the medium CP diet was particularly critical, as balancing amino acid supplementation and total protein can be challenging at this level, given the metabolic demand for both essential and non-essential amino acids for tissue synthesis and maintenance. All diets were subjected to proximate and chemical analysis according to AOAC (1990) to verify nutrient composition.

Ingredient	Treatment 1	Treatment 2	Treatment 3
Maize grain	68	70	70
Soybean meal	15	14.63	5
Wheat bran	1	6	17.87
Fishmeal	13.57	5.95	3
Dicalcium phosphate	0.42	0.57	0.5
Salt	0.5	0.5	0.506
Oyster shell	1.02	1.3	1.5
Premix*	0.5	0.5	0.5
Lysine	0	0.15	0.9
Methionine	0	0.4	0.25
Total	100 kg	100 kg	100 kg
Nutrient Composition calculated			
Crude Protein %	20.08	17.33	13.69
Calcium %	1.08	1.06	1.06

Available P %	0.57	0.57	0.49
ME, Kcal/Kg	3021.59	2976.96	2865.30
Methionine %	0.41	0.46	0.48
Lysine %	1.3	1.35	1.37
Sodium %	0.46	0.44	0.37
Chlorine %	0.31	0.31	0.31

*Vitamin A, 8,000,000 IU; Vitamin B1, 1300 mg, Vitamin B2, 2500 mg, Vitamin D3, 3000 IU; Vitamin E, 10, 000 IU; Vitamin K3, 1,500 mg; Vitamin B6, 1,000 mg; Vitamin B12, 6 mg, Nicotinic Acid, 5,000 mg, Pantothenic Acid, 4000 mg; Choline Chloride, 8000 mg; Copper, 2,500 mg; Cobalt, 700 mg; Iron, 4,500 mg; Zinc, 55, 000 mg; Methionine, 50,000 mg; Lysine, 200,000 mg; Selenium (1%), 1,300 mg; Iodine, 2,000 mg; Manganese, 60, 000 mg; Antioxidant, 625 mg.

3.3 Experimental Birds and Management

One hundred and thirty-nine (139) experimental keets from Lamdi Farms and hatchery, Tamale were reared in an open-sided deep litter housing system with fresh softwood shavings (5 cm deep) and with *ad libitum* access to a starter, grower, and finisher diets and water throughout the experimental duration. The keets were brooded in a deep litter structure for the first thirty (30) days post-hatch. After the brooding period, keets of similar sizes were weighed and randomly allocated to 15-floor pens (2.24 m²) of 5 replicate pens per treatment, each housing 10 birds. Each pen was provided with feeding and watering troughs. Treatments were arranged in a completely randomized design (CRD). The Guinea fowls were offered feed and water *ad libitum* throughout the starter, grower, and finisher phases.

3.4 Data Collected

3.4.1 Growth performance

Feed consumption, body weight, gain, feed conversion ratio (feed: gain) and livability were calculated weekly. Feed consumption was calculated by subtracting the feed leftover from the total feed offered. The body weight was measured by dividing the cumulative pen weight by the number of birds in the pen. Gain was calculated as the difference between the birds' body weight and their initial body weight. Feed Conversion Ratio (FCR) was calculated by

dividing the difference between the pen weight and the sum of the initial bird weight and dead bird weight, by the feed consumption for the same period. Livability was calculated by dividing the number of birds by the initial total number of birds and multiplying by 100. The pens were monitored for mortality twice daily and post-mortem examinations were conducted on dead birds throughout the study period. Feed intake and feed conversion ratio (feed intake/weight gain) were corrected for mortality.

3.4.2 Haematology and biochemical analysis

Five birds from each treatment at day 93 were sampled for haematological analysis. A 25-gauge needle was used to draw 2 ml of blood from the wing vein of each selected Guinea fowl after disinfecting the area by swabbing with 70 percent alcohol. The needle was directed into the wing vein in the direction of the flow of blood. The blood was deposited in an evacuated tube containing an anticoagulant and was sent to the laboratory for analysis.

