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Review
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PRODUCTION SYSTEMS AND PHENOTYPIC VARIABILITY OF THE GUINEA FOWL (*Numida meleagris*) IN SUB SAHARA AFRICA

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Abstract: The diversity of natural biological resources is at the heart of concerns on food security and climate change. Originating in Africa, guinea fowl constitutes an alternative source of income and protein of animal origin that can be easily mobilized, mainly for rural populations. How-ever, relatively little information is available on its production system, while its genetic diversity remains an enigma in most Sub Sahara African countries. This study therefore aimed to review the production systems and phenotypic variability of the guinea fowl (*Numida meleagris*) in Sub Sahara Africa. It revealed that this species is distributed almost all over the Africa; it is more frequent in many African countries where some studies showed that this species is extensively family farm with a variability of morphometric characters that is a function of sex and environment as well as the production system. This variability seems to indicate its adaptation to environmental conditions. The present review also revealed the need to extend studies to all the agro-ecological zones of Sub Sahara Africa in order to undertake global actions for a sustainable exploitation of the guinea fowl. This would necessarily include variability studies for its genetic improvement, preservation and conservation.

Keywords: Production system, Phenotype, Guinea fowl, Sub Sahara Africa

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1. Introduction

Biodiversity refers to the biological diversity of living organisms (fauna, flora, microorganisms) at different levels of ecological organization. It is expressed in terms of specific, genetic and ecosystem diversity and includes its composition, structure, and functions. One of the challenges is to maintain these properties, the evolutionary capacities of living organisms and their ability to adapt to global changes. Agriculture depends on biodiversity, on the proper functioning of ecosystems through the biological diversity necessary for domestication, soil fertility or pollination (Couvet, 2015). Consequently, the future of biodiversity and agriculture are linked. For this to, it is necessary to understand their interactions and therefore their present and future dynamics, especially since the current needs of an ever-growing human population are linked to the proper control of current resources of all kinds with a view to their sustainable exploitation. Therefore, the characterization of local species and their production systems was identified as the first field of global interest for the sustainable management of animal genetic resources (FAO, 2008). Indeed, the optimal use of animal genetic resources depends on a good knowledge of their genetic basis, especially in view of the constantly changing environment (FAO, 2008; Groeneveld et al., 2010). The absence of coherent management strategies for domesticated species has resulted, among other things, in the weakening of performance, uncontrolled crossbreeding and the loss of their diversity (Chepnda, 2012). In general, the state of biodiversity loss of animal resources in the world is alarming and is relatively undocumented on the African continent in general and in Sub Sahara Africa in particular (FAO, 2015a).

A lot of attention has been paid to industrial livestock farming which has become very unsustainable and fragile in the face of global changes; yet non-conventional species are better adapted and resistant to weather as well as to diseases in various environments. They are sources of animal protein and income mainly for rural and peri-urban populations (McGowan et al., 2012). Among these species, the guinea fowl represents 3% of the world's poultry population (FAO, 2008). In addition to its socio-economic and environmental interest (Annor et al., 2013; Dongmo et al., 2016; Djonwe, 2017; Massawa et al., 2020), the genetic diversity of guinea fowl remains puzzling. Hence, this study aims at reviewing the production systems and phenotypic variability of the guinea fowl species in order to undertake actions for its sustainable exploitation as well as its genetic improvement and preservation.

2. Origin and Domestication of Guinea Fowl

Numida meleagris is the wild ancestor of the West African subspecies *Galeata* which gave rise to the domestic guinea fowl. The Latin name 'Meleagris' comes from Greek mythology where the legend of the Argonauts reveals that when the Greek hero Meleager lost his sisters, they cried themselves to death, so the goddess Artemis transformed them into birds called 'guinea fowls' to save them from the flames of hell. Guinea fowl are therefore Meleager's sisters, and Aristotle described them as Meleagris in the fourth century BC (Le Coz-douin, 1992; Savadogo, 2013).

