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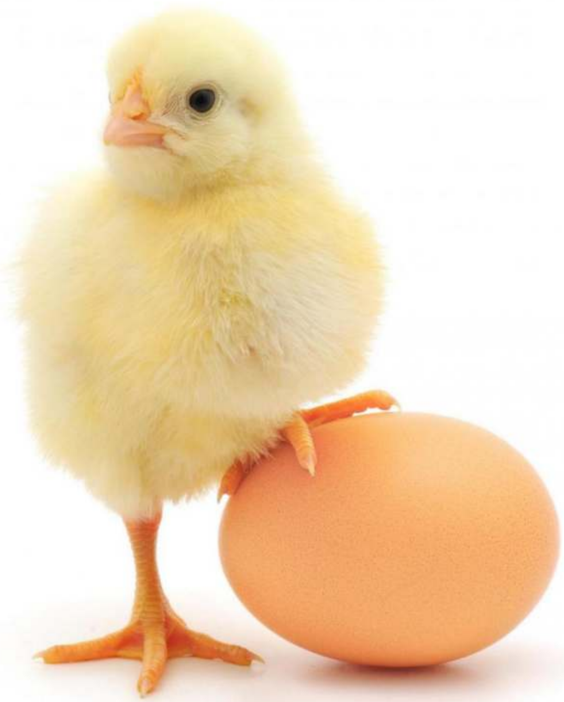

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Comparison of Effective Population Size, Rate and Level of Inbreeding and its Potential Impact on Village Chicken Populations of Southern Africa

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Abstract: The term village chicken best describes the scavenging chickens because of the effect of the village socio-economic and biophysical environment on the production and health status of the chicken. These chickens are predominantly farmed in African villages by small holder farmers. The purpose of this study was to compare rates and levels of inbreeding in village (free range) chickens in Southern Africa. In addition the study sought to investigate the major economic traits that could be negatively affected by inbreeding. The study was carried out in 2007 and 2009 by sampling households in five agro-ecological zones (AEZ) in Zimbabwe and three farming regions in South Africa. Data was captured in the form of surveys conducted using pre-tested questionnaires and included farmer socio-demographic information and household chicken flock sizes and composition. Data was also captured on traits that chicken farmers target when selecting or culling the flocks by ranking traits in order of importance, one being most important and eight being the least important. Three parameters i.e. effective population size (N_e), rate of inbreeding (ΔF) and the level of inbreeding (F) were estimated using different mathematical formulas. Statistical analysis of the effect of agro-ecological zone and country on each of the three parameters was done using Generalized Linear Models procedure in SAS. Results showed that Limpopo province of South Africa and AEZ III of Zimbabwe had highest and lowest N_e, respectively. Consequently, Limpopo and AEZ III had the lowest and the highest ΔF respectively. Both effective population size and rate of inbreeding varied significantly ($p<0.05$) between farming regions/agro ecological zones within countries. It was observed that chicken body size, reproductive performance, mothering ability and health were ranked high while body conformation and morphological traits (plumage color and comb shape) were ranked the least important traits for choosing animals for breeding and for culling chickens from the flock.

Key words: Village chicken, inbreeding, effective population size, farming region

INTRODUCTION

Chicken production plays a significant role in the economy of African countries (Aboe *et al*., 2006). Understanding chicken production systems is vital for future breed improvement and conservation programs. Poultry farming particularly village chicken farming is one of the least expensive livestock farming activities that most low income households can rely on for their livelihoods. The name village or indigenous chickens refers to local chickens that are native to a particular area (Msoffe *et al*., 2005; Tadelle, 2003). These chickens have not been fully characterized in terms of their genetic diversity and distribution in the Southern African region (Muchadeyi *et al*., 2007). The chickens survive under harsh climatic stress existing within Southern African and are regarded as an important genetic reservoir developed over thousands of years and successful in extreme and unusual environments with limited veterinary and management input (Delany, 2003; Hall and Bradely, 1995). Very little is known about the genetic composition and diversity of most of these chicken populations (Muchadeyi *et al*., 2007), The diversity of these chicken populations is however thought to be threatened by indiscriminate crossbreeding with exotic breeds as well as uncontrolled mating systems that might lead to high levels of inbreeding. Under village chicken production systems the chickens roam and mate freely and in cases where effective populations' sizes are low inbreeding could result. In small population, inbreeding is a function of low effective population size (Hedrick, 2005). Studies on flock structures have shown an average sex ratio of 1 cock: 5 hens in most African countries (Aboe *et al*., 2006; Gondwe and Wollny, 2007; Muchadeyi *et al*., 2007). There is high level of cock sharing as the majority of households do not own cocks. It is not clear how such practices influence inbreeding.