3.4.2.1 Measurement of haematological parameters

Haematological indices assessed included red blood cell (RBC) count, haemoglobin concentration (Hb), packed cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC), red cell distribution width (RDW), platelets (PLT) and mean platelet volume (MPV) and platelet distribution width (PDW). Full blood count (FBC) was measured by a five (5) parts (differentials) fully automated BC 5800 haematology system, (Mindray, Germany) according to the manufacturer's instructions. Principles employed included impedance method for RBC and PLT counting; Cyanide free reagent for haemoglobin test; and Flow Cytometry (FCM) + Laser light scatter + Chemical dye method for WBC differential

analysis and WBC counting. Leucocytes indices embraced level of White blood cells (WBC), percentage neutrophils, lymphocytes, monocytes, eosinophil and basophils.

3.4.4 Gastrointestinal pH

Immediately after cervical dislocation of 2 birds per replicate pens at d 93, they were dissected and the crop, proventriculus, gizzard, duodenal, jejunal, ileal, and caecal pH were measured using a pH tester (Hanna instruments, UK) as described by Zanu *et al.* (2023), by directly inserting the pointed tip into the digesta in the lumen of the proximal end of each segment of the same bird whilst ensuring that the pH electrode did not touch the walls. Once all the readings for each bird had been taken the probe was rinsed with distilled water. The mean of the two readings per segment of the tract was then calculated.

3.4.5 Carcass and organ weight

The liver, breast meat, thigh, heart, and empty gizzard were taken from the sampled birds used for the determination of gut pH and weighed. Each part was expressed as a percentage of live BW.

3.4.5 Bone traits

On d 65 and 93 post-hatch, femur, and tibiae were collected from the right leg of sampled birds used for the gut pH and carcass traits to determine the bone dimensions and bone breaking strength. The dimensions of the femur and tibia were measured by measuring the length (mm) (from the tip of the proximal end to the tip of the distal end) and width (mm) (at the medial region) using a digital calliper. For the determination of breaking strength (BS), the femur and tibiae were defleshed by hand using a scalpel. The resulting femur and tibiae were then subjected to testing on a universal texture analyzer (Inspekt table50-1,

Hegewald & Peschke, Meß- Germany) set up with a 50 KN load cell and 3-point fixture bed at a test speed of 10 points of data per second. The machine was run by a BenQ computer (24 Inch IPS monitor) with Blue Hill 3 software.

3.5 Data Analysis

Using the General Linear Model technique of Minitab version 20.3, data on various parameters were subjected to statistical analysis using analysis of variance (ANOVA) for a completely randomized design. Fisher LSD means separation test was used to make pairwise comparisons between treatment means ($P < 0.05$).

CHAPTER FOUR: RESULTS

4.1 Effects of Experimental Diets on the Growth Performance of Guinea Fowls at d 44

On day 44, dietary treatments influenced ($P < 0.05$) the BW and gain of the birds, implying that birds fed 20.08 % and 17.33 % crude protein recorded higher BW, and gain compared to those on 13.69 %. Moreover, birds fed diets containing the high (20.08 %) and medium CP (17.33 %) had better feed conversion ratios ($P < 0.05$) compared to birds on the low (13.69 %) CP (Table 4.1).

4.2 Effects of Experimental Diets on the Growth Performance of Guinea Fowls d 0-51 and 0-58

As shown in Table 4.2 and Table 4.3, birds fed medium crude protein diets (17.33 %) and the high CP (20.08 %), had higher BW and gain ($P < 0.05$) compared to those on the low CP (13.69) diet recording the lowest BW and gain on day 51 and 58 of the experiment. Over the same period, feed conversion ratio although not significant ($P > 0.05$) was better in birds fed the medium (17.33 %) compared to their counterparts on the high CP (20.08 %) and low CP (13.69), respectively. All other performance variables were non responsive ($P > 0.05$) to the dietary treatments over the same period.

Table 4.1: Effects of Experimental Diets on the Growth Performance of Guinea fowls at d 44

Treatment	Livability, %	BW, g	Gain, g	Intake, g	FCR
T1	100.0	229.8 ^a	68.22 ^a	424.2	6.249 ^b
T2	95.28	228.5 ^a	72.30 ^a	449.5	6.217 ^b
T3	97.78	204.5 ^b	39.33 ^b	398.7	10.17 ^a
SEM	2.110	4.200	4.110	50.70	0.752
P-Value	0.320	0.002	0.000	0.782	0.004

