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Genotype-Environmental (G X E) Interaction for Body Weights for Kuchi Chicken Ecotype of Tanzania Reared Under Intensive and Extensive Management

By J. Lwelamira

Institute of Rural Development Planning, Dodoma, Tanzania.

Abstract – This study was carried out with the aim of determining magnitude of G x E interaction for body weights for Kuchi chicken ecotype of Tanzania reared under intensive (on-station) and extensive (free-range) management systems. Body weight was assessed at 8 (Bwt8), 12(Bwt12), 16(Bwt16), and 20(Bwt20) weeks of age. Results for this study indicated average performance in all body weight measurements was significantly higher under intensive management compared to extensive management ($P < 0.001$), signifying two diverse environment and hence possibility for G x E interaction. Based on magnitude of genetic correlation for the same trait measured in two environments (*rg*) G x E interaction for all body weight measurements were found to be substantial (i.e. biologically important). Value for *rg* was 0.745, 0.757, 0.752 and 0.753 for Bwt8, Bwt12, Bwt16 and Bwt20, respectively. Since breeding program for improving performance of the ecotype would be more feasible under intensive management and hence more likely to take place under such environment, based on results of this study, if such breeding program is to be implemented, sensitization of smallholder farmers (beneficiaries of the breeding program) to shift from their current system of management (extensive management) to at least semiintensive system of management is recommended for minimizing the effect of G x E interaction.

Keywords : *Breed, environment, local chickens, performance.*

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I. Introduction

Indigenous (local) chickens account for majority of chicken population in developing world including Tanzania. These chickens are mostly kept under extensive management in rural areas. Studies have shown at least 80% of rural households of Sub- Saharan Africa keep local chickens (Aini, 1990; Msoffe, 2003; Illango *et al*., 2005; Dana *et al*., 2011). Although the sector have been contributing substantially to household income and nutrition for majority of poor rural communities (Pedersen, 2002; Aganga *et al*., 2003; Muchadeyi *et al*., 2005; 2007; Alabi *et al*., 2006), however, its expansion has been limited by low productivity. Poor management practices, high prevalence of diseases and low genetic potential of the stock have been the main factors associated with low productivity of the sector (Pedersen, 2002; Magwisha *et al*., 2002; Rosa dos Anjos, 2005; Lwelamira, 2007). Therefore, among others, for improving performance of local chickens and hence improved productivity of the sector, interventions to improve their genetic potential through appropriate breeding programs are inevitable. Breeding programs involving selection within local chicken stocks have been suggested as the best way of improving their genetic potential. This approach would offset some weaknesses encountered in other genetic improvement approaches (i.e. crossbreeding with exotic chickens). Some of these weaknesses include reduced broodiness and survival rate (Tadelle *et al*., 2000; Udo *et al*. 2001; Dana, 2011). Furthermore, selection within local chicken stocks would also enhance conservation of indigenous genetic resources, a current global move (Kosgey, 2004; Msoffe, 2003, Lwelamira, 2007; Dana, 2011). Successful selective breeding program requires sufficiently large population, pedigree recording, accurate measurement of individual performance and the capacity to minimize environmental variation (Besbes, 2009). These conditions can hardly be met under smallholder farmers' conditions in tropics. Accurate record keeping by smallholder farmers in tropics have proven to be difficult due to involvement of smallholder farmers in many farm activities and hence less time for recording, and complexity of recording process (Kiwuwa, 1992; Jaitner *et al*., 2001; Wollny *et al*., 2002; Lwelamira, 2007). Therefore, selective breeding program for improving genetic potential of local chickens is more likely to take place under central breeding station (Intensive management). However, since management under station would definitely be different from extensive management (under smallholder farmers conditions i.e. on-farm) where improved genetic stock is going to perform, this may result into Genotype by Environment Interaction (G x E). Magnitude of G x E need to be quantified (known) to determine whether it would have a significant effect on the performance of the birds and hence its biological importance. This is the birds and hence its biological importance. This is through estimation of genetic correlation between the same trait measured in two environments (Falconer, 1952; Robertson, 1959; Sorensen, 1977; Falconer and Mckay, 1996; Calus *et al*., 2002; Mulder and Bijma,

Author : Institute of Rural Development Planning, P.O. BOX 138, Dodoma, Tanzania. E - mail: jlwelamira@yahoo.com

