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Full Length Research Paper

Desired-gain selection indices for improving performance of two Tanzania local chicken ecotypes under intensive management

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A study was carried out to evaluate various desired-gain selection indices (Yamada index) in improving performance of two chicken ecotypes of Tanzania viz. Kuchi and Tanzania Medium (Medium). The indices for Kuchi ecotype were geared at improving body weight at 16 (Bwt16) weeks of age while those for Medium ecotype were geared at improving egg production and related traits. These traits included age at first egg (AFE), egg production in the first 90 days after sexual maturity (EN-90) and egg weight (EW). Apart from production traits, antibody responses (Ab) against Newcastle disease virus vaccine was also included in some selection indices in both ecotypes. Furthermore, correlated responses to some egg quality traits namely egg shape index (ESI) and eggshell thickness (STH) were also studied. Results indicated that it would take between 5 to 6 generations of selection in Kuchi to improve Bwt16 either singly or together with Ab from their current levels of 1394 g and 5 (HIlog$_2$) to the desired averages of 1800 g and 6 (HIlog$_2$), respectively. On the other hand results indicated that it would take between 8 to 11 generations of selection in Medium ecotype to improve either AFE and EN-90 or together with EW or Ab or both of them from their current averages of 168 days, 49 eggs, 42 g and 5 (HIlog$_2$) to the desired averages of 154 days, 68 eggs, 50 g, and 6 (HIlog$_2$), respectively. Based on the number of generations required to achieve desired gains and correlated responses, some selection indices were recommended.

Key words: Breeding, desired gain, local chicken, selection indices.

INTRODUCTION

Low genetic potential for production traits and frequent outbreak of diseases specifically Newcastle disease has been noted in a significant number of studies to be among the major factors limiting productivity of the local chickens in the Tropics (Katule, 1991; Alexander, 2001; Pedersen, 2002). Their performance can partly be improved substantially by crossbreeding with improved/ specialized egg type or meat type chickens as it has been shown in previous studies (Ali et al., 2000; Pedersen, 2002; Theerachai et al., 2003; Segura-Correa et al., 2004). However, these crossbreeding programs are threatened by current global move on conservation of indigenous genetic resources (Msoffe, 2003; Kosgey, 2004). Therefore, there is a need for looking for alternative approaches for genetic improvement. Genetic improvement through selection within local chickens could be a good option. A recent study by Lwelamira (2007) in two Tanzania local chicken ecotypes viz. Kuchi and Tanzania Medium (Medium) have shown existence of significant additive genetic variation in various traits in these ecotypes and hence expecting adequate response to selection. Based on their performances, the study further revealed Kuchi ecotype to be a good starting material for improving meat production and Medium ecotype for egg production. Since relative economic weights for various traits in these ecotypes are lacking as it has been in most other local/unimproved chicken strains/groups (Menge et al., 2005), this study was therefore carried out to evaluate various desired-gain selection indices for improving Kuchi ecotype for meat

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Table 1. Desired-gain selection indices for Kuchi and Medium ecotypes

Ecotype	Index	Ab	Bwt16	AFE	EN-90	EW
Kuchi	I_{1k}	+	+	-	0	-
	I_{2k}	-	+	-	0	-
	I_{3k}	+	+	-	-	-
Medium	I_{1m}	+	0	+	+	+
	I_{2m}	-	0	+	+	+
	I_{3m}	-	-	+	+	+
	I_{4m}	+	-	+	+	+
	I_{5m}	+	0	+	+	0
	I_{6m}	-	0	+	+	0
	I_{7m}	-	-	+	+	0
	I_{8m}	+	-	+	+	0

Ab= Antibody response against Newcastle disease virus (NDV) vaccine (primary humoral immune response at 4 weeks of age assessed two weeks post vaccination); Bwt16 = Body weight at 16 weeks of age; EN-90 = Egg number in the first 90 days; EW = Egg weight between 33 to 36 weeks of age, AFE= age at first egg; + = A trait is improved, 0 = A trait is held constant, - = A trait is dropped from the index.

production and Medium ecotype for egg production.

MATERIALS AND METHODS

Various desired gain selection indices specific for each ecotype were constructed and compared. Previous study by Lwelamira (2007) showed that Kuchi ecotype had good prospects for further improvement in terms of meat production, and Medium ecotype for egg production. Therefore, selection indices were constructed with the intention of improving meat production for Kuchi and egg production for Medium ecotype (Table 1).