T1, 20.08 %.; T2,17.33 %; T3, 13.69 %.; BW, Body weight; FCR, Feed conversion ratio corrected, SEM, Standard error of mean.^{ab} - Means with different superscripts in a column are significantly different ($p < 0.05$)

Table 4.2: Effects of experimental diets on the growth performance of Guinea fowls d 0-51

Treatment	Livability, %	BW, g	Intake, g	Gain, g	FCR
T1	100.0	284.9 ^a	699.1	123.3 ^a	5.696
T2	95.28	289.3 ^a	688.3	133.1 ^a	5.189
T3	97.78	240.9 ^b	602.1	75.72 ^b	8.478
SEM	2.110	9.170	61.20	8.400	0.936
P-Value	0.320	0.005	0.491	0.001	0.059

T1, 20.08 %.; T2,17.33 %; T3, 13.69 %.; BW, Body weight; FCR, Feed conversion ratio corrected, SEM, Standard error of mean, ^{ab} - Means with different superscripts in a column are significantly different ($p < 0.05$)

Table 4.3: Effects of experimental diets on the growth performance of Guinea fowls d 0-58

Treatment	Livability, %	BW, g	Intake, g	Gain, g	FCR
T1	100.0	338.0 ^a	868.7	176.4 ^a	4.950
T2	95.28	348.7 ^a	900.3	192.5 ^a	4.690
T3	95.78	270.5 ^b	771.4	105.3 ^b	8.050
SEM	2.250	12.10	60.90	11.00	1.060
P-Value	0.300	0.001	0.331	0.000	0.081

T1, 20.08 %; T2, 17.33 %; T3, 13.69 %; BW, Body weight; FCR, Feed conversion ratio corrected, SEM, Standard error of mean, ^{ab}- Means with different superscripts in a column are significantly different ($p < 0.05$)

4.3 Effects of Experimental Diets on the Growth Performance of Guinea Fowls at d 65, 93 and 100

Experimental diets significantly affected ($P < 0.05$) all the growth performances of birds except livability, intake and FCR on day 65 through to d 93 and 100 of the experiment. Birds fed diets containing medium and high CP gained more and recorded higher BW compared to those on low CP, (Tables 4.4, 4.5 & 4.6).

Table 4.4: Effects of experimental diets on the growth performance of Guinea fowls d at 65

Treatment	Livability, %	BW, g	Intake, g	Gain, g	FCR
T1	97.78	404.9 ^a	1225	243.3 ^a	5.077
T2	95.28	418.4 ^a	1229	262.2 ^a	4.708
T3	91.78	322.1 ^b	1057	156.9 ^b	6.907
SEM	3.980	14.30	74.80	13.30	0.636
P-Value	0.579	0.001	0.201	0.001	0.066

T1, 20.08 %.; T2,17.33 %; T3, 13.69 %.; BW, Body weight; FCR, Feed conversion ratio corrected, SEM, Standard error of mean.^{ab}- Means with different superscripts in a column are significantly different ($p < 0.05$).

Table 4.5: Effects of experimental diets on the growth performance of Guinea fowls at d 93

Treatment	Livability, %	BW, g	Intake, g	Gain, g	FCR
T1	74.22	686.8 ^a	3171 ^a	525.2 ^a	6.080
T2	73.39	726.5 ^a	3106 ^b	570.2 ^a	5.452
T3	65.44	545.7 ^b	2472 ^b	380.5 ^b	6.609
SEM	4.290	27.60	1420	26.90	0.326
P-Value	0.315	0.001	0.008	0.001	0.079

T1, 20.08 %.; T2,17.33 %; T3, 13.69 %.; BW, Body weight; FCR, Feed conversion ratio corrected, SEM, Standard error of mean, ^{ab}- Means with different superscripts in a column are significantly different ($p < 0.05$)

Table 4.6: Effects of experimental diets on the growth performance of Guinea fowls at d 100

Treatment	Livability, %	BW, g	Intake, g	Gain, g	FCR
T1	76.44	508.3 ^a	1828 ^a	346.8 ^a	5.324
T2	71.17	515.2 ^a	1878 ^a	358.9 ^a	5.237
T3	65.44	361.7 ^b	1065 ^b	196.5 ^b	5.487
SEM	4.630	33.50	166	32.10	0.256
P-Value	0.281	0.011	0.008	0.006	0.786