2005; Nauta, 2009). Knowing the magnitude of G x E problem under particular situation would help in determining whether strategies to reduce the problem are necessary. Results from random samples of mature birds from rural areas of Tanzania done in previous studies (Lawrence, 1998) as well as growth studies under both extensive and intensive management for some Tanzania local chickens (Msoffe, 2003; Lwelamira *et al*., 2008; 2009) indicated *Kuchi* to be superior to other ecotypes in terms of body weight and growth rate hence good starting material for developing meat chickens for production under extensive management. Therefore, in this regard, this study aimed at determining the magnitude of G x E interaction for *Kuchi* chicken ecotype of Tanzania kept under both intensive (station) and extensive/on- farm management (i.e. under smallholder farmers conditions). This would help in determining whether strategies to reduce the problem of G x E interaction are required during genetic improvement of *Kuchi* chicken ecotype through selection.

II. Materials and Methods

a) Study site and experimental materials

This study was carried out at Sokoine University of Agriculture (SUA) poultry research unit, Morogoro, Tanzania and two nearby villages (i.e. *Kauzeni* and *Mgambazi*). The place is located at an altitude of about 525m, above sea level. The relative humidity at the location is about 81%, while the monthly mean and maximum temperatures are 18.7 and 30.1° C, respectively. The area has annual mean rainfall of 846mm. Experimental chicks were derived from parental stock for *Kuchi* chicken ecotype obtained from drier parts of North West Tanzania.

b) Mating, hatching and management of experimental materials on-station

Twenty four (24) cocks were mated to 175 hens with number of hens per cock ranging from 5 to 8 with average of 7. (All birds were wing tagged for identification/ for keeping pedigree). Before mating, hens were rested without a cock for a period of three weeks in order to ensure that upon mating, a known/planned cock has fertilized the eggs. Mating was done repeatedly after every one week with mating and egg collection period lasting for three days and one week, respectively in each cycle. After every mating, transferring of hens to individual battery cages was done with the purpose of identifying and marking the eggs from each hen before incubation in order to keep track on pedigree. A total of 645 chicks were produced in eleven hatches. Upon hatching, not all hens possessed chicks, therefore the chicks above were the progeny of 163 hens. Hatched chicks were wing tagged and housed in floor pens up to 12 weeks of age. Thereafter they were transferred to individual cages. Birds were fed a starter ration (20% CP and 2800 Kcal ME/kg) from day old to 8th week of age, growers ration (16% CP and 2750 Kcal ME/kg) from 9th to 16th week of age, and layers ration (17%CP and 2700 Kcal ME/kg) from 17th week of the age to the rest of the period. Parent stock was also fed the same layers ration. Water was supplied on ad libitum basis. Birds were also vaccinated routinely against Gumboro and Newcastle disease (ND).

c) Mating, hatching and management of experimental materials on-farm

After the end of mating and hatching period in on-station experiment, the parent stock (with birds still with their wing tags for identification) was taken to the field for on-farm experiment. A total of 146 hens and 22 cocks for *Kuchi* chicken ecotype were supplied to 68 farmers, that is, 30 and 38 farmers from *Mgambazi* and *Kauzeni* villages, respectively. Each farmer was given 2 to 3 hens. Criteria for the choice of the farmers were based on the willingness of a farmers to participate in construction of a chicken house, which could accommodate at least 3 adult *Kuchi* birds on individual compartments, and to participate in a training (a three day training) on how experimental birds should be managed and willing to adopt that management system. The building materials for construction of chicken houses were supplied by the Enhancement of Health and Productivity of Smallholder Livestock in East Africa (PHSL) project. A farmer only contributed a space for building a chicken house around his/her homestead and labour.

