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The effect of 20-week pullet weight on full-sexual maturity characteristics in a parent-stock layer strain

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ABSTRACT

The body weight of 20-week-old pullets (PW20) could be managed to influence desired performance at full sexual maturity (FSM) in layers. This was examined in Bovan Nera (BN) parent stock using 22 batches of average of 3896 birds per batch at 20 weeks, raised from year 1999 to 2008. Data were collected on fourteen performance and hatching traits. The GLM, means procedure, Pearson's correlation for association study, Multiple linear regression (MLR) for relationship analysis and Tukey's HSD procedure for mean separation $_{(\alpha=0.05)}$ of SAS/STAT (2013) were employed in a completely randomized design (CRD). PW20 had direct effect ($p < 0.05$) on weight gain from 21 weeks to full maturity (WTF), age at full maturity (AFM) and egg weight at full maturity (EWF). The 20-week low body weight of 1500-1600g had positive effect on compensatory WTF, increased AFM and EWF, produced an auto-correlation with AFM, fertility of eggs set (FES), hatchability of eggs set (HES) and day-old pullet chicks (DPC) hatched at full maturity (PDC, $r = 0.906 – 0.959$, $p = 0.05$). The medium body weight (1601-1700g) positively associated with AFM ($r = 0.594$, $p = 0.05$), with birds in the weight group attaining full maturity at the earliest age of 199 days. The high body weight (1701-1800g) class produced the highest egg weight (60.20 g), was positively correlated with hen day egg production (HDF, $r = 0.998$; $p = 0.05$) and negatively associated with WTF and PFM ($r > - 0.974$, $p = 0.05$) due to the feed restriction leading to reduced weight gain to full maturity. The medium weight produced earliest AFM and high positive associations with fertility, hatchability and day-old pullets hatched at full sexual maturity. For optimum performance, the PW20 medium weight of 1601 – 1700 g/bird is recommended to breeders and producers.

Keywords: Egg weight; full maturity; persistency; predictability; weight gain

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Introduction

Body weight is an important productivity trait and genetic trait for chicken development and management. It influences egg weight, productivity, breeding success and profitability of chicken enterprises (Kumar *et al.*, 2003; Jesuyon, 2011). Productivity of a flock can be measured by the number of quality eggs produced and the number of quality chicks obtained from hatching eggs (Paraguassu & Arango, 2012) but body weight at the point of lay (week 20) is an important indicator of productivity of chicken flocks (Paraguassu & Arango, 2012). Sexual maturity in poultry could be classified into two namely early maturity and full maturity. The early maturity is loosely called early sexual maturity (ESM). It is generally attained and measured at the point when 5% of birds in a flock are in lay. This point reflects a combination of specific age, average body and average egg weight (122 days, 1460 - 1493 g and 42.90 - 55.69 g respectively) at first egg-lay in laying birds (Jesuyon, 2011, 2017; Izundu *et al.,* 2019). Early onset of sexual maturity leads to increased egg number but it is associated with small-sized eggs.

Amira (2008) reported that birds that attained sexual maturity at an early age produced the highest number of eggs (42.6) compared with other groups which produced 28.2 to 30.6 eggs within the first 90 days after sexual maturity. However, when sexual maturity is delayed, larger eggs are produced but the total number of eggs produced is reduced. Quail pullets attaining early sexual maturity at 139-143 days and those that attained ESM at greater than 159 days produced 120 and 109 eggs respectively (Hassan & Hameed, 2019; Tan *et al.,* 2021). Hays (1952) reported that early maturing birds' layed eggs that were 0.89 g smaller than the eggs laid by the medium-maturing pullets, while the medium-maturing pullets showed an average egg weight of 2.75 g smaller than that of the late maturing birds. Delayed sexual maturity is beneficial to hatching operations, because it results in production of medium-sized eggs and bigger chicks, as egg weight and chick weight at hatch have been positively correlated with values from 0.967 and above (Chimezie *et al.,* 2020).

Thus, hatchery operators obtain great benefit by setting heavier eggs (Egbeyale *et al.*, 2015) for more viable chicks. Full sexual maturity (FSM) is attained when a flock of birds has laid its peak hen-day production (HDP), usually at 75 to 95%. At this period, all birds in the flock are expected to be sexually matured and actively in-lay. Birds which are not in lay at this point may be culled to maintain productivity. The FSM point in a flock is influenced by quality of rearing, strain genetics, weight gain, feed consumption and flock egg-laying capacity. Data on FSM characteristics of chicken flocks in an environment could aid in determining optimum productivity and hatching parameters of flocks. They are also needed for adequate evaluation of genetic potential, adaptability and subsequent post-peak productivity and performance of imported strains in the tropics. However, information on FSM for domestic chicken is scarce in literature. This study was designed to investigate the effect of 20-week body weight on FSM productivity and hatching parameters in Bovan nera parent-stock layers.