T1, 20.08 %.; T2, 17.33 %.; T3, 13.69 %.; BW, Body weight; FCR, Feed conversion ratio corrected, SEM, Standard error of mean. ^{ab}- Means with different superscripts in a column are significantly different ($p < 0.05$)

4.4 Effects of Experimental Diets on the Carcass Traits (% BW) of Guinea Fowls d 65 and d 93

Dietary treatments did not affect ($p > 0.05$) the carcass traits measured on d 65 of the feed trial (Table 4.7). However, on d 93, dietary treatments had a significant effect ($p < 0.05$) on the gizzard weight of experimental birds. The diet containing low levels of dietary CP (13.69 %) produced birds whose gizzard weights were higher ($p < 0.05$) than their counterparts on the high and medium dietary CP levels. Aside the gizzard, all other carcass traits were non-responsive to the dietary treatments on the same period (Table 4.7).

Table 4.7: Effects of experimental diets on the carcass weight (% BW) of Guinea Fowl D 65

Treatment	Heart	Liver	Gizzard	Breast	Thigh
T1	0.045	0.113	0.247	0.179	0.431
T2	0.039	0.113	0.257	0.191	0.426
T3	0.041	0.112	0.291	0.174	0.391
SEM	0.003	0.008	0.018	0.011	0.014
P-Value	0.500	0.998	0.229	0.554	0.148

T1, 20.08 %.; T2, 17.33 %.; T3, 13.69 %.; BW, Body weight; SEM, Standard error of mean.

Table 4.8: Effects of Experimental Diets on the carcass weight (% LBW) of Guinea fowl d 93

Treatment	Heart	Liver	Gizzard	Breast	Thigh
T1	0.034	0.090	0.150 ^b	0.183	0.469
T2	0.033	0.095	0.156 ^b	0.161	0.479
T3	0.032	0.092	0.198 ^a	0.159	0.447
SEM	0.002	0.006	0.012	0.014	0.010
P-Value	0.853	0.870	0.030	0.445	0.100

T1, 20.08 %; T2, 17.33 %; T3, 13.69 %; BW, Body weight; SEM, Standard error of mean, ^{ab}- Means with different superscripts in a column are significantly different ($p < 0.05$)

4.5 Effects of Treatments on Bone Weight and Dimension of Guinea Fowl d 65

Except for Tibial length, all other bone parameters measured on day 65 were non-responsive ($P > 0.05$) to dietary treatments. The tibial length of birds fed diets containing high CP (20.08 %) appeared longer ($P < 0.05$) than that of those fed medium (17.33 %) and low CP (13.69 %) diets, respectively (Table 4.9).

4.6 Effects of Treatments on Bone Weight and Dimension of Guinea Fowl d 93

On day 93, femur length and tibial length were affected ($P < 0.05$) by dietary treatment, indicating that the medium CP (17.33 %) diet produced birds whose femur length and tibial length were improved compared to the high CP (20.08 %) and low CP (13.69 %) diets, respectively (Table 4.10).

Table 4.9: Effects of treatments on bone weight and dimension of Guinea fowls d 65

Treatment	Tibia Weight (g)	Femur Weight (g)	Tibia Length (mm)	Femur Length (mm)	Tibia Diameter (mm)	Femur Diameter (mm)
T1	0.355	0.308	67.05 ^a	28.44	29.52	4.702
T2	0.346	0.299	62.99 ^b	27.27	27.54	4.367
T3	0.337	0.305	61.06 ^b	30.94	21.98	4.372
SEM	0.010	0.012	1.280	2.790	2.560	0.187
P-Value	0.468	0.849	0.018	0.647	0.140	0.378

T1, 20.08 %; T2, 17.33 %; T3, 13.69 %. And SEM, Standard error of mean; ^{ab}- Means with different superscripts in a column are significantly different ($p < 0.05$)

Table 4.10: Effects of treatments on bone weight and dimension of Guinea fowl d 93

Treatment	*Tibia Weight (%)	*Femur Weight (%)	Tibia Length (mm)	Femur Length (mm)	Tibia Diameter (mm)	Femur Diameter (mm)
T1	0.409	0.376	91.74 ^b	70.72 ^a	5.509	6.022
T2	0.398	0.358	94.53 ^a	71.66 ^a	5.628	5.952
T3	0.393	0.350	86.14 ^c	66.61 ^b	5.203	5.664
SEM	0.010	0.009	0.767	0.580	0.112	0.168
P-Value	0.539	0.174	0.000	0.000	0.051	0.318

T1, 20.08 %; T2, 17.33 %; T3, 13.69 %. And SEM, Standard error of mean. ^{ab}- Means with different superscripts in a column are significantly different ($p < 0.05$), *Value expressed as a percent of live body weight.