Selection indices were constructed according to Yamada et al. (1975) (that is desired-gain indices) as applied in subsequent studies (Gill and Verma, 1983; Hazary et al., 1998; Nishida et al., 2001; Noda et al., 2002; Kaushik and Khanna, 2003). The indices were evaluated in terms of number of generations required to achieve the pre-defined/ desired gains and correlated responses.

Use of index I in selection usually involves calculation of weighting factors **b** for traits to be used as selection criteria (equation 1).

$$\mathbf{I} = \mathbf{b'} \mathbf{X} \qquad (1)$$

Where: I= Selection index; b = n × 1 vector of weighting factors; **X** = $n \times 1$ vector of source of information, usually phenotypic measurements on the candidate for selection or its relatives.

In the present study, information source (**X**) was individual own performance for antibody response and body weight, and fullsib averages for egg production and related traits.

Based on the Yamada index, **b** in the present study was calculated as:

$$\mathbf{b} = (\mathbf{G'}\mathbf{R})^{-1}\mathbf{Q} \qquad (2)$$

Where:

G = $n \times m$ genetic variance-covariance matrix of the traits used as selection criteria and traits in the breeding objectives;

Q = $m \times 1$ vector of intended genetic changes for m traits assigned by breeder;

R = $n \times n$ matrix of Wright's coefficients of relationship.

Genetic variance-covariances were derived from genetic parameters estimated for these ecotypes in a study by Lwelamira (2007). These are presented in Table 2.

Desired genetic changes for various traits (that is **Q**) were calculated as the difference between desired and observed means. Intended performances /improvement and hence desired gains/ genetic changes for traits highlighted for improvement in different selection indices in Tables 1 are presented in Table 3.

These intended performances were chosen in such a way that they are within the capacity of the population as shown by performance of some individuals in an environment under consideration. Furthermore, the chosen intended performances were close to the performance of the crosses between local and exotic birds (Ali et al., 2000; Theerachai et al., 2003). In addition, the chosen intended performance for body weight also depended on weight at which a chicken can be marketed (that is at least 1 kg) (Pedersen, 2002; Theerachai et al., 2003; Acamovic et al., 2005). Based on the capacity of Kuchi population, body weight at 16 weeks of age (Bwt16) was chosen as the target body weight in various selection indices as it is possible to target much higher weights in a breeding objective (that is above 1.5 kg under intensive conditions, and hence chickens would be fetching good prices) compared to body weights at 8 and 12 weeks of age, and at earlier age than at 20 weeks of age (Lwelamira, 2007).

Furthermore, based on Yamada index, expected genetic gains per generation in all k traits under study (that is direct and correlated responses) including m traits in the breeding objectives was calculated using equation 3.

$$\Delta G^{*'} = \frac{i_I}{\sigma_I} . b' RG^{*} \qquad (3)$$

Table 2. Genetic variance-covariances for Kuchi and Medium ecotypes.

Ecotype		Ab	Bwt16	AFE	EN-90	EW
Kuchi	Ab	0.304	-4.000	-	-0.100	-
	Bwt16	-4.000	5268.000	-	-58.680	-
	EN-90	-0.100	-58.680	-	20.170	-
Medium	Ab	0.307	-3.84	-0.23	-0.11	-0.07
	Bwt16	-3.84	3963.2	-137.85	-51.36	35.75
	AFE	-0.23	-137.85	108.73	-7.98	5.66
	EN-90	-0.11	-51.36	-7.98	26	-1.76
	EW	-0.07	35.73	5.66	-1.76	6.09

Ab = Antibody response against Newcastle disease virus (NDV) vaccine (primary humoral immune response at 4weeks of age assessed two weeks post vaccination) (HIlog$_2$); Bwt16 = body weight (g) at 16 weeks of age; EN-90 = egg number in the first 90 days; EW = egg weight (g) between 33 to 36 weeks of age; AFE = age at first egg (days).

Table 3. Observed and desired mean and desired gain for Kuchi and Medium ecotypes under intensive management system.