Materials and Methods

Location of Study

The experiment was conducted at the CHI farms limited – a parent stock commercial farm in Ibadan, located on coordinates 7.2228, 3.8106 along Olode/Ikija Road Oyo State, Nigeria.

Experimental Design

The study adopted completely randomized design (CRD) to study the effect of treatment on the various parameters of study. The treatment was the body weight of the pullets during their 20th week of growth.

Management of *Birds*

All 22 batches of Bovan Nera (BN) strain were reared under same management over a period of 10 years, with standard and adequate nutrition (CP = 18%; ME = 2800 kCal/kg), feeding method was restricted during rearing and free (ad-libitum) feeding was administered during laying for all flocks, body weight was managed through grading at 10 -16 weeks of age during rearing. The birds were raised under CHI Ltd.'s full veterinary programme (Table 1) and good environment from day-old to 75 weeks on the deep litter system. Average population for each batch was 3247 females and 649 cocks (mating ratio 5:1) at twenty weeks of age. The body weight classes of flocks at 20-weeks were low = 1500 – 1600 g (8 batches); medium = 1601 – 1700 g (9 batches) and high = 1701 -1800 g (5 batches), making a total of twenty-two batches used for the study.

TABLE 1

Vaccination programme used on the farm

Vaccine/Drug	Age in days	Dose	Concentration	Remarks
IBH 120	1	1/2	300 ml/1000	Spray
LIVACOx	4	Full	4litres/1000	Oral/Drinking
ND Clone+M. A.	10	Full	500ml/1000	Water
IBD (Ist Dose)	14	Full	15 litres/1000	Oral
IBD (2nd Dose)	24	Full	20 litres/1000	Water
ND Clone + M. A.	31	Full	1 litre/1000	Spray
Fowl Pox	49	Full	Jab	Wingweb
Avian Encephalomyelitis	70	Full	30 litres/1000	Oral
IBH 120	105	Full	35 litres/1000	Water
IBH 120	266	Full	40 litres/1000	Water

Data collection

Data on the twenty-two (22) batches of Bovan Nera (BN) parent-stock from 1999 to 2008 were collected for the research. These were obtained from farm and hatchery records. Data were organized by traits and recorded on weekly basis for each batch. Information from the secondary data were recorded on fourteen (14) productivity traits (farm) and hatching characteristics (hatchery). Productivity traits were pullet body weight at 20-weeks (PW20), feed intake from 21-week to peak egg production at full maturity (F21F), feed intake at full maturity (FFM), weight gain from 21 weeks to full maturity (WTF), age at full maturity (AFM), pullet weight at full maturity (PFM), hen-day production at full maturity (HDF), egg weight at full maturity (EWF), persistency in egg lay at full maturity (P80) measured at ≥ 80% HDP. The hatching characteristics were number of eggs-set at full maturity (ESF), number of fertile eggs candled at full maturity (FES), number of eggs hatched on eggs-set at full maturity (HES), number of day-old pullet chicks hatched on eggs-set at full maturity (PDC), number of rejected chicks and unhatched eggs on eggs-set at full maturity (RCU). From F21F and WTF, daily feed intake from 21-weeks to full maturity (DFI) and daily weight gain from 21-weeks to full maturity (DWG) were derived. The persistency in lay was measured as the number of weeks for which a batch lay at least an average HDP of 80% or more. The batches were treated as replicates in the study.

Statistical linear model

The linear statistical model for the GLM analysis was of the form:

$Y_{ij} = \mu + T_i + \varepsilon_{ij}$

Y_{ij} = Observed response at full maturity in ith pullet weight group, jth replicate.

μ = Overall and unknown mean

T_i = Effect of 20-week body weight i, (i = low: 1500-1600g, medium: 1601-1700g, high: 1701-1800g)

ε_{ij} = Random error component committed NID $(0, \delta^2)$

Analysis of Data

Data were subjected to General Linear Model (GLM) for analysis of variance. Differences in means were separated with the Tukey's HSD procedure $_{\alpha=0.05.}$ The Statistical Analytical

Systems® (SAS, 2013) computer software was used for analysis.