4.6.1 Effects of treatments on bone breaking strength of Guinea fowls d 65 and d 93

According to results in Table 4.11, neither the tibia nor femur breaking strengths of the experimental birds were influenced ($P > 0.05$) by dietary treatment on day 65 and day 93 of the experiment.

Table 4.11: Effects of experimental diets on bone-breaking strength of Guinea fowls d 65 and 93

Treatment	d 65		d 93	
	Tibia BS (N)	Femur BS (N)	Tibia BS (N)	Femur BS (N)
T1	50.80	61.20	132.4	202.1
T2	51.90	73.80	117.3	173.3
T3	46.70	72.80	121.4	148.7
SEM	6.990	9.920	12.00	17.90
P-Value	0.859	0.619	0.666	0.151

T1, 20.08 %; T2, 17.33 %; T3, 13.69 %; BS, breaking strength, and SEM, Standard error of mean.

4.7 Effects of Treatments on Gastrointestinal pH of Guinea Fowls d 93

None of the pH of the intestinal segments measured on d 93 was significantly affected ($P > 0.05$) by dietary treatment (Table 4.12).

Table 4.12: Effects of experimental diets on the gastrointestinal pH of Guinea fowls d 93

Parameter	Crop	Provent	Gizzard	Duodenum	Ileum	Jejunum	Caecum
T1	4.584	1.068	1.882	5.409	6.903	5.694	6.640
T2	5.021	1.079	2.370	5.741	6.780	5.793	6.507
T3	4.778	1.059	1.920	5.380	6.494	5.616	6.558
SEM	0.143	0.037	0.194	0.154	0.242	0.113	0.077
P-Value	0.138	0.929	0.184	0.226	0.491	0.555	0.488

T1, 20.08 %; T2, 17.33 %; T3, 13.69 %; SEM, Standard error of mean

4.8 Effects of Treatments on Haematological Traits of Guinea Fowls d 93

On day 93 of the study (Table 4.13), it was observed that none of the haematological parameters measured were significantly affected by the dietary treatments ($P > 0.05$). Although statistically not significant, birds on the low crude protein diet (13.69 %) record higher white blood cell (WBC), red blood cell (RBC), and glucocorticoid-remediable aldosteronism (GRA) counts compared to those on the high (20.08 %) and medium (17.33 %) crude protein diets. Birds on the medium crude protein diet, however, showed slightly higher GRA values than those on the high crude protein diet.

Table 4.13: Effects of experimental diets on haematological traits of Guinea fowls d 93

Parameter	T1	T2	T3	SEM	P-Value
WBC (10 ⁹ /L)	114.6	104.0	116.4	3.590	0.064
LYM (10 ⁹ /L)	97.89	90.86	99.12	2.680	0.103
MID (10 ⁹ /L)	9.646	8.952	9.708	0.361	0.295
GRA (10 ⁹ /L)	7.050	4.140	7.540	1.040	0.081
LYM (%)	85.44	87.52	85.24	0.878	0.169
MID (%)	8.420	8.640	8.320	0.116	0.179
GRA (%)	6.140	3.840	6.440	0.891	0.120
RBC (10 ¹² /L)	2.068	2.116	2.250	0.050	0.060
HGB (g/dL)	10.58	12.42	13.00	1.060	0.278
HCT (%)	31.30	31.64	33.70	0.811	0.118
MCV (fL)	131.2	149.6	149.6	10.80	0.406
MCH (pg)	60.72	58.76	57.92	1.540	0.444
MCHC (g/dL)	40.10	39.26	38.68	0.691	0.374
RDW-SD (fL)	90.34	87.42	87.00	2.060	0.481
RDW- CV (%)	13.06	12.99	12.76	0.321	0.789
PLT (10 ⁹ /L)	10.80	9.200	9.600	1.440	0.723
MPV (fL)	5.880	5.880	5.800	0.192	0.944
PDW (%)	12.80	10.10	11.44	0.942	0.170
PCT (%)	0.006	0.005	0.006	0.001	0.664
P- LCR (%)	0.940	0.840	0.680	0.204	0.670

T1, 20.08 %.; T2, 17.33 %; T3,13.69 %.; SEM, Standard error of mean; RBC, red blood cell; WBC, white blood cell; HGB, haemoglobin; HCT, hematocrit; MCV, mean corpuscular volume; MCH, mean corpuscular haemoglobin; MCHC,mean.