Inbreeding is the mating of related individuals that are more closely related than the average of a breed (Falconer and Mackay, 1996; Oldenbroek, 2007; Wang,

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1997). When dispersal options are limited and mating with relatives is likely, close inbreeding and the resultant loss of fitness to the chicken population would need to be considered. Inbreeding tends to result in more homozygous animals and can have dire consequences in cases where unfavored genes surface influencing an individual's phenotype. Generally, the effects of inbreeding manifest as reduction in fertility and viability particularly through low rates of survival and growth (Falconer and Mackay, 1996; Hedrick, 2005). There is a shortage of information of estimates of rates and levels of inbreeding in extensively raised poultry production systems in Southern Africa. Such information is crucial in designing village-based selection schemes for genetic improvement where there is no pedigree or performance recording. Data was collected in the five agro-ecological regions of Zimbabwe and three farming regions in South Africa which allowed the estimation of rates and levels of inbreeding in extensively raised village chickens. The purpose of this study was to compare rates and levels of inbreeding in village (free range) chickens in Southern Africa. In addition, the study sought to investigate the major economic traits that could be negatively affected by inbreeding.

MATERIALS AND METHODS

Description of study sites: The study was carried out by sampling households located in villages of districts in South Africa and Zimbabwe during the period between 2007 and 2009. Ninety-eight households known to keep chickens were randomly selected from 23 villages of Vhembe and Mopani Districts in the Limpopo Province, Kgalagadi and Namaqua Districts of the Northern Cape Province and Alfred Nzo and OR Tambo Districts of the Eastern Cape Province of South Africa. For each district, 2-5 villages were selected and the distance between villages within a district ranged from 20-40 km, 100-500 km between districts within a province and over 1000 km between provinces. In Zimbabwe, five districts, Risitu, Hurungwe, Gutu, Gokwe-South and Beitbridge in agro-ecological zones I, II, III, IV and V respectively were used for this study. Communal areas in these districts practice mixed crop-livestock farming with average land holdings of 2.6 ha/household. In each district, 7-10 villages located in 2 wards remote from the growth point centres were randomly selected. Villages close to growth centres were not sampled as they tend to have the influence of the urban farming community. The list of households in each village was provided by the Agricultural Research and Extension Department (AREX). Household were selected based on ownership of chickens and willingness to participate. Using this criterion, a total of 317 households were chosen from 39 villages. Participation in the study was voluntary but farmers needed to own chickens reared under semi-extensive and extensive system of production. In this system, chickens scavenge for food and water. In some households chickens were provided with housing especially at night. Most of the farmers did not keep pedigree and production traits records and there were no elaborate health control programs for the chickens. Households were randomly selected from 7 to 10 villages in each district.

Data collection: A survey was conducted using a pre-tested questionnaire which was administered to randomly selected households in each selected district in Zimbabwe and South Africa. Data that was collected included farmer socio-demographic information and household chicken flock sizes and composition. In addition data was collected on the traits that the farmers target when selecting breeding stock or culling chickens from their flocks.

Farmers were asked to rank the criteria used in breed selection in order of importance from one being the most important criteria to eight the least important. Lastly, farmers were asked through an open-ended question to which extent they practice culling and the criteria they use. For the listed culling criteria, farmers were asked to rank them in order of importance using the same ranks as for criteria used in trait selection. This was done since different farmers used different criteria and measures to cull their chickens.

