Chapter

Utilization and Conservation of Landrace Chickens of Nigeria: Physical and Performance Characteristics, Issues and Concerns

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Abstract

The Nigerian indigenous chickens (NICs) are a critical component of the global animal genetic resources. They are distributed in rural areas, kept by the majority of the rural poor. They constitute different strains, or ecotypes local to tribes, regions, or ecological zones and are valued for their disease resistance, adaptation, and yield of valuable products and income on marginal inputs making them a low risk species. They are hence a unique and vital genetic resource and gene pool for present and long-term genetic improvement and human need for food and sustenance. The NIC is however; threatened by extinction owing to neglect, negative selection, breed substitution, and genetic introgression. There is need to draw research and policy attention to the conservation of NICs in accord with the global effort for the conservation of indigenous chickens which is probably the most neglected among farm animal species. The present review therefore, focuses on the physical and performance characteristics, genetic diversity and improvement, utilization and conservation of NIC genetic resources.

Keywords: indigenous chickens, ecotypes, chicken genetic resources, genetic diversity, ex situ conservation, in situ conservation

1. Introduction

Indigenous chicken biodiversity encompasses the genetic variants within and between native chickens distributed around the world [1]. They are domesticated but unselected and unimproved autochthonous populations characterized by tremendous variation in physical, genetic, and productive attributes [2, 3] and known by various native names; and whose attributes are best described by farmers in their home communities. Native chicken population is vital in the livelihood of resource poor house-holds and marginal rural communities in Africa, providing nutrition, cash flow reserve, recreation and cultural roles [4]. In Nigeria, ICs makeup about 80% of poultry population [5, 6]. The Nigerian indigenous chicken (NIC) is classified into three major phenotypes with regards to body weight. Dwarf, normal, and heavy types are generally distinguished [7] but more recent classifications

recognize two broad body weight categories namely light body weight, and heavy body weight [8]. Plumage or feather color (pigmentation) include black, brown, gray, ash, white, red, and mottled; various color combinations [9–12] and feather patterns. Feather distribution is predominantly complete but limited in some phenotypes such as naked neck, frizzle, and short flight feather types [7]. Feather structure is predominantly normal, and seldom frizzle and silky [7]. Comb type is mostly single but rose, pea, walnut, duplex, and crest phenotypes also occur in decreasing frequencies [13–15]. Ear lobe is mostly present but absent in some dwarf ecotypes and color is mostly red or white. Wattle color is red or white while shank and skin color is often white or yellow but could be grayish, ash, blackish or bluish [9, 12, 13]. Beak color could be white, yellow, brown, or black. Some of the major physical attributes reflect environmental adaptations such as large comb, limited feather distribution, and frizzle feather structure for enhanced heat dissipation and body temperature regulation [16].

The genetic background of body size, feather structure and distribution are body size genes (DW/dw), plumage distribution genes (Na/na), feather structure genes (F/f), and numerous plumage color and color pattern genes [6, 16–18]. Morphological, physical, and performance characteristics along with biochemical, and molecular markers have been employed for genetic diversity evaluation in ICs [19–21]. Results indicate that NICs are a unique and vital genetic resource and gene pool for present and future production and breeding imperatives. The NIC is however; threatened by extinction owing to under valuation and utilization, diseases, predation, negative selection, breed substitution and genetic dilution, necessitating urgent action by research and policy makers towards the conservation of native chickens which is probably the most neglected farm animal genetic resources [16, 22–24]. The present study aims to collate information on qualitative and quantitative trait characteristics and variation, genetic diversity and improvement, and conservation issues and concerns of NICs, to draw attention to the extent of IC biodiversity and the need for action to improve the production, utilization, valuation and conservation of Nigerian's landrace chickens.

2. Physical and qualitative attributes of Nigerian indigenous chickens

Physical and qualitative trait evaluation reflects the effects of genes, and the impact of the environment; and enhances the understanding of local adaptations, which impact performance [14, 25]. Natural selection as well as mutations could throw up unique phenotypes, genes, and genotypes that have special adaptation and utility in specific environments. Characterization of the physical and qualitative traits for local adaptations facilitates selection for traits that enhance fitness and performance [13, 14]. Variation in physical and qualitative traits of NICs is expected given the diverse agro ecological climates, centuries of migration and interbreeding, natural and man-made challenges including disease, predation, and negative selection to which ICs have been subjected [6, 7, 16, 26].

2.1 Plumage type, distribution, color, and color patterns in Nigerian indigenous chickens

Plumage type (smooth plumage and frizzle plumage) and plumage distribution (complete plumage and naked neck) are genetically determined. The genetic background of plumage type is the autosomal dominant frizzle (F) and recessive smooth (f) feathering genes while the genetic basis of feather distribution is the autosomal dominant naked neck (Na) and recessive complete feathering (na)

genes. Two forms of genetically determined melanin pigment (eumelanin and pheomelanin) define plumage color [27, 28] but the genetic background of plumage color in ICs is very complex. Generally, the e locus genes or alleles, secondary pattern genes, eumelanin enhancers or melanizers, eumelanin restrictors (generally called Columbian restrictors), eumelanin diluters or demelanizers, pheomelanin intensifiers or red enhancers, and pheomelanin diluters or gold diluters essentially determine plumage color and color pattern [29, 30].

The degree of expression of the e locus genes and secondary color/pattern genes determine the degree of melanization and hence deviation from ground color [28]. In the absence of pigmentation, plumage color is called silver which looks white. In wild type phenotype, the ground color is yellow to brown called gold and the presence of red enhancers boosts (intensifies) gold to a (dark) red color while presence of red diluters dilutes (tones) gold to a yellow, cream or lemon color [30]. The ground color can hence be silver, cream, yellow, gold, brown, or red, depending on the presence and dose of pheomelanin modifying genes [30].

The typical free range IC closely approximates the wild type (Red jungle fowl) plumage phenotype (most likely genotype) and is sexually dimorphic in plumage color; hens being more ground colored than roosters [30]. A significant deviation of today's ICs from the classical phenotype is expected owing to centuries of migration, natural selection (including predation mostly directed at chickens having brightly colored plumage), negative selection to fulfill cultural and ritual roles, intensification of production and artificial selection by man (increasing expression of the 'domesticated phenotype') [31, 32], and interbreeding between phenotypes (also genotypes). Consequently, plumage color phenotypes reported for adult NICs range from full ground color to full black color. Findings however, vary by source of samples (on-farm vs. market samples), system of production (intensive vs. semi-intensive vs. extensive) due to differences in flock structure (male:female; adult:grower), and environmental effects on plumage genotype and phenotype [32]. In heavy ecotype (HE) ICs, [33] reported plumage color as white, white and black, gold and black, black, barred, brown, brown and black, gold, and gold and brown. Indigenous chickens assembled from local markets within Makurdi and environ in Benue State, Northcentral Nigeria revealed black, light brown, white, spotted, and mottled phenotypes at 32.22, 12.22, 7.78, 21.11 and 26.67%, respectively [9]. In 2420 mature ICs from 100 farm families in Dekina, Kogi State, Northcentral Nigeria [10] observed plumage colors of brown, brown and black, black, black with white, white, and brown with black and white at 41.75, 35.5, 10.25, 6.50, 2.75, and 3.25%, respectively. Within Yoruba and Fulani ecotypes belonging to households in Ogbomosho, Oyo State, Southwestern Nigeria [11] observed plumage colors of white, black, brown, ash, red, and yellow in 15.07 and 20.6, 25.67 and 31.55, 9.34 and 10.69, 9.42 and 6.52, 9.11 and 12.13, and 0.00 and 2.35%, for Yoruba and Fulani ecotypes, respectively. Whitish brown and multicolor plumages were observed in 31.4 and 13.3%, and 0.00 and 2.87% of chickens, respectively. In 7091 ICs (2467 males and 4624 females reared semi-intensively) from rural households in Gwer-West, Benue State, Nigeria, [13] observed complete white, brown, and black; brown with black spotting, black with white spotting, and white with black spotting phenotypes in 15.55, 12.71, and 19.79; 12.89, 29.01, and 10.05%, respectively. In a population of Tiv and Fulani ICs reared intensively at Ekpehe in Makurdi Benue State, Nigeria, [14] reported nine plumage colors made up of three single or solid colors (brown, 11.54%, black, 3.85%, and light brown, 7.69%) and six color combinations (silver with brown, 6.25%; mottled brown, 19.20%; mottled black, 11.54%; black with brown, 23.08%; mixed gray, 3.85%, and mottled white, 3.85%) in the Tiv chickens. Within the Fulani ecotype, brown, white, and black were the solid colors at frequencies of 17.31, 3.08, and 5.77%, respectively while mixed colors included

