AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT

EFFECT OF DIFFERENT LEVELS OF BREWER'S SPENT SORGHUM (PITO MASH) SUPPLEMENTED WITH EXOGENOUS ENZYMES ON THE REPRODUCTIVE PERFORMANCE, BLOOD PROFILE, AND ECONOMIC EFFICIENCY OF INDIGENOUS GUINEA FOWL

DENNIS KODZO AWALIME

MASTER OF PHILOSOPHY IN (ANIMAL PRODUCTION)

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Development

MAY, 2025

DECLARATION

STUDENT'S DECLARATION

I, Dennis Kodzo Awalime, 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.

Dennis Kodzo Awalime (Student)

Signature ....

Date ..../............./.................

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this thesis was supervised in accordance with the guidance on the supervision of thesis laid down by the Akenten-Appiah Menka University of Skills Training and Entrepreneurial Development Mampong-Ashanti (AMMUSTED).

Dr. Fritz R.K.Bonsu (Supervisor)

Signature ....

Date ..../.............../......................

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To my friends, I say: God richly bless you - especially Rebecca Akumblim, Joan Tenu and Musah Issak.

DEDICATION

This study is dedicated to my wife, Perfect Ofori, and my children: Elnaam, Lordina, and Jasmine Awalime.

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LIST ABBREVIATION

ABBREVIATION	Definition
ANF	Anti- nutritional factors
AOAC	Association of Official Analytical Chemists
BSG	Brewer's spent grain
BWG	Body weight gain
CF	Crude fibre
^{0}C	Degree Celsius
CP	Crude protein
DCP	Dicalcium Phosphate
FCR	Feed conversion ratio
FI	Feed intake
HDEP	Hen day egg production
ME	Metabolizable energy
NRC	National Research Council
NFE	Nitrogen free extract
PM	Pito mash
SAS	Statistical analysis system
T	Treatment
WG	Weight Gain

ABSTRACT

This study evaluated the effect of different levels of brewer's spent sorghum (pito mash) supplemented with exogenous enzymes on the reproductive performance, blood profile, and economic efficiency of indigenous Guinea fowl. A total of 60 sixteen-week-old Guinea fowl were randomly assigned to four dietary treatments in a completely randomized design (CRD). Each treatment had three replicates, with five Guinea fowl per replicate in a male-to-female ratio of 1:4. The dietary treatments included: T1 (control, 0 % pito mash), T2 (15 % pito mash), T3 (20 % pito mash), and T4 (25 % pito mash), with 0.02 % Ronozyme enzyme included in all pito mash-based diets. Data were collected on feed intake, water intake, egg production, egg characteristics, fertility, hatchability, keet characteristics (chick body length, beak length, shank length, and body weight), haematological and biochemical parameters, and economic efficiency. Egg production, fertility, and hatchability were not significantly affected ($P > 0.05$), suggesting that pito mash inclusion did not compromise reproductive performance. Yolk colour and Yolk height were significantly ($P < 0.05$) influenced by the dietary pito mash, with T2 (20 % pito mash) recording the highest values. Keet characteristics, including body weight and body measurements were comparable across treatments. Haematological and biochemical parameters remained within normal physiological ranges, indicating that brewer's spent grain inclusion did not adversely affect bird health. Results showed that dietary inclusion of pito mash significantly ($P < 0.05$) reduced feed cost per kilogram and total feed cost, with T4 (25% pito mash) recording the lowest feed cost However, the analysis showed that dietary Brewer's spent grain, supplemented with exogenous enzymes, and did not improve feed utilization efficiency in Guinea fowl. It was concluded that dietary Brewer's spent grain, at inclusion levels up to 25%, may not adversely affect reproductive performance or blood indices, but may also not offer a financial advantage despite its lower cost in Guinea fowl layer production.

CHAPTER ONE: INTRODUCTION

1.1 Background to the Study

Globally, Guinea fowl (*Numida meleagris*) meat is a delicacy with demand being higher than supply and can be a tool for poverty reduction (Nahashon *et al.,* 2006; Alemayehu, 2018). Guinea fowl meat is high in protein and low in fat content, thus it is highly priced compared to chicken meat (Musundire, 2016). Guinea fowl production could be more efficient for meat production compared to domesticated fowls as their feed cost per kg edible parts is less than that of the chicken (Alemayehu, 2018). When compared to local chickens, Guinea fowl has numerous advantages. These advantages include low production costs, premium quality meat, greater capacity to scavenge for insects and grains, better ability to protect itself against predators and resistance to common poultry diseases (Abudabos *et al.,* 2013).

Guinea fowl production provides one of the best alternatives for the rural populace to access meat and eggs as well as potential for revenue generation through sales of live fowl and eggs. Guinea fowl are kept for egg and meat production (Smith, 2001; Adebayo *et al.,* 2018), and poultry farmers want birds that will maximize production at an economic rate and still maintain a market carcass value at the end of production. Nsoso *et al*. (2006) and Nahashon *et al*. (2007) noted that Guinea fowl showed consistent significant increase in body weight over time but are slow in growth rates compared to broilers which reach 1.5 to 2 kg in 6-8 weeks. Adewale *et al*. (2018) also reported that Guinea fowls tend to be slow in growth, weighing less than 1 kg at eight weeks of age. Adjetey *et al.* (2014) reported that Guinea fowl has a characteristic low live weight compared to chicken.

In many West African countries especially Ghana, the major hindrances to Guinea fowl are seasonal changes, nutrition, poor reproductive performance and lack of proper management practices for efficient production (Kyere *et al.,* 2021). Variation in day length, nutrition and egg size affect the reproductive and growth performance of indigenous Guinea fowls. It is well known that the reproductive performance of Guinea fowl in Ghana and Africa is very poor due to insufficient lighting regimen (Annor, 2012). The year- round production of Guinea fowl is not possible without proper lighting management; especially with regard to increase in day length (Kyere, 2017).

1.2 Problem Statement

The major problem of poultry production is the high cost of feeding the birds, which affect productivity and profitability (Oluyemi *et al*., 2007). This is because feed cost alone can be as high as 75 % of the total cost of commercial poultry production (Ravindra, 2013). Maize is the most important grain used in poultry rations, sorghum grain (milo) rank second, and wheat ranks third (Blakely and Bade, 1994). The cost of maize as a feed ingredient has been increasing due to high demand and occasional scarcity of this ingredient. This situation has led to increase in production cost and added pressure on poultry producers (Oluyemi *et al.,* 2007). Therefore, alternative and cheaper materials should be searched for and used as poultry feed (Aderimi & Tewe, 2001). Due to high cost and scarcity of maize as feed ingredient, Oluyemi and Roberts (2008) recommended that there should be a shift to ingredients that face less competition, such as agricultural by-products or non-conventional feed resources, which can help reduce the pressure on conventional feed ingredients.

Brewer's spent sorghum ('pito' mash) is a by-product obtained after the brewing of beer (pito). It has sorghum grain as its raw material. Dry 'pito' mash is a moderate source of energy and contains about 20 % crude protein (Korankye *et al*., 2020). This makes it a suitable feed ingredient for feeding livestock like the Guinea fowl.

The high cost of poultry feed is a major constraint in developing countries; where feed expenses account for about 65 – 80 % of the total production cost (Ahaotu *et al.,* 2017a). In contrast, feed cost developed countries are typically around 50 – 60 % (Ahaotu *et al.,* 2017c). The demand for cereals, namely millet, sorghum, maize,and rice for human consumption is high making them costly to feed to poultry.

According to Kusina *et al*. (2012), using exogenous feed enzymes in monogastric diets is a useful strategy for allowing for flexibility in diet composition, as well as for reducing feed costs, improving feed digestibility, and minimizing environmental pollution. According to Jajere *et al*. (2018), for exogenous enzymes to be as efficient as possible, they must balance out the function of the animal's endogenous substances. Plant-based raw materials may have anti-nutritional factors that limit the availability of nutrients by preventing endogenous enzymes from accessing them, which prevents digestion (Kobe *et al*., 2020). In addition to breaking down bound nutrients, exogenous enzymes reduce the cost of producing feed (Sarica *et al*., 2019). According to Saleh *et al*. (2019), animal rations contain trace amounts of exogenous enzymes such as phytase, protease, and xylanase which are produced from microbial sources.

It has been demonstrated that the use of exogenous enzymes in animal feed improves the body's ability to absorb nutrients that would not otherwise be available (Moreki, 2013).

The demand for cereals namely millet, sorghum maize and rice for human consumption is high making it costly to feed to poultry. It is therefore needful to find suitable but cheaper source of feed for Guinea fowl (Agbolosou *et al.,* 2014). Consequently, there is the need to undertake investigation to determine the effect of varying levels of brewer's spent sorghum (pito mash) supplemented with exogenous enzyme on the reproductive performance, blood profile and economic efficiency of indigenous Guinea fowl.

1.3 Objective of the Study

The main objective was to determine the suitability of brewer's spent sorghum (pito mash) supplemented with exogenous enzymes on the reproductive performance, blood profile and economic efficiency of indigenous Guinea fowl.

1.3.1 Specific objectives

The specific objectives were to determine the effect of different levels of brewer's spent sorghum (pito mash) supplemented with exogenous enzymes on:

1. egg production and egg characteristics
2. reproductive traits (fertility and hatchability)
3. keets morphometric characteristics
4. haematological and biochemical analysis
5. economic efficiency of the feed

CHAPTER TWO: LITERATURE REVIEW

2.1 Origin of the Guinea Fowl

The domestic Guinea fowl, *Numida meleagris,* is a poultry bird that derives its name from the Guinea Coast of West Africa where it originates (Annor *et al.,* 2012; Moreki & Radikara, 2012). The Guinea fowl is a bird that belongs to a group Carinatae (flying birds), order Galliformes (includes turkeys, chickens and peasants), and the family Numididae (that is the Guinea fowl of African origin). It belongs to the genus *Numida* (Moreki & Radikara, 2012). The genus has two types; *Numida ptilorhycha*, that is the blue-wattled Guinea fowl and *Numida meleagris* that is red-wattle Guinea fowl of West Africa. The wild Guinea fowl is native to West Africa but are now reared in many parts of the world. Guinea fowl are domesticated and are usually raised under the same principles as the domestic fowl (Annor *et al.,* 2012).

2.2 Guinea fowl production in the world

Guinea fowl production has long been a significant component of rural livelihoods across sub-Saharan Africa, particularly in Ghana, where studies show they comprise about 7 % of the national poultry population and often generate more income than local chickens (Avornyo *et al.,* 2013; FAO, 2014). Smallholder farmers in northern Ghana typically rear guinea fowl in free-range or semi-intensive systems, relying on scavenging with limited feed supplementation. Flock sizes usually range between 5 and 60 birds, with the more common pearl, lavender, and white strains (Abdul-Rahman & Adu, 2017).

Globally, helmeted guinea fowl have spread beyond Africa and are now found in climates such as Europe, Asia, North America, and parts of Australia, where they are valued both for meat production and ornamental purposes (Moreki & Radikara, 2013). Guinea fowl meat is leaner, firmer, and richer in protein than chicken, with lower fat content, enhancing its appeal in specialty and health-conscious markets (Abdul-Rahman & Adu, 2017).

The economic and nutritional benefits of guinea fowl in Africa are well documented. A recent review highlights that guinea fowl production supports food security and poverty alleviation through egg and meat sales while requiring minimal input costs and benefiting from high disease resistance (Adeoye-Oyebamiji, 2024). In West African regions, such as Benin, Ghana, and Cameroon, households use guinea fowl production to diversify livelihoods, generate ready cash, and improve protein intake especially critical during lean agricultural periods (Adeoye-Oyebamiji, 2024; Avornyo *et al.,* 2017).

However, the industry faces challenges. Poor keet survival, low hatchability, limited access to veterinary services, and weak value chain infrastructure restrict scaling of guinea fowl production in Africa (FAO, 2014). In Zimbabwe, average hatchability was 63.8 % and keet survival around 75 %, with better performance linked to supplementary feeding and improved housing. Complementary support initiatives such as the West Africa Agricultural Productivity Programme in Ghana have strengthened capacity through provision of incubators, feed inputs, and technical training, enabling many farmers to expand production despite persistent systemic constraints (Avornyo *et al.,* 2013). Guinea fowls are reared on commercial basis in countries such as India, Belgium, France, Italy, South Africa and Ghana. However, in West Africa where the Guinea fowl originates, it is still raised on small scale basis under the traditional system of management with a local chicken hen or a Guinea hen brooding on the eggs to hatch and taking care of the keets (Ahiagbe *et al.,* 2016).

Fertile Guinea fowl eggs are normally given to the domestic chicken to incubate with or without a mixture of chicken eggs, where the domestic village chickens are reared alongside the Guinea fowl (Abdul-Rahman, 2017). Guinea fowl eggs takes between 26 to 28 days to hatch with the keets weighing about 24 to 25 g. It is therefore a usual scene to see a domestic chicken hen with a mixture of chicks and keets in these households.

The sub-humid tropical pearl Guinea fowls are monogamous and seasonal breeders and so there are periods within the year when their eggs are in abundant and other periods when they are scarce. The seasonality in reproduction has been recognized as one of the major problems that may hinder large-scale commercial Guinea fowl production (Mallam, & Mangaru, 2019).

2.3 Guinea Fowl Production in Ghana

In Ghana, Guinea fowl are found mostly in the northern sector of the country (Northern, Savanna, North East, Upper East and Upper West Regions) where they live in groups, either in the wild or domesticated in semi-intensive systems although they are also found in Southern Ghana, especially in the transitional zone and in the coastal Savannah zone (Agbolosu *et al.,* 2012; Annor *et al.,* 2012). Throughout Ghana, Guinea fowl are mostly on free range system and it is estimated that 9 out of every 10 households in the Savannah areas rear this bird which plays pivotal roles in the food and nutrition security in many farming households with limited gender bias (Annor *et al.,* 2012). The grey breasted and helmeted Guinea fowl (*Numida meleagris*) is the indigenous and common breed in the Savannah zone of Ghana where the estimated population of Guinea fowl is about 1,030,000, accounting for 25 % of the total population of poultry in that part of the country (Annor *et al.,* 2012). According to the authors, for generations, farmers in the Northern regions have been raising the bird alongside their core farming activities and have been the major source of Guinea fowl products consumed in the country. In recent times, commercial Guinea fowl farmers are emerging in both southern and northern Ghana. Asamoah and Yamoah, and Akate Farms are examples in Southern Ghana whilst Alhassan and Atibire Farms are examples in the northern Ghana. In both cases, the farmers practice intensive system of Guinea fowl production with some of the day-old keets imported from Europe. Comparatively, Guinea fowl in Ghana perform poorly as compared to their counterparts in Europe (Nuamah *et al.,* 2020).

The poor productivity can be attributed to the fact that the bird is raised under the free-range production system with its challenges such as poor health, poor feeding as well as the use of unimproved breeds (Annor *et al.,* 2012). According to Avornyo *et al.* (2016), over 95 % of farmers provided some form of housing including mud huts, wooden coops or cemented structures. Poor housing has been associated with low productivity in Guinea fowl. All farmers in the Upper East Region provided supplementary feeding while majority of farmers provided supplementary feeding in Northern (former) and Upper West Regions (Avornyo *et al.,* 2016). Termites and maize were the most common supplementary feed ingredients provided in both former Northern and Upper West Regions, respectively, during keet and adult stages. Despite the economic and nutritional importance of raising Guinea fowl in the country, the provision of sufficient feed has remained a significant obstacle to raising Guinea fowl to reach their maximum growth and reproductive potential. This is because there is a dearth of empirical research data on optimising the nutritional needs of Guinea fowl, especially with regard to the use of non-conversional feed resources (Jacob & Pestacore, 2022; Araújo *et al.*, 2023). Hatchability and fertility are two other significant issues with Guinea fowl production. According to Teye & 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 eggshells of Guinea hens result in lower hatchability than those of chickens.