Estimation of effective population size, rate and level of inbreeding: Effective population size, N_e, makes it possible to consider an ideal population of size N in which all parents have an equal expectation of being parents of any progeny individual (Hedrick, 2005). To estimate the effective population sizes of village chicken populations per household and their differences by village and district and agro-ecological region, the following equation was used:

$$N_e = \frac{4N_m N_f}{N_m + N_f}$$

where, N_e is the effective population size, N_m and N_f are the numbers of reproductively active chickens i.e., adult cocks and hens, respectively. It was assumed that all chickens mated at random and that copulatory success was the same for all cocks in the flock. Effective population size is a value which attempts to account for evolutionary factors allowing investigation of factors causing deviations from the ideal (Hedrick, 2005). Understanding of effective population size and adequate sex ratio enables efficient mating practices that minimize inbreeding.

The rate of inbreeding in the populations of chickens (ΔF) was estimated using the formula for each household flock:

$$\Delta F = ½N_e$$

The rate of change of inbreeding (ΔF) predicts the probability of homozygous genes that a new progeny will carry.

The level of inbreeding per household flock was calculated using the formula:

$$F_t = 1 - \left[1 - \left(\frac{1}{2N_e}\right)\right]^t$$

where, F_t is the level of inbreeding after t generations. The level of inbreeding was simulated for the exact flock compositions and environmental conditions after one, five, ten, fifty and 100 generations. This was done to test whether there was a significant increase or decrease of inbreeding levels as generations increased.

Statistical analysis: The Generalized Linear Models procedure in (SAS, 2007) was used to analyze the effects of agro-ecological zone or farming region, country and sex of household head on the estimates of effective population size, rate and level of inbreeding. Pair-wise comparisons of least square means were performed using the PDIFF procedure.

Model: The model applied was:

$$Y_{ijk} = \mu + C(AEZ_i)_j + SHH_k + e_{ijk}$$

where, Yijk = the estimated household flock effective population size (N_e), rate of inbreeding (ΔF) or level of inbreeding (F):

μ = the overall mean

- AEZ_i: Fixed effect of agro-ecological zone or farming zone (5 zones in Zimbabwe and 3 regions in South Africa)
- C_j: The effect of country (either South Africa or Zimbabwe)
- SHH_k: fixed effect of sex of household head (either male or female) and
- e_{ijk}: Will be the effect of an error value on the model

Preferred traits for breeding and culling village chickens: To determine the major traits that could be affected by the current breeding practices and the effects of farming region or eco-zone on the traits used for selecting breeding animals or for culling chickens, a non-parametric Kruskal Wallis test (NPAR1WAY procedure of SAS, 2007) was used to test whether median ranks attached to each criterion used in either choosing breeding stock, or culling chickens varied among farming of agro-ecological zones. The Kruskal Wallis test generated the median ranks whose significance was tested using a Chi square test (SAS, 2007).

RESULTS

Household chicken flock sizes and composition: Table 1 summarises the village chicken flock sizes and composition in the five agro-ecological zones of Zimbabwe as well as the three farming regions of South Africa. In South Africa, highest flock sizes and number of cocks were observed in the Limpopo province. In Zimbabwe, AEZ III had the highest chicken flock sizes. However, the number of cocks and hens were found to be lower in this region. In all the sampled regions of South Africa and Zimbabwe, the number of hens per household was higher than the number of mature cocks. Highest chicken flock sizes and higher number of cockerels, pullets and chickens were observed in the five agro ecological zones of Zimbabwe.

Effective population size rate and level of inbreeding: The average effective population size (N_e) was 4.32 for all the eight provinces. Overall, South Africa had the highest N_e compared to Zimbabwe (Table 2). The effective population size varied significantly ($p<0.05$) between the farming regions and agro ecological zones. The rate of inbreeding in the eight regions averaged 0.116. The rate of inbreeding in Limpopo province in South Africa was significantly lower ($p<0.05$) than that of the other two farming region regions of South Africa and the five eco-zones of Zimbabwe. The inbreeding level after one generation was the same as the inbreeding rate (F-rate) and was therefore not included in Table 2. At the fifth, tenth and fiftieth generations, Limpopo province of South Africa is expected to have lower levels of inbreeding compared to the Eastern and Northern Cape provinces as well as the five agro-ecological zones of Zimbabwe. The simulation indicated an increase in inbreeding level as the number of generations increased and the populations are expected to be fixed after 50 generations.