Ecotype	Trait	Unit	Observed mean	Desired mean	Desired change	Percentage change (%)
Kuchi	Ab	HI (log$_2$)	5.0	6	1	20
	Bwt16	gram	1394	1800	406	29
Medium	Ab	HI (log$_2$)	5.1	6	0.9	18
	EN-90	No.	49	68	19	39
	EW	Gram	42	50	8	19
	AFE	Days	168	154	-14	8

Ab = Antibody response against Newcastle disease virus (NDV) vaccine (primary humoral immune response at 4weeks of age assessed two weeks post vaccination); Bwt16 = body weight at 16 weeks of age, EN-90 = egg number in the first 90 days, EW = egg weight between 33 to 36 weeks of age, AFE = age at first egg.

Where:

i_I = intensity of selection based on the index;
σ_I = standard deviation of the index calculated as shown in equation 4;
Δ**G*** = k x 1 vector of genetic gains per generation in k traits;
G* = n x k genetic variance-covariance matrix.

$$\sigma_I = \sqrt{(\mathbf{b'Pb})} \quad 4$$

Where **P** is an n x n phenotypic variance-covariance matrix.

Again as with genetic variance-covariances, **P** and **G*** were also derived from a study by Lwelamira (2007). Phenotypic variance-covariances are presented in Table 4. Genetic variance-covariances including all traits recorded (that is traits included in the indices and those not included but their correlated responses were examined) for the purpose of determining **G*** are presented in Table 5.

The number of generations q required to attain the pre-defined breeding objectives was calculated using equation 5 (Yamada et al., 1975; Nishida et al., 2001). All matrix equations were solved using Interactive Matrix Language (IML) procedures of SAS (2000).

$$q = \frac{\sigma_I}{i_I} = \frac{\sqrt{(\mathbf{b'Pb})}}{i_I} \quad 5$$

Population structure and derivation of selection intensities

In this study it was assumed that in each generation 40 best males are randomly mated to 240 best females with a mating ratio of one male to six females. Due to fertility and hatchability problems, the average number of progeny per dam obtained in the study by Lwelamira (2007) under intensive management was 4 and 5 for Kuchi and Medium ecotypes, respectively. However, the average number of progeny per dam could be increased by increasing the number of hatches, by improving hatchability (that is hatchability of fertile eggs for the parent stock was 63% for Kuchi and 66% for Medium ecotypes) and by improving egg storage conditions before hatching (Abdou et al., 1990; Ruiz and Lunam, 2002). Since the parent stock in the study by Lwelamira (2007) was collected from field and consisted of mature birds, in which some of them were likely to be too old for good laying performance, the average laying rate for the parent stock was low (around 35%) compared to that of

Table 4. Phenotypic variance-covariances for Kuchi and Medium ecotypes.

Ecotype		Ab	Bwt16	AFE	EN-90	EW
Kuchi	Ab	1.126	-4.64	-	-0.17	-
	Bwt16	-4.64	11972.74	-	-112.94	-
	EN-90	-0.17	-112.94	-	63.04	-
Medium	Ab	1.06	-7.996	-0.45	-0.38	-0.215
	Bwt16	-7.996	9436.18	-182.6	-90.44	67.8
	AFE	-0.45	-182.6	209.09	-18.85	7.57
	EN-90	-0.38	-90.44	-18.85	86.68	-3.57
	EW	-0.215	67.8	7.57	-3.57	12.18

Ab = Antibody response against Newcastle disease virus (NDV) vaccine (primary humoral immune response at 4weeks of age assessed two weeks post vaccination) ($HIlog_2$); Bwt16 = Body weight (g) at 16 weeks of age; EN-90 = egg number in the first 90 days; EW = egg weight (g) between 33 to 36 weeks of age; AFE = age at first egg (days).

around 50% for their offspring, in which all of them were young (that is in their early period of laying). Hence, by involving young mature breeding females in the breeding program, as would be the case in the current simulation work, it would more likely result into increased number of progeny per dam. Moreover, since hatchability under artificial incubation is known to be negatively affected by the age of the dam (Tona et al., 2001), therefore by involving relatively young mature hens as breeding females, would result into increased hatchability and hence the number of offspring per dam. Consequently, in the current study it was assumed that on average each female produces 10 progeny, with 5 chicks of each sex (that is in total there would be 2400 chicks). Taking into account mortality/loss of about 10% by the time birds are selected and mated, then the total number of birds available for selection would be 2400 - (2400 x 0.10) = 2160 (that is 1080 birds for each sex). Therefore, by selecting around 40 best males and 240 best females in each generation would lead to the proportion selected of about 3.7 and 22.2% for males and females, respectively giving an average selection intensity of 1.78. This average selection intensity is within the range of that of around 1.5 to 2 mostly used in commercial chicken breeding (Ameli et al., 1991; Su et al., 1997).