The guinea fowl originated in Africa (Hasting, 1984; Moreiki and Seabo, 2012). Because of its origin in North Africa and Guinea, it was called the 'Numidian fowl' and the 'Guinea fowl' respectively by the Romans; hence the English name 'guinea fowl' by Le coz-douin (1992). Because of the colorful appearance of its plumage, the Portuguese called it "pintata", then "pintada" by the Spanish and finally "pintade" by the French. According to the Robert dictionary, this term first appeared in the French language in 1643 (Nagalo, 1984). In his “Systema Naturae", the 18th century Swedish naturalist Charle Linnaeus describes the common guinea fowl as *Numida meleagris* (Le coz-douin, 1992), thus associating its legendary origin with its geographical origin.

The guinea fowl is widely distributed in Africa where it lives either in small groups or in large flocks (Cauchard, 1971 cited by Nagalo, 1984) and where it is widely reared in farms (Nwagu and Alawa, 1995). Meleagriculture, which has long been practiced by the Peuhl in a purely traditional way, is nowadays widespread in most parts of the world (Boko, 2004). However, history reveals that the guinea fowl was first domesticated in ancient Greece and by the Romans (Salichon, 1983; Ikani and Dafwang, 2004; Moreki and Seabo, 2012). Genetic selection from African strains, characterised by better zootechnical performance, has led to the industrial production of guinea fowl in Europe, North America and Australia (Bonds, 1997; Boko et al., 2012).

3. Geographic Distribution

In addition to its undoubted African origin (Hastings, 1984), the guinea fowl is also reared extensively in temperate zones where it represents a significant market (Gnassimgbe, 1983). It was introduced to the Americas around 1508 by the Genoese together with the first black slaves from Guinea led by Spanish settlers (Nagalo, 1984). The expansion of the guinea fowl occurred in two periods as presented first by Cauchard (1971), then by Gnassimgbé (1983) and Nagalo (1984):

- Ancient times during which guinea fowl migrated from West Africa to North Africa, specifically to Egypt and progressively to Ancient Greece and then to the Mediterra-nean coast;
- Modern times during which the expansion of the guinea fowl was made from the Af-rican cradle to Portugal, then to France, Siberia, the Antilles and Java. France is now the largest producer of guinea fowl (Champagne and Leveque, 2007; Agreste, 2011; Champagne and Segret, 2013).

In Africa, almost all guinea fowl species are still found either in the wild, sometimes semi-domesticated and/or domesticated, and very few in captivity, depending on the region. This population seems to be poorly characterized due to a general lack of information. In Came-roon, guinea fowl farming is highly concentrated in the northern, Far North, North and Ada-mawa regions respectively; but also in the Central and Littoral regions, mainly at poultry mar-kets, while in West Cameroon, the species present seems to be dominated by imported strains (Ngandeu and Ngatchou, 2006; DREPIAEN, 2011; MINEPAT, 2014) (Figure 1).

4. Production Systems

In Sub Sahara Africa, guinea fowl farming is practiced in a free roaming system and is not very productive in general, but there are a few modern farms that mainly use improved strain from imports (Sayila, 2009; Boko et al., 2012; Annor et al., 2013; Dongmo et al., 2016; Massawa et al., 2020). The daily monitoring of flocks of up to 15 guinea fowls is generally carried out by women and children, but decisions are made by men (Laurenson, 2002; Dahouda et al., 2007; Bouba, 2017; Dao, 2018). However, as there are no prohibitions, meleagriculture is practiced by all social classes. The principal production goal of guinea fowl is for sales (90%) and own consumption of eggs and meat; however, this species is also used for gifts and prestige. Its breeding constitutes a form of saving and relatively easy to carry out (Ikani and Dafwang, 2004; Djovonou, 2010)

This type of farming is similar to that of local chickens, with the difference that guinea fowl require more space, that is about 5 adults guinea fowl per square meter instead of about 10 in the case of chicken (CTA, 1990; Meutchieye and Djiotsa, 2015).