Figure 1 shows simulations of levels of inbreeding that are expected if the current flock sizes and structures are maintained through time. It is evident that the levels of inbreeding would drastically increase reaching levels greater than 90% after fifty generations.

Traits used for selecting breeding chickens: The traits used by farmers in South Africa to select chickens to use as breeding animals are listed in Table 3. Data for trait preferences for Zimbabwe's village chicken breeding stock was reported by Muchadeyi *et al.* (2009). Farmers in both South Africa and Zimbabwe ranked chicken body size as an important trait to use when selecting breeding animals. In addition to body size, farmers in South Africa used body conformation and reproductive performance as selection criteria while Muchadeyi *et al.* (2009) reported that farmers in Zimbabwe focused mainly on reproductive performance; in particular, the mothering ability of hens. Availability was ranked low on the list by Zimbabwe farmers.

Traits used for culling chickens: A list of traits used by South African farmers to cull chickens is presented in Table 4. Muchadeyi *et al.* (2009) presented data on culling traits for village chickens in Zimbabwe. Across all farming regions of South Africa, chicken body size, health and reproductive performance were ranked highly. This is a similar finding to that of Muchadeyi *et al.* (2009) on agro-ecological zones of Zimbabwe. Farmers culled small sized chickens, those in poor health and associated with poor reproductive performance particularly hens with poor mothering ability. Old chickens that had stayed in the flock for at least two years were also culled. Comb shape and plumage shape and color were the least ranked traits in all the farming regions and agro ecological zones.

DISCUSSION

The mean flock sizes reported for Zimbabwe and South Africa (10 to 20 chickens/household) were within the range for most of African countries (Kelly *et al.*, 1994; Mwalusanya *et al.*, 2002; Mushi *et al.*, 2006). The differences in the average flock sizes depends on the hatching rate, effects of endermic diseases, landholding sizes, cropping patterns, amount of time farmers allocate to tending their flocks and the capacity these to provide a scavenging feed resource (Maphosa *et al.*, 2005; Mwalusanya *et al.*, 2002). The proportion of chicks and growers in all flocks was low indicating high mortalities caused by diseases, pests and predators. Chicks and growers are particularly vulnerable and require special care. Failure of chicks and growers attaining adulthood when they can breed is one reason contributing to a skewed flock composition. In all farming regions and agro-ecological zones, there were fewer cocks than hens with even other households not owning their own breeding cocks. There were marginally more hens in village chicken flocks in South Africa than Zimbabwe with the Limpopo farming zone having the highest average numbers of both hens and cocks (8.12 and 2.64 hens and cocks, respectively). It was noted also that there is considerably high levels of haphazard sharing of breeding stock within village rather than between villages which could be contributing to the high levels of inbreeding. In Ethiopia it was also observed that majority of communal farm households did not own their own breeding males and shared with neighbors (Dana *et al.*, 2010). Sharing of breeding males was random and done in the absence of records of farms and animals involved and in majority of cases only neighboring flocks were engaged in cock sharing. A major weakness of such practice is that a few males could be used to breed many hens over a prolonged period of time. This could result in a low effective population size and elevated inbreeding rates in these extensively raised village chicken populations.

Table 1: Table displaying the mean (standard deviation) chicken flock sizes and composition in the three farming regions and five agro ecological zones of South Africa and Zimbabwe

