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STRAIN EFFECTS ON ASSOCIATION AND RELATIONSHIP BETWEEN PRODUCTIVITY AND HATCHABILITY TRAITS IN POULTRY LAYERS AT FULL SEXUAL MATURITY

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ABSTRACT

The effect of strain on the association and relationship among productive and hatching traits at full-sexual maturity in Bovan Nera (BN) and Isa Brown (IB) parent-stock layers was investigated. Data on productive and hatchability traits were obtained on 22 batches of BN and IB each, between 2009 and 2019, from a reputable parent stock breeding company in Ibadan, Nigeria. Data were subjected to Pearson's correlation and regression procedures using the Statistical Analytical Systems, version 9.0. Paired correlation parametric indices and regression equations differentiated between the two strains investigated. A significant association of weight gain at full maturity with feed intake at full maturity in IB ($r = -0.54$, $p < 0.01$) as against a weak/insignificant association in BN was observed. Feed intake from first egg at full maturity was identified as most important trait for improved hen-day egg productivity at full maturity and beyond in IB. Viable day-old pullet chicks hatched in the BN could be predicted with high level of accuracy ($R^2 = 0.83$, RMSE = 2.75). Regression analyses showed that both strains belong to distinct genotypic classes with different and specific genetic attributes.

Key words: correlated traits, day-old pullet chicks, hen-day egg production, layer strains, pullet weight at full maturity

INTRODUCTION

Pullet weight, egg weight, hen-day egg production and number of day-old pullet chicks hatched are important traits to target at full sexual maturity (FSM) in layer breeders for optimum genetic expression, productivity and continued profit maximization. Body and egg weight are highly heritable and important productivity and hatchability traits for poultry breeding. A positive genetic correlation between pullet weight and egg weight has been reported (Chomchuen *et al*., 2022). Similarly, Oke *et al.* (2004) found a positive phenotypic correlation between body weight and egg number. In contrast to above, Harms *et al.* (1982) reported negative correlation between body weight and egg number. In chickens, FSM occur at peak egg production (the point when the highest egg number is laid in a flock), and could be attained at 26-30 weeks of age. It is important to understand the association and relationship among productive and hatching traits at the FSM point as influenced by genotype. This is because FSM behaviour is a pointer to flock genetic ability, productivity and subsequent laying behaviour. Factors that affect productivity and hatching characteristics at full sexual maturity include strain, genetics (genotype), feed intake, survivability, flock health, management practices and age at peak-of-lay (Farooq *et al.,* 2012). Within a flock, egg production could be influenced by environmental conditions, flock number, feed consumption and quality, stage of production, flock health and age in lay (Amin and Nawawi, 2013).

The use of correlation and multiple linear regression models has been employed in recent times to study linearized interrelationships between productivity, egg and hatching traits in poultry (Baykalir and Aslan, 2020; Ikeh and Okwesili, 2021). Ayeni *et al.* (2018) also studied the relationship of egg weight with egg quality traits, hatchability and hatchling weight. Estimates of fertility, hatchability and number of chicks hatched are important in evaluating the economic efficiency of parent stocks, and are measures of the genetic quality and reproductive fitness of individual bird, flock, strain and breed in a population (Oleforuh-Okoleh, 2016). The present study was undertaken to assess the effect of strain on co-relationships among productivity and hatchability traits at full sexual maturity in layers. This knowledge could enhance better management and breeding of layers for optimum chicks' production. The research hypothesized that associations and relationships among traits would be influenced by strains at FSM.

MATERIALS AND METHODS

Study Location

This was a reputable commercial breeder farm and hatchery in Ibadan, South-west Nigeria.

Description of Strains

The study materials were Bovan Nera (BN) and Isa Brown (IB) parent stock layers. The BN has a black-spotted white plumage; whereas, IB hens are white while he cocks are red in plumage.

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Source and Type of Data Collected

Data from 2009 to 2019 on productivity and hatchability traits at the peak egg production point, representing attainment of full sexual maturity, were collected from twenty-two batches of each genotype. Each batch had an average population of 3,986 pullets and 600 cocks at point-of-lay.

Traits Measured and Evaluated

Twelve productivity and hatchability traits were recorded namely: feed intake from first egg to full maturity point (FFF, kg), pullet weight at 20-weeks (PW20, g), weight gain from 21 weeks to full maturity (WGF, g), feed intake at 21-weeks to full maturity (F21F, kg), feed intake at full maturity point (FFM, g), age at full maturity (AFM, weeks), pullet weight at full maturity (PFM, g), hen-day egg production at full maturity (HDF, %), egg weight at full maturity (EWF, g), persistency of egg production at full maturity (P80 at ≥ 80% HDP, weeks), eggs-set at full maturity (ESF, %), fertility of eggs-set at full maturity (FEF, %), hatchability of eggs-set at full maturity (HEF, %), day-old pullet chicks hatched at full maturity (PDC, %), reject day-old chicks and unhatched eggs at full maturity (RCU, %).

Farm Management

All batches of Bovan Nera (BN) and Isa Brown (IB) parent-stock layers were reared under same management with adequate feeding, nutrition, veterinary care and biosecurity.

Statistical Analysis

Data were classified by strain (22 batches each) and subjected to Pearson's bi-variate correlation and multiple linear regression analyses ($\alpha < 0.05$) through the GLM procedures of Statistical Analytical Systems, version 9.0 (SAS/STAT, 2013).

RESULTS

Table 1 shows the matrix of correlation between paired traits at FSM in BN and IB. Both strains showed highly negative correlation of PW20/WGF (r = –0.419, –0.669, $p < 0.05$); positive EWF/HEF (r = 0.495, 0.583, $p < 0.05$) and a negative correlation of PDC/RCU (r = –0.703, $p < 0.001$) in BN only. In contrast, both strains exhibited dissimilarity in several paired correlations. In BN, PW20 was positively correlated with F20F/AFM/FEF (r = 0.418, 0.454, 0.490, $p < 0.05$), and also show positive correlation of WGF with PFM/EWF (r = 0.825, 0.432, $p < 0.05$); F20F with AFM/HEF/PDC (r = 0.491, 0.493, 0.518, $p < 0.05$); PFM/EWF (r = 0.632, $p < 0.05$); and EWF with FEF/PDC (r = 0.496, 0.495, 0.537, $p < 0.05$). Similarly, in IB correlated traits of PW20 with FFM/EWF/HEF (r = 0.614, 0.642, 0.608, p = 0.001); WGF/FFM (r = –0.512, $p < 0.01$); F20F/EWF (r = 0.527, $p < 0.01$); PFM/HEF (r = 0.636, $p < 0.001$) and EWF/HEF (r = 0.583, $p < 0.01$) were revealed. Genotypic differences between strains were also exposed in the positive correlation of AFM with PFM/EWF/FEF/HEF/PDF (r = 0.447, 0.462, 0.699, 0.493, 0.678, $p < 0.05$); FEF with HEF/PDC (r = 0.813, 0.901, $p < 0.0001$); HEF with PDC/RCU (r = 0.923, –0.679, $p < 0.0001$) and the negative correlation of PDC with RCU (r = –0.703, $p < 0.001$) in BN strain. Whereas, only FFM was significantly correlated with EWF and HDF (r = 0.656, 0.449, $p < 0.05$) in IB strain.

Table 2 presents the full standardized multiple linear regression equations of PFM on productivity traits. Only PW20 and WGF revealed important effects explaining the variability in PFM. The AFM, F21F and FFM revealed very small and equal effect sizes on PFM in both strains. For every unit change in pullet weight at full maturity (PWF), both strains contributed almost equal units of PW20, while BN contributed about twice (1.68) the amount of WGF by IB. The R^2 of equations for both strains were perfect and highly significant ($p < 0.001$). The VIF ranged from 2.19 to 2.21 while the SEE and DW were small at 0.00 respectively for both strains.

Table 3 reveals the causal relationships between HDF and productivity traits. The WFM, AFM, FFF, F21F, FFM, EWF and P80 (–0.366 to 0.908) all contributed to the variability in HDF in both strains of the parent-stock layers. The BN contributed more units of AFM, F21F and FFM while IB contributed more units of PFM, FFF, EWF and P80 to unit change in HDF. The SEE was medium to high at 27.77 to 39.08 in both strains. The R^2 were 0.276 and 0.414, DW was 1.37 and 2.45, while VIF were 2.19 to 18.61 for BN, and 1.38 to 24.18 for IB. The equations of both strains were not significant ($p > 0.05$).

Table 4 shows the relationship of PDC with productivity and hatchability traits of the parent-stock layers. All the six independent traits contributed to the variability involved in day-old pullet chicks' production. The BN contributed more units of EWF, HDF, FEF and HEF, while IB contributed more units of PWF and P80 to PDC production. The R^2 were 0.834 and –0.148, SEE were 92.07 and 50.99, whereas VIF ranged from 1.68 to 4.16 and 1.92 to 2.68. The DW statistics were 0.606 and 1.23 for BN and IB, respectively.

DISCUSSION

Correlation of traits of same origin is useful for understanding linear associations between paired traits, and studying correlated responses for indirect selection purposes in poultry breeding (Perio *et al.,* 2021). The many phenotypic associations of paired traits within strains were medium to large, and this rendered them critical for management and breeding purposes. A selection for appropriate pullet weight at 20 weeks would influence feed intake from 21 weeks to full maturity, weight gain from 21 weeks to full maturity, age at full maturity and fertility of eggs set in BN. The BN could also be improved by direct and combined selection of feed intake from 21 weeks to full maturity, age at full maturity and egg

Table 1: Pearson's correlation matrix for productivity and hatchability traits at full sexual maturity in Bovan Nera and Isa Brown parent stock layers in Ibadan Nigeria

								Bovan Nera							
	Traits	PW20	WGF	F21F	AFM	PFM	FFM	EWF	HDF	P80	ESF	FEF	HEF	PDC	RCU
	PW20 (kg)	-	–0.419*	0.418*	0.454*	0.167	0.123	0.239	0.245	0.302	0.381	0.490*	0.360	0.387	–0.013
	WGF (g)	–0.669***	-	–0.104	0.151	0.825****	0.289	0.432*	–0.253	–0.074	0.036	–0.049	0.124	0.064	–0.214
I	F21F (kg)	0.381	–0.269	-	0.491**	0.147	0.073	0.162	0.360	–0.001	0.278	0.453	0.493*	0.518*	–0.397
s	AFM (days)	0.300	–0.090	0.250	-	0.447*	0.078	0.462*	–0.080	0.178	0.360	0.699**	0.493**	0.678**	–0.337
a	PFM (g)	0.395	0.418	0.139	0.253	-	0.390	0.632**	–0.122	–0.130	0.280	0.253	0.367	0.316	–0.251
	FFM (g)	0.614***	–0.512**	0.250	0.227	0.110	-	0.683**	0.318	0.292	0.232	0.307	0.323	0.237	–0.007
B	EWF (g)	0.642***	–0.386	0.527**	0.432	0.301	0.656***	-	0.040	0.409	0.342	0.496*	0.495*	0.537*	–0.330
r	HDF (%)	0.353	–0.184	0.037	0.104	0.203	0.449*	0.302	-	0.560*	–0.067	0.032	0.009	0.097	–0.147
o	P80 (%)	0.193	–0.256	–0.293	–0.198	–0.081	0.288	–0.025	0.560	-	0.138	0.323	0.222	0.432	–0.429
w	ESF (%)	0.115	0.037	0.242	0.229	0.181	–0.197	0.148	0.345	–0.453	-	0.256	0.175	0.193	0.065
n	FEF (%)	0.114	0.243	0.242	0.229	0.181	–0.197	0.148	0.345	–0.453	–0.148	-	0.813****	0.901****	–0.328
	HEF (%)	0.608***	–0.075	0.327	0.381	0.636***	0.433	0.583**	0.342	0.054	0.300	0.348	-	0.923****	–0.679****
	PDC (%)	0.239	0.062	0.207	0.206	0.359	0.449	0.317	0.391	0.286	–0.061	–0.307	0.459	-	–0.703***
	RCU (%)	–0.071		–0.105	–0.067	–0.326	0.104	–0.064	–0.127	0.277	–0.437	–0.308	–0.596	–0.095	-

P20 - pullet weight at 20 weeks, WTF - weight gain from 20 weeks to full maturity, FFM - feed intake at full maturity, AFM - age at full maturity, PFM - hen weight at full maturity, EWF - egg weight at full maturity, HDF - hen-day egg production at full maturity, P80 - persistency of hen-day egg production, ESF - eggs set at full maturity, FEF - fertility of eggs set at full maturity, HEF - hatchability of eggs set at full maturity, PDC - pullet chicks hatched at full maturity, RCU - reject chicks and unhatched eggs at full maturity. Significance levels are 0.0001 - ****; 0.001 - ***; 0.01 - **; 0.05 - *, > 0.05 - not significant

Table 2: Standardized multiple linear regression of pullet weight on productivity traits of parent stock layer strains at full sexual maturity in Ibadan, Nigeria

Model	$Y = \mu + bX_1 + cX_2 + dX_3 + eX_4 + fX_5 + \mathcal{E}$; where X_1 = PW20, X_2 = WGF, X_3 = AFM, X_4 = F21F, X_5 = FFM, $\mathcal{E}$ = SEE											
Traits	Constant	PW20	WGF	AFM	F21F	FFM	SEE	*Adj R²*	Model			
Coefficients	μ	b	c	d	e	f	Ɛ	R^2_a	*p*	RMSE	VIF	DW
Bovan Nera	0.000	0.564	1.093	7.778^{-14}	4.576^{-14}	-1.974^{-14}	0.000	1.000	0.0001	0.000	2.190	0.000
Isa Brown	0.000	0.553	0.651	7.496^{-14}	-4.956^{-14}	1.567^{-14}	0.000	1.000	0.0001	0.000	2.205	0.000

Y - PFM - pullet weight at full maturity in g; μ - constant; b - PW20 - pullet weight at twenty weeks old in g; c - WGF - pullet weight-gain from 20 weeks to full maturity in g; d - AFM - age at full maturity in weeks; e - F21F - pullet feed intake from 21 weeks to full maturity in kg; f - FFM - feed intake at full maturity; Ɛ - SEE - standard error of estimates; *Adj* R^2 - adjusted coefficient of multiple determination; *p* - model significance; RMSE - root mean square error; VIF - variance inflation factor; DW - Durbin Watson statistics; b, c, d, e, f - standardized coefficients of predictor traits

Table 3: Standardized multiple linear regression of hen-day egg production on productivity traits of parent stock layer strains at full sexual maturity in Ibadan, Nigeria

Model:	$Y = \mu + aX_1 + bX_2 + cX_3 + dX_4 + eX_5 + fX_6 + gX_7 + \mathcal{E}$; where X_1 = PFM, X_2 = AFM, X_3 = FFF, X_4 = F21F, X_5 = FFM, X_6 = EWF, X_7 = P80, $\mathcal{E}$ = SEE												
Traits	Constant	PFM	AFM	FFF	*F21F*	FFM	EWF	P80	SEE	*Adj R²*	Model			
Coefficients	μ	a	b	c	d	e	f	g	Ɛ	R^2_a	*p*	RMSE	VIF	DW
Bovan Nera	0.000	–0.325	0.908	–1.114	–0.116	0.519	0.235	0.461	27.773	0.276	0.265	2.345	18.010	1.368
Isa Brown	0.000	0.074	–0.355	0.883	–0.385	–0.665	0.387	0.776	39.078	0.414	0.074	2.271	24.180	2.452

Y - HDF - hen-day egg production at full maturity in %, μ - constant; a - PFM - pullet weight at full maturity in g; b - AFM - age at full maturity in weeks; c - FFF - feed intake from first egg to full maturity in kg; d - F21F - feed intake from 21 weeks to full maturity in kg; e - FFM - feed intake at full maturity in g; f - EWF - egg weight at full maturity in g; g - P80 - persistency of egg production at full maturity in weeks; Other abbreviations are as explained in Table 2.

