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Morphological and carcass traits of three chicken genotypes under free-range, semiintensive, and intensive housing systems

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Abstract: The present study evaluated the effect of housing system on morphometric and carcass traits of 3 chicken genotypes. In total, 180 cockerels and 180 pullets of 6 weeks old were studied. A randomized complete block design in factorial arrangement, with 18 experimental units of 20 birds each, was applied. Treatments consisted of 3 genotypes consisting of purebred Naked Neck (NN) birds and two crossbreeds (Rhode Island Red × Naked Neck = RNN, Black Australorp × Naked Neck = BNN) and 3 housing systems (free-range, semiintensive, and intensive). Regarding males, RNN chickens had the highest weight at slaughter (1491.12 ± 64.10 vs. 1390.30 ± 49.15 and 1333.76 ± 37.54 g; P = 0.0009), dressed weight (870.12 ± 32.32 vs. 794.07 ± 24.75 and 724.51 ± 10.50 g; P < 0.0001), and breast weight (158.35 ± 8.03 vs. 128.26 ± 11.06 and 118.37 ± 8.18 g; P < 0.0001) as compared to BNN and NN. In terms of housing system, keel length (10.66 ± 0.15 and 10.42 ± 0.11 vs. 9.93 ± 0.15 cm; P < 0.0004), weight at slaughter (1482.78 ± 50.15 and 1498.02 ± 33.65 vs. 1234.37 ± 19.95 g; P < 0.0001), and dressed weight (829.78 ± 37.63 and 829.05 ± 24.74 vs. 729.87 ± 15.49 g; P = 0.0007) were higher in semiintensive and intensive birds as compared to free-range birds. Regarding females, drumstick length (11.66 ± 0.25 vs. 10.47 ± 0.23 and 10.36 ± 0.31 cm; P = 0.0007), drumstick weight (124.93 ± 13.70 vs. 93.41 ± 2.91 and 86.43 ± 2.51 g; P < 0.0001), and thigh weight (132.85 ± 13.23 vs. 107.68 ± 2.05 and 97.13 ± 3.42 g; P < 0.0001) were higher in intensive birds than free-range and semiintensive systems. In conclusion, RNN and BNN chickens of both sexes had better morphological and carcass traits during the growing stage as compared to NN.

Key words: Housing system, crossbred chicken, purebred chicken, morphometrics, carcass traits

1. Introduction

Genetic improvement in rural poultry can be accomplished by selection or crossbreeding while selection procedures are long-term but definite. Crossbreeding of indigenous germplasm with exotic breeds gives an advantage for artificial selection for performance of exotic breeds and natural selection for resistance and acclimatization of indigenous breeds for the local environment [1]. Crossbreeding results in the development of birds that have better growth, morphometric, and carcass characteristics and reproductive traits, hence reducing the total cost of production [2,3].

Birds under free-range housing systems have access to enriched environments that promote behavioral activities, i.e. scratching and foraging, and improve the overall welfare of the birds. Environmental enrichment can stimulate and encourage explorative behaviors and create a series of behavioral opportunities [4]. The benefits of such enrichments are numerous and give an opportunity to birds for more even distribution, which reduces aggression, stress, and fear response [5]. Such types of housing systems coupled with higher welfare standards can produced a better quality of poultry meat that is more suitable for consumer preferences in Europe, America, and Asia [4,6].

Meat quality attributes of organic and free-range housed chickens are considered more valued as far as quality is concerned. There are numerous factors that affect the quality of meat, such as genotype, nutrition, housing system, slaughter age, and motor activity [7–9]. Indigenous chicken breeds are generally nominated for free-range housing systems because of their hardy nature and better acclimatization in extreme weather conditions. Moreover, some studies reported that under intensive housing systems birds are unable to exploit their maximum genetic potential and their growth is limited because of deficient nutrition [10,11].

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The quality of meat is a complex trait affected by genetic and nongenetic factors, and the variation in meat quality within and between birds can be wide [12]. Therefore, alternative housing systems and genotypes need to be further investigated. It is necessary to provide concrete information regarding new genotypes to help producers and consumers make informed decisions. Moreover, there is little information regarding the performance of some indigenous breeds and their crossbreds. Therefore, the present study was planned to determine the diversity of different chicken genotypes and to develop a dual-purpose chicken breed having better growth and carcass traits that can be reared under different housing systems.

2. Materials and methods

The present study was planned to evaluate different housing systems and their effects on morphometric traits and carcass characteristics in three different genotypes of Rhode Island Red (RIR), Black Australorp (BAL), and Naked Neck (NN) chickens during the growing phase. This study was conducted at the Department of Poultry Production, University of Veterinary and Animal Sciences (UVAS), A-Block, Ravi Campus, Pattoki, Pakistan. Pattoki is located at 31°1′0″N, 73°50′60″E with an altitude of 186 m. The city experiences a normally hot and humid tropical climate with maximum temperature ranging from 13 °C in winter to 43 °C in summer.

2.1. Ethics

The care and use of birds were performed in accordance with the laws and regulations of Pakistan and approved by the Committee of Ethical Handling of Experimental Birds (No. DR/124), UVAS.

2.2. Population size

A baseline population of pure NN, RIR, and BAL birds already maintained at the Indigenous Chicken Genetic Resource Centre (ICGRC) comprised a total of 450 birds (90 male + 360 female), with 150 from each breed (30 male + 120 female). RIR and BAL males were crossed with NN females and their progeny were selected for this experiment. In addition, NN males were also crossed with NN females. A total of 480-day-old chicks including 160 from each crossbred of Rhode Island Red × Naked Neck (RNN), Black Australorp × Naked Neck (BNN), and Naked Neck × Naked Neck (NN) hatched at the Avian Research and Training Centre, UVAS, Lahore, and were moved to the ICGRC, A-Block, UVAS, Ravi Campus, Pattoki. These chicks were brooded in a well-ventilated open-sided house with standard management conditions until 6 weeks. Birds were provided with a commercial broiler breeder ration formulated according to the recommendations of the NRC [13] and Leeson and Summers [14] (Tables 1 and 2), and birds' daily allowances were increased as required (Table 3). In the brooding period, birds were vaccinated against ND and IB according to the schedule of the local area.

Table 1. Nutrient composition of experimental rations for different phases.

Nutrients	Grower
	(7–16 weeks)
CP (%)	14
ME (kcal/kg)	2850
Ca (%)	0.87
Avg. P (%)	0.38
Lysine (%)	0.70
Methionine (%)	0.30
Na (%)	0.19

Table 2. Composition of experimental rations (starter and grower).