dull brown (2.69%), mixed gray (5.77%), mixed black (13.46%), black and brown (17.37%), mottled brown (13.46%), mottled white (9.46%), and mottled black (11.53%). Daikwo et al. [12] observed five single plumage color phenotypes viz. black, white, brown, ash, and red at 39.43, 23.02, 15.47, 11.13, and 9.43%, respectively and multicolored phenotypes (1.51%) in 1060 adult ICs from 208 households in Bekwara, Cross River State, Nigeria. In a recent survey of seven council wards, four villages/ward, 4 to 5 households/village, and 5 to 7 mature ICs/household, [15] observed six unicolored plumage phenotypes consisting of black, white, brown, gray, ash, and red; and a series of mixed colored plumage phenotypes viz. multicolored, black and white, gray and white, black and brown, reddish black, and ash with black. Of these single plumage colors and color mixtures, black, white and brown were predominant (36.23, 20.00, and 13.02%, respectively) while ash was the least frequent (0.57%). In a population of heavy ecotype (HE) ICs genetically improved for egg production and body weight at first egg by within ecotype selection for six generations, there was preponderance of pheomelanin-based feather colors and color combinations/patterns (white, yellow, gold, red, and brown) while in unimproved light ecotype (LE) ICs, eumelanine-based feather colors were more dominant (**Table 1**, **Figure 1**). The range of plumage colors and color combinations reported for the NICs indicate tremendous plumage color variation and diversity and results are similar to those of ICs from other countries in Africa [27, 34].

2.2 Distribution of comb type, beak, ear lobe, and wattle colors

Comb type in the NIC has been reported to include single, rose, pea, buttercup, walnut, and cushion varieties with single comb being the most predominant followed by rose, pea, buttercup, walnut and cushion in decreasing order. Daikwo et al. [10] observed single, pea, and rose combs with frequencies of 51.0, 28.0, and 21.0%, respectively in ICs from Dekina in Kogi State, Northcentral Nigeria while Rotimi et al. [13] observed 88.49, 7.03, 3.90, 0.32%, and 0.26% for single, rose, pea, buttercup, and cushion combs, respectively in ICs from Gwer-West, Benue State, Nigeria. From 1,700 ICs (Fulani = 900, and Tiv = 800 ecotypes), three comb types: single (99.23%), rose (0.38%) and walnut (0.39%) in Fulani ecotype and two types: single (99.62%), and walnut (0.38%) in Tiv ecotype were reported [14]. From 1,060 adult ICs (444 males and 616 females) from Bekwara in Cross River State, South–south Nigeria, [12] reported three comb types: single (88.49%), rose (7.17%), and pea (4.34%). Data presented showed male to female ratio of 95.5:83.4, 1.8:6.2, and 2.7:10.4% for single, pea, and rose combs, respectively. A similar study in the same area observed five comb types namely single (24.20%), pea (38.90%), rose (18.50%), double (13.70%), and walnut (4.70%) [15]. Four comb types (single, 43.33%; pea, 23.33%; rose, 17.78%; and walnut, 15.36%) were reported in ICs from Markudi in Benue State, Northcentral Nigeria [9] while [11] observed single comb (94.27 and 80.44), rose (2.75 and 11.34), and pea (2.98 and 8.21%) for Yoruba and Fulani ecotypes, respectively in ICs from Ogbomosho in Oyo State, Southwestern Nigeria. Comb color did not vary within and between populations and sexes being 100% red [11, 14]. Elsewhere in Africa [27] observed a preponderance of pea comb (range, 49–56%; overall, 53%) followed by rose comb (range, 12–22%, overall, 16%) out of the five comb types (single, rose, pea, walnut, and duplex) present in five IC ecotypes or strains of Ethiopia. The authors reported higher percentage rose, and pea combs in females compared to males, while more males had duplex, single, and walnut combs compared to females.

Beak color in NICs was reported to include white, yellow, brown, black, ash, pink, and orange. White beak (41.16%), black (31.61%), and yellow (27.23%) were observed in IC population from Gwer-West in Benue State, Northcentral

Trait		[1]LE (No.)	Freq. (%)	[2]HE (No.)	Freq. (%)
Comb type	Single	61	100.00	30	93.75
	Rose			2	6.25
Comb color	Red	46	75.41	32	100.00
	Red and black	11	18.03		
	Black	4	6.56		
Wattle color	Red	39	63.93	32	100.00
	Red-black	15	24.59		
	Pink	7	11.48		
Beak color	Black	25	40.98	1	3.13
	Black and slate	14	22.95		
	Black and brown	1	1.64		
	Yellow	5	8.20	4	12.50
	Yellowish brown	1	1.64		
	Brown	15	24.59	10	31.25
Ear lobe	Present	51	83.61	32	100.00
	Absent	10	16.39		
Ear lobe color	Red	32	62.75	16	50.00
	Pink	19	37.25		
	White			8	25.00
	White and red			8	25.00
Skin color	Yellow				
	Yellowish white	34	55.74	4	12.50
	Blackish (slate)				
	Ash-gray	25	40.98		
	White	2	3.28	28	87.50
Shank color	Black/ash/gray	31	50.82	1	3.13
	Yellow	16	26.23	10	31.25
	White/slate	3	4.92		
	Yellowish-white (cream)	10	16.39	21	65.63
Plumage color (sex)	Black	16 (F)	26.23	1 (F)	3.13
	Black and gold/yellow	2 (F)	3.28		
	Black and white	10 (F)	16.39	1 (F)	3.13
	Gold, ash, black	1 (F)	1.64		
	Brown and gold	1 (F)	1.64	1 (F)	3.13
	Gold, brown, black, ash	3 (F)	4.92	1 (F)	3.13
	Red, gold, black	2 (M)	3.28	2 (M)	6.25
	Red and white			1 (M)	3.13
	Red, gold, white			8 (M)	25.00
	White, gold, brown			1 (M)	3.13
	White			3 (M)	9.38

Trait		[1]LE (No.)	Freq. (%)	[2]HE (No.)	Freq. (%)
	White and gold			3 (M)	9.38
	Brown and black	14 (F)	22.95	1 (F)	3.13
	Brown	6 (F)	9.84	1 (F)	3.13
	Brown and white spots	6 (F)	9.84	3 (F)	9.38
	Gold, white, black			1 (M)	3.13
	Mottled (brown, black, ash, white, gold)			1 (F)	3.13
	White and brown			3 (F)	9.38

[1]LE: unselected light ecotype (bantam or dwarf) chickens;
[2]HE: sixth generation heavy ecotype ICs

Table 1.
Qualitative traits of light (LE) and heavy (HE) ecotype NICs.

Nigeria [13] while [14] observed mostly brown (44.23 and 43.90%), black (35.00 and 36.50%), and white beak (20.74 and 19.60%) for Tiv and Fulani IC ecotypes, respectively. Yellow, brown, ash, white, pink, and orange colored beak were observed in ICs from Bekwara, Cross River State, Nigeria at 21.10, 11.10, 9.10, 6.80, 1.90 and 1.10%, respectively [15]. In the study by [34], beak color was yellow (32.48%), white (33.73%), brown (26.30%), and black (7.75%).