Parent stock kept at Sokoine University of Agriculture, Poutry Research Unit, was vaccinated against ND and Gumboro two weeks and one week, respectively before being taken to the field. Furthermore, while in poultry research unit at the University waiting to be taken to the field, hens were kept separately from cocks for a period of three weeks to avoid mating before experiment (To avoid fertilization of egg by unplanned cock during on-farm experiment). Initially each farmer was supplied with two hens for *Kuchi* chicken ecotype, however due to fertility problems some farmers (few) were given up to 3 hens. Upon arrival to the field, hens were placed in individual compartments and each hen was mated to a specific cock while in individual compartments (that is, hens were not allowed to go out to mate with other unplanned cocks). Three to four nearby farmers were supplied with one cock for the ecotype and these farmers were sharing the cock for mating their hens. Each farmer was staying with a breeding cock for 3 to 4 days and passes it on to another farmer. Furthermore, hens were also let to lay, incubate and hatch their eggs while in individual compartments. Confinement of hens in individual compartments during mating up to hatching was done to avoid mix-up of cocks. This was done with the help of field supervisors (two field supervisors per village).

Tasks of field supervisors were recording, medication, vaccination, tagging of birds, that is, newly hatched chicks and ensuring that birds are managed by farmers according the protocol of the experiment. During mating, incubation and hatching periods, birds were supplied with water and layers ration (17% CP and 2700 Kcal ME/kg) on *ad libitum* basis. At this period parent stocks were also given antihelmintics (*Kukuzole*®) and broad spectrum antibiotics (*OTC-plus*®) regularly (prophylactic treatments) according to manufacturer instructions, and their bodies/houses were dusted with pesticides (*Dudu-dust*®) to control external parasites. Feeds and medications were supplied by the project. A total of 554 chicks were hatched. Hatching was done in a period extending from Mid- April, 2005 to Early August, 2005. After hatching chicks were tagged and hens continued to stay in confinement with their chicks for a period of ten days. While in confinement birds were fed chick starter ration (20% CP and 2800 Kcal ME/kg). The purpose of confining chicks in the early days of their lives was to minimize mortalities due to predation. After the end of confinement period birds were freed and chicks left to move out (scavenging) with their mothers. At this stage birds were depending entirely on scavenging feed. Due to fertility problems, not all hens supplied to farmers possessed chicks. Therefore the above chicks were progeny of 101 hens. The vaccination regimes for chicks were as in the on-station.

d) Traits studied

Body weights measured in grams were recorded on all individuals at 8, 12, 16 and 20 weeks of age (i.e. Bwt8, Bwt12, Bwt16, and Bwt20, respectively). However, due to mortalities, about 596, 593, 586 and 580 chicks on-station ; and 404, 392, 382 and 373 chicks on- farm were available for weighing at 8, 12, 16 and 20 weeks of age respectively.

e) Statistical analysis

i. *Descriptive statistics*

Descriptive statistics were generated using the SAS (2000) General Linear Models (GLM) procedure.

ii. *Estimation of genetic correlation between the same trait measured in two environments*

Genetic correlation for the same trait measured in two environments was estimated using equation 1 proposed by Robertson (1959) as applied by Sørensen (1977).

$$\sigma^2_{SxE} = \frac{\sigma_{A1} - \sigma_{A2}}{2} + \sigma_{A1} . \sigma_{A2} . \left(1 - r_g\right)$$

Equation 1

Where, $\sigma^2_{S\times E}$ = Sire by environment interaction component of variance;

σ_{A1} = square root of additive genetic variation in environment 1;

σ_{A2} = square root of additive genetic variation in environment 2;

r_g = genetic correlation between the same trait measured in two environments.

The interaction component of variance was estimated using MIXED procedure of SAS (2000) using statistical model 1. (The same model was also used to test the fixed effect of sex and environment). Additive genetic variances in respective environments were estimated based on sire components of variances as per Falconer and Mckay (1996). MIXED procedures of SAS (2000) were also used to estimate sire components of variances using statistical model 2. Only sires (cocks) (about 22 sires) with chicks both on- station and on-farm were involved in this analysis. Before analyses data were adjusted for significant effect of other fixed factors such as hatch (on-station environment), hatching month and farm (on-farm environment) using GLM procedures of SAS (2000).

$$Y_{ijkl} = \mu + C_i + E_j + S_k + (ES)_{jk} + e_{ijkl} \ldots$$ Model 1

Where:

Y_{ijkl} = record of l^{th} individual from i^{th} sex, j^{th} environment, and k^{th} sire;

μ = overall mean;

C_i = fixed effect of i^{th} sex;

E_j = fixed effect of j^{th} environment;

S_k = random effect of k^{th} sire, *NID* $(0, \sigma_s^2)$;

$(ES)_{jk}$ = random interaction effect of sire and environment;

e_{ijkl} = random effect peculiar to each individual distributed as *NID*$(0, \sigma_e^2)$.

$$Y_{ijk} = \mu + C_i + S_j + e_{ijk}$$ Model 2

Where:

Y_{ijkl} = record of k^{th} individual from i^{th} sex and j^{th} sire;

μ = overall mean;

C_i = fixed effect of i^{th} sex;

S_j = random effect of j^{th} sire, *NID* $(0, \sigma_s^2)$;

e_{ijk} = random effect peculiar to each individual distributed as *NID*$(0, \sigma_e^2)$.