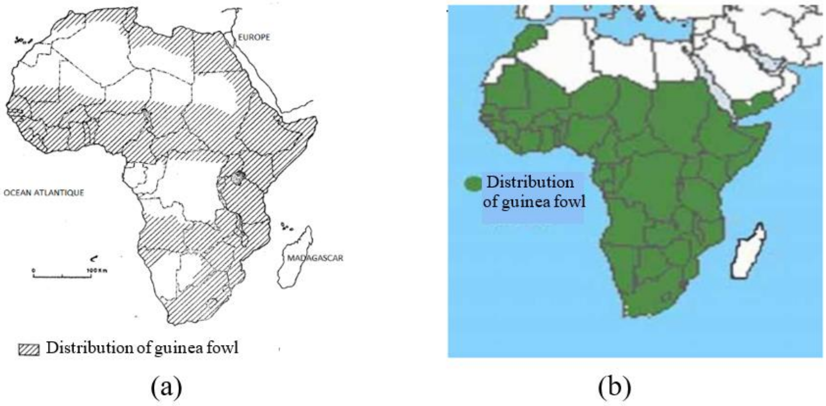

Figure 1. Distribution of guinea fowl in Africa (a)= ancient times; (b)= modern times (Gnassimgbé, 1983).

The birds roam throughout the day and find shelters around family compounds at the end of the day for the night. No importance is generally attached to rearing equipment such as feeders, troughs, and other (Saina et al., 2005; Sanfo et al., 2007$_a$; Moreiki, 2009; Moreiki and Seabo, 2012).

Guinea fowl's diet consists of greens, kitchen scraps and seeds. Guinea fowl has an omnivorous tendency. Very few producers formulate complete feeds for guinea fowl. However, there are a few pasture-based farms and sometimes distribution of maize seed, oilcake, meal and millet as supplements (Bastianelli et al., 2002; Sanfo et al., 2009; Dahouda, 2009; Savadogo, 2013; Dongmo et al., 2016; Massawa et al., 2020).

The guinea fowl can fall victim to almost all health and technical constraints encountered in village chicken farming. Although it is less susceptible to Newcastle disease, it remains an important reservoir. The guinea fowl is particularly susceptible to internal parasites (Nagalo, 1984; Susan, 1992; Sidibe, 2001; Bastianelli et al., 2002; Massawa et al., 2020).

Sex ratio is generally not respected; however, a ratio of one male to four females is sometimes observed. A female guinea fowl lays between 80-100 eggs of 43g on average per year. Laying starts from the 8th month and the brooding period is 28 days. Because of the guinea fowl's poor brooding ability, its eggs are usually given to hens or ducks for brooding (SAILD, 2001; Sanfo, 2005; Sanou, 2005; Sanfo et al., 2007$_b$; Sanfo et al., 2008; Dongmo et al., 2016; Massawa et al., 2020). Meleagriculture is still primitive, and its practice is essentially traditional in Sub-Sahara Africa.

Faced with the multifactorial constraints that reduce guinea fowl productivity and despite empirical research, breeders develop endogenous know-how, including the cutting of feathers to prevent guinea fowl from flying away, the provision of supplementary feed, generally consisting of a few handfuls of cereals for habituation and the placing of eggs under hens and ducks for brooding (Biagini, 2006; Dongmo et al., 2016).

Although the commercial circuit of Meleagriculture products is not well defined in Cameroon, the average market price of an adult guinea fowl (12 weeks old) of about 2.5 kg live weight is around 2.5 euros (SAILD, 2001; Dongmo et al., 2016). This price is generally higher for females than males because of weight dimorphism in favor of females. Guinea fowl appears to be less expensive in rainy season than in dry season. However, the average price of the products of mixed farming remains lower than those of the local hen (Fotsa et Poné, 2001).

5. Morphometric Characteristics

Preliminary studies of the phenotypic biodiversity of guinea fowl in Sub Sahara Africa reveal variability in morphological (Figure 2) and biometric (Table 1) characteristics.

In addition, the same source inventoried nineteen colors whose photos could not be represented. These include in particular: blue coral, Buff White, Chamois, Coral White, Dundotte, Grey, Lakenpur, Light gray, Lilac, opal white, Pearl, porcelain white, Silverwing, Splattered, Spotted, white-breasted pearl, White-breasted purple, White of Dondotte, Wild type.

With few exceptions, most of the work carried out in Africa on the variability of the qualitative traits of the local guinea fowl populations listed almost the same colors as recorded by AU-IBAR (2015). The morphological characteristics observed in guinea fowl are variable, which is mostly due to environmental and/or genetic effects as well as the production system. Plumage and tarsi coloration change with age (AU-IBAR, 2015), while mumps color differs according to light and certain periods of excitement (Boussini, 1995; Agbolosu et al., 2015); the color of the skin is linked to the breeding system but mainly the diet (Agbolosu et al., 2015; Panyako et al., 2016). Sex discriminating variables are crest shape, live weight and barbels development as well as calls. Males have more developed barbels directed towards the front of the bill while females have less developed barbels directed towards the back of the bill. Similarly, a male has more developed crests than female. Some producers differentiate sex based on egg shape: eggs with pointed tips are males while round tips represent females (Annor et al., 2013; Issoufou, 2016, Bouba, 2017, Djonwe, 2017; Meutchieye et al., 2018;

Mwandwe, 2019; Gondebne, 2019). However, the studies of visible polymorphism in guinea fowl in many countries of Africa are limited to a few localities, although guinea fowl seems to be present in almost all agro-ecological zones of the Sub Sahara Africa.

Table 1 summarizes some of the measurable variables that allow for better discrimination of guinea fowl in Sub Sahara Africa.

Table 1 shows a diversity of values for the quantitative variables considered. From the same authors, it was revealed that there were intra and inter-meleagre population differences ac-cording to zone and sex. This suggests that these variables are the most discriminating of guinea fowl populations in Sub Sahara Africa. However, the influence of farming systems and socio-economic characteristics on all guinea fowl phenotypic variables remains.

Preliminary analysis of phylogenetic relationships and the structure of common guinea fowl populations in the Sudano-Sahelian zone of Cameroon based on 13 body measurements made it possible to distinguish 03 genetic types categorized into 2 subgroups according to genetic distances and inter and intra population variation (Dongmo et al., 2020).

6. Genetic Identification of Guinea Fowl

6.1. Karyotype

In the Galliformes order, the chromosome number is quite conservative and ranges from 76 to 84 (Takagi and Sasaki, 1974; Stock and Bunch, 1982; Belterman and de Boer, 1984) and that of the guinea fowl is estimated to be between 74 and 78 chromosomes (Piccinni and Stella, 1970; Takahashi and Hirai, 1974). Research by Shibusawa *et al* (2002) indicates that the guinea fowl genetic material consists of 38 pairs of autosomes and one pair of homogamous gonosomes in the male (ZZ) and heterogamous gonosomes in the female (ZW) in the ZZ/ZW system, i.e., 2n = 78. Indeed, almost all birds, some reptiles, butterflies, fish and amphibians are grouped in this system, whereas mammals are in the XX/XY system (Manjeli et al., 2009). As in the hen, karyotyping of the guinea fowl can be done following either of the protocols described by Eldrige (1985); Austic and Nesheim (1990); Popescu *et al.* (1998). However, compared to chicken, the karyotype shows differences in telocentric chromosome 3, chromo-metacentric chromosome 5, acrocentric chromosomes 6 and 7, and submetacentric chromosome Z (Shibusawa et al., 2002). Goswami and Harpreet (1996) showed that the hen and guinea fowl are genetically very close and the crossing of these two species results in a hybrid ('Numigal') with a karyotype of 70 chromosomes (2n = 70).

6.2. Genetic formulas

The genetic formula proposed by Colona quoted by Dams (1996) with corresponding feather colors are shown in Table 2.