White, red, brown, yellow, ash, and black were the range of ear lobe colors reported for NIC by several studies [9, 11, 13, 14] with white followed by red ear lobes being predominant (range: 52.00–79.37 and 20.63–45.00%, for white and red ear lobes, respectively) in the populations studied by [9, 11, 13] while [14] reported preponderance of brown and black ear lobes.

Wattle color was reported to be white and red by [13] with white wattle being the more frequent (68.02 vs. 31.98%). Reports describing wattle color are very scanty. **Table 1** shows the comb, beak and wattle colors observed in improved HE and unimproved LE NICs while **Figure 1** shows birds with some plumage color phenotypes.

2.3 Body, eye, and shank colors of Nigerian indigenous chickens

Three shank colors: yellow (18.89 and 27.23%), white (38.89 and 41.16%) and black (42.22 and 31.61%) were reported by [9, 13], respectively in ICs from Benue State (Northcentral Nigeria) while three shank colors: white (36.15%), green (12.69%), and black (51.15%), and two shank colors (white, 70.00% and black, 30.00%) were reported in Tiv and Fulani ICs, respectively by [14]. The authors observed three eye colors namely yellow (50.77%), white (20.00%), and brown (29.23%) in Tiv ecotype and two colors in Fulani ecotype namely yellow and brown at 76.90 and 23.10%, respectively. All the birds (100%) had white skin. From ICs of Cross River State, [12] reported five eye colors (black, brown, dark red, orange, and pink), and two skin colors of white and yellow. Of the five eye colors, black was most frequent at 44.72% followed by brown (27.74%) while pink was the least frequent at 5.09%. White skin predominated over yellow skin in the sampled population (75.85 vs. 24.15%). Odah et al. [15] reported 10 shank colors in IC population from the same state. These were yellow, black, white, greenish, milky, ash, dark-ash, pink, red, and light brown with yellow being the most frequent (31.90%) followed by black (19.60%), and white (18.50%) while red and light brown were the least frequent (0.40%, respectively). In this same population eye color were six namely black, light brown, dark brown, dark red, orange, and pink with black, light brown and dark brown predominating (44.72, 14.91 and 12.83%, respectively)

Figure 1.
Plumage colors of some landrace chickens of Nigeria (unimproved and improved ecotypes). (A): Unimproved light ecotype (dwarf) ICs of various plumage and shank colors (females). (B): Unimproved light ecotype (dwarf) ICs of black plumage and mostly black shank color (females). (C): Heavy ecotype (HE) ICs (G_o generation) subjected to selection for growth and egg production traits. (D): Predominantly brown 2nd generation HE ICs (females). (E): Predominantly black plumage 2nd generation HE ICs (females). (F): Black, browm, and white plumage female progeny of 6th generation HE ICs. (G): Predominantly white plumage male progeny of 6th generation HE ICs. (H): Red/gold and white plumage male progeny of 6th generation HE ICs.

and the least frequent being pink (5.09%). In Dekina in Kogi State, Northcentral Nigeria, four shank colors were reported namely, black (13.75%), yellow (40.50%), black and yellow (37.25%), and white (8.50%) [10].

3. Productive characteristics of Nigerian indigenous chickens

Body weight, and morphometric traits; egg production traits, semen quality, fertility, hatchability, and chick survival; feed intake and feed efficiency have been used to characterize NICs for productive potentials. Body weight, and morphometric evaluations quantify growth potential, and meat yield while Egg production, semen traits, fertility, hatchability, and chick survival evaluate laying and reproductive capacities. These variables determine commercial value which, in addition to cultural and social utility, constitute conservation value.

3.1 Body weight, and linear body traits of Nigerian indigenous chickens

Early reports classified NICs based on location/tribal ecotypes. In southeastern Nigeria, [35] identified three location ecotypes (Nsukka, Owerri, and Awgu ecotypes) while [36] identified two tribal ecotypes (Yoruba and Fulani ecotypes). Odubote [16] observed that none of the location or tribal ecotypes was unique in any of the attributes and that the only striking phenotypic difference between these ecotypes is in their mature body size. The author hence distinguished three types namely dwarf, normal size and heavy body (Fulani) types. A more recent classification advocated only two categories based on mature body weight namely, light body weight ecotype (light ecotype, LE) and heavy body weight ecotype (heavy ecotype, HE) [8]. The LE represents the chicken type from rainforest and derived savannah agro-ecological zones, whose mature body weight ranges from 0.68–1.5 kg and includes dwarf and normal size types referred to as rain forest, swamp, or Yoruba chickens by some authors [6, 11, 17, 22] while the HE are those of the guinea savannah, Sahel savannah and some montane regions, whose mature body weight ranges from 0.90–2.5 kg referred to as Fulani, and Tiv chickens by some authors [11, 21].

The wide range of body weight within ecotypes reflect genotypic differences, differences in husbandry system, and level of input; body weight being generally lower in free range, scavenging system. Early studies reported mature (> 20 weeks) body weight range of 1.0 to 1.76 kg for extensive system [37, 38] and 768 to 1096 g at 20 weeks of age for on-station populations [39–42]. More recently, a mean range of 1.32 to 2.0 kg was reported for extensive system [10, 13, 15, 43] while for intensive system, 20 week body weight was reported as 771.11 and 765.94 g for LE parent and inbred projeny, respectively [44]; and 1.42, 1.39, and 1.30 kg for normal feather, naked neck, and frizzle ICs, respectively [45]. Momoh et al. [46] showed that HE and LE ICs differed significantly in body weight from hatch to 20 weeks of age (**Table 2**). Oleforuh-Okoleh et al. [52] reported higher body weight in normal feathered ICs compared to naked neck chickens at 4 and 8 weeks of age (312.06 ± 7.71 vs. 287.13 ± 6.17 g, and 931.72 ± 23.85 vs. 844.30 ± 21.84 g, respectively) but similar values at 12 and 16 weeks of age. Body length, chest girth, leg length, and shank circumference were also higher in normal feathered chickens at 4 weeks of age while chest girth, leg length, and shank length were higher at 8 weeks of age while [15] reported linear body values of 42.7 ± 0.03, 55.8 ± 0.21, 12.2 ± 0.04, 9.8 ± 0.02, 25.0 ± 0.70, and 8.9 ± 0.50 cm for body circumference, body length, shank length, keel length, wing length, and neck length, respectively in ICs from Bekwara in Cross River State, South–south Nigeria. Sanusi and Oseni [53] evaluated Fulani ecotype chickens under intensive and pasture production systems and reported significant effect of sex of chicken on body weight from 10 to 20 weeks of age as well as significant interaction effect of sex and production system on body weight. Males averaged 1343.43 ± 55.2 vs. 1295.57 ± 59.12 g while females averaged 938.66 ± 60.3 vs. 1061.805 ± 59.9 g for intensive vs. pasture systems, respectively.