CHAPTER FIVE: DISCUSSION

It is imperative to optimise nutritional requirements to improve Guinea fowl production in terms of growth performance, carcass quality, and bone health. Dietary protein is one important factor that influences these traits. Okyere *et al.* (2020a) asserted that the performance of Guinea fowls is influenced by the quality of their diet because a deficiency of protein has been linked to stunted growth (Khairunnesa *et al.*, 2016), which in turn impacts the overall performance of Guinea fowls. This chapter discusses how three dietary protein levels, supplemented with crystalline lysine and methionine, affect the growth performance, carcass traits, haematology, and bone characteristics of pearl Guinea fowls.

5.1 Effects of Experimental Diets on Growth Performance of Guinea Fowls

The growth performance of Guinea fowls is greatly influenced by protein, which is an essential part of their diet. A diet rich in protein can help Guinea fowls grow faster, convert feed more efficiently, and gain more weight. In this study, it was found that increasing dietary protein levels improved the growth performance parameters that were measured throughout the experimental period. In comparison to birds fed low levels (13.69 %) of CP, those fed high (20.08 %) and medium levels (17.33 %) of CP showed higher BW and gain. Although there was no significant difference between the high and medium CP diets, the values recorded for BW, gain, and FCR of birds on the medium level of CP (17.33 %) were numerically better than those on the high (20.08 %) CP levels, thereby giving the birds on the medium level (17.33 %) of CP an advantage over their counterparts on the high CP and low CP diets. Okyere *et al.* (2020a) and Hounkpêvi *et al.* (2024) reported that feeding Guinea fowls high levels of CP resulted in improved growth performances, indicating that the higher the CP, the better the performance. The results of the present study, however, contradict the reports from these previous authors, Okyere *et al.* (2020a) and Hounkpêvi *et al.* (2024), as a medium-level

(17.33%) CP diet, instead of a high CP diet, resulted in better growth performance of the Guinea fowls.

Although feed intake did not differ significantly among treatments, the poorer feed conversion ratio observed in the low-protein group indicates inefficient nutrient utilisation. This may be attributed to the higher ME: CP ratio, which promotes energy storage as fat rather than lean tissue deposition (Sell et al., 1985; Lamot, 2017; Gous et al., 2018). Consequently, maintaining an appropriate balance between energy and protein is critical to achieving optimal growth and feed efficiency.

The lack of significant differences in livability among treatments suggests that variations in protein level did not adversely affect bird health or survival under the experimental conditions. However, the notable decline in performance under the lowest protein diet underscores the importance of formulating diets that support both metabolic efficiency and growth potential.

5.2 Effects of Experimental Diets on Carcass Weight (% BW) of Guinea Fowls

Except for the gizzard weight (% BW), which was increased by the low CP diet (13.69%), no other carcass characteristic was affected by the different CP levels in the diets. It has been widely accepted that high-protein diets promote muscle growth and development, which subsequently influence total carcass yield (Alippi *et al.*, 2012; Wang *et al.*, 2017). But unlike the fast growth rate that comes from feeding high-protein diets, low-protein feeds like the one in this study can occasionally help regulate the rate of growth in poultry. Slower growth can allow skeletal and muscle development to catch up with the bird's overall size, resulting in a more balanced and well-proportioned carcass (Roul, 2020). Conversely, a rapid growth rate can lead to larger but less developed muscles. Contrary to reports from Hounkpêvi *et al.* (2024), who noted improvements in the weights of leg muscle, liver, jejunum, and ileum when birds were fed a high-protein diet.

The low-CP diet in this study improved the weight of the gizzard at the expense of the high-CP diet. The higher gizzard weight in birds fed the lowest protein diet suggests a compensatory physiological response to increased fibre or reduced nutrient density in the feed. Similar observations were reported by Mateos et al. (2012), who noted that low-protein diets stimulate greater gizzard development as birds adapt to process larger feed volumes or less nutrient-dense diets.