	R.S.A.			Zimbabwe				
Country	E.C.	L.P.	N.C.	I	II	III	IV	V
Total chickens	11.51 (9.33)	14.60 (12.09)	10.62 (7.79)	19.210 (13.462)	16.04 (14.75)	13.30 (10.51)	19.49 (12.13)	10.78 (9.27)
Chicks	0.94 (2.04)	1.98 (3.46)	1.12 (2.10)	7.14 (7.63)	7.21 (9.84)	7.22 (9.04)	8.563 (9.30)	1.31 (3.59)
Pullets	0.61 (2.14)	1.08 (2.18)	1.02 (3.32)	3.97 (6.40)	1.27 (2.62)	0.59 (1.60)	2.75 (4.80)	1.26 (2.94)
Cockerels	0.33 (1.39)	0.58 (1.40)	0.90 (2.38)	0.71 (2.47)	0.83 (1.86)	0.77 (1.32)	1.03 (2.47)	0.43 (1.72)
Hens	7.41 (7.10)	8.12 (6.43)	6.26 (4.54)	6.00 (4.25)	5.50 (4.21)	4.29 (3.30)	5.59 (3.66)	6.23 (3.98)
Cocks	2.00 (1.95)	2.64 (2.42)	1.52 (1.13)	1.30 (1.02)	0.96 (1.073)	0.77 (1.13)	1.47 (1.26)	1.66 (0.94)

AEZ: Agro-Ecological Zone; E.C: Eastern Cape Province; N.C: Northern Cape; L.P: Limpopo Province; I: Chimanimani; II: Hurungwe; III: Gutu; IV: Gokwe-S; V: Beitbridge

Table 2: Effect of farming region within country on different parameters

	R.S.A.			Zimbabwe				
Parameter	E.C.	L.P.	N.C.	I	II	III	IV	V
N_e	5.90 (0.54)^{cd}	7.10 (0.52)^{e}	4.80 (0.55)^{cd}	4.07 (0.38)^{bc}	3.32 (0.48)^{ab}	2.17(0.45)^{a}	4.12 (0.37)^{bc}	4.99 (0.63)^{cd}
F-Rate	0.11 (0.068)^{b}	0.093 (0.047)^{a}	0.12 (0.054)^{b}	0.12 (0.043)^{b}	0.12 (0.57)^{b}	0.13 (0.055)^{b}	0.12 (0.0428)^{b}	0.11 (0.039)^{ab}
F-level 5	0.42 (0.20)^{ab}	0.37 (0.15)^{b}	0.46b (0.16)^{a}	0.47 (0.13)^{a}	0.46 (0.16)^{a}	0.48 (0.16)^{a}	0.44 (0.13)^{a}	0.43 (0.12)^{a}
F-level 10	0.63 (0.23)^{ab}	0.58 (0.19)^{b}	0.69 (0.19)^{a}	0.70 (0.15)^{a}	0.68 (0.17)^{a}	0.71 (0.17)^{a}	0.67 (0.15)^{a}	0.66 (0.14)^{a}
F-level 50	0.950 (0.089)^{b}	0.949 (0.097)^{b}	0.978 (0.043)^{ab}	0.986 (0.030)^{a}	0.982 (0.034)^{a}	0.986 (0.028)^{a}	0.985 (0.027)^{a}	0.990 (0.024)^{a}
F-level 100	0.990 (0.026)^{a}	0.988 (0.037)^{a}	0.998 (0.0065)^{a}	0.999 (0.0046)^{a}	0.999 (0.0044)^{a}	0.999 (0.0027)^{a}	0.999 (0.0039)^{a}	0.999 (0.0021)^{a}

^{abc}Values within a row with the same superscript are not significantly different (p>0.05)

Table 3: Trait used by farmers when selecting chickens to use a breeding stock in South Africa

	Province, mean(SD)			
Traits	E.C.	L.P.	N.C.	Sig
Body size	1.53 (0.75)	1.22 (0.47)	1.79 (0.83)	*
Body conformation	2.25 (0.62)	1.95 (0.59)	2.16 (0.62)	ns
Plumage color	2.24 (0.82)	2.27 (0.63)	2.05 (0.99)	ns
Comb Shape	3.00 (0.00)	3.00 (0.00)	-	ns
Temperament	2.57 (0.79)	2.00 (0.00)	-	*
Reproductive performance	2.58 (0.77)	1.83 (0.79)	-	*
Availability	2.25 (1.04)	2.00 (1.16)	1.00 (0.00)	ns
Sig	*	*	*	