Genetic resource	Hatch	4	8	12	16	20	Reference
DSIC (male)	29 ± 1.0	124 ± 9.2	311 ± 26.4	702 ± 55.3		1096 ± 84.1	[44]
DSIC (female)	23 ± 1.6	104 ± 14.5	262 ± 4.8	605 ± 67.5		948 ± 130.6	
RFIC (male)	24 ± 0.8	99 ± 6.6	255 ± 19.7	615 ± 41.3		810 ± 46.7	
RFIC (female)	25.6 ± 0.7	104 ± 5.9	242 ± 17.1	533 ± 35.7		768 ± 36.6	
[1]HE	30.30 ± 0.17	151.41 ± 1.74	344.19 ± 4.14	667.98 ± 6.30	791.52 ± 6.24	911.59 ± 6.33	[47]
HE	30.2 ± 0.06	157 ± 0.45	350 ± 3.01	720 ± 9.47	840 ± 9.35	976 ± 11.2	[48]
LE	24.2 ± 0.05	139 ± 2.24	299 ± 3.01	560 ± 4.31	707 ± 4.89	831 ± 5.52	
HE x LE	25.1 ± 0.04	147 ± 2.13	335 ± 2.81	700 ± 4.21	819 ± 4.86	937 ± 7.32	
LE x HE	28.6 ± 0.07	148 ± 2.03	331 ± 2.43	693 ± 3.51	806 ± 4.18	934 ± 4.54	
NF		312.06 ± 7.71	931.72 ± 23.85	1180.59 ± 32.45	1635.08 ± 43.62		[49]
Na		287.13 ± 6.17	844.30 ± 21.84	1158.15 ± 25.71	1587.98 ± 40.00		
NF x FF	25.48 ± 0.40	86.3 ± 0.54	267.78 ± 3.68	620.22 ± 9.99	819.14 ± 9.30	1040.52 ± 12.34	[50]
FF x NF	26.51 ± 0.38	87.18 ± 0.51	268.57 ± 3.52	608.15 ± 10.13	821.59 ± 8.83	1047.45 ± 13.47	
NF x Na	26.10 ± 0.19	83.57 ± 0.69	264.11 ± 3.19	639.49 ± 7.94	842.29 ± 5.88	1088.20 ± 12.21	
Na x NF	25.76 ± 0.43	80.91 ± 0.87	257.16 ± 3.01	500.53 ± 7.11	793.95 ± 5.84	1017.63 ± 10.79	
FF x Na	28.61 ± 0.34	91.87 ± 0.78	283.50 ± 2.41	526.81 ± 7.84	734.41 ± 7.38	1040.49 ± 13.06	
Na x FF	28.95 ± 0.45	88.29 ± 0.91	270.13 ± 1.92	623.18 ± 7.10	817.42 ± 6.71	1121.78 ± 9.94	
E x NF	26.45 ± 0.35			508.60 ± 29.85			[51]
E x Na	26.00 ± 0.26			519.43 ± 35.46			
E x F	26.50 ± 0.73			609.58 ± 16.86			
NF x E	29.84 ± 0.32			1039.15 ± 52.18			
Na x E	30.83 ± 0.59			910.88 ± 67.15			

Genetic resource	Hatch	4	8	12	16	20	Reference
F x E	30.22 ± 0.30			1141.88 ± 42.28			
E x (E x NF)	24.19 ± 0.50			1014.38 ± 71.90			
E x (E x Na)	26.42 ± 0.54			956.11 ± 69.54			
E x (E x F)	23.71 ± 0.40			645.00 ± 34.51			
E x (NF x E)	30.48 ± 0.38			1752.23 ± 42.49			
E x (Na x E)	30.00 ± 0.43			1223.13 ± 74.60			
E x (F x E)	31.33 ± 0.47			1976.67 ± 97.60			

DSIC: derived savannah IC; RFIC: rainforest IC; HE, LE: heavy, light, ecotype; NF, Na, FF: normal feather, naked neck, frizzle, E: exotic broiler;
[1]HE: 0–8 wk. (sexes combined), 12–20 wk. (female).

Table 2.
Body weight of various genetic groups involving IC eco- or geno-types as reported in different ecological zones.

3.2 Egg production, semen quality, fertility and hatchability potentials

Egg production of NICs is reported to be very low especially in traditional scavenging system. Egg production ranged from 22 to 80 eggs/hen/year [10, 15, 47, 50, 51, 54], laid in 2 to 3 clutches of size 4 to 14 eggs [10, 38, 55–57] and of weight, 25 to 35 g [10, 15, 58]. Reasons for poor egg production include poor genetic potential, disease, poor nutrition, broodiness and rearing of chicks, and social behavior [6, 10, 15]. Hatchability values reported across zones, ecotypes, and populations ranged from 60 to 100% [10, 15, 51, 55–57]. For on-station populations, a range of 35 to 175 eggs laid in 90 to 500 days, and of mean weight 28.78 to 43.9 g, was reported by various studies using deep litter or battery cage systems [35, 39, 59–64]. Age at first egg (AFE) ranged between 148.4 and 176.9 days (d) [60, 65]. More recently, [63] reported AFE of 156 to 159 d, and egg number and egg weight to 90 d of 34.04 ± 1.15 to 37.38 ± 2.21 eggs and 35.27 ± 0.31 to 35.73 ± 0.59 g, respectively over three generations while [66] reported AFE, body weight at first egg (BWFE), egg production (EN), egg weight (EW), clutch size (CS), and pause length (PL) to range between 22 and 31 and 20 and 23 d, 1350 and 1650 and 1300 and 1440 g, 78 and 174 and 58 and 128 eggs, 35.72 and 52.50 and 35.36 and 50.61 g, 3 and 9 and 2 and 6 eggs, and 1 and 3 and 1 and 6 d, for Fulani and Yoruba ecotypes, respectively in Southwest Nigeria. Gwaza et al. [67] reported AFE of 199.72 ± 0.089 and 195.30 ± 0.104 d and BWFE of 1.486 ± 0.104 and 1.186 ± 0.022 kg for Tiv and Fulani ICs, respectively. In the high rainforest zone of Nigeria, [17] observed no effect of genotype on fertility and embryo mortality between normal feathered, frizzle and naked neck ICs but percent hatchability was highest in normal feathered (86.36%). Fertility (range: 76.67–90.53), hatchability (range: 83.50–91.36), dead in shell (range: 8.23–9.46), and weak in shell (range: 0.32–1.32) did not differ significantly between naked neck, normal feathered, and frizzled ICs and an exotic broiler strain. For semen quality [68] reported higher mean ejaculate volume, sperm concentration, sperm motility, and vigor in local compared to exotic cocks at different collection frequencies and intervals. Omeje and Udeh [69] had shown that feed restriction adversely affected semen production in exotic than local cocks and that only the local cock yielded semen at once in four days feeding. Naked neck and normal feathered ICs had significantly higher sperm concentration and motility compared to Nera Black, White Leghorn, Giriraja, and an indigenous breed (FUNAAB Alpha) [70]. Ajayi et al. [71] showed that naked neck cocks had higher semen concentration than frizzle and normal feathered cocks ($4.85 \times 10^9 \pm 0.03$/ml vs. $3.26 \times 10^9 \pm 0.94$ and $3.33 \times 10^9 \pm 0.57$/ml, respectively) and there was higher sperm motility in naked neck and frizzled chickens compared to normal feathered while normal feathered and frizzled had higher semen volume compared to naked neck. Udeh et al. [72] studied the value of linear body measures to predict semen traits of local and exotic cocks and reported higher semen volume in local compared to exotic cocks, and positive correlation between wing length and percent live sperm in local chickens while beak length, sperm concentration, and motility; comb length and sperm concentration; and shank length and sperm motility were positively correlated in exotic cocks. Oke and Ihemeson [45] had observed no effect of genotype on total reproductive organ weight in normal feathered, frizzle and naked neck ICs (14.1, 11.2, and 11.6 g, respectively) but higher ($p \leq 0.05$) testis weight, semen volume, sperm concentration and motility in normal feathered (11.7 g, 0.25 ± 0.02 ml, $270 \times 10^9 \pm 5.99$/ml, and 77%, respectively) and naked neck (10.1 g, 0.24 ± 0.02 ml, $250 \times 10^9 \pm 6.00$/ml and 65.8%, respectively) chickens compared to the frizzled genotype (7.07 g, 0.15 ± 0.03 ml, $198 \times 10^9 \pm 11.5$/ml and 52.5%, respectively).

4. Genetic improvement of productivity of Nigerian indigenous chickens

Genetic improvement of NICs in growth traits, egg production, fertility and hatchability has been the objective of numerous studies. These studies involve crossbreeding between ecotypes, and genotypes; ICs with exotic breeds/strains; and selection within ecotypes.

4.1 Crossbreeding between Nigerian indigenous chicken ecotypes, and genotypes

The extensive genetic diversity between IC ecotypes as well as within and between population variations in productive traits provide opportunity for improvement of performance through within and between population selective breeding. Ogbu and Omeje [26] reported high within population variation in growth traits in NICs which could be exploited for genetic improvement while [73] recorded improved growth performance following positive assortative mating in NIC populations. Egahi et al. [48] evaluated the effect of crossbreeding between NIC genotypes and reported the body weight of progenies of crosses between normal feathered, frizzle, and naked neck ICs to range from 25.48 ± 0.40 to 28.95 ± 0.45 g for hatch weight, 80.91 ± 0.87 to 91.87 ± 0.78 g, 257.16 ± 3.01 to 283.50 ± 2.41 g, 500.53 ± 7.11 to 639.49 ± 7.94 g, 734.41 ± 7.38 to 842.29 ± 5.88 g, and 1017.63 ± 10.79 to 1121.78 ± 9.94 g, for 4, 8, 12, 16, and 20 weeks of age, respectively (**Table 2**) while [67] observed significant effect of sire, dam, and ecotype on AFE and BWFE of Fulani and Tiv ICs and positive genetic correlations between AFE, BWFE, and EW; and EW, egg length (EL), and egg diameter (ED). Additive genetic heritability (h^2) of AFE, BWFE, EW, EL, and ED for Fulani and Tiv ICs were 0.358 and 0.438, 0.420 and 0.398, 0.482 and 0.642, 0.182 and 0.000, and 0.051 and 0.309, respectively. For egg production pattern (clutch size, clutch number, pause number, and pause length), h^2 values were 0.358, 0.412, 0.045, and 0.036, respectively in Fulani chickens and 0.428, 0.391, 0.063, and 0.048, respectively in Tiv chickens [74]. High positive genetic correlations (range: 0.78 to 0.88) were reported between BWFE and AFE, BWFE and EW, EW and EL, and EW and ED. Agu et al. [75] reported significant effect of sire on AFE, weight of first egg (WFE), egg production (EN), egg mass (EM), egg weight (EW), thigh length, back width, and neck length in HE ICs of Southeastern Nigeria. Heritability values for EW, EN, and EM was 0.31 ± 0.30, 0.16 ± 0.13, and 0.28 ± 0.24, respectively and ranged from 0.13 ± 0.23 to 0.52 ± 0.24 from 4 to 20 weeks of age for thigh length, 0.23 ± 0.23 to 0.41 ± 0.29 for back width, and 0.10 ± 0.18 to 0.52 ± 0.44 for neck length. Momoh et al. [46] showed that main (HE x LE) and reciprocal (LE x HE) crossbred progenies were similar in body weight to the HE chickens but superior to the LE chickens. Momoh and Nwosu [76] evaluated the genetic parameters of body weight (BW), body weight gain (BWG), and feed conversion ratio (FCR) in HE, LE, HE x LE, and LE x HE populations and reported h^2 values of 0.17 ± 0.19, 0.08 ± 0.10, and 0.19 ± 0.22 for BW at hatch, respectively. The corresponding values for BW from week 4 to week 20 of age ranged from 0.16 ± 0.18 to 0.43 ± 0.26, 0.16 ± 0.13 to 0.25 ± 0.17, and 0.20 ± 0.21 to 0.36 ± 0.28, respectively. For daily gain from 4 to 20 weeks, 0.03 ± 0.11 to 0.12 ± 0.14, 0.21 ± 0.15 to 0.89 ± 0.50, and 0.10 ± 0.16 to 0.80 ± 0.14, respectively were reported while 0.13 ± 0.16 to 0.41 ± 0.25, 0.10 ± 0.10 to 0.46 ± 0.24, and 0.11 ± 0.16 to 0.24 ± 0.23, respectively were reported for FCR.

4.2 Crossbreeding of Nigerian indigenous chicken ecotypes, and genotypes with exotic breeds

Crossbreeding NICs with exotic breeds/strains is advocated to exploit the high genetic distance and variation between ICs and exotic strains believed to enhance hybrid vigor, heterosis, and breed complementarity. Omeje and Nwosu [58] evaluated progenies of crosses between NIC (LC) and Gold link (GL, an exotic breed) and reported reduced age at first egg (AFE) in LC x GL progenies compared to LC, GL, and GL x LC (155.4 ± 1.49 vs. 157.8 ± 3.21, 169.2 ± 1.65, and 169.7 ± 3.74 d, respectively). Authors also reported superior egg weight for GL, GL x LC, and LC x GL compared to LC (53.44, 47.74, and 47.02 vs. 38.63 g, respectively). The corresponding values for egg mass was 12.12, 10.18, and 8.89 vs. 5.64 kg, respectively. An improvement in annual egg production from 146 eggs/hen for LC to 213 eggs/hen for GL x LC was reported by [77]. Fewer but longer pauses and shorter but more pauses were observed in LC and LC x GL; and GL and GL x LC, respectively. It was also observed that hybrids of crosses involving LC, Yaffa (Y) and GL exotic chickens [LC(Y x GL), GL (Y x LC), and Y x GL] were superior to LC in egg weight (51.91, 52.07, and 54.22 vs. 40.36 g, respectively), and egg mass (5.40, 5.37, and 6.10 vs. 3.32 kg, respectively) [78] while [79] reported superior body weights for GL, GL x LC, and [GL(GL x LC)] in growth and egg production compared to LC attributed to dominance, epistasis, and/or maternal effects. Oluyemi [80] reported heterosis of 12 week body weight in progenies of LC x White Rock and LC x Rhode Island Red (RIR) to range from 4.0 to 12.4% while significant improvement in BWFE, WFE, ASM, egg production (EN_{90}) and egg weight (EW_{90}) to 90 d was observed in LC x RIR males backcrossed to RIR dams [81]. Ukpong [82] observed improved meat yield in crosses of LC x Abor acre (AA) broiler chickens relative to LC while [49] reported improved growth performance and feed conversion in F_2 (main and reciprocal backcross groups) compared to F_1 counterparts in crosses of Abor Acre broiler breeder and native chicken genotypes (**Table 2**). Nwachukwu et al. [18] had shown that main crossbred progenies of AA x LC genotypes were inferior in body weight at first egg to their reciprocal crossbred counterparts (960.00, 812.50 and 1030.00 vs. 1891.67, 1576.50 and 2072.00 g, respectively). The latter group also had higher values for WFE, EN_{90}, egg length, yolk index, albumen weight, and Haugh unit and crosses involving the frizzle genotype were superior to crosses involving other IC genotypes. Adeleke et al. [83] crossed complete feathered, frizzle and naked neck ICs to Anak titan (AT) broilers and reported significant effect of sire, dam, and progeny genotype on growth traits. Anak titan sire significantly improved 8 to 20 week body weight compared to IC sires. Significant sire genotype effect on fertility and percent dead in shell was also reported in IC genotypes crossed to AT [84]. Frizzled sire had highest fertility (90.5%) and produced eggs with highest hatchability (91.4%) and least embryo mortality (7.5%) while AT dams produced eggs with highest fertility and hatchability (88.2 and 94.6%, respectively). Main and reciprocal crosses involving the frizzle genotype were also better in the traits studied [84]. Ayorinde et al. [85] observed superior body weight in Fulani ecotype X Dominant black (FE x DB) progenies compared to FE, DB, and DB x FE at 21 weeks of age (1408.50 ± 3.5 vs. 1350.60 ± 4.5, 1388.60 ± 3.2, and 1375.00 ± 3.2 g, respectively). All crossbred genotypes were superior in early (0 to 13 weeks) body weight to FE. Udeh and Omeje [86] reported heterosis of body weight in native and exotic inbred chicken crosses with native X exotic being higher than exotic X native, and native backcrosses being higher than exotic backcrosses. The authors concluded that body weight heterosis resulted from complete dominance in native backcrosses

while 2–3 locus parental epistasis involving complementary genes were responsible for heterosis observed in exotic backcrosses. Udeh [87] reported significant differences in age at first egg (AFE), BWFE and WFE among native X exotic inbred chicken groups. Inheritance of AFE and WFE was attributed to additive (e.g., sire) and non-additive (e.g., dam) genetic effects while dominance effect was responsible for inheritance of BWFE. Udeh [88] showed that crossing IC with inbred progenies of H and N brown nick, and Black Olympia, improved BW and BWG from hatch to 20 weeks of age relative to IC due to significant direct additive, maternal additive and direct heterotic effects. Significant genotype effect on fertility, and hatchability and improved BW and EW in LE x Isa Brown progenies compared to LE was reported by [69].

Reported heritability (h^2) estimates of production traits in crosses between local chickens and exotic breeds vary widely being specific for populations, point of estimation, and age of birds. Akinokun and Dettmers [89] reported values of 0.15, 0.02 and 0.25 for age at sexual maturity (ASM), 4 months, and 8 months egg production, respectively; 0.20 to 0.54 for egg weight to 7 months of lay; 0.51, 0.41 and 0.27 for 4, 12, and 20 week body weight, respectively; and realized heritability of 0.27 and 0.24 for 4 months egg production in 2nd and 3rd generation, respectively. Oluyemi [90] had reported h^2 value of 0.31 for 12 week body weight while [91] reported values of 0.35 to 0.74, 0.31 to 0.89, and 0.27 to 0.49 for body weight from sire, dam, and sire + dam variance components in progenies of crosses involving ICs, Yaffa and Goldlink. The same authors reported heritability of 0.46 ± 0.24 for egg weight and 0.36 ± 0.18 for shell thickness. Udeh [92] reported h^2 values of 0.08 to 0.80, 0.03 to 0.69, and 0.22 to 0.47 for BW, shank length, and wing length, respectively, and positive genetic correlation (except for SL and WL) and phenotypic correlation coefficients that ranged from 0.18 to 0.96 and 0.10 to 0.91, respectively among BW, SL, and WL at different ages in NICs.

4.3 Genetic improvement of Nigerian indigenous chickens through selection

Relatively few studies that are far in between have been undertaken to evaluate selection response in NICs. The earliest report on genetic selection [80] observed poor selection response in body weight in NICs over 7 generations while [93] reported genetic gain of 2.20 and 2.48 eggs for first and second generations, respectively. Recently, a number of studies demonstrated significant improvement of growth and egg production traits. In light ecotype (LE) IC, [63] reported improvement in BWFE, EN, EW, and WFE but increased AFE following three generations of index selection (G_0 to G_2). Values reported for selected vs. control groups ranged from 962.50 ± 23.33 to 1062.90 ± 18.06 vs. 880.14 ± 16.72 to 892.10 ± 18.85 for BWFE, 33.40 ± 1.23 to 47.18 ± 2.36 vs. 34.04 ± 1.15 to 37.38 ± 2.21 eggs for EN, 36.51 ± 0.55 to 38.64 ± 0.49 vs. 35.27 ± 0.31 to 35.73 ± 0.59 g for EW, 30.62 ± 0.92 to 31.92 ± 0.63 vs. 29.44 ± 0.37 to 29.99 ± 0.66 g for WFE, and 159.47 ± 1.97 to 164.78 ± 2.40 vs. 158.40 ± 1.13 to 159.48 ± 1.47 d for AFE. From the same population cumulative selection differential (CumΔs) of 269.38 g, 1.58 g, and 3.88 eggs and realized genetic gain per generation of 94.22 g, 0.84 g, and 4.85 eggs, for BWFE, EW, and EN, respectively were reported [94]. Pooled heritability estimates over the three generations was 0.56, 0.44, and 0.28 for BWFE, EN, and EW, respectively while genetic correlation values were 0.41 for BWTE and EW, −0.18 for BWFE and EN, and − 0.23 for EN and EW [95]. Ogbu et al. [96] estimated the economic, and relative economic weights of BW, EW and EN to 16 weeks of lay in heavy ecotype IC (HE) over three generations (G_0 to G_2) for use in construction of selection indices and reported values of 7.47 and 3.15, 13.67

and 5.77, and – 2.37 and – 1.00, respectively in G_0,; 13.07 and 3.82, 23.69 and 6.93, and – 3.42 and – 1.00, respectively in G_1; and 16.80 and 2.89, 30.75 and 5.28, and – 5.82 and – 1.00, respectively in G_2 generation. Using an index of weighted breeding values that considered the heritability, relative economic weight, and standardized trait values, [97] reported expected average direct genetic gain per generation for short term (16 weeks) egg production of 12.58 eggs, 1.98 g, and 25.04 g for EN, EW, and BWFE, respectively; realized genetic gain of 2.19 and 1.59 eggs for EN, 1.65 and 0.26 g for EW, and – 25.60 and 123.64 g for BWFE for G_0 and G_1, respectively; and corresponding values for ratio of realized to expected genetic gain of 2.27 and 1.22, 3.15 and 0.24, and 0.95 and 2.21, respectively. The authors reported h^2 estimates that ranged from 0.12 to 0.24 for EN, 0.34 to 0.43 for EW and 0.57 to 0.69 for BWFE. For males, improvement in 39 week body weight was observed with realized genetic gain of 284.22 and 111.87 g for G_0 and G_1, respectively and average expected gain of 508.50 g per generation following mass selection. Ogbu [98] had reported improvement in BW from hatch to 39 weeks following mass selection in male HE IC with final body weight increased from 1372.66 ± 16.46 g in G_0 to 1768.75 ± 33.15 g in G_2 implying a cumulative gain of 925.76 g over three generations. The author reported h^2 estimate of 0.24 ± 0.27 to 0.59 ± 0.45 and 0.13 ± 0.49 to 0.25 ± 0.31 across the three generations for BW from 12 to 20 and 39 weeks of age, respectively. Agbo [99] furthered the selection for improved growth and egg production in HE ICs from 4th to 6th generation and reported improvement in short term (16 weeks) EN and EW from 89.98 ± 0.81 eggs and 43.52 ± 0.08 g, respectively in G_4 to 94.98 ± 0.51 eggs and 45.06 ± 0.12 g, respectively in G_6, and mean realized genetic gain of 119.18 g for 39 week BW in males. The author reported h^2 values of range 0.28 to 0.52 for EW, 0.14 to 0.45 for EN, and 0.23 to 0.69 for BWFE and relative economic weight of 2.02 to 2.24, 2.45 to 2.78, and – 1.00 for EW, EN, and BWFE, respectively. These studies indicate that NICs can be improved for commercial utility as layer or dual purpose bird (meat and egg production) using within ecotype selection.

5. Genetic diversity and distance within and between ecotypes, and genotypes

Studies to evaluate genetic diversity and distance within and between NICs involved phenotypic and molecular evaluation of different ecotypes, genotypes and populations [19–21]. Ige [100] using correlation and regression models estimated genetic parameters of BW and linear body traits to evaluate genetic distance between Yoruba (YE) (light) and Fulani (FE) (heavy) IC ecotypes. Correlation coefficients ranged from 0.30 to 0.89 and 0.40 to 0.99 in male and female FE, respectively and from 0.20 to 0.88 and 0.15 to 0.85 in female and male YE, respectively. Coefficient of determination (R^2) ranged from 0.20 to 0.91, 0.10 to 0.76, and 0.22 to 0.94 for linear, quadratic and cubic functions, respectively in YE and 0.55 to 0.94, 0.64 to 0.81, and 0.55 to 0.86, respectively in FE. The IC ecotypes showed strong discriminatory power (98.29%) but low genetic distance (Euclidean genetic distance = 11.2) indicating close relationship. Using canonical discriminant analysis [19] evaluated the diversity among NIC genotypes and reported highest discriminatory power in Body weight, thigh length, and body width. Mahalanobis distance measure indicated closer relationship between normal feathered and naked neck (3.371) compared to normal feathered and frizzle genotype (4.626). Gwaza et al. [101] however reported wide genetic diversity in body dimensions among isolated populations of Tiv chickens. Ukwu et al. [102] evaluated within ecotype genetic