Feed ingredient (%)	Grower
	(7–16 weeks)
Corn	61.55
Soybean meal	31.70
Fish meal	0.00
Soybean oil	3.00
DCP	1.70
NaCl	0.30
Methionine	0.12
Total	100
Nutrient levels	
DM	89.5
Crude protein	20.02
ME (kcal/kg)	3020
Calcium	0.91
Phosphorus	0.35
Lysine	1.09
Methionine	0.43

During the growing phase, out of 480 birds, cockerels and pullets were separated at the end of the 6th week, and 360 birds (2 sexes × 3 genotypes × 3 housing systems × 20 birds = 360) comprising 180 cockerels and 180 pullets, with 60 (30 cockerels and 30 pullets) from each genotype of RNN, BNN, and NN, were subjected to 3 housing systems (free-range, semiintensive, and intensive). A randomized complete block design was employed with 18 experimental units comprising 20 birds of each sex.

Table 3. Weekly feed allowance (g) in growing phase (7–16 weeks).

Age (weeks)	Housing system		
	Free-range	Semiintensive	Intensive
7	0	12	24
8	0	14	28
9	0	15	30
10	0	15	30
11	0	17	34
12	0	18	36
13	0	19	38
14	0	19	38
15	0	20	40
16	0	21	42

2.3. Free-range, semiintensive, and intensive system

All the experimental birds were individually tagged and maintained in an open-sided shed (6.1 m L × 6.1 m W × 3.66 m H) oriented east to west. A patch of fertile land measuring 10 m L × 2.99 W (stocking density = 0.23 m^2/bird) located in front of the shed was used as a range area. The free-range area was enriched with grasses and plants [mung (*Vigna radiata* L.), black-eyed pea (*Vigna unguiculata* L.), French pea (*Phaseolus vulgaris* L.), and Lucerne (*Medicago sativa* L.)]. In the ranging area, two rows were made by using fishing nets (one for free-range and other for semiintensive). Fresh water was ensured ad libitum through manual drinkers. For the protection of the birds wire-mesh enclosures 2.44 m high were installed surrounding the range area. In free-range and semiintensive systems, birds were given access to vegetation and drinking water from 0600 to 1800 hours and 0600 to 1200 hours, respectively. The latter was offered with 50% grower ration in the evening.

In the intensive housing system, birds from both sexes and three crossbreeds were managed in a well-ventilated poultry shed in a battery cage system (FACCO, Poultry Equipment-C3) and were fed commercial grower ration as per the recommendations of the NRC [13]. The daily allowance was increased corresponding to their growth and requirements.

2.4. Parameters studied

2.4.1. Morphometric traits

During the growth phase (7–16 weeks), morphometric traits of each sex were measured on a weekly basis. Data were recorded with the help of a measuring tape (FT-070, China) regarding body, shank, keel, neck, drumstick and beak length, shank and drumstick circumference, wingspread, and body weight, which were recorded with the help of an electrical weighing balance (Wei Heng, China).

2.4.2. Carcass characteristics

At the end of 16 weeks, 54 birds (27 cockerels and 27 pullets; 3 birds from each treatment group) were randomly picked and slaughtered in a halal fashion to record the carcass characteristics of live and dressed weight, dressing %, and weight of giblets (liver, gizzards, and heart), breast, drumstick, thigh, and wings [15].

2.5. Statistical analysis

Collected data regarding welfare, growth, and carcass traits were analyzed by two-way ANOVA technique assuming genotypes and housing systems as main effects. Data were analyzed separately for males and females to assess the effect of treatments within sex. GLM procedures were used in SAS software [16], and significant means were separated through Tukey's HSD test [17] considering significance at $P \leq 0.05$. The following mathematical model was used:

$$Y_{ijk} = \mu + \beta_i + \tau_j + (\beta \times \tau)_{ij} + \epsilon_{ijk}$$

where Y_{ijk} is the observation of the dependent variable recorded for the jth housing system in the ith block, μ is overall population mean, β_i is effect of the ith block (i = 1, 2, 3), τ_j is effect of the jth housing system (j = 1, 2, 3), $(\beta \times \tau)_{ij}$ is interaction between block and housing system, and ϵ_{ijk} is residual error of the kth observation on the jth treatment in the ith block, NID ~ 0, σ^2.

3. Results and discussion

3.1. Morphometric traits

Morphometric traits differed among housing systems, genotypes, and their interactions (Tables 4–7). Regarding males, mean keel length, drumstick length, drumstick circumference, shank circumference, beak length, and wingspread differed significantly among genotypes. Keel length was maximum in BNN chickens followed by NN and RNN ($P < 0.0001$). Drumstick length was higher in NN chickens than BNN and RNN (12.24 vs. 11.65 and 11.47 cm; $P = 0.0029$). Similarly, maximum drumstick circumference was recorded in NN chickens as compared to RNN and BNN (8.63 vs. 7.23 and 7.04 cm; $P = 0.0029$). Sank circumference was higher in BNN chickens followed by RNN and NN ($P < 0.0001$). Higher beak length was noted in RNN and BNN chickens than NN (3.28 and 3.23 vs. 3.12 cm; $P = 0.0008$). Maximum wingspread was found in NN and BNN chicken as compared to RNN (9.02 and 8.93 vs. 8.28 cm; $P = 0.0002$). In terms of housing systems, significant differences were observed regarding keel length, drumstick length, drumstick circumference, and beak length. Keel length was higher in semiintensive and intensive birds as compared to free-range birds (10.66 and

Table 4. Effect of genotype and housing system on male morphometric traits at 16 weeks of age.[1]

Trait (cm)	Genotype			P-value	Housing system			P-value
	RNN (n = 60)	BNN (n = 60)	NN (n = 60)		FR (n = 60)	SI (n = 60)	I (n = 60)	
BL	61.22 ± 0.83	60.02 ± 1.07	59.97 ± 0.56	0.4238	61.59 ± 0.73	60.02 ± 0.53	59.71 ± 1.14	0.2312
KL	9.90[c] ± 0.14	10.80[a] ± 0.15	10.31[b] ± 0.10	<0.0001	9.93[b] ± 0.15	10.66[a] ± 0.15	10.42[a] ± 0.11	<0.0004
DL	11.47[b] ± 0.13	11.65[b] ± 0.10	12.24[a] ± 0.24	0.0029	11.93[a] ± 0.18	11.98[a] ± 0.17	11.46[b] ± 0.17	0.0468
DC	7.23[b] ± 0.12	7.04[b] ± 0.11	8.63[a] ± 0.06	<0.0001	7.86[a] ± 0.12	7.38[b] ± 0.15	7.65[a] ± 0.13	0.0028
SL	9.12 ± 0.20	9.34 ± 0.31	9.22 ± 0.17	0.8108	8.99 ± 0.14	9.36 ± 0.32	9.33 ± 0.20	0.4626
SC	3.62[b] ± 0.05	3.87[a] ± 0.05	3.45[c] ± 0.04	<0.0001	3.58 ± 0.05	3.66 ± 0.06	3.70 ± 0.04	0.2148
BKL	3.28[a] ± 0.04	3.23[a] ± 0.03	3.12[b] ± 0.02	0.0008	3.23[a] ± 0.04	3.13[b] ± 0.02	3.26[a] ± 0.03	0.0043
WS	8.28[b] ± 0.15	9.02[a] ± 0.14	8.93[a] ± 0.10	0.0002	8.68 ± 0.12	8.68 ± 0.15	8.87 ± 0.14	0.5064

[a–c] Means in a row with no common superscript differ significantly at P ≤ 0.05.
[1] Values are least square mean ± standard error.
RNN = Rhode Island Red × Naked Neck; BNN = Black Australorp × Naked Neck; NN = Naked Neck; FR = free-range; SI = semiintensive; I = intensive; BL = body length; KL = keel length; DL = drumstick length; DC = drumstick circumference; SL = shank length; SC = shank circumference; BKL = beak length; WS = wing span.