The Pearson's correlation procedure of SAS/STAT® (2013) software was used to study the linear association between pairs of traits ($p < 0.05$). Multiple linear regression (MLR) procedure was employed to analyze and expose the linear relationship between a dependent trait (Y) and one or more independent traits (Xs). The regression model used was:

$Y = a + bX \pm \mathcal{E}$, ($R^2$); where

Y = Number of or percent day-old pullet chicks hatched at full sexual maturity in Bovan nera. This is the dependent trait in the study.

a = general constant

b = coefficient of predictor variables at full sexual maturity

X = predictor variable (s). These are the independent variables in the regression model, namely

Fertility of eggs set (FES) or hatchability of eggs set (HES).

Ɛ = standard error of estimate of equation

Hypothesis of study

The hypothesis for research was that 20-week pullet weight will have influence on FSM productivity traits and hatching parameters.

Results and Discussion

Table 2 reveals the significant ($p < 0.05$) effect of 20-week pullet weight (PW20) on WTF, AFM, EWF ($p < 0.05$) and a marginal effect ($p < 0.09$) on RCU. The DFI, DWG, FFM, PFM, HDF and P80 were not significantly different between the PW20 classes ($p > 0.05$). The low weight (1500 – 1600 g) class gained more weight (404 g) than the medium and high weight classes (239 and 246 g) respectively from 21-weeks to full maturity point in 216 days. The medium weight class (1601-1700 g) attained AFM at 17 and 37 days earlier than the low and high weight classes whose AFM were 216 and 236 days. Egg weight was highest at 60.20 g in the high weight class, while the low and medium weight classes were 56.46 and 53.97 g respectively. Persistency in lay at ≥ 80% (P80) lasted for 7 weeks in the high weight birds, but only for 4 weeks in the low and medium groups. There was no significant ($p > 0.05$) effect of PW20 on egg hatching parameters of the Bovan pullets at full sexual maturity point. The CV (%) values obtained for RCU, WTF and P80 were high from 35 -78.5%.

TABLE 2

Effect of 20-week body weight on production traits and hatching parameters at full sexual maturity in Bovan nera layer parent stock in Ibadan Nigeria

20-wk Weight (PW20)	Class	DFI (g/day)	WTF (g)	DWG (g/day)	FFM (g/day)	AFM (dys)	PFM (g)	EWF (g)	HDF (%)	P80 (wk)	ESF (%)	FES (%)	HES (%)	DPC (%)	RCU (%)
1500-1600 (1556.60)	Low	107.31	404.40^a	5.59	109.70	216^b	1961.00	56.46^b	82.76	4.00	88.59	80.17	71.20	33.49	9.93
1601-1700 (1639.72)	Medium	100.77	238.55^b	4.25	108.97	199^a	1878.27	53.97^b	83.17	4.40	99.72	80.55	67.82	30.93	15.96
1701-1800 (1740.30)	High	111.45	245.70^b	2.79	114.57	236^b	1986.55	60.20^a	83.83	7.00	99.45	90.60	82.06	38.99	9.67
Mean (1634.55)	Mean	103.86	277.21	4.40	109.90	208	1911.76	55.45	83.17	5.00	96.70	82.46	71.57	33.22	13.09
SEM	SEM	4.58	24.70	0.46	1.98	0.69	22.50	0.73	0.77	0.93	2.60	2.15	3.04	1.43	1.28
CV (%)	CV	20.88	38.39	50.08	0.46	9.24	5.67	5.33	4.45	78.47	11.42	10.78	18.24	17.56	37.30
P	*P*	*0.690*	*0.023*	*0.205*	*0.703*	*0.018*	*0.179*	*0.011*	*0.926*	*0.587*	*0.268*	*0.246*	*0.308*	*0.166*	*0.090*

Notes: *DFI = Daily feed intake from 21 weeks to full maturity, WTF = Weight gain from 21 weeks to full maturity, DWG = Daily weight gain from 21 weeks to full maturity, FFM = Feed intake at full maturity, AFM = Age at full maturity, PFM = Pullet 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, FES = Fertility of eggs set at full maturity, HES = Hatchability of eggs set at full maturity, DPC = Day-old pullet chicks hatched at full maturity, RCU = Rejected chicks and unhatched eggs at full maturity, Superscripts a, b, c, show significant differences at α = 5%*