diversity at the hemoglobin (Hb) locus in Tiv chickens and observed three Hb genotypes (Hb^{AA}, Hb^{AB}, and Hb^{BB}) at frequencies 0.40, 0.32, and 0.24, respectively resulting from two Hb alleles at frequencies 0.60 for Hb^{A} and 0.40 for Hb^{B}. Tiv chickens showed moderate Hb heterozygosity of 0.48. Adenaike et al. [20] investigated genetic diversity in NIC genotypes and Nera Black chickens based on variation in *zyxin* and TNFRSF1A genes. Highest nucleotide substitution per site (D_{xy} = 0.081) was reported for TNFRSF1A gene sequences in normal feathered and naked neck chickens while frizzle and Nera Black chickens had the lowest value of D_{xy} = 0.065. For *zyxin* gene sequences, normal and frizzle feathered chickens had highest D_{xy} value of 0.6551 vs. 0.0739 for Nera Black and naked neck. Mean haplotype diversity and average number of nucleotide difference in TNFRSF1A gene sequences was highest in Nera Black (0.923 and 3.967, respectively) while frizzle chickens had the corresponding lowest values (0.00489 and 3.143, respectively). The authors inferred high nucleotide divergence, haplotype diversity and restricted gene flow among the chicken genotypes. Gambo et al. [21] studied diversity and genetic distance within and between Tiv (TE) and Fulani (FE) ecotypes based on blood proteins (Hb, albumin, transferrin and carbonic anhydrase) electrophoresis. Two Hb genotypes (Hb^{AA} and Hb^{AB} at frequencies 0.125 and 0.875, respectively in TE, and 0.538 and 0.462, respectively in FE), three albumin genotypes (AB, and AC at frequencies 0.026 and 0.974, respectively in TE, and AA and AC at frequencies 0.077 and 0.923, respectively in FE), six transferrin genotypes (AA, AB, AD, BB, BD, and DD at frequencies 0.054, 0.027, 0.297, 0.162, 0.378, and 0.082, respectively in TE and AA, AD, and DD at frequencies 0.568, 0.243, and 0.189, respectively in FE), and four carbonic anhydrase genotypes (AA, AB, AC, and BB at frequencies 0.20, 0.175, 0.525, and 0.100, respectively in TE and AA, AB, and AC at frequencies 0.263, 0.026, and 0.711, respectively in FE) were reported. Thus Hb^{AA} and Hb^{AB} were most abundant in TE and FE (0.875 and 0.538, respectively). Genotype AC for albumin, BD and AA for transferin and AC for carbonic anhydrase were the most frequent in the two ecotypes while albumin genotypes AA and AB were absent in TE and FE, respectively. The authors inferred a common origin for the two ecotypes but positive genetic distance between them attributable to divergence from one locality to another. Ige and Salako [103] employed direct gene counting and dendogram following cellulose acetate electrophoresis to evaluate genetic variation at the transferrin locus and established genetic relationships within and between FE and YE chickens. The authors reported six phenotypes (AA, AB, AC, BB, BC, and CC at genotypic frequencies 12.5, 10.0, 7.5, 35.0, 17.5, and 15.0%, respectively in YE, and 11.19, 16.6, 2.8, 22.2, and 27.7%, respectively in FE) controlled by three co-dominant alleles (Tf^{A}, Tf^{B}, and Tf^{C} at frequencies 0.35, 0.20, and 0.43, respectively in YE and 0.21, 0.32, and 0.44, respectively in FE). Dendogram clustering analysis indicated 72% genetic similarity within FE, 58% within YE, 70% between the two ecotypes, and no genetic relationship between transferrin locus and phenotypic traits such as sex, plumage color, and comb type of chicken. Ige et al. [22] considered the variation at globulin (95SKDa), transferrin (66KDa), albumin (36KDa), and post albumin (29KDa) loci using sodiumdodecylsulphate polyacrylamide gel electrophoresis to evaluate the genetic similarity of YE ICs. Similarity indices for transferrin, albumin, globulin, and post albumin were 58, 19, 18, and 40%, respectively indicating genetic similarity at the transferrin locus but wide variation at the other blood protein loci. The authors also inferred that the YE IC populations were still under natural selection. Adeleke et al. [104] had reported mean genetic similarity index of 55% between normal feathered, frizzle feathered and naked neck IC genotypes using blood protein polymorphisms and inferred clearly separated genotypes with naked neck genotype being the most diverged.

6. Conservation of Nigerian indigenous chicken genetic resources: issues and concerns

Nigerian ICs have evolved as homeostatic populations with adaptive and neutral diversity and capacity to respond to changing environmental conditions in diverse ways [6, 7, 16]. Experts believe that diverse unselected indigenous animal resources that harbor high proportions of neutral and adaptive diversity represent equivalent genetic resources in the absence of wild ancestors, and should be conserved with high national priority [105]. Emerging diseases, climate change, and changes in nutritional needs of humanity are unforeseeable. Consequently, overall genetic resources defined by adaptive and neutral diversity must be maintained in order to conserve the potential to react to future challenges [105–107].

There is dearth of data on the extinction risk status of NICs but commentators agree that IC genetic resources are the most endangered and under conserved animal genetic resources [6, 108, 109] with extinction risk of 33% [110] and about 40% of breeds with unknown extinction risk status [111]. Studies have shown the dwindling frequency or apparent loss of rare NIC phenotypes such as the crested head, feathered shank or ptylopody, polydactyl or 5 toed, short flight feathered, and dwarf types, naked neck, frizzle, and silky, and major genes such as naked neck (Na), frizzle (F), dwarf (Dw), ptylopody (Fsh), and polydactyl (Po) believed to enhance survival and performance in tropical environments [6, 16, 112].

6.1 Drivers of erosion and loss of indigenous chicken genetic resources

The declining animal genetic resources in developing countries has been blamed on a number of factors defined by scholars to threaten production, utilization, and conservation of native animal populations including ICs [24, 113, 114]. A brief overview of these factors will provide the background for suggested mitigation strategies.

a. Pressure to substitute indigenous types with exotic breeds

   The notion within professionals, and policy makers that husbandry of landrace chickens is an economic waste put pressure on farmers to cull local strains in favor of exotic breeds [23] leading to loss, sometimes irretrievably, rare IC genetic resources [23, 24].

b. Introgression of exotic genes into native animal genetic base

   To meet growing animal food demands due to increasing human population and rise in income, policy makers, researchers, and farmers advocate crossbreeding of local strains and exotic breeds without long-term breeding objectives [23, 98, 115]. These activities dilute and narrow indigenous animal genetic base and lead to loss of important traits for survival and production in scavenging husbandry system and harsh (disease endemic and high temperature) environments [23, 24, 115, 116]. Reduced fitness of resulting hybrids have been reported in chickens and other species [24, 117], and no commercial breed has resulted from decades of crossbreeding involving NICs and exotic breeds [98]. Similar scenario has been reported in other African countries [23, 24, 115, 118, 119].

c. Radical shift in production system and poor economic valuation of ICs

   The shift from small scale, subsistence production to large scale, intensive holdings alienates indigenous strains [24, 120, 121], resulting in loss of IC

genetic resources [111]. Following the adoption of backyard or family poultry that employs exotic breeds, the family local chicken was substantially eliminated [121]. In addition, native chickens have attracted poor economic appeal because only direct use commercial products (without adaptive potentials) have been used in economic assessment of chicken genetic resources [23, 24].

d. Globalization and livestock revolution

The expanding industrial poultry production coupled with increased farm input costs necessitate that breeds that produce more efficiently are adopted in place of indigenous strains [122–124]. Furthermore, increased globalization of animal production and worldwide movement of germplasm fuel breed replacement against ICs leading to decline and loss in IC genetic resources [23, 117, 122].

e. Disease, Predators, negative selection and cultural practices

Endemic diseases and predators cause the loss of ICs [23, 48] and force many marginal families to discontinue investment in IC production [23]. Culling the best chickens for income and other functions (food, festivals, cultural, religious or ritual practices, i.e., negative selection) [16, 125], without a breeding programme for their replacement, depletes IC genetic resources.

6.2 Key concerns on loss of indigenous chicken genetic resources

The concern about loss of IC genetic resources stems from the multifaceted economic, environmental and socio-cultural consequences highlighted by numerous studies [6, 7, 16, 24, 109, 113].

a. Extinction of native strains and loss of overall genetic diversity and heritable variations with co-adapted genes and gene complexes that may be useful to meet breeding goals now and in the long-term [24, 105, 126].

b. Depletion of adaptive genes and traits, reduced fitness and evolutionary potentials, resulting in reduced flexibility of future breeding options [6, 108, 109, 111].

c. Limited gene flow between populations, genetic bottleneck, low effective population size and heightened inbreeding, loss of reproductive capacity, fecundity, and survivorship [105, 122, 126].

d. Loss of key genetic attributes for chicken production in marginal environments, and in disease and parasite endemic regions [16, 24, 105], resulting in loss of livelihood [24, 109], irreversible social disintegration, and human migration [24, 127, 128].

e. Loss of cultural identity and pride since ICs are associated with peoples, and tribes, and are integral part of their culture, tradition and wellbeing [23, 109, 129].

f. Loss of valuable animal models for biomedical research and training [24, 130] and loss in country gross domestic product (GDP) accounted for by indigenous chicken production subsector [24].

6.3 Schemes to conserve Nigerian indigenous chicken genetic resources

Conservation of IC genetic resources can be ex situ or in situ or both. Ex situ conservation involves ex situ in vivo which is conservation of genetic resources away from their traditional breeding and production environments or locality as in live animal facilities (zoological gardens, parks, on-station farms) [131, 132], and ex situ cryopreservation which is conservation of genetic materials such as semen, oocytes, embryos, and deoxyribonucleic acids (DNAs) in gene banks [131, 132]. In situ conservation on the other hand is conservation of living genetic resources in their natural habitat or production environment such as on-farm populations or community based production facilities [24, 131].

Animal research stations, parks, and zoological gardens exist in few states in Nigeria but ICs are not currently included in these facilities. Ex situ in vivo facilities face challenges such as inadequate infrastructure, low technical capacity, obsolete legislation, and epileptic funding. Apart from these, ex situ in vivo conservation implies that animals are kept in managed environments such that natural selection may no longer be solely responsible in shaping attributes [105, 132]. Being isolated and with limited gene flow, ex situ in vivo populations express limited genetic diversity with time [105, 132]. Coupled with decreasing census number, they become genetically distinct from the source population [24, 105]. The resulting small effective population, high rate of inbreeding, loss of fitness, reproductive failure, poor fecundity and survivorship lead to high extinction risk [105, 109].

Ex situ conservation in gene banks is an effective means of conserving critical genetic resources from rare and extremely threatened animal species. Large biological materials representing tremendous genetic diversity can be stored in gene banks. These materials are however, none homeostatic entities that do not respond to environmental challenges and so do not undergo natural selection and evolution. Consequently, they reflect only the genetic diversity of the source population at point of collection. Semen, oocytes, DNA, etc. do not reflect the historical, ecological, cultural, traditional, and economic values of the source population and do not fulfill these roles. Furthermore, ex situ conservation runs on sophisticated technology, and infrastructure, high level technical and human resources, and huge capital investments which many third world countries including Nigeria may not afford at present [24, 133]. Despite the many treaties on conservation of biological diversity, the topic of conservation is not a priority in many third world countries battling to feed increasing human populations [24, 133].

In situ conservation aims to maintain animal populations in original habitats under the management of traditional keepers. In addition to minimizing ecological disruption, it is dynamic, allowing genes to evolve subject to the environment [133]; encourages native production systems, historical, and socio-cultural roles and values [24], livelihood, food security, panmixis, gene flow and biodiversity, natural selection and evolution, and development of adaptive capacity [24, 122, 133].

To be successful, in situ conservation requires the participation of farmers who become owners and managers of the conservation [122, 133]. It must be implemented using community-based management initiatives aimed to enhance IC production and returns, and promote food security. It has been emphasized that substitution of ICs with exotic breeds and adoption of modern technology and breeding practices that enhance productivity of chickens cannot be halted because providing adequate animal food for the increasing human population from finite resources is of primary concern to policy makers and farmers [122, 133]. Furthermore, profit motives drive economic endeavors. Consequently, a convincing instrument that could sway farmers to rear ICs is to provide economic incentives as compensation for roles in IC conservation.

6.4 Optimum conservation strategy for indigenous chicken genetic resources

The combination of ex situ and in situ conservation could be optimal for IC genetic resources [24, 109, 133]. Ex situ in vivo conservation could maintain diverse NICs in production and genetic improvement facilities with well-defined improvement programme [23, 109] that aim to preserve heritable variations, prevent fixation of deleterious alleles, and retain high reproductive fitness and adaptive potential [109] while in situ conservation would maintain ICs as on-farm populations. The segregation of conserved and genetic improvement populations will enable a separated but connected programme whereby conserved populations feed genetic improvement while maintaining high genetic diversity to ensure resilience and adaptability [109]. On-farm conservation implemented with well defined, and appropriately valued productive and adaptive traits, with market niches for all potentials, and with well informed, and adequately motivated IC farmers, will serve as reservoir of raw genetic diversity and together with ex situ populations, supply critical materials for conservation in gene banks. To determine appropriate compensation for rearing ICs, the model proposed by [133] for determining compensation for on-farm conservation of landrace crop varieties could be adopted. Using this model, economic incentive or compensation is the difference in net revenue or net profit between IC and exotic chicken production by each participating farmer. A number of national and international agencies are deploying this economic incentive strategy to encourage farmers to conserve landrace crops on-farm [133]. To secure effective cooperation, communities must be made aware of the costs and benefits of interventions, the capacity of proposed actions to achieve set objectives, and the economic benefits accruable to the farmer and community [133]. A rational farmer will usually shift from IC or exotic chicken production after comparing the expected annual profit of each enterprise. The proposed compensation framework will help to determine the critical diversity to conserve, the current diversity that maximizes total productivity, the risk of diversity loss due to changing economic, production and technological constraints and the optimal cost of conservation [133].

Critical to NIC conservation is proper characterization and economic valuation to enhance conservation value [6, 16, 108, 109]. Characterization should aim at comprehensive knowledge of the ecotype phenotypic and genotypic characteristics including data on population size and structure, geographical distribution, the production environment, and within and between breed genetic diversity [109, 122]. Conservation value is enhanced by appraisal of the relative importance of NICs from the farmer's perspective and the value placed on the characteristics, and maintenance of IC diversity [109, 122]; creation of appropriate breeding objectives to maximize the value and contribution of ICs to livelihood, and food security; and provide incentives including knowledge and infrastructure for local communities to keep and maintain IC genetic resources in their respective ecological context, thereby achieving conservation as well as maintaining rural livelihood and food security. Conservation priority should be given to ICs proven to be free of admixes of foreign genetic elements, and should be focused on the zones that contain maximum IC diversity to minimize the cost of conservation [108, 133].

7. Conclusion

Nigerian ICs are a genetically complex and critical animal genetic resource characterized by unique genetic attributes, diversity, and heritable variations. Conservation of the total diversity of NICs is very crucial because genetic

complexity is requisite for evolutionary adaptation and adaptation is key to long-term survival. There is need to prioritize conservation of NICs (an invaluable national heritage) to stem the loss of IC genetic resources. Adoption of suggested conservation strategies would lead to the realization of this goal.

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