The absence of significant differences in liver and heart weights among treatments implies that moderate reductions in dietary protein did not adversely affect metabolic or cardiovascular organ development. This aligns with the findings of Firman and Boling (1998), who reported that early dietary protein manipulation within practical limits does not impair vital organ function in broilers.

Likewise, the relative weights of breast and thigh muscles were not significantly influenced by dietary treatment, suggesting that short-term reductions in dietary protein did not substantially alter carcass muscle deposition. However, the trend toward lower breast yield in birds fed reduced protein diets may reflect limited amino acid availability for muscle accretion, as supported by Kazem and Imari (2024), who demonstrated that inadequate protein intake can redirect energy toward maintenance and fat storage rather than lean tissue synthesis.

5.3 Effects of Experimental Diets on Bone Weight, Bone Dimension and Bone Breaking Strength of Guinea Fowls

It has been demonstrated that several factors, including nutrition, either directly or indirectly affect bone and bone strength (Rath *et al.*, 2000; Whitehead, 2000). For vertebrates to grow normally, bone development is essential (Almeida Paz and Bruno, 2006). Protein is also equally important as calcium and phosphorus (Hunt *et al.*, 2009) and according to Hounkpèvi *et al.*

(2024), protein is an important component of bones and should be consumed in sufficient amounts to maintain the health of the bones. Dietary protein level exerted a significant influence on bone morphometry, particularly on tibia and femur lengths, while bone weight and diameter were not significantly affected. Birds receiving moderate to high protein diets exhibited longer tibiae and femora compared with those fed the lowest protein level, indicating that adequate protein intake supports skeletal growth and mineralisation. This finding agrees with previous studies demonstrating that protein adequacy during the growth phase enhances bone development through improved amino acid supply for collagen synthesis and calcium deposition (Rath *et al.*, 2000; Shim *et al.*, 2012). The lack of significant variation in bone weight and diameter across treatments suggests that protein restriction primarily affects bone elongation rather than overall bone mass or density. Similar observations were made by Talaty *et al.* (2010), who reported that moderate reductions in dietary protein altered bone length but not cortical thickness in broilers. The shorter bones observed in birds fed the lowest protein diet may be attributed to impaired osteoblastic activity and reduced nutrient availability necessary for endochondral ossification, processes known to be sensitive to dietary protein and energy balance (Liu and Kim, 2023). While protein doesn't directly influence bone development, it can affect the mineral composition of the bone. According to Dao *et al.* (2022), feeding birds low-protein diets decreased some mineral elements in the femur and tibia of birds. In another study, Abdulla *et al.* (2017) observed that high dietary energy levels in poultry have been linked to bone health issues, including effects on bone mass, strength, turnover, and the possibility of bone problems like weakness, deformity, and breakage. This, therefore, could suggest that the Guinea fowls on the diet that contained 17.33 % CP and 2976.96 Kcal/Kg ME had a protein and energy ratio that was sufficient to encourage healthy bone development. The results of this study differ from those of Hounkpêvi *et al.* (2024), who reported that varying crude protein levels in the diet had no significant effect on tibia and femur length. Oluwabiya

et al. (2022) also after feeding groups of pullets with varying amounts of crude protein, observed that the pullets' bone traits were unaffected by the variation in crude protein content in the diet.

5.4 Effects of Experimental Diets on Gastrointestinal pH of Guinea Fowls

A consensus exists that high dietary protein levels can lower the pH of the gut because protein digestion causes the gut to produce acids, which lower pH levels. Nutrient absorption and digestion from feed are optimised at lower pH levels (Humer *et al.*, 2015). Dietary protein level did not significantly influence the pH of any gastrointestinal segment in Guinea fowls at 93 days of age. The absence of significant differences across treatments suggests that variations in dietary crude protein within the tested range were not sufficient to alter the acid–base environment of the digestive tract. This finding is consistent with previous reports indicating that gastrointestinal pH is more strongly regulated by physiological and microbial mechanisms than by moderate dietary nutrient adjustments (Svihus, 2011; Abdaljaleel, 2018).