The Pearson's correlation coefficients (Tables 3 and 4) reveal important linear association between pairs of traits. Among birds of low body weight, PW20 positively correlated with each of AFM, FES, HES and PDC ($r > 0.906$, $p = 0.05 – 0.01$); WTF positively correlated with PFM ($r = 0.98$, $p = 0.01$); AFM positively correlated with PDC ($r = 0.882$, $p = 0.05$). The EWF positively correlated with P80 ($r = 0.999$, $p = 0.05$). The FES positively correlated with each of HES and PDC ($r = 0.956$, $p = 0.01$) while HES positively correlated with PDC ($r = 0.996$, $p = 0.001$). In medium weight class, PW20 positively correlated with AFM ($r = 0.594$, $p = 0.05$); WTF positively correlated with PFM ($r = 0.947$, $p = 0.0001$); FFM positively correlated with EWF and HDF ($r > 0.509$, $p < 0.05$); EWF positively correlated with FES ($r = 0.780$, $p = 0.05$); while HES correlated positively with PDC, but negatively with - RCU ($r > 0.817$, $p = 0.01$). The high weight class associated PW20 with -WTF, and -PFM negatively, and positively with HDF ($r > 0.974$, $p < 0.05$); WTF correlated positively with each of PFM, and EWF; and negatively with - HDF ($r > 0.981$, $p < 0.05$); PFM correlated positively with EWF, and negatively with - HDF ($r > 0.994$, $p < 0.05$); EWF correlated negatively with -HES and - PDC ($r = 0.997$, $p < 0.05$); while P80 correlated positively with ESF, and negatively with - RCU ($r > 0.997$, $p = 0.05$). All paired correlation values declared were positive (except pairs of HES/RCU in medium weight class and PW20/WTF, PW20/PFM, WTF/HDF, EWF/HES, EWF/PDC and P80/RCU in the high body weight class), high hip equations ($r > 0.5$) and significant ($p < 0.05$).

Regression explains the effect of one or more independent traits on the dependent trait of interest in a group. Table 5 reveals that stepwise regression of percent day-old pullet chicks (DPC) hatched at full sexual maturity on either fertility of eggs set or hatchability of eggs set (FES or HES. Regression models serve to predict the dependent trait: day-old pullet chicks - from the independent traits: FES or HES. The model produced in the low weight class, an intercept and R^2 of 33.93 and 0.001; but the medium class birds exposed an intercept, standardized coefficient of **FES** and R^2 of -38.12, **0.96** and 0.89. The high body weight birds unveiled 3.06, **0.99** and 0.99 respectively for prediction of viable day-old pullet chicks hatched. The R^2 of equations were high in the medium and high weight classes but low in the low weight class (0.001, 0.89, 0.99); while the Durbin Watson statistics values ranged from 0.91-2.00. All relationship equations reported were highly significant ($p = 0.000 - 0.036$).

TABLE 3

Pearson's phenotypic correlation matrix for paired characters at full sexual maturity in Bovan Nera layer parent stock in Ibadan Nigeria

							Low body weight							
	TRAITS	**PW20**	**WTF**	**FFM**	**AFM**	**PFM**	**EWF**	**HDF**	**P80**	**ESF**	**FES**	**HES**	**DPC**	**RCU**
	PW20 (g)	-	0.234	0.411	**0.938****	0.421	0.332	-0.353	-0.672	0.610	**0.906***	**0.935***	**0.959****	-0.108
	WTF (g)	-0.017	-	0.778	0.504	**0.980****	0.764	-0.235	0.826	0.752	-0.171	-0.087	-0.033	-0.313
	FFM (g)	-0.038	0.274	-	0.545	**0.809***	**0.946****	-0.112	0.805	0.701	0.286	0.179	0.241	0.335
Medium	AFM (days)	**0.594***	0.093	-0.029	-	0.659	0.528	-0.478	-0.500	-0.790	0.760	0.848	**0.882***	-0.313
	PFM (g)	0.307	**0.947******	0.249	0.280	-	0.780	-0.291	0.662	0.859	0.033	0.120	0.178	-0.326
body	EWF (g)	0.003	0.458	**0.719****	0.287	0·441	-	-0.178	**0.999***	0.738	0.270	0.206	0.265	0.192
	HDF (%)	0.016	-0.076	**0.509***	-0.026	-0.067	0.257	-	0.635	-0.016	-0.396	-0.569	-0.527	0.557
weight	P80 (%)	0.204	-0.037	0.224	0.286	0.033	0.423	0.594	-	-	-	-	-	-
	ESF (%)	0.172	-0.488	-0.150	-0.404	-0.417	-0.536	0.176	0.389	-	0.325	0.367	0.440	-0.180
	FES (%)	0.263	-0368	0.405	0.620	0.423	**0.780***	0.490	0.858	-0.510	-	**0.956****	**0.969****	0.155
	HES (%)	0.307	0.368	0.365	0.381	0.435	0.647	0.307	0.376	0.363	0.718	-	**0.996*****	-0.142
	DPC (%)	0.269	0.231	0.171	0.501	0.294	0.602	0.486	0.795	-0.445	0.896	**0.875****	-	-0.121
	RCU (%)	-0.216	0.026	0.155	-0.210	-0.034	-0.211	-0.364	-0.665	0.193	-0.510	**-0.817****	**-0.838****	-