III. Results and Discussion

a) Body weights for the ecotype under intensive and extensive management

Results from Table 1 indicate average body weights under intensive management were higher than those under extensive management, implying higher growth rate under intensive management compared to extensive management. Body weights under extensive management were around 70% of the correspondent body weights under intensive management. These differences in performance between the two environments were statistically significant (P< 0.0001) (Table 2). Relatively lower average weight under

extensive management, a system used by majority of smallholder farmers in tropics (Aini, 1990; Msoffe, 2003; Muchadeyi *et al*., 2005; Lwelamira, 2007), reflects sub-optimal conditions to support production under such system. Studies elsewhere in tropics have indicated nutrient deficiency and prevalence of diseases under extensive (free range) system of management to be high, a condition which contribute heavily to poor performance of chickens under such system (Magwisha *et al*., 2002; Hørning *et al*., 2003; Otim, 2005; Rosa dos Anjos, 2005; Goromela *et al*., 2006). Significant differences in these two environments on the performance of the ecotype can lead to G X E interaction (Tolon and Yalcin, 1997; Sørensen, 1999; Maniatis and Pollot, 2002; N'dri et al., 2007). However, magnitudes of G x E interaction in the studied traits need to be quantified to determine its importance (Falconer, 1952; Robertson, 1959; Sorensen, 1977; Calus *et al*., 2002; Mulder and Bijma, 2005; Nauta, 2009; Ibi et al., 2005; Nauta, 2009) and hence implication for breeding schemes for this ecotype.

Table 1: Lsmeans for body weights under intensive and extensive management

Sex	Trait	Intensive management		Extensive management	
		N	Lsmeans (s.e)	N	Lsmeans (s.e)
M	Bwt8 (g)	279	541 (3.2)	201	375(3.9)
	Bwt12 (g)	278	1026 (5.8)	195	739 (7.4)
	Bwt16 (g)	274	1449 (6.1)	190	1024 (9.4)
	Bwt20 (g)	270	1706 (6.9)	186	1240 (10.2)
F	Bwt8 (g)	317	438 (2.5)	203	320 (3.5)
	Bwt12 (g)	315	883 (5.6)	197	632 (7.2)
	Bwt16 (g)	312	1339 (5.9)	192	925 (8.3)
	Bwt20 (g)	310	1587 (6.2)	187	1135 (9.6)

Lsmeans= Least square means; s.e = standard error; M and F = Males and females, respectively; Bwt8, Bwt12, Bwt16, and Bwt20= Body weight at 8, 12, 16, and 20 weeks of age, respectively.

Table 2: Type 3 Tests of fixed effects for body weights

Trait	Effect	DF	F value	P- value
Bwt8	Environment	1	257	< 0.0001
	Sex	1	337	< 0.0001
Bwt12	Environment	1	599	< 0.0001
	Sex	1	410	< 0.0001
Bwt16	Environment	1	630	< 0.0001
	Sex	1	282	< 0.0001
Bwt20	Environment	1	710	< 0.0001
	Sex	1	290	< 0.0001

Bwt8, Bwt12, Bwt16, and Bwt20= Body weight at 8, 12, 16, and 20 weeks of age, respectively

