Determination of relative economic weights of growth and egg production traits in Nigerian indigenous chicken

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Abstract

The relative economic weight (REW) of a trait is the additional gain/loss from a unit change in the trait relative to other traits in an individual. They are used to calculate aggregate economic values for purposes of genetic improvement in animals. The present study was designed to evaluate the bio-economic variables of growth and 16 weeks egg production parameters: egg number (EN_{16}), egg weight (EWT_{16}), body weight at first egg (BWTFE), body weight at 16 week of lay ($BWTE_{16}$), cost of feed, and revenue from eggs and chicken carcass, feed conversion ratio (FCR_{16}), and body weight gain (BWG_{16}) in the Nigerian indigenous chicken, and to determine the economic weights (EW) and REW of EN_{16} , EWT_{16} and $BWTE_{16}$ for G_0 , G_1 , and G_2 generations. A total of 250 pullets (20 week old, point of lay) from a population of heavy body weight local chickens were used for the study. The birds were housed individually in cages, fed optimally on layers mash (G_0 and G_1 : 100g/bird/day; G_2 : 125g/bird/day) and given water ad libitum. Data included EN_{16} , EWT_{16} , $BWTE_{16}$, BWTFE, and prices of feed, eggs and spent hens, FCR_{16} and BWG_{16} . Data on EN_{16} , EWT_{16} , $BWTE_{16}$ and BWTFE were compared across generations using ANOVA and with other variables were used to generate the EW of the traits. The EW were then standardized relative to that of $BWTE_{16}$. Results showed that EW and REW of EN_{16} , EWT_{16} and $BWTE_{16}$ were 7.47 and 3.15, 13.67 and 5.77 and -2.37 and -1.00, respectively in G_0 ; 13.07 and 3.82, 23.69 and 6.93, and -3.42 and -1.00, respectively in G_1 ; 16.80 and 2.89, 30.75 and 5.28 and -5.82 and -1.00, respectively in G_2 generation. Thus EN_{16} and EWT_{16} enhanced while $BWTE_{16}$ depressed the worth of the hen as a layer. EWT_{16} was more important than EN_{16} and both were more important than $BWTE_{16}$ economically. Therefore, EWT and EN are the major bio-economic variables of the local hen as an egg chicken.

Keywords: Aggregate value, economic weight, egg production, native chicken hen, selection index.

Introduction

The net economic value of an animal is a function of the many traits contributing to its economic worth (Liinamo, 2003). These traits weighted by their relative economic values are included in selection criteria for

improvement of net economic worth (Liinamo, 2003). For rapid genetic progress, only the most important traits are included in selection indices. The weighting of different traits defined in the breeding goals according to their relative economic importance is an essential

component of multiple trait selection index method (Shadparvar *et al.*, 2005). Indeed, consideration of 'what type' to breed mainly concerns the relative importance of different traits possessed by animals (Liinamo, 2003). The economic weight (value) of a trait measures the average amount which a given variation in the trait actually raises or lowers the net phenotypic merit of the animal (Lerner, 1958). Rendered differently, it measures the net increase or decrease in profit of the production enterprise for a unit of change in one trait independent of effects from genetic change in other traits included in the definition of aggregate breeding value (Haze, 1943; Groen *et al.*, 1997; Shadparvar *et al.*, 2005). Relative economic weights also reflect changes in production cost and hence cost to consumers of animal products since they are functions of income and expenses of a production system (Groen *et al.*, 1989a; Shadparvar *et al.*, 2005). In addition, economic values depend on the definition of the production system, the goal to be optimized and particular production circumstances (Groen *et al.*, 1997). Relative economic values of traits defined in a breeding objective and included in a selection index weights the traits according to their relative contribution to the overall economic worth of the animals in a population and hence according to their relative impact on profit of the livestock enterprise (Wolfova *et al.*, 2005; Borg *et al.*, 2007).

