Review [Revisión]

FACTORS AFFECTING PRODUCTIVE PERFORMANCE OF GUINEA FOWL: A REVIEW †

[FACTORES QUE AFECTAN EL DESEMPEÑO PRODUCTIVO DE LA GALLINA DE GUINEA: UNA REVISIÓN]

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SUMMARY

Background. Guinea fowl (*Numida meleagris)* is used as an alternative for the production of meat with high nutritional value; however, there are several factors that affect their productive performance. **Objective.** Review the main factors that affect the productive performance of the guinea fowl described in the worldwide literature. **Methodology.** A bibliographic review in the databases of Scopus, NCBI, Springer, Science direct, Google Scholar, Redalyc, and other repositories was carried out. The keywords for the search were: Guinea fowl, *Numida meleagris*, productive performance and body weight gain. **Results.** The production system is one of the main factors that affect the productive performance of the Guinea fowl. Birds raised in semi-intensive conditions have better weight gains compared to those that are kept under an extensive system. Mortality in the extensive system increases due to poor or no disease prevention practices and natural predators. The increase in population density under intensive management conditions negatively affects the performance and welfare of Guinea fowl. Ignorance of the energy and protein requirements causes a deficient productive performance in weight gains. Genetic factors also play a role; in Africa local varieties that have not been genetically improved are bred in extensive systems obtaining low yields, compared to developing countries. Birds hatch from large eggs with shorter storage periods had better growth performance. **Implications.** There is limited information on the main aspects related to the raising of the Guinea fowl, including the factors that affect its productive performance. Ignorance of the productive parameters favors the displacement of Guinea fowl production by other poultry species, such as chicken. **Conclusions.** Breeding the Guinea fowl as an alternative for meat and egg production must be accompanied by the disclosure of productive parameters to improve their production performance.
Key words: body weight; growth; *Numida meleagris*; semi-intensive conditions; weight gain.

RESUMEN

Antecedentes. La gallina de Guinea (*Numida meleagris)* se utiliza como alternativa para la producción de carne con alto valor nutritivo; sin embargo, existen varios factores que afectan su desempeño productivo**. Objetivo.** Revisar los principales factores que afectan el desempeño productivo de la gallina de Guinea descritos en la literature a nivel mundial. **Metodología.** Se realizó una revisión bibliográfica en las bases de datos de Scopus, NCBI, Springer, Science direct, Google Scholar, Redalyc y otros repositorios. Las palabras clave para la búsqueda fueron: gallina de Guinea, *Numida meleagris*, rendimiento productivo y ganancia de peso corporal. **Resultados.** El sistema de producción es uno de los principales factores que afectan el rendimiento productivo de la gallina de Guinea. Las aves criadas en condiciones semi-intensivas tienen mejores ganancias de peso en comparación con

† *Submitted June 22, 2021 – Accepted April 14, 2022.* http://doi.org/10.56369/tsaes.3861

ISSN: 1870-0462.

las que son mantenidas bajo un sistema extensivo. La mortalidad en el sistema extensivo se incrementa debido a las deficientes o nulas prácticas de prevención de enfermedades y los depredadores naturales. El aumento en la densidad de población bajo condiciones de manejo intensivas afecta negativamente el rendimiento y el bienestar de las gallinas de Guinea. El desconocimiento de los requerimientos de energía y proteína, provocan un deficiente rendimiento productivo en las ganancias de peso. Los factores genéticos también influyen, en África las variedades locales que no han sido mejoradas genéticamente son criadas en sistemas extensivos obteniendo bajos rendimientos, en comparación con países en desarrollo. Las aves que nacen de huevos grandes y de periodos de almacenamiento cortos tuvieron un mejor rendimiento de crecimiento. **Implicaciones.** Existe información limitada sobre los principales aspectos relacionados con la crianza de la gallina de Guinea, incluyendo los factores que afectan su desempeño productivo. El desconocimiento de los parámetros productivos, favorece el desplazamiento en la producción de las Gallinas de Guinea por otras especies avícolas, como el pollo. **Conclusiones.** La crianza de la gallina de Guinea como alternativa para la producción de carne y huevo debe ir acompañada de la divulgación de parámetros productivos para mejorar su desempeño productivo.
Palabras clave: peso corporal; crecimiento; *Numida meleagris*; condiciones semi-intensivas; ganancia de peso.

INTRODUCTION

Guinea fowl or “helmeted guineafowl” is a poultry species native to Africa. Its name derives from the coast of Guinea in West Africa, where it is believed to have originated (Issaka and Yeboah, 2016). In recent years, the Guinea fowl was introduced to various parts of the world (Madzimure *et al*., 2011), where different common dual-purpose varieties of it are used, such as Pearl Grey, Lavender, Royal Purple, and White (Kgwatalala *et al.,* 2020), and specialized varieties, such as the French (Nahashon *et al*., 2006a).

In Africa, Guinea fowl production is mainly practiced under semi-intensive or extensive production systems (traditional or free range), at the subsistence level and with few system inputs (Issaka and Yeboah, 2016; Abdul-Rahman *et al*., 2017; Zvakare *et al*., 2018; Kouassi *et al*., 2019; Soara *et al*., 2020). On the other hand, in countries such as France, Italy, the United States, Belgium, and Scandinavian countries, Guinea fowl production is carried out under intensive systems (Nahashon *et al*., 2009; Bernacki *et al*., 2012). In the United States, for example, interest in Guinea fowl as an alternative to produce meat has been increasing. In fact, in such country, numidiculture has proven to be a profitable activity (Nahashon *et al*., 2006a), due to the nutritional value and yield of the guinea fowl carcass, reported by various authors (Mareko *et al*., 2006; Kokoszynski *et al*., 2011; Bernacki *et al*., 2012; Hoffman and Tlhong, 2012; Camas-Robles *et al*., 2020), standing out for its delicacy and flavor, compared to chicken, turkey, and duck meat (Araújo *et al.,* 2019). Likewise, Guinea fowl eggs are gaining relevance in the US market as an alternative for the production of eggs for dishes (Nahashon *et al*., 2006b). Other important characteristics of Guinea fowl are their good adaptability, high resistance to some common diseases in poultry, and low production costs (Agwunobi and Ekpenyong, 1990; Abdul-Rahman *et al*., 2017).

Because Guinea fowl is a poorly known poultry, many parameters involved in its production and performance are still unknown, including the factors that affect them (Kgwatalala *et al*., 2020; Ahiagbe *et al*., 2021). Previously, Nwagu (1997) researched the factors that affect the fertility and hatchability of Guinea fowl eggs in Nigeria. In this regard, some authors (Issaka and Yeboah, 2016; Koné *et al*., 2018; Zvakare *et al*., 2018) identified that low productivity in guinea fowl production in African countries is related to the lack of knowledge of producers on the adequate management of the flocks, a situation that limits their performance. Therefore, to improve the productive performance of the Guinea fowl, as well as the quality of its products, it is important that farmers and technicians understand the factors that affect this type of birds. In this sense, the present paper reviews the available scientific literature regarding the main factors that affect the productive performance of Guinea fowl in worldwide production.

METHODOLOGY

A bibliographic review was carried out in the most important databases worldwide, including Scopus, NCBI, Springer, Science direct, Google Scholar, Redalyc, and other repositories. The information search period was in the months of August 2020 to June 2021. Scientific articles, electronic books, disclosure reports, conference abstracts, written mainly in english, were considered. Keywords in english and their equivalents in spanish were used to carry out the search, these were: Guinea fowl, *Numida meleagris*, productive performance and body weight gain. Those papers that were not specific to the poultry species of interest were excluded.

FACTORS AFFECTING THE PRODUCTIVE PERFORMANCE

In poultry, the evaluation of the productive performance is based on measuring some parameters, such as the growth rate measured as body weight gain (BWG), feed intake (FI), and feed conversion ratio (FCR), among important traits (Al-Marzooqi *et al*., 2019). It is known that Guinea fowl have a lower productive performance than chickens. Consequently, it costs significantly less to produce 1 kg of chicken meat than it does for Guinea fowl meat; however, Guinea meat shows better nutritional quality (Agwunobi and Ekpenyong, 1990). Many factors influence the productive performance of the Guinea fowl, including external factors such as the type of production system, the type of housing, and some management practices. In addition, some factors have a permanent long-term influence, such as nutrition, genotype, and pre-incubation and incubation conditions. Some of these factors are described below.

PRODUCTION SYSTEMS AND HOUSING TYPE

As mentioned before, the predominant production system in Guinea fowl rearing throughout the world is the extensive. In this system the birds are kept free or in open-air poultry houses. However, the extensive production system represents an important challenge in Guinea fowl production (Moreki and Radikara, 2013). Precarious conditions, malnutrition and poor infrastructure compromise the productive performance of the birds (Zvakare *et al*., 2018). Additionally, poor or no disease prevention practices and natural predators contribute to high mortality rates (Saina *et al*., 2005). Various authors (Nwagu and Alawa, 1995; Saina *et al*., 2005; Issaka and Yeboah, 2016; Kouassi *et al*., 2019; Adu-Aboagye *et al*. 2020) identified that high mortality rates (40-60%) are the main limitation for the reproduction of Guinea fowl. According to Ahiagbe *et al*. (2021), the high rate of keet mortality in the first weeks post-hatch 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.

In Vietnam (Dong Xuan *et al*., 2015), Benin (Houndonougbo *et al*., 2017a), and Turkey (Yamak *et al*., 2018), it was reported that Guinea fowl kept under a semi-intensive production system (in confinement), showed higher BWG, compared to that recorded in extensively reared Guinea fowl (1610 g vs 1269 g, 825.9 g vs 622.8 g, and 979.23 g vs 953.59 g, respectively). This is in line with the results reported in intensive rearing (Nahashon *et al*., 2006a, 2009; Nobo *et al*., 2012; Khairunnesa *et al*., 2016; Houndonougbo *et al*., 2017b) and semi-intensive or extensive rearing (Ahiagbe *et al*., 2021) of Guinea fowl. These studies also allowed to identify that the birds raised under an extensive production system had a higher FI and, consequently, a lower FCR. The differences in the productive parameters reported between the studies could be due to the nutrition, variety or genotype used, even to the Genotype × Environment interactions. The latter occurs when a breed or genotype that performed better in one system may not perform better in another system of the same magnitude (Bekele *et al*., 2009). The above suggests that confinement could be more efficient and profitable than the extensive production system. This is important given that live weight is an important factor, and is directly related to profitability in the breeding of Guinea fowl, since the market price of poultry (for meat production) is determined chiefly by this traits (Khairunnesa *et al*., 2016).

The type of housing influences to some extent the productive performance of poultry, Oke *et al*. (2015) evaluated the effects of three types of housing (open air, deep-bed, and battery cage) on the BWG of Guinea fowls. The results showed that the body weight of the birds kept in the open air was similar to that of the deep-bed hens, but significantly higher than that registered in the birds reared in battery cages. According to those authors, the low performance shown by Guinea fowl kept in battery cages could be due to stress levels, since they also determined that rectal temperature, breathing rate, and blood glucose levels were significantly higher in these birds. The study showed that conventional battery cage systems are not suitable for housing guinea fowl. Janneke de Jonge and van Trijp, (2013), Zhao *et al*., (2014) and Sánchez-Casanova *et al*., (2020) in chicken reported the positive effect that “open-air” production systems have on the well-being of chickens; however, yield, meat quality, and mortality rate are compromised to some extent. For example, Sarica et al. (2019) reported higher yellowness (b^*) values of breast meat in Guinea fowl raised in a free-range system compared to those raised indoors (7.55 vs 6.59). The authors cited indicate that the higher b^* value obtained in breast meat could be due to higher fat content, as well as physical exercise during grazing.

Population density is one of the main housing factors that influences the development of poultry (Sánchez-Casanova *et al*., 2020). Previously, it was reported that a higher population density affects the welfare of poultry, by reducing the allocation of feeder space; consequently, aggression, chronic stress, and even mortality could be induced (Thogerson *et al*., 2009). Population density varies between species or varieties and is calculated based on body mass (in kg) per unit of housing space (in m^2/cm^2) (Thaxton *et al*., 2006). Oke *et al*. (2020) evaluated three population densities (14 birds/m^2, 16 birds/m^2, 18 birds/m^2, and 20 birds/m^2) on the productive performance and welfare of African Guinea fowl, finding that the BWG of the birds kept at 14 birds/m^2 and 16 birds/m^2, obtained week 16 of age was significantly higher than the other stock densities. Likewise, both the FI of the birds and the ratio of heterophiles/lymphocytes increased significantly as did population density. The authors concluded that a population density greater than 16 birds/m^2 negatively affects the performance and well-being of the Guinea fowl; the latter evaluated by the heterophile/lymphocyte ratio, which is accepted as a measure of the physiological response of immunosuppression and stress (Círule *et al*., 2012). For the case of Guinea pullets of the Pearl Grey variety for replacement, Nahashon *et al*. (2011)

determined that the optimal population density should be approximately 18 birds/m^2, since it allows to obtain a better BWG and FCR per area. On the other hand, in laying guinea fowls, a density of 1 bird/cage (1394 cm^2/bird) significantly improves egg production per bird (Nahashon *et al*., 2006b).

NUTRITION

One of the main problems that Guinea fowl production faces in developing countries is inadequate nutrition (Okyere *et al*., 2020). In fact, the literature regarding nutritional factors that impact Guinea fowl productivity is scarce. Energy and crude protein (CP) are very important nutrients for poultry. Energy is used for the proper functioning of the body, and can be obtained from simple carbohydrates, fats, and proteins, while the function of dietary protein is to supply amino acids for maintenance, muscle growth, and the synthesis of egg protein. Metabolizable energy (ME) is the conventional measure of the available energy content of feed ingredients and poultry requirements (Ravindran, 2013).

Nahashon *et al*. (2005) evaluated three concentrations of ME (3050 kcal/kg, 3100 kcal/kg, and 3150 kcal/kg) and CP (21 %, 23 %, and 25%) in the diet on the productive performance of French Guinea fowl. The results showed that the birds fed the diet containing 3100 ME/kg and 3150 kcal ME/kg had a higher BWG and lower FI and FCR ($p<0.05$). Furthermore, the FI of birds fed diets with 25% CP was significantly higher than the other concentrations of CP in the diet. BWG and FCR were better in birds fed diets with 25 % and 23% CP. The study allowed to determine that diets based on 3100 kcal ME/kg and 23% CP or with 3150 kcal ME/kg and 21% CP can be used efficiently by French Guinea fowls. Nahashon *et al*. (2006c) found effect of three concentrations of ME (2900 kcal/kg, 3000 kcal/kg, and 3100 kcal/kg) and CP (17 %, 19 %, and 21%) in the diet on the growth of Guinea fowl keets from the Pearl Grey variety. The study showed that the birds fed with 2900 ME/kg and 3000 kcal ME/kg of feed and with diets of 24 % and 21% CP showed higher FI. BWG rates were significantly higher in birds fed 3000 kcal ME/kg, 3000/3100 kcal ME/kg, and 3100/3200 kcal ME/kg. Birds that received diets with 24% and 21% CP also showed a higher BWG. The FI proportions were lower in birds fed 3000 kcal ME/kg, 3100 kcal ME/kg, and 3100/3200 kcal ME/kg of diet. Likewise, keets fed diets with 17 % or 19% CP showed lower FCR. Therefore, diets containing 3000 kcal ME/kg and 3100 kcal ME/kg can be used more efficiently by Pearl Grey Guinea fowl keets aged 0-5 weeks and 5-16 weeks, respectively. Furthermore, these birds used most efficiently the diets containing 24 % and 17% CP at 0 weeks to 8 weeks and 9 weeks to 16 weeks of age, respectively. Seabo *et al*. (2011) study the effects of different levels of CP (14 %, 16 %, and 18%), all with the same energy level, 2800 kcal/kg, on the growth of Guinea fowl reared under intensively condition, from week 6 to week 12. The study identified that FI increased significantly with increasing levels of 16% and 18% CP; consequently, BWG also increased significantly between treatments. In turn, FCR improved significantly as CP levels increased. Recently, Okyere *et al*. (2020) determined the effect of diets with different CP percentages (16, 18, 20, and 22) on the growth performance of indigenous Guinea fowl in Ghana. Birds fed diets containing 22% crude protein (CP) were found to show higher BWG. FI increased significantly with the increase of CP in the diets. Based on these results, it is recommended that producers of native Guinea fowl use diets based on a 22% CP content and 3000 kcal ME/kg to 3150 kcal ME/kg during the growth stage to optimize productivity.

Amino acids are essential for the formation of proteins that participate in the physiological processes of poultry. However, not all the necessary amino acids are found in sufficient quantity, so they can be supplied in diets with the aim of improving the productive performance of animals (Ravindran, 2013). For example, Bhogoju *et al*. (2017) evaluated the effect of different concentrations of digestible lysine (0.80 %, 0.86 %, 0.92 %, 0.98 %, 1.04 %, 1.10 %, 1.16 %, and 1.22%) on the productive performance of Pearl Grey Guinea hens. Females showed better performance with diets based on 1.04 % and 0.80% lysine, during weeks 0 to 4 and 5 to 12, respectively. On the other hand, males responded better to diets containing 1.10 % and 0.80% lysine at the same age of females. Therefore, it is recommended to use these concentrations of lysine to feed these birds. In another study (Gholipour *et al*., 2019) determined the effects of dietary supplementation of L-glutamine (0.5 % and 1%) on the productive performance of Guinea fowl. As expected, BWG was higher in the L-glutamine supplemented treatments. The best FCR was obtained with the diet supplemented with 0.5% L-glutamine; additionally, the intestinal morphometry of the birds was significantly improved.

GENETICS

Establishment of selection programs for improvement in growth and productivity requires the estimation of genetic parameters for these traits. However, there are very few studies on the estimation of the genetic parameters in Guinea fowl (Shoyombo *et al*., 2021). Ebegbulem and Okon (2018) reported, in Nigerian Guinea fowl, that heritability for body weight ranged from 0.40 to 0.81, while repeatability estimates were at a range of 0.20 to 0.40 at 8 weeks and 12 weeks of age. In the same way, Doudu *et al*. (2020) conducted a study to estimate heritability of body weight and body weight gain in indigenous Guinea fowls and found that heritability values for body weight decreased with the age of the birds. The heritability estimates of body weight gain on the other hand did not follow a particular trend with respect to age in both sexes. However, these were moderate at month 2 (0.66) and 6 (0.48) but low at month 4 (0.54) and 8 (0.34) in the males, whereas in the female counterparts the estimates were moderate at month 2 (0.70) and 4 (0.46) and low at 6 (0.38) and 8 (0.32). Heritability estimates for feed intake were low in the males (0.28) and females (0.36). FCR heritability estimates were higher in females compared to males (0.44 vs 0.40). A recent study (Agbolosu 2021) reported that the heritability estimates of body weight for Guinea fowl were low (0.06 for BW to 36 weeks) to moderate (0.51 for BW to 32 weeks). The heritability estimate for BW to 20 weeks was zero. Estimates of heritability for growth rates were medium (0.39 for daily gain from 4 to 8 weeks) to high (0.78 for daily gain from 8 to 12 weeks), except post brooding daily gain from 8 to 20 weeks which had a low heritability value (0.22).

In poultry, there are several factors associated with the genetic structure (genotype, breed, variety, line, lineage, among others) that impact growth performance and productivity (Benyi *et al*., 2015). In the literature, different BWG rates are reported for different varieties and/or ecotypes of Guinea fowl throughout the world (Table 1), which suggests that the genetic of Guinea fowl has an important effect on the performance. Fajemilehin (2010) determined the effect of the variety (Pearl, Ash, and Black) on the BWG of Guinea fowl. Keets of the Pearl variety had a lower body weight than the rest at birth (week 0); however, this handicap was overcome between 6 and 10 weeks of age. Thereafter and until week 28, the Guinea Pearl hens showed the highest BWG. Later, Bernacki *et al*. (2013) compared the growth performance of two varieties of Guinea fowl (White and Pearl). The BWG of the White Guinea fowl was significantly higher through the 4 weeks of the study. From week 8 to 12, the Pearl Guinea fowl showed a higher BWG; however, these birds presented a higher FI throughout the experiment. In another study by Szalay *et al*. (2016), BWG and FCR were compared between two Hungarian Guinea Landrace fowl ecotypes: Godollo and Hortobagy, and a local ecotype. The highest BWG and the lowest FCR at 14 weeks of age were obtained in Guinea fowl of the Godollo ecotype. Therefore, the authors suggest the use of this ecotype for meat production. In Africa, the Guinea fowls used in poultry production systems are mainly of local varieties, so they have not yet been genetically improved. Houndonougbo *et al*. (2017a) evaluated the growth performance of three local varieties of Guinea fowl (Common, Bonaparte, and White) in regions of Benin. The results showed that variety had a significant effect on the BWG of the birds. The highest body weights at week 12 were observed for the White Guinea fowl, while the lowest weights were those of the Bonaparte Guinea fowl. Duodu *et al*. (2018) also reported the effect Pearl, Lavender, White, and Black varities on the productivity of indigenous Guinea fowl from Ghana. It was determined that in week 8 the Pearl and White fowl showed a significantly higher BWG; however, at 16, 24, and 32 weeks of age, the BWG was significantly higher in Pearl Guinea fowl. Regarding the FI and FCR, there were no significant differences among varieties. According to those authors, the findings obtained should be used in selection or crossbreeding programs to improve the productivity of this poultry species. In this sense, Kgwatalala *et al*. (2020) recently reported on the growth evaluation of crossed Guinea fowl (Royal purple × White) in

Table 1. Mean body weight gains registered in some varieties/ecotypes of Guinea fowl at week 12 of age in different countries around the world.

Variety/ecotype	Country	Mean BWG (g)	References
Pearl	Nigeria	510.41	Fajemilehin (2010)
Ash		466.93	
Black		478.09	
White	Poland	1054.00	Bernacki et al (2013)
Pearl		1081.00	
Godollo	Hungary	1311.18*	Szalay et al (2016)
Hortobagy		1219.43*	
Local		1153.53*	
Common	Benin	626.56	Houndonougbo et al (2017a)
Bonaparte		563.36	
White		687.10	
Pearl	Ghana	768.00	Duodu et al (2018)
Lavender		695.00	
White		714.00	
Black		694.00	
Royal purple	Botswana	1129.39	Kgwatalala et al (2020)
White		979.83	
Crossbred (Royal purple×White)		1082.71	
Common	Mexico	1161.56*	Camas-Robles et al (2020)

*BWG was registered at week 14 of age.

relation to the purebred parent varieties. However, there were no significant differences between the BWG of males and females of the three varieties at all ages. However, Royal purple males showed a higher BWG than White males from week 12 to week 16 of age. Therefore, the crossing was effective in improving the growth of the White variety, but had no beneficial effect on the growth of the Royal purple variety. Other study (Ebegbulem and Asuquo, 2018) was carried out to evaluate the growth performance of the Black and Pearl guinea fowl and their crosses. The following three mating groups were established: Pearl male × Pearl female (P×P), Black male × Black female (B×B) and Black male × Pearl female (B×P). The results of the study showed that all the growth performance traits studied did not differ significantly across the genotype groups, except body weight at 10, 12 and 14 weeks of age, with higher values for birds of the P×P pure line.

EGG SIZE AND STORAGE

Some egg characteristics and incubation conditions can guarantee better early growth performance of poultry (Boleli *et al*., 2016). The weight and size of the egg are important characteristics that influence the performance of keets after hatching, so they have an important economic impact (Iqbal *et al*., 2017). Oke *et al*. (2012) evaluated the effects of egg size (25-36 g, and 37-47 g) on the early growth of two varieties of Guinea fowl (Pearl and Lavender) reared in humid tropic conditions. Keets hatched from heavier eggs were significantly heavier than those from the low egg weight, from week 3 to week 9 of age. Likewise, they showed a lower feed conversion rate, which suggests that the birds from heavier egg group were more efficient. Similarly, Kyere *et al*. (2017) evaluated the early growth of Guinea fowl, but from eggs of three sizes (23-39 g, 40-42 g, and 43-49 g), identified as small, medium, and large, respectively. The results showed that the keets hatched from large and medium eggs presented a higher FI; consequently, they obtained a higher BWG. However, the medium egg keets showed better FCR. The authors attribute such results to the fact that large egg keets tend to be born with a higher body weight, therefore, they show a higher food intake to maintain themselves physiologically. The previous results suggest that producers should select eggs of a larger size (between 37g to 47 g), to guarantee good growth performance in Guinea fowl.

Several studies have shown that the storage time of eggs before incubation affects also the quality and early performance of keets (Ruiz and Lunam, 2002; Tona *et al*., 2003; Goliomytis *et al*., 2015). As for the Guinea fowl, little has been evaluated regarding this factor. Recently, Kouame *et al*. (2019, 2020) researched the effects of the storage time of hatching eggs on the juvenile growth of Guinea fowl. The eggs were stored 3 d, 7 d, 11 d, and 15 d~~days~~ before incubation. This study allowed to identify that keets hatched from eggs stored for 3 d and 7 d~~ays~~ showed a higher BWG than eggs stored for 11 d~~ays~~. FI did not differ between treatments; however, FCR was significantly higher in the 15-day-old egg group. This suggests that storing guinea fowl hatching eggs for more than 7 d~~ays~~ negatively affects post-hatching growth.

CONCLUSION

Guinea fowl under semi-intensive conditions will be more efficient and profitable if they are provided open-air housing, while maintaining good animal welfare, with a maximum density of 16 birds/m^2. Diets must contain at least 22% crude protein and 3000 to 3100 kcal ME/kg during the growth stage. The White Guinea fowl variety is outstanding in productive performance; however, it is necessary to take advantage of selection programs or crossing local varieties with better adaptability to improve their productivity. The eggs selected for incubation should be greater than 37 g in weight, to obtain better juvenile growth of the Guinea fowl. The storage at 18 °C and relative humidity of 70% of the eggs should not be longer than 7 d~~ays~~ to obtain better weight gain of the keets. Breeding the Guinea fowl as an alternative for meat and egg production must be accompanied by the disclosure of productive parameters to improve their production performance.

Founding. The authors declare that did not receive funding

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

Compliance with ethical standards. Due to the nature of the work (review), the authors have nothing to declare.

Data availability. All the works reviewed are cited in the present work.

Author contribution statement (CRediT). R. Portillo-Salgado – conceptualization, investigation, methodology, writing, original draft., **J. Bautista-Ortega** – writing, supervision, original draft., **A.J. Chay-Canul** – writing, supervision., **R.E. Sánchez-Casanova** – writing, review & editing., **J.C. Segura-Correa** –review & editing., **F.A. Cigarroa-Vázquez** – methodology, supervisión, writing, original draft.

REFERENCES

Adu-Aboagye, G., Nyameasem, J.K., Ahiagbe, K.M.J., Ansah, K.O., Zagbede, G.A. and Agbe, K.K., 2020. Reproductive traits of the indigenous Guinea fowl under tropical humid conditions; the effect of egg size. *Livestock Research for Rural Development*, Volume 32, Article #55. Retrieved June 15, 2021, from http://www.lrrd.org/lrrd32/4/gadua32055.html

Agbolosu, A.A., 2021. Genetic Parameters of Growth Traits of Indigenous Guinea Fowls (*Numida meleagris galeatea*) from Northern Ghana. *Asian Journal of Research in Animal and Veterinary Sciences*, 8(4), pp. 121–130. https://www.journalajravs.com/index.php/AJRAVS/article/view/30176/56628

Agwunobi, L.N. and Ekpenyong, T.E., 1990. Nutritive and economic value of Guinea fowl (*Numida meleagris*) production in developing countries. *Journal of the Science of Food and Agriculture*, 52, pp. 301–308. https://doi.org/10.1002/jsfa.2740520303

Ahiagbe, K.M.J., Amuzu-Aweh, E.N., Bonney, P., Nyameasem, J.K., Avornyo, F.K., Adenyo, C., Amoah, K.O., Naazie, A. and Kayang, B.B., 2021. Comparison of early growth and survivability in indigenous guinea fowls from Northern Ghana. *Tropical Animal Health and Production*, 53, pp. 89. https://doi.org/10.1007/s11250-020-02510-4

Al-Marzooqi, W., Al-Maskari, Z.A.S., Johnson, E.H., Al-Kharousi, K., Mahgoub, O., Al-Saqri, N.M. and El Tahir, Y., 2019. Comparative evaluation of growth performance, meat quality and intestinal development of indigenous and commercial chicken strains. *International Journal of Poultry Science*, 18, pp. 174–180. https://dx.doi.org/10.3923/ijps.2019.174.180

Araújo, I.C.S., Lucas, L.R., Machado, J.P. and Mesquita, M.A., 2019. Macroscopic embryonic development of Guinea fowl compared to other domestic bird species. *Revista Brasileira de Zootecnia*, 48: e20190056. http://doi.org/10.1590/rbz4820190056

Abdul-Rahman, I.I. and Adu, Y.E., 2017. The role of the rural farmer in guinea fowl Numida meleagris value chain, a case study of the Tolon district. *Livestock Research for Rural Development*, Volume 29, Article #72. Retrieved June 15, 2021, from http://www.lrrd.org/lrrd29/4/iddr29072.html

Ahiagbe, K.M.J., Amuzu-Aweh, E.N., Bonney, P., Nyameasem, J.K., Avornyo, F.K., Adenyo, C., Amoah, K.O., Naazie, A. and Kayang, B.B., 2021. Comparison of early growth and survivability in indigenous guinea fowls from Northern Ghana. *Tropical Animal Health and Production*, 53, 89. https://doi.org/10.1007/s11250-020-02510-4

Bekele, F., Gjoen, H.M., Kathle, J., Adnoy, T. and Abebe, G., 2009. Genotype X environment interaction in two breeds of chickens kept under two management systems in Southern Ethiopia. *Tropical Animal Health and Production*, 41, pp. 1101–1114. https://doi.org/10.1007/s11250-008-9290-7

Benyi, K., Tshilate, T.S., Netshipale, A.J. and Mahlako, K.T., 2015. Effects of genotype and sex on the growth performance and carcass characteristics of broiler chickens. *Tropical Animal Health and Production*, 47, pp. 1225–1231. https://doi.org/10.1007/s11250-015-0850-3

Bernacki, Z., Bawej, M. and Kokoszyński, D., 2012. Quality of meat from two guinea fowl (*Numida meleagris*) varieties. *Archiv fur Geflugelkunde*, 76(3), pp. 203–207. https://www.european-poultry-science.com/Quality-of-meat-from-two-guinea-fowl-span-classws-name-Numida-meleagrisspan-varieties,QUlEPTQyMjA5NDEmTUlEPTE2MTAxNA.html

Bernacki, Z., Kokoszynski, D. and Bawej, M., 2013. Evaluation of some meat traits in two Guinea fowl genotypes. *Archiv fur Geflugelkunde*, 77(S), pp. 116–122. https://www.european-poultry-science.com/Evaluation-of-some-meat-traits-in-two-guinea-fowl-genotypes,QUlEPTQyMjEyMzYmTUlEPTE2MTAxNA.html

Bhogoju, S., Nahashon, S.N., Donkor, J., Kimathi, B., Johnson, D., Khwatenge, C. and Bowden-Taylor, T., 2017. Effect of varying dietary concentrations of lysine on growth performance of the Pearl Grey guinea fowl. *Poultry Science*, 96, pp. 1306–1315. https://doi.org/10.3382/ps/pew395

Boleli, I.C., Morita, V.S., Matos Jr, J.B., Thimotheo, M. and Almeida, V.R., 2016. Poultry egg incubation: Integrating and optimizing production efficiency. *Brazilian Journal of Poultry Science*, Special Issue 2 Incubation / 001-016. https://doi.org/10.1590/1806-9061-2016-0292

Camas-Robles, G., Ruiz-Sesma, B., Mendoza-Nazar, P., Portillo-Salgado, R., Hernández-Marín, A. and Cigarroa-Vázquez, F., 2020. Productive behavior and composition of the carcass of the Guinea fowl (*Numida meleagris*). *Abanico Veterinario*, 10, pp. 1-14. http://dx.doi.org/10.21929/abavet2020.34

Cīrule, D., Krama, T., Vrublevska, J., Rantala, M.J. and Krams, I., 2011. A rapid effect of handling on counts of white blood cells in a wintering passerine bird: a more practical measure of stress? *Journal of Ornithology*, 153(1), pp. 161-166. http://dx.doi.org/10.1007/s10336-011-0719-9

Dong Xuan, K.D.T., Szalay, I., Duc Tien, P., Minh Thu, P.T. and Lan Phuong, T.N., 2015. Production studies of a Guinea fowl variety of hungarian origin in the tropical regions of Vietnam. *Athens Journal of Sciences*, 2(3), pp. 203-212. https://doi.org/10.30958/ajs.2-3-4

Duodu, A., Annor, S. Y., Kagya-Agyemang, J.K. and Kyere, C.G., 2018 Influence of strain on production and some other traits of indigenous Guinea fowls (*Numida meleagris*) in Ghana. *Current Journal of Applied Science and Technology*, 30(2), pp. 1-7. https://doi.org/10.9734/CJAST/2018/44123

Doudu, A., Annor, S.Y., Kagya-Agyemang, J.K., Zagbede, G.A. and Kyere, C.G., 2020. Phenotypic and Genetic Parameter Estimates for Local Guinea Fowl Production and Some Other Traits. *Asian Journal of Biochemistry, Genetics and Molecular Biology*, 4(1), pp. 1-12. https://doi.org/10.9734/ajbgmb/2020/v4i130095

Ebegbulem, V.N. and Asuquo, B.O., 2018. Growth performance and carcass characteristics of the Black and Pearl Guinea fowl (*Numida meleagris*) and their crosses. *Global Journal of Pure and Applied Sciences*, 24, pp. 11-16. https://dx.doi.org/10.4314/gjpas.v24i1.2

Ebegbulem, V.N. and Okon, B., 2018. Genetic Parameter Estimates of Guinea Fowl (*Numida Meleagris*) in South-South Region of Nigeria. *Journal of Ethology & Animal Science*, 1(1). https://medwinpublishers.com/JEASc/JEASc16000103.pdf

Fajemilehin, S.O.K. 2010. Morphostructural characteristics of three varieties of greybreasted helmeted Guinea fowl in Nigeria. *Internationa Journal of Morphology*, 28(2), pp. 557-562. https://scielo.conicyt.cl/scielo.php?script=sci_abstract&pid=S0717-95022010000200036&lng=en&nrm=iso

Gholipour, V., Chamani, M., Shahryar, H.A., Sadeghi, A. and Aminafshar, M., 2019. Effects of dietary L-glutamine supplement on performance, characteristics of the carcase and intestinal morphometry in guinea fowl chickens (*Numida meleagris*). *Italian Journal of Animal Science*, 18(1), pp. 513–521. https://doi.org/10.1080/1828051X.2018.1544856

Goliomytis, M., Tsipouzian, T. and Hager-Theodorides, A.L., 2015. Effects of egg storage on hatchability, chick quality, performance andimmunocompetence parameters of broiler chickens. *Poultry Science*, 94, pp. 2257–2265. https://doi.org/10.3382/ps/pev200

Hoffman, L.C. and Tlhong, T.M., 2012. Proximate and fatty acid composition and colesterol content of different cuts of guinea fowl meat as affected by cooking method. *Journal of Science of Food Agriculture*, https://doi.org/10.1002/jsfa.5682

Houndonougbo, P.V., Chrysostome, C.A.A.M., Mota, R.R., Hammami, H., Bindelle, J. and Gengler, N., 2017a. Phenotypic, socio-economic and growth features of Guinea fowls raised under different village systems in West Africa. *African Journal of Agricultural Research*, 12(26), pp. 2232–2241. https://doi.org/10.5897/AJAR2017.12411

Houndonougbo, P.V., Mota, R.R., Chrysostome, A.A.C., Bindelle, J., Hammami, H. and Gengler, N., 2017b. Growth and carcass performances of guinea fowls reared under intensive system in Benin. *Livestock Research for Rural Development*, Volume 29, Article #193. Retrieved February 6, 2021, from http://www.lrrd.org/lrrd29/10/rrmo29193.html

Iqbal, J., Mukhtar, N., Rehman, Z.U., Khan, S.H., Ahmad, T., Anjum, M.S., Pasha, R.H. and Umar, S., 2017. Effects of egg weight on the egg quality, chick quality, and broiler performance at the later stages of production (week 60) in broiler breeders. *Journal of Applied Poultry Research*, 26, pp. 183–191. https://doi.org/10.3382/japr/pfw061

Issaka, B.Y. and Yeboah, R.N., 2016. Socio-economic attributes of guinea fowl production in two districts in Northern Ghana. *African Journal of Agricultural Research*, 11(14), pp. 1209–1217. https://doi.org/10.5897/AJAR2015.10258

Janneke de Jonge. and van Trijp, H.C.M., 2013. The impact of broiler production system practices on consumer perceptions of animal welfare. *Poultry Science*, 92, pp. 3080–3095. https://doi.org/10.3382/ps.2013-03334

Kgwatalala, P., Manyeula, F. and Sefemo, C., 2020. Growth performance of Royal purple and White guinea fowl varieties and their crosses under an intensive management system. *African Journal of Agricultural Research*, 16(9), pp. 1228–1232. https://doi.org/10.5897/AJAR2020.14804

Khairunnesa, M., Das, S.C. and Khatun, A., 2016. Hatching and growth performances of guinea fowl under intensive management system. *Progressive Agriculture*, 27, pp. 70–77. https://doi.org/10.3329/pa.v27i1.27544

Kokoszynski, D., Bernacki, Z., Korytkowska, H., Wilkanowska, A. and Piotrowska, K., 2011. Effect of age and sex on slaughter value of Guinea fowl (*Numida meleagris*). *Journal of Central European Agriculture*, 12, pp. 255–266. https://doi.org/10.5513/JCEA01/12.2.907

Koné, G.A., Kouassi, G.F., Kouakou, N.D.V. and Kouba, M., 2018. Diagnostic of guinea fowl (*Numida meleagris*) farming in Ivory Coast. *Poultry Science*, 97, pp. 4272–4278. https://doi.org/10.3382/ps/pey290

Kouassi G.F., Koné, G.A., Good, M. and Kouba, M., 2019. Factors impacting Guinea fowl (*Numida meleagris*) production in Ivory Coast. *Journal of Applied Poultry Research*, 28, pp. 1382–1388 https://doi.org/10.3382/japr/pfz079

Kouame, Y.A.E., Nideon, D., Kouakon, K. and Tona, K., 2019. Effect of guinea fowl egg storage duration on embryonic and physiological parameters, and keet juvenile growth. *Poultry Science*, 98, pp. 6046–6052. https://doi.org/10.3382/ps/pez264

Kouame, Y.A.E., Kpomasse, C.C., Daouda, L., Oke, O.E., Voemesse, K., Okanlawon, M.O., Kouakou, K. and Tona, K., 2020. Effect of egg storage duration on growth performance, blood parameters and breast meat quality of guinea fowl (*Numida meleagris*). *European Poultry Science*, 84. https://doi.org/10.1399/eps.2020.312

Kyere, C.G., Annor, S.Y., Kagya-Agyemang, J.K. and Korankye, O., 2017. Effect of egg size and day length on reproductive and growth performance, egg characteristics and blood profile of the Guinea fowl. *Livestock Research for Rural Development*, Volume 29, Article #180. Retrieved February 7, 2021, from http://www.lrrd.org/lrrd29/9/kyer29180.html

Madzimure, J., Saina, H. and Ngorora, G.P.K., 2011. Market potential for guinea fowl (*Numida meleagris*) products. *Tropical Animal Health and Production*, 43, pp. 1509–1515. https://doi.org/10.1007/s11250-011-9835-z

Mareko, M.H.D., Nsoso, S.J. and Thibelang, K. 2006., Preliminary carcass and meat characteristics of Guinea fowl (*Numida meleagris*) raised on concrete and earth floors in Botswana. *Journal of Food Technology*, 4, pp. 313–317. https://medwelljournals.com/abstract/?doi=jftech.2006.313.317

Moreki, J.C. and Radikara, M.V., 2013. Challenges to commercialization of Guinea fowl in Africa. *International Journal of Science and Research*, 2(1), pp. 436–440. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.674.9101&rep=rep1&type=pdf#:~:text=The%20main%20challenges%20in%20smallholder,support%20from%20government%20extension%20services.

Nahashon, S.N., Adefope, N., Amenyenu, A. and Wright, D., 2005. Effects of dietary metabolizable energy and crude protein concentrations on growth performance and carcass characteristics of french Guinea broilers. *Poultry Science*, 84, pp. 337–344. https://doi.org/10.1093/ps/84.2.337

Nahashon, S.N., Aggrey, S.E., Adefope, N.A. and Amenyenu, A., 2006a. Modelling growth characteristics of meat-type Guinea fowl. *Poultry Science*, 85, pp. 943–946. https://doi.org/10.1093/ps/85.5.943

Nahashon, S.N., Adefope, N.A., Amenyenu, A. and Wright, D., 2006b. Laying performance of Pearl Gray fowl hens as affected by caging density. *Poultry Science*, 85, pp. 1682–1689. https://doi.org/10.1093/ps/85.9.1682

Nahashon, S.N., Adefope, N., Amenyenu, A. and Wright, D., 2006c. Effect of varying metabolizable energy and crude protein concentrations in diets of Pearl Gray Guinea fowl pullets 1. Growth performance. *Poultry Science*, 85, pp. 1847–1854. https://doi.org/10.1093/ps/85.10.1847

Nahashon, S.N., Adefope, N., Amenyenu Tyus, J. and Wright, D., 2009. The effect of floor density on growth performance and carcass characteristics of French guinea broilers. *Poultry Science*, 88, pp. 2461–2467. https://doi.org/10.3382/ps.2008-00514

Nahashon, S.N., Adefope, N. and Wright, D., 2011. Effect of floor density on growth performance of Pearl Grey guinea fowl replacement pullets. *Poultry Science*, 90, pp. 1371–1378. http://dx.doi.org/10.3382/ps.2010-01216

Nobo, G., Moreki, J.C. and Nsoso, S.J., 2012. Feed intake, body weight, average daily gain, feed conversion ratio and carcass characteristics of helmeted Guinea fowl fed varying levels of phane meal (*Imbrasia belina*) as replacement of fishmeal under intensive system. *International Journal of Poultry Science*, 11, 378–384. https://dx.doi.org/10.3923/ijps.2012.378.384

Nwagu, B.I. and Alawa, C.B.I., 1995. Guinea fowl production in Nigeria. *World's Poultry Science Journal*, 51, pp. 261–270. https://doi.org/10.1079/WPS19950018

Nwagu, B.I., 1997. Factor affecting fertility and hatchability of guinea fowl eggs in Nigeria. *World's Poultry Science Journal*, 53, pp. 279–286. https://doi.org/10.1079/WPS19970022

Oke, U.K., Ariwodo, C.A., Herbert, U., Ukachukwu, S.N., Ukwueni, I.A., Akinmutimi, A.H., Ezeigbo, I.I. and Chukwu, D.O., 2012. Impact of egg size on the fertility, hatchability and early growth traits of two varieties of guinea fowl in a humid tropical environment. *Journal of Animal Science Advances*, 2(Suppl. 3.2), pp. 299–305. https://mouau.afribary.org/work/view/influence-of-egg-size-on-the-fertility-hatchability-and-early-growth-traits-of-two-varieties-of-guinea-fowl-in-a-humid-tropical-environment-7-2

Oke, O.E., Adejuyigbe, A.E., Idowu, O.P., Sogunle, O.M., Ladokun, A.O., Oso, A.O., Abioja, M.O., Abiona, J.A., Daramola, J.O., Whetto, M., Jacobs, E.B., Williams, T.J. and Njoku, C.P., 2015 Effects of housing systems on reproductive and physiological response of guinea fowl (*Numida meleagris*). *Journal of Applied Animal Science*, 8(1), pp. 47–55. https://www.thaiscience.info/Journals/Article/JAAS/10972296.pdf

Oke, O.E., Oso, A., Iyasere, O.S., Adebowale, T., Akanji, T., Odusami, O., Udehi, S. and Daramola, J.O., 2020. Growth performance and physiological responses of helmeted guinea fowl (*Numida meleagris*) to different stocking densities in humid tropical environment. *Agricultura Tropica et Subtropica*, 53(1), pp. 5–12. https://doi.org/10.2478/ats-2020-0001

Okyere, K., Kagya-Agyemang, J.K., Annor, S.Y., Asabere-Ameyaw, A., Kyere, C.G., Fiashide, N. and Setsiwah, W., 2020. Effects of graded dietary protein on growth and laying performance of Pearl Guinea fowl (*Numida meleagris*). *Journal of Applied Life Sciences International*, 23(6), pp. 23–29. https://doi.org/10.9734/jalsi/2020/v23i630168

Ravindran, V., 2013. Poultry feed availability and nutrition in developing countries. In Poultry Development Review. Food and Agriculture Organization of the United Nations (FAO). Rome, Italy. pp. 59–76.

Ruiz, J. and Lunam, C.A., 2002. Effect of pre-incubation storage conditions on hatchability, chick weight at hatch and hatching time in broiler breeders. *British Poultry Science*, 43(3), pp. 374–83. https://doi.org/10.1080/00071660120103648

Saina, H., Kusina, N.T., Kusina, J.F., Bhebhe, E. and Lebel, S., 2005. Guinea fowl production by indigenous farmers in Zimbabwe. *Livestock Research for Rural Development*, Volume 17, Article # 101. Retrieved February 2, 2021, from http://www.lrrd.org/lrrd17/9/sain17101.htm

Sánchez-Casanova, R., Sarmiento-Franco, L., Phillips, C.J.C. and Zulkifli, I., 2020. Do free-range systems have potential to improve broiler welfare in the tropics? *World's Poultry Science Journal*, https://doi.org/10.1080/00439339.2020.1707389

Sarica, M., Boz, M.A., Yamak, U.S. and Ucar, A., 2019. Effect of production system and slaughter age on some production traits of guinea fowl: Meat quality and digestive traits. *South African Journal of Animal Science*, 49 (No. 1). https://doi.org/10.4314/sajas.v49i1.22

Seabo, D., Moreki, J.C., Bagwasi, N. and Nthoiwa, G.P., 2011. Performance of Guinea fowl (*Numida meleagris*) fed varying protein levels. *Online Journal of Animal and Feed Research*, 1(6), 255–258.

Shoyombo, A.J., Yakubu, A., Adebambo, A.O., Popoola, M.A., Olafadehan, O.A., Wheto, M., Alabi, O.O., Osaiyuwu, H.O., Ukim, C.I., Olaynju. and Adebambo, O.A.A., 2021. Characterisation of indigenous helmeted guinea fowls in Nigeria for meat and egg production. World's Poultry Science Journal, 77(4), pp. 1037–1058. https://doi.org/10.1080/00439339.2021.1974287

Soara, A.E., Talaki, E. and Tona, K., 2020. Characteristics of indigenous guinea fowl (*Numida meleagris*) family poultry production in northern Togo. *Tropical Animal Health and Production*, 52, pp. 3755–3767. https://doi.org/10.1007/s11250-020-02413-4

Szalay, I.T., Lan Phuong, T.N., Ferenez, T.R., Dong Xuan, D.T., Kustos, K. and Kovacsne Gaal, K.J., 2016. Assessing meat production of 3 Hungarian Landrace Guinea Fowl ecotypes reserved for *in vivo* conservation. *Journal of Applied Poultry Research*, 25, pp. 139–144. https://doi.org/10.3382/japr/pfv071

Thaxton, J.P., Dozier, W.A., Branton, S.L., Morgan, G.W., Miles, D.W., Roush, W.B., Lott, B.D. and Vizzier-Thaxton, Y.V., 2006. Stocking density and physiological adaptative responses of broilers. *Poultry Science*, 85, pp 819–824. https://doi.org/10.1093/ps/85.5.819

Thogerson, C.M., Hester, P.Y., Mench, J.A., Newberry, R.C., Okura, C.M. and Pajor, E.A., 2009. The effect of feeder space allocation on productivity and physiology of Hy-Line W-36 hens housed in conventional cages. *Poultry Science*, 88, pp. 1793–1799. https://doi.org/10.3382/ps.2009-00011

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, pp. 736–741. https://doi.org/10.1093/ps/82.5.736

Yamak, U.S., Sarica, M., Boz, M.A. and Ucar, A., 2018. Effect of production system (barn and free range) and slaughter age on some production traits of guinea fowl. *Poultry Science*, 97: pp. 47–53. https://doi.org/10.3382/ps/pex265

Zhao, Z.G., Li, J.H., Li, X. and Bao, J., 2014. Effects of housing systems on behaviour, performance and welfare of fast-growing broilers. *Asian-Australasian Journal of Animal Sciences*, 27(1), pp. 140–146. https://doi.org/10.5713/ajas.2013.13167

Zvakare, P., Mugabe, P.H. and Mutibvu, T., 2018. Guinea fowl (*Numida meleagris*) production by small-holder farmers in Zimbabwe. *Tropical Animal Health and Production*, 50, pp. 373–380. https://doi.org/10.1007/s11250-017-1442-1