Table 4: Standardized multiple linear regression of day-old pullet chicks on productivity and hatchability traits of parent stock layer strains at full sexual maturity

Model	$Y = \mu + bX_1 + cX_2 + dX_3 + eX_4 + fX_5 + gX_6 + \mathcal{E}$; where X_1 = PFM, X_2 = EWF, X_3 = HDF, X_4 = P80, X_5 = FEF, X_6 = HEF, $\mathcal{E}$ = SEE											
Traits	Constant	PFM	EWF	HDF	P80	FEF	HEF	SEE	*Adj R²*	Model			
Coefficients	μ	b	c	d	e	f	g	Ɛ	R^2_a	*p*	RMSE	VIF	DW
Bovan Nera	0.000	0.083	0.123	0.165	0.005	0.618	0.349	92.068	0.833	0.127	2.750	4.164	0.606
Isa Brown	0.000	0.163	0.065	0.022	0.249	0.043	0.263	50.985	–0.148	0.686	5.268	2.684	1.228

Y - PDC, day-old pullet chicks hatched in %; μ - constant; b - PFM, pullet weight at full maturity in g; c - EWF, egg weight at full maturity in g; d - HDF, hen-day egg production at full maturity in %; e - P80, persistency of egg production at full maturity in weeks; f - FEF, fertility of eggs set at full maturity in %; g - HEF, hatchability of egg set at full maturity in %; Other abbreviations are as explained in Table 2.

weight at full maturity for indirect selection and improvement of fertility, hatchability and day-old pullet chicks' levels simultaneously. Since hatching of day-old pullet chicks is negatively associated with percent reject chicks and unhatched eggs, a combined selection for fertility, hatchability and number of day-old pullet chicks reduces the quantity of reject chicks and unhatched eggs simultaneously. Thus, the BN exhibits a genetically positive and medium associations of EWF with each of fertility, hatchability and quantity of day-old pullet chicks hatched, but displayed a negatively high association of these traits with reject chicks and unhatched eggs.

In the IB, selection for appropriate pullet weight at 20 weeks could improve weight gain to full maturity, feed intake at full maturity, egg weight at full maturity and hatchability of eggs set at full maturity simultaneously; while feed intake at full maturity would improve egg weight and hen-day egg production at full maturity. Provision of adequate quality feed at full maturity point also translated to higher egg weight and hen-day egg production, while high pullet weight at full maturity translated to high level of hatchability of eggs set. Above findings support the report that body weight and egg weight demonstrate positive genetic correlation (Di Masso *et al*., 1998). Pullet weight at 20 weeks demonstrated a reverse association with weight gain from 21st week to full maturity in both strains. A high pullet weight at full maturity could be attained by targeting high pullet weight at 20 weeks in both strains. Findings in both BN and IB conform with the report of Ng'ambi *et al.* (2013) and Ayeni *et al.* (2018) on positive association of egg weight with each of hatchability and chick hatch weight; and with Fathi *et al.* (2022) that egg weight directly affects hatchability, embryonic mortality, hatching weights and subsequent chick performance. Smith and Bohren (1975) had reported that as age of pullet increased, hatching time declined while egg weight and hatchability increased. The negative correlation of weight gain at full maturity with feed intake at full maturity in the IB meant a relatively low feed intake at full maturity compared to BN. The associations of age at full maturity; with each of pullet weight, egg weight, fertility of eggs set, hatchability of eggs set and day-old pullet chicks hatched (all at full maturity) were medium in BN, but appeared unimportant in IB. Increasing feed intake from 21st week to full maturity led to early maturity, is associated with lower age at full maturity. This could be important for optimum hatchability of eggs set and quantity of day-old pullet chicks hatched in the BN, although this appeared less effective in the IB because it is an early-laying strain (Jesuyon and Olawumi, 2020). Present correlation values of BN and IB were higher than those reported in naked neck, smooth feathered, and frizzled feathered chickens on EWF/FES, 0.50, 0.15 vs 0.33, 0.29, 0.24; EWF/HES, 0.50, 0.58 vs –0.11, 0.10, 0.12 (Oleforuh-Okoleh, 2016); FES/HES, 0.81, 0.35 vs 0.59, 0.31, 0.27; FES/PDC, 0.90, –0.31 vs 0.42, 0.18, –0.13); while HES/PDC, 0.92, 0.46 vs 0.82, 0.82, 0.89 (Bobbo *et al.,* 2013). The higher values in present study were probably due to the better genetic make-up of BN and IB strains. Similarly, due to direct correlation between paired traits, an appropriate egg weight at full maturity will automatically select for optimum fertility, hatchability and percentage day-old pullet chicks hatched in BN, but for only hatchability in IB strain. The genotypic differences observed on correlated traits between strains unveil the genetic differences in attributes and expression pathways. The similarities and differences in direct linear associations in both strains implicate the development of specific and different management approaches and breeding strategies for specific strains. Thus, the linear phenotypic correlation values obtained in this study reveal the composite genotypic differences (Namkoong, 1985) between the BN and IB layer strains.

Multiple linear regression model is useful for studying causal effects, relationships and comparative contributions of independent regressor traits to unit change of dependent variables in both strains. This model reveals better genetic ability in the IB for pullet weight at full maturity, due to higher contributions of pullet weight at 20 weeks and weight gain from 21 weeks to full maturity; while BN was superior in its contribution of feed intake from 21 weeks to full maturity to pullet weight at full maturity. The high causal effects and contributions of pullet weight at 20 weeks and weight gain from 21 weeks to full maturity point are important practically for attaining the optimum pullet target-weight at full maturity in both strains. Thus, manipulation of flocks for increased feed intake from first-egg point could lead to optimum pullet weight at 20 weeks and high body weight gain from 21 weeks to full maturity. The low coefficients of age at full maturity, feed intake from 21 weeks to full maturity and feed intake at full maturity indicate their low contributions to attainment of optimum pullet weight at full maturity point in both strains. The model is highly efficient as the low SEE ensures higher efficiency of the equations. The causal effect of PW20 was similar in both strains but weight gain at full maturity had higher causal effect in BN than IB (1.09 vs 0.65), revealing a higher WGF magnitude of 1.7 times better in BN than IB strain. The attainment of optimum pullet weight at full maturity would depend on pullet weight at 20-l weeks and quantitative feed management from 21 weeks onward. This is important for post 20-week body weight development in the lighter IB strain for optimum weight at full maturity. This approach to management requires dedicated and skillful management. The VIF detects magnitude or number of inflated variances caused by multi-collinearity among regressors in a regression. It makes coefficients of traits consistent but unreliable. The value of 2.2 for both strains revealed no multicollinearity among regressors of both equations predicting pullet weight at full maturity. The DW statistics which detects autocorrelation in the residuals from a regression analysis, reported low value (below 2), indicating positive autocorrelation among predictor traits. This study differed from Nosike *et al.* (2017) who regressed body weight of Arbor Acres, Ross and Marshall at 2, 4, 6 and 8 weeks from linear body measurements.

The regression equations of hen day production at full maturity on productivity traits revealed that all predictors demonstrated variable levels of causal effects on HDF in both strains. The BN demonstrated better contributions of age at full maturity, feed intake from 21 weeks to full maturity and feed intake at full maturity point than the IB by 1.26, 0.269, 1.18 units; while IB was better on the contributions of pullet weight at full maturity, feed intake from first-egg to full maturity and persistency of egg production at full maturity to percentage hen-day egg production at full maturity by 0.399, 1.997, 0.152, and 0.315 units, respectively. The high SEE observed meant that predictive equations were not very efficient, while the large significance ($p > 0.05$) meant that equations were not important for practical usage, but adequate for comparison, understanding relationships, magnitude of causal effects and contributions of predictor traits to hen-day egg production at full maturity. For hen-day egg production at full maturity, both strains displayed similar genetic ability ($\mu = 0$). The regression equation of BN revealed that adequate feeding level of standard diet from 21 weeks onward would influence age at full maturity, feed intake at full maturity for optimum hen-day egg production at full maturity. In contrast, management strategies would differ in the IB strain. The management strategy should commence at first-egg (at about 16 weeks of age) through feed-flashing (provision of extra hours of light at night for extra feeding till full sexual maturity) to encourage better pullet weight development, egg weight and high persistency of egg production at full sexual maturity. The VIF obtained revealed severe increase in the variance of the regression coefficients in HDF prediction equations of both strains (18.01, 24.18), leading to non-independent linear relationships among predicting traits (PFM, AFM, FFM, and EWF). Although, this does not reduce overall predictive power of equations, but the yield coefficients in equations are not statistically significant. The DW statistics of 1.40 in BN showed positive, while the 2.45 in IB revealed negative autocorrelation among predictor variables, respectively. This practical approach to improving and predicting hen-day productivity at full maturity differ from many published studies as it commences with purposive management from as early as 21 weeks as in the BN. Adams and Bell (1980) proposed a model for hen-day egg production on flock age, Muramatsu *et al.* (1994) constructed a computer simulation model for predicting egg production and growth performance of laying hens, while Ali *et al.* (2003) predicted percentage egg lay from a second power linear model on number of hen-housed. Ahmad (2011) proposed the general regression neural network model to predict egg production in commercial layer strains.

The prediction of percentage day-old pullet chicks hatched depended on the causal effects of pullet weight, egg weight, hen-day egg production, persistency of egg production, fertility and hatchability of eggs set (all at full sexual maturity). The BN revealed better contributions of egg weight, hen-day egg production, fertility and hatchability of eggs set at full maturity to unit change in percentage day-old pullet chicks hatched by 0.058, 0.143, 0.575, and 0.086 units. The IB strain contributed more units of pullet weight at full maturity and persistency of egg production to unit change in percentage day-old pullet chicks hatched than BN by 0.08 and 0.244 units. The equation of BN strain could be of more practical importance ($R^2 = 0.83$) although not statistically significant ($p > 0.05$). The use of both equations is beneficial for comparison and not for practical purposes on the field since they would cause attendant errors in prediction values due to their high SEE, leading to low accuracy of prediction. The low DW statistics of 0.606 to 1.23 show that predictor traits are positively correlated in the equations of both strains. The high values of VIF from 2.7 to 4.2 indicates the high strength of the correlations among the several independent traits in the multiple regression equations of both strains. Since these were influencing each other, they could not be really independent. The low DW values of 0.61 to 1.23 revealed that predictor traits were only moderately and positively correlated in both strains. Oleforuh-Okoleh (2016) regressed hatchability from external egg quality traits. This work is distinct from early hatchability prediction in Ross broiler during the first eleven days by Trukhachev *et al.* (2017), where chick hatch predictability was based on a proposed formula and biological control; whereas, Bouba *et al.* (2021) predicted hatchability of parent and grand-parent layer strains on breeder age, egg weight uniformity, egg storage duration, season, egg weight loss, strain and their interactions by means of linear regression and machine learning models. They concluded that ensemble machine learning models were superior than the linear regression model based on R^2 and RMSE.

The percentage of day-old pullet chicks hatched in BN were influenced by higher genetic ability for fertility of eggs set, hatchability of eggs set, hen-day egg production and egg weight (all at full sexual maturity); while same trait (PDC) was dictated by hatchability of eggs set, persistency of eggs, egg production and pullet weight at full maturity in IB strain. These traits would constitute major causal components for maintenance of productivity in respective strains at full sexual maturity point and during post-peak period. Although, the genetic potential for hen-day egg production and egg weight at peak productivity are high, percent pullet chicks hatched is anchored on fertility and hatchability of eggs set in BN; but same trait is mainly dependent on pullet weight, persistency and hatchability of eggs set in IB. While efforts should be on improving optimum egg weight and hen-day egg production at full maturity in BN, an improvement of pullet weight and persistency of egg production at full maturity in IB would improve day-old pullet chicks' productivity. The strong coefficients for hatchability of eggs at full maturity displayed by both strains revealed that an improved or optimum hatchability would improve percentage day-old pullet chicks hatching in both genotypes.

CONCLUSION

Correlation values within strains presented opportunity for indirect selection of traits. The 20-week pullet weight is found important for management and breeding in both strains. Genetic ability for hen-day egg production and day-old pullet chicks' hatching differ in both strains.

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