Table 5. Interaction effects (genotype × housing system) on male morphometric traits at 16 weeks of age.[1]

Trait (cm)	RNN			BNN			NN			P-value
	FR (n = 20)	SI (n = 20)	I (n = 20)	FR (n = 20)	SI (n = 20)	I (n = 20)	FR (n = 20)	SI (n = 20)	I (n = 20)	
BL	63.26 ± 1.54	61.33 ± 2.34	59.40 ± 1.76	62.42 ± 1.23	60.02 ± 1.17	57.62 ± 2.68	59.09 ± 0.79	58.71 ± 0.76	62.11 ± 1.16	0.0827
KL	9.43[d] ± 0.26	10.37[bc] ± 0.26	9.90[cd] ± 0.18	10.37[bc] ± 0.30	11.22[a] ± 0.27	10.80[ab] ± 0.17	9.99[cd] ± 0.15	10.38[bc] ± 0.22	10.57[abc] ± 0.15	<0.0001
DL	11.59[b] ± 0.17	11.36[b] ± 0.32	11.47[b] ± 0.17	11.44[b] ± 0.14	11.87[b] ± 0.23	11.65[b] ± 0.14	12.76[a] ± 0.43	12.71[a] ± 0.24	11.25[b] ± 0.47	0.0002
DC	7.80[b] ± 0.16	6.73[c] ± 0.25	7.16[c] ± 0.15	7.09[c] ± 0.18	6.99[c] ± 0.23	7.04[c] ± 0.14	8.68[a] ± 0.10	8.44[a] ± 0.07	8.76[c] ± 0.14	<0.0001
SL	8.74 ± 0.23	9.50 ± 0.47	9.12 ± 0.27	8.99 ± 0.15	9.68 ± 0.83	9.34 ± 0.42	9.23 ± 0.31	8.89 ± 0.22	9.52 ± 0.33	0.7729
SC	3.50[cde] ± 0.08	3.74[abc] ± 0.10	3.62[bcd] ± 0.04	3.83[ab] ± 0.09	3.92[a] ± 0.11	3.87[a] ± 0.07	3.42[de] ± 0.05	3.34[e] ± 0.04	3.59[bcd] ± 0.10	<0.0001
BKL	3.37[ab] ± 0.07	3.07[de] ± 0.03	3.40[a] ± 0.06	3.27[abc] ± 0.08	3.18[cde] ± 0.04	3.23[bcd] ± 0.04	3.06[e] ± 0.02	3.12[cde] ± 0.04	3.16[cde] ± 0.05	<0.0001
WS	8.13[d] ± 0.21	8.44[bcd] ± 0.34	8.28[cd] ± 0.24	8.97[abc] ± 0.24	9.06[ab] ± 0.28	9.02[ab] ± 0.22	8.93[abc] ± 0.08	8.56[bcd] ± 0.13	9.31[a] ± 0.21	0.0027

[a–e] Means in a row with no common superscript differ significantly at P ≤ 0.05.
[1] Values are least square mean ± standard error.
RNN = Rhode Island Red × Naked Neck; BNN = Black Australorp × Naked Neck; NN = Naked Neck; FR = free-range; SI = semiintensive; I = intensive; BL = body length; KL = keel length; DL = drumstick length; DC = drumstick circumference; SL = shank length; SC = shank circumference; BKL = beak length; WS = wing span.

Table 6. Effect of genotype and housing system on female morphometric traits at 16 weeks of age.[1]

Trait (cm)	Genotype			P-value	Housing system			P-value
	RNN (n = 60)	BNN (n = 60)	NN (n = 60)		FR (n = 60)	SI (n = 60)	I (n = 60)	
BL	55.96 ± 1.06	55.89 ± 1.10	54.62 ± 0.42	0.4686	55.74^{a} ± 0.78	57.79^{a} ± 0.69	52.94^{b} ± 1.12	0.0005
KL	9.55^{b} ± 0.24	10.45^{a} ± 0.24	9.97^{ab} ± 0.13	0.0078	9.52^{b} ± 0.20	10.47^{a} ± 0.20	9.99^{ab} ± 0.23	0.0046
DL	10.53 ± 0.32	10.69 ± 0.31	11.26 ± 0.17	0.1227	10.47^{b} ± 0.23	10.36^{b} ± 0.31	11.66^{a} ± 0.25	0.0007
DC	6.65^{b} ± 0.17	6.48^{b} ± 0.15	8.07^{a} ± 0.09	<0.0001	7.42^{a} ± 0.14	6.75^{b} ± 0.19	7.03^{b} ± 0.16	0.0017
SL	7.78 ± 0.22	8.16 ± 0.30	7.85 ± 0.10	0.4490	7.84 ± 0.13	8.25 ± 0.29	7.70 ± 0.21	0.2025
SC	3.45^{b} ± 0.07	3.65^{a} ± 0.08	3.20^{c} ± 0.05	<0.0001	3.52^{a} ± 0.06	3.54^{a} ± 0.07	3.25^{b} ± 0.07	0.0028
BKL	3.04^{ab} ± 0.04	3.11^{a} ± 0.03	3.00^{b} ± 0.02	0.0552	3.09 ± 0.04	3.04 ± 0.03	3.02 ± 0.03	0.2711
WS	7.55^{b} ± 0.19	8.29^{a} ± 0.18	8.21^{a} ± 0.08	0.0020	8.20 ± 0.15	8.07 ± 0.17	7.77 ± 0.16	0.1384

$^{a–b}$ Means in a row with no common superscript differ significantly at P ≤ 0.05.
[1] Values are least square mean ± standard error.
RNN = Rhode Island Red × Naked Neck; BNN = Black Australorp × Naked Neck; NN = Naked Neck; FR = free-range; SI = semiintensive; I = intensive; BL = body length; KL = keel length; DL = drumstick length; DC = drumstick circumference; SL = shank length; SC = shank circumference; BKL = beak length; WS = wing span.

Table 7. Interaction effects (genotype × housing system) on female morphometric traits at 16 weeks of age.[1]

Trait (cm)	RNN			BNN			NN			P-value
	FR (n = 20)	SI (n = 20)	I (n = 20)	FR (n = 20)	SI (n = 20)	I (n = 20)	FR (n = 20)	SI (n = 20)	I (n = 20)	
BL	57.21^{ab} ± 1.57	57.99^{a} ± 1.35	52.67^{bc} ± 2.32	56.91^{ab} ± 1.53	60.02^{a} ± 1.17	50.75^{c} ± 2.28	53.12^{bc} ± 0.62	55.37^{abc} ± 0.80	55.39^{abc} ± 0.68	0.0004
KL	8.79^{c} ± 0.38	10.40^{ab} ± 0.41	9.47^{bc} ± 0.40	9.73^{bc} ± 0.39	11.25^{a} ± 0.34	10.37^{ab} ± 0.44	10.03^{b} ± 0.20	9.74^{bc} ± 0.80	10.15^{b} ± 0.31	0.0003
DL	10.30^{bc} ± 0.46	9.57^{c} ± 0.63	11.73^{a} ± 0.48	10.16^{bc} ± 0.43	10.08^{bc} ± 0.56	11.85^{a} ± 0.53	10.97^{abc} ± 0.25	11.42^{ab} ± 0.33	11.41^{ab} ± 0.29	0.0017
DC	7.54^{a} ± 0.27	5.88^{c} ± 0.22	6.54^{bc} ± 0.26	6.83^{b} ± 0.26	6.19^{bc} ± 0.27	6.42^{bc} ± 0.23	7.88^{a} ± 0.14	8.18^{a} ± 0.19	8.14^{a} ± 0.15	<0.0001
SL	7.78 ± 0.27	8.12 ± 0.47	7.45 ± 0.37	8.02 ± 0.26	8.69 ± 0.71	7.76 ± 0.48	7.73 ± 0.15	7.93 ± 0.16	7.90 ± 0.20	0.6049
SC	3.54^{ab} ± 0.09	3.57^{ab} ± 0.13	3.24^{bc} ± 0.13	3.77^{a} ± 0.14	3.76^{a} ± 0.12	3.44^{ab} ± 0.15	3.26^{bc} ± 0.06	3.28^{bc} ± 0.09	3.06^{c} ± 0.09	<0.0001
BKL	3.12^{ab} ± 0.07	3.02^{b} ± 0.08	2.97^{b} ± 0.05	3.21^{a} ± 0.06	3.04^{ab} ± 0.04	3.08^{ab} ± 0.05	2.94^{b} ± 0.03	3.05^{ab} ± 0.04	3.01^{b} ± 0.05	0.0467
WS	7.79^{abc} ± 0.28	7.69^{bc} ± 0.37	7.18^{abc} ± 0.32	8.64^{a} ± 0.30	8.31^{ab} ± 0.34	7.91^{a} ± 0.31	8.18^{ab} ± 0.14	8.22^{ab} ± 0.14	8.21^{ab} ± 0.14	0.0174

$^{a–c}$ Means in a row with no common superscript differ significantly at P ≤ 0.05.
[1] Values are least square mean ± standard error.
RNN = Rhode Island Red × Naked Neck; BNN = Black Australorp × Naked Neck; NN = Naked Neck; FR = free-range; SI = semiintensive; I = intensive; BL = body length; KL = keel length; DL = drumstick length; DC = drumstick circumference; SL = shank length; SC = shank circumference; BKL = beak length; WS = wing span.

10.42 vs. 9.93 cm; P < 0.0004). Higher drumstick length was observed in semiintensive and free-range birds than intensive system (11.98 and 11.93 vs. 11.46; P = 0.0468). Drumstick circumference was maximum in free-range and intensive birds as compared to semiintensive birds (7.86 and 7.65 vs. 7.38 cm; P = 0.0028). Higher beak length was noted in intensive and free-range birds than semiintensive birds (3.26 and 3.23 vs. 3.13 cm; P = 0.0043). In the interaction between genotypes and housing systems, significant differences were observed regarding keel length (P < 0.0001), drumstick length (P = 0.0002), drumstick circumference (P < 0.0001), shank circumference (P < 0.0001), beak length (P <0.0001), and wingspread (P = 0.0027).

Regarding females, significant differences were observed regarding keel length, drumstick circumference, shank circumference, beak length, and wingspread. Keel length was higher in BNN than RNN chickens (10.45 vs. 9.55 cm; P = 0.0078). Higher drumstick circumference was found in NN chicken as compared to RNN and BNN (8.07 vs. 6.65 and 6.48 cm; P < 0.0001). Shank circumference was higher in BNN chickens followed by RNN and NN (P < 0.0001). Maximum wingspread was recorded in BNN and NN chickens compared to RNN (8.29 and 8.21 vs. 7.55 cm; P = 0.0020). In terms of housing systems, significant differences were observed regarding body length, keel length, drumstick length, drumstick circumference, and shank circumference. Body length was maximum in semiintensive and free-range birds compared to the intensive system (57.79 and 55.74 vs. 52.94 cm; P = 0.0005). Higher keel length was found in semiintensive birds as compared to the free-range system (10.47 vs. 9.52 cm; P = 0.0046). Drumstick length was greater in intensive birds than free-range and semiintensive systems (11.66 vs. 10.47 and 10.36 cm; P = 0.0007). Higher drumstick circumference was observed in free-range birds as compared to intensive and semiintensive systems (7.42 vs. 7.03 and 6.75 cm; P = 0.0017). Shank circumference was higher in semiintensive and free-range birds than the intensive system (3.54 and 3.52 vs. 3.25 cm; P = 0.0028). In the interaction between genotypes and housing systems, significant differences were observed regarding body length (P = 0.0004), keel length (P = 0.0003), drumstick length (P = 0.0017), drumstick circumference (P < 0.0001), shank circumference (P <0.0001), beak length (P = 0.0467), and wingspread (P = 0.0174).

The present study aimed to explore the genetic potential of different chicken genotypes under alternative production systems. On an overall basis, birds reared under free-range and semiintensive housing systems showed improved keel and drumstick length and drumstick circumference. Regarding genotypes, improved morphometric traits, i.e. keel and beak length, drumstick and shank circumference, and wingspread of BNN and RNN chickens, could be attributed to the genetic basis. This corresponds to the findings of Fadare et al. [18], who found variation in morphometric traits among Naked Neck, Frizzled Feathered, and Normal Feathered birds crossed with Exotic Giri-Raja chickens. Similarly, Qureshi et al. [19] reported variation in morphological traits among different varieties of Aseel chicken breeds in the Hyderabad district of Pakistan.

3.2. Carcass characteristics

Carcass traits differed among housing systems, genotypes, and their interactions (Tables 8–11). Regarding males, significant differences were observed in carcass traits among different genotypes. RNN chickens had the highest weight at slaughter as compared to BNN and NN (1491.12 vs. 1390.30 and 1333.76 g; P = 0.0009). Dressed weight was higher in RNN chickens followed by RNN and NN (P < 0.0001). Higher carcass yield was observed in RNN chickens than NN (58.55% vs. 54.56%; P = 0.0145). Liver weight was higher in NN chickens as compared to BNN and RNN (37.82 vs. 23.51 and 23.02 g; P < 0.0001). Higher gizzard weight was observed in NN and RNN chickens than BNN (25.03 and 20.75 vs. 15.24 g; P = 0.0001). Breast weight was maximum in RNN chickens as compared to BNN and NN (158.35 vs. 128.26 and 118.37 g; P < 0.0001). Intestinal weight was higher in BNN and NN chickens than RNN (66.59 and 63.80 vs. 52.01 g; P = 0.0011). Maximum intestinal length was noted in NN chickens as compared to RNN and BNN (153.38 vs. 133.61 and 130.59 cm; P = 0.0009). Drumstick weight was higher in BNN chickens than NN and RNN (142.74 vs. 122.57 and 120.50 g; P = 0.0002). Higher thigh weight was observed in BNN than NN (157.86 vs. 133.12 g; P = 0.0148). In terms of housing systems, significant differences were observed regarding weight at slaughter, dressed weight, carcass yield, liver weight, gizzard weight, breast weight, intestinal weight, and intestinal length. Birds under intensive and semiintensive systems had the highest weight at slaughter (1498.02 and 1482.78 vs. 1234.37 g; P < 0.0001) compared to free-range birds. Dressed weight was higher in semiintensive and intensive birds as compared to the free-range system (829.78 and 829.05 vs. 729.87 g; P = 0.0007). Higher carcass yield was found in free-range birds than semiintensive and intensive systems (59.21% vs. 55.87% and 55.35%; P = 0.0139). Liver weight was higher in semiintensive birds as compared to free-range and intensive systems (32.91 vs. 26.12 and 25.32 g; P = 0.0064). Gizzard weight was maximum in semiintensive birds compared to the intensive system (23.34 vs. 18.26 g; P = 0.0234). Higher breast weight was noted in free-range birds as compared to the semiintensive system (149

Table 8. Effect of genotype and housing system on male carcass traits at 16 weeks of age.[1]

Trait	Genotype			P-value	Housing system			P-value
	RNN (n = 9)	BNN (n = 9)	NN (n = 9)		FR (n = 9)	SI (n = 9)	I (n = 9)	
WAS	$1491.12^{a} \pm 64.10$	$1390.30^{b} \pm 49.15$	$1333.76^{b} \pm 37.54$	0.0009	$1234.37^{b} \pm 19.95$	$1482.78^{a} \pm 50.15$	$1498.02^{a} \pm 33.65$	<0.0001
DW	$870.12^{a} \pm 32.32$	$794.07^{b} \pm 24.75$	$724.51^{c} \pm 10.50$	<0.0001	$729.87^{b} \pm 15.49$	$829.78^{a} \pm 37.63$	$829.05^{a} \pm 24.74$	0.0007
CY	$58.55^{a} \pm 0.97$	$57.22^{ab} \pm 0.84$	$54.56^{b} \pm 1.26$	0.0145	$59.12^{a} \pm 0.76$	$55.87^{b} \pm 1.17$	$55.35^{b} \pm 1.12$	0.0139
LW	$23.02^{b} \pm 1.07$	$23.51^{b} \pm 2.01$	$37.82^{a} \pm 2.68$	<0.0001	$26.12^{b} \pm 2.79$	$32.91^{a} \pm 3.32$	$25.32^{b} \pm 2.63$	0.0064
HW	6.24 ± 0.77	7.57 ± 0.54	7.86 ± 0.95	0.1697	7.53 ± 0.72	6.84 ± 0.82	7.29 ± 0.86	0.7250
GW	$20.75^{a} \pm 1.78$	$15.24^{b} \pm 1.29$	$25.03^{a} \pm 2.32$	0.0001	$19.42^{ab} \pm 1.66$	$23.34^{a} \pm 3.32$	$18.26^{b} \pm 0.84$	0.0234
BW	$158.35^{a} \pm 8.03$	$128.26^{b} \pm 11.06$	$118.37^{b} \pm 8.18$	<0.0001	$149.00^{a} \pm 8.03$	$119.94^{b} \pm 15.26$	$136.05^{ab} \pm 3.43$	0.0010
IW	$66.59^{a} \pm 6.13$	$52.01^{b} \pm 3.06$	$63.80^{a} \pm 3.84$	0.0011	$52.92^{b} \pm 3.02$	$69.46^{a} \pm 5.52$	$60.02^{b} \pm 4.46$	0.0005
IL	$133.61^{b} \pm 5.71$	$130.59^{b} \pm 2.90$	$153.38^{a} \pm 5.42$	0.0009	$127.19^{b} \pm 5.29$	$150.10^{a} \pm 5.13$	$140.28^{ab} \pm 4.63$	0.0017
NW	48.06 ± 3.49	49.17 ± 3.04	52.91 ± 2.82	0.2364	48.83 ± 3.49	52.51 ± 2.69	48.80 ± 3.23	0.3539
WW	77.77 ± 5.24	77.37 ± 3.59	71.68 ± 4.00	0.3454	70.85 ± 4.79	80.45 ± 3.43	75.51 ± 4.34	0.1351
DMW	$120.50^{b} \pm 4.98$	$142.74^{a} \pm 6.63$	$122.57^{b} \pm 3.19$	0.0002	122.27 ± 4.45	133.40 ± 3.92	130.14 ± 8.57	0.0641
TW	$140.23^{ab} \pm 6.68$	$157.86^{a} \pm 9.38$	$133.12^{b} \pm 4.10$	0.0148	134.07 ± 7.65	153.76 ± 6.88	143.36 ± 7.74	0.0640
R&BW	200.56 ± 8.28	215.86 ± 8.35	196.47 ± 13.17	0.2921	192.35 ± 10.95	218.82 ± 10.61	201.55 ± 7.72	0.1265

[a–c] Means in a row with no common superscript differ significantly at P ≤ 0.05.
[1] Values are least square mean ± standard error.
RNN = Rhode Island Red × Naked Neck; BNN = Black Australorp × Naked Neck; NN = Naked Neck; FR = free-range; SI = semiintensive; I = intensive; WAS = weight at slaughter (g); DW = dressed weight (g); CY = carcass yield (%); LW = liver weight (g); HW = heart weight (g); GW = gizzard weight (g); BW = breast weight (g); IW = intestinal weight (g); IL = intestinal length (cm); NW = neck weight (g); WW = wings weight (g); DMW = drumstick weight (g); TW = thigh weight (g); R&BW = ribs and back weight (g).

vs. 119.94 g; P = 0.0010). Intestinal weight was higher in semiintensive birds than intensive and free-range systems (69.46 vs. 60.02, 52.92 g; P = 0.0005). Maximum intestinal length was found in semiintensive bird as compared to the free-range system (150.10 vs. 127.19 cm; P = 0.0017). In the interaction between genotypes and housing systems, significant differences were observed regarding weight at slaughter (P < 0.0001), dressed weight (P = 0.0001), carcass yield (P = 0.0162), liver weight (P < 0.0001), heart weight (P = 0.0285), gizzard weight (P = 0.0018), breast weight (P < 0.0001), intestinal weight (P < 0.0001), intestinal length (P = 0.0015), neck weight (P = 0.0003), wings weight (P = 0.0051), drumstick weight (P = 0.0003), and thigh weight (P = 0.0207).

Regarding females, significant differences were observed in carcass traits among different genotypes and housing systems. BNN and RNN chickens had higher weight at slaughter than NN (1175.39 and 1168.32 vs. 1057.10 g; P < 0.0001). Dressed weight (P < 0.0001) and carcass yield (P < 0.0001) were higher in RNN chickens followed by BNN and NN. Higher gizzard weight was observed in BNN chickens than RNN and NN (26.67 vs. 19.09 and 17.05 g; P < 0.0001). RNN chickens had the highest breast weight followed by BNN and NN (P < 0.0001). Intestinal length was greater in NN chickens than RNN (142.52 vs. 123.62 cm; P = 0.0427). Higher neck weight was noted in BNN chickens as compared to NN (42.07 vs. 35.96 g; P = 0.0255). BNN chickens had the highest wings weight (P < 0.0001), drumstick weight (P < 0.0001), and thigh weight (P < 0.0001), followed by RNN and NN. Ribs and back weight were higher in BNN and RNN chickens than NN (192.79 and 189.37 vs. 167.99 g; P < 0.0001). In terms of housing systems, intensive birds had the highest weight at slaughter, followed by semiintensive and free-range birds (P < 0.0001). Dressed weight was higher in intensive birds as compared to the semiintensive system (628.83 vs. 600.24 g; P = 0.0059). Carcass yield was higher in the semiintensive system, followed by the free-range and intensive systems (P < 0.0001). Intensive birds had the highest gizzard weight followed by free-range and semiintensive systems (P < 0.0001). Intestinal length was maximum in intensive birds compared to the semiintensive

Table 9. Interaction effects (genotype × housing system) on male carcass traits at 16 weeks of age.

Trait	RNN			BNN			NN			P-value
	FR (n = 3)	SI (n = 3)	I (n = 3)	FR (n = 3)	SI (n = 3)	I (n = 3)	FR (n = 3)	SI (n = 3)	I (n = 3)	
WAS	1260.36^{c} ± 52.31	1663.00^{a} ± 47.32	1550.00^{ab} ± 34.64	1244.18^{c} ± 31.37	1385.18^{bc} ± 56.78	1541.53^{ab} ± 51.51	1198.59^{c} ± 5.49	1400.14^{bc} ± 17.22	1402.54^{bc} ± 53.65	<0.0001
DW	774.04^{bcd} ± 19.21	952.33^{a} ± 47.96	884.00^{ab} ± 42.15	722.11^{cd} ± 23.26	808.30^{abcd} ± 42.66	851.79^{abc} ± 25.21	693.45^{d} ± 17.31	728.71^{cd} ± 4.68	751.36^{bcd} ± 12.24	0.0001
CY	61.50^{a} ± 1.02	57.19^{ab} ± 1.28	56.97^{ab} ± 1.45	58.02^{ab} ± 0.56	58.34^{ab} ± 1.69	55.31^{ab} ± 1.59	57.84^{ab} ± 1.18	52.07^{b} ± 0.88	53.78^{b} ± 2.82	0.0162
LW	24.73^{bc} ± 0.79	24.99^{bc} ± 0.83	19.35^{c} ± 1.52	17.43^{c} ± 0.59	29.58^{bc} ± 3.13	23.52^{bc} ± 1.16	36.21^{ab} ± 1.72	44.15^{a} ± 4.63	33.10^{ab} ± 5.43	<0.0001
HW	5.96^{ab} ± 1.17	8.67^{a} ± 0.59	4.09^{b} ± 0.10	7.52^{ab} ± 0.49	8.28^{ab} ± 1.01	8.91^{a} ± 0.69	9.12^{a} ± 1.45	5.56^{ab} ± 2.01	8.88^{a} ± 0.80	0.0285
GW	20.33^{bcd} ± 2.52	26.48^{ab} ± 0.34	15.44^{cd} ± 1.03	13.98^{cd} ± 0.68	12.08^{b} ± 1.82	19.66^{bcd} ± 0.69	23.96^{abc} ± 0.93	31.45^{a} ± 5.23	19.67^{bcd} ± 0.99	0.0018
BW	168.50^{ab} ± 0.96	178.22^{a} ± 7.20	128.32^{cd} ± 4.63	155.64^{abc} ± 11.31	87.92^{e} ± 2.59	141.23^{abc} ± 7.87	122.86^{cde} ± 9.58	93.66^{de} ± 13.41	133.58^{bc} ± 3.42	<0.0001
IW	60.73^{bc} ± 1.29	89.81^{a} ± 1.66	49.23^{bc} ± 2.94	42.10^{c} ± 1.90	52.27^{bc} ± 1.03	61.67^{bc} ± 3.48	55.93^{bc} ± 3.22	66.31^{b} ± 1.44	69.15^{ab} ± 10.78	<0.0001
IL	120.18^{b} ± 12.35	140.65^{ab} ± 1.53	140.00^{ab} ± 10.07	120.34^{b} ± 3.00	139.25^{ab} ± 0.38	132.18^{b} ± 0.80	141.06^{ab} ± 5.44	170.40^{a} ± 2.03	148.67^{ab} ± 9.32	0.0015
NW	44.28^{ab} ± 2.07	60.99^{a} ± 1.41	38.91^{b} ± 2.64	41.35^{b} ± 0.85	50.48^{ab} ± 4.05	55.67^{ab} ± 6.42	60.87^{a} ± 5.50	46.06^{ab} ± 3.08	51.80^{ab} ± 0.48	0.0003
WW	77.56^{abc} ± 8.12	93.25^{a} ± 2.58	62.50^{c} ± 4.57	70.02^{abc} ± 4.23	71.72^{abc} ± 2.22	90.36^{ab} ± 2.09	64.98^{bc} ± 12.29	76.39^{abc} ± 1.02	73.68^{abc} ± 2.15	0.0051
DMW	131.96^{bc} ± 5.29	126.12^{bcd} ± 1.93	103.41^{d} ± 6.24	121.43^{bcd} ± 9.85	146.89^{ab} ± 3.78	159.91^{a} ± 5.82	113.43^{cd} ± 5.15	127.18^{bcd} ± 5.46	127.11^{bcd} ± 1.71	0.0003
TW	141.77^{ab} ± 7.32	160.63^{ab} ± 2.08	118.28^{b} ± 5.24	135.87^{ab} ± 23.88	173.00^{a} ± 3.14	164.70^{ab} ± 9.82	124.59^{b} ± 1.45	127.66^{ab} ± 2.25	147.11^{ab} ± 6.74	0.0207
R&BW	201.41 ± 11.48	225.78 ± 1.97	174.50 ± 5.44	214.98 ± 19.95	212.73 ± 18.24	219.34 ± 9.74	160.65 ± 10.50	217.94 ± 31.17	210.80 ± 4.97	0.0917

$^{a–e}$ Means in a row with no common superscript differ significantly at P ≤ 0.05. [1] Values are least square mean ± standard error.
RNN = Rhode Island Red × Naked Neck; BNN = Black Australorp × Naked Neck; NN = Naked Neck; FR = free-range; SI = semiintensive; I = intensive; WAS = weight at slaughter (g); DW = dressed weight (g); CY = carcass yield (%); LW = liver weight (g); HW = heart weight (g); GW = gizzard weight (g); BW = breast weight (g); IW = intestinal weight (g); IL = intestinal length (cm); NW = neck weight (g); WW = wings weight (g); DMW = drumstick weight (g); TW = thigh weight (g); R&BW = ribs and back weight (g).

system (140.72 vs. 120.36 cm; P = 0.0250). Intensive birds exhibited higher neck weight (45.11 vs. 35.61 and 33.54 g; P = 0.0002), wings weight (66.10 vs. 57.39 and 54.06 g; P < 0.0001), drumstick weight (124.93 vs. 93.41 and 86.43 g; P < 0.0001), thigh weight (132.85 vs. 107.68 and 97.13 g; P < 0.0001), and ribs and back weight (209.66 vs. 174.42 g; P < 0.0001) as compared to free-range and semiintensive birds. In the interaction between genotypes and housing systems, significant differences were observed regarding weight at slaughter (P < 0.0001), dressed weight (P < 0.0001), carcass yield (P < 0.0001), liver weight (P = 0.0070), heart weight (P = 0.0021), gizzard weight (P < 0.0001), breast weight (P = 0.0219), intestinal weight (P = 0.0028), intestinal length (P = 0.0192), neck weight (P = 0.0009), wings weight (P = 0.0019), drumstick weight (P < 0.0001), thigh weight (P < 0.0001), and ribs and back weight (P < 0.0001).

Table 10. Effect of genotype and housing system on female carcass traits at 16 weeks of age.[1]

Trait	Genotype			P-value	Housing system			P-value
	RNN	BNN	NN		FR	SI	I	
WAS	1168.32^{a} ± 56.02	1175.39^{a} ± 31.51	1057.10^{b} ± 53.23	<0.0001	1050.03^{c} ± 54.35	1126.53^{b} ± 29.45	1224.25^{a} ± 48.35	<0.0001
DW	686.54^{a} ± 13.59	625.37^{b} ± 6.96	532.26^{c} ± 53.23	<0.0001	615.10^{ab} ± 9.35	600.24^{b} ± 31.07	628.83^{a} ± 30.66	0.0059
CY	59.49^{a} ± 2.10	53.40^{b} ± 0.90	50.74^{c} ± 1.05	<0.0001	54.94^{b} ± 1.81	57.46^{a} ± 2.28	51.22^{c} ± 0.63	<0.0001
LW	22.26^{b} ± 1.65	23.25^{b} ± 1.44	32.27^{a} ± 1.77	<0.0001	26.30 ± 3.16	24.05 ± 1.63	27.44 ± 1.48	0.1694
HW	6.13 ± 0.44	7.12 ± 0.97	6.23 ± 0.37	0.2739	6.01 ± 0.38	6.21 ± 0.41	7.26 ± 0.96	0.1465
GW	19.09^{b} ± 1.61	26.67^{a} ± 4.91	17.05^{b} ± 1.29	<0.0001	20.88^{b} ± 1.11	16.68^{c} ± 1.15	25.07^{a} ± 5.30	<0.0001
BW	142.70^{a} ± 4.57	130.53^{b} ± 2.22	96.52^{c} ± 2.72	<0.0001	126.31 ± 6.49	117.95 ± 6.90	125.50 ± 9.02	0.0671
IW	56.84 ± 2.08	59.12 ± 1.70	55.53 ± 3.32	0.3683	59.73 ± 2.40	54.54 ± 2.80	57.23 ± 1.95	0.1450
IL	123.62^{b} ± 6.48	130.23^{ab} ± 6.21	142.52^{a} ± 5.41	0.0427	135.28^{ab} ± 8.77	120.36^{b} ± 2.90	140.72^{a} ± 4.43	0.0250
NW	36.24^{ab} ± 2.16	42.07^{a} ± 4.11	35.96^{b} ± 1.94	0.0255	35.61^{b} ± 1.70	33.54^{b} ± 2.21	45.11^{a} ± 3.33	0.0002
WW	62.66^{b} ± 1.24	71.00^{a} ± 4.21	43.88^{c} ± 1.79	<0.0001	57.39^{b} ± 3.62	54.06^{b} ± 4.12	66.10^{a} ± 5.56	<0.0001
DMW	106.84^{b} ± 6.33	117.30^{a} ± 13.05	80.63^{c} ± 2.88	<0.0001	93.41^{b} ± 2.91	86.43^{b} ± 2.51	124.93^{a} ± 13.70	<0.0001
TW	111.61^{b} ± 5.79	130.93^{a} ± 11.82	95.12^{c} ± 4.65	<0.0001	107.68^{b} ± 2.05	97.13^{b} ± 3.42	132.85^{a} ± 13.23	<0.0001
R&BW	189.37^{a} ± 13.10	192.79^{a} ± 11.48	167.99^{b} ± 7.40	<0.0001	174.42^{b} ± 5.73	166.07^{b} ± 6.09	209.66^{a} ± 14.13	<0.0001

$^{a–c}$ Means in a row with no common superscript differ significantly at P ≤ 0.05.
[1] Values are least square mean ± standard error.
RNN = Rhode Island Red × Naked Neck; BNN = Black Australorp × Naked Neck; NN = Naked Neck; FR = free-range; SI = semiintensive; I = intensive; WAS = weight at slaughter (g); DW = dressed weight (g); CY = carcass yield (%); LW = liver weight (g); HW = heart weight (g); GW = gizzard weight (g); BW = breast weight (g); IW = intestinal weight (g); IL = intestinal length (cm); NW = neck weight (g); WW = wings weight (g); DMW = drumstick weight (g); TW = thigh weight (g); R&BW = ribs and back weight (g).

Slaughter, dressed, and gizzard weights were higher in intensive and semiintensive birds as compared to free-range birds. Carcass yield was maximum in free-range birds compared to semiintensive and intensive birds. The most likely explanation of this variation in carcass traits is that the quality of meat largely depends upon differences in activity level because of outdoor access. Other studies also reported that breast yield linearly increased in Sequin yellow chickens; however, thigh, leg, and foot yield decreased linearly with increasing free-range days [20]. In another study, higher breast and thigh yield were also reported in Ross male chickens when exposed to outdoor access [21]. Moreover, carcass traits improved when the birds were given access to the free-range area, which enhanced the activity of the birds and improved comfort and welfare [22].

Regarding genotypes, RNN chickens had better slaughter, dressed, breast, and intestinal weights and carcass yield than BNN and NN chickens. Wings, thigh, drumstick, and ribs and back weight were maximum in BNN chickens compared to RNN and NN chickens. Variation in carcass traits is due to higher breast and leg yields of slow-growing genotypes, which might be attributed to a large size of muscle fiber if achieved by muscle fiber hypertrophy [23,24]. Variation among chicken breeds due to muscle fiber is largely associated with selection. Findings of the present study correspond with the study of Devatkal et al. [12], who found variation in carcass traits among different meat-type chickens. Higher slaughter weight was observed for white broiler and the lowest for Aseel. However, dressing percentages did not differ among different genotypes. In this study, liver and gizzard weights were found to be higher in NN chickens than RNN and BNN, which might be due to the fact that indigenous chickens are more aggressive and active even under intensive conditions, which leads to higher energy dissipation. Similarly, another study reported differences in carcass traits between indigenous Thai and crossbred chickens [25].

It was concluded that RNN and BNN chickens of both sexes had better morphological and carcass traits during the growing stage as compared to NN. Chickens (males as

Table 11. Interaction effects (genotype × housing system) on female carcass traits at 16 weeks of age.

Trait	RNN			BNN			NN			P-value
	FR (n = 3)	SI (n = 3)	I (n = 3)	FR (n = 3)	SI (n = 3)	I (n = 3)	FR (n = 3)	SI (n = 3)	I (n = 3)	
WAS	1028.47^{e} ± 9.17	1087.49^{c} ± 5.90	1389.00^{a} ± 12.12	1247.68^{b} ± 4.90	1050.15^{d} ± 4.05	1228.34^{b} ± 4.04	873.95^{f} ± 8.76	1241.95^{b} ± 4.02	1055.41^{d} ± 7.50	<0.0001
DW	650.76^{b} ± 8.31	681.85^{ab} ± 6.29	727.00^{a} ± 25.24	597.78^{c} ± 2.00	640.30^{bc} ± 1.85	638.02^{bc} ± 1.43	596.75^{c} ± 4.70	478.56^{d} ± 2.02	521.46^{d} ± 4.10	<0.0001
CY	59.85^{b} ± 1.09	66.31^{a} ± 0.76	52.32^{de} ± 1.37	56.93^{bc} ± 0.38	51.32^{def} ± 0.27	51.94^{de} ± 0.29	48.05^{f} ± 0.26	54.77^{cd} ± 0.42	49.41^{ef} ± 0.53	<0.0001
LW	22.52 ± 4.37	19.23 ± 2.17	25.03 ± 0.40	18.08 ± 0.22	26.32 ± 2.46	24.63 ± 1.83	37.56 ± 1.29	26.60 ± 1.88	32.65 ± 1.48	0.0070
HW	7.06^{ab} ± 0.61	6.08^{b} ± 1.06	5.25^{b} ± 0.20	4.98^{b} ± 0.43	5.91^{b} ± 0.25	10.46^{a} ± 1.55	5.98^{b} ± 0.33	6.65^{ab} ± 0.85	6.07^{b} ± 0.83	0.0021
GW	24.66^{b} ± 0.26	16.18^{cd} ± 2.42	16.43^{cd} ± 1.34	17.75^{bcd} ± 1.10	16.18^{cd} ± 2.23	46.07^{a} ± 0.62	20.24^{bc} ± 1.08	18.21^{bcd} ± 1.88	12.71^{b} ± 0.40	<0.0001
BW	148.51^{a} ± 6.15	130.36^{ab} ± 6.65	149.23^{a} ± 7.33	124.38^{bc} ± 2.45	131.42^{ab} ± 4.32	135.79^{ab} ± 1.08	106.03^{cd} ± 2.86	92.05^{d} ± 2.18	91.47^{d} ± 2.77	0.0219
IW	58.82^{ab} ± 1.82	55.41^{ab} ± 4.76	56.31^{ab} ± 4.77	53.65^{ab} ± 3.04	62.13^{a} ± 1.28	61.59^{a} ± 1.17	66.72^{a} ± 3.60	46.08^{b} ± 2.18	53.79^{ab} ± 2.39	0.0028
IL	126.04^{bc} ± 19.93	118.37^{c} ± 4.88	126.44^{bc} ± 7.85	120.98^{c} ± 9.36	118.11^{c} ± 4.95	151.61^{ab} ± 2.55	158.81^{a} ± 4.08	124.61^{bc} ± 6.27	144.12^{abc} ± 0.70	0.0192
NW	36.81^{b} ± 2.14	29.62^{b} ± 2.36	42.28^{b} ± 2.38	30.73^{b} ± 3.09	38.53^{b} ± 1.54	56.95^{a} ± 3.13	39.30^{b} ± 1.02	32.48^{b} ± 5.45	36.10^{b} ± 1.62	0.0009
WW	65.45^{b} ± 1.08	59.11^{bc} ± 2.52	63.43^{b} ± 0.76	62.76^{b} ± 3.31	64.06^{b} ± 4.34	86.18^{a} ± 3.03	43.95^{d} ± 2.85	39.00^{d} ± 1.61	48.69^{cd} ± 2.04	0.0019
DMW	101.54^{c} ± 6.30	89.39^{cd} ± 1.42	129.60^{b} ± 3.73	91.14^{cd} ± 2.30	91.40^{cd} ± 1.99	169.35^{a} ± 1.16	87.54^{cd} ± 1.84	78.50^{d} ± 4.61	75.85^{d} ± 6.09	<0.0001
TW	109.64^{bc} ± 1.13	95.64^{c} ± 4.49	129.54^{b} ± 9.55	108.58^{bc} ± 4.66	107.02^{bc} ± 5.61	177.19^{a} ± 4.11	104.82^{bc} ± 4.57	88.73^{c} ± 1.87	91.81^{c} ± 12.72	<0.0001
R&BW	166.34b^{cd} ± 2.76	161.48^{cd} ± 6.29	240.28^{a} ± 7.96	160.66^{cd} ± 3.28	184.86^{bc} ± 9.75	232.86^{a} ± 11.14	196.26^{b} ± 3.06	151.88^{d} ± 4.81	155.84^{cd} ± 4.59	<0.0001

$^{a–f}$ Means in a row with no common superscript differ significantly at P ≤ 0.05. [1] Values are least square mean ± standard error.
RNN = Rhode Island Red × Naked Neck; BNN = Black Australorp × Naked Neck; NN = Naked Neck; FR = free-range; SI = semiintensive; I = intensive; WAS = weight at slaughter (g); DW = dressed weight (g); CY = carcass yield (%); LW = liver weight (g); HW = heart weight (g); GW = gizzard weight (g); BW = breast weight (g); IW = intestinal weight (g); IL = intestinal length (cm); NW = neck weight (g); WW = wings weight (g); DMW = drumstick weight (g); TW = thigh weight (g); R&BW = ribs and back weight (g).

well as females) reared under a semiintensive system had maximum keel length during the growing stage compared to free-range and intensive birds.

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