b) Genetic correlation between the same trait measured in two environments

To quantify Genotype- Environment (G x E) Interactions for studied traits in order to determine whether they are biologically important or not (Falconer, 1952; Robertson, 1959; Falconer and Mckay, 1996 ; Calus *et al*., 2002; Sorensen, 1977, Mulder and Bijma, 2005), genetic correlation of the same trait measured in two environments (Intensive vs extensive management) were estimated for all body weight measurements under study. Results are presented in Table 3. Results indicate genetic correlation for the same trait measured under intensive and extensive management (i.e. on-station vs on-farm) varied from 0.745 to 0.757. According to Robertson (1959), Falconer (1952) and Mulder and Bijma (2005) classifications, in which a value of genetic correlation equal to or above 0.80 (i.e ≥ 0.80) is considered to have no substantial/biologically important G x E interactions, genetic correlations obtained in this study indicate substantial G x E interactions for all body weight measurements. Significant G x E interactions for body weights were also reported by several authors in broilers. Sørensen (1977) reported a genetic correlation for body weight at 5 weeks of age for broilers under high and low protein diets to be 0.33. Similarly, in an experiment by Pakdel (2004) studying the effect of cold stress on Ascites (a disease associated with high growth rates in broilers) in broilers reported a genetic correlation between body weight at 6 weeks of age for broilers measured under normal and cold stress to be 0.56. Substantial G x E interaction were also reported for egg production and related traits by Mukherjee (1980) in egg type chickens evaluated in Berlin, Germany (Temperate climate) and Kuala Lumpur, Malaysia (Tropical environment) with genetic correlations between the same trait in the two environments ranged from 0.41 to 0.64. The existence of significant G x E interaction for the same trait measured in two environments indicates that different sets of genes and involved in the expression of the traits in the two environments

(Sørensen, 1977; Hohenboken, 1985; Togashi *et al*., 2001; Lin and Togashi, 2002; Mulder and Bijma, 2005; Charo-Karisa, 2006). Hence improvement obtained in one environment would not be fully realized in another environment where G x E interaction is significant.

Majority of poultry farmers in the country are smallholder farmers rearing their chickens under extensive management (Msoffe, 2003; Lwelamira, 2007). Since G x E interactions for body weights for *Kuchi* chicken ecotype obtained in this study were substantial, this suggest that selection for improving performance of *Kuchi* chicken ecotype for use by farmers should be carried out under extensive management to counteract effect of G x E (Sorensen, 1999; Mulder and Bijma, 2005; Charo- Karisa, 2006; Lwelamira, 2007; Nauta, 2009). However, such breeding program can be expensive and difficult to implement as it would require close supervision in recording and mating processes. The need for large pedigreed population together with the need to minimize environmental variations if selective breeding program is to be implemented (Besbes, 2009), conditions which can hardly be met under smallholder farmers' conditions in tropics are another obstacles for implementing such programs under extensive/ smallholder farmers' condition. Farmers under smallholder conditions are usually occupied with many tasks/activities and hence accurate record keeping under such conditions has proven to be difficult due to lack of time by smallholder farmers. Other factors include ignorance and complexity of recording process (Kiwuwa, 1992; Jaitner *et al*., 2001; Wollny *et al*., 2002; Kosgey, 2004; Lwelamira, 2007). Therefore, alternatively, selection for improving performance of *Kuchi* chicken ecotype can be carried out under intensive management (Central Breeding Station) and distribute selected stock to farmers (Two- tier breeding scheme with closed nucleus). However, farmers would be required to change their current system of management and practice at least semi- intensive system of management to minimize environmental differences and hence minimizing G x E interactions (Sorensen, 1999; Lwelamira, 2007).

Table 3 : Genetic correlations among body weights measured in two environments (i.e. on-station and on-farm management)

Trait	σ^2_{A1}	σ^2_{A2}	r_g
Bwt8	2524	2312	0.745
Bwt12	4341	4275	0.757
Bwt16	4956	5570	0.752
Bwt20	5005	5840	0.753

σ^2_{A1} = Additive genetic variance under intensive management (on- station); σ^2_{A2} = Additive genetic variance under extensive management (on-farm); r_g = Genetic correlation for the same trait measured in the two environment; Bwt8, Bwt12, Bwt16, and Bwt20 = Body weight at 8, 12, 16, and 20 weeks of age, respectively.

IV. Conclusion and Reccomendations

Results for this study indicated substantial G x E interactions for all body weight measurements for *Kuchi* chicken ecotype for two environments under study (on-station and on-farm). Since breeding program for improving performance of the ecotype would be more feasible under on-station (intensive management) and hence more likely to take place on-station, therefore, if such breeding program is to be implemented, sensitization of smallholder farmers (beneficiaries of the breeding program) to shift from their current system of management (extensive management) to at least semi intensive system of management would be inevitable as this would minimize the effect of G x E interaction.