Notes: *PW20 = Pullet weight at 20-week, WTF = Weight gain from 20 weeks to full maturity, FFM = Feed intake at full maturity, AFM = Age at full maturity, PFM = Pullet weight at full maturity, EWF = Egg weight at full maturity, HDF = Hen day production at full maturity, P80 = Persistency of hen day production, ESF = Eggs set at full maturity, FES=Fertility of eggs set at full maturity, HES = Hatchability of eggs set at full maturity, DPC = Day-old pullet chicks hatched at full maturity, RCU=Rejected chicks and unhatched eggs at full maturity, Significant levels: $p \leq 0.0001$=****, $p \leq 0.001$ = ***, $p \leq 0.01$ = **, $p \leq 0.05$ = **

TABLE 4

Pearson's phenotypic correlation matrix for paired characters at full sexual maturity in Bovan Nera layer parent stock in Ibadan Nigeria

							High body weight							
	TRAITS	**PW20**	**WTF**	**FFM**	**AFM**	**PFM**	**EWF**	**HDF**	**P80**	**ESF**	**FES**	**HES**	**DPC**	**RCU**
	PW20 (g)	-	**-0.990***	-0.558	0.427	**-0.974***	-0.945	**0.998***	0.705	0.654	0.686	0.914	0.928	-0.666
	WTF (g)	**-0.424***	-	0.667	-0.550	**0.996***	**0.981***	**-0.999****	-0.598	-0.541	-0.782	-0.962	-0.971	0.555
	FFM (g)	0.059	0.325	-	-0.989	0.732	0.800	-0.678	0.194	0.262	-0.987	-0.846	-0.828	-0.247
	AFM (days)	**0.414***	0.191	0.078	-	-0.621	-0.700	0.560	-0.339	-0.404	0.951	0.756	0.734	0.390
	PFM (g)	0.105	**0.856******	**0.391***	**0.447***	-	**0.994***	**-0.997***	-0.526	-0.465	-0.833	-0.982	-0.988	0.480
Whole	EWF (g)	0.146	**0.491****	0.683	**0.462***	**0.632*****	-	-0.984	-0.434	-0.369	-0.887	**-0.997***	**-0.998***	-0.384
	HDF (%)	-0.034	-0.093	0.318	-0.080	-0.122	0.040	-	0.589	0.530	0.789	0.965	0.974	-0.544
Flock	P80 (%)	0.301	-0.074	0.292	0.178	0.130	0.409	**0.560***	-	**0.997***	-0.031	0.358	0.389	**-0.999***
	ESF (%)	0.379	0.057	0.232	0.360	0.280	0.342	-0.067	0.138	-	-0.101	0.292	0.3324	-0.999
	FES (%)	**0.508***	-0.033	0.307	**0.698****	0.253	**0.496***	0.032	0.323	0.256	-	0.922	0.909	0.085
	HES (%)	0.442	0.101	0.323	**0.587***	0.367	**0.495***	0.009	0.222	0.175	**0.812******	-	0.999*	-0.307
	DPC (%)	0.437	0.059	0.238	**0.678****	0.316	**0.537***	0.097	0.432	0.193	**0.901******	**0.923****	-	-0.339
	RCU (%)	-0.121	-0.161	-0.006	-0.337	-0.251	-0.330	-0.147	-0.429	0.065	-0.328	**-0.679****	**-0.703****	-

Notes: *PW20 = Pullet weight at 20-week, WTF = Weight gain from 20 weeks to full maturity, FFM = Feed intake at full maturity, AFM = Age at full maturity, PFM=Pullet weight at full maturity, EWF = Egg weight at full maturity, HDF = Hen day production at full maturity, P80 = Persistency of hen day production, ESF = Eggs set at full maturity, FES = Fertility of eggs set at full maturity, HES = Hatchability of eggs set at full maturity, DPC = Day-old pullet chicks hatched at full maturity, RCU = Rejected chicks and unhatched eggs at full maturity, Significant levels: $p \leq 0.0001$=****, $P \leq 0.001$ = ***, $p \leq 0.01$ =**, $p \leq 0.05$ =**