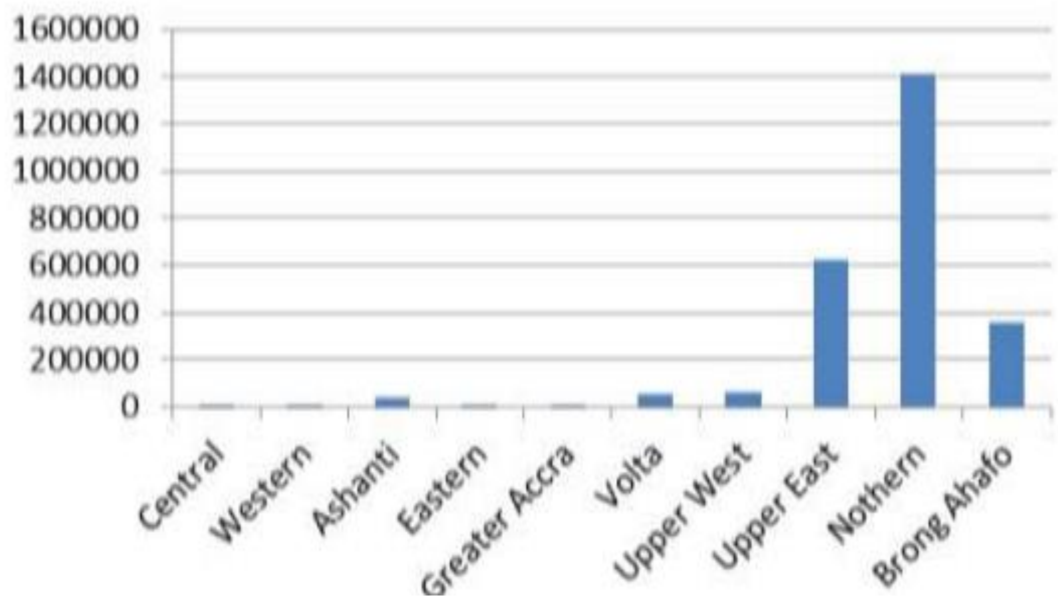

Fig 2.1: Regional Distribution of Guinea Fowl in Ghana

Source : (Issaka & Yeboah, 2016).

2.4 Species and Breeds of Guinea fowl

The most numerous and widely distributed species is the helmeted Guinea fowl *Numida meleagris* (Biswas, 1999). There are three well-known types of helmeted Guinea fowl, 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. It is also characterized by shanks of slate grey colour and more or less dark grey-blue plumage with many rounded small white spots. The lavender type has paled purple colour with black shanks, pink slate or mixture of pink and black shanks. The white type has the ordinary white colour with pink shanks or slate shanks white or pink wattles (Payne, 1990; Koney, 1993; Annor *et al*., 2012).

Table 2.1: Common Species of Guinea Fowl

Genus	Species	Description
Agelastes	*Agelastes meleagrides*	White breasted Guinea fowl
	Agelastes niger	Black breasted Guinea fowl
Numida	*Numida meleagris*	Helmeted Guinea fowl
Guttera	*Guttera plumefera*	Plumed Guinea fowl
	Guttera pucherani	Crested Guinea fowl
Acryillium	*Acryillium vulturinum*	Vulturine Guinea fowl

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

Plate 1: Peal Guinea fowl

Plate 2: White Guinea fowl

Plate 3: Lavender

Plate 4: Black Guinea fowl

Photographs of common breeds of helmeted Guinea fowl reared in Ghana.

Source: Annor et al., (2012).

2.5 Challenges to Guinea Fowl Production

Guinea fowl are attractive to small scale farmers due to their adaptability to different environmental conditions (Yamak *et al.,* 2016) and they require low production costs. These characteristics are favaourable to the poor and low-income earners found in rural communities who derive subsistence from Guinea fowl (Obike *et al.,* 2011). According to Ebegbulem (2018), a major challenge militating against the production of Guinea fowl in Nigeria is the predominance of free-range management system which is plagued by various challenges such as high keet mortality, theft, predation, poor feeding and disease prevalence. It was recommended that there is the need to improve its management in terms of proper and adequate nutrition, efficient disease prevention and management, adequate housing as well as good management practices tailored to suit its natural behaviour to ensure an optimum productivity in the Guinea fowl enterprise. Issaka & Yeboah (2016) also indicated that the main constraints to Guinea fowl production in Ghana include high keet mortality rates, inadequate access to veterinary services, and low productivity of local breeds, unstable prices and poor management practices.

2.5.1 Breeding stock acquisition

The seasonality of breeding has been recognized as one of the major drawbacks to large-scale Guinea fowl production when using the indigenous breed (Avornyo *et al*., 2016). 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.

2.5.2 Availability of Feed

According to Mohammed & Ahmed (2015), scavenging is the main feeding system under free-range Guinea fowl production in rural areas where the birds feed mainly on insects, leaves, grass seeds, tubers and sedges 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 fowl have a unique ability to utilize a wide range of flora and fauna as feed resource base.

2.5.3 Growth traits and productivity

The productivity of the Ghanaian local Guinea fowl is far below that observed in European breeds (Table 2.2). Indigenous Guinea fowl breeds generally have slow growth rate and utilize feed less efficiently than chickens (Kusina, 2012; Annor *et al*., 2012). The slow growth rate of Guinea fowl 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). Guinea fowl reared under the intensive management system have superior production performance than those reared under both semi-intensive and extensive management systems (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).

2.5.4 Research in genetic improvement

A lot of genetic research has been carried out on the Guinea fowl 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 fowl production has become commercially viable (FAO, 2014). According to Avornyo *et al*. (2016), 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 fowl 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 due to the cost involved and seasonality of their eggs (Iddrisu, 2014).

2.5.5 Breeding season of Guinea fowl

Most wild Guinea fowl birds breed during a restricted period of the year irrespective of the latitude at which they are found (Annor, 2013). The restriction is usually imposed by the seasonal availability of the appropriate food resources required for feeding and fledging the young (Thapa *et al*., 2021). The sub-humid tropical pearl female Guinea fowl are monogamous (Oke *et al*., 2003) and seasonal breeders (Annor, 2012). The seasonality in reproduction has been recognized as one of the major problems that may hinder large-scale commercial Guinea fowl production. Factors responsible for this seasonality are not yet clearly known (Oke *et al*., 2003).

2.5.6 Sexing Guinea fowl

Sexing has been a serious challenge in the effective selection and breeding of Guinea fowl. The inability of the farmers to separate the sexes makes it difficult to raise a breeder or layer stock (Jacob & Pescatore, 2013). Farmers and breeders have difficulty using the external features of Guinea fowl to separate between males and females from day-old to one month of age. In some birds such as the domestic chicken (*Gallus domesticus*), it is easier to differentiate between the sexes at the early ages using morphological characteristics. Morphological traits have been used successfully to predict the sex of Guinea fowl after one month of hatching. Arhin *et al.* (2018) indicated that in using egg shape to pre-determine the sex of Guinea fowl, eggs (Figure 2.2) with narrow and pointed end indicated males whereas those with the narrow end slightly rounded were females. Similarly, a study by Annor *et al.* (2013) also pointed out that at day-old, swollen leg indicated males whilst non swollen leg depicted females. When keets are raised above ground level by holding the wings, those with stretched leg showed males but non-stretched legs indicated females. At four months males produced monosyllabic sound like "kirkekekekeke" but their female counterparts gave disyllabic sound such as "chekwen chekwen" (Annor *et al.* 2013).

In using wattles to determine the sex, Arhin *et al.* (2018) again indicated that males have wattles shortly attached to the jaws with a much bigger, coarse and thicker dangling lobe whilst females (Figure 2.2) showed less pronounced and flatter wattles. Another study by Idahor and Akinola (2015) also revealed that, at four months old, the appearance of a rudimentary phallus as a feature to differentiate between both sexes revealed that males show the phallus when they are 4 weeks old but females do not at that age. At four months the sound, wattles and phallus and other morphological traits (head width, head, neck, body, shank, tail, thigh and wattle lengths, helmet thickness, pelvic inlet, wing span, and leg length) were measured to differentiate between males from females.

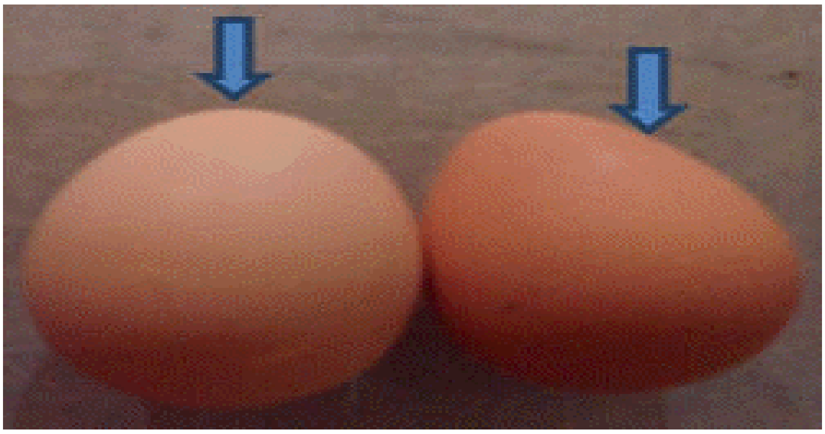

Figure 2.2: Female (left) egg oval at the end and Male (right) egg pointed at the end
Source: Arhin et al. (2018)

Figure 2.3: Female Guinea fowl (cupped wattles) and Male Guinea fowl (flat wattles).
Source: Arhin et al. (2018).

2.5.7 Housing

Poor housing, free range system and low level of housing continue to pose a serious challenge in Guinea fowl rearing. According to Ebegbulem (2018), the system of production of Guinea fowl in Ghana and most other African countries is mostly extensive, (the free-range system). Moreki & Radikara (2013) also noted that poor housing poses a serious challenge to Guinea fowl rearing. Due to poor housing, predation rates are high. The author observed low egg productivity due to frequent change of laying spot in the bush leads to eggs being preyed upon. An earlier study by Kebede *et al.* (2012) also reported that lack of and/or poor housing also contributes to high deaths due to poor climatic conditions, increased incidences of theft, and difficulties in getting birds to carry out vaccination schedules. Boko *et al.* (2011) estimated that, the mortality rate of keets within the first two months of life to be > 50 %. This high loss of keets contributes to Guinea fowl flocks not increasing in numbers over time.

Management practices such as feeding, watering, housing, health-care and general sanitation contributes very immensely to the productivity of rural poultry. 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; Naandam & 1ssah, 2012). Guinea fowl are much more active than chickens and are not as easily tamed**.** 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 fowl farmers (80.6 %) raise their birds on purely extensive system, with few of them (16.7 %) practising the semi-intensive system (Naazie *et al.,* 2007) in the northern regions of Ghana. Under the extensive system, the birds are exposed to a lot of dangers that impede their performance in terms of growth and laying. Housing (wooden coops or mud pens), if any, are provided only at night. Boko *et al.* (2011) 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 poorly constructed. Houses are small in sizes, roofed with thatch, poorly ventilated, inadequate space with narrow entrance causing overcrowding which leads to easy spread out of diseases in the houses (Boko *et al.,* 2011; Kebede *et al.,* 2012).

Figure 2.4: A typical coop used to house poultry overnight.
Source: Boko et al. (2011)

Water is provided in locally made clay pots with small holes around which makes it difficult for young birds to reach and drink water. These pots are rarely washed due to the design. Therefore, a lot of dirt settles at the bottom of the pots. This could cause the spreading of disease very fast among the birds. Health-care practices are poor at the rural level.

2.6 Nutrient Requirement of Guinea fowl

Many studies have been carried out on the nutritional requirements of the Guinea fowl. According to Ayeni (1983) and Ikani & Dafwang (2004), Guinea fowl have been reported to have similar gastrointestinal tract as the domestic fowl, and their requirements for many nutrients are similar. A crude protein level of 24 % with an energy level of 3000 kcal/kg for a starter with a gradual reduction in these levels in the second month is recommended (Iddrisu, 2014). Guinea fowl have a unique ability to utilize a wide range of flora and fauna as feed resource bases. Ayeni *et al.* (1983) also recommended a 9.16 % crude protein diet supplemented with insects to achieve optimal commercial performance at minimal cost. Biswas (1999) and Ikani & Dafwang (2004) observed that in their natural environment in Africa, insects, grass seeds, and tubers form the Guinea fowl feed, but if fed supplements such as ground maize, Guinea corn, millet with chopped scraps of cooked meat or fish meal or when termites are used as supplements they grow faster.

According to Iddrisu (2014), Guinea fowl have the highest protein requirements between 5 and 10 weeks of age. Mandal *et al.* (1999), as cited by Iddrisu (2014), reported that the requirements for metabolizable energy (ME) for Guinea fowl vary between 11.30 and 12.13 MJ/kg DM during the 0 to 4 and 5 to 12 weeks of age, respectively with 220, 200 and 160 g CP/kg DM during 0 to 4, 5 to 8 and 9 to 12 weeks of age. It has been reported by Galor (2009) that from day one to 25 weeks of age, the quantity of feed used under controlled feeding ranges between 9.75kg and 10kg per cock or 11.5 kg and 12 kg per served Guinea fowl hen. Breeders/ layers require 16.5-17 % crude protein and energy levels of 2750 kcal/kg (Teye & Gyawu, 2002). Oke *et al.* (2004) in an experiment to determine the phenotypic correlations among body weight, egg weight, egg index and egg quality factors as well as regression equations that can be used to establish models for predicting body weight, fed Guinea fowl layers (26-52 weeks of age) on a diet containing 17.5 % crude protein and 2650 kcal/kg ME. The mature body weight when the highest egg production was obtained was 1274 g to 2883 g and their average mature body weight was 1266 g. They concluded that phenotypic improvement efforts in the pearl Guinea fowl should be concentrated on establishing a uniform flock body weight of at least 1250 g at sexual maturity. Adeyemo *et al.* (2006) experimented on birds fed with 18 %, 16 %, 14 % and 12 % CP and ME of 2600 kcal/kg to test for the best performance of layers. Birds raised on 18 % CP and 16 % CP dropped their eggs at 162 days old while those 14 % CP and 12 % CP dropped theirs at 166 and 175 days respectively. Considering other parameters, they concluded that, it is most economical to produce a dozen eggs on the 16 % crude protein diet. Ideally, a laying Guinea fowl hen requires 110 g of feed per day from 32 weeks of age to maximize egg production (Galor, 2009). Tables 2.3 and 2.4 give the nutritional requirements of broiler and breeder Guinea fowls respectively.

Table 2.3: Nutritional requirements of Guinea fowl broilers

Age (week)	Protein (%)	EV kcal/kg	AFN (g)	Lysine	Met	Met+ Cys	Ca	P
0 – 5	25.5	3200	25.30	1.38	0.55	1.00	1.00	0.39
5 – 8	20	3100	50 - 60	0.99	0.42	0.88	0.90	0.35
8 – 12	18	3100	70 – 80	0.79	0.33	0.66	0.80	0.33

Source: Ikani & Dafwang (2004). Met=Methionine; Cys=Cysteine; EV=Energy values in kcal/kg; AFN=Amount of feed needed per day.

Table 2.4: Nutritional requirement of Guinea fowl Layers

Age (week)	Protein (%)	EV kcal/kg	AFN (g)	Lysine	Met+ Cys	Ca	P
1 – 6	22	3000	25 – 27	1.20	0.81	0.70	0.40
6 – 28	14.0	2800	55 – 60	0.65	0.59	0.60	0.35
Breeder	17 – 18	2800	70 – 80	0.90	0.59	2.70	0.55

Source: Ikani and Dafwang (2004). Met=Methionine; Cys=Cysteine; EV=Energy values in kcal/kg; AFN=Amount of feed needed per day.

2.7 Feed and Feeding of Guinea Fowl

Guinea fowl are reported to grow slowly and utilize feed less efficiently than chickens (Amajioyi, 2017). The problems of growth in Guinea fowl can be associated with nutrition and selection. Though Guinea fowl have similar gastrointestinal tract to that of chickens, it may not be correct that it translates into similar nutrient requirements. There are other factors as genetics which contribute to the nutrient requirements. Various researchers have recommended high protein levels of 15-22 % for good performance of Guinea fowl with reduction as bird's mature (Amajioyi, 2017). Presently in Ghana there is no commercially compounded feed for Guinea fowl. Birds are allowed to scavenge for most of their food around the village. This observation is in line with the report of Dahouda *et al*. (2017) that Guinea fowl keepers do not practice any rationale feeding system for their birds. Gono *et al*. (2012) observed that in addition to scavenging most of the farmers provided small amounts of supplementary feed to their birds. This is in agreement with the report of Kusina *et al*. (2012) who noted that feed was given to birds in haphazard manner.

Lack of information about feed requirements contributed to early keet mortality, besides, a large percentage of farmers keep the birds on free range because there is little knowledge on the nutrient requirements. Moreki & Seabo (2012) observed that because there were no formulated rations for domesticated Guinea fowl, farmers resorted to feeding their Guinea fowl with commercial broiler chicken and layer chicken diets, with cereal grains and green vegetables as supplementary feeds. Dahouda *et al*. (2017) however noted that there was more feed available for poultry after harvesting from December to February but that this supplementation was sub-optimal and could not meet the nutrient requirements of the birds.

In an attempt to solve the feed and feeding problems of the Guinea fowl, different levels of feeding trials were conducted at the different phases of growth in order to establish feeding standards for Guinea fowl. This includes the brooding, growing and the laying phases. Also, works were done on non-conventional feedstuffs for feeding Guinea fowls in order to minimize the cost of feeding (Mohammed, 2013; Dei *et al*., 2015). Adult Guinea fowl require minimal upkeep. Guinea fowls are able to forage for themselves and are able to meet most of their nutrition requirements on their own. Guinea fowl consume a variety of insects (mosquitoes, ticks, and beetles), grass, weed seeds, slugs, worms, and caterpillars. Guinea fowl need to consume greens in order to maintain good digestion. Guinea fowl need a higher protein feed than chickens but do quite well on regular poultry diets. Keets need a 24 to 26 percent protein ration for the starter feed. The protein level should be reduced to 18 to 20 percent for the fifth to eighth weeks. After that, feed a regular laying mash, which usually contains 16 percent protein (Mohammed, 2013; Dei *et al*., 2015).

2.8 The Use of Non-Conventional Feed Resources

The rising cost of conventional feed ingredients, such as maize and soybeans, has made poultry production more expensive, particularly for small and medium-scale farmers. As a result, there is growing interest in utilizing non-conventional feed ingredients that are locally available and often more affordable. Non-conventional feeds refer to alternative ingredients such as agro-industrial by-products, leaves, and other plant materials not traditionally used in poultry diets. These feeds have the potential to reduce feed costs, enhance sustainability, and support the growth of poultry in resource-limited settings

(Amata, 2014). However, the use of non-conventional feeds also poses certain challenges regarding nutrient availability, palatability, and potential anti-nutritional factors (ANFs). Studies have shown that non-conventional feed ingredients can have varying effects on the growth performance of poultry, depending on their nutrient composition and inclusion levels.

For example, cassava peels, which are high in fibre but low in protein, may reduce growth rates if included at high levels without proper supplementation (Adeyemo *et al*., 2016). However, when supplemented with protein-rich ingredients such as moringa or soybean meal, cassava peels can be effectively utilized in poultry diets without negatively affecting performance (Ogbuewu & Mbajiorgu, 2023). Brewer's spent grain (pito mash), used in poultry diets, contain relatively high levels of ANFs such as phytates and non-starch polysaccharides (NSPs), which can reduce nutrient digestibility (Ravindran, 2013). The inclusion of enzymes such as phytase or xylanase can improve nutrient availability and enhance the overall performance of birds fed diets containing Brewer's spent grain (Selle *et al*., 2009).

One of the main challenges associated with non-conventional feeds is the presence of ANFs, which can inhibit nutrient availability and absorption which can reduce the overall performance of Guinea fowl. For example, cassava peels contain cyanogenic glycosides, which can be toxic if not properly processed (Devi & Diarra, 2021). Similarly, Leucaena leaves contain mimosine, an alkaloid that can cause toxicity in poultry if consumed in large quantities (Norfadhilah, 2019). Proper processing methods such as drying, boiling, or fermentation can help reduce the levels of ANFs in non-conventional feed ingredients, making them safer for poultry consumption. Enzyme supplementation has also been widely studied as a strategy to mitigate the negative effects of ANFs in non-conventional feeds. For example, the addition of phytase to diets containing Brewer's spent grain has been shown to increase phosphorus availability and improve growth performance (Selle *et al*., 2009). Similarly, the use of xylanase or other NSP-degrading enzymes can enhance the digestibility of fibre-rich ingredients, leading to better feed efficiency (Ravindran, 2013).

2.8.1 The need for non-conventional feed resources

There are serious shortages in some animal feeds of the conventional type. The grains are required almost exclusively for human consumption. With increasing demand for livestock products as a result of rapid growth in the world population and shrinking land area, future hopes of feeding the animals and safeguarding their food security will depend on the better utilization of non-conventional feed resources that do not compete with human food. The availability of feed resources and their rational utilization for livestock represents possibly the most compelling task facing planners and animal scientists in the world. The situation is acute in numerous developing countries where chronic annual feed deficits and increasing animal populations are common, thus making the problem a continuing saga (Norfadhilah, 2019). Thus, non-conventional feeds could partly fill the gap in the feed supply, decrease competition for food between humans and animals, reduce feed cost, and contribute to self- sufficiency in nutrients from locally available feed sources (Rashid, 2020; Beriso, 2022; Kolawole & Mustapha, 2023). It is therefore imperative to examine for cheaper non-conventional feed resources that can improve intake and digestibility of low-quality forages. Feedstuffs such as fish offal, cassava peel, palm kernel cake, sugarcane bagasse, rice bran, maize bran, cocoa bean waste, coconut meal, corn cob, moringa leaf, leucaena leaf, local brewery and distillery by-products such as pito mash, sisal waste, and coffee pulp are commonly used in Ghana and could be invaluable feed resources for small and medium size holders of livestock (Nortey *et al*., 2015; Amoah *et al*., 2017).

2.8.2 Agro-industrial by-products for livestock

Appropriate use of relatively inexpensive agricultural and industrial by-products is of paramount importance for profitable livestock production. However, the high cost and low availability of conventional livestock feedstuffs frequently demand consideration of by-products even if the efficiency of utilization is low (Kolawole & Mustapha, 2023). Efficient use of by-products relies on their chemical and physical properties, which influence production system outputs. In developing countries like Ghana, grains, which form the bulk of concentrate feeds for poultry, is both in short supply and expensive due to direct competition with human food uses (Kusi *et al*., 2015). The increasing human demands for several foods (i.e. olive oil, vegetables, wine, fruit juices, etc.) led to a considerable increase of lands occupied by crops producing these feeds. Consequently, huge amounts of agro-industrial by-products are available in numerous developing countries (e.g. maize bran, rice bran, wheat bran, copra cake, pito mash etc.), which are still not fully utilized in poultry feeding. Most of these agro-industrial by-products are low in major nutrients. Moreover, the difficulty of the use of these feed sources as fresh material for extended periods and the lack of efficient ways for their integration in feeding calendars may account for their under-utilization (Onte *et al*., 2019).

2.9 Feed Additives in Poultry Production

Feed additives make up a small percentage of animal feed, yet they can have a significant impact by enhancing feed utilization, increasing growth efficiency, and reducing diseases (Cherian, 2020). The commonly used feed additives in poultry production are pro- and prebiotics, antioxidants, enzymes, and antibiotic growth promoters and each has a unique function. The feed enzyme market has expanded significantly over the last five years, mostly as a result of rising raw material costs (Ravindran, 2013). Even with increased acceptability, there are still many unanswered concerns about how to employ enzymes to provide consistent effects and reactions to enzyme supplementation. However, these inconsistent answers highlight both the existing constraints and the possible ways to improve the advantages of using enzymes. Three essential elements are inescapably linked to limitations in enzyme responses: the substrate, the bird, and the enzyme.

Enzymes decrease nutrient loss and lower environmental pollution by enhancing digestion, which increases nutrient availability (Cherian, 2020). According to Pirgozliev (2019), enzymes are proteins that catalyze particular chemical processes and are specific to a particular substrate. The use of exogenous feed enzymes is one of the ways for nutritionists to create diets more economically while enhancing the efficiency of feed and still giving consumers the most economical source of protein because feed costs make up the greater percentage of all input costs (Davids & Meyer, 2017; Boyd *et al*., 2018).

2.9.1 The use of exogenous enzymes in poultry production

According to Kusina *et al*. (2012), using exogenous feed enzymes in monogastric diets is a useful strategy for allowing for flexibility in diet composition, as well as for reducing feed costs, improving feed digestibility, and minimizing environmental pollution. According to Jajere *et al*. (2018), for exogenous enzymes to be as efficient as possible, they must balance out the function of the animal's endogenous substances. Plant-based raw materials have anti-nutritional factors that limit the availability of nutrients by preventing endogenous enzymes from accessing them, which prevents digestion (Kobe *et al*., 2020). In addition to breaking down bound nutrients, exogenous enzymes reduce the cost of producing feed (Sarica *et al*., 2019). According to Saleh *et al*. (2019), animal rations contain trace amounts of exogenous enzymes such as phytase, protease, and xylanase which are produced from microbial sources.

It has been demonstrated that the use of exogenous enzymes in animal feed improves the body's ability to absorb nutrients that would not otherwise be available (Moriki, 2013). The addition of enzymes reduces the adverse effects of ANFs and boosts profitability in poultry production (Sarica *et al*., 2019). Approximately 1.67-1.88 MJ of energy per kilogram of feed is not being digested in a conventional corn-soybean diet without enzyme supplementation (Robinson *et al*., 2016). Enzymes can be used to increase protein, fat, and carbohydrate availability as well as to increase more energy being made available for utilization.

In poultry feed, enzymes can be added either separately or in the form of multi-enzyme complexes (MEC) (Saeed *et al*., 2019). Positive outcomes have been reported for both MEC and single. There has been contradictory research on the effectiveness of supplementing with non-starch polysaccharide degrading enzymes in addition to phytase. While NSPase and protease possess distinct target substrates, their actions complement one another because NSPase releases many nutrients and reduces mucus production in the gastrointestinal tract (Mele *et al*., 2016). According to Saeed *et al*. (2019), the bird's response to MEC use is influenced by its genetic ancestry, age, nutrition, and MEC dose.

Adding enzymes to poultry feed, either separately or in combination, has several advantages:

i. The release of encapsulated starch in the cell wall minimizes the variation in apparent metabolizable energy (AME) and performance (Moriki, 2010).

ii. Less digesta viscosity lowers the amount of wet litter and sticky droppings, which lowers the risk of dermatitis (Moriki, 2013).

iii. Due to the immature GITs, young chicks are particularly vulnerable to the negative impact of NSP. Enzymes called carbohydrases help to keep the gut healthy so that an inflammatory gut does not impair performance (Robinson *et al*., 2016).

iv. By reducing the digesta viscosity and changing gut microbes by promoting the growth of beneficial microbes, body weight (BW), gain, and feed conversion ratio (FCR) are improved (Sarica *et al*., 2019).

v. Short-chain fatty acids (SCFA) such as butyrate and acetate are produced by multi-enzyme complexes. Butyrate serves as an energy source for the intestinal epithelial cells in the stomach, promoting both their proliferation and differentiation to improve digestive health (Robinson *et al*., 2016).

vi. Phytase inclusion enhances growth performance and carcass characteristics of broilers by releasing trapped phosphorus (P) and other nutrients (Saeed *et al*., 2020).

vii. Because nutrients are being utilized, feed costs are decreased (Molden *et al*., 2010).

viii. The amount of undigested nutrients excreted into the environment is decreased, which reduces its contribution to environmental contamination (Robinson *et al*., 2016).

2.9.2 Influence of exogenous enzyme on growth performance of Guinea fowl

The poultry industry has witnessed significant advancements in feed additives aimed at improving the growth performance and overall health of birds. One such additive gaining attention is the exogenous enzyme which is designed to enhance nutrient utilization in poultry diets, thereby positively influencing Guinea fowl growth and performance. Studies by Choct *et al*. (2010) have shown that the inclusion of exogenous enzymes in broiler diets leads to increased enzymatic activity, particularly in the hydrolysis of NSPs and proteins. A study by Bedford & Cowieson (2012) demonstrated that the addition of exogenous enzyme to duck diets resulted in improved feed conversion ratios (FCR), indicating enhanced utilization of nutrients for growth. The increased efficiency in converting feed into body mass suggests the economic feasibility of incorporating exogenous enzymes in poultry production systems.

When a multi-enzyme complex was introduced to the diets of Guinea fowl fed maize and soybean meal, Rios *et al*. (2017) assessed its effects on the growth performance, energy, and amino acid consumption of the birds. According to the authors, feed conversion ratio, digestible energy, and digestible amino acid levels all improved with enzyme addition. Idahor *et al*. (2005) found that adding feed enzyme to a diet containing 50 Kcal/kg less ME than the control diet at a rate of 0.05 g/kg did not significantly affect weight gain. However, it did significantly increase feed intake and decreased feed conversion rate (FCR) during the initial (1-28 days) and overall (1-42 days) growing periods. However, during the finisher phase (29–42 days), these authors did not find any appreciable variations in these parameters. The research conducted by Galor *et al*. (1983) also demonstrated that adding an exogenous enzyme to chicken feed (0.05 g/kg) increased weight gain and feed conversion ratio (FCR) by 8 % when the diet was corn-based and sunflower meal; feed intake was unaffected.

Nutrient digestibility was improved in the diet that included enzyme supplements (Galor et al., 1983). These results support the hypothesis that, in comparison to high-digestible feedstuffs, the positive effects of NSP-degrading enzymes may be slightly greater with low-digestible feedstuffs such as sunflower meal (14–18 % crude fibre). A study by Chalghoumi *et al*. (2020) reported that supplementing Ronoxyme WX at 0.02 g/kg improved final live body weight (BW), daily body weight gain (BWG), daily feed intake (FI), FCR, and production index for broilers from day 7-21 and day 22-37 but was statistically similar to the standard control diet.

2.10 Growth Performance of the Guinea Fowl

2.10.1 Body weight gain of Guinea fowl

Body weight gain is vital for the success of any poultry and livestock industry. The growth performance observed in any livestock species depends on the environment (Kerketta and Mishra, 2016). The environment comes in the form of feeding and watering, housing, stocking rate, photoperiod, geographical location, and others. Intensive rearing of the Guinea fowl leads to higher growth performance (Nesa & Das, 2018). Growth of the Guinea fowl is expected to increase when birds are fed diets containing considerable amounts of protein (Adjetey, 2009). Growth occurs in the Guinea fowl mainly through nutrition (Morek*, et al*., 2011). The Guinea fowl becomes matured and ready for slaughter at the sixteen week with mean weight of 1072 g and 822 g for intensive and semi intensive rearing systems respectively (Saina, 2005). Teye, Gyawu, and Agbolosu (2001) conducted research and compared the growth potential and carcass yield of the local and exotic Guinea fowl at the slaughter age of eighteen weeks and recorded 1112.5g and 2014.58g for local and exotic breeds respectively. This implies that Guinea fowl can be raised using either intensive or semi-intensive system for better market weight for slaughter.

A study conducted by Naandam (2015) on the performance of Guinea keets under extensive rearing at two locations in the Tolon-Kumbungu district in Ghana reported a mean weekly weight gain of 47 g. Results from the studies on the effect of different dietary protein (16,18, 20 and 22 %) on Guinea fowl performance resulted in an average weekly daily gain of 45 g (Adjetey, 2009). It has been established from the studies from Annor *et al*. (2012) who reported weekly body gains of 41 g in local breeds and 108 g in the European Guinea fowl breeds. The average weekly body gains of the Guinea fowl of three different genotypes reported from the study of Ebegbulem and Asuquo (2018) was 66g. Considering other parameters, they concluded that, was most economical to raise Guinea keets at sixteen percent crude protein diet.

2.10.2 Matured weight of Guinea fowl

The final body weight, which is usually the time for disposing the Guinea fowl determines the market value. Guinea fowl record higher body weights when reared in cages (Alli *et al*., 2016). The matured age of the Guinea fowl is about 16-24 weeks at which time the bird is ready for slaughter with an average carcass weight of 1.3kg (Nsoso *et al*., 2006) and the proportion of feathers on the bird is relatively lower (Mróz *et al*., 2016). However, Saina (2005) reported a range of maturity in the Guinea fowl to be between twelve and forty weeks. Guinea fowl reared on intensive and semi intensive systems gave an average weight of 1.07kg and 0.82kg at the end of the sixteen week in Zimbabwe (Saina, 2005). Adebayo *et al*. (2018) argued that the body weight of Guinea fowl increases with the increase in dietary protein when a mean body weight of 1.35 kg was recorded for 14, 16 and 18 % dietary protein levels for a period of 6 to 12 weeks under intensive rearing. Annor *et al*. (2013) reported average weight of 1.2 kg and 2.5 kg for local and European breeds respectively at 24 weeks of age. Guinea fowl hatched from larger egg sizes attain higher body weights at maturity which is attributed to increased feed intake of the birds (Kyere, 2017). The influence of varying concentrations of dietary crude protein on body weight gain of the pearl Guinea fowl at 9 to 27 weeks of age recorded an average body weight of 896 g (Adjetey, 2009). Average body weight of the indigenous Guinea fowl in Ghana at 18 weeks of age was reported to be 1112.5 g (Annor *et al.,* 2012).

When birds were fed different experimental diets containing bovine blood blended with cassava from 5-23 weeks, an average body weight of 1.06 kg was recorded (Iddrisu, 2014). The morpho structural estimates of traits in the Guinea fowl recorded a mean body weight of 0.97 kg (Variedades, 2010). The studies conducted on performance of Guinea fowl fed varying levels of Phane meal and using fishmeal as control under intensive system of rearing resulted in a mean of 1.1 kg for Guinea hens and 1.086 kg for Guinea cocks at thirteen weeks of age (Nobo *et al*., 2012). Reports from the study of performance of Guinea fowl hatched from varied egg sizes recorded a six months average body weight of 1.17 kg (Kyere, 2017). The average weight of Guinea cocks and hens within 13-16 weeks measures 1.29 kg and 1.32kg respectively (Kokoszyński *et al*., 2011) whilst Onunkwo & Okoro (2015) recorded an average final body weight of 1.42 kg for Guinea hens at 26 weeks. Reports from feeding Guinea fowl with varied crude protein levels resulted in average matured weight of 1.25kg for Guinea cocks and 1.31kg for Guinea hens (Korankye, 2019).

2.11 Reproductive Performance of Guinea Fowl

2.11.1 Fertility of Guinea fowl eggs

Guinea fowls are birds that are known to practice monogamy and therefore in order to maximize the fertility of Guinea eggs, a mating ratio of 1cock: 1 hen should be maintained (Khairunnesa, Das, & Khatun, 2016). The Guinea egg has a good fertility in relation to other strains of birds (Duodu *et al.,* 2018). The mating system used in Guinea fowl may affect the fertility of the Guinea eggs (Khairunnesa *et al.,* 2016). The fertility of Guinea eggs are negatively affected when stored over a long period of time (Downes, 1999). The fertility of Guinea eggs increases when the Guinea hen is artificially inseminated (Bernacki & Kokoszynski, 2013). The fertility of Guinea eggs can be estimated as a ratio of the number of fertile eggs to the number of eggs set expressed as a percentage (Kyere *et al.,* 2017). Fertility of Guinea eggs set for incubation can be determined by candling. This is usually done on the fourteenth and twenty first day of incubation (Yaro, 2016). In the Northern Region of Ghana, the fertility of Guinea eggs is determined by the sound produced when the outer surface of the egg is scratched by the finger nail; loud sound produced indicates infertility and eggs are removed (Karbo & Avornyo, 2006).

A fertility of 80 % has been recorded in the Guinea fowl eggs (Khairunnesa *et al.,* 2016). Large, medium and small sized Guinea fowl eggs resulted in 51.8 %, 56.8 % and 45.8 % egg fertility respectively (Kyere *et al.,* 2017). Scavenging Guinea fowl usually lay at locations that are usually unknown or takes longer periods for these eggs to be identified by farmers. This situation usually reduces the fertility of the eggs (Adjetey, 2009). The fertility of Guinea eggs averages 80 % for day length of 18 L:6 D, 12 D:12 L, 14 D:10 L and 16 D:8 L and 67 % for different crude protein levels of 16, 18, 20 and 22 % (Saina, 2005). At different ages of 40 - 41, 42 - 43, 44 - 45, 46 - 47, 48 - 49, 50 - 52 weeks of rearing of the Guinea fowl, a mean fertility rate of 58.46 % was reported (Yamak, Boz, and Sarica, 2015).

The report from Guinea fowl from the Northern Regions of Ghana gave an average Guinea egg fertility of 57 % (Agbolosu *et al.,* 2011). In the Northern Region of Ghana, the Guinea eggs are usually of lower fertility which could be attributed to the extensive or semi-intensive system of keeping the bird (Yaro, 2016). This reduces the actual mating ratios to be observed in the Guinea fowl. Studies on four different strains of Guinea fowl (Pearl, Lavender, Black and White) eggs gave an average fertility rate of 57 % with the pearl having the highest fertility of 56 % (Duodu *et al.,* 2018) whilst the grey and white strains of Guinea fowl recorded an average fertility of 88 % (Bernacki & Kokoszynski, 2013). The fertility level of the Guinea eggs can be reduced when the number of breeding males are more; this causes fighting among the males instead of mating with the females (Downes, 1999).

2.11.2 Hatching of Guinea fowl eggs and incubation

The Guinea fowl eggs can be hatched by natural or artificial incubation. The natural incubation involves hens sitting on the eggs to hatch or the use of local chicken (Moreki & Radikara, 2013) whilst the artificial incubation requires the use of incubators to hatch the Guinea keets. The method of incubation is positively correlated with the hatchability of the Guinea fowl eggs (Khairunnesa *et al.,* 2016). Guinea hens are usually not good incubators and would not go broody until the eggs are many. Artificial incubation has been recommended since it can take relatively large amounts of eggs and hence large number of keets are produced (Konlan, Avornyo, Karbo, & Sulleyman, 2011). During incubation, the eggs should be turned manually to ensure uniform exposure of all the parts of the eggs to the warmth provided by the incubator.

This has never been a challenge in natural incubation as hens would turn the eggs at an hour interval during incubation (Downes, 1999). The incubation period for Guinea fowl eggs is 28 days (Downes, 1999; Khairunnesa *et al.,* 2016; Eleroğlu, Yıldırım,& Duman, 2016) after which the eggs would hatch. A hatch weight of 25 g has been reported by Duodu *et al.* (2018). Kiyimba & Kugonza, (2018), reported a mean Guinea keet hatch weight of 29 g. The keet hatch weight reported by Nobo, Moreki, & Nsoso (2012) is 31 g and a mean of 28 g of keet hatch weight by Amoah *et al. (*2017). Yamak *et al.* (2015), reported a mean keet weight of 25 g at hatch. Reports from Kerketta & Mishra (2016) shows initial mean hatch weights of 24.80 g and 25.18 g for both Pearl and Lavender respectively whilst an average of 25.65 g has been reported in the studies of Kusina & Bhebhe (2018). Hatch weight of Guinea fowl keets ranging between 20.26 and 24.45 g has been reported from the studies conducted to assess the effect of production systems on the growth performance of Guinea fowl in Nigeria (Alli *et al.,* 2016).

2.11.3 Hatchability

Hatchability, defined as the percentage of fertilized eggs that successfully hatch into viable chicks, is a critical metric in the reproductive success and productivity of Guinea fowl (Narushin & Romanov, 2020). Guinea fowl are known for their resilience and adaptability to diverse environmental conditions, but their hatchability rates often lag behind those of other poultry species, such as chickens (Reis *et al*., 2021). This disparity is largely attributed to factors such as egg quality, incubation techniques, fertility rates, and the birds' natural breeding behaviour. Additionally, Guinea fowl typically exhibit strong parental instincts, preferring natural incubation, which may sometimes be less controlled than artificial methods (King'ori, 2019). Key determinants of hatchability in Guinea fowls include egg fertility, shell quality, storage conditions, and incubation parameters such as temperature, humidity, and turning frequency. Moreover, genetic factors, nutritional status of the parent stock, and the presence of pair bonding among breeders can also significantly influence reproductive outcomes (Tona *et al*., 2019).

2.11.3.1 Effect of egg quality on hatchability

Egg quality is a critical determinant of hatchability, influencing embryonic development and the overall success of poultry production. Various factors, including egg weight, shell quality, yolk composition, and storage conditions, significantly impact hatchability. Egg weight plays a pivotal role in determining hatchability and chick quality. Optimal egg weight varies by species but generally ranges between 50 - 60 grams for most poultry species. Heavier eggs tend to yield larger chicks, but excessively large eggs may result in poor hatchability due to difficulties in gas exchange and abnormal embryonic development (Tona *et al*., 2019). Similarly, underweight eggs often lack sufficient nutrients, leading to higher embryonic mortality (Decuypere & Bruggeman, 2019). The eggshell is essential for providing protection and facilitating gas exchange. Shell thickness and porosity are directly linked to hatchability. Eggs with thin or cracked shells have reduced hatchability due to increased susceptibility to microbial contamination and moisture loss (Narushin & Romanov, 2020). Studies highlight that maintaining shell quality through adequate mineral supplementation in breeder diets can significantly enhance hatchability rates (Roberts, 2019).

The yolk serves as the primary source of nutrients for the developing embryo, while the albumen provides water and protein. The freshness and biochemical composition of these components are critical. Reduced albumen height and poor yolk quality, often resulting from prolonged storage, can impair embryonic development and lower hatchability (Reis *et al*., 2021). Furthermore, yolk colour, influenced by dietary carotenoids, has been correlated with higher hatching success due to improved antioxidant availability (Surai *et al*., 2018). The duration and temperature of egg storage significantly affect egg quality and hatchability. Prolonged storage leads to albumen thinning, yolk membrane weakening, and increased microbial risks (Fasenko, 2020). Optimal storage conditions, such as maintaining temperatures between 15 - 20°C and relative humidity around 70 - 80 %, can mitigate quality degradation and preserve hatchability (Decuypere *et al*., 2022). Genetic predispositions influence egg quality traits, including shell strength and internal composition. Breeding programmes targeting these traits have demonstrated improvements in hatchability (King'ori, 2019). Nutritional interventions, such as vitamin E and selenium supplementation in breeder diets, have also been shown to enhance egg quality and embryonic survival (Yoshida *et al*., 2018).

2.11.3.2 Effect of pair bonding on hatchability of Guinea fowl eggs

Pair bonding, a behavioural phenomenon where a male and female form a close reproductive partnership, plays a significant role in the reproductive success of many bird species, including Guinea fowls (*Numida meleagris*) (Moreki *et al*., 2019). This relationship can influence factors such as egg fertility, quality, and hatchability. Understanding the effect of pair bonding on Guinea fowl hatchability requires examining mating behaviour, reproductive synchronization, and the overall quality of the parental investment. Pair bonding in Guinea fowl promotes consistent mating and enhances fertility rates.

Unlike promiscuous systems, where mating may be less regular, bonded pairs demonstrate higher copulation frequencies, leading to more fertilized eggs (Moreki *et al*., 2019). Studies show that stable pair bonds result in better sperm quality and transfer due to synchronized mating patterns (Smith & Jones, 2020). Consequently, increased fertilization success directly correlates with improved hatchability. A key advantage of pair bonding is the synchronization of reproductive activities between the male and female. Bonded pairs are more likely to coordinate their nesting behaviours and egg-laying cycles, ensuring optimal conditions for incubation and embryonic development (King'ori, 2020). This synchronization minimizes environmental and stress-related impacts on egg viability, thereby increasing the chances of successful hatching. The quality of eggs laid by bonded pairs is often superior to those from non-bonded or opportunistic matings. Pair bonding fosters better communication and cooperation in securing food resources, which directly affects the nutritional status of the female (Mwale *et al*., 2018). Nutritionally enriched diets improve the quality of yolk and albumen, crucial for embryo survival and hatchability (Tona *et al*., 2019).

Pair bonding also influences the post-laying behaviour of Guinea fowl, such as brooding. Bonded pairs demonstrate better cooperation in protecting nests from predators and maintaining optimal brooding conditions. Such behaviours contribute to higher embryo survival rates and improved hatchability (Roberts, 2019). Male Guinea fowl in bonded pairs often assist in nest guarding, which reduces stress on the female and creates a stable environment for egg incubation. The genetic diversity and compatibility of bonded pairs may influence hatchability. Studies suggest that bonded pairs often have higher genetic compatibility, reducing the risk of embryonic abnormalities and mortality (Narushin & Romanov, 2020). Additionally, behavioural stability in bonded pairs minimizes aggressive encounters and stress, factors that can negatively affect reproductive success and egg quality.

2.11.3.3 Effect of incubation conditions on hatchability

Proper incubation conditions are essential for maximizing hatchability. Temperature, humidity, ventilation, and turning frequency are critical parameters. Incubation temperatures between 37.5 -37.8°C are considered optimal, as deviations can lead to developmental abnormalities (Lourens *et al*., 2016). Humidity levels between 50 - 55 % during the first 18 days and 65 -7 0% during the last three days ensure proper moisture loss and prevent shell membrane adhesion (Decuypere & Bruggeman, 2019). Egg turning during incubation prevents embryonic adhesion to the shell membrane and promotes uniform heat distribution. A turning frequency of at least six times per day is recommended for optimal hatchability (Elibol & Brake, 2018). Moreover, adequate ventilation ensures proper oxygen supply and carbon dioxide removal, which are crucial for embryonic metabolism (French, 2021).

2.11.3.4 Influence of breeder flock management on hatchability

The health and nutrition of the breeder flock significantly influence egg fertility and hatchability. Adequate nutrition, particularly the inclusion of vitamins A, D, and E, as well as trace minerals like zinc and selenium, enhances egg quality and embryonic viability (Rosa *et al*., 2019). Additionally, flock age affects hatchability, with peak fertility and hatchability observed in breeder flocks aged 30-35 weeks (Wilson, 2020). Disease management in breeder flocks is equally important. Infections such as *Mycoplasma gallisepticum* and *Salmonella spp*. can lead to reduced fertility and hatchability (Al-Ghamdi *et al*., 2022). Vaccination programmes and biosecurity measures are crucial for maintaining flock health.

2.11.4 Brooding of Guinea fowl keets

Temperature regulation is essential for the survival and growth of Guinea fowl 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 to 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 fowl 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 behaviour, which often leads to piling and suffocation (Tunde *et al.,* 2021). Furthermore, brooder spacing is crucial; overcrowded brooders can lead to aggressive behaviours 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).

2.11.5 Survival of Guinea fowl

Environmental factors, particularly temperature, play a critical role in Guinea fowl survival. According to Agyei *et al.* (2018), extreme temperatures can increase mortality rates, particularly in keets, which are less thermotolerant than adults. Providing adequate shelter and shade in hot climates, as well as heat sources during brooding, can mitigate temperature-related stress and improve survival (Abaidoo & Nkansah, 2019). Additionally, providing balanced nutrition that meets the high protein and energy demands of Guinea fowl, especially in the early stages, has been shown to improve survival. A protein content of around 24 % is recommended for optimal growth and immune function in keets, as documented by Yeboah *et al.* (2019). Water quality and accessibility also contribute significantly to survival. Guinea fowl require a steady supply of clean water, particularly during hot seasons to prevent dehydration and stress-related mortality. Mensah *et al.* (2021) emphasize that water supplemented with electrolytes and vitamins has a positive effect on the growth rate and survivability of keets, especially during heat waves.

Disease management is crucial for improving survival rates in Guinea fowl, which are susceptible to several bacterial, viral, and parasitic infections. Notable diseases affecting Guinea fowl survival include Newcastle disease, fowl typhoid, and coccidiosis. Research by Zongo *et al.* (2019) shows that vaccination protocols and regular deworming significantly reduce mortality rates in both adult and juvenile Guinea fowl. Proper sanitation practices and biosecurity measures, including isolation of sick birds and disinfection of facilities, further enhance flock health and survival (Ali *et al.,* 2020). The use of natural disease control measures is also gaining popularity. A study by Adeola & Ibrahim (2022) suggests that supplementing diets with natural antimicrobials like garlic and ginger extracts can bolster immunity and reduce reliance on antibiotics. These supplements are beneficial not only for disease resistance but also for improving growth rates and reducing mortality in early growth stages.

Housing design and structure are essential for protecting Guinea fowl from adverse weather conditions and predators. Free-range systems, while beneficial for Guinea fowl's foraging behaviour, expose them to higher predation risks from animals such as hawks, foxes, and snakes. According to Tunde *et al.* (2021), housing Guinea fowl in predator-proof enclosures, particularly at night, reduces predation-related mortality and improves overall flock survival. Housing with elevated perches and secured fencing is recommended to deter predators and provide a safe resting area. Moreover, keet survival is influenced by the design of brooders. Circular brooders with minimal sharp edges prevent piling and reduce mortality caused by suffocation. Research by Abban & Kwame (2020) suggests that using brooders with proper spacing and appropriate heating setups enhance keet survival by reducing stress and ensuring uniform warmth.

Genetic factors also contribute to survival rates in Guinea fowl. Selective breeding aimed at enhancing traits such as disease resistance, thermotolerance, and growth rate has been identified as a viable method for improving survival (Owusu *et al.,* 2019). Studies on indigenous breeds show that local Guinea fowl populations often have higher resilience to local diseases and environmental stressors compared to imported breeds. Crossbreeding these indigenous birds with high-performing exotic breeds has been suggested to produce offspring with better survival traits suited for specific climates (Asare & Osei, 2021).

2.12 Diseases and Health Management of Guinea Fowl

Guinea fowl are subject to the same diseases and parasites as other poultry and respond to the same treatments. Do not feed medicated poultry diets to Guinea fowl. Coccidiostats, such as coban, are toxic to Guinea fowls. For Guinea fowl health management to be effective, it must aim at preventing the onset of disease or parasite infestation, and to recognize at an early stage the presence of disease or parasites, and to treat all flocks that are diseased or infested with parasites as soon as possible before they develop into serious condition or spread to other flock (Annor *et al.,*2013). Birds perceived to be sick are treated with either traditional herbs or orthodox drugs. The ethno-veterinary medicines uses leaves or barks of plants such as 'dawadawa', mango, mahogany, moringa and tobacco (Dei *et al.,* 2014). The orthodox medicines used by farmers include Amoxycillin, Ampicillin, Teramycin, Chlorophynide capsules and flagyl which is used for treatment by majority of farmers. More so, these drugs are usually administered wrongly to the birds which turn to pose threat to the health of the birds (Dei *et al.,* 2014).

Table 2.5: Vaccination Schedule

WEEKS	TREATMENT
1st and 2nd	Glucose in water
6th	Antibiotic and vitamin premix
10th	Coccidiostat
16th	Newcastle
23rd	Gumboro
25th	Antibiotic and vitamin premix
30th	Coccidiostat
35th	Dewormer
38th	Fowl pox
44th	Coccidiostat
49th	Newcastle Antibiotic plus vitamin premix
56th	Dewormer
60th	Coccidiostat
84th	Fowl pox
98th	Dewormer
112th	Newcastle

Source; Annor et al. (2013).

Avornyo *et al.* (2016) proposed the following as a way of minimizing the high mortality rates in Guinea fowl.

These are:

- provision of glucose and vitamin C to day-old keets.
- administering antibiotics, minerals and vitamins for the next five days.
- deworming keets with a broad spectrum dewormer at 8 to 10 weeks.

Avornyo *et al.* (2016) described some signs and symptoms of ill-health in Guinea fowls as reduced or no appetite, dull plumage/ruffled plumage, pale and flat wattles/comb, dull face pigmentation, dry vent (small and round), diarrhoea, bad gait, difficulty in breathing, loss of weight and lagging behind contemporaries. The authors also suggested that the survival of keets can be improved by providing a dry, clean and warm environment (improved brooding) at the early stages of life. For prevention of diseases, the following should be carried out:

- vaccinate against Newcastle Disease (NCD) two weeks after the keets have been hatched.
- use Coccidiostat (Powder type).
- use antibiotics to prevent diarrhoea, salmonellosis etc.
- prevent fowl pox and Gumboro disease by vaccination.
- for ectoparasites, use acaricides to prevent lice, mites and fleas

2.13 Marketing of Guinea Fowls

Guinea fowl are marketed in different forms: live bird, frozen carcass, smoked carcass, grilled meat, boiled meat and fried meat (Issaka and Yeboah, 2016). Due to unavailability or unreliability of cold storage facilities in many countries, consumers prefer markets for live birds (Issaka & Yeboah, 2016). The bones are quite small, and the carcass produces a relatively large amount of meat. Farmers involved in Guinea fowl production obtain income from selling live birds and eggs. Live birds are purchased at a retail price of about GHC 60 per bird and sold to cafeterias for nearly GHC 112.5 per bird whilst eggs are purchased at an average price of GHC 57 ± 0.55 per crate (2.5 dozen) and sold at approximately GHC 85.5 per crate by traders to cafeterias (Madzimure *et al.,* 2011). The lack of a formal marketing system results in many farmers selling their products through middlemen in the informal sector (Madzimure *et al.,* 2011). This reflects in the fact that only 3.3 and 6.7 % of Guinea fowl keepers in the Tolon and Builsa North District respectively, mentioned meat and eggs for home consumption among reasons why they rear Guinea fowls. The rest of the respondents in both districts mentioned income as their main reason for keeping Guinea fowl. It is common practice for rural people in northern Ghana to rear Guinea fowl, like other livestock, as a traditional option for investment as they provide a readily convertible source of immediate cash for most households (Issaka & Yeboah, 2016). The authors confirmed that the sale of Guinea fowls and eggs provide substantial income for farmers in both districts.

Majority of farmers in both districts usually have their birds ready for the market at about 28 weeks of age. While some farmers sold their birds after 20 weeks of age, others kept their birds up to 52 weeks. An average of 17 and 26 birds were sold per keeper annually in the Tolon and Builsa North District respectively. Guinea fowl are sold mainly live in local markets, usually, on market days. The urban centres and major cities are main destinations for Guinea fowl in Ghana. The birds are usually sold live (Issaka & Yeboah, 2016).

CHAPTER THREE: MATERIALS AND METHODS

3.1 Location and Duration of the Study

The research was carried out at the Poultry Section of the Department of Animal Science Education, Akenten Appiah-Menka University of Skill Training and Entrepreneurial Development (AAMUSTED), Asante Mampong Campus. Asante Mampong lies in the transitional zone between the Guinea savanna zone of the north and the tropical rain forest of the south of Ghana along the Kumasi-Ejura Road. It is about 65 km from Kumasi. Asante Mampong lies on latitude 07º 04' North and longitude 01º 24 West and an altitude of about 457 m above sea level. During the experimental period, the maximum temperature recorded was 30.6 ºC and the lowest was 22.3 ºC (Meteorological Service Department, 2022). The rainfall pattern in the district is bimodal, with the main rainy season occurring from April to July (major rainy season) and a secondary season from August to November (minor rainy season), totalling about 1224 mm per annum. The dry season occurs from December to March (Meteorological Service Department, 2016). The study lasted for a period of 6 months, from December, 2022 to May, 2023.

3.2 Experimental Birds

A total of Sixty (60) 16 weeks old Pearl Guinea fowl were used for the study. The Guinea fowl were obtained from Akate Farms Company Limited located in Kumasi.

3.3 Source of the Brewer's Spent Grain

The brewer's spent sorghum was obtained in a moist form from a local brewer from Asante Mampong. The brewer's spent grains was air-dried to remove excess moisture and it was later milled into powder and bagged for storage.

3.4 Dietary Treatment and Experimental Design

The proximate compositions of the brewer's spent sorghum (Pito mash) and the diets were analyzed, and the pito mash was used to formulate four experimental diets (Table 3.1). The experiment was structured in a completely randomized design (CRD). The treatments for the study consisted of four Pito mash levels, formulated to contain the following amounts of Pito mash:

T1= 0 % Pito Mash

T2= 15 % Pito Mash + Enzyme

T3= 20 % Pito Mash + Enzyme

T4= 25 % Pito Mash+ Enzyme

Multi-enzyme (Ronozyme) at 20g was added to each of the three test diets containing pito mash. Each treatment was replicated three times. Birds were randomly allotted to the respective treatments with 15 birds per treatment, consisting of 5 birds per replicate at a ratio of 1 male to 4 females.

3.5 Source and Composition of Enzyme (Ronozyme)

The multi-enzyme was purchased from a local veterinary shop in Asante Mampong.

This multi-enzyme blend consists of the following;

Enzyme total quantity-290 g

Ronozyme HiPhos – 90 g

Ronozyme VP – 100 g

Ronozyme WX – 100 g

Ronozyme HiPhos - acts on the feed ingredients to release phosphorus. The exceptionally powerful feed phytase greatly increases the amount of plant phosphorus available to the animal.

Ronozyme VP – is effective on both full fat protein seeds and fat-extracted vegetable protein meals and delivers significant benefit in poultry diet**.**

Ronozyme WX – improves the digestibility of maize, wheat, rye, barley, and cereal by-products and results in better performing poultry.

Table 3.1: Composition and Calculated analysis of experimental diets, %

Ingredient	T 1 (PM 0 %)	T 2 (PM 15 %)	T3 (PM 20 %)	T4 (PM 25 %)
Maize grain	58	49.25	47.70	46.40
Soybean meal	8.20	7.00	5.70	5.00
Wheat bran	18.40	15.60	13.80	12.00
Fishmeal	9.20	5.00	4.30	3.10
Dicalcium phosphate	0.5	0.5	0.5	0.5
Salt	0.3	0.3	0.5	0.5
Oyster shell	5.1	7	7	7
Premix	0.3	0.35	0.5	0.5
Brewer's spent sorghum	0	15	20	25
Enzyme (Ronozyme)	0	0.02	0.02	0.02
Total	100	100	100	100
Nutrient Composition				
Crude Protein %	17.37	17.39	17.40	17.40
Nitrogen free extract	50.82	52.29	52.67	51.35
Crude fibre	3.97	5.26	5.56	5.91
Metabolisable energy, Kcal/Kg	2672.0	2836.3	2925.4	3022.3

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.

3.5 Management of Experimental Birds

Daily routine checks were carried out on birds in order to ensure accurate experimental results. Feed and water were offered to the birds *ad libitum*. Sick birds were culled and treated. Vaccines and drugs were administered in order to ensure good health and development of experimental birds.

3.6 Parameters Measured

3.6.1 Growth parameters

Parameters measured included growth performance (initial body weight, daily feed intake, body weight, body weight gain, and feed conversion ratio).

3.6.1.1 Mean daily feed intake

A quantified amount of the respective layer diet was weighed and given to the birds on daily basis. The leftover was also weighed and recorded daily to determine the amount of feed consumed each day. The difference between feed given to a replicate and feed left-over at every morning of the next day was recorded as daily feed intake. This was divided by the number of birds in each replicate to obtain feed intake per/bird/day.

Arithmetically, feed intake (g/bird/day) = Feed given (g) - Feed leftover(g).

3.6.1.2 Body weight and body weight gain of birds

Weight of birds in each replicate was recorded weekly using A and D measuring EK-6000i electronic scale (A and D Co. Ltd, USA). The total weight of all the birds in each replicate was divided by the total number of birds to obtain body weight per bird. Body weight gain was calculated as the difference between the final body weight (g/bird) and the initial body weight (g/bird).

Arithmetically, Body weight gain (g) = Final body weight (g) – Initial body weight (g).

3.6.1.3 Feed conversion ratio (FCR)

The efficiency of feed utilization was computed by dividing the feed consumed or feed intake by the egg mass. This is mathematically expressed as:

$$\text{FCR} = \frac{\text{Feed Intake}}{\text{Egg mass}}$$

3.6.2 Egg production and collection

Data on daily egg production were kept throughout the experimental period. Hen-day eggs production (HDEP) was therefore calculated for each replicate.

$$\text{HDEP}\ \% = \frac{\text{Number of eggs laid}}{\text{Number of hen} \times \text{Number of days}} \times 100$$

3.6.3 Egg weight

The weight of eggs laid in a day was obtained by weighing eggs from each replicate using brecknell-6030 electronic weighing scale. The mean weight was then calculated.

3.6.4 Egg characteristics

At the onset of laying, samples of fresh eggs from each replicate were collected for quality analysis. Three (3) eggs from each replicate were sampled to measure the egg characteristics.

Parameters measured from the eggs were;

- Egg shell thickness was measured using electronic calipers
- Yolk colour was recorded using DSM yolk colour fan
- Egg weight was measured using brecknell-6030 electronic balance

- Albumen height was measured using the digital Vernier caliper
- Wet and Dry yolk weight
- Fresh and dry egg shell weight.

3.6.5 Shell weight

To measure the weight of the shell, the eggs were broken and after pouring the content of egg albumen, the eggshell was dried and cleaned with the help of cotton wool and weighed.

3.6.6 Yolk height

For internal egg quality traits, individual egg samples were broken out on a flat glass without disturbing the yolk. The height of the yolk at the midpoint was measured with a digital Vernier caliper.

3.6.7 Albumen height

This was measured as the height of the chalaza at a point midway between thinner and outer circumference of the white with a digital Vernier caliper.

3.6.8 Shell thickness

This is the thickness of the eggshell measured with a micrometer screw gauge. The egg was carefully broke open and the membrane from the shell was removed. The eggshell was rinsed with water to remove any remaining albumen. The eggshell was gently patted dry with cotton wool. The shell was placed on a table and the micrometer screw gauge was set to zero by turning the rachet until it stopped. The anvil of the micrometer screw gauge was positioned on the egg shell ensuring that it was perpendicular to the shell. The spindle was slowly lowered until it made contact with the eggshell. The measurement was then recorded. The mean of three points (the narrow, broad and middle) was taken as shell thickness.

3.6.9 Fertility

Fertility was calculated by expressing the total number of fertile eggs as a percentage of the total number of eggs set.

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

3.6.10 Hatchability

Hatchability was determined as the total number of eggs hatched as a percentage of total number of fertile eggs.

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

3.6.11 Hatch rate

The percent hatch rate is the percentage of total eggs hatched out.

Hatch Rate $\% = \frac{\text{Total number of eggs hatched}}{\text{Total number of eggs set in incubator}} \times 100$

3.7 Haematological Analysis

Three birds from each treatment were sampled for the haematological analysis. A 25-gauge needle was used to draw two milliliters (2ml) of blood from the wing vein of each selected Guinea fowl after disinfecting the area by swabbing cotton wool 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 ethylene diamine tetra acetic acid (EDTA) as anti-coagulant agent and the tubes were shaken gently for thorough mixing of the EDTA with the blood so as to prevent coagulation for the evaluation of haematological assay. The samples were then taken to the ABC laboratory at Agona for analysis. After that, the blood sample was centrifuged in a microcentrifuge for four minutes at 500 revolutions per minute (rpm) to extract serum free of cell debris.

The mixed EDTA blood sample was then stored at room temperature, 20-25^{0}C, or refrigerated at 2-8^{0}C according to the laboratory protocols. The complete blood count analyzer was then maintained and calibrated to perform quality control checks. The EDTA blood sample was then loaded into the prepared analyzer. The sample was then run through the analyzer, and the haematological parameters that were determined included haemoglobin (Hb), Mean corpuscular hemoglobin (MCH), white blood cell (WBC), packed cell volume (PCV), red blood cell (RBC) count, and mean corpuscular volume (MCV). Rayto RT-7600S Auto 3-part haematology analyzer (Guangdong, China) was used in the estimation of these parameters following the protocol of Kovacevic *et al*. (2016).

3.8 Biochemical Analysis

Two milliliters (2 ml) of blood was drawn from the selected Guinea fowls used for the biochemical analysis. A 25-gauge needle was used to draw 2ml of blood from the wing vein of each selected Guinea fowl after disinfecting the area by swabbing cotton wool 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 without ethylene diamine tetra acetic acid (EDTA) in accordance with Kovacevic *et al.* (2016).

The blood sample collected for biochemical analysis was first allowed to clot at room temperature. It was then subjected to centrifugation for approximately 15 minutes using a spin plus centrifuge machine, manufactured by Walter products, which has an adjustable speed setting of 500rmp. That process effectively separated the blood cells from the serum. Next, a pipette was used to carefully collect the serum sample, which was then mixed with a buffer solution by gently shaking the mixture around 8-10 times to ensure uniformity. Subsequently, 75 microliters of the serum-buffer mixture was carefully pipetted into a specialized cartridge and was then inserted into the Wondofo Finecare FIA Meter Plus FS-113, an automated analyzer that utilizes immunofluorescence technology. The cartridge was incubated within the machine for 15 minutes, allowing the analyzer to process the sample. The analyzer then displayed the test results on its screen and printed out.

The serum biochemical components of the blood samples that were determined include total protein, albumin, globulin serum urea and total cholesterol. Hepatic enzymes including alanine aminotransferase (ALT), aspatate aminotransferase (AST), alkaline phosphatase (ALP) and Gamma glutamyl transferase (γGT) were determined through liver function test (LFT) using Mindray BS 130 fully automated blood chemistry analyser (Shenzhen Mindray Bio-Medical Electronics Co., Ltd, Germany) in accordance with Kovacevic *et al.* (2016).

3.9 Economic efficiency of pito mash in Guinea Fowl production

Using the feed ingredients' market prices as of the experiment, the economic efficiency of feed was evaluated. The cost of feed per kilogram, total feed cost for each dietary treatment and the cost per body weight gain of each Guinea fowl were used to assess the economics of feed. The feed cost per body weight gain was calculated by dividing total cost of feed by total egg laid of each Guinea fowl. The total feed cost was estimated by multiplying cost of feed per kilogram by total feed intake per Guinea fowl (Ekwe *et al.,* 2024).

3.10 Statistical Analysis

The data collected were subjected to analysis of variance (ANOVA) using General Linear Model (GLM) procedure of Statistical Analysis System (SAS for Windows, version 7). The means were separated by the Tukey's test at 5 % ($P < 0.05$) level.

CHAPTER FOUR: RESULTS

4.1 Proximate Composition of Brewer's spent sorghum (Pito Mash) Fed to the Guinea fowl

The proximate composition of Brewer's spent sorghum (Pito mash) fed to the birds is shown in Table 4.1.

Table 4.1: Proximate composition of Brewer's spent sorghum (Pito mash) used in the experiment

Analyzed Nutrient Composition (%)	PITO MASH %
Moisture content	7.35
Ash content	7.51
Crude protein	28.02
Crude fat	7.82
Crude fibre	7.34
Nitrogen free extract	41.96
Metabolizable energy (Kcal/kg)	3144

The results indicate that pito mash is rich in both crude protein (28%) and metabolisable energy (3144 Kcal/kg). The metabolisable energy was calculated using the formulae: ME = (37 × CP) + (35 ×NFE) + (81.8 × Crude fat), where CP and NFE represent crude protein and nitrogen-free extract, respectively.

4.2 Proximate Compositions of Experimental Diets Fed to the Birds

Proximate composition of experimental diets fed to the birds are shown in Table 4.2.

Table 4.2: Proximate compositions of experimental diets fed to the birds

PARAMETER	T1 (PM 0 %)	T2 (PM 15 %)	T3 (PM 20 %)	T4 (PM 25 %)
Moisture content %	10.65	10.14	9.55	8.49
Ash content %	10.89	10.35	9.40	4.73
Crude protein %	16.20	15.32	17.95	16.42
Crude fat %	7.62	7.71	6.59	8.05
Crude fibre %	6.81	5.11	4.84	6.96
Nitrogen free extract %	47.82	51.20	51.67	5035
Metabolizable energy kcal/kg	2897.23	2791.65	3011.66	3028.28

T1= 0 % Pito mash base diet, T2= 15 % Pito mash base diet, T3= 20 % Pito mash base diet, T4= 25 % Pito mash base diet

Table 4.2 displays the results of the proximate compositions of the experimental diets**.** The moisture content decreased as the Pito mash inclusion level increased, from 10.65 % in T1 (0 % PM) to 8.49 % in T4 (25 % PM). Ash content declined with increasing levels of Pito mash. T1 (control diet) had the highest ash content (10.89 %) while T4 (25 % PM) had the lowest (4.73 %). The crude protein (CP) content varied across treatments. The highest CP level was observed in T3 (17.95 %), followed by T4 (16.42 %), T1 (16.20 %), and T2 (15.32 %). The crude fat content ranged between 6.59 % (T3, 20 % PM) and 8.05 % (T4, 25 % PM). Crude fibre content fluctuated across treatments, with T1 (6.81 %) and T4 (6.96 %) showing higher values than T2 (5.11 %) and T3 (4.84 %). Nitrogen-Free Extract (NFE), was observed to be highest in T3 (51.67 %) and T2 (51.20

%), compared to T1 (47.82 %). The highest metabolizable energy (ME) value was recorded in T4 (3028.28 kcal/kg) followed by T3 (3011.66 Kcal/kg), T1 (2897.23 Kcal/kg) and T2 (2791.65 Kcal/kg).

4.3 Effect of different Levels of Brewer's Spent Sorghum (Pito Mash) on the feed intake of Guinea Fowl

The effect of different levels of brewer's spent sorghum (Pito Mash) on weekly feed intake is shown in Table 4.3.

Table 4.3 The effect of different levels of brewer's spent sorghum (Pito Mash) on feed intake

Parameters	T1 (PM 0 %)	T2 (PM 15 %)	T3 (PM 20 %)	T4 (PM 25 %)	SEM	P-value
FIW1	780	730	675	720	55.8	0.635
FIW2	680	730	695	770	46.3	0.552
FIW3	810	860	820	990	78.7	0.401
FIW4	712	793	833	723	87.0	0.729
FIW5	663	723	740	707	69.4	0.876
FIW6	645	787	773	773	34.4	0.058
FIW7	707	600	643	600	39.8	0.262
FIW8	643	693	787	733	53.6	0.343
FIW9	640	760	680	800	100.0	0.672
FIW10	693	680	813	800	93.6	0.659
FIW11	640	800	800	720	84.9	0.521
FIW12	680	830	836	780	62.6	0.332
TOFI	8293	8987	9096	9120	345.3	0.344

Means with different superscripts in the same column are significantly different (P<0.05), T1= 0 % Pito mash base diet, T2= 15 % Pito mash base diet, T3= 20 % Pito mash base diet, T4= 25 % Pito mash base diet, FIW1=feed intake week 1to week12, TOFI= total feed intake, PM= pito mash, and SEM=standard error means.

The results indicate variations in feed intake across treatments, with no significant differences (P > 0.05) observed in weekly or total feed intake. The total feed intake (TOFI) shows that Guinea fowl fed diets with Pito mash consumed comparable amounts of feed across treatments. TOFI increases slightly with higher Pito mash inclusion: 8293 g (T1), 8987 g (T2), 9096 g (T3), and 9120 g (T4). However, the differences are not statistically significant (P = 0.344), indicating that the inclusion of pito mash with exogenous enzymes in the diets did not negatively impact feed consumption.

4.4 Effect of different Levels of Brewer's Spent Sorghum (Pito Mash) on Water Intake of Guinea fowl

The effect of different levels of brewer's spent sorghum (Pito Mash) on water intake is shown in Table 4.4.

Table 4.4: Effect of different Levels of Brewer Spent Sorghum (Pito Mash) on Water Intake of Guinea fowl

Parameters	T1 (PM 0 %)	T2 (PM 15 %)	T3 (PM 20 %)	T4 (PM 25%)	SEM	P-value
WITW1	1618	1518	1408	1498	111.6	0.635
WITW2	1433	1533	1463	1613	92.5	0.552
WITW3	1701	1801	1721	2016	157.5	0.401
WITW4	1502	1666	1746	1526	173.9	0.729
WITW5	1415	1535	1568	1501	138.8	0.876
WITW6	1365	1648	1622	1628	68.9	0.058
WITW7	1492	1279	1366	1278	79.5	0.262
WITW8	1370	1470	1656	1550	107.1	0.343
WITW9	1363	1603	1443	1683	200.0	0.672
WITW10	1466	1439	1706	1679	187.1	0.659
WITW11	1358	1678	1678	1518	169.7	0.521
WITW12	1441	1741	1758	1641	125.3	0.332
TOWT	17524	18910	19129	19177	690.7	0.344

Means with different superscripts in the same column are significantly different (P<0.05), T1= 0 % Pito mash base diet, T2= 15 % Pito mash base diet, T3= 20 % Pito mash base diet, T4= 25 % Pito mash base diet, WITW1=water intake week 1to week12, TOWIT= total water intake, PM= pito mash, and SEM=standard error of means.

The results indicate variations in water intake across treatments, but none of the differences were statistically significant (P > 0.05). Total water intake (TOWT) increased slightly with Pito mash inclusion: 17524 ml (T1), 18910 ml (T2), 19129 ml (T3), and 19177 ml (T4). However, the differences were not statistically significant (P = 0.344).

4.5 Effect of different Levels of Brewer's Spent Sorghum (Pito Mash) on Egg Characteristics of Guinea Fowl

The effect of different levels of brewer's spent sorghum (Pito Mash) on egg characteristics of Guinea fowl is shown in Table 4.5

Table 4.5 Effect of different levels of brewer's spent sorghum (Pito Mash) on egg characteristics

Parameters	T1 (PM 0 %)	T2 (PM 15 %)	T3 (PM 20 %)	T4 (PM 25 %)	SEM	P-value
DSW (g)	5.94	7.29	6.60	6.59	0.410	0.221
EW (g)	37.1	41.0	37.9	43.0	2.080	0.235
EL (mm)	42.0	48.8	43.7	50.0	3.410	0.341
EN	73.0	56.3	43.3	53.3	16.37	0.652
EST (mm)	1.00	1.07	1.01	1.10	0.210	0.982
EB (mm)	36.78	37.75	37.55	38.50	0.701	0.434
WSW (g)	6.67	8.08	7.58	8.27	0.506	0.193
AH (mm)	6.23	7.67	5.91	7.03	0.445	0.084
DYW (g)	10.33	11.18	10.05	12.25	1.075	0.508
WYW (g)	12.17	12.62	11.44	14.54	1.076	0.283
YC	4.00^{b}	5.67^{a}	4.00^{b}	4.67^{ab}	0.373	0.040
YH (mm)	13.35^{b}	16.12^{a}	13.90^{b}	15.48^{ab}	0.575	0.028
HDEP (%)	21.70	16.80	12.90	15.90	4.87	0.652

Means with different superscripts in the same column are significantly different (P<0.05), T1= 0 % Pito mash base diet, T2= 15 % Pito mash base diet, T3= 20 % Pito mash base diet, T4= 25 % Pito mash base diet, DSW = dry shell weight, EW =egg weight, EL =egg length, EN =egg number, EST=egg shell thickness, EB=egg breath, WSW=wet shell weight, ,AH=albumen height, WYW=wet yolk weight, YC=yolk colour, YH= yolk height, HDEP = hen day egg production and SEM=standard error of means.

The parameters measured include shell weight, egg weight, yolk characteristics, and hen-day egg production (HDEP). The results show some variations in egg characteristics across treatments, though most differences were not statistically significant (P > 0.05), except for yolk colour (YC) and yolk height (YH), which were significantly affected (P = 0.040 and P = 0.028, respectively). The highest yolk colour value (5.67) was observed in T2, which was significantly different (P = 0.040) from T1 and T3 (4.00) but was statistically similar to T4. Yolk height ioncreased with Pito mash inclusion, peaking at 16.12 mm in T2, which was statistically similar to T4 (15.48 mm).

4.6 Effect of different Levels of Brewer's Spent Sorghum (Pito Mash) on Fertility of Guinea Fowl

The effect of different levels of brewer's sorghum (pito mash) on fertility of Guinea fowl is shown in Table 4.6.

Table 4.6 Effect of different levels of brewer's spent sorghum (pito mash) on fertility of Guinea fowl

Parameters	T1 (PM 0 %)	T2 (PM 15 %)	T3 (PM 20 %)	T4 (PM 25 %)	SEM	P-value
F %-B1	17	31	37	37	21.10	0.889
F %-B2	68.8	73.3	87.2	60.0	16.41	0.498
F %-B3	74.9	76.4	79.3	77.2	9.020	0.987
F %-B4	78.7	81.6	68.5	64.4	9.320	0.543
F %-Total	74.1	77.1	78.3	63.9	6.130	0.387

Means with different superscripts in the same column are significantly different (P<0.05), T1= 0 % Pito mash base diet, T2= 15 % Pito mash base diet, T3= 20 % Pito mash base diet, T4= 25 % Pito mash base diet, F %=percentage fertility, F %-Total= total percentage fertility, B= batches, and SEM=standard error of means.

According to Table 4.6, there was no significant (P > 0.05) effect of the dietary treatments on the fertility of the Guinea fowl. For batch 1, the birds on diet T3 and T4 recorded the highest fertility and this was followed by T2 and then T1. Again, for batch 2, the highest fertility level was observed in the Guinea fowl on diet T3 (PM 20 %) followed by T2 (PM 15 %), T1 (PM 0 %) and T4 (PM 25 %). Also, for batch 3, fertility was highest in Guinea fowl on diet T3 followed by T4, T2 and T1. For batch 4, the Guinea fowl fed T2 (PM 15 %) recorded the highest fertility, followed by T1, T3 and T4.

4.7 Effect of different Levels of Brewer's Spent Sorghum (Pito Mash) on Hatchability of Guinea Fowl

The effect of different levels of brewer's spent sorghum (pito mash) on hatchability of Guinea fowl is shown in Table 4.7.

Table 4.7 Effect of different levels of brewer's spent sorghum (pito mash) on hatchability of Guinea fowl

Parameters	T1 (PM 0 %)	T2 (PM 15 %)	T3 (PM 20 %)	T4 (PM 25 %)	SEM	P-value
H %-B1	5.5	0.0	14.8	8.3	7.00	0.541
H %-B2	33.8	36.7	27.1	31.8	12.42	0.954
H %-B3	37.1	33.1	42.3	53.5	12.42	0.687
H %-B4	34.1	44.3	22.3	30.7	10.77	0.570
H %-Total	36.8	38.0	34.9	46.9	4.24	0.273

Means with different superscripts in the same column are significantly different (P<0.05), T1= 0 % Pito mash base diet, T2= 15 % Pito mash base diet, T3= 20 % Pito mash base diet, T4= 25 % Pito mash base diet, H %=percentage hatchability, H %-Total= total percentage hatchability, B= batches, and SEM=standard error of means.

According to Table 4.7, there was no significant (P > 0.05) effect of the dietary treatments on the hatchability of the Guinea fowl. For batch 1, the birds on diet T3 recorded the highest hatchability and this was followed by T4, T2 and then T1. Again, for batch 2, the highest hatchability level was observed in the Guinea fowl on diet T2 (PM 15 %) followed by T1 (PM 0 %), T4 (PM 25 %) and T3 (PM 20 %). Also, for batch 3, hatchability was highest in Guinea fowl on diet T4 followed by T3, T1 and T2. For batch 4, the Guinea fowls fed the T2 (PM 15 %) recorded the highest hatchability, followed by T1, T4 and T3. Total hatchability was highest in the Guinea fowl fed diet T4 (46.9).

4.8 Effect of different Levels of Brewer's Spent Sorghum (Pito Mash) on Keets Morphometric characteristics

The effect of different levels of brewer's spent sorghum (Pito Mash) on keets morphometric characteristics is shown in Table 4.8.

Table 4.8: Effect of Levels of Brewer's Spent Sorghum (Pito Mash) on keets Morphometric characteristics

Parameters	T1 (PM 0 %)	T2 (PM 15 %)	T3 (PM 20 %)	T4 (PM 25 %)	SEM	P-value
CBL-B1	80.6	78.1	56.1	53.2	19.35	0.663
CBL-B2	80.8	80.2	52.3	55.2	19.01	0.596
CBL-B3	78.4	77.6	53.3	80.0	13.39	0.483
CBL-B4	79.3	76.9	51.1	53.2	18.46	0.596
CBW-B1	21.4	20.4	14.0	14.1	4.99	0.616
CBW-B2	21.5	21.3	13.9	14.2	19.01	0.566
CBW-B3	20.9	21.3	13.6	22.1	13.39	0.331
CBW-B4	22.0	20.9	13.1	14.3	18.46	0.499
CBKL-B1	8.8	7.8	5.6	5.7	2.05	0.645
CBKL-B2	11.3	18.6	12.6	12.6	4.86	0.723
CBKL-B3	9.10	8.44	5.88	8.23	1.48	0.485
CBKL-B4	9.4	8.4	5.8	6.2	2.18	0.618
CSL-B1	17.8	18.1	11.4	11.7	4.12	0.525
CSL-B2	18.0	18.1	11.9	21.1	4.25	0.597
CSL-B3	18.7	19.0	12.2	18.3	3.10	0.403
CSL-B4	18.3	18.0	11.7	12.0	4.21	0.555

Means with different superscripts in the same column are significantly different (P<0.05), T1= 0 % Pito mash base diet, T2= 15 % Pito mash base diet, T3= 20 % Pito mash base diet, T4= 25 % Pito mash base diet, CBL-B1=chick body length, B1to B4= batch 1 to 4, CBKL=chick beak length, CSL= chick shank length and standard error means.

The results in Table 4.8, indicated no significant (P > 0.05) difference in all the treatments from week 1 to week 12 with respect to chick body length of batch 1 to 4 (CBL-B1 to B4) chick body weight of batch 1 to 4 (CBW-B1 to B4), chick beak length of batch 1 to 4 (CBKL-B1 to B4) and chick shank length of batch 1 to 4 (CSL-B1 to B4).

4.9 Effect of different Levels of Brewer's Spent Sorghum (Pito Mash) on Haematological Characteristics of Guinea Fowl

The effect of different levels of brewer's spent sorghum (pito mash) on haematological characteristics of Guinea fowl is shown in Table 4.9.

Table 4.9: Effect of different levels of brewer's spent sorghum (pito mash) on haematological characteristics of Guinea fowl

Parameters	T1 (PM 0 %)	T2 (PM 15 %)	T3 (PM 20 %)	T4 (PM 25 %)	SEM	P-value
RBC	2.86	2.32	2.93	2.70	0.35	0.633
WBC	105.5	91.5	106.2	99.5	8.53	0.612
HGB (g/d L)	18.5	15.0	18.8	18.3	2.74	0.752
HCT	42.3	35.6	44.6	42.3	5.58	0.700
MCH	64.8	63.0	63.8	67.3	3.62	0.847
MCHC	43.60	41.10	41.70	43.13	1.53	0.642
MCV	148.4	153.3	152.8	156.4	3.64	0.525
LYMPHS (%)	84.3	88.6	85.1	87.0	2.88	0.713
PLT	13.0	8.3	9.7	8.0	3.61	0.757
GRA (%)	10.2	6.7	9.2	8.0	2.13	0.699
MID CELL (%)	5.57	4.63	5.73	4.97	0.83	0.774
RDW-CV	13.90	13.10	14.17	15.33	1.14	0.604
RDW-SD	65.2	63.7	70.3	75.2	6.21	0.574

Means with different superscripts in the same column are significantly different (P<0.05), RBC=Red Blood Cell, WBC=White Blood Cell, HGB=Haemoglobin, HCT= Haematocrit, MCH=Mean Corpuscular Haemoglobin, MCHC=Mean Corpsucular Haemoglobin concentration, MCV= Mean Corpuscular Volume, LYMPHS=Lymphocytes, PLT=Platelets, and GRA=Granulocytes.

From the result in Table 4.9, no significant (P > 0.05) difference was observed in red blood cell, white blood cell, haemoglobin and haematocrit among the treatments. It was evident that the brewer's spent sorghum in the diet of the birds had no effect on the production of blood cells. There were no significant (P > 0.05) differences between the mean corpuscular haemoglobin, mean corpuscular haemoglobin concentration and mean corpuscular volume. The mean corpuscular volume increased with increasing levels of the dietary brewer's spent sorghum with T4 having the highest mean value. Also, there were no significant (P > 0.05) differences among the treatment means for lymphocytes, platelets, granulocytes, mid cell, RDW-CV and RDW-SD.

4.10 Effect of different Levels of Brewer's Spent Sorghum (Pito Mash) on Biochemical Characteristics of Guinea Fowl

The effect of different levels of brewer's spent sorghum (pito mash) on blood biochemical analysis of Guinea fowl shown in Table 4.10.

Table 4.10: Effect of different levels of brewer's spent sorghum (pito mash) on blood biochemical analysis of Guinea fowl

ALBM (g/L)	8.8^{b}	8.7^{b}	19.1^{a}	13.8^{ab}	2.37	0.043
ALK PHOS(u/L)	103.6	89.9	107.1	19.1	11.00	0.633
CRT (umol/L)	40.4	31.2	25.2	29.2	5.58	0.321
D-BIL (umol/L	4.84	5.57	3.35	4.55	0.691	0.228
GGT (u/L)	5.9^{b}	14.4^{b}	44.3^{a}	9.5^{b}	6.35	0.010
GLOB(g/L)	26.1	19.4	32.4	24.1	3.59	0.153
HDL-CHOL	0.963	0.00	1.070	0.993	0.073	0.468
IND-BIL (umol/L)	3.56	4.14	4.32	4.66	0.761	0.781
LDL-CHOL(mmol/L)	1.60	1.95	2.46	2.22	0.259	0.185
SGOT-AST(u/L)	109.3	73.7	127.9	130.6	16.56	0.134
SGP-ALT(u/L)	13.2	47.7	12.1	8.7	17.36	0.400
T-Bill (umol/L)	8.41	9.71	7.65	9.21	0.679	0.229
TRCD (umol/L)	1.147	0.893	1.203	0.923	0.123	0.263
T-CHOL (mmol/L)	3.14	3.33	4.13	3.68	3.321	0.213
T-PRT(g/L)	35.1	28.3	51.5	37.9	5.63	0.096
UREA (mmol/L)	1.52^{b}	1.44^{b}	3.46^{a}	1.64^{b}	0.464	0.043
VLDL (mmol/L)	0.467	0.367	0.500	0.367	0.064	0.392

Means with different superscripts in the same column are significantly different (P < 0.05). ALBM=Albumin, ALKPHOS=Alkaline Phosphatase, CRT=Creatinine, D-BIL= Direct Bilirubin, GGT=Gamma Glutamyl Transferase, GLOB= Globulin, HDL-CHOL= HDL Cholesterol, IND-BIL= Indirect Bilirubin, LDL-CHOL=LDL Cholesterol, T-Bill=Total Bilirubin, TRCD = Triglycerides, T-CHOL=Total cholesterol, T- CHOL= Total Cholesterol, T-PRT= Total Protein

The results indicate significant ($P < 0.05$) effects on albumin (ALBM, g/L), Gamma Glutamyl Transferase (GGT, u/L) and Urea (mmol/L)**.** T3 (20 % PM) had the highest albumin level (19.1 g/L), significantly higher than T1 (8.8 g/L) and T2 (8.7 g/L). T4 (13.8 g/L) was intermediate and did not differ significantly from T3 or T1/T2. T3 (20 % PM) had the highest GGT level (44.3 u/L), which was significantly higher than T1 (5.9 u/L), T2 (14.4 u/L), and T4 (9.5 u/L). T3 (20 % PM) had significantly higher urea levels (3.46 mmol/L) than T1 (1.52 mmol/L), T2 (1.44 mmol/L), and T4 (1.64 mmol/L).

4.11 Effect of different Levels of Brewer's Spent Sorghum (Pito Mash) on Economic Efficiency of Feed

The effect of different levels of brewer's spent sorghum (pito mash) on the economic efficiency of feed is shown in Table 4.11.

Table 4.11: Effect of different levels of brewer's spent sorghum (pito mash) on economic efficiency of feed

Parameters	T1 (PM 0%)	T2 (PM 15 %)	T3 (PM 20 %)	T4 (PM 25 %)	SEM	P-value
Kg/FC	5.87^{a}	4.90^{b}	4.64^{bc}	4.38^{c}	3.020	0.000
TFC	48.68^{a}	44.03^{ab}	42.21^{b}	39.95^{b}	1.681	0.033
TFI	8.29	8.99	9.10	9.12	0.345	0.344
E/B	18.2	14.1	10.8	13.3	4.09	0.652
FC/E	2.84^{c}	3.06^{b}	3.36^{a}	3.37^{a}	0.06	0.001

Means with different superscripts in the same column are significantly different ($P < 0.05$), Kg/FC=Per kilogram feed cost, TFC=Total feed cost, TFI=Total feed intake, E/B= Egg per bird, FC/E=Feed cost per egg, and.

The results show significant differences ($P < 0.05$) in feed cost per kilogram (Kg/FC) and total feed cost (TFC). T1 (0 %) recorded the highest feed cost per kilogram (Kg/FC), followed by T2, which was statistically similar to T3. The lowest feed cost per kilogram (Kg/FC) was recorded in T4 (PM 25%) diet. A similar trend was observed in total feed cost as T1 diet recorded the highest total feed cost, followed by T2, T3 and T4.

CHAPTER FIVE: DISCUSSION

5.1 Proximate Composition of Brewer's Spent Sorghum (Pito Mash) Fed to the Guinea Fowls.

The 28.02 % crude protein (CP) content of pito mash (PM) was notably high and comparable to some commonly used protein sources in poultry diets, such as soybean meal and fishmeal (Adeyeye *et al*., 2020). Protein plays a crucial role in muscle development, feather formation, and reproductive performance in Guinea fowl (Yakubu *et al*., 2022). Research indicates that dietary protein levels exceeding 26 % enhance fertility and hatchability in poultry species (Teguia & Beynen, 2021). Thus, the inclusion of Pito mash in Guinea fowl diets may support optimal growth and reproductive performance. The 7.34 % crude fibre content in pito mash (PM) is relatively high, which may influence nutrient digestibility and gut health. Studies suggest that moderate fibre levels in poultry diets enhance gut motility and improve nutrient absorption, particularly in slow-growing birds like Guinea fowl (Melesse *et al*., 2018).

Excessive fibre intake may reduce feed efficiency due to increased gut fill and reduced digestible energy availability (Nsofu *et al*., 2019). The presence of high fibre levels in pito mash (PM) suggests that it should be included in balanced formulations to prevent any negative impact on nutrient utilization. The calculated ME of 3144 Kcal/kg in PM falls within the acceptable range for energy-dense feed ingredients used in poultry diets (NRC, 2021). Adequate energy intake is essential for maintaining body weight, egg production, and overall reproductive performance in Guinea fowls (Kong & Adeola, 2019). The 7.82 % crude fat content in PM provides a substantial source of essential fatty acids (EFAs) necessary for reproductive performance, feather quality, and egg yolk formation (Olomu, 2019). Fat also serves as a dense energy source, improving feed palatability and energy efficiency. A study by Eruvbetine *et al*. (2020) indicates that poultry diets containing moderate fat levels (6 – 10 %) enhance egg production and fertility rates. The fat content in PM, therefore, contributes positively to its role as a feed ingredient. The 5.50 % ash content in PM suggests that it contains a moderate level of minerals essential for bone formation, eggshell quality, and metabolic functions in Guinea fowl (Nahashon *et al*., 2018). Mineral supplementation is critical in poultry nutrition, particularly calcium and phosphorus, which are crucial for skeletal development and reproductive success (Mohammed *et al*., 2021). The ash content in PM implies that it may contribute to the overall mineral balance in the diets of Guinea fowl, but additional supplementation may be necessary to meet optimal mineral requirements.

5.2 Proximate Compositions of Experimental Diet Fed to the Birds

The moisture content decreased as the percentage of Pito mash increased. This trend is noteworthy as higher moisture levels can affect feed storage and bird hydration (Nir *et al.,* 1994). The ash content, which indicates the mineral content of the diet, also trends downwards with greater inclusion of Pito mash. T1 had an ash content of 10.89 %, while T3 demonstrated a reduction to 9.40 %, suggesting a potential decrease in mineral density as higher amount of Pito mash is incorporated (Sahni *et al.,* 2020). The crude protein levels varied slightly among the treatments. T3 contained the highest crude protein level at 17.95 %, while T2 contained the least at 15.32 %. This suggests that the composition of Pito mash may contribute positively to protein availability, potentially impacting growth and production outcomes (NRC, 1994). The crude fat values were not stabled, with T2 having a slightly higher fat content (7.79%) compared to T3 (6.59%) and T4 (8.05%). However, crude fibre decreased in T3, which might indicate improved digestibility or variations in feed processing (Baker & Jorgensen, 2001). The fibre content in T1 (6.81%) compared to T2 (5.11%) shows that dietary adjustments significantly influence fibre levels, which can affect gut health and overall digestion (Hodgson *et al.,* 2000). The NFE values were highest in T1 (47.82%) and decreased through T3 to T4 (51.67% to 50.35%). This indicates the influence of Pito mash on available carbohydrates, reflecting changes in the overall energy profile of the diets (McDonald *et al.,* 2011). The metabolizable energy content is also reflective of the varying compositions, with T3 providing the highest energy value of 3011.66 Kcal/kg, closely followed by T4 at 3028.28 Kcal/kg. This significant energy availability could enhance weight gain and overall performance in birds (Frye, 1995).

5.3 Effect of different Levels of Brewer's Spent Sorghum (Pito Mash) on Feed Intake by Guinea Fowls

Feed intake is a crucial factor in poultry nutrition as it directly influences growth performance, nutrient utilization, and overall production efficiency (Kong & Adeola, 2019). The results from the current study indicate no significant difference in weekly feed intake (FIW) and total feed intake (TOFI) among the treatment groups, despite increasing levels of brewer's spent sorghum (Pito Mash, PM) inclusion in the diets. These findings suggest that Guinea fowl can tolerate PM up to 25 % inclusion level without adverse effects on feed consumption. The total feed intake (TOFI) values ranged between 8293 g (T1, 0% PM) and 9120 g (T4, 25% PM), with no statistically significant differences. Similar patterns were observed in weekly feed intake, indicating that the inclusion of PM did not deter feed consumption in the Guinea fowl. This result is consistent with studies by Adedokun *et al*. (2021) and Melesse *et al*. (2019), which reported that alternative feed ingredients such as brewer's spent sorghum, maize bran, and other agro-industrial by-products do not significantly impact feed intake when properly formulated in poultry diets.

The crude protein (CP) content of Pito Mash (28.02 %) was relatively high compared to conventional cereal grains such as maize, which typically contains 8–10 % CP (NRC, 2021). High protein levels may enhance the palatability of the diet, encouraging consistent feed intake across treatments. Adeyeye *et al*. (2020) reported that poultry species, including Guinea fowls, adjust their feed consumption based on dietary protein content to meet their metabolic requirements. The present findings align with the study by Yakubu *et al*. (2022), which found that replacing maize with alternative protein-rich ingredients did not negatively affect feed consumption in slow-growing poultry species. One notable characteristic of Pito Mash in this study, was its high crude fibre content (7.34 %), which exceeds the levels found in most conventional poultry diets. In theory, excessive dietary fibre may lead to reduced feed intake due to gut fill effects (Melesse *et al*., 2018).

The present study did not show significant reductions in feed consumption, perhaps, due to the supplementation of enzyme in the diets which helped in breaking down the fibre. Studies by Nahashon *et al*. (2018) suggest that Guinea fowl possess a more developed gizzard and caeca, which enable them to digest fibre more efficiently than fast-growing broiler chickens. Despite the high fibre content of PM, Melesse *et al*. (2018) indicated that dietary fibre also enhances gut motility and microbial fermentation in the hindgut, which may contribute to better feed digestion. The ability of Guinea fowl to tolerate fibrous feed ingredients aligns with previous research by Teguia & Beynen (2021), which found that including up to 30 % maize bran in poultry diets did not negatively impact feed intake.

Although no significant differences were observed across treatments, some fluctuations in weekly feed intake (FIW) were recorded. Feed intake tended to be lower in early weeks (FIW1–FIW5) and increased in later weeks (FIW6–FIW12). That pattern is in line with findings by Adedokun *et al*. (2021), who reported that Guinea fowl exhibit gradual increases in feed intake as they age due to higher energy demands for growth and body maintenance. The higher feed intake during weeks 6 to 12 may also be attributed to physiological changes associated with increasing body weight and metabolic rate (Yakubu *et al*., 2022). Similar results were reported by Melesse *et al*. (2019), who observed that indigenous Guinea fowl species show progressive increases in feed intake until maturity, after which feed consumption stabilizes.

Importantly, feed intake directly influences reproductive efficiency in Guinea fowl. Adequate intake of essential nutrients particularly protein, energy, and minerals are critical for the development of reproductive organs, onset of lay, and sustained egg production. High-protein diets enhance follicle development, oviduct growth, and yolk formation (Zanu *et al.,* 2012). Additionally, proper feed consumption supports hormonal regulation, including oestrogen and luteinizing hormone production, which are essential for ovulation and fertility (Oke *et al*., 2017). The consistent feed intake observed across all pito mash (PM) inclusion levels suggests that the birds' nutritional requirements were met without compromise, thereby supporting optimal conditions for reproductive performance. Furthermore, the use of Pito Mash as a sustainable protein source can contribute to cost-effective feeding strategies without negatively impacting reproductive outcomes making it a viable option for smallholder farmers aiming to improve both productivity and reproductive success in Guinea fowl.

5.4 Effect of different Levels of Brewer's Spent Sorghum (Pito Mash) on Water Intake of Guinea Fowl

The present study assessed the impact of incorporating Pito Mash (PM) at 0 %, 15 %, 20 %, and 25 % inclusion levels on weekly and total water intake (TOWT) of Guinea fowl. The results revealed no significant difference in total water intake across treatments, suggesting that the dietary inclusion of PM does not adversely affect water consumption in Guinea fowl. One of the most notable characteristics of PM is its high crude fibre content, which is significantly higher than that of conventional feed ingredients such as maize (NRC, 2021). In poultry, dietary fibre affects water intake by influencing gut motility, digesta viscosity, and osmoregulation (Melesse *et al*., 2019). Generally, high-fibre diets increase water consumption due to the higher water-holding capacity of fibre, which affects digesta movement and faecal moisture content (Sundu *et al*., 2020). Despite PM being rich in fibre, no significant increase in water intake was observed in this study.

The result of this study agrees with those of Yakubu *et al*. (2022), that Guinea fowl possess a well-developed gizzard and caeca, enabling efficient digestion of fibre-rich diets without excessive water intake. The findings suggest that the fibre content of PM did not exceed the tolerance threshold that would trigger excessive water consumption in Guinea fowl.

A similar study by Adeyeye *et al*. (2020) on broiler chickens fed brewer's spent grain reported a moderate increase in water intake at higher inclusion levels (above 30 %), but the differences were not statistically significant. This suggests that poultry species, particularly Guinea fowl, can adapt to fibre-rich diets without experiencing significant physiological stress related to water regulation. Water intake in poultry is influenced by ambient temperature, metabolic rate, and evaporative cooling needs (Yakubu *et al*., 2022). The weekly variations in water intake (WITW1 to WITW12) showed fluctuations, but these were not statistically significant. The highest water intake was recorded in weeks 3, 6, and 12, which could be attributed to increased growth rate, metabolic heat production, and seasonal temperature changes. Weeks 1–5: Water intake was relatively stable, consistent with the early growth phase, where metabolic demands were moderate. Weeks 6–12: Increased water intake was observed, which aligns with findings by Olomu (2019) that suggest older birds require more water due to increased metabolic rate and higher feed consumption.

Adequate water intake is crucial for optimal reproductive performance in poultry, including Guinea fowl. Water plays a key role in nutrient transport, thermoregulation, and metabolic processes that underpin follicle development, ovulation, egg formation, and sperm viability. A Study by El-Deek & Al-Harthi (2004) have shown that water deprivation or inadequate hydration can lead to reduced egg production, poor egg quality, and decreased fertility in birds. The findings from this study therefore imply that incorporating up to 25 % Pito Mash in the diets of Guinea fowl does not negatively impact water intake and, by extension, should not hinder reproductive functions. Moreover, the maintenance of normal water intake levels supports hormonal regulation and physiological balance required for reproductive processes such as laying and hatching.

The tolerance of Guinea fowl to fibre-rich diets without a compensatory increase in water intake is beneficial for reproductive performance, especially in rural and semi-arid settings where water availability may be limited. This makes PM a viable and sustainable feed ingredient that can support both growth and reproductive efficiency in Guinea fowls.

5.5 Effect of different Levels of Brewer's Spent Sorghum (Pito Mash) on Egg Characteristics of Guinea Fowl

The present study showed numerical variations among treatment groups of Egg weight (EW), egg length (EL), and egg number (EN) with the highest values recorded in T4. Previous studies have reported that dietary fibre content from agro-industrial by-products such as maize bran, rice bran and brewer's spent sorghum can influence egg size and production (Oliveira *et al*., 2019). The presence of fibre in Pito Mash diets might have modulated nutrient digestibility and absorption, impacting egg characteristics (Adeyeye *et al*., 2020). The dry shell weight (DSW) and wet shell weight (WSW) showed non-significant variations, but there was a slight increase in shell thickness (EST) in the PM-supplemented diets. The increase in shell quality parameters at higher PM inclusion may be attributed to the supplementation of exogenous enzyme in the PM diet which might have caused the release of calcium and phosphorus in brewer's spent grain (Ravindran, 2021). Adequate calcium and phosphorus levels are critical for shell formation, and studies have shown that dietary fibre sources with balanced mineral profiles can support shell integrity (Suk & Park, 2019).

There was a significant difference observed in yolk colour (YC) and yolk height (YH), with T2 (15 % PM) showing the highest values. The increased yolk pigmentation in PM-based diets may be linked to the presence of xanthophylls and carotenoids in the brewer's spent grain, which enhance yolk colouration (Lokaewmanee *et al*., 2018). The improvements in yolk height could be due to the higher protein and lipid content in Pito

Mash, which enhances yolk formation (Khairi *et al*., 2022). Hen-day egg production (HDEP) showed no significant variation among dietary treatments. However, a slight numerical increase in egg production was observed in PM-based diets. This observation aligns with previous studies where moderate fibre inclusion in layer diets was associated with stable production performance due to enhanced gut health and nutrient retention (Abdel-Moneim *et al*., 2020). Nevertheless, excessive fibre levels beyond optimal thresholds may reduce nutrient digestibility and egg production efficiency (Singh *et al*., 2021). The albumen height (AH) did not differ significantly across treatments, indicating that Pito Mash inclusion did not negatively affect albumen quality. Albumen height is a key indicator of egg freshness and protein quality, and previous research suggests that dietary protein balance is essential for maintaining this trait (Jones *et al*., 2020). The stability of this parameter suggests that Pito Mash, when properly formulated in diets, can sustain egg quality without adverse effects.

5.6 Effect of different Levels of Brewer's Spent Sorghum (Pito Mash) on Fertility of Guinea Fowl

There was no significant effect of the dietary treatments on the fertility of the Guinea fowl, indicating that the inclusion of Pito mash up to 25 % did not adversely affect fertility. The result of this study are consistent with previous studies suggesting that alternative feed ingredients can be incorporated into poultry diets without compromising reproductive performance when properly balanced (Olomu, 2011). For batch 1, the birds on diet T3 (PM 20 %) and T4 (PM 25 %) recorded the highest fertility rates, followed by T2 (PM 15 %) and T1 (PM 0 %). This suggests that moderate to high levels of pito mash may enhance fertility, potentially due to its fibre content and fermentation by-products that can improve gut health and nutrient utilization (Muthusamy *et al*., 2014).

Similarly, in batch 2, the highest fertility level was observed in Guinea fowl on diet T3 (PM 20 %), followed by T2 (PM 15 %), T1 (PM 0 %), and T4 (PM 25 %). This trend may indicate that moderate inclusion levels provide an optimal balance of nutrients, as excessive fibre at higher levels could negatively impact nutrient absorption and reproductive performance (Chaudhary *et al*., 2020). For batch 3, fertility was highest in Guinea fowl on diet T3, followed by T4, T2, and T1. This further supports the hypothesis that a 20 % Pito mash inclusion level may enhance fertility, possibly due to improved gut microbiota activity, as reported in previous studies on alternative feed sources (Jiang *et al*., 2012). For batch 4, Guinea fowl fed the T2 (PM 15 %) diet recorded the highest fertility, followed by T1, T3, and T4. The variability in results across batches suggests that additional factors, such as age, environmental conditions, and genetic variability, may also play a role in fertility outcomes (King'ori, 2011).

5.7 Effect of different Levels of Brewer's Spent Sorghum (Pito Mash) on Hatchability of Guinea Fowl

There was no significant effect of dietary inclusion of brewer's spent grain (pito mash) on hatchability of Guinea fowl eggs across different batches. However, there were variations in hatchability percentages among the treatment groups, with batch 3 (T4, 25 % PM) recording the highest hatchability (53.5 %) and batch 1 (T2, 15 % PM) recording the lowest hatchability (0.0 %). The total hatchability percentage was highest in birds fed T4 (46.9 %) and lowest in T3 (34.9 %). Hatchability is influenced by several factors, including egg quality, incubation conditions, and the nutritional composition of the breeder diet (King'ori, 2011). Nutrient balance, particularly protein, essential fatty acids, and micronutrients, plays a crucial role in embryo viability and successful hatching (Bain *et al*., 2016). The observed trend in hatchability suggests that increasing levels of pito mash beyond 20 % (T3) in the diet may enhance hatchability, likely due to the exogenous enzyme supplementation which improved nutrient digestibility in brewer spent grain diets. A study by Mussatto *et al*. (2006) has shown that brewer's spent grain is rich in proteins, fibre, and fermentable carbohydrates, which may enhance gut health and nutrient absorption in poultry. However, its high fibre content could also limit nutrient utilization when included at excessive levels without enzyme supplementation. This may explain why the hatchability rate in the 25 % pito mash group (T4) was higher than in other groups but still varied among batches, possibly due to differences in egg quality or parental nutrition. Additionally, a study by Józefiak *et al*. (2010) on poultry nutrition suggests that dietary fibre levels must be optimized to avoid potential negative effects on reproductive efficiency and embryonic development. Environmental conditions such as humidity, temperature, and egg turning during incubation are also key determinants of hatchability (Decuypere & Bruggeman, 2007). While the study did not assess incubation conditions directly, variations in hatchability across treatments and batches might be linked to slight differences in incubation parameters.

5.8 Effect of different Levels of Brewer's Spent Sorghum (Pito Mash) on Keets Morphometric characteristics

The results indicate no significant effect of dietary pito mash inclusion on the keets characteristics across all batches. Parameters such as chick body length (CBL), chick body weight (CBW), chick beak length (CBKL), and chick shank length (CSL) remained statistically similar across treatments. These findings suggest that the inclusion of up to 25 % pito mash in the diet did not significantly influence early chick growth and morphological traits. Chick body length (CBL) and chick body weight (CBW) are important indicators of early growth performance, which can be influenced by diet composition, nutrient availability, and feed digestibility (Gous, 2017). The lack of significant variation in these traits suggests that brewer's spent sorghum (pito mash) did not impair growth performance, likely because the dietary protein and energy levels remained within optimal ranges for Guinea fowl development. According to Leeson and Summers (2020), alternative feed ingredients such as agro-industrial by-products can be incorporated into poultry diets without adverse effects, provided that amino acid balance and digestibility are maintained. Chick beak length (CBKL) and chick shank length (CSL) are morphological traits that can be influenced by mineral nutrition, particularly calcium and phosphorus availability (Nahashon *et al*., 2019). The fact that these parameters remained unaffected suggests that the experimental diets provided adequate mineral nutrition. Previous studies on broiler chickens have reported similar findings when unconventional feed ingredients (brewer's spent grains) were used, indicating that growth and skeletal development can remain stable when diets are properly formulated (Olomu, 2011).

5.9 Effect of different Levels of Brewer's Spent Sorghum (Pito Mash) on Haematological Characteristics of Guinea Fowl

The haematological results showed no significant differences in red blood cell (RBC) count, white blood cell (WBC) count, haemoglobin (HGB), haematocrit (HCT), and other related parameters among treatments. These findings suggest that varying levels of brewer's spent sorghum (pito mash) in the diet had no adverse effects on the blood profile of the Guinea fowl. The RBC values obtained across treatments (2.32–2.93 × 10^6/µL) are within the normal range (2.5–3.5 × 10^6/µL) reported by Ayorinde *et al*. (2018) for healthy Guinea fowl. Similarly, the WBC values (91.5–106.2 × 10^3/µL) conformed to the standard reference range (85–110 × 10^3/µL) for Guinea fowls (Ogbe *et* *al*., 2019). This suggests that the immune response of the birds was not compromised by the dietary inclusion of pito mash. Haemoglobin levels (15.0–18.8 g/dL) and haematocrit values (35.6–44.6 %) also fall within the reference ranges of 13.5–20.0 g/dL and 35–50 %, respectively, as reported by Melesse *et al*. (2020). These findings imply that the oxygen-carrying capacity of the blood was maintained, indicating no adverse impact on erythropoiesis or overall bird health. Furthermore, the lack of significant differences in Mean Corpuscular Haemoglobin (MCH), Mean Corpuscular Haemoglobin Concentration (MCHC), and Mean Corpuscular Volume (MCV) suggests that brewer's spent sorghum did not induce anaemia or alter erythrocyte morphology (Teguia *et al*., 2019). The non-significant changes in platelet count (PLT), lymphocytes, and granulocytes indicate that immune function was not negatively affected.

5.10 Effect of different Levels of Brewer's Spent Sorghum (Pito Mash) on Biochemical Characteristics of Guinea Fowl

The biochemical analysis revealed significant differences in albumin (ALBM), gamma-glutamyl transferase (GGT), and urea levels across dietary treatments. Albumin, a key plasma protein responsible for maintaining osmotic pressure and transporting various biomolecules, was significantly elevated at 20 % Pito Mash inclusion level (T3: 19.1 g/L), indicating enhanced protein metabolism or improved utilization of dietary protein (Yakubu *et al.,* 2021). This observed increase may be attributed in part to the inclusion of exogenous enzymes in the diets, which enhance the digestibility of crude protein by breaking down complex fibre structures and anti-nutritional factors commonly found in agro-industrial by-products like brewer's spent sorghum (Olukosi *et al.,* 2010; Onyimonyi *et al.,* 2012). Improved protein digestion increases amino acid absorption, thereby supporting hepatic synthesis of albumin.

According to Oke *et al.* (2020), the albumin values recorded fall within the normal physiological range of 8–20 g/L for Guinea fowl, further suggesting that enzyme supplementation may have optimized nutrient utilization without causing metabolic stress. Similarly, the significant elevation of GGT in T3 (44.3 u/L), an enzyme linked to liver function and amino acid metabolism, might indicate increased hepatic processing of dietary nutrients. The detoxification burden from fibre-rich Pito Mash can stimulate GGT activity; however, the observed values remained within the normal range of 5–50 u/L (Adebayo *et al.,* 2018). This supports the notion that exogenous enzymes possibly facilitated the breakdown of indigestible fractions, reducing liver workload and enhancing overall metabolic efficiency (Adeyemo & Longe, 2012).

The highest urea concentration observed in T3 (3.46 mmol/L) points to heightened protein turnover or nitrogen excretion, a likely consequence of improved amino acid availability due to enzyme action (Oboh *et al*., 2020). Urea, a by-product of protein metabolism, reflects both kidney function and dietary protein intake. The values recorded were within the standard range of 1–4 mmol/L reported by Melesse *et al*. (2020), indicating stable renal function. Overall, the integration of exogenous enzymes appears to have enhanced the bioavailability of nutrients in Pito Mash-based diets, thereby positively influencing metabolic indicators like albumin, GGT, and urea in Guinea fowl.

5.11 Effect of different Levels of Brewer's Spent Sorghum (Pito Mash) on Economic Efficiency of Feed

The highest feed cost per kilogram recorded in the T1 (0 % PM) group reflects the high expense associated with conventional feed ingredients such as maize and soybean meal, which are commonly used in poultry diets (Olukosi *et al.,* 2020). As the inclusion level of pito mash (PM) increased, the feed cost per kilogram decreased, with the lowest cost observed in T4 (25 % PM), agreeing with previous studies that reported significant reductions in feed costs when agro-industrial by-products like brewer's spent sorghum (BSG) were incorporated into poultry diets (Fasuyi & Akindahunsi, 2009; Bello et al., 2022). This cost reduction is attributed to the local availability and low market price of BSG, which is often treated as waste by breweries.

Interestingly, the highest feed cost per egg was recorded in the 25 % PM group, although it was not significantly different from the 20 % PM group. This may suggest that at higher inclusion levels, despite lower cost per kilogram of feed, feed conversion efficiency may decrease, potentially due to limitations in the digestibility of the fibrous content of PM (Khan *et al.,* 2021). This is supported by Sundu *et al.* (2005), who noted that while BSG contains useful protein and fiber, its high non-starch polysaccharide (NSP) content can hinder nutrient absorption unless enzyme supplementation or proper processing is applied.

Conversely, birds on the 0 % PM diet had the lowest feed cost per egg, likely due to higher nutrient density and better feed efficiency of conventional diets. However, the overall total feed cost remained highest in this group, indicating that while feed conversion was more efficient, the high cost of ingredients led to greater overall expenditure, a pattern similarly reported by Oloruntola *et al.* (2016), who compared conventional and BSG-based layer diets.

The decreasing trend in total feed cost from T1 to T4 corresponds with the increasing level of PM inclusion and reaffirms the potential of BSG as a cost-saving alternative feed ingredient. This is particularly relevant in regions where feed accounts for over 70% of total poultry production costs (FAO, 2013). The absence of significant effects on total feed intake and egg output per bird suggests that up to 25 % inclusion of PM does not compromise palatability or laying performance, which agrees with findings by Ani and Okorie (2009), who observed no adverse effects on egg production when BSG replaced part of the energy source in layer diets.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on the results obtained, the following conclusions were drawn.

1. The dietary inclusion of Brewer's spent grain up to 25% supplemented with exogenous enzymes, only nominally increased feed and water intake in Guinea fowls but the changes were not statistically significant.
2. The dietary inclusion of brewer's spent sorghum (Pito mash) at the 20 % level, supplemented with exogenous enzymes, improved yolk colouration and yolk height, but the results obtained were not statistically different from those obtained with the 25% inclusion level.
3. Twenty percent (20 %) inclusion level of brewer's spent sorghum (Pito mash) supplemented with exogenous enzymes marginally improved fertility of the Guinea fowl
4. Twenty five percent (25 %) inclusion level of brewer's spent sorghum (Pito mash) supplemented with exogenous enzymes marginally improved hatchability of the Guinea fowl eggs
5. The dietary treatments had no significant influence on the keets morphometric characteristics such as chick beak length, chick body length, chick body weight, and chick shank length.
6. Guinea fowl can tolerate up to 25 % dietary brewer's spent sorghum, supplemented with exogenous enzyme, without experiencing negative effects on growth performance, haematological, and blood biochemical profile.
7. Dietary inclusion brewer's spent sorghum (Pito mash) up to 25 %, supplemented with exogenous enzymes, reduced feed cost (cost/kg feed), but did not improve feed utilization efficiency (cost/egg).

6.2 Recommendations

Based on the conclusions drawn from the study, the following recommendations were made.

1. Nutrient partitioning between growth and egg production in Guinea fowl should be thoroughly assessed before farmers are encouraged or discouraged from adopting the cheaper pito mash- containing diets.
2. Further research should be conducted to evaluate the effects of exogenous enzymes on feed digestibility.

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