RESULTS

Desired-gain selection indices/ breeding scenarios for Kuchi ecotype

Responses per generation in various traits resulting from various desired-gain selection indices for Kuchi ecotype under intensive management are shown in Table 6. Selection index coefficients are presented in Table 7. Results show that predicted direct response to selection in 16 weeks body weight under intensive management ranged from 70 to 81 g per generation. Results from Table 6 also reveal that all selection indices considered for Kuchi predicted to result into favourable correlated responses to other body weight measurements (24 - 81 g per generation), egg weight (0.5 to approximately 1 g per generation), and age at sexual maturity (- 2 to -3 days per generation) with little change in eggshell thickness and egg shape index. Dropping antibody response (humoral immune response) from the index (I_{2k}) resulted into a slight deterioration of this trait. On the other hand, in situation where egg number was dropped from the index (that is control of change in egg number not considered) (I_{3k}), this was predicted to result into substantial drop in egg number per generation (that is approximately one egg per generation).

Results from present study further show that the number of generations required achieving the desired gains ranged from 5 to 6 generations (Table 6). Assuming that the activities of mating, collection of eggs, incubation and hatching; rearing of birds from day old to sexual maturity; and recording of egg production for a period of 3 months after sexual maturity for birds from all hatches/batches lasting for about 2, 6, and 5 (that is 2 + 3) months, respectively, as it has been shown in a study by Lwelamira (2007), this would lead to a generation interval of 13 months (that is 2 + 6 + 5) for selection index I_{1k} and I_{2k} (where apart from improving body weight, egg number is also held constant), and 8 months (that is 2 + 6) for selection index I_{3k} (where control of correlated response in egg number is ignored). Hence, to attain the desired gain in body weight it would require 6.3, 5.4 and 3.6 years of selection for index I_{1k}, I_{2k} and I_{3k}, respectively.

Desired-gain selection indices/breeding scenarios for Medium ecotype

Results from Table 8 show that the number of generations required for achieving the desired gains in various selection indices for Medium ecotype in which their coefficients are presented in Table 9 ranged from 8 to 11 generations, which are higher than those obtained in various selection indices for achieving the desired gains in Kuchi under intensive management. Again by assuming a generation interval of 13 months as in some breeding scenarios/selection indices for Kuchi under

Table 5. Genetic variance-covariances including all traits for determination of G* for Kuchi and Medium ecotypes.

Ecotype		Ab	Bwt8	Bwt12	Bwt16	Bwt20	AFE	EN-90	EW	STH	ESI
	Ab	0.304	-2.086	-3.2	-4	-3.04	-0.10	-0.10	-0.015	-0.05	0.17
Kuchi	Bwt16	-4	1797.55	3654.74	5268	5315.49	-143.84	-58.68	43.35	-9.85	17.38
	EN-90	-0.10	-9.27	-37.7	-58.68	-81.35	-7.7	20.17	-2.32	-1.32	0.134
	Ab	0.307	-1.76	-3.2	-3.84	-3.04	-0.23	-0.11	-0.07	0.017	0.18
	Bwt16	-3.84	1508.21	3202.66	3963.2	4238.96	-137.85	-51.36	35.73	-7.63	-5.1
Medium	AFE	-0.23	-9.03	-72.34	-137.85	-195.94	108.73	-7.98	5.66	0.63	2.54
	EN-90	-0.11	-16.19	-38.32	-51.36	-83.84	-7.98	26	-1.76	-0.46	2.07
	EW	-0.07	9.26	35.67	35.73	57.97	5.66	-1.76	6.09	-0.15	0.60

Ab = Antibody response against Newcastle disease virus (NDV) vaccine (primary humoral immune response at 4weeks of age assessed two weeks post vaccination) ($HIlog_2$); Bwt8, Bwt12, Bwt16 and Bwt20 = body weight (g) at 8, 12, 16 and 20 weeks of age, respectively; AFE = age at first egg (days); EN-90 = egg number in the first 90 days after sexual maturity, EW, STH and ESI = egg weight (g), shell thickness (µ) and egg shape index (%), respectively, between 33 to 36 weeks of age.

Table 6. Direct and correlated responses per generation resulting from various desired gain selection indices for Kuchi ecotype.