Effect of 20-week body weight on flock performance

The effect of PW20 on WTF, AFM and EWF suggests that at high body weight egg weight would possibly increase, although AFM would be higher than in other weight classes at full sexual maturity. The pullets in the medium weight class at 20-weeks produced the least egg weight by 3.74 – 6.23 g among classes. In contrast, the low weight class which demonstrated very high compensatory growth of 404.4 g form the 20th week to full maturity, produced eggs of similar weight to the medium weight class. The effect of low weight was bridged earlier through management by ad-libitum feeding during the day and midnight feed flashing (Farghly *et al.*, 2019), thereby encouraging compensatory growth between 20 weeks and full sexual maturity. PW20 did not reveal important influence on DFI, DWG, FFM, PFM, HDF, P80 and hatching parameters, probably due to feed and body weight management techniques employed. Unrestricted feeding was employed to encourage compensatory growth in the low-weight class while restricted feeding was applied to reduce growth in the high weight class to make pullet classes attain full maturity at the right body weight of about 1878 g, attain high body weight uniformity of 75% and above; and right body composition (dos Santos, 2017) and electrolyte at full maturity.

TABLE 5

Normal and standardized multiple regression equations for quantity of viable day-old chicks hatched at full sexual maturity in Bovan Nera layer parent stock in Ibadan

Trait	Weight group	Component	Parameter	Std. Estimate	SEE	*P>F*	VIF	Adj. R^2	CV	DW
	Low	Intercept	33.92	0	7.020	0.000	0.000	0.001	29.25	2.000
	Medium	Intercept	-38.116	0	13.575	0.036	0.000	0.893	7.427	0.919
		FES	0.854	**0.964**	0.167		1.000			
Day-old pullet chicks (DPC, %) hatched at full sexual maturity	High	Intercept	3.062	0	1.208	0.021	0.000	0.998	0.164	1.444
		HES	0.4338	**0.999**	0.015		1.000			
	Whole Flock	Intercept	-15.921	0	8.136	0.0004	0.000	0.825	8.21	0.648
		FES	0.601	**0.920**	0.097		1.000			

Notes: *FES=Fertility of eggs set at full maturity, HES=Hatchability of eggs set at full maturity, SEE= standard error of estimate, VIF= variance inflation factor, Adj. R^2 = adjusted R-squared, CV = coefficient of variation, DW = Durbin Watson statistics*

Thus, proper management techniques are required for pullets from 20-weeks onward to promote optimum genetic expression of productive and hatching parameters at full maturity in BN layers. This point is further supported by the low CV of 0.46 – 5.67 (high uniformity for DWG, HDF, EWF and PFM) obtained on the productive traits at FSM except the weight gain from 21-week to full maturity and persistency of egg production. The medium weight flock seemed to exhibit the normal genetic potential without ad-libitum or restricted feeding, and thus gained the least body weight to full sexual maturity at an early age of 199 days; but produced the lowest egg weight. The low weight class exhibited compensatory growth on *ad-libitum* feeding and feed-flashing, increasing feed intake and fat deposition (Hornick *et al*., 2000), resulting in late sexual maturity for 17 days and producing medium-sized eggs.

The consumption of compensatory feeds in the low-weight class from 21-weeks of age probably stimulated secretion of more insulin and maintained high plasma growth hormone concentration, thus allowing more nutrients to be used for growth (Hornick *et al.,* 2000). Lean tissues were deposited initially through protein synthesis, but this could have decreased later, so that thereafter high feed intake could lead to fat deposition (Hornick *et al.,* 2000). Thus, compensatory growth from 21 weeks to peak production point could be attributed to the ability of lower weight birds to utilize available feeds for accretion of fat in body tissues for overall development. Feed-restriction in the high weight class might cause a reduction of feed consumed. Thus, growth (body weight) and development were reduced to appropriate constitutions at full sexual maturity.

Although, weight gain at full maturity (WTF) point in the medium and high weight flocks were similar, body weight at 20-weeks caused a reversal of AFM and EWF between the two classes. This explains why the birds with the higher body weight laid heavier eggs at late maturity time (37 days late) than in medium weight class. Persistency of egg lay refers to the number of weeks during which a constant level of egg production is maintained. Birds in the high weight class exhibited the best persistency of egg lay due to the effect of the feed restriction imposed; to enhance protein synthesis for lean tissue deposition, body development and better body weight uniformity (Hornick *et al.,* 2000). The high persistency in lay observed for seven weeks was partly due to the high body weight uniformity, adequate nutrition, adequate level of feeding, good health care and good welfare status of the hens (Bain, 2016).

In this class, PW20 imposed a negative association with WTF, and also, between WTF and AFM, although these associations are dependent on quantity of feed consumed (NDVSU, 2024). The egg weight at full sexual maturity was also dependent on the pullet weight at 20-weeks. The age of birds at full maturity (AFM) in each of the classes responded differently to the effect of body weight at 20-weeks and subsequent feed supply from 21-weeks to FSM. As a result, birds in each weight class attained FSM at different AFM. Egbeyale *et al.* (2015) reported that birds from small-sized eggs (Dominant Black layers) matured earlier (145.67 days) than birds from big-sized eggs. This could be due to the improper implementation of feed management techniques employed in the present study. Paraguassu & Arango (2012) reported that flock age (at maturity) affects egg size, hatchability and chick size. This trend was observed in present study among the body weight classes.

Good management practices, nutrition and adequate lighting programs also ensure good egg production and optimum egg size, as they lead to positive breeder performance, chick quality, survival and growing ability (El-Sabrout, 2022; https://www.fao.org/3/y5169e/y5169e05.htm). Thus, the final pullet weight at full maturity (PFM) of classes became similar, due to the feed and body weight management techniques imposed on the flock between 21 weeks and FSM. Birds from the low weight flocks showed the best WTF and compensatory growth with *ad-libitum* feeding. However, the medium weight class of 1600 - 1700 g at 20-weeks recorded the lowest age at full sexual maturity and lowest DFI of 101 g/day. The high body weight class of 1700 - 1800 g at 20-weeks had a strong, linear but negative association with WTF and PFM, but a positive association with HDF.

In order to increase and maintain egg lay persistency (in weeks) and reduce RCU in flock to < 10%, birds could be reared to a target body weight range of 1701 – 1800 kg at 20 weeks. This could then be followed with a feed restriction strategy of ≤ 104 g/day/bird in birds that fall within the high weight class. This high persistency of egg production at ≥ 80% for 7 weeks in the high weight class implies that they had the best uniformity in body weight at FSM. This high persistency of egg lay at FSM could have been influenced by the high PW20 and good flock weight uniformity induced through feed restriction and body weight grading of the pullets. Flock weight uniformity is the percentage of individuals within ±10 % range of the mean weight of a flock. It depends on the variability of weight within flock (Pasveer, 2021) and this influences egg productivity and livability in layers (Abbas *et al.*, 2010). Poor flock management may yield poor uniformity of less than 70% (ab-neo.com/news/importance-uniformity-broiler flock#; https:// www.poultryworld.net/health-nutrition/importance-of-broiler-flock-uniformity).

Therefore, a good PW20 will relate to an optimum AFM while a poor PW20 with high level of feeding would trigger compensatory weight gain from 20-week till the age of attainment of full sexual maturity (usually late AFM) and medium egg size. A high PW20 would require feed restriction. The high CV of 37-78.5% obtained on RCU, WTF and P80 opens up an opportunity for selection and further improvement of unclassified or natural BN flock - to further increase persistency of egg production and decreasing rejected day-old chicks simultaneously in the hatchery.

Effect of 20-week body weight on hatching parameters:

In contrast to its influence on productivity, PW20 seemed to have no statistical effect ($p > 0.05$) on hatching parameters of the BN layers (Table 3). This could mean that factors other than ESF, FES, HES, PDC and RCU could have been responsible for the observed variability among the weight groups. Within the low weight class, the strong linear and positive association between PW20 and AFM, FES, HES and PDC meant that the 1500 -1600 g body weight pullets at 20-weeks associated with medium sexual maturity age, high fertility, hatchability and chicks hatched. Body weight management during rearing could target a mean of ≥ 1557 g at 20 weeks, followed by ad-libitum feeding (≥ 107 g/day/bird) for compensatory growth to full maturity weight of 1961 ± 5% g for optimum productivity. The medium weight class of birds which correlated PW20 with age at full sexual maturity meant that sexual maturity was attained earlier than in other classes.

This is always the desire of the farmer in order to obtain more hatching eggs, but these early eggs could be small (53 g), so that egg setting would be delayed till a desired egg weight (58 g) is obtained. The weight gain from week 21 onward should be monitored along with feed intake (≥ 101 g/day/bird) to facilitate high hen weight at full maturity (≥ 1878 ± 5% g) for heavier eggs to be laid. Ideally for best hatchability and chick quality, the minimum egg weight for setting and hatching of day-old chicks is 58-61 g in layer chickens (https://hn-int.com/hatching-egg-management-2/#). The high weight birds present a different correlation profile. The negative association of WTF and PFM; and the positive association of HDF with PW20, mean that weight gain to full maturity should be reduced through feed restriction for pullets to attain an optimum body weight of 1987 g at full maturity. The feed-restriction technique produced highest egg weight of 60 g and highest percentage chick production (39%) at full maturity. The delay in full sexual maturity or late maturity of birds (236 days) indicates the effect of feed restriction. A slow, step- down lighting program could also be used during rearing stage to modify egg weight profile due to its ability to slow down or delay the rate of sexual maturity for optimized hatchability and chick quality (Paraguassu & Arango, 2012). Similarly, body weight and egg size were improved as a flock aged (Paraguassu & Arango, 2012) after onset of FSM.