The relatively stable pH values observed throughout the gastrointestinal tract reflect normal digestive function, with acidic conditions in the proventriculus and gizzard facilitating enzymatic protein breakdown and more neutral to slightly alkaline conditions in the small intestine supporting nutrient absorption. Similar pH patterns have been described in poultry by Rodjan *et al.* (2018), who noted that the gastric regions maintain low pH due to hydrochloric acid secretion, while the intestinal sections exhibit higher pH values to optimise enzyme activity and microbial balance.

Although slight numerical variations were observed, particularly in the crop and gizzard of birds on the moderate-protein diet, these were not statistically significant. Such trends may indicate minor adaptive responses in digestive secretions to dietary composition, as previously reported by Zhang *et al.* (2023), who found that diet structure and nutrient density can subtly affect digesta pH by modifying retention time and microbial fermentation.

This observation contrasts with reports from several studies where feeding broiler chickens diets containing moderate to high crude protein levels (approximately 20–24% CP) improved the health of the gastrointestinal tract and enhanced small intestinal mucosal structure (Swatson *et al.*, 2002; Gilbert *et al.*, 2022).

5.5 Effects of Experimental Diets on Haematological Traits of Guinea Fowls

The protein content of poultry diets can significantly influence haematological parameters, which are important indicators of physiological and immune status. Low dietary protein has been associated with reduced white blood cell (WBC) counts and impaired immunity (Mitruka and Rawnsley, 1977). In the present study, however, birds fed low levels of dietary crude protein (CP) exhibited higher ($P>0.05$) WBC, red blood cell (RBC), and granulocyte (GRA) counts compared to those on medium and high CP diets. This contrasts with the findings of Rafiu *et al.* (2021), who reported that Guinea fowls fed a high-CP diet (20%) had higher WBC counts than those fed 16%, 18%, and 22% CP diets.

The haematological values obtained in this study fall within the normal physiological ranges reported for healthy Guinea fowls and other poultry species, WBC ($20\text{--}35 \times 10^9/\text{L}$), RBC ($2.5\text{--}3.5 \times 10^{12}/\text{L}$), Hb (9–13 g/dL), and PCV (30–40%) (Mitruka and Rawnsley, 1977; Taleb *et al.*, 2017). This indicates that, despite the reduced CP content, the experimental diets adequately supported normal haematopoiesis and immune competence. The relatively higher values observed for WBC and RBC under the low-CP treatment suggest efficient utilization of dietary nutrients and sufficient metabolizable energy (2865.30 kcal/kg), which may have compensated for the lower protein level. Adequate energy availability facilitates erythropoiesis and immune cell production, ensuring birds maintain stable physiological function (Taleb *et al.*, 2017).

CHAPTER SIX: CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The following conclusions were made at the end of the feed trial:

1. The diet containing 17.33 % CP with 0.15 % and 0.4 % crystalline lysine and methionine supplementation is ideal for promoting better growth performance in Guinea fowls.
2. Bone traits of Guinea fowls were enhanced when birds were fed 17.33 % CP with 0.15 % and 0.4 % crystalline lysine and methionine supplementation.
3. A 13.69% crude protein diet supplemented with 0.9% crystalline lysine and 0.25% methionine enhanced gizzard weight in Guinea fowls, though the biological mechanisms and health implications require further investigation. The gastrointestinal pH of Guinea fowls was not influenced by the varied crude protein levels and the crystalline amino acid supplementation of experimental diets.
4. All haematological indices of Guinea fowls studied were not significantly influenced by dietary treatment; nevertheless, the white blood cell, red blood cell, and GRA levels of Guinea fowls were increased numerically by feeding a diet containing 13.69 % CP with 0.9 % and 0.25 % crystalline lysine and methionine supplementation.

6.2 Recommendations

At the end of the feed trial, the following recommendations were made:

1. For optimal growth performance and better bone traits, Guinea fowls could be fed diets containing 17.33 % CP and supplemented with 0.15 % and 0.4 % of crystalline amino acids, respectively.
2. A cost-benefit analysis should be conducted to determine whether supplementing low-protein diets with crystalline amino acids is economically viable for Guinea fowl production.

3. Similar studies should be conducted on other breeds of Guinea fowls to assess the impact of different dietary crude protein levels and amino acid supplementation on growth performance, carcass quality, bone traits, and haematological parameters.

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