Methods for the determination of relative economic weights of traits vary (Shadparvar *et al.*, 2005). Usually the relative importance of traits are subjectively determined for each kind of animal, region, type of farming system, marketing system and situation and almost for each breeder (Smith *et al.*, 1986; Hazel

et al., 1994; Shadparvar *et al.*, 2005). In countries where farm products are graded and market prices are standardized, economic values of traits are determined from production data and market costs (Ibi *et al.*, 2006; Okeno *et al.*, 2011a). Okeno *et al.* (2011b) estimated the economic values of traits that influence profitability in indigenous chickens in Kenya using a deterministic bio-economic model. Economic values can also be obtained as partial regression coefficients of net value of the individual on the separate component traits (Cunningham, 1969; Aubry *et al.*, 1998; Choy *et al.*, 2012). Furthermore, simulation of production and marketing systems has been suggested as a more precise method of determining the relative economic values of traits (Cartwright *et al.*, 1975; Cartwright, 1979; Shadparvar *et al.*, 2005).

There is dearth of information on the relative economic values of important traits of Nigerian indigenous chicken (NIC). This has hampered the inclusion of economic indices among the criteria for the selection and genetic improvement of the NIC. The present study was therefore conducted to determine the relative economic values of body weight, egg weight and egg production during short term (16 weeks) egg production for three generations in a population of Nigerian Indigenous Chicken (NIC) which could be used as added information to facilitate their selection and genetic improvement.

Materials and methods

Location of the study: The study was conducted at the Local Chicken Production and Research Unit of the Department of Animal Science, University of Nigeria, Nsukka in Enugu State. Nsukka is located on latitude 05° 22' North and longitude

07°24' East with annual rainfall range of 1567.05 to 1846.98mm, minimum and maximum daily temperature of 20.99 and 30.33° C, respectively and relative humidity of 46.68 to 76.20% (weather data, Department of Crop Science, University of Nigeria, Nsukka, unpublished).

Management of Experimental Animals: A total of 250 NIC of mixed varieties (G_0 generation) at point of lay (20 wk old) generated from a base population of heavy body weight (heavy ecotype) local chickens were used for the study. The birds were housed individually in laying cages in an open sided, well ventilated building roofed with asbestos roofing sheets for heat insulation. The birds were vaccinated against endemic diseases during the brooding and rearing phases and a booster dose of Newcastle disease was given prior to the commencement of the study. The birds were also dewormed and given prophylactic medications against bacteria and protozoan diseases in the area. They were fed 16.50 % CP and 2600 Kcal ME/kg layers mash at the rate of 100g/bird/day in G_0 and G_1 generations but 125g/bird/day in G_2 generation because of improvement in body weight. Water was provided *ad libitum*.

Production of G_1 and G_2 populations: At the end of the short term (16 weeks) egg production, all surviving hens were subjected to selection using an index incorporating the studied traits weighted by their heritabilities and relative economic weights. The selected hens were mated to contemporary local chicken cocks (sibs as sires) selected on the basis of body weight performance using mass selection. Progenies from these mating make up the G_1 population. The G_2 population was also generated likewise from selected G_1 hens

and cocks.

Data collection: Data collected in each generation included feed intake (FI_{16}) during 16 weeks of lay (short term egg production), body weight at first egg (BWFE) and at 16 weeks of lay ($BWTE_{16}$), egg number (EN_{16}) and egg weight (EWT_{16}) to 16 weeks of lay, market prices of local chicken eggs and birds obtained by sale of eggs laid by the birds and sale of healthy spent hens, and feed prices as the cost of layers mash formulated for the birds. Feed conversion ratio (FCR_{16}) and body weight gain (BWG_{16}) during 16 weeks of lay were determined from BWT and FI data in each generation.