In poultry, FES could be influenced by management factors such as sex ratio, libido of males, age of cocks, while HES could be controlled by improved egg shell thickness through calcium supplementation, pre-setting egg handling and production management, hatchery biosecurity and standard incubator conditions for high profitability (Pinchasov, 1991). He further reported a decline in the correlation of hatching egg weight with chick weight irrespective of hen age. Egg weight has great influence on egg hatchability (Fathi *et al.,* 2022). Egg weight is also a major factor that affects the weight of day-old chicks (Abiola *et al.*, 2008; Garip & Dere, 2011; Egbeyale *et al.*, 2013; Anandh *et al.*, 2012). The size of an egg is influenced by nutritional factors such as dietary protein (Jesuyon, *et al.*, 2020), amino acid adequacy and linoleic acid content (Najib & Al-Yousif, 2014).

Other factors controlling egg weight are genetic markers (Lacin *et al.*, 2008), stage of sexual maturity, age and drugs (Wu *et al.*, 2005). Differences in the hatching ability of eggs of different weight have also been reported (Ramaphala & Mbajiorgu, 2013), but eggs that are too large or small have poor hatchability. Graded hatching eggs would exhibit better hatchability and chick weight uniformity. Chick uniformity could also be improved by setting hatching eggs according to parent-source, batch, sorting to standard weight of ≥ 58 g, and maintaining these groupings till chicks are placed in the brooder house (Paraguassu & Arango, 2012). Good hatchability has also been reported to be positively associated with a high yolk percentage of hatching eggs (Cavero *et al.,* 2011).

Prediction of day-old pullet chicks as influenced by 20-week body weight (PW20)

Bovan Nera pullets of low weight revealed a mean hatchability on eggs set of 71% (n > 200). The percent day-old pullet chicks hatched was predicted better from the fertility in the medium weight group; but hatchability record (after candling) in the high weight birds. In both weight categories, the normal and standardized equations displayed better predictability of day-old chicks hatched (R^2 > 0.89) than the low weight birds (R^2 = 0.001). This might be partly because both showed low coefficient of variation (< 10%) for PDC hatched. Both groups revealed similar contributions (0.96 – 0.99) to unit change in DPC hatched. The high significance (p < 0.036) of all equations meant that they could be used for practical predictions, although the low weight equation could be highly unreliable due to low R^2.

The low Durbin Watson value (< 2.00) revealed a strong and positive autocorrelation of percent pullet day-old chicks hatched with fertility of eggs set and with hatchability of eggs set, in the medium and high classes respectively. This is good for prediction. However, hatchability is a complex flock-age dependent trait which is controlled by genetic and environmental factors (Wolc & Olori, 2009). The prediction of hatchability of quality chicks within a narrow hatching-time or window is a common practice among commercial hatcheries (Paraguassu & Arango, 2012). The final expression of genetic potential of BN for day-old pullet chicks hatched depends on a complex interaction of multiple factors, including genetics. Environmental and management factors are important drivers of the performance of commercial layers. They interact together to produce a wide variety of positive or negative effects. An improved day-old pullet chicks' productivity would bring higher economic returns for commercial farmers.

Conclusion and Recommendation

The application of 20-week body weight for management of Bovan Nera improved WTF, AFM and EWF performance on-farm, while

PW20 positively was correlated with AFM in the medium weight layers. This result suggested a 20-week bodyweight target of 1640 g per pullet to farmers. The 20-week weight of low bodyweight pullets auto-correlated positively with FES, HES and PDC after body weight grading, followed by daily ad-libitum/ compensatory and night flash feeding from 21 weeks. This produced compensatory growth and thus ensured high number of eggs and chicks at FSM. The high weight class produced the highest quantity of hatched chicks. A high flock-average 20-week pullet weight of 1701 – 1800 g/bird is recommended for higher hen day egg production, higher persistency, good hatchability and day-old pullets hatched at full sexual maturity. This may enhance optimal genetic performance in Bovan Nera beyond sexual maturity period. These management techniques are recommended to farmers. The percent viable day-old pullets hatched can be predicted from either fertility record in the medium weight group or hatchability record in the high body weight group.

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