Thus, the color Isabelle (Table 2) is determined by a gonosomal gene, i.e., linked to sex. The male guinea fowl carrying this gene is therefore homogamous recessive (is is) or dominant (Is Is), whereas the female guinea fowl with two different sex chromosomes, one of which is identical to the male's, is heterogamous (Is Is). Apart from the Isabelle gene, the other genes are dependent on an autosomal recessive gene, i.e., not linked to sex.

According to the reference classification (version 5.1, 2015) of the International Ornithological Congress (phylogenetic order), there are 04 genera of guinea fowl divided into 06 species (Table 3).

Table 1. Average values of some bodies measurements of local guinea fowl in Sub Sahara Africa

Sources	Variables						
	PV	PT	LA	EA	LCo	LP	LT
Fajemilehin (2010)	967.12	30.19	23.02	-	41.75	13.74	8.94
Ogah (2013)	1420.00	35.37	19.34	-	-	11.87	7.73
Payako *et al.* (2015)	1446.60	-	25.30	-	44.04	-	9.68
Issoufou (2016)	1064.00	25.82	-	42.77	40.44	12.88	6.41
Dongmo *et al.* (2018)	1210.00	32.36	-	36.56	43.40	11.99	6.64
Massawa (2018)	2110.00	31.62	22.83	45.65	37.93	8.97	6.14

PV expressed in grams and other variables in centimeters; PV= live weight, PT= thoracic circumference, LA= wing length, EA= wingspan, LCo= body length, LP= leg length, LT= tarsal length.

Table 2. Genetic formula with different colors of the corresponding guinea fowl plumage (Dams, 1996)

Guinea fowl with pearl		Guinea fowl with no pearl	
Pure gray	PP LL CC Is- (Is Is for males)	Violet	pp LL CC Is- (Is Is for males)
Lilac	PP ll CC Is- (Is Is for males)	Azure	pp ll CC Is- (Is Is for males)
Isabelle	PP LL CC is- (is is for males)	Rachel	pp LL CC is- (is is for males)
Chamois (white)	PP LL cc Is- (Is Is for males)	Fulvette	pp LL cc Is- (Is Is for males)