Determination of Economic Weights (EW): At the end of 16 weeks of lay of all birds in the flock, economic weights of $BWTE_{16}$, EWT_{16} and EN_{16} were calculated using the production and market (bio-economic) variables generated. The following deterministic model was used.

$$1. \quad \text{Economic weight (EW of } BWTE_{16} \text{)} \\ = R - (XY/Z) = R - (FCR_{16} \times Y)$$

Where,

R = Revenue accruable from a unit (1 g) chicken,

X = Daily feed intake (g/bird/day),

Y = Cost of a unit (1 g) feed input,

Z = Daily weight gain (g),

FCR_{16} = Feed conversion ratio at 16 wk egg production.

Assumption

- Only cost of feed significantly influenced the production cost and hence profit.
- Prices of inputs and products were assumed constant within each

generation.

2. Economic weight (EW) of EWT_{16}
 $= R - (XY)$

Where, X and Y are as defined above and R = Revenue accruable from additional eggs from a hen due to 1g increase in egg weight. This was calculated as cumulative gain in egg weight per hen divided by the mean egg weight for the population multiplied by the unit price of eggs.

Assumption

Increases in egg weight in each generation did not incur additional costs from feed input. Thus $Y = 0$; so that $XY = 0$; and Economic weight of $EWT_{16} = R$.

3. Economic weight (EW) of EN_{16}
 $= R - (XY)$

Where, X and Y are as defined for EWT_{16} and R = Revenue accruable from additional eggs from a hen due to 1 % increase in percent egg production. This was calculated by multiplying the additional eggs by the unit price of eggs.

Relative economic weight (REW): The relative economic weights of the traits for each generation were obtained by standardizing the economic values relative to the value for $BWTE_{16}$. This was done by expressing the economic weights of the other traits as ratios of the economic weight of $BWTE_{16}$ (Becker, 1997).

$$\begin{aligned} \text{Thus: } REW_{BWTE_{16}} &= EW_{BWTE_{16}} / EW_{BWTE_{16}} \\ REW_{EWT_{16}} &= EW_{EWT_{16}} / EW_{BWTE_{16}} \\ REW_{EN_{16}} &= EW_{EN_{16}} / EW_{BWTE_{16}} \end{aligned}$$

The economic weights and relative economic weights for the traits in G_1 and G_2 generations were determined by similar

calculations using performance values, prices of products and cost of input obtained in each generation (Table 2). Data on the performance traits ($BWTE$, $BWTE_{16}$, EWT_{16} , and EN_{16}) were subjected to analysis of variance (ANOVA) to compare between generations.

Results and Discussion

Table 1 shows the proximate composition of the experimental diets while Table 2 shows the production parameters and the economic variables for the calculation of economic and relative economic weights of the traits. There were increases in the performance traits across generations. Body weight at first egg ($BWTFE$) decreased slightly in G_1 generation but increased significantly ($P < 0.05$) in G_2 generation. Body weight at end of 16 weeks of lay ($BWTE_{16}$) also followed the same trend. Egg weight (EWT_{16}) and egg production (EN_{16}) increased progressively across generations. The values obtained for these traits agree considerably with values reported for indigenous chickens of Nigeria by Ndofor-Foleng *et al.* (2006). In a simulation study of the biological, management and nutritional variables of indigenous chicken production systems in Kenya, (Menge *et al.*, 2005) found egg weight to be 44g for confined full ration system which is higher than the value of $41.27 \pm 0.06g$ and $42.92 \pm 0.06g$ in G_0 and G_1 generations, respectively but very close to the value obtained in G_2 generation ($43.33 \pm 0.07g$). However the value reported by Menge *et al.* (2005) were mean egg weight over the first laying cycle whereas the values reported in the present study were short term mean egg weights. Egg weight increases with age of lay and is expected to be higher for full cycle

Table 1: Composition of experimental diet (layers mash)