Index	Ab	Bwt8	Bwt12	Bwt16	Bwt20	AFE	EN-90	EW	STH	ESI	Gen
I_{1k}	(0.17)	23.80	48.31	(69.92)	70.31	-2.50	(0.00)	0.50	-0.24	0.39	5.80
I_{2k}	-0.07	28.18	56.42	(81.12)	80.83	-2.65	(0.00)	0.58	-0.22	0.28	5.00
I_{3k}	(0.18)	24.96	51.58	(74.83)	76.31	-2.21	-0.95	0.63	-0.19	0.39	5.43

Gen = number of generations required to achieve the desired gains; Ab = Antibody response against Newcastle disease virus (NDV) vaccine (primary humoral immune response at 4weeks of age assessed two weeks post vaccination) ($HIlog_2$); Bwt8, Bwt12, Bwt16 and Bwt20 = body weight (g) at 8, 12, 16 and 20 weeks of age, respectively; AFE = age at first egg (days); EN-90 = egg number in the first 90 days after sexual maturity, EW, STH and ESI = egg weight (g), shell thickness (µ) and egg shape index (%), respectively, between 33 to 36 weeks of age. Figures in parentheses are direct response to selection (that is traits included in the index), while those out of parentheses are correlated responses (that is traits not included in the index).

Table 7. Selection index coefficients for Kuchi ecotype.

Index	Ab	Bwt16	EN-90
I_{1k}	4.473	0.083	0.529
I_{2k}	-	0.080	0.463
I_{3k}	4.347	0.080	-

Ab = Antibody response against Newcastle disease virus (NDV) vaccine (primary humoral immune response at 4 weeks of age assessed two weeks post vaccination) ($HIlog_2$); Bwt16 = body weight (g) at 16 weeks of age; EN-90 = egg number in the first 90 days.

intensive management (that is 2 months for mating, egg collection, incubation and hatching; 6 months for rearing birds to sexual maturity, 5 months for egg recording for chicks from all hatches), the required number of generations to achieve the desired gains in selection index I_{1m}, I_{2m}, I_{3m}, I_{4m}, I_{5m}, I_{6m}, I_{7m}, and I_{8m} would correspond to 11.5, 11.2, 11.2, 11.5, 8.8, 8.4, 8.4 and 8.7 years of selection, respectively.

It can also be seen in Table 8 that gain per generation in various desired-gain selection indices for egg number and age at first egg was around 2 eggs, and -1 to -2 days, respectively, with little change in shell thickness and egg shape index. In situations where egg weight was also improved (Selection index I_{1m}, I_{2m}, I_{3m}, and I_{4m}), gain per generation for this trait ranged from 0.76 to 0.78 g.

Results from Table 8 further show that in selection indices where either body weight (which is antagonistic to egg number), or humoral immune responses are dropped from the index, it was predicted to result into slight parameters to range from 12 to 15 g per generation. In

Table 8. Direct and correlated responses per generation resulting from various desired- gain selection indices for Medium ecotype.

Index	Ab	Bwt8	Bwt12	Bwt16	Bwt20	AFE	EN-90	EW	STH	ESI	Gen
I_{1m}	(0.09)	-1.26	0.74	(0.00)	2.26	(-1.32)	(1.79)	(0.76)	-0.06	0.28	10.60
I_{2m}	-0.01	-1.25	0.72	(0.00)	2.08	(-1.35)	(1.84)	(0.77)	-0.06	0.22	10.36
I_{3m}	-0.02	0.41	4.00	4.00	6.04	(-1.36)	(1.84)	(0.78)	-0.07	0.22	10.31
I_{4m}	(0.09)	-0.19	2.85	2.58	4.81	(-1.32)	(1.80)	(0.76)	-0.06	0.28	10.58
I_{5m}	(0.11)	-0.33	0.15	(0.00)	-1.17	(-1.72)	(2.34)	(0.00)	-0.05	0.26	8.13
I_{6m}	-0.012	-0.29	0.11	(0.00)	-1.52	(-1.80)	(2.44)	(0.00)	-0.06	0.19	7.79
I_{7m}	-0.01	-1.05	-1.37	-1.82	-3.32	(-1.81)	(2.45)	(0.00)	-0.06	0.19	7.75
I_{8m}	(0.11)	-1.72	-2.58	-3.35	-4.50	(-1.74)	(2.37)	(0.00)	-0.05	0.26	8.04

Gen = number of generations required to achieve the desired gains; Ab = Antibody response against Newcastle disease virus (NDV) vaccine (primary humoral immune response at 4weeks of age assessed two weeks post vaccination) ($HIlog_2$); Bwt8, Bwt12, Bwt16 and Bwt20 = body weight (g) at 8, 12, 16 and 20 weeks of age, respectively; AFE = age at first egg (days); EN-90 = egg number in the first 90 days after sexual maturity, EW, STH and ESI = egg weight (g), shell thickness (µ) and egg shape index (%), respectively, between 33 to 36 weeks of age. Figures in parentheses are direct response to selection (that is traits included in the index), while those out of parentheses are correlated responses (that is traits not included in the index).

Table 9. Selection index coefficients for Medium ecotype.

Index	Ab	Bwt16	AFE	EN-90	EW
I_{1m}	3.397	-0.008	-0.333	1.597	3.573
I_{2m}	-	-0.012	-0.360	1.543	3.552
I_{3m}	-	-	-0.320	1.593	3.382
I_{4m}	3.505	-	-0.303	1.633	3.461
I_{5m}	3.315	0.008	-0.140	1.516	0.549
I_{6m}	-	0.004	-0.167	1.463	0.529
I_{7m}	-	-	-0.182	1.445	0.587
I_{8m}	3.209	-	-0.170	1.481	0.659

Ab = Antibody response against Newcastle disease virus (NDV) vaccine (primary humoral immune response at 4 weeks of age assessed two weeks post vaccination) ($HIlog_2$); Bwt16 = Body weight (g) at 16 weeks of age; EN-90 = Egg number in the first 90 days; EW = Egg weight (g) between 33 to 36 weeks of age; AFE = age at first egg (days).

changes in these traits and in number of generations required to achieve the desired gains (that is efficiency).

DISCUSSION

Desired-gain selection indices/ breeding scenarios for Kuchi ecotype

Predicted direct response to selection in 16 weeks body weight ranged from 70 to 81 g per generation. Compared to gain per generation achieved in previous studies for selection for body weights it is difficult to make direct comparison due to differences in either selection procedures employed, selection intensities used, or age at which the body weight was intended to be improved. In a study by Su et al. (1997) in broilers, gain per generation for body weight at 6 weeks of age under intensive management of about 45 g based on mass selection was reported. On the other hand Bhusan et al. (1998) reported predicted gain per generation in broilers resulting from selection based on indices incorporating body weight at 6 and 8 weeks of age and feed utilization contrast, using similar traits, response of up to 56 g per generation were reported in broilers by Singh et al. (2000).

Considering the mean body weight at 12 weeks of age for Kuchi averaged over both sexes of 954 g under intensive management obtained in the study by Lwelamira (2007), and correlated responses for 12 weeks of age of around 280 g after the entire period of selection (that is gain per generation x number of generations required to achieve the desired gain) in all selection indices considered, the expected average body weight at 12 weeks of age after completion of the selection process is estimated to be 1234 g. Furthermore, considering local chickens in the tropics are starting to be marketed when their average body weight is around 1 kg and above (Pedersen, 2002; Theerachai et al., 2003; Acamovic et al., 2005), therefore after selection, Kuchi can start to be marketed at 12 weeks of age under intensive management, and at 16 weeks of age they would be having a weight of more than 1500 g (that is 1800 g) (Table 3) and hence fetching higher prices. In addition, after the entire period of selection, on average, the resultant stock would be able to attain age at sexual maturity 12 to 15 days earlier and lays eggs weighs 3 to 4 g more (that is gain per generation x number of generations required to achieve the desired gain) compared to the average performance of the current population.

Results from this study indicate selection index I_{3k} takes few years (3.6 years) compared to other breeding scenarios considered for Kuchi ecotype. Although few years are required to attain the desired gain in body weight for this selection index, and it is cheap in terms of recording as egg production has been ignored, however, this selection index is predicted to result into noticeable drop in egg number (approximately 1 egg per generation), a trend which is undesirable. Therefore, given the situation where resources are available, it could be better to use those selection indices which control response in egg number (that is selection index I_{1k} and I_{2k}). An additional advantage of using selection index I_{1k} is that apart from improving body weight, humoral immune response against NDV vaccine is also improved. This breeding strategy could be recommended at the expense of one more year of selection relative to selection index I_{2k}. Although the majority of farmers in the tropics rear their chickens under extensive management (Tadelle et al., 2003; Njenga, 2005), the stock obtained from improving this ecotype under intensive management can benefit those farmers who would be able to shift from current system of management to at least semi-intensive system of management.

Desired-gain selection indices/breeding scenarios for *Medium* ecotype

Variable direct response per generation between some selection indices with respect to some egg traits has been obtained in this study. As with body weight, it is difficult to make direct comparisons of responses per generation obtained in the present study with those from other studies due to differences in either selection methods or selection intensities used. However, the response obtained in the present study would definitely be lower than selection based on single trait as selection for antagonistic traits (that is egg weight and egg number) are always expected to lower the magnitude of genetic response (Pattanayak and Patro, 1995; Pakdel, 2004). For example, values ranging from 1.2 to 2.2 g per generation in egg weight, which are much higher than the response predicted in the present study, were reported for single trait selection for egg weight in Scandinavian egg type chickens (Kolstad, 1980; Liljedahl and Weyde, 1980; Sørensen et al., 1980).

The observed slight decline in body weight and humoral immune response in this study when these traits were dropped from the index could be attributed to the favourable relationship existing between age at first egg and egg weight with body weight, which were also included in the indices, and the low genetic correlation between humoral immune response and production traits revealed in a previous study by Lwelamira (2007).

The purpose of various selection indices/breeding programs in the current study as far as the Medium ecotype is concerned was mainly to improve egg production and related traits together with antibody response (humoral immune response) against NDV vaccine. It could also be desirable to improve these traits without affecting other important traits negatively that is decrease in body weight. Given that dropping of body weight into indices that involve all three egg traits (that is AFE, EN-90, EW) did not result into significant change per generation in this trait. Therefore, for the selection indices given for Medium ecotype, it could be logical to concentrate on those which ignore body weight from the index (that is Selection index I_{3m}, I_{4m}, I_{7m} and I_{8m}). Apart from some egg production and related traits, humoral immune response against NDV vaccine is also improved in selection indices I_{4m} and I_{8m}. Furthermore, since eggs from local chickens can be marketed with the current low egg weight without a problem (Mlozi, 2006; Lwelamira, 2007), then the two selection indices (I_{4m} and I_{8m}) could be selection indices of choice among the four above (that is those ignoring body weight in the index). However, for selection index I_{4m} it would require approximately 3 more years of selection to achieve the desired gains compared to selection index I_{8m}. Therefore, the choice among these two indices will depend on availability of resources. After the entire period of selection average egg number in the first 90 days after sexual maturity is expected to be increased by 19 eggs, age at first egg (that is age at sexual maturity) decreased by 14 days, and humoral immune response increased by around 1($HIlog_2$) in both selection indices (that is I_{4m} and I_{8m}) compared to the average performance of the current population. Furthermore, average egg weight is expected to be improved by 8 g for selection index I_{4m}. In this regard, egg number in the first 90 days after sexual maturity, age at first egg, humoral immune response and egg weight would have been improved from their current population mean of 49 eggs, 168 days, 5.1 ($HIlog_2$) and 42 g to 68 eggs, 154 days, 6 ($HIlog_2$) and 50 g, respectively, after selection.

As stated earlier, the majority of farmers in the tropics reside in rural areas and keep their chickens under extensive management, therefore, breeding programs for improving egg production under intensive management can benefit those farmers who are ready to shift from extensive system of management to semi-intensive system of management as this will reduce the magnitude of genotype by environment interactions (Sørensen, 1999; Ali, 2002).

Conclusion

The study conclude that, approximately 5 to 6 generations of selection which corresponds to around 4 to 6 years of selection would be required for Kuchi chicken ecotype for improving Bwt16 either singly or together with Ab from their current population mean of 1394 g and 5 ($HIlog_2$) to the desired population mean of 1800 g and 6 ($HIlog_2$), respectively. As for medium ecotype, it would require approximately 8 to 11 generations of selection which corresponds to around 8 to 12 years of selection to improve either AFE and EN-90 or together with EW or Ab or both of them from their current population mean of 168 days, 49 eggs, 42 g and 5 ($HIlog_2$) to the desired population mean of 154 days, 68 eggs, 50 g, and 6 (HIlog2), respectively. The number of years of selection required to attain the desired gains for the studied chicken ecotypes indicates that it will not take too long to reach the target (desired performance) if selection breeding programs would be initiated.

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