Trait not used for ranking

Table 4: Mean ranks (standard deviation) attached to traits used by farmers when culling chickens in the three provinces of South Africa

	R.S.A.		
Trait	E.C.	N.C.	L.P.
Body size	2.0 (0.89)	1.57 (0.82)	1.42 (0.703)
Plumage color	2.55 (0.69)	2.23 (0.96)	2.75 (0.50)
Comb Shape	3.00 (0)	-	-
Plumage type	2.39 (0.70)	2.129 (0.49)	2.25 (0.50)
Health	2.46 (0.78)	2.00 (1.4)	2.73 (0.47)
Body Conformation	2.10 (0.74)	-	2.00 (1.00)
Age	1.71 (0.93)	2.00 (1.0)	1.85 (0.73)
Reproductive performance	2.56 (0.81)	1.857 (0.69)	2.20 (0.86)
Temperament	2.60 (0.55)	1.00 (0)	-

-Trait not used for culling

Overall, the estimates of effective population size per household were very low in all farming zones. Limpopo farming zone had the highest (Ne = 7.10) with agro-ecological zone II the lowest (Ne = 2.17). This is an important result because the effective population size is an important determinant of the rate and level of inbreeding. The low levels of effective population size make the village chicken population exceptionally vulnerable to the potentially detrimental effects of inbreeding. Sexual diphormism in maturation and growth of chickens makes males more vulnerable to mortalities and thus produces a skewed sex ratio towards hens that further reduces the effective population size. From a theoretical standpoint, the low rates of effective population size are worrying and could signal a population of village chickens that is prone to the effects of genetic drift, loss of variability and inbreeding assuming that there is predominant random mating in the village chicken flocks. The highest N_e of Limpopo province in South Africa is higher than that recorded in literature (Abdelqader *et al*., 2007; Dana *et al*., 2010) while the lower N_e of AEZ II of Zimbabwe is lower than that reported in the same studies. Such high variability shows the differences in the village chicken production systems of the different countries and the need to tailor program interventions for the different populations.

Inbreeding was noted to be reaching considerably high levels in the village flocks mainly due to small flock sizes, fewer cocks and absence of pedigree records which all increase the chances of related chickens mating. In a breeding program, the rate of accumulation of inbreeding (ΔF) is more important than actual inbreeding level (F) due to its influence on genetic progress (Pante *et al*., 2001). Normally, ΔF measures the extra number of generations a population can actually survive or be kept before reaching a critical level of inbreeding. On average, ΔF was found to be 0.116 for whole village chicken population. Agro-ecological zone III in Zimbabwe was found to have the village chickens with the highest ΔF (0.130) and Limpopo farming zone in South Africa had the lowest (0.0930).

In this study we also predicted levels of inbreeding if the flock structure and sizes remain the same for up to a hundred generations. The predictions showed that after fifty generations, the level of inbreeding would be very high at over 90% in all agro-ecological zones. This indicates that there is a long term risk of keeping village chicken breeding stock flock sizes low. This would contribute to loss of important alleles and genetic diversity of this important genetic reservoir of important traits. There is also the danger that selection programmes would fail to realize high response if the genetic variability is drastically reduced.

The consequences of inbreeding are potentially severe with the potential effects including population decline and possible extinction. With the levels of inbreeding recorded in the populations of village chickens exceeding 10%, inbreeding depression and reduced fitness of inbred individuals could be a result. High rates of inbreeding reduce genetic variance. The rates of inbreeding estimated for the village chickens in this and other studies (Abdelqader *et al*., 2007; Dana *et al*., 2010) are critical as they are slightly above the accepted range for avoiding loss of fitness (Meuwissen and Woolliams, 1994). It is therefore important to monitor the rate and levels of inbreeding so that ways to avoid its accumulation and detrimental effects can be sought.

Tolerable rate of inbreeding might vary among populations and traits depending on the inbreeding depression in production traits and fitness and permissible rates of inbreeding may differ from one breeding program to another (Gjerde *et al*., 1996). Traits with high heritability are less affected by inbreeding depression since many genes impact that particular trait.

The reproductive performance, age and health of chicken are crucial for farmers when culling and selecting chickens for breeding purposes. In Bangladesh, chicken production improved the status of landless women through access to more food, income and labour as well as increased social status in the rural community (Saleque and Mustafa, 1996). Plumage color and other morphological traits are the least important traits when culling chickens and this is because these traits are of no value to farmers that practice village chicken farming not for traditional purposes but for dietary and monetary purpose. The same production traits were also highly regarded when selecting cocks to mate with hens. Cock size, performance and shape were highly regarded as these ensure high chances for good progeny.

In addition to growth and chicken health, farmers were highly concerned with mothering ability of hens. This implied that there is concern with chicks reaching the adult stage. High level of chick mortality due to lack of supplementary feeding, predators and to some extent diseases (Aini, 1990) characterises most village chicken production systems. Also studies in Mali by (Wilson *et al*., 1990) revealed that chick mortality was in the range of 60% within the first three months after hatching. With such high chick mortalities, selecting for mothering ability is one way of ensuring chicks are able to reach slaughter or reproductive maturity.

Chicken health was also highly rated trait for culling and selecting for chickens. In other studies of village chickens have been described as reservoir for unique genetic diversity adaptable to local disease conditions (Sonaiya, 1990; Sorensen, 2001; Spielman *et al*., 2004). A study in Morocco (Bouzoubaa *et al*., 1992) has revealed that up to 58% of the village chickens had antibodies against *Salmonella gallinarum* and *S. pullorum*. Similar findings were reported by (Adesiyun *et al*., 1984) from Nigeria. Chrysostome *et al*. (1995) reported that 10% of the village chickens had antibodies against *S. pullorum* and that 62% had antibodies against *Mycoplasma gallisepticum*. Village birds do not receive any medical care and are ever faced with danger of parasite and disease invasion hence chickens that do show signs of illness are culled and only those that appear healthy are selected. Tracking different antibodies present within each population was beyond the scope of this study. Other studies however, have shown that village chickens have antibodies for different diseases (Adesiyun *et al*., 1984; Aini, 1990, Chrysostome *et al*., 1995).

Production traits such as chicken body size, reproductive performance, chicken health and mothering ability were used by most farmers and highly ranked when selecting breeding animals or culling chickens from the flock. It would be expected that these traits will be most affected by inbreeding if the chicken populations are not managed differently. Selection and culling in village chickens flocks are important forces that help direct genetic improvement. The findings that farmers rank traits for selection and culling of chickens provides ample evidence that there are deliberate efforts by farmers to direct genetic progress in their flocks. However, the effect of the selection and culling on the gene and genotypic frequencies and ultimately levels of inbreeding could not be ascertained. The practice mostly likely alters the numbers of males and females that are either retained for the breeding stock thereby affecting the size of effective population size which in turn contributes to inbreeding levels.

To improve similar investigations in future, parentage analysis using molecular genetics techniques could be used. In any breeding program, complete pedigree information is necessary for the accurate estimation of rates and levels of inbreeding (Caballero, 1994). However, in village chickens flocks no pedigree records are kept. Caballero (1994) highlighted that micro-satellite markers could be used to establish the parentage of selected individual/s. Although expensive, such methods give more reliable estimates of N_e, F and ΔF. Populations can be kept for more generations of selection while keeping the rate of inbreeding under control by following a designed mating system and keeping reasonably high effective population size (Pante *et al*., 2001).

Conclusion and recommendations: Effective population sizes for village chickens in Southern Africa estimated from demographic data were found to be very low. This has provided evidence of probable high levels of inbreeding in these flocks. Production traits such as body size, health and reproductive traits could be influencing genetic diversity and directing genetic progress in these chicken populations. It is recommended that conservation programmes be implemented that target loss of genetic diversity in village chickens by, among other ways, reducing the rate and levels of inbreeding. The sex ratios present an opportunity for farmers to target measures such as cock exchange as a vehicle to reduce the levels of inbreeding in the flocks. As a way of reducing the rate of inbreeding, farmers could swap cockerels and hens with their neighbours from distant villages. This is to stop closely related chickens from mating.

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