Ingredient	Composition (%)
Maize	43.0
Wheat offal	18.0
Soya bean cake	17.5
Palm kernel cake	9.0
Fish meal	2.5
Bone meal	3.0
Lysine	0.25
Methionine	0.25
Vitamin premix	0.25
Salt	0.25
Oyster shell	6.0
Total	100
Calculated:	
Crude protein (%)	-16.5
Energy (Kcal ME/kg)	- 2600

production than for short term production. The same investigators reported a laying percentage of 75 which agrees with our value of 75.6% in G_0 generation but inferior to the values for G_1 and G_2 generations (77.79 ± 0.14 and $79.38 \pm 0.19\%$, respectively). This is related to the effect of selection for improved egg production (egg weight and laying performance) in the present study. In the same study the authors reported simulated values for live weight of pullets at 21 weeks of age and mature (> 40 week) weight of hens as 1.38 and 1.63kg, respectively both of which are in high accord with the body weight range of 1304.84 – 1428.48g (mean, 1354.57g, ~ 1.36 kg) obtained for BWTFE (20 – 24 weeks) and 1449.02 – 1588.90g (mean, 1504.12g, ~ 1.50 kg) obtained for BWTE₁₆ (36 – 40 weeks) across generations. The variation in the values observed for the traits across generations in the present study is due to genetic improvement in the traits following selection. Besides, variation in

generational mean values of productive traits in selected and unselected populations are expected due to sampling variation and fluctuating environmental effects (Fairfull and Gowe, 1990). Also, linear increases in generational mean values of productive traits following selection have been reported by other workers (Nwagu *et al.*, 2007).

Table 2 also shows that performances in the other traits studied as well as the market variables (cost of input, prices of products, and revenue from unit increases of products) changed over time. For instance, following increases in BWTE₁₆ to 1588.9g in G_2 generation was a concomitant increase in daily feed requirement per bird from 100g in G_0 and G_1 generations to 125g in G_2 generation. The increased feed requirement coupled with rising market cost of feed (< 0.034 , < 0.048 and < 0.068 /g for G_0 , G_1 and G_2 generations, respectively) led to increases in cost of feed per gramme gain from < 2.64 in G_0 generation to < 5.94 in G_2 generation. The gain in body weight from G_1 to G_2 generation (0.14 g) was however poor compared to the rise in daily feed intake (25g/day) such that feed conversion ratio (FCR) was inferior in G_2 compared to previous generations (87.27 vs 77.68). Meanwhile revenue from a gramme of chicken remained relatively the same across generations (0.27, 0.30 and 0.28 for G_0 , G_1 and G_2 generations, respectively). On the other hand, revenue from eggs more than doubled from < 6.67 /egg in G_0 generation to < 15.00 /egg in G_2 generation reflecting the sensitivity of price of eggs to changes in price of feed and other inputs. The near stable price of 1g of chicken over generations indicate lack of sensitivity in price of local chicken carcass to increases in price of feed and this is probably responsible for the poor contribution of

Table 2: Bio-economic variables for the determination of economic and relative economic weights of growth and egg production traits in NIC

Bio-economic variable	Generation		
	G ₀	G ₁	G ₂
Trait: BWTE ₁₆			
Mean BWTFE	1330.44	1304.84	1428.48
Mean BWTE ₁₆ (g)	1474.44	1449.02	1588.90
BWG ₁₆ (g)	1.29	1.29	1.43
Daily FI ₁₆ (g)	100	100	125
FCR ₁₆	77.52	77.52	87.41
Cost of 1g layers mash (<)	0.034	0.048	0.068
Cost of feed for 1g gain (<)	2.64	3.72	5.94
Revenue from 1g live weight (<)	0.27	0.30	0.28
Trait: EN ₁₆			
Average rate of lay to 16 wks (%)	75.60	77.79	79.38
Eggs per bird at average rate of lay for 16 wk	84.67	87.12	88.91
Number of eggs from 1% increase in lay	85.79	88.24	90.03
Gain in eggs due to 1% increase in lay	1.12	1.12	1.12
Unit price of eggs (<)	6.67	11.67	15.00
Trait: EWT ₁₆			
Egg per bird at average rate of lay for 16 wks	84.67	87.12	88.91
Gramme egg from 1g increase in egg weight (g)	84.67	87.12	88.91
Mean egg weight for population (g)	41.27	42.92	43.33
Additional eggs from 1g increase in egg weight	2.05	2.03	2.05
Unit price of eggs (<)	6.67	11.67	15.00

