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Characterisation of indigenous helmeted guinea fowls in Nigeria for meat and egg production

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SUMMARY
There is increasing interest in sustainable poultry production in developing economies. This review provides an insight into guinea fowl production in Nigeria as a means of additional high-quality poultry meat and egg production. Under the smallholder scavenging system, flock size of the four investigated plumages (Pearl, Lavender, Black and White) of indigenous helmeted guinea fowl in Nigeria typically ranges from 6 to 9 birds per household, 14-week mean live weight from 917 to 975 g, dressed weight at this age from 700 to 737 g and dressing percentage from 74 to 76%. Under the backyard system of production, mean egg number is typically about 80 eggs per hen/annum while under intensive management it can be up to 147 eggs per hen/annum and egg weight from 29 to 38 g. Under smallholder conditions, hatchability of fertile eggs can range from 70 to 86% while under improved housing and rearing conditions it can be as high as 89%. The present information could be exploited in formulating appropriate management strategies and breeding decisions for sustainable production of hybrid improved guinea fowls, thereby contributing to food security in Nigeria.

KEYWORDS
Guinea fowl; meat yield; eggs; improvement; Nigeria

Introduction

Poultry breeding is gaining worldwide recognition as the fastest-growing agricultural subsector, especially in developing countries (Mottet and Tempio 2017). Indigenous poultry accounts for more than 80% of poultry that are reared in backyard flocks in some developing countries such as Ghana, Nigeria, Ivory Coast, Senegal, Cameroon, Zambia, LAO PDR and Myanmar (Guèye 1998; NAPRI 2005; Henning *et al.* 2005; Pym *et al.* 2006; Yakubu 2013; FAO 2014; Yakubu *et al.* 2020). The world poultry meat output in 2019 was estimated at

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133.6 million tons (carcase weight equivalent), with a 2.4% growth rate projected for year 2020 (FAO 2020). The helmeted Guinea fowl (*Numida meleagris*) is a widespread and abundant terrestrial game bird. It is found in the wild and in a wide range of sub-Saharan Africa, with open country vegetation types [This is where between 70–60% and 20–10% of a defined area is covered by *Trees* and *Shrubs*, the crowns (the total of an individual plant's aboveground parts, including stems, leaves and reproductive structures) are usually not interlocking] (Geldenhuys *et al.* 2013; Jajere *et al.* 2018). However, it is gradually being domesticated alongside other poultry species, especially chickens. There are varieties of these birds characterised by varying plumage colours (Houndonougbo *et al.* 2017a; Traoré *et al.* 2018). Guinea fowl products are a ready source of animal protein (meat and eggs) and income, as well as a source of manure for the enrichment of the soil. These contribute reliably to food security (regular availability of good quality food, low food costs, balanced nutrition and food safety) and livelihood of the rural dwellers (Xuan *et al.* 2015; Macharia *et al.* 2017; Aryee *et al.* 2019; Souleymane *et al.* 2019; Krunt *et al.* 2021), who are the main custodians of these birds.

One of the best alternatives for sustainable poultry production by the rural dwellers in Nigeria is guinea fowl production (Yakubu *et al.* 2014). Guinea fowl population (16,976,907 birds) in Nigeria ranked second after chicken (101,676,710 birds) (NBS-FMARD 2012). The lean meat with its characteristic flavour is relished by the local population in Nigeria. The increasing interest in guinea fowl in Nigeria is as a result of the fact that they are vigorous, adapt well to local climatic conditions and possess the ability to evade or protect themselves from predators. They can also control ticks and other pests and are more disease resistant with greater scavenging capacity for grains and insects than their chicken counterparts (Nwagu and Alawa 1995; Ayorinde 1999; Ikani and Dafwang 2004; Solomon *et al.* 2013). Guinea fowl's meat also contains more dry matter and protein and less fat than chickens (Musundire *et al.* 2017).

Egg production in domestic guinea fowl reaches its peak in the rainy season (Bernacki *et al.* 2013b; Kouassi *et al.* 2019). The hen starts laying eggs at 28–32 weeks of age depending on the breed, husbandry, and environment (Hien 2002). Egg production falls within a wide range – from 70 to 220 eggs and depends greatly on breeding level and rearing system (Ivanova *et al.* 2020). The guinea fowl egg has a distinctive pyriform shape but it is pointed at one end and rounded at the other. The average length of the egg is 4.78 cm while the diameter is 3.80 cm (Ayorinde 1987a). The egg has high biological value in terms of protein, phospholipid, essential amino acids, and vitamins for the human diet (Oluwafemi and Udeh 2016; Kouassi *et al.* 2020). Guinea fowl is a good alternative to chicken in terms of eggshell quality and egg safety (Krunt *et al.* 2021). Due to the fact that guinea fowl is easily stressed, an important step in the development of its production on both industrial and local scales is artificial incubation of the eggs (Araújo *et al.* 2019).

It has been reported that guinea fowl production has an unexploited potential for industrial growth, making it more valuable than at present in developing countries (Fajemilehin 2010; Moreki *et al.* 2010; Abdul-Rahman and Adu 2017). An important goal of the 2030 Agenda for Sustainable Development is to ensure that small producers and the rural poor can improve productivity, increase and diversify income and improve resilience, while preserving the natural resource base. The programme which is part of the Sustainable Development Goals (SDGs) was developed by FAO (2019) and is global in scope (Africa: Cabo Verde, Ethiopia, Ghana, Kenya, the Niger, Nigeria, Rwanda, Senegal, the United Republic of Tanzania, Togo and Zambia Asia: Afghanistan, Bangladesh, Cambodia, Nepal, Pakistan and Sri Lanka Eastern

Europe and Central Asia: Albania, Armenia, Azerbaijan, Belarus, Georgia, Kyrgyzstan, Republic of Moldova, Turkey and Ukraine Latin America and Caribbean: Costa Rica, Cuba and El Salvador). The objective is to enable partner countries to produce and use more comprehensive data on SDG indicators, allowing them to design effective evidence-based national strategies to ensure that relevant SDG targets are met. In this context, there is the need for substantial genetic improvement of guinea fowls in terms of increased productivity and higher reproduction rates to meet the increasing demand. This study is a review of typical husbandry and of the phenotypic, physiological, biochemical and molecular genetic characteristics of these birds, with an aim to define the potential for genetic improvement of indigenous helmeted guinea fowls in Nigeria.

Classification of indigenous helmeted guinea fowls in Nigeria

The helmeted guinea fowl (*Numida meleagris*) belongs to the Galliformes order and the Numididae family. They are indigenous to West Africa North of the Equatorial forest. The name 'Guinea' arose from the belief that the birds originated from the coast of Guinea in West Africa (Teye and Gyawu 2002). However, archaeozoological and artistic evidence suggests that the domestication of this species might have occurred about 2,000 years BP in Mali and Sudan (Vignal *et al.* 2019).

In Nigeria, the Guinea fowl is a common game bird found mainly in the Savanna region of Northern Nigeria (NBS-FMARD 2012; Onunkwo and Okoro 2015). Among the domestic types in Nigeria, which the peasant farmers have long identified and given local names based on their colourations which are Pearl (Sake), Lavender (Hurudu), Black (Angulu) and White (Faren Zabi) (Ikani and Dafwang 2004). According to Ikani and Dafwang (2004), the Pearl variety is the most common and probably the first to be developed from the Wild West African birds.

Qualitative and quantitative traits

Qualitative traits are useful to farmers and breeders for identification and classification of guinea fowl and to meet consumer preferences for specific phenotypic traits (Agbolosu *et al.* 2014). The wild guinea fowl is phenotypically characterised by blue-grey feathers with white dots. However, there are several variations of this colour pattern including the lighter (Lavender) and the darker or melanic (purple) forms. The Lavender colouration has been associated with the lilac mutation of the melanophilin (MLPH) locus (Burke *et al.* 2007). Also, in a study on melanism in the guinea fowl (*Numida meleagris*), Vidal *et al.* (2010) reported that the black phenotype is caused by a deletion and the loss of one amino acid (p.Phe256del) in the melanocortin 1 receptor (MC1R) gene.

There are no pure genotypes of guinea fowl in Nigeria as the birds have not been bred selectively. However, there are different colour patterns of mixed guinea fowls in Nigeria. They include the Pearl, Lavender, Black and White variations or patterns (Fajemilehin 2010; Ebegbulem and Asuquo 2018). Umosen *et al.* (2008) reported that wattle shape and size observed in heavier adult males appeared elongated, large and folded upwards at their margins and were also inclined at an angle to the axis of the upper jaw when compared to those of the females. Long, slightly curved caudally and sharply pointed (males) and short thin and almost straight (female) helmets have been reported (Adedeji *et al.* 1994). The same authors reported that filoplumes were longer and more numerous on the cranial one-third of the dorsal part of the neck of males, whereas they were shorter and very few in females. In a study to establish the degree of relatedness of qualitative traits in guinea fowls, Abazuh *et al.* (2019) observed that skin, shank, eyes and helmet colours including feather morphology formed a sub cluster, while beak colour stood apart in the phylogenetic relationship tree.

Phenotypic characterisation of birds is the first step in designing appropriate breeding and selection programmes. Yakubu (2013) suggested that knowledge of body size and skeletal dimensions in poultry could be used to determine genetic differences between populations. Fajemilehin (2010) found in 28-week-old grey-breasted helmeted guinea fowl of Pearl, Ash (Lavender) and Black in Nigeria mean body weights of (980.15, 970.43 and 950.78 g), body length (41.68, 41.81 and 41.75 cm), body girth (30.47, 30.00 and 30.10 cm), wing length (22.96, 23.13 and 22.97 cm), keel length (15.15, 15.12 and 14.92 cm), drumstick length (13.89, 13.68 and 13.66 cm) and shank length (9.03, 8.85 and 8.93 cm), respectively. The differences observed in body weight could be attributed to its sensitivity to the environment compared to other body traits.

Under intensive management system, Oke *et al.* (2014) compared body traits of Pearl Male (PL/PL) x Pearl female (PL/PL) and Lavender Male (La/La) x Lavender female (La/La) matings. The 8-week parameters for PL/PL and La/La unsexed birds were reported as follows: body weight (380.0 ± 0.01 and 375.01 ± 0.0 g; $P < 0.05$), breast length (6.90 ± 0.04 and 4.79 ± 0.0 cm; $P < 0.05$), breast girth (21.02 ± 0.03 and 20.70 ± 0.05 cm; $P < 0.05$), thigh length (9.13 ± 0.03 and 9.04 ± 0.05 cm; $P > 0.05$) and shank length (4.13 ± 0.05 and 4.08 ± 0.04 cm; $P > 0.05$), respectively. However, Ebegbulem and Asuquo (2018) gave 8-week values of 464.91, 458.99 and 454.05 g for PL/PL, Black male x Black female (BL/BL) and BL/PL, respectively. This is an indication that these birds are of small body size. There is need, therefore, for genetic improvement of the stock.

Physiological characterisation

Blood parameters of helmeted guinea fowl can be used for clinical evaluation and can also serve as markers for selection of breeding stock (Penkov *et al.* 2019). Adedibu *et al.* (2014) suggested that packed cell volume (PCV; 35.71–37.14%), haemoglobin (Hb; 13.61–14.19 g/dL) and mean corpuscular haemoglobin concentration (MCHC; 33.92–40.63 g/dL) could be used to identify genetic variation to be exploited for guinea fowl breeding in Nigeria. However, these parameters were affected by strain, sex and system of production. Similarly, Okoro *et al.* (2011) reported that sex and production system (extensive and battery cage) had significant effects on haematological and serum biochemical indices of helmeted guinea fowls. Using haematological parameters, the males had higher PCV (41.33 vs. 31.67%), Hb (13.73 vs. 10.60 g/dl) and red blood cell (RBC) (1.45 vs. 0.80 $x10^{12}$/L), relative to their female counterparts and recorded higher values for mean corpuscular volume (MCV) (412.17 vs. 302.83 FL) and mean corpuscular haemoglobin (MCH) (139.50 vs. 101.17 pg). There were no significant differences in the values of white blood cell count (WBC), MCHC, neutrophils, lymphocytes, monocytes, eosinophils and basophils. The higher values recorded for males were attributed to their increased courting around the females during the breeding season, which was the period of blood collection in the study. Production system only significantly affected WBC ($x10^9$/L), with higher value recorded for extensive system compared to the battery cage (1.73 vs. 1.28). In the evaluation of the serum biochemical indices, males had higher chloride (100.17 vs.

88.50 Mmol/l) and serum glutamate-oxaloacetate transaminase SGOT (IU/L) – alanine transaminase (ALT) (27.33 versus 16.67), while females had higher glucose (257.00 vs. 185.50 mg/dl). There were no significant differences in Na^+, bicarbonate, Ca^{2+}, cholesterol, total protein, albumin, globulin, total bilirubin, conjugated bilirubin, serum glutamate-pyruvate transaminase (SGPT) (IU/L) – amino transaminase (AST) and alkaline phosphate. The effect of production system was only significantly evident in SGPT (IU/L) – (AST), with higher value recorded for the extensive system (Okoro *et al.* 2011). Sex differences in blood parameters had also been reported in guinea fowls in North-Western Nigeria (Uko and Ataja 1996). In these authors' findings, male guinea fowls had greater MCV than females (104.23 vs. 98.5 um^3). Conversely, female guinea fowls possessed higher MCHC (31.5 vs. 20.7%) and PLT counts (24.5 vs. 23.9 $\times 10^3/mm^3$) than males. These values are at variance with those obtained by Okoro *et al.* (2011). However, the observed variations could be as a result of the source of the birds. While those of the former were sourced in the Central Market, birds of the later were reared extensively and in battery cage. This may affect the physiological status of the birds. Based on some observed variations in serum biochemical indices, the adaptability and performance of birds can be improved. Serum proteins, enzymes and bilirubin have been established as genetic markers in farm animals (Pagot 1992). Selection of males can also be done using enzymes to improve fertility and or hatchability of females (Orunmuyi *et al.* 2007).

Blood protein polymorphism has been extensively used for genetic differentiation among populations, phylogenetic and evolutionary studies including biosystematics. Oguntunji *et al.* (2014) characterised indigenous helmeted guinea fowl of Nigeria, using four blood protein markers-namely Hb, carbonic anhydrase (CA), transferrin (Tf) and albumin (Alb). All the four protein markers were reported to be polymorphic. The corresponding genotypes were AA, AB and BB (Hb); FF, FS and SS (CA), AA, AB and BB (Tf) and AA, AB and BB (Alb). The respective gene frequencies were Hb A and B, 0.35 and 0.65; CA F and S, 0.93 and 0.07; Tf A and B, 0.53 and 0.47 and Alb A and B, 0.53 and 0.47. Average estimated genetic diversity (heterozygosity) across the genetic systems was reported to be moderate (0.40).

In a related study in four guinea fowl varieties in Nigeria, Fajemilehin (2014) reported the presence of two Hb genotypes (AA and AB) in each variety. Hb A and B gene frequencies were 0.96 and 0.04 (Pearl), 0.95 and 0.05 (Lavender), 0.96 and 0.04 (Black) and 0.95 and 0.05 (White). The Tf and CA were monomorphic in all the varieties. The dendogram clustered all the varieties as two homogenous groups. The Chi-squared (χ^2) values showed departure from Hardy-Weinberg's Equilibrium in all the four varieties. The highest genetic distance was observed between Pearl and Black (70.7) while the least was between White and Black (5.4).

Prevalence of F, A and B genes suggests their relevance to the survival and adaptability of the birds to their natural habitat. It is possible that the balance between the adaptive values of different gene types under varying environments is responsible for gene maintenance. Generally, the extreme temperatures (acute cold or sultry heats), the extreme forms of relief (dessert or mountain) or precarious nutrition and breeding conditions favour the fixing of the alleles F, A and B (Yakubu and Aya 2012; Oguntunji *et al.* 2014). In a related study in chickens, Orunmuyi *et al.* (2020) submitted that the AA had significantly higher body weight (g) than AB and BB (1296.43 g, 1029.59 g, and 884.46 g, respectively). This is an indication that the polymorphic forms of haemoglobin can be used for body weight selection. However, this assertion needs to be verified in larger samples over a long period of time.

There is dearth of information on thermo-physiological parameters of helmeted guinea fowl in Nigeria. However, Oke *et al.* (2015) reported that rectal temperature was significantly higher in birds in battery cages compared to those on deep litter and free range (42.21 vs. 40.84 and 40.27). Respiratory rate was also higher among birds in cages (74.40) followed by those on free range (61.10) while the least was recorded for birds on deep litter (41.60). There was no significant difference in the values of heart rate for birds in cages (168.0), in free range (165.2) and on deep litter (142.40). Guinea fowls appear to be more sensitive to temperature than other commercial poultry (Hughes 1986). The higher temperature of birds in cages may be attributed to lower air velocities. Ruzal *et al.* (2011) observed that the surface temperature of laying birds exposed to air velocities of 0.5, 1.5, and 2 m/s at 35°C was higher than that at 3 m/s. Therefore, increasing the volume and velocity of air moving over birds will enhance heat loss in birds. The mechanism of such heat loss includes convection, removal of heat trapped within the poultry house, and reduction of the effect of high humidity on evaporative cooling (Daghir 2008).

Production systems

Guinea fowl farmers are basically involved in three major production systems in Nigeria (Yakubu *et al.* 2014). These include the 1) Extensive System (Free range): Here the birds are allowed to roam freely within the surroundings without any confinement. They scavenge for food and can receive little or no supplementary grain. There is no health control programme; 2) Semi-intensive System (Partial confinement): The birds here can have partial housing, especially for the night. They are given supplementary feeds with occasional medications; 3) Intensive System (Complete enclosure): The birds are under intensive management in modern housing and are fed with commercial feeds and subjected to standard and regular health and vaccination programmes including biosecurity measures. Under the intensive system, birds are reared in a deep litter or kept in battery cages (Alli *et al.* 2016a). These authors further reported that point of lay birds raised in cages had better total weight gain (774 vs. 651 g) from 4 to 20 weeks of age compared to those raised in a deep litter. While total feed intake from 4 to 20 weeks of age was higher for birds raised on deep litter (5602 vs. 5119 g), feed conversion ratio from 4 to 20 weeks of age was better in birds raised in cages (7 vs. 9). The higher feed intake by birds in a deep litter can be attributed to their ability to move around thereby dissipating more energy compared to their caged counterparts. Birds in cages are known to experience cage fatigue. For better feed conversion ratio performance therefore, Nahashon *et al.* (2006) recommended cage density of 1 bird/cage (1,394 cm^2/bird). There was no significant difference in terms of mortality between birds in a deep litter and those kept in battery cage (Alli *et al.* 2016a). Keet mortality of the range 13.3–35.6% was obtained in a deep litter system by Twumasi *et al.* (2020). Mohammed and Dei (2017) found higher mortality (81.9%) in birds using traditional brooding (i.e. mother hen) and managed under the semi-intensive system in comparison with 15% of those subjected to improved brooding (i.e. confined in raised wire floor cages covered with black polythene sheet) and birds managed under the intensive system. In another study, Saina (2005) obtained higher mortality in guinea fowl reared under the semi-intensive (16.7%) compared to the intensive system (3.3%). Poor housing (buildings or structures with inadequate facilities where welfare and health of birds are compromised) has been identified as a major cause of poor growth performance, reduced egg production and high mortality in commercial guinea fowl production in Nigeria (Ebegbulem 2018).

Flock size under backyard systems of production ranged from 6.29 to 9.94 with cock: hen ratio of 1:1.7 to 1.46. Average effective population size (Ne) and the rate of inbreeding (ΔF) values of 493 and 0.00101 (0.1%) indicate that the present guinea fowl populations are not at the brink of extinction. This assertion may only be specific for the study period when the above values were obtained, which is subject to change from one generation to another (Yakubu *et al.* 2014). However, Nwagu and Alawa (1995) and Obike *et al.* (2011) reported that a sex ratio of 1:4 could lead to good fertility under intensive system of production in Nigeria. In a related study in Ghana, Abdul-Rahman and Adu (2017) reported that flock size of most farmers ranged from 5 to 25 animals, while in Cameroun, it ranged from 5 to 10 adult birds (Massawa *et al.* 2020).

In a study carried out by Yakubu *et al.* (2014), Newcastle disease was the most prevalent disease (63.2%) affecting guinea fowl in Nigeria, followed by Coccidiosis (18%), Helminthosis (10.3%) and Ectoparasites (8.55%). In Ghana, results showed 24.2% (37/153) of guinea fowls tested positive for ND antibodies (Boakye *et al.* 2016). Solomon *et al.* (2013) observed virulent Newcastle disease virus in guinea fowls with high sequence similarity (99.3–100%) between viruses in this study with strains reported for Niger and Cameroun. This gives insights into the ecology of virulent Newcastle disease viruses. Therefore, there is the possibility of some cross-border movement and trade in live poultry. Wing drooping (89.3%), diarrhoea (67.4%) and drowsiness (64.7%) were the main clinical symptoms of diseases observed in Togo (Soara *et al.* 2020). Disease treatment involves the use of conventional veterinary products and ethno-veterinary plant products as drugs (Yakubu *et al.* 2014; Soara *et al.* 2020). Keet mortality is higher under smallholder settings in Nigeria. Yakubu *et al.* (2014) obtained 16.4% keet deaths/flock. However, in Burkina Faso, 33.1–68.9% of young birds were lost between hatching and 4 weeks of age (Sanfo *et al.* 2007) while a range of 10 to 40% were obtained in Zimbabwe (Zvakare *et al.* 2018).

Disease, which accounts for more than half of mortality cases, is the most frequently reported cause of bird losses in village and other free range poultry (Otte *et al.* 2021). The poor condition of guinea fowl house may also expose the birds to risk agents such as predators. In the free-range production system, predators such as snakes, wild cats, dogs, and hawks constitute a serious mortality problem especially to the keets (Ebegbulem 2018). Birds poorly housed are also prone to diseases and pathogens (Kouassi *et al.* 2019). In this way, the provision of suitable houses with adequate space for exercise will go a long way in curtailing mortality problem. In order to improve the survival rate of birds, community-based poultry health management (CBM) may be adopted. This strategy involves investment by governments and development agencies in the dissemination of information regarding best husbandry practices to poultry interest groups (Sodjinou *et al.* 2012).

Nutrition

Nutrition is an important factor in the growth and development of poultry. Smallholder guinea fowl farmers rely greatly on available kitchen waste, millet, corn, sorghum, rice, bran (energy sources), green fodder, sprouted grains and fruits (vitamin sources), salt and pounded shells (mineral sources), and teres, legumes and soybean draff (protein sources) as the main dietary constituents of scavenging birds (Houndonougbo *et al.* 2017a). In a study in the Kainji Lake Basin Area of Nigeria on the feed of the grey-breasted helmeted guinea-fowl, crop contents included grass seeds (35 ± 5.5%), insects (21.6 ± 5.1%), Cyperus bulbs (17.4 ± 5.1%), fruits of dicotyledons (11.3 ± 3.0%), leaves and other vegetable matter (9.9 ± 2.8%), pebbles (1.9 ± 0.8%) and water moisture ingested with feed (3%) (Ayeni 2008). The author opined that availability of feed may be influenced by seasonality, annual bush burning and flood level control along the draw-down areas of the lake. The effect of feeding experimental diets varying in energy (2500, 2600 and 2700 kcal/kg) and protein (15%, 16% and 17% CP) levels and their interaction on the carcase characteristics of guinea fowl has also been documented (Odukwe *et al.* 2017). The birds were 3 weeks old at the start of the experiment, while carcase data were collected when the birds were 8 weeks of age. The best interaction effect in terms of carcase performance was recorded in the diet containing 2700 kcal/kg ME x 15% CP. The birds here were better in live weight (LW), wing weight (WW), breast weight (BW) and back weight (BWT) (Table 1).

In contrast, Amoah *et al.* (2018) recommended 24% CP and 12.5 MJ ME/kg for keets during the first 8 weeks of growth in Ghana. Okeke *et al.* (1986) formulated guinea fowl diets of five calcium levels (1.20, 1.95, 2.70, 3.45 and 4.20%) containing 0.6% fixed phosphorus and 18% CP. The diets were fed to 110 guinea fowl hens in early lay selected randomly from a flock and allocated to ten groups. Thirty male guinea fowls were also randomly allocated in groups of three to each of the ten deep litter pens. Data collection lasted eleven weeks. They concluded that at fixed phosphorus level of 0.6%, the performance of the birds in Nigeria is remarkable if the calcium level is 2.70% of diet dry matter.

Unlike chickens, there are no commercial intensive production (units) involving formulated diets of guinea fowl in Nigeria. Farmers usually resort to feeding their guinea fowls with commercial broiler chicken and layers diets. This may partly be due to dearth of knowledge on comprehensive nutrient requirements of the different categories of guinea fowls in the country. The less research efforts on the nutrition of guinea fowl may due to its competition with chickens. Since the poultry industry requires investments to be turned to profits within the shortest possible time, more attention is given to chicken production. However, this trend needs to be addressed as more consumers show interest in guinea fowls. Moreki and Seabo (2012) and Camas-Robles *et al.* (2020) also stated that guinea fowls were fed with commercial chicken feed in Botswana and Brazil, respectively. However, in countries such as Australia, France and Italy, formulated rations for Guinea fowls are available from commercial feed millers (GALOR 1985; Embury 2001). For optimum production, breeding objectives should integrate feed sources in addition to other environmental factors (Tixier-Boichard 2020).

Production

Meat production

One of the most important economic indices of guinea fowl is its potential to produce meat of a good quality. Live weight (LW) (0–14 weeks of age) before slaughtering (917–975 g), slaughter weight (weight after bleeding) (827–887 g) and dressed weight (700–737 g) have been reported in helmeted guinea fowls in Nigeria (Ebegbulem and Asuquo 2018) (Table 2).

Table 1. Effect of interaction between protein and energy levels on carcase characteristics of helmeted guinea fowls.

Parameter	Energy x protein interaction									SE M
	2500 kcal/ kg × 15% C P	2500 kcal/ kg × 16% C P	2500 kcal/ kg × 17% C P	2600 kcal/ kg × 15% C P	2600 kcal/ kg × 16% C P	2600 kcal/ kg × 17% C P	2700 kcal/ kg × 15% C P	2700 kcal/ kg × 16% C P	2700 kcal/ kg × 17% C P	
LW (kg/b)	1.17^{c}	1.25^{abc}	1.20^{bc}	1.20^{bc}	1.40^{b}	1.40^{b}	1.48^{a}	1.23^{abc}	1.47^{a}	0.02
DW (g/b)	608.33	625.00	666.67	725.00	733.33	693.33	683.33	641.67	708.33	10.80
TW (g/b)	12.43	12.19	11.58	10.61	10.71	11.24	12.38	12.60	12.24	1.02
WW (g/b)	17.55^{bcd}	19.05^{bcd}	16.25^{ad}	14.04^{d}	21.49^{bc}	20.42^{bcd}	28.77^{a}	18.70^{bcd}	23.56^{ab}	3.10
NW (g/b)	4.11	5.51	5.14	4.52	5.65	5.89	6.73	5.10	6.58	0.60
DS (g/b)	12.50	12.23	11.58	10.89	10.97	11.19	11.69	11.88	11.76	0.96
BW (g/b)	21.33^{cd}	18.48^{de}	21.53^{cd}	15.05^{e}	21.79^{cd}	24.67^{bc}	31.17^{a}	22.64^{cd}	28.47^{ab}	3.12
BWT (g/b)	13.95^{b}	14.60^{b}	15.14^{b}	13.89^{b}	16.30^{b}	17.59^{ab}	22.66^{a}	16.13^{b}	19.09^{ab}	1.67

LW = live weight, DW = dressed weight, TW = thigh weight, WW = wing weight, NW = neck weight, DS = drumstick, BW = breast weight, BWT = back weight
Means within the rows with different superscripts are significantly different at $P > 0.05$
SEM = standard error of the mean.

Table 2. Mean carcase characteristics of three genotypes of guinea fowl (0–14 weeks).

	Genotype			
Parameters	P x P	B x B	B x P	SEM
Live weight (g)*	975	917	950	6.91
Slaughter weight (g)*	887	827	857	17.34
Dressed weight (g)	737	700	708	11.11
Dressing percent (%)	75.2	75.8	74.5	0.52

P x P = a cross between Pearl male x Pearl female; B x B = a cross between Black male and Black female; B x P = a cross between Black male x Pearl female.
Means across the rows did not differ significantly at P > 0.05; SEM = standard error of the mean.
* At point of slaughter.

The dressing percentages were 75.8, 75.2 and 74.5 for the Black male x Black female (B x B), Pearl male x Pearl Female (P x P) and Black male x Pearl female (B x P) genotypes, respectively. The live weight result (14-week-old birds) is in consonance with the submission of Fajemilehin (2010) where there was no significant difference between Pearl and Black (599.24 vs. 572.54 g). However, under tropical conditions of Nigeria, Pearl had significant higher values than Lavender (Ash or Grey) in terms of live weight (400 vs. 317 g), slaughter weight (349 vs. 273 g), shank weight (15.50 vs. 8.60 g), thigh weight (25.80 vs. 18.78 g), breast weight (51.53 vs. 45.51 g), drum stick (20.50 vs. 17.50 g), wing weight (33.4 vs. 29.50 g), back (39.80 vs. 31.50 g) and neck (9.95 vs. 8.60 g) (Oke *et al.* 2014). Slaughter weight of the range of 812–890 g has been reported for five local guinea fowl varieties (Common, Bonaparte, Grey, White and Black) in Benin Republic (Houndonougbo *et al.* 2017b). In another study, Koné *et al.* (2020) obtained greater carcase weight (1037 vs 786 g) and carcase yield (79.8 vs. 78.6%) in French Galor guinea fowl compared to the African guinea fowl at 16 weeks of age in a deep litter system. The dressed weight reported for Nigerian guinea fowl is higher than the 638.7 cold dressed weight (g/kg BW) obtained in Zimbabwe (Musundire *et al.* 2018). In another study, the 14-week live weight, slaughter weight and dressed weight of the Nigerian local guinea fowl (Ebegbulem and Asuquo 2018) are lower than the 1.5 kg, 1.4 kg and 1.0 kg reported for the same three parameters in 12-week-old guinea fowl of the exotic 'Golden Sovereign' broiler strain under tropical conditions of Nigeria (Agwunobi and Ekpenyong 1990). Similarly, the 14-week live weight values reported for Nigerian local guinea fowl are lower than the 1054 g and 1081 g reported for White and Pearl guinea fowl under temperate conditions (Bernacki *et al.* 2013a). They are also smaller in size compared to 16-week old French Galor guinea fowl with a final body weight of 1.3 kg (Koné *et al.* 2020). The differences could be as a result of genetics and varying environmental conditions. The European breeds or strains are products of many years of selective and genomic breeding. This confers their superiority over their African counterparts that are largely unselected. Therefore, it is quite possible for crosses involving local and exotic strains to yield better results.

Egg production

Egg production in guinea fowl peaks in the rainy season (April–October) (Nwagu and Alawa 1995) and low in the wild (12–20 eggs/bird/), but domesticated stock start laying at 28–32 weeks of age, yielding 60–90 eggs per reproductive female per season (Ayorinde 1991a). Under the backyard system of production, Yakubu *et al.* (2014) reported overall average total egg production of 79 eggs per annum. This value is comparable to the range of 41–114 egg/hen reported in Ghana (Avornyo *et al.* 2016) but lower than the 89 ± 50 eggs per annum reported by Kusina *et al.* (2012) in Zimbabwe. In another study, Bernacki *et al.* (2013b) reported an average production of 87 eggs and 90 eggs by White and Grey guinea fowl, respectively, reared under temperate conditions.

Onunkwo and Okoro (2015) studied the egg production performance of Pearl, Lavender and Black helmeted guinea fowl under humid tropical conditions in Nigeria. Egg collection data started when the birds were 28 weeks old and lasted 18 weeks. An average of 147 eggs per production cycle was recorded. Pearl and Lavender birds produced more eggs (162.7 and 156.8, respectively) than their Black counterparts (120.7). Pearl and Lavender varieties also had higher hen day egg production of 25.7 and 25.8%, respectively, compared to the Black variety (21.3%). However, there was no significant difference in their feed per dozen egg production (g) of 4652.7, 4672.4 and 4641.5 for Black, Lavender and Pearl, respectively.

The egg production characteristics of Pearl helmeted guinea fowl from age 26 to 52 weeks were reported by Oke *et al.* (2004). These authors observed that average body weight at first egg was 1163 ± 85.02 g while the mature body weight, when the highest egg production was obtained, ranged from 1274 ± 13 g to 1288 ± 16 g. The average egg number per hen/week ranged from 1.5 to 5.95, while mean egg weight ranged from 29.1 to 38.4 g. The body weights of the hens suggest that indigenous stock are closer to a light egg-type laying breed. Obike *et al.* (2011) reported that Pearl birds had lower albumen diameter than their Black counterparts (61.27 ± 2.02 mm vs. 66.97 ± 1.20 mm). The body weights at first egg obtained in that study are similar to those reported by Alli *et al.* (2016b) for both systems: cage (1015 g) and deep litter (1029 g). However, under improved genetic and environmental conditions, there is room for increase in the number of eggs produced by guinea fowl hens.

Reproduction

Guinea fowl production has the potential to contribute meaningfully to the food security of the nation. That contribution depends upon the reproductive potential of the birds (Yamak *et al.* 2016). Akilarasan *et al.* (2017) reported that fertility and hatchability are major impediments to Guinea fowl production. In an experiment involving Pearl guinea fowls in Nigeria, Ayorinde (1989) reported that once or twice weekly insemination with 0.10 ml diluted semen gives improved egg fertility compared to insemination with 0.5 ml diluted semen., Hudson *et al.* (2017) reported that for optimum fertility and hatchability in guinea fowl, insemination of 75 million spermatozoa diluted in Beltsville Poultry Semen Extender (BPSE) once in 4 d and 100 million spermatozoa diluted in BPSE or Instruments for Veterinary Medicine (IMV) once in 5 d coupled with vaginal douching is recommended. Ayorinde *et al.* (1989) reported average egg fertility in Ash, Black, Pearl and White birds over three production years as 50.0, 51.8, 52.9 and 0% while mean hatchability of fertile eggs (%) was 81.1, 89.3 and 87.1, respectively. Also, Yakubu *et al.* (2019) recorded in the Pearl strain mean fertility and hatchability of 56.0% and 73%, respectively. In Ghana, fertility rate of the guinea fowl was 56.9%, whereas the hatching rate was 82.2% under artificial incubation (Adu-Aboagye *et al.* 2020). In a related study, Akilarasan *et al.* (2017) reported fertility and fertile hatchability values of 67.88 and 86.22%, respectively, under tropical conditions of India.

Under smallholder conditions in Nigeria, Yakubu *et al.* (2014) reported hatchability values of fertile eggs of 70.1, 71.4 and 72.2%. Hatchability of 86.3% had also been recorded when guinea fowl eggs were hatched using the Nigerian local chicken hens (Obun 2004). These values are comparable to the 72% hatching rate in Ivory Coast (Koné *et al.* 2018) but higher than the 63.8% observed in Zimbabwe (Zvakare *et al.* 2018).

Certain factors affect the fertility and hatchability of guinea fowl eggs in Nigeria (Nwagu 1997). These include genetic constitution and a wide range of environmental factors such as severe nutritional deficiencies, certain drugs, feed contamination with pesticides and mycotoxins, egg handling, storage conditions, fumigation procedures, incubation temperature, humidity and ventilation rates. Collection of eggs from the wild can also affect fertility and hatchability (Ayanwale and Kudu 2001; Yakubu *et al.* 2014). Ayorinde (1987b) reported that high temperature and low relative humidity significantly reduced hatchability. Hatchability was carried out after 0–21 days of storage at room temperature (21.11°C) or air-conditioned storage (12.78°C). Eggs stored broad-end-up or sideways had a significantly better chance of hatching than those stored small-end-up. Hatchability of guinea fowl eggs was higher in the late rainy and early dry seasons compared to the early rainy season (Yakubu *et al.* (2019).

Sexing

Accurate identification of sex in birds is important for the management and conservation of avian wildlife in several ways, namely in the development of population, behavioural and ecological studies as well as in the improvement of *ex situ* captive breeding programmes (Morinha *et al.* 2012). This is particularly so in bird species that are monomorphic (guinea fowl inclusive) or only sexually dimorphic in adult stages (Çakmak *et al.* 2017) and thus difficult to separate the sexes using external body characteristics (Purwaningrum *et al.* 2019). In Nigeria, Adedeji *et al.* (1994) used external morphology to differentiate female and male guinea fowl. They submitted that the sex of 93.3%, 91.7% and 86.7% of the sixty birds dissected influenced helmet size and shape, wattle size and shape, and number and distribution of filoplumes on the proximal one-third of the neck, respectively. In a related study in Nigeria, Onunkwo and Okoro (2015) reported that sexing of keets can be carried out through visualisation of the vent and listening to the cry of the birds. It was also reported that the males made a 'kee ke kee ke' sound, whereas the females made a 'buck-wheat buck-wheat' or 'put-rock put-rock' sound. The use of vocalisation for sexual differentiation in poultry has been reported (Hamadani *et al.* 2020).

In Ghana, guinea fowls were sexed using the vent, biometric and molecular techniques (Abdul-Rahman *et al.* 2015). Females had a wider pelvic inlet than male birds from first week of age until the end of the study. Males had longer and thicker phalli than their female counterparts at 8 weeks of age. Combining the biometric variables in a discriminant function, males could be distinguished from females with accuracy of 94%. The sex of guinea fowl was accurately determined using the primer set 2550 F/2718 R. Females produced 2 bands of 396 bp and 344 bp, whereas males only produced the larger band (Abdul-Rahman *et al.* 2015). Molecular techniques, therefore, may offer a better means of assessing sex in Nigerian indigenous guinea fowl, as accuracy is higher than with conventional methods of sexing (He *et al.* 2019). Also, it permits early sex determination of birds, which is crucial for controlled breeding for both production and conservation. However, molecular sexing may not be farmers' friendly, especially under low-input farming system.

Whole genome sequencing and genomewide association studies

Understanding the genetic changes underlying phenotypic variation in guinea fowls may facilitate efforts towards further improvement. Studies involving the detection of genomic regions showing selection signatures putatively related to past and potential future targets of domestication, breeding and selection can be executed using Whole Genome Sequencing (WGS) and Genome Wide Association Studies (GWAS) (Vignal *et al.* 2019). In Nigeria, there is no documented record on the use of WGS and GWAS in detecting genomic regions that harbour genes in association with distinct morphological and physiological traits in helmeted guinea fowl. Hence, the dire need for research efforts in this direction.

Genetic improvements

Establishment of a selection programme for improvement in growth, carcase, egg and fertility requires the estimation of genetic parameters for these traits. Ebegbulem and Okon (2018) reported that heritability for body weight ranged from 0.40 – 0.81, while repeatability estimates were at a range of 0.20 – 0.40 at 8 – 12 weeks of age in the Nigerian helmeted guinea fowl. Body circumference was estimated to be 0.66 – 0.84 heritable and 0.33 – 0.42 repeatable. Heritability for body weight and linear body traits generally increased with age. The use of genetic information to improve the performance of animals is receiving increased attention (Sevillano *et al.* 2019). It is also imperative to define the crossbreeding system at the commercial crossbred level to improve purebred performance (Esfandyari *et al.* 2018). However, there are very few studies on crossbreeding of guinea fowl in Nigeria. Ayorinde (1991a) reported 12-week body weight of about 530 g for unimproved Nigerian indigenous helmeted guinea fowl, whereas 770 and 1200 g weights were recorded for their improved local and exotic counterparts, respectively. In another conventional crossbreeding experiment, Ayorinde (1991b) compared from 0 to 18 weeks of age the performance of the crossbreds of local unimproved Pearl (RBC) and improved local Pearl (SLP) with improved exotic Pearl (EP) and that of the 'purebreds' of the RBC, SLP and EP. The results indicated improved body weight and efficiency of feed utilisation in crossbreds of SLP and EP (SLEP) and RBC and EP (RBEP) relative to the local parents. They concluded that this information may be exploited in the genetic improvement of body weight of indigenous helmeted guinea fowl in Nigeria. However, in France, the French Galor guinea fowl, which is more superior in performance than the African local types, has been developed. The breed is a product of over 50 years of genetic selection (GALOR 2021). There are two labels of Galor guinea fowl (GI 543 and GL 213). The GI 543 guinea fowl may be distinguished by its grey plumage and predominantly black legs. The GI 543 day-old guinea fowl may be distinguished by their good growth, a good feed conversion ratio and good yield. On the other hand, The GL 213 guinea fowl may be distinguished by its grey plumage and predominantly black legs. It is characterised by moderate growth, a good feed conversion ratio and good yields (GALOR 2021). The Galor breed has been introduced to Nigeria with better fertility (94.5%) and hatchability (91.4%)

values (Dzungwe *et al.* 2018). This breed has also been found to perform well in Ivory Coast (Kouassi *et al.* 2019; Koné *et al.* 2020). It is quite possible that the use of genomic information for selection of the breeding stock may offer better results.

Conclusion

There are great prospects in helmeted guinea fowl production in Nigeria. These will go a long way in complementing other poultry species, especially chickens, thereby contributing positively to food security, livelihood and empowerment of the resource-poor farmers. However, efforts should be made to scale up guinea fowl production from smallholdings to a more commercially viable enterprise. This can be executed through improvement in management and adoption of innovative technologies in housing, nutrition and health, including genetic improvement in the fertility, hatchability, body weight and egg number under tropical conditions. In this way, crossing using artificial insemination technique involving the French Galor guinea fowl or 'Golden Sovereign' broiler strain and the Nigerian local will give meat of a higher quality. Artificial brooding (from 0 to 8 weeks of age), whereby keets are confined in cages made of hardwood, wire-mesh, and aluminium roofing sheet, will go a long way in improving their performance. Commercial feed production from locally sourced materials will ensure availability of cheap feeds to farmers. Adequate biosecurity measures, regular monitoring of birds and precise medication and vaccinations will attenuate diseases problem under intensive system, while the use of Community-based poultry health management (CBM) will be suitable for smallholder farmers.

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