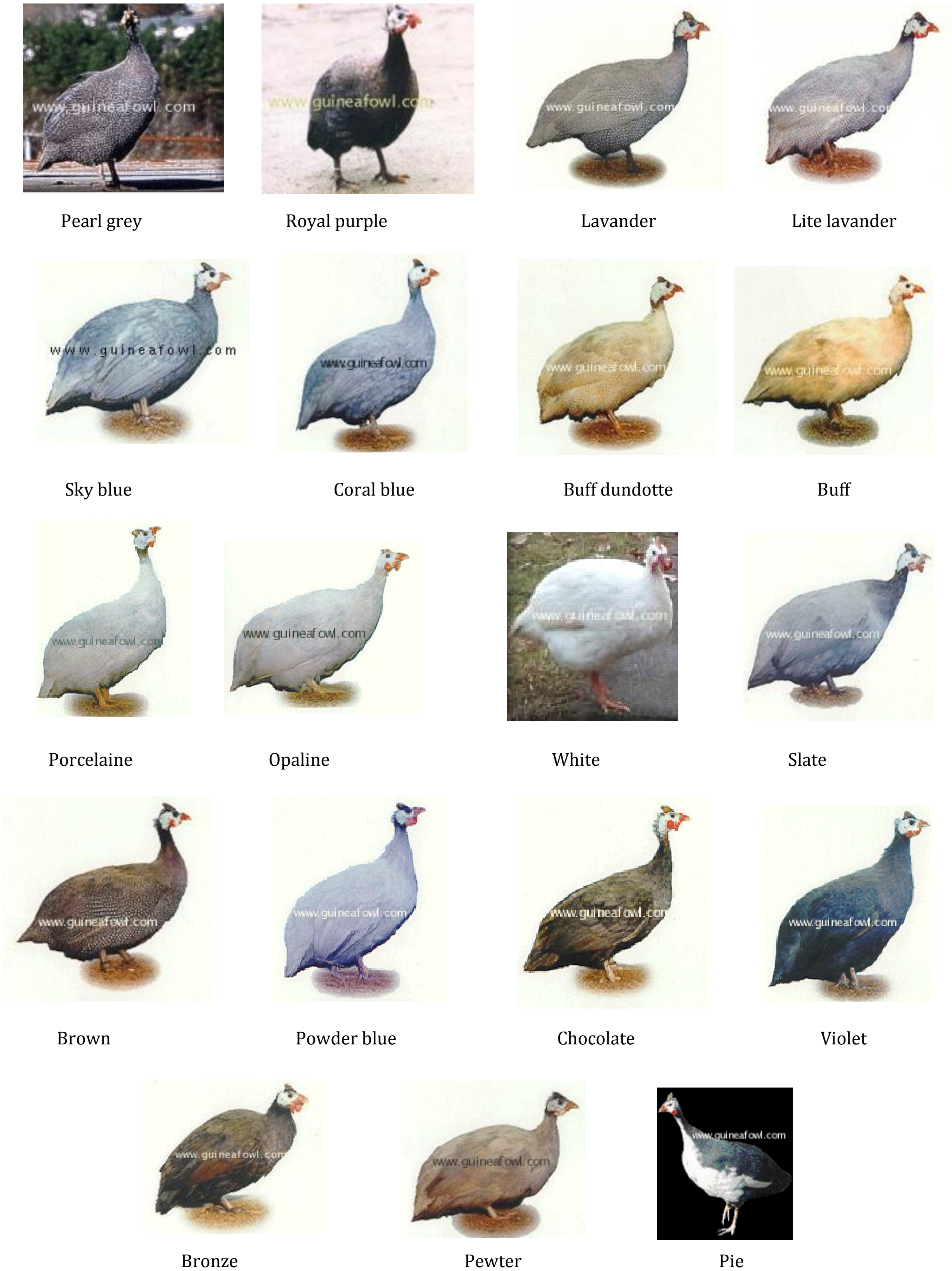

Figure 2. Color diversity of guinea fowl in Sub Sahara Africa (AU-IBAR, 2015)

Table 3. Genus, species, and description of the guinea fowl in the taxonomic order (Annor et al., 2013)

Genus	Species	Description
Agelaste	*Agelaste meleagrides*	White-breasted guinea fowl
	Agelaste niger	Black-breasted guinea fowl
Numida	*Numida meleagris*	Helmeted guinea fowl
Guttera	*Guttera plumifera*	Black-breasted guinea fowl
	Guttera pucherani	Crested guinea fowl
Acryllium	*Acryllium vulturinum*	Vulturine guinea fowl

7. Conclusion

The guinea fowl is an alternative protein resource, a source of income and animal protein for the rural population essentially, and its breeding is not subject to any prohibition. In Sub Sahara Africa, this breed is practiced in an extensive family system, with a variability of morphometric traits. Under the influence of gender and environment as well as the production system, this variability reflects its adaptation to environmental conditions. However, the information currently available is insufficient to make decisions related to the genetic improvement of guinea fowl in sub-saharan Africa as well as their conservation. In addition, its exploitation dominated by direct harvesting from the wild contributes to a genetic imbalance with the consequence of the disappearance of the species. The present review reveals the need to undertake global actions for the sustainable exploitation of the guinea fowl which would necessarily include a study of its variability for genetic improvement and conservation. It would also be necessary to consider genotypic research in order to determine candidate genes linked to the adaptation traits of guinea fowl as well as to meat and egg production for future exploitation.

Author Contributions

The percentage of the author(s) contributions is presented below. All authors reviewed and approved the final version of the manuscript.

	D.D.F.	F.M.	M.J.	D.K.F.	M.K.J.P.
C	30	20	20	10	20
D	100				
S		40		20	40
DCP	60		40		
DAI	50	10	20	10	10
L	60	10	10	10	10
W	60	10	10	10	10
CR	20	20	20	20	20
SR	45	15	10	15	15
PM	20	20	20	20	20

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management.

Conflict of Interest

The authors declared that there is no conflict of interest.

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