growth after BWTFE to the income of intensive local chicken egg production in the present study. There seems to be a threshold body weight beyond which further increases in body weight of laying chickens constitute economic drain on the enterprise. On the contrary, egg production (laying performance) made up of egg number (EN) and egg weight (EWT) is the major performance index of a layer enterprise accounting for over 90 % of the profit from commercial egg production.

Thus increase in laying performance implies higher revenue and hence more profit for the enterprise at the same maintenance cost (that is, no increase in feed input).

The economic weights calculated for the different traits varied widely over generations (Table 3) and this is related to the varying production and economic indices (Shadparvar *et al.*, 2005; Ibi *et al.*, 2006). Economic weights of BWTE₁₆ were -

Table 3: Economic weight (EW) of growth and egg production traits of NIC

Generation	Trait		
	BWTE ₁₆	EWT ₁₆	EN ₁₆
G ₀	-2.37	13.67	7.47
G ₁	-3.42	23.69	13.07
G ₂	-5.82	30.75	16.80

BWTE₁₆, EWT₁₆, and EN₁₆: Body weight, egg weight, and egg number to 16 weeks of lay, respectively.

2.37, -3.42 and -5.82 for G_0 , G_1 and G_2 generations, respectively. The corresponding values for EN_{16} were 7.47, 13.07 and 16.80, and for EWT_{16} 13.67, 23.69 and 30.75, respectively. Economic weight of $BWTE_{16}$ was the least and negative across generations reflecting the lowest contribution of $BWTE_{16}$ to profit and negative relationship between cost of input (feed) to attain increased body weight and the gain in terms of revenue from such increases in body weight during the short term laying phase. The observed variation in economic weights of traits across generation is in line with reports of similar studies (Harris and Newman, 1992; Shadparvar *et al.*, 2005; Ibi *et al.*, 2006). Economic weights are, therefore, not permanent (or fixed) for any production system (Groen *et al.*, 1997; Shadparvar *et al.*, 2005) but are usually reviewed whenever production, market demands and premiums make large and presumably permanent changes (Groen *et al.*, 1997; Shadparvar *et al.*, 2005).

The economic weights of the different traits showed marked sensitivity to changes in production parameters across generations (Fig. 1). Whereas EN_{16} and EWT_{16} increased with increases in the production parameters, $BWTE_{16}$ decreased with increases in $BWTE_{16}$ across generations. Wood and Buddiger (2007) reported exponential increases in economic value of egg production with increasing egg number in breeder turkeys and this represented the increasing cost of eggs and subsequently live poults (Wood and Buddiger, 2007).

The relative economic values of the traits are presented in Table 4. The relative economic weights were 3.15, 3.82 and 2.89 for EN_{16} for G_0 , G_1 and G_2 generations, respectively. For EWT_{16} , the corresponding values were 5.77, 6.93 and 5.28 while for

Fig. 1: Evolution of economic weight of EN_{16} , EWT_{16} , and $BWTE_{16}$ over G_0 , G_1 , and G_2 generations.

$BWTE_{16}$ the relative economic weight was -1.00 across the three generations. These values reflect the relative economic

Table 4: Relative economic weight (REW) of growth and egg production traits of NIC

Generation	Trait		
	BWTE ₁₆	EWT ₁₆	EN ₁₆
G ₀	-1.00	5.77	3.15
G ₁	-1.00	6.93	3.82
G ₂	-1.00	5.28	2.89

BWTE₁₆, EWT₁₆, EN₁₆: Body weight, egg weight and egg number to 16 weeks of lay, respectively.

importance of the three traits, that is, their relative contribution to the overall economic (Naira) worth of the local chicken layer. As stated earlier, egg production (egg number and egg weight) is the major index of performance of egg chickens accounting for over 90% of the revenue or income accruable from an egg production enterprise (Oluyemi and Roberts, 2000). The same could apply to the local hen reared for production. Revenue from local chicken eggs could come from the sale of table eggs, fertile eggs or hatched chicks. Egg weight influences market price of table and fertile eggs as well as hatched chicks since the size of the egg influences the size of the chick as well as post hatch growth performance (Hartmann *et al.*, 2003; Ogbu *et al.*, 2012). Thus eggs of market sizes (small, medium and large) will command better prices than pee wees. Consequently, both the number of eggs laid and the size of each egg are important economic variables for egg chicken production and both traits are usually included in selection indices for genetic improvement of egg production in laying stocks (Nwagu *et al.*, 2007). On the contrary, revenue from chicken carcass come from culls at the end of the laying phase (spent layers) or sale of non producing hens which make little or no significant contribution to profitability. Menge *et al.* (2005) using a bio-economic model identified two principal revenue

components for the indigenous layer chicken as sale of eggs and culls. In the study, simulated revenue from cull hens (chicken carcass) was 104.52 Kenya shillings (KSh) while that from eggs was 450 KSh (1US\$ = KSh. 75.00) reflecting the greater contribution of egg production to the aggregate economic value of the local layer hen. In the present study, egg number and egg weight had heavier economic weights (mean per generation: 5.99 and 3.86, respectively) than BWTE₁₆. This result shows that besides the correlated effect of body weight on egg weight, it does not contribute directly and significantly to the performance index of a layer bird. BWTE₁₆ had negative economic value because of the negative relationship between revenue from a unit gain in body weight and the cost of feed consumed to attain the unit gain after attainment of sexual maturity (age at first egg). The heavier weighting of egg weight over egg number (5.77 vs 3.15 in G₀, 6.93 vs 3.82 in G₁ and 5.28 vs 2.89 in G₂) reflect the need to genetically improve the egg weight (egg size) of local chicken eggs (along with increases in laying rate) which has been reported to be predominantly of small sizes (pee wees) (Adedokun and Sonaiya, 2001; Peters *et al.*, 2002). The higher economic and relative economic weights of egg weight compared to egg number could also minimize the effect of negative genetic

relationship between rate of egg production and egg weight when both traits are selected simultaneously in a genetic improvement programme. In an estimate of relative economic weights of production traits in a commercial strain of White Leghorn, Reetu *et al.* (2009) reported values of -1.0 for 18 week body weight, age at sexual maturity and 32 week body weight, respectively; 2.0 for 40 week egg production and 11.0 for 35 week egg weight. Relative economic values for productive traits in the indigenous chickens of Nigeria are absent in literature but the values reported here are similar in direction to values reported by Nordskog, (1981) for egg type chickens. Relative economic values per genetic standard deviation calculated from data reported by Bennett *et al.* (1981) for egg type chickens were 4.20, 2.10 and 1.00 for egg number, egg weight and body weight, respectively reflecting the degree to which each trait influenced the economic breeding value of the particular breed of chicken as well as the influence of different production and marketing systems and situations on economic weights of the same traits (Smith *et al.*, 1986; Hazel *et al.*, 1994).

Conclusion

Unit increases in EN and EWT over the short term laying period contributed positively to the net value of the native layer chicken while unit increases in BWT depressed the net worth of the hen as a layer. Selection indices to improve aggregate value of the layer bird should aim to increase the rate of egg production (EN) and egg weight and maintain body weight during egg production within narrow limits by weighting performances in these traits with appropriate relative economic values.

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