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References Références Referencias

1. Aini, I., 1990. Indigenous chicken production in South-east Asia. World's Poult. Sci. J., 46: 51-57.
2. Alabi, R.A., A.O. Esobhawan and M.B. Aruna, 2006. Econometric determination of contribution of family poultry to women's income in Niger-delta, Nigeria. J. of Central Europ. Agric.,7:753-760.
3. Besbes, B., 2009. Genotype evaluation and breeding of poultry for performance under suboptimal village conditions, World's Poult. Sci. J., 65: 260–271
4. Calus, M.P.L., A.F. Groen and G. De Jong, 2002. Genotype x environment interaction for protein yield in Dutch dairy cattle as quantified by different models. J. Dairy Sci., 85:3115-3123.
5. Charo-Karisa, H., 2006. Selection for growth of Nile Tilapia (*Oreochromis niloticus* L.) in low input environments. PhD Thesis. Wageningen University, Wageningen, The Netherlands. 176pp.
6. Dana, N., 2011. Breeding programs for indigenous chicken in Ethiopia. Analysis of diversity in production systems and chicken populations. PhD thesis, Wageningen University, The Netherlands. 148pp.
7. Dana, N., E.H. van der Waaij and J.A.M. van Arendon, 2011. Genetic and phenotypic parameter estimates for body weights and egg production in Horro chicken of Ethiopia. Trop. Anim. Health Prod., 43:21–28.
8. Falconer, D. S., 1952. The problem of environment and selection. Am. Nat., 86(830): 293-298.

9. Falconer, D.S and T.F.C. Mackay, 1996. Introduction to Quantitative Genetics. 4th Ed. Longman, London, UK
10. Goromela, E.H., R.P. Kwakkel, M.W.A. Verstegen, and A.M. Katule, 2006. Strategies to optimize the use of scavengeable feed resource base by smallholders in traditional poultry production systems in Africa: A review. African J. of Agric. Res. 1 (3): 91-100.
11. Hohenboken, W.D., 1985. Genotype x Environment Interaction. In: *World Animal Science, A basic Information*: *General and Quantitative Genetics* (Edited by Chapman, A.B), Elsevier Science Publishing Company Inc. NY. pp 151-163.
12. Hørning, G., Rasmussen, S., Permin, A. and Bisgaard, M. (2003). Investigations on the Influence of Helminth Parasites on Vaccination of Chickens against Newcastle Disease Virus under Village Conditions. Trop. Anim. Health and Prod., 35(5): 415 – 424.
13. Ibi, T., H. Hirooka, A. K. Kahi, Y. Sasae and Y. Sasaki, 2005. Genotype x environmental interaction effects on carcass traits in Japanese Black cattle. J. Anim. Sci., 83:1503-1510.
14. Illango, J., W. Olaho-Mukani, G. Mukiibi-Muka, P.P. Abila and A. Etoori, 2005. Immunogenecity of a locally produced Newcastle disease I-2 thermostable vaccine in chickens in Uganda. Trop. Anim. Health. and Prod., 37: 25-31.
15. Jaitner, J., J. Sawe, E. Secka-Njie, L. Dempfe, 2001. Ownership pattern and management practices of small ruminants in The Gambia – Implication for breeding programme. Small rumin. Res., 40: 101 - 108.
16. Kiwuwa, G.H., 1992. Breeding strategies for small ruminant productivity in Africa. In. Rey, B, Lebbie, S.H.B, Reynolds, L (Eds). Small ruminant research and development in Africa, Proceeding of the First Biennial Conference of the Africa Small Ruminants Research Network, ILRAD, Nairobi, Kenya, 10-14 December,1990, pp. 423 -434.
17. Kosgey, I. S., 2004. Breeding objectives and breeding strategies of small ruminants in tropics. PhD thesis, Wageningen University, The Netherlands. 272pp.
18. Lawrence, P.M.M., 1998. Ecotypes and natural disease resistance among scavenging local chickens of Tanzania. M.Sc. thesis. The Royal Veterinary and Agricultural University (RVAU), Copenhagen, Denmark. 97pp.
19. Lin, C.Y. and K. Togashi, 2002. Genetic improvement in the presence of genotype by environment interaction. Anim. Sci. J., