



Comparison of early growth and survivability in indigenous guinea fowls from Northern Ghana

Kurukulasuriya Mariesta Jayaroshini Ahiagbe¹ · Esinam Nancy Amuzu-Aweh² · Patrick Bonney¹ · John Kormla Nyameasem¹ · Franklin Kodzo Avornyo¹ · Christopher Adenyo³ · Kwame Owusu Amoah¹ · Augustine Naazie² · Boniface Baboreka Kayang²

Received: 24 July 2020 / Accepted: 3 December 2020 / Published online: 7 January 2021

© The Author(s), under exclusive licence to Springer Nature B.V. part of Springer Nature 2021

Abstract

Three guinea fowl populations from Northern Ghana were compared in terms of their body weight, growth rates, and survivability during the first 11 weeks of life. Keets ($n = 865$) were hatched from eggs collected from 32 sampling areas divided into eleven subpopulations within three populations in Northern Ghana. Together with an experimental flock maintained at Animal Research Institute (ARI flock), these birds were raised and appraised for weekly body weights, weekly growth rates, and survivability. Weekly body weights did not differ significantly ($p > 0.05$) among the three populations, although ARI flock were significantly heavier ($p < 0.05$) compared to the main populations until the fourth week. In contrast, among the subpopulations, significant differences emerged in body weights from the second week and were more pronounced from the sixth week. Growth rates measured as weekly weight gains also differed significantly among subpopulations beyond the second week, although differences in growth rates were not significantly different among whole populations. The mean values for total feed intake, daily feed intake, and feed conversion ratio (FCR) did not vary significantly ($p > 0.05$) between the populations. Therefore, although the variations in body weight and growth rates were limited among the populations, there existed significant variations among subpopulations, creating opportunities to establish genetically divergent populations for growth rate and to improve early growth rates and body weights in local guinea fowls by selection. High survivability observed in the ARI flock compared to keets from the three populations of Northern Ghana was likely due to good breeder stock management practices despite their common ancestry.

Keywords Body weight · Growth rate · Guinea fowls · Survivability · Northern Ghana

Introduction

The helmeted guinea fowl (*Numida meleagris*) is one of the important animal genetic resources of the African continent. It is thought to have originated from the Coast of Guinea (Newbold 1926), an area that spans the coastal zone of present-day West Africa. Since its introduction to Europe

during colonization, guinea fowl production has been improved to large-scale commercial operations in some European countries and the USA (Nahashon et al. 2006) with integrated improvements in nutrition and husbandry coupled with genetic improvement by selective breeding.

They are raised mainly under semi-intensive or extensive system with minimal farm inputs in many African countries including Botswana (Moreki and Seabo 2012), Benin (Dahouda et al. 2007), Nigeria (Ogah 2013), Zimbabwe (Kusina et al. 2012), Ghana (Avornyo et al. 2016), and others (Moreki and Radikara 2013). In Ghana, guinea fowl is the most common poultry species in the northern part of the country (Agbolosu et al. 2012a), where almost every rural household keeps a few birds in their backyard (Dei and Karbo 2004). While meat and eggs from guinea fowls provide protein in the rural diet, income from guinea fowl production helps the inhabitants to meet their daily needs, often providing

✉ Boniface Baboreka Kayang
bbkayang@ug.edu.gh

¹ Animal Research Institute, Council for Scientific and Industrial Research, P.O. Box AH 20, Achimota, Accra, Ghana

² Department of Animal Science, University of Ghana, Legon, Ghana

³ Livestock and Poultry Research Centre, University of Ghana, Legon, Ghana

direct investments for crop farming (Avornyo et al. 2016; Issaka and Yeboah 2016).

The majority of the guinea fowl farmers (98%) in Northern Ghana (NG) depend solely on local varieties of guinea fowls and rearing specialized exotic breeds improved for meat is negligible (FAO 2014; Avornyo et al. 2016). However, these rich genetic resources are not well characterized. Published literature on important production characteristics including body weight, growth rate, and disease resistance of local Ghanaian guinea fowl varieties is scanty. There have been no reports on breeding programs for genetic improvement of these varieties or phenotypic recording schemes to facilitate initiation of long-term breeding programs for local guinea fowls. However, available evidence suggests the existence of diversity among the local varieties kept by local farmers in NG (Kayang et al. 2010) providing opportunities for future breeding programs. Agbolosu et al. (2012b) observed significant differences in body weights of local guinea fowls originating from the Upper West Region, Upper East Region, and Northern Region (former) of Ghana during the eighth to eighteenth weeks growth period.

Most long-term breeding programs aiming at selecting divergent lines for faster growth in chicken have used body weights and growth rates during the juvenile stage with body weight at the eighth week being the most commonly used selection criterion (Flisar et al. 2014). Despite the importance of body weight and growth rate data during juvenile growth phase in poultry for selective breeding for faster growth, there is still a paucity of published literature on body weight traits, growth rate traits, and their variations among the local guinea fowl populations of NG during the brooding period that include the first 8 weeks of the production cycle.

Although growth remains a priority trait in poultry breeding in all economic species, other characteristics pertaining to fertility and survivability should not be overlooked during breed improvement (ALBC 2007). While high survivability is an important production trait to be improved or maintained when aiming for genetic gains in growth rate, it is even more important for breeds meant for dissemination to resource poor poultry farmers with limited access to veterinary care as those in the northern part of Ghana.

Therefore, this study sought to characterize and compare three main guinea fowl populations from the Upper East Region (UER), Former Northern Region (FNR, which now includes Northern, North East, and Savannah Regions), and Upper West Region (UWR) in terms of their body weight, growth rate, and survivability during the early growth period. The study also compared the subpopulations of local guinea fowls raised within these three populations for the same quantitative traits. Such information would be of immense importance for researchers who plan to design and implement sustainable breeding programs to facilitate sustainable utilization

of this less well studied but important animal genetic resource in Africa and the world at large.

Materials and methods

Source of experimental animals

Eggs from laying helmeted guinea fowls (*Numida meleagris*) were collected from 32 selected guinea fowl growing areas from three main populations of Northern Ghana (TPNG). The three main populations of Northern Ghana included guinea fowl populations from the Upper East Region (UER; Fig. 1), Former Northern Region (FNR; Fig. 2), and Upper West Region (UWR; Fig. 3). After the completion of this study, FNR was split into three administrative regions namely North East Region, Northern Region, and Savannah Region. Therefore, it is important to note that FNR currently includes three regions. Additionally, eggs from a breeder flock maintained at the Animal Research Institute of the Council for Scientific and Industrial Research (CSIR-ARI) were also collected. The breeder flock at CSIR-ARI was from keets hatched from eggs collected a year earlier from the same sample locations of UER, FNR, and UWR.

Each of the TPNG was divided into three or four subpopulations based on their origin to compare guinea fowl populations within the main populations for the purpose of this study. The UER subpopulations were E1, E2, E3, and E4, the FNR subpopulations were N1, N2, N3, and N4, and the UWR subpopulations were W1, W2, and W3 (Figs. 1, 2, and 3, respectively). After collection and assembly, eggs were airlifted from a central location in the capital (Tamale) of the FNR to CSIR-ARI, Accra. Eggs were handled according to standard procedures of handling breeding eggs from the collection of eggs at sampling locations until incubation.

Animals

In total, 865-day-old keets from the four main study populations including UER ($n = 250$), FNR ($n = 242$), UWR ($n = 322$), and the experimental breeder stock maintained at CSIR-ARI ($n = 51$) were used for the study. Day-old keets from each population were randomly assigned in replicates of 40–50 birds with nearly an equal number of keets from a subpopulation represented in all replicates for a given main population. Therefore, both UER and FNR had six replicates each, while UWR had eight replicates. The population from CSIR-ARI (ARI flock; ARI population) was included in one replicate of the total 21 replicates. All keets were individually tagged within the first 24 h after hatching with caution to minimize stress and trauma during handling.

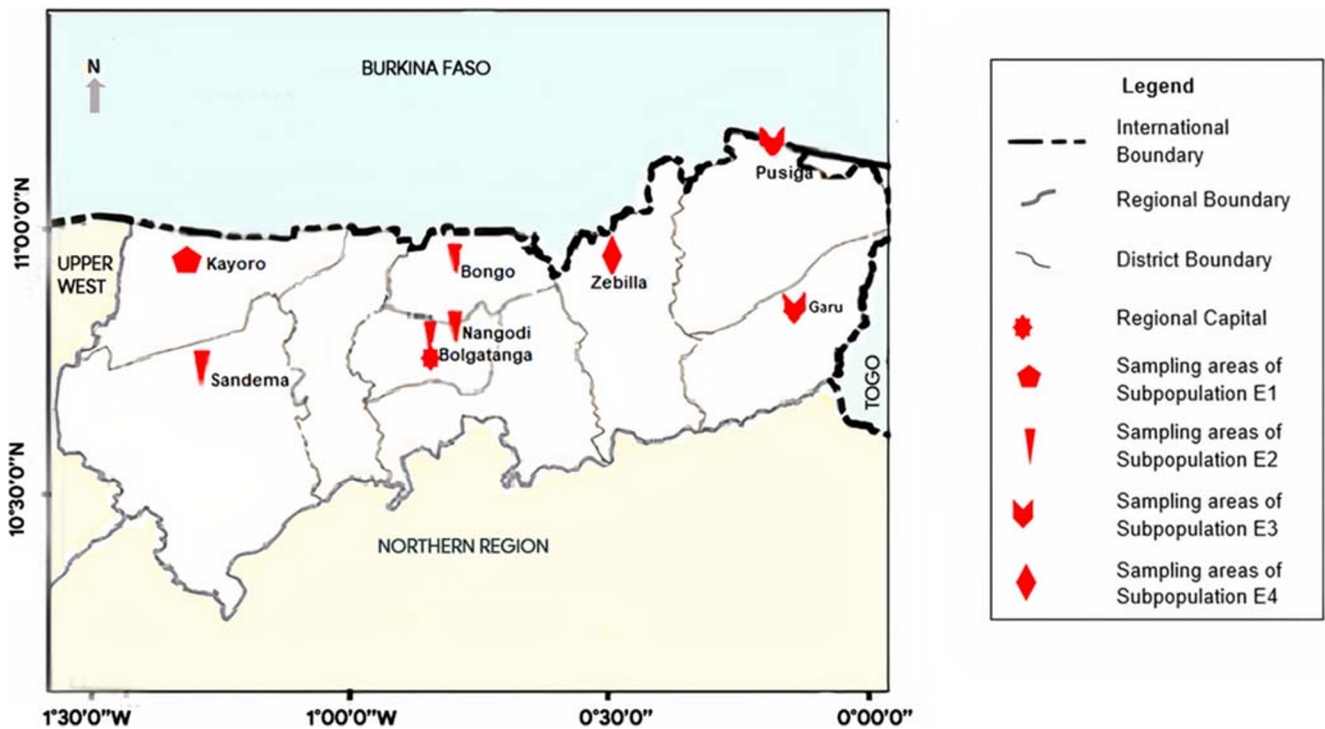


Fig. 1 Sampling areas in the Upper East Region

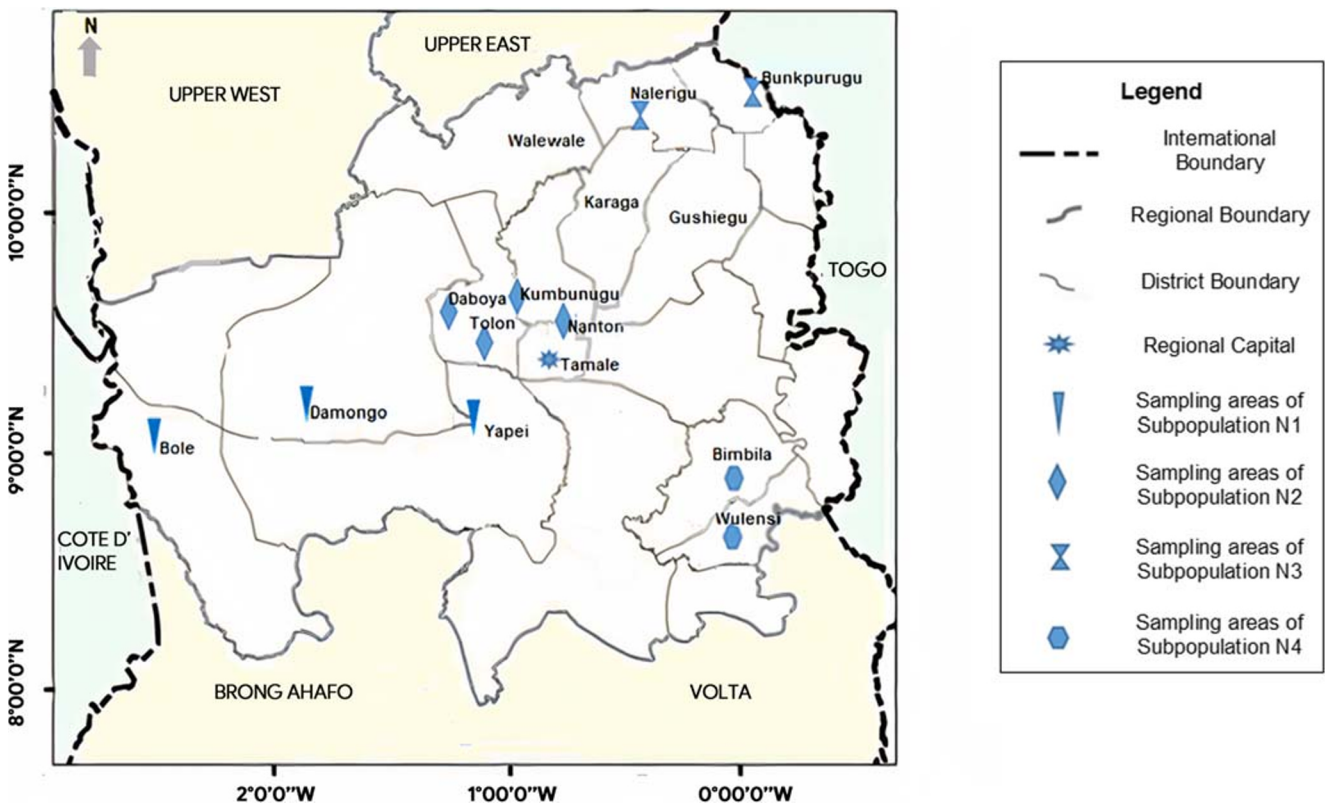


Fig. 2 Sampling areas in the Former Northern Region

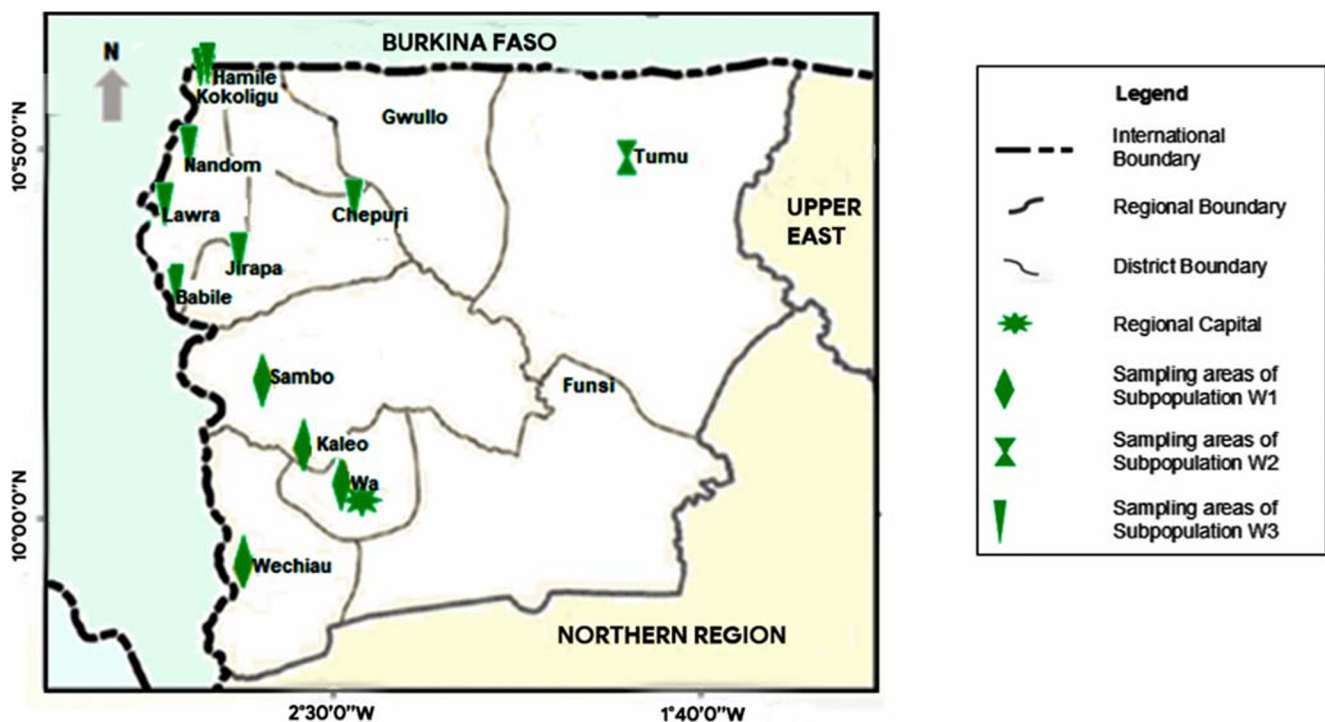


Fig. 3 Sampling areas in the Upper West Region

Management of experimental animals

Keets belonging to all replicates were raised at the brooder house of the Guinea fowl Resource Centre, Animal Research Institute, Accra, Ghana. Replicates were housed within compartments each measuring 1 m × 1.5 m × 2.5 m for length, breadth, and height, respectively. The brooder pens were preheated 24 h before receiving the keets. Keets were then brooded with provision of artificial light and heat tightly regulating the temperatures at 35 °C, 33 °C, 31 °C, and 29 °C from the first to the fourth week, respectively, with the help of gas brooders. Beyond the fourth week, internal temperature of the brooder house was maintained at 29 °C up to the eighth week. Best practices for preparing the brooder house and biosafety during daily operations were adhered to according to procedures of Ahiagbe et al. (2016) during the entire brooding period of 8 weeks. A vaccination schedule was followed according to recommendations by Ahiagbe et al. (2016). From day one up to 8 weeks, keets were fed with a formulated diet containing 24% crude protein (CP) and 12.5 MJ metabolizable energy (ME)/kg (Table 1). Feed and water were available ad libitum.

At 8 weeks, surviving birds ($n=222$) were transferred to a deep litter house, where they were randomly reassigned to replicates consisting of 15–18 birds. In all, UER ($n=34$), NR ($n=64$), UWR ($n=73$), and ARI

($n=51$) populations had 2, 4, 4, and 3 replicates, respectively. Each replicate was housed in a compartment at a stocking density of twenty growers per square meter. From 8 to 12 weeks, the birds were fed with a formulated grower diet with 16.37% CP and 11.23 MJ ME/kg (Table 1). Feed and water were available ad libitum. A prophylactic health management plan for raising growers was followed ensuring biosafety during daily operations. In the 12th week, guinea fowl growers were distributed to guinea fowl farmers as per the requirements of the associated research and development project.

Data collection

Body weight of each bird was recorded using an electronic balance at week 1 (BW1), week 2 (BW2), week 3 (BW3), week 4 (BW4), week 6 (BW6), week 7 (BW7), week 9 (BW9), and week 11 (BW11). Weight gain per week was used as an indicator of growth rate for selected time intervals. Recorded body weights were used to determine growth rates (Formula 1) between weeks 1 and 2 (GR1), weeks 2 and 3 (GR2), weeks 3 and 4 (GR3), weeks 4 and 6 (GR4), weeks 6 and 7 (GR5), weeks 7 and 9 (GR6), weeks 9 and 11 (GR7), and the overall growth rate between weeks 1 and 11 (GRO). The body weights in between the specified weeks could not be measured due to unavailability of

Table 1 Composition of diets fed to guinea fowls at different stages of growth

Ingredients (%)	0–8 weeks	9–12 weeks	Guinea fowl breeders
Maize	62.30	55.00	60.00
Soybean meal	21.00	15.00	17.70
Wheat bran	–	14.00	5.00
Di-calcium phosphate	0.70	0.90	0.90
Limestone	0.90	2.00	8.40
Salt (NaCl)	0.15	0.20	0.25
Lysine	0.15	0.20	0.20
Methionine	0.15	0.10	0.10
Fishmeal	13.20	1.00	3.00
Vitamin and mineral premix*	0.25	0.25	0.25
Palm oil	1.20	1.35	2.20
Palm Kernel Cake (PKC)	–	10.00	2.00
Total	100	100	100
Calculated composition			
Metabolizable energy (MJ/kg)	12.50	11.23	11.60
Crude protein (%)	24.00	16.37	16.92
Lysine (%)	1.39	0.80	0.92
Methionine (%)	0.57	0.30	0.35
Crude fiber (%)	2.42	4.54	2.82
Crude fat (%)	3.70	5.02	5.29
Calcium (%)	1.31	1.06	3.40
Available phosphorus (%)	0.47	0.37	0.36
**P:E	19.20	14.58	14.59

*Vitamin and mineral premix per 100-kg diet: vitamins, vitamin A (8×10^5 IU); vitamin D3 (1.5×10^4 IU); vitamin E (250 mg); vitamin K (100 mg); vitamin B2 (2×10^2 mg); vitamin B12 (0.5 mg); folic acid (50 mg); nicotinic acid (8×10^2 mg); calcium pantothenate (200 mg); choline (5×10^3 mg); trace elements, Mg (5×10^3 mg); Zn (4×10^3 mg); Cu (4.5×10^2 mg); Co (10 mg); I (100 mg); Se (10 mg); antioxidants, butylated hydroxy-toluene (1×10^3 mg). Carrier: calcium carbonate qsp (0.25 kg)

**P:E, protein:energy (g protein/MJ ME)

electricity at the experimental pens on those days. Feed intake per replicate was recorded daily and was used to calculate mean feed intake for the entire study period per population. Feed conversion ratio (FCR) was calculated using Formula 2. Mortalities were recorded daily and used to calculate percentage mortalities per week according to Yassin et al. (2009) using Formula 3.

Growth rate measured as weekly weight gain

$$= \frac{\text{Final weight} - \text{Initial weight}}{\text{Time interval (weeks)}} \quad (1)$$

Feed conversion ratio (FCR)

$$= \frac{\text{Total feed consumed per bird}}{\text{Total weight gain per bird}} \quad (2)$$

Percentage mortality at week N

$$= \left(\frac{\text{No. of mortalities during week } N}{\text{No. of keets at day 1}} \right) 100 \quad (3)$$

Data analysis

Data collected were entered into Microsoft Excel spreadsheets and validated. Analysis of variance (ANOVA) was performed for weekly body weights and growth rates at specified time intervals using the generalized linear model below.

$$Y_{ijk} = \mu + P_i + S_j + e_{ijk}$$

where, Y_{ijk} is the given dependable variable, μ is the overall mean, P_i is the effect of i th sample population, S_j is the effect of j th subpopulation, and e_{ijk} is the random error. The traits used as dependable variables included the body weights measured at first, second, third, fourth, sixth, seventh, ninth, and eleventh weeks, growth rates measured at specific weekly intervals of 1–2, 2–3, 3–4, 4–6, 6–7, and 9–11, and the overall growth rate. Least square means (LSM) and standard error (SE) were calculated. Multiple pairwise comparisons were done using Tukey's method. All statistical analysis was performed using R Version 0.99.489 (R Core Team 2016).

Results

Body weight traits

The mean body weights of the four main guinea fowl populations consisting of the TPNG and ARI flock measured at various ages during their early growth performance appraisal are presented in Table 2. Body weights at week one did not vary significantly ($p > 0.05$) among the TPNG. However, all TPNG differed significantly from the offspring of the experimental breeder flock of CSIR-ARI at week one. At week two, the mean body weights between Upper East and ARI flocks were comparable but differed from the other populations. The differences in body weights by population were not statistically significant ($p > 0.05$) beyond the sixth week.

Table 3 shows the weekly mean body weights of keets from the different subpopulations within each of TPNG. The mean body weights at week one were not different when compared among the subpopulations within TPNG but with some subpopulations significantly differing from that of the ARI flock ($p < 0.05$). Contrary to the TPNG, body weights of birds of subpopulations differed significantly beyond the sixth week with subpopulations demonstrating more pronounced effects on body weights ($p < 0.01$) beyond 6 weeks. All keets in subpopulation E1 of the UER died in the first week and so there was no data for that subpopulation.

Growth curves of guinea fowls from three populations of Northern Ghana and their subpopulations

The growth curves for guinea fowls from TPNG and CSIR-ARI from week one to week eleven are given in Fig. 4. Growth curves for the guinea fowls from all the eleven subpopulations are compared in Fig. 5 while growth curves for each of the subpopulations in UER, FNR, and UWR with CSIR-ARI flock are presented for comparisons within the main populations in Figs. 6, 7, and 8 respectively.

Growth rates

Mean growth rates among the TPNG together with the experimental flock at CSIR-ARI are given in Table 4. Growth rates between the first and second week did not differ significantly ($p > 0.05$). Variation in growth rate was significant ($p < 0.05$) between some main populations during the period between weeks 2 and 4. Beyond the sixth week, growth rates did not differ among guinea fowls from the three main populations and CSIR-ARI flock.

However, the variation in growth rates within the subpopulations was significant ($p < 0.05$) beyond the second week (Table 5). Between the first and second week, birds from the subpopulations grew at similar rates. Performance of local guinea fowls from subpopulations within the main populations was different in terms of their overall growth rate.

Table 2 Mean body weights (g) of local guinea fowls from three populations of Northern Ghana and ARI flock at various ages

Trait		UER	FNR	UWR	CSIR-ARI
BW1	LS mean	37.40 ^b ± 1.61(131) [§]	34.89 ^b ± 1.43(165)	35.09 ^b ± 1.23(223)	46.36 ^a ± 2.60(50)
	Range	34.24–40.56	32.07–37.70	32.67–37.52	41.25–51.48
BW2	LS mean	46.92 ^a ± 0.89(111)	43.39 ^b ± 0.81(135)	43.05 ^b ± 0.69(184)	47.98 ^a ± 1.34(49)
	Range	45.17–48.67	41.80–44.97	41.69–44.41	45.35–50.61
BW3	LS mean	64.95 ^a ± 1.82(84)	62.57 ^{ab} ± 1.57 (114)	58.25 ^b ± 1.34(155)	63.23 ^{ab} ± 2.41(49)
	Range	61.36–68.54	59.49–65.65	55.61–60.90	58.48–67.98
BW4	LS mean	81.84 ^{ab} ± 3.05 (66)	78.76 ^{ab} ± 2.44 (103)	72.76 ^b ± 2.12(137)	84.41 ^a ± 3.57(49)
	Range	75.85–87.83	73.97–83.56	68.60–76.92	77.38–91.44
BW6 ^{NS}	LS mean	134.16 ± 6.99 (49)	128.85 ± 5.34 (84)	127.81 ± 4.85 (102)	140.23 ± 7.22 (48)
	Range	120.39–147.93	118.33–139.37	118.26–137.36	126.01–154.44
BW7 ^{NS}	LS mean	181.38 ± 10.18 (42)	180.59 ± 7.78 (72)	174.59 ± 7.33 (81)	191.65 ± 9.84 (47)
	Range	161.31–201.44	165.27–195.92	160.14–189.04	172.27–211.04
BW9 ^{NS}	LS mean	270.66 ± 15.38 (34)	257.56 ± 11.21 (64)	262.96 ± 10.29 (73)	288.03 ± 13.52 (46)
	Range	240.33–300.98	235.46–279.66	242.68–283.24	261.37–314.68
BW11 ^{NS}	LS mean	369.05 ± 19.44 (33)	353.52 ± 14.07 (63)	367.39 ± 13.65 (67)	384.09 ± 16.84 (46)
	Range	330.71–407.39	325.77–381.27	340.48–394.30	350.89–417.29

BW_n, body weight at week *n*, *n* = 1, 2, 3, 4, 6, 7, 9, 11. Means of populations within a row with different superscripts differ significantly ($p < 0.05$)

^{NS} Comparisons among the means of populations are not statistically significant at 95% confidence level

[§] Numbers within parenthesis represent the number of observations

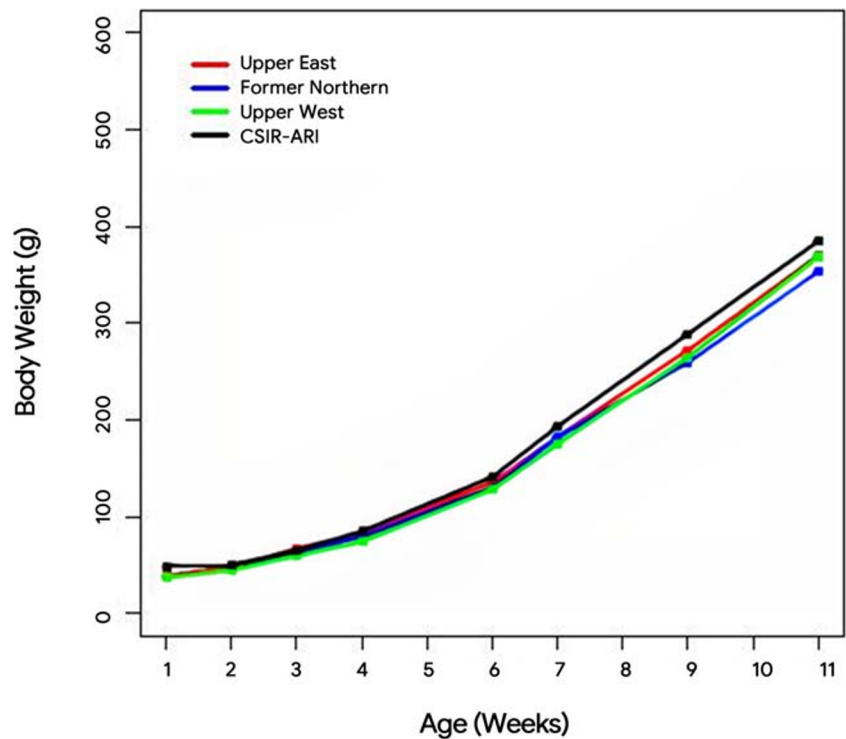
Table 3 Comparison of mean body weights (g) of local guinea fowls at different ages by subpopulations in the TPNG and ARI flock

Subpopulation/ population	BW1	BW2	BW3	BW4	BW6	BW7	BW9	BW11
E2	38.00 ^{ab} ± 1.94 (91) [§]	47.56 ^a ± 1.06 (77)	67.42 ± 2.26 (53)	85.53 ^{ab} ± 3.86 (38)	136.29 ^c ± 9.41 (23)	185.15 ^b ± 14.73 (17)	266.71 ^c ± 24.31 (12)	341.53 ^b ± 31.63 ^b (11)
E3	36.52 ^{ab} ± 8.28 (5)	52.47 ^{ab} ± 5.37 (3)	80.33 ^{ab} ± 9.49 (3)	110.20 ^{ab} ± 23.82 (1)	180.80 ^{abc} ± 45.15 (1)	294.90 ^{ab} ± 60.74 (1)	386.40 ^{abc} ± 84.22 (1)	459.60 ^{ab} ± 104.91 (1)
E4	35.96 ^{ab} ± 3.13 (35)	44.79 ^{ab} ± 1.67 (31)	58.63 ^{ab} ± 3.11 (28)	75.59 ^b ± 4.58 (27)	130.34 ^c ± 9.03 (25)	173.98 ^b ± 12.40 (24)	267.40 ^{abc} ± 18.38 (21)	379.15 ^b ± 22.89 (21)
N1	34.28 ^b ± 2.57 (52)	40.80 ^b ± 1.55 (36)	57.88 ^{ab} ± 3.11 (28)	67.03 ^b ± 4.58 (27)	106.19 ^c ± 9.85 (21)	157.13 ^b ± 16.23 (14)	230.04 ^{ac} ± 22.51 (14)	323.15 ^b ± 28.04 (14)
N2	34.79 ^b ± 2.35 (62)	44.56 ^{ab} ± 1.25 (55)	61.56 ^{ab} ± 2.32 (50)	76.53 ^b ± 3.59 (44)	114.52 ^c ± 7.52 (36)	156.20 ^b ± 10.27 (35)	240.02 ^{ac} ± 14.89 (32)	333.34 ^b ± 18.84 (31)
N3	35.63 ^{ab} ± 3.50 (28)	41.74 ^{ab} ± 1.86 (25)	62.32 ^{ab} ± 3.59 (21)	80.55 ^b ± 5.46 (19)	133.24 ^{bc} ± 11.66 (15)	189.34 ^b ± 17.53 (12)	253.99 ^{ac} ± 25.39 (11)	329.97 ^b ± 31.63 (11)
N4	35.61 ^{ab} ± 3.86 (23)	47.08 ^{ab} ± 2.13 (19)	74.83 ^a ± 4.24 (15)	108.11 ^a ± 6.61 (13)	206.03 ^a ± 13.03 (12)	278.50 ^a ± 18.31 (11)	398.41 ^a ± 31.83 (7)	540.63 ^a ± 39.65 (7)
W1	36.12 ^{ab} ± 1.95 (90)	44.11 ^{ab} ± 1.08 (74)	58.29 ^b ± 2.10 (61)	72.84 ^b ± 3.18 (56)	129.16 ^c ± 6.81 (44)	173.87 ^b ± 9.60 (40)	266.52 ^{ac} ± 14.66 (33)	368.56 ^b ± 20.19 (27)
W2	36.38 ^{ab} ± 4.14 (20)	44.92 ^{ab} ± 2.26 (17)	64.06 ^{ab} ± 3.99 (17)	83.48 ^{ab} ± 5.96 (16)	160.79 ^b ± 12.07 (14)	217.46 ^{ab} ± 16.85 (13)	329.29 ^{bc} ± 24.31 (12)	434.95 ^{ab} ± 30.29 (12)
W3	34.05 ^b ± 1.74 (113)	41.87 ^b ± 0.96 (93)	56.95 ^b ± 1.87 (77)	70.06 ^b ± 2.95 (65)	115.97 ^c ± 6.81 (44)	155.71 ^b ± 11.48 (28)	233.49 ^a ± 15.13 (28)	337.31 ^b ± 19.82 (28)
ARI	46.34 ^a ± 2.62 (50)	47.98 ^a ± 1.33 (49)	63.23 ^{ab} ± 2.37 (48)	84.41 ^{ab} ± 3.44 (48)	140.23 ^c ± 6.66 (47)	191.65 ^b ± 9.05 (45)	288.03 ^{abc} ± 12.70 (44)	384.09 ^b ± 15.82 (44)

BWn, body weight at week n , $n = 1, 2, 3, 4, 6, 7, 9, 11$. E2, E3, E4, subpopulations in the Upper East Region; N1, N2, N3, N4, subpopulations of the former Northern Region; W1, W2, W3, subpopulations of the Upper West Region. Means of subpopulations within a column with different superscripts differ significantly ($p < 0.05$)

[§] Numbers within parenthesis represent the number of observations.

Fig. 4 Growth curves for guinea fowls from the Upper East, former Northern, and Upper West regions and the breeder flock at CSIR-ARI during the early growth stage (0–11 weeks)



Feed intake

The mean values for total feed intake, daily feed intake, and FCR did not vary significantly ($p > 0.05$) between the main populations (Table 6). Due to the experimental design adopted by raising birds of different subpopulations together in a replicate, to avoid experimental bias originating from lower numbers of birds in some subpopulations, feed intake was not measured per subpopulation.

Survivability

The highest mortalities were reported during the first week post-hatch accounting for more than 50% of total mortalities observed during the study period for each of the main

populations and subpopulations excluding the ARI flock. A summary of percentage mortalities at weekly intervals is presented in Table 7. The cumulative mortalities for TPNG by the eighth week are also given in Table 7 due to relatively high rate of mortalities recorded by local guinea fowl farmers in NG during the first 8 weeks of rearing. The survivability plots for TPNG, CSIR-ARI flock, and subpopulations, CSIR-ARI flock are presented in Figs. 9 and 10 respectively.

Discussion

Due to the importance of carcass weight at the end of the production cycle, body weights are important quantitative

Fig. 5 Growth curves for guinea fowls from designated subpopulations within the Upper East, former Northern, and Upper West regions and ARI flock during the early growth stage (0–11 weeks)

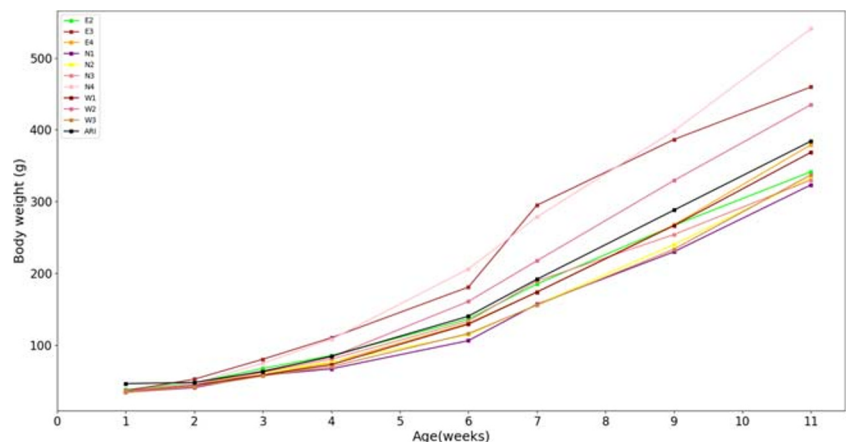
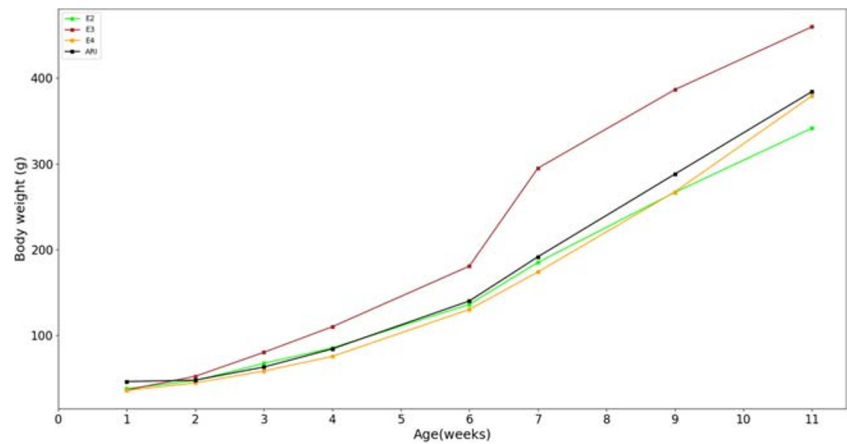


Fig. 6 Growth curves for guinea fowls from subpopulations within the Upper East Region and CSIR-ARI flock



traits for poultry farmers. Although guinea fowls have been improved for faster growth and higher carcass weight in France, Belgium, and the USA and growth characteristics are available for some of such breeds in literature (Nahashon et al. 2006), there is limited literature on factors influencing body weight and early growth in guinea fowls. Most of our current understanding on factors affecting body weight during early growth stage in poultry comes from the experiments involving broiler chicken breeds.

Body weight traits in broilers have been reported to be influenced by factors that have permanent or long-term influence on growth such as genetic makeup of juveniles and management practices throughout the growth period (Ayorinde 2007). However, there is also another subset of factors that influence body weight traits especially during the post-hatch growth which include maternal nutrition, breeder age, pre-incubation, and incubation conditions of eggs, the effects of which subside with advancement in age in broiler chicks (Decuyper and Bruggeman 2007).

The growth rate during the first week is usually slow due to the time taken by the chicks to increase digestive enzyme activity, feed utilization, and acclimatization to life outside the egg. Therefore, body weight of chicks within the first week is largely a function of hatch weight. Several factors

including maternal diet, length of pre-incubation egg storage, and age of breeders have been reported to influence hatch weight and by extension body weights within the first week of age (Decuyper and Bruggeman 2007). Nahashon et al. (2007) compared laying performance of guinea fowl breeders fed with diets containing varying levels of metabolizable energy and crude protein and recorded the best hatch weight in offspring from guinea hens fed with a diet including 24% and 21% crude protein between 0 and 8 weeks and 9 and 16 weeks, respectively, during the growth of breeders. This provides strong evidence for major influence of maternal diet on hatch weight, hence early post-hatch weight in guinea fowls. Longer pre-incubation storage of eggs has also been associated with lower hatch weights (Reis et al. 1997; Tona et al. 2003; Tona et al. 2004) and body weight at day seven in broiler chicks (Tona et al. 2004).

During the current study, week one body weights (BW1) of local guinea fowls did not vary significantly ($p > 0.05$), though the Upper East Region recorded the highest BW1 among the TPNG. Keets from the experimental breeder flock at ARI had significantly heavier BW1 than keets from the TPNG. Although all the four populations were raised under identical management conditions after hatch, fed with a similar diet, the influence of the maternal diet on body weight within the first

Fig. 7 Growth curves for guinea fowls from subpopulations within the former Northern Region and CSIR-ARI flock

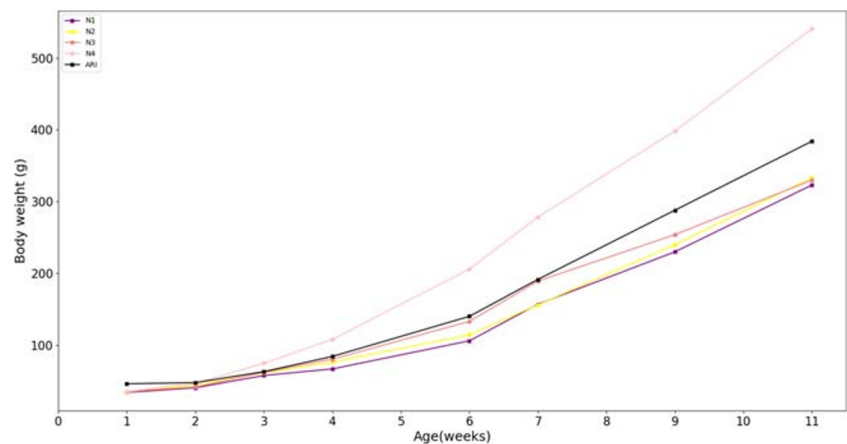
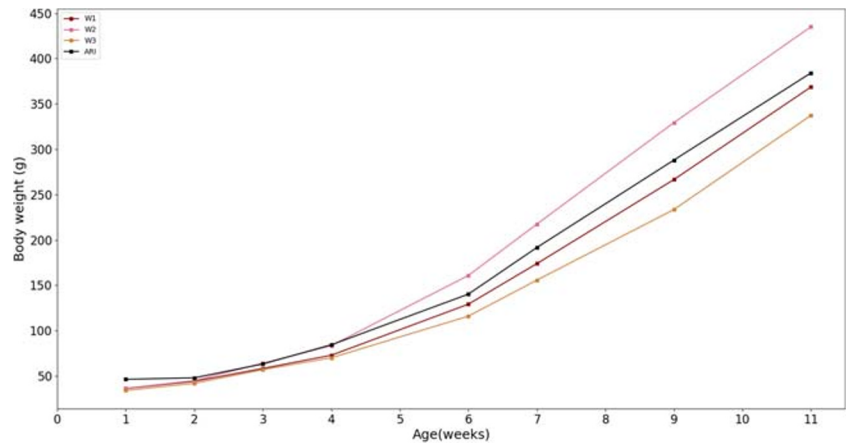


Fig. 8 Growth curves for guinea fowls from subpopulations within the Upper West Region and CSIR-ARI flock



week cannot be overlooked. According to Avornyo et al. (2014), the practice of maintaining a separate breeder stock is non-existent in production systems prevailing in Northern Ghana. Therefore, breeder hens are left to scavenge with limited supplementary feed that included maize or millet (Avornyo et al. 2016). The experimental flock at CSIR-ARI represents the offspring from a base population originally from the same sample locations of NG a year earlier. However, the parents were raised under best management practices recommended for raising breeders and provided with a formulated breeder diet according to Ahiagbe et al. (2016). Therefore, difference in maternal diet might be a major

contributing factor for significantly higher BW1 in the CSIR-ARI population.

Although eggs laid within the last 24 h were requested from farmers during egg collection in the current study, the exact age of eggs could be longer due to poor record keeping. Older but fertile layers are reported to lay heavier eggs reflected in higher hatch weights of their offspring compared to younger layers of the broiler lines (Tona et al. 2003; Tona et al. 2004). Ages of the layers in the TPNG were not available due to poor record keeping by the farmers. Therefore, better maternal nutrition and shorter pre-incubation storage might be among the main contributing factors for observed higher BW1 in ARI flock.

Table 4 Comparison of growth rates (g/week) of guinea fowls from three populations of Northern Ghana and the experimental flock at CSIR-ARI

Trait		UER	FNR	UWR	CSIR-ARI
GR1 ^{NS}	LS mean	8.40 ± 1.86	7.41 ± 1.68	6.73 ± 1.44	1.19 ± 2.80
	Range	4.75–12.05	4.10–10.72	3.90–9.56	−4.30 - 6.68
GR2 ^{***}	LS mean	16.53 ^{ab} ± 1.16	17.67 ^a ± 0.99	13.62 ^b ± 0.86	15.09 ^{ab} ± 1.54
	Range	14.24–18.82	15.70–19.63	11.93–15.30	12.06–18.12
GR3 ^{**}	LS mean	16.15 ^{ab} ± 1.55	14.71 ^b ± 1.23	13.60 ^b ± 1.08	21.18 ^a ± 1.82
	Range	13.10–19.19	12.27–17.14	11.48–15.72	17.61–24.75
GR4 ^{NS}	LS mean	25.07 ± 2.08	23.84 ± 1.59	25.22 ± 1.44	27.45 ± 2.15
	Range	20.97–29.17	20.70–26.97	22.38–28.06	23.22–31.68
GR5 ^{NS}	LS mean	46.63 ± 3.84	49.55 ± 2.93	40.73 ± 2.76	49.73 ± 3.71
	Range	39.07–54.19	43.77–55.32	35.29–46.18	42.43–57.03
GR6 ^{NS}	LS mean	42.65 ± 3.31	43.22 ± 2.39	44.68 ± 2.22	47.47 ± 2.86
	Range	36.13–49.17	38.51–47.94	40.29–49.06	41.83–53.12
GR7 ^{NS}	LS mean	49.47 ± 3.32	47.19 ± 2.41	49.27 ± 2.33	48.03 ± 2.88
	Range	42.91–56.02	42.45–51.94	44.67–53.87	42.36–53.71
GRO ^{***}	LS mean	17.89 ^b ± 1.43	20.92 ^b ± 1.29	18.08 ^b ± 1.11	31.81 ^a ± 2.15
	Range	15.08–20.69	18.38–23.46	15.91–20.26	27.60–36.03

GR, growth rate; GR1, GR between weeks 1 and 2; GR2, GR between weeks 2 and 3; GR3, GR between weeks 3 and 4; GR4, GR between weeks 4 and 6; GR5, GR between weeks 6 and 7; GR6, GR between weeks 7 and 9; GR7, GR between weeks 9 and 11; GRO, overall GR between weeks 1 and 11. Means of populations within a row with different superscripts differ significantly at ^{**}*p* < 0.05, ^{***}*p* < 0.001

^{NS} Difference of means between the populations are not statistically significant at 95% confidence level

Table 5 Growth rates (g/week) of local guinea fowls across the designated subpopulations within three populations of Northern Ghana

Subpopulation/ population	GR1 ^{NS}	GR2**	GR3**	GR4**	GR5**	GR6**	GR7**	GRO **
E2	8.25 ± 2.24	17.49 ^{ab} ± 1.44	16.00 ^{bc} ± 1.97	22.56 ^c ± 2.75	45.88 ^{abc} ± 5.77	42.30 ^b ± 5.52	38.40 ^b ± 5.55	14.15 ^{bc} ± 1.63
E3	15.60 ± 11.36	27.87 ^{ab} ± 6.06	14.20 ^{abc} ± 12.15	35.30 ^{abc} ± 13.20	114.10 ^{ab} ± 23.79	45.75 ^{ab} ± 18.30	36.60 ^{ab} ± 18.41	27.08 ^{abc} ± 8.25
E4	8.06 ± 3.53	13.49 ^b ± 1.98	16.43 ^{bc} ± 2.34	26.97 ^{bc} ± 2.64	44.35 ^{bc} ± 4.86	42.69 ^b ± 3.99	55.88 ^{ab} ± 4.02	26.27 ^{ac} ± 2.57
N1	4.88 ± 3.28	15.39 ^{ab} ± 1.98	8.26 ^c ± 2.34	18.58 ^c ± 2.88	49.82 ^{abc} ± 6.36	41.04 ^b ± 5.08	46.56 ^{ab} ± 4.92	15.71 ^{bcc} ± 2.38
N2	8.71 ± 2.65	16.19 ^{ab} ± 1.48	13.34 ^{bc} ± 1.83	18.53 ^c ± 2.20	40.06 ^{bc} ± 4.02	40.86 ^b ± 3.23	45.35 ^b ± 3.31	20.75 ^{bcd} ± 1.93
N3	5.66 ± 3.93	19.17 ^{ab} ± 2.29	16.92 ^{abc} ± 2.79	24.79 ^{bc} ± 3.41	55.60 ^{abc} ± 6.87	35.11 ^b ± 5.52	37.99 ^b ± 5.55	20.06 ^{bcd} ± 2.86
N4	10.76 ± 4.51	24.77 ^a ± 2.71	29.51 ^a ± 3.37	47.75 ^a ± 3.81	72.79 ^a ± 7.17	70.83 ^a ± 6.92	71.11 ^a ± 6.96	32.41 ^{ad} ± 3.28
W1	6.79 ± 2.29	12.79 ^b ± 1.34	13.83 ^{bc} ± 1.64	25.99 ^{bc} ± 1.99	42.47 ^{bc} ± 3.76	44.17 ^b ± 3.18	48.04 ^{ab} ± 3.54	19.02 ^{bcc} ± 1.66
W2	7.32 ± 4.77	19.15 ^{ab} ± 2.54	18.60 ^{abc} ± 3.04	37.45 ^{ab} ± 3.53	48.87 ^{abc} ± 6.60	54.35 ^{ab} ± 5.28	52.83 ^{ab} ± 5.31	32.34 ^{ad} ± 3.47
W3	6.57 ± 2.04	13.06 ^b ± 1.20	12.18 ^c ± 1.51	20.56 ^c ± 1.99	34.47 ^c ± 4.50	41.13 ^b ± 3.46	48.92 ^{ab} ± 3.48	14.73 ^c ± 1.48
CSIR-ARI	1.19 ± 2.81	15.09 ^{ab} ± 1.51	21.18 ^{ab} ± 1.75	27.45 ^{bc} ± 1.95	49.73 ^{abc} ± 3.55	47.47 ^{ab} ± 2.76	48.03 ^{ab} ± 2.77	31.81 ^a ± 2.04

GR, growth rate measured as weekly weight gain; GR1, GR between weeks 1 and 2; GR2, GR between weeks 2 and 3; GR3, GR between weeks 3 and 4; GR4, GR between weeks 4 and 6; GR5, GR between weeks 6 and 7; GR6, GR between weeks 7 and 9; GR7, GR between weeks 9 and 11; GRO, overall GR between weeks 1 and 11; E2, E3, E4, subpopulations in the Upper East Region with surviving birds; N1, N2, N3, N4, subpopulations of the former Northern Region; W1, W2, W3, subpopulations of the Upper West Region. Means of subpopulations within a column with different superscripts differ significantly ($p < 0.05$)

^{NS} Difference between the means per subpopulation is not significant ($p > 0.05$)

There were significant differences between the BW2, BW3, and BW4 between some populations with no significant differences between the Upper East and CSIR-ARI that recorded comparable mean body weights. There have been no previous reports on body weights during post-hatch growth compared among the same three populations from Northern Ghana for comparisons with observations of the current study. Dei et al. (2009) recorded slightly higher body weights at week four for local guinea fowls intensively raised within cages in a study conducted to compare different brooding options.

The variations in body weights observed during the current study beyond the sixth week were not statistically different among the TPNG. This was contrary to observations by Agbolosu et al. (2012a) who reported significant differences

in the overall body weights beyond 8 weeks of age for the TPNG. However, Agbolosu et al. (2012a) did not compare body weights from hatch to the eighth week. The Upper East Region was the best performing in terms of weekly body weights for most weeks during the current study compared with the former Northern and Upper West Regions. Agbolosu et al. (2012a) also reported the Upper East Region as the best performing in terms of overall body weight for growth period between 8 and 16 weeks. Avornyo et al. (2016) observed that the proportion of farmers providing supplementary feeding is higher in the Upper East Region and included millet as a major supplementary feed in that region. Pearl millet, the variety of millet popularly grown in the Upper East Region, contains a higher protein and iron percentage compared to maize (FAO 1995). This difference in the quality

Table 6 Comparison of feed consumption and feed conversion ratio of local guinea fowls from three populations of Northern Ghana and ARI flock

Parameter	Population			
	UER	FNR	UWR	CSIR-ARI
Final weight ^{NS} (g/bird)	369.05	353.52	367.39	384.09
Initial weight* (g/bird)	37.40 ^a	34.89 ^a	35.09 ^a	46.36 ^b
Total weight gain ^{NS} (g/bird)	331.65	318.63	332.30	337.73
Average daily weight gain ^{NS} (ADWG, g/bird/day)	4.74	4.55	4.75	4.82
Total feed intake ^{NS} (g)	1266.90	1315.94	1322.55	1357.67
Daily feed consumption ^{NS} (g/bird/day)	18.10	18.80	18.89	19.40
FCR ^{NS}	3.82	4.13	3.98	4.02

^{NS} Variations between means within a row are not statistically significant at 95% confidence level

*Variations between means within a row are statistically significant at 95% confidence level, where means that differ bear different superscripts

Table 7 Percentage mortalities of guinea fowls at weekly intervals across the four populations and subpopulations

Pop. Subpop.	Initial No.	Mortalities (%)													
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Cumulative at week 8	Week 9	Week 10	Week 11	Week 12	
E1	16	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	
E2	152	40.13	9.21	15.79	9.87	0.09	0.66	3.95	3.29	82.99	0.00	0.66	0.00	0.00	
E3	21	76.19	9.52	0.00	9.52	0.00	0.00	0.00	0.00	95.24	0.00	0.00	0.00	0.00	
E4	61	42.62	6.56	4.92	1.64	0.02	1.64	1.64	4.92	63.95	0.00	0.00	0.00	0.00	
UER	250	48.00	8.00	10.80	7.20	6.00	0.80	2.80	3.20	86.80	0.00	0.40	0.00	0.00	
N1	83	37.35	19.28	9.64	1.20	0.05	2.41	8.43	0.00	78.36	0.00	0.00	0.00	0.00	
N2	88	29.55	7.95	5.68	6.82	9.09	0.00	1.14	3.41	63.64	0.00	1.14	0.00	0.00	
N3	45	37.78	6.67	8.89	4.44	0.09	0.00	6.67	2.22	66.76	0.00	0.00	0.00	0.00	
N4	27	14.81	14.81	14.81	7.41	3.70	0.00	3.70	14.81	74.07	0.00	0.00	0.00	0.00	
FNR	243	32.10	12.35	8.64	4.53	0.07	0.82	4.94	3.29	66.74	0.00	0.41	0.00	0.00	
W1	123	26.83	13.01	10.57	4.07	8.13	1.63	3.25	5.69	73.98	0.00	4.88	0.00	0.00	
W2	36	44.44	8.33	0.00	2.78	0.03	2.78	2.78	2.78	63.92	0.00	0.00	0.00	0.00	
W3	163	30.67	12.27	9.82	7.36	11.04	1.84	9.82	0.00	82.82	0.00	0.00	0.00	0.00	
UWR	322	31.06	12.11	9.01	5.59	0.09	1.86	6.52	2.48	68.72	0.00	1.86	0.00	0.00	
CSIR-ARI	51	1.96	1.96	0.00	0.00	1.96	0.00	1.96	0.00	7.84	1.96	0.00	0.00	0.00	

Pop., population; Subpop., subpopulation; E2, E3, E4, subpopulations in the Upper East Region (UER) with surviving birds; N1, N2, N3, N4, subpopulations of the former Northern Region (FNR); W1, W2, W3, subpopulations of the Upper West Region (UWR)

and quantity of supplementary feed probably contributed to higher body weights from weeks one to four in birds from the Upper East Region combined with genetic factors.

Juvenile body weights observed during the current study at a given age varied from previously reported values for similar

age groups in different varieties of helmeted guinea fowls in other countries. Fajemilehin (2010) reported slightly greater values for body weight at 4 and 8 weeks in cross-bred helmeted guinea fowls in Nigeria. Mohammed and Dei (2017) observed higher values for guinea keets at 8 weeks raised within

Fig. 9 Survival plots for the four populations from the Upper East, former Northern, and Upper West Regions and CSIR-ARI flock

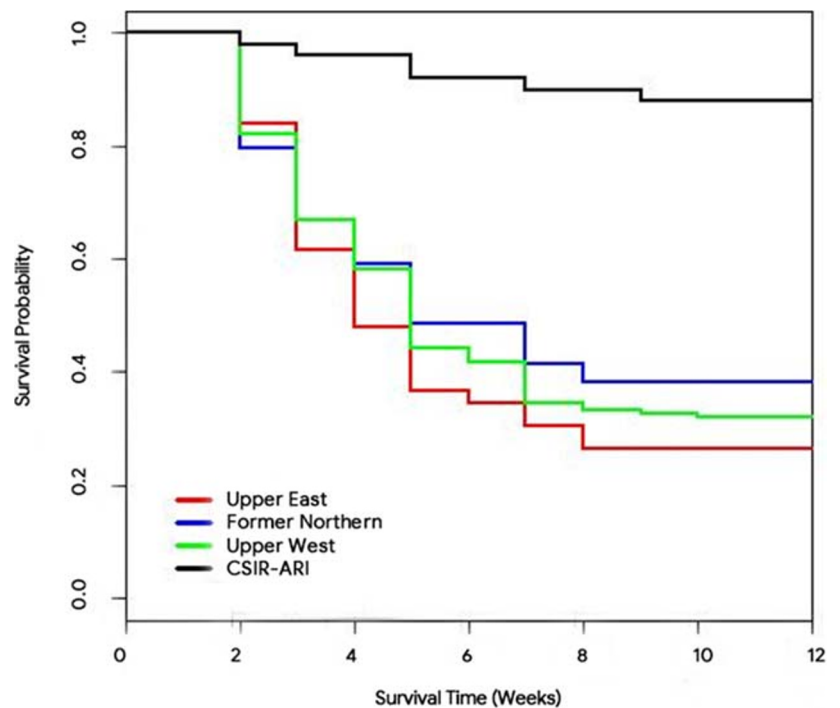
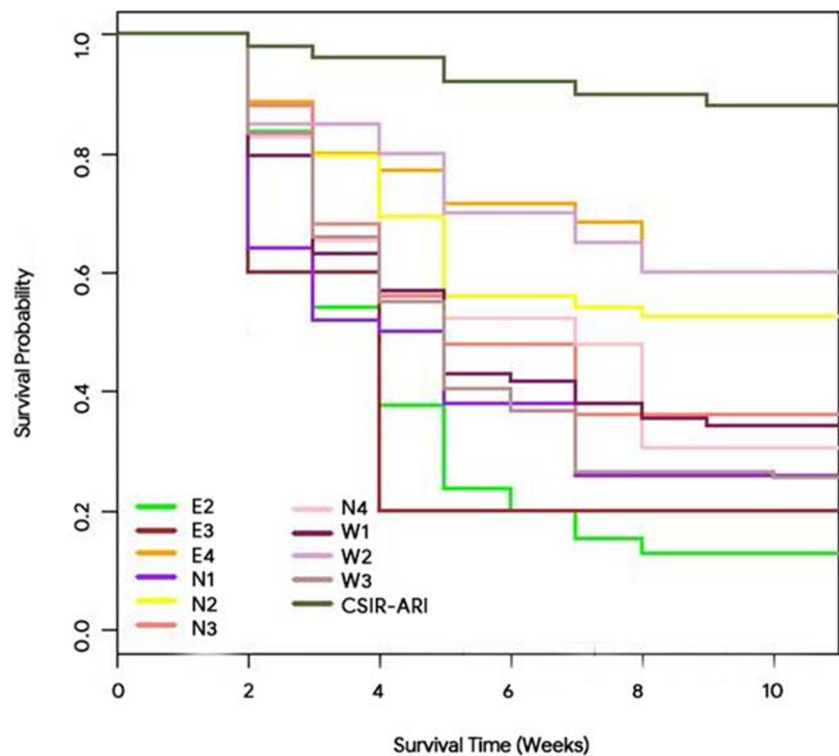


Fig. 10 Survival plots for the subpopulations within the three populations of guinea fowls of NG and CSIR-ARI flock



cages under intensive system in the Northern Region (former) of Ghana. Dahouda et al. (2007) reported higher values for 10-week-old local varieties in the Republic of Benin. BW1 to BW4 observed during the current study were comparable to body weights at similar ages reported by Khairunnesa et al. (2016) for helmeted guinea fowl varieties in Bangladesh. Body weights of pearl gray guinea fowls that have been genetically improved for higher body weight and faster growth reported by Nahashon et al. (2006) in the USA drastically varied from the values observed during the current study. However, it should be noted that performance of populations in different experiments cannot be compared due to differences in experimental conditions and breed differences.

Remarkably high values for juvenile body weights of improved varieties is undoubtedly due to the genetic gain achieved over years of selection. Greater maternal nutrition ensured in standard breeder flocks coupled with good breeder stock management may be the second dominant reason for this observed difference. Avorny et al. (2016) indicated that 98% of farmers in NG depend on the local varieties that have not been improved by selection. The same study indicated that farmers do not maintain a separate breeder stock even within their flocks. Irrespective of age, they are raised under extensive or semi-intensive production systems (Avorny et al. 2016) where nutrition demands of breeding hens are hardly met. These observations highlight the importance of long-term selection programs and management of breeder stock with improved nutrition in confinement in order to increase juvenile body

weights in local guinea fowls and possibly to achieve better carcass yield.

Although the variation of weekly body weights among TPNG was statistically insignificant beyond the sixth week, differences in body weights between the subpopulations were significant beyond the sixth week even at 99% confidence level. This suggests that although overall the main populations did not exhibit significant variations in body weights, there was a high degree of variations between the subpopulations. These variations are also vivid when growth curves are compared among the subpopulations within a region. As indicated from calculated contrasts between the subpopulations designated during this study, the variations between subpopulations of the Former Northern Region were prominent. Formerly, the Northern Region was the largest region among the administrative regions of Northern Ghana covering a larger geographical area that probably resulted in populations with greater variation.

Faster growth has been the primary breeding objective in most past breeding programs in poultry (Flisar et al. 2014). Due to the importance of post-hatch growth to the poultry farmer, factors affecting post-hatch growth have been extensively studied for broilers. Genetic factors, post-hatch diet, and early access to feed have been known to influence the weekly weight gains to the end of the growth period in chicken (Noy and Sklan 1997) while pre-incubation storage time of eggs and age of hens have been reported to influence the weight gain during early post-hatch growth (Tona et al. 2004).

In the current experiment, the differences among populations in the mean weekly weight gains were significant from

the second week up to the fourth week, but with no further significant variations beyond the sixth week. Keets were transported to the brooder facility within an hour post-hatch to minimize delays and stress due to treatments such as weighing and tagging at hatch, to give them access to feed within 24 h post-hatch and to nullify the effects of varying fasting times on post-hatch growth. After hatch, they were fed with the same diet ensuring equal access to feeders. Representation of keets was approximately equal in all replicates per population. Therefore, observed variations in early post-hatch growth between some of the main populations that subsided beyond the fourth week are likely due to pre-experimental factors that have transient effects such as age of breeders and preincubation storage of eggs possibly interacting with genetic factors.

Significant contrasts in weekly weight gains between the subpopulations that persisted beyond the sixth week might have been influenced by some pre-experimental conditions interacting with genetic influences. As these contrasts persisted and became dominant until the end of study period, the influence of these genetic factors is likely to play a significant role on growth rate and remain to be characterized.

Indeed, genetic variations within adapted guinea fowl populations in Europe and the USA have been utilized to establish genetically stable faster growing guinea fowl breeds by commercial breeding companies. Nahashon et al. (2006) reported remarkably high growth rates for pearl gray guinea fowls compared to growth rates observed during current study and rates reported in similar studies across Africa due to obvious genetic gain achieved by years of selection in faster growing breeds. When compared with other studies involving unimproved local varieties elsewhere, local birds from the current study areas performed better than local varieties of Bangladesh for the first 3 weeks with a reverse trend for the remaining weeks according to reports by Khairunnesa et al. (2016). However, growth rates observed during the current study and those reported by other studies cannot be compared in absolute terms due to differences in experimental, pre-experimental conditions, and genetic factors that influence post-hatch growth. A pre-requisite for funding of the current study was the distribution of grower guinea fowls to beneficiary farmers at 12 weeks. Therefore, no data beyond 12 weeks could be recorded.

The current study provides strong evidence for the existence of phenotypic variations in body weight and growth traits *within* the local guinea fowl populations of Northern Ghana. These variations provide opportunities to select phenotypically divergent lines for growth rates from local guinea fowls. However, care should be taken to retain traits related to disease resistance, fertility, and vigor that are of interest to smallholder guinea fowl farmers.

Reported growth rates of improved varieties raised in France, Belgium, and the USA are remarkably higher but

exotic varieties are generally less adapted to climatic conditions prevalent in the guinea savannah ecozone. Past poultry breeding programs that overlooked the adaptive features of local breeds to tropical climate and production systems opting for breed replacement or crossbreeding with exotic breeds have recorded little successes (FAO 2007). Considering the non-sustainability of breeding programs to disseminate improved breeder stock to smallholder farmers and observations from the current study, it is recommended that future research should further explore observed variations that exist within the local populations of guinea fowls and design breeding programs to develop fast growing strains from local populations instead of opting for breed replacement or cross breeding.

The feed intake and FCR did not vary significantly between the TPNG. To avoid experimental bias from raising birds of subpopulations in separate pens due to different number of birds per subpopulation that survived, the birds from different subpopulations were randomly allocated to replicates of main populations. Hence, the feed intake was only measured at population levels and variation in FCR and its influence on observed variations within subpopulations cannot be discussed. Agbolosu et al. (2012a) also observed no significant differences in feed efficiency (1/FCR) between the birds from the TPNG.

Survivability is an important economic trait in commercial poultry production. During the current study, the highest mortalities were reported during the first week in all the populations and the subpopulations. During the first week, chicks undergo a major shift in their physiology as they change from a yolk sac dependent mode of nutrition to feeding solid feed independently (Decuypere et al. 2001). The additional stress created during this transformation must be a major factor predisposing keets to high mortalities during the first week. While high mortalities later in life are largely functions of genotype and management of growers, high mortality in chicken during the first week is largely affected by the quality of the day-old chicks (Decuypere et al. 2001; Kidd 2003). Therefore, high level of mortalities that subside with age as observed during this study is likely due to low quality of day-old keets hatched from the eggs collected from the TPNG. By contrast, the CSIR-ARI flock exhibited the lowest mortalities during the first week indicating improvements in quality of keets in that group.

High rate of keet mortality during the first 8 weeks post-hatch has been a persistent challenge among guinea fowl farmers from NG according to previous reports by Teye and Adam (2000) and more recent reports by Avornyo et al. (2016). The trend is similar across tropical Africa (Bessin et al. 1998; Boko et al. 2011; Moreki and Radikara 2013). A similar trend was observed for the groups representing the TPNG and subpopulations of Northern Ghana during the current study with survivability increasing beyond eighth week in all groups.

In tropical Africa, majority of mortalities before the eighth week have been attributed to bad weather and diseases (Dahouda et al. 2007; Boko et al. 2011). Informed by these observations, improving the microclimate of keets during the first 8 weeks with provision of heat, light, water, and a well-balanced diet have been proposed and have been proved to significantly reduce mortalities (Dei et al. 2009; Avornyo et al. 2015; Ahiagbe et al. 2016; Mohammed and Dei 2017). Although best practices during brooding have been widely disseminated in NG with some farmers adopting them, guinea fowl farmers still record high keet mortalities (Avornyo et al. 2016). On the other hand, survivability of chicks during brooding appears to be more complex and is influenced by several factors related to breeders such as breeder strain, breeder age (Peebles et al. 1999), breeder nutrition (Heier et al. 2002), factors related to egg such as egg size (Decuyper et al. 2001), pre-incubation storage conditions of the eggs (Tona et al. 2004), and incubation conditions (Lourens et al. 2005) beside post-hatch brooding.

In the current study, all birds were fed with a formulated diet, with provision of heat, light, and adhering to strict bio-safety guidelines, according to the best brooding practices as per the current understanding. However, survivability was still low in keets hatched from the eggs collected from the TPNG. Although all the groups were hatched at the same time and raised under the same conditions, ARI flock exhibited remarkably low levels of mortalities compared to other groups. This flock was established from parents hatched from eggs collected a year earlier from the same locations as the birds used for the comparative growth appraisal and has not been subjected to selection. Considering the common practices of obtaining eggs from their own farm or from neighbors for incubation in Northern Ghana (Avornyo et al. 2016), they can be assumed to be not significantly different in descent from the birds used for present comparative growth performance trial. However, the parents of CSIR-ARI keets were being raised under best practices for breeder stock management fed with a breeder diet, a health management plan and under strict biosafety measures. Unlike the breeder flock of CSIR-ARI, laying guinea hens raised by the majority of farmers are not raised intensively and are not provided adequate feed but are left to scavenge with the rest of the flock. The resulting inadequate maternal diet and poor maternal health may be major contributing factors to high mortalities during keet stage beside other pre-incubation factors affecting the egg and the chick quality. Improved maternal diet with supplementation of vitamins E and D and other micronutrients has been demonstrated to directly improve immunity in chicks. Supplementation of breeder diet with vitamin and mineral premixes has resulted in increased antibody production in chicks. Similarly, zinc supplementation in the breeder diet has been demonstrated to improve both cellular immunity, humoral immunity, and *Escherichia coli* resistance in chicks (Kidd 2003).

Therefore, this study provides evidence for mortalities that cannot be maintained even by the best practices of post-hatch brooding as also reported by some farmers and highlights the complex factors that predispose local keets to high rates of mortality. However, the remarkable improvement observed in the CSIR-ARI flock in terms of survivability suggests that such mortalities can be overcome by integrating best practices of breeder stock management, pre-incubation treatment of breeding eggs, and post-hatch brooding. Observed symptoms before mortality included paralysis and nervous-like symptoms and may suggest possible vertical transfer of pathogens from parents that could not be controlled during egg collection and needs further investigation.

Conclusion

Variation among the three main populations of local guinea fowls studied from Northern Ghana is minimal in terms of juvenile body weights and early growth rates. However, there exist variations within these populations and among the sub-populations of local varieties for traits of juvenile body weights and growth rates that should be further explored and if possible utilized for selection to ensure sustainable management of the genetic resource of indigenous guinea fowls as an alternative to breed replacement or cross breeding with exotic breeds. The high rate of keet mortality in the first 8 weeks post-hatch which is common throughout NG is likely to be best managed by integrating best practices of breeder stock management, best practices for pre-incubation treatment of breeding eggs with best practices for post-hatch brooding.

Funding information The study was funded by the World Bank through the Phase II of West Africa Agricultural Productivity Programme (WAAPP II).

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The manuscript does not contain data related to any clinical study or patient data.

References

- Agbolosu, A. A., Teye, G. A., Adjetey, A. N. A., Addah, W. and Naandam, J., 2012a. Performance characteristics of growing indigenous guinea fowls from Upper East, Upper West and Northern Region of Ghana. *Agriculture and Biology Journal of North America*, 3(8), 336–339. <https://doi.org/10.5251/abjna.2012.3.8.336.339>.
- Agbolosu, A. A., Teye, G. A., Jebuni, S. N., Ansah, T. and Naandam, J., 2012b. Comparative study of growth and laying performance of indigenous layer guinea fowls (*Numida meleagris*) from Upper

- East, Upper West and Northern regions of Ghana. *Agriculture and Biology Journal of North America*, 3(9), 354-359.
- Ahiagbe, K. M. J., Karbo, N., Avomyo, F., Nyame-ase, J. K., Adu-Aboagye, G., Amoah, K. O., Affedzie-Obresi, S., Beckley, C. S. K. and Duncan, J. L., 2016. Improving Guinea Fowl Keet Survivability in Ghana: A manual for management of keet mortalities using an integrated approach (CSIR-Animal Research Institute, Accra, Ghana), ISBN: 978-9988-2-41248-5.
- ALBC, 2007. Selecting for Meat Qualities and Rate of growth. In: Chicken assessment for improving productivity. American Livestock Breed Conservancy, Pittsboro, North Carolina, USA, 1–8.
- Avomyo, F. K., Salifu, S., Panyan, E. K., Al-Hassan, B. I., Ahiagbe, M. and Yeboah, F., 2014. Social and Economic Profitability of Guinea Fowl Production – A baseline study in project districts, **CSIR-Animal Research Institute**.
- Avomyo, F. K., Munkaila, L., Allegye-Cudjoe, E., Karbo, N. and Atosona, B. S., 2015. A comparison of six treatments for controlling mortality of keets in the wet season of the Northern Region of Ghana. *Ghana Journal of Science*, 55(1), 15-25.
- Avomyo, F. K., Salifu, S., Panyan, E. K., Al-Hassan, B. I., Ahiagbe, M. and Yeboah, F. K., 2016. Characteristics of guinea fowl production systems in northern Ghana. *Livestock Research for Rural Development*, 28(8), Article 134.
- Ayorinde, K. L., 2007. Body weight increase of indigenous pearl guinea fowl in Nigeria through crossbreeding. *British Poultry Science*, 32(2), 295-301. <https://doi.org/10.1080/00071669108417353>.
- Bessin, R., Belem, A. M. G., Bousini, H., Compaore, Z., Kaboret, Y. and Dembele, M. A., 1998. Causes of young guinea fowl mortality in Burkina Faso. *Revue d'élevage et de médecine vétérinaire des pays tropicaux. The Journal of Animal Husbandry and Veterinary Medicine in Tropical Countries*, 51(1), 87-93.
- Boko, C. K., Kpodekon, M. T., Farougou, S., Dahouda, M., Youssao, A. K. I., Aplogan, G. L., Zanou, J. and Mainil J. G., 2011. Farmer perceptions and pathological constraints in helmeted guinea fowl farming in the Borgou department in North-East Benin. *African Journal of Agricultural Research*, 6(10), 2348-2357.
- R Core Team, 2016. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: <https://www.R-project.org/>.
- Dahouda, M., Toleba, S. S., Youssao, A. K. I., Kogui, S. B., Aboubakari, S. Y. and Hornick, J. L., 2007. Guinea fowl rearing constraints and flock composition under traditional management in Borgou Department, Benin. *Family Poultry*, 17(1&2), 3-14.
- Decuypere, E. and Bruggeman, V., 2007. The endocrine interface of environmental and egg factors affecting chick quality. *Poultry Science*, 86(5), 1037–1042. <https://doi.org/10.1093/ps/86.5.1037>.
- Decuypere, E., Tona, K., Bruggeman, V. and Bamelis, F., 2001. The day-old chick: A crucial hinge between breeders and broilers. *World's Poultry Science Journal*, 57, 127–138.
- Dei, H. K. and Karbo, N., 2004. Improving Small holder Guinea fowl Production in Ghana: A training manual. University for Development Studies, Tamale and Animal Research Institute (CSIR), Nyankpala Station, Tamale, Ghana.
- Dei, H. K., Alidu, I., Otchere, E. O., Donkoh, A., Boa-Amponsem, K. and Adam, I., 2009. Improving the brooding management of local guinea fowl (*Numida meleagris*). *Family Poultry*, 18(1), 3–5.
- Fajemilehin, S. O. K., 2010. Morphostructural characteristics of three varieties of grey-breasted helmeted Guinea fowl in Nigeria. *International Journal of Morphology*, 28(2), 557-562.
- FAO, 1995. Sorghum and millets in human nutrition, FAO Food and Nutrition Series, No. 27, Food and Agriculture Organization of the United Nations, Rome, Italy. ISBN 92-5-103381-1
- FAO, 2007. The state of the Worlds Animal Genetic Resources for Food and Agriculture. Commission on Genetic Resources for Food and Agriculture, Barbara Rischkowsky and Dafydd Piling (Eds.), Food and Agriculture Organization of the United Nations, Rome, Italy.
- FAO, 2014. Poultry Sector Ghana. FAO Animal Production and Health Livestock Country Reviews. No. 6. Food and Agriculture Organization of the United Nations, Rome, Italy.
- Flisar, T., Malovrh, Š., Terčič, D., Holcman, A. and Kovač, M., 2014. Thirty-four generations of divergent selection for 8-week body weight in chickens. *Poultry Science*, 93(1), 16–23. <https://doi.org/10.3382/ps.2013-03464>
- Heier, B. T., Hogasen, H. R. and Jarp, J., 2002. Factors associated with mortality in Norwegian broiler flocks. *Preventive Veterinary Medicine*, 53, 147–157.
- Issaka, B. Y. and Yeboah, N. Y., 2016. Socio-economic attributes of guinea fowl production in two districts in Northern Ghana. *African Journal of Agricultural Research*, 11(14), 1209–1217.
- Kayang, B. B., Youssao, I., Inoue, E., Naazie A., Abe, H., Ito, S. and Inoue-Murayama, M., 2010. Genetic Diversity of Helmeted Guinea fowl (*Numida meleagris*) Based on Microsatellite Analysis. *The Journal of Poultry Science*, 47, 120-124. <https://doi.org/10.2141/jpsa.009103>.
- Khairunnesa, M., Das, S. and Khatun, A., 2016. Hatching and growth performances of guinea fowl under intensive management system. *Progressive Agriculture*, 27(1), 70-77. <https://doi.org/10.3329/pa.v27i1.27544>.
- Kidd, M. T., 2003. A treatise on chicken dam nutrition that impacts on progeny. *World's Poultry Science Journal*, 59, 475–494.
- Kusina, N. T., Saina, H., Kusina, J. F. and Lebel, S., 2012. An insight into guinea fowl rearing practices and productivity by guinea fowl keepers in Zimbabwe. *African Journal of Agricultural Research*, 7(25), 3621-3625.
- Lourens, A., van den Brand, H., Meijerhof, R. and Kemp, B., 2005. Effect of eggshell temperature during incubation on embryo development, hatchability, and posthatch development. *Poultry Science*, 84, 914–920.
- Mohammed, A. and Dei, H. K., 2017. Comparative performance of guinea keets managed under two brooding systems in the Tolon district of Northern Region of Ghana. *UDS International Journal of Development*, 4(1), 42-45.
- Moreki, J. C. and Radikara, M. V., 2013. Challenges to Commercialization of Guinea Fowl in Africa. *International Journal of Science and Research*, 2(11), 436–440.
- Moreki, J. C. and Seabo, D., 2012. Guinea fowl production in Botswana. *Journal of World's Poultry Research*, 2(1), 1-4.
- Nahashon, S. N., Aggrey, S. E., Adefope, N. A., Amenyenu, A. and Wright, D., 2006. Growth Characteristics of Pearl Gray Guinea Fowl as Predicted by the Richards, Gompertz, and Logistic Models. *Poultry Science*, 85, 359–363.
- Nahashon, S. N., Adefope, N. A., Amenyenu, A. and Wright, D., 2007. Effect of Varying Concentrations of Dietary Crude Protein and Metabolizable Energy on Laying Performance of Pearl Grey Guinea Fowl Hens. *Poultry Science*, 86, 1793–1799. <https://doi.org/10.1093/ps/86.8.1793>
- Newbold, S., 1926. A historical note on the guinea-fowl. *Sudan Notes and Records*, 9(1), 125-129.
- Noy, Y. and Sklan, D., 1997. Posthatch development in poultry. *Journal of Applied Poultry Research*, 6(3), 344–354. <https://doi.org/10.1093/japr/6.3.344>
- Ogah, D. M., 2013. Variability in Body Shape characters in an indigenous guinea fowl (*Numida meleagris* L.). *Slovak Journal of Animal Science*, 46(3), 110-114.
- Peebles, E. D., Doyle, S. M., Pansky, T., Gerard, P. D., Latour, M. A., Boyle, C. R. and Smith, T.W., 1999. Effects of breeder age and dietary fat on subsequent broiler performance, Growth, mortality, and feed conversion. *Poultry Science*, 78, 505–511.

- Reis, L. H., Gama, L. T. and Soares, M. C., 1997. Effects of short storage conditions and broiler breeder age on hatchability, hatching time and chick weight. *Poultry Science*, 76, 1459–1466.
- Teye, G. A. and Adam, M., 2000. Constraints to Guinea fowl production in northern Ghana: A case study of the Damongo area. *Ghanaian Journal of Agricultural Science*, 33, 153–157.
- Tona, K., Bamelis, F., De Ketelaere, B., Bruggeman, V., Moraes, V. M. B., Buyse, J., Onagbesan, O. and Decuypere, E., 2003. Effects of egg storage time on spread of hatch, chick quality, and chick juvenile growth. *Poultry Science*, 82, 736–741.
- Tona, K., Onagbesan, O., De Ketelaere, B., Decuypere, E. and Bruggeman, V., 2004. Effects of age of broiler breeders and egg storage on egg quality, hatchability, chick quality, chick weight, and chick posthatch growth to forty-two days. *Journal of Applied Poultry Research*, 13(1), 10–18. <https://doi.org/10.1093/japr/13.1.10>.
- Yassin, H., Velthuis, A. G. J., Boerjan, M. and van Riel, J., 2009. Field study on broilers' first-week mortality. *Poultry Science*, 88, 798–804. <https://doi.org/10.3382/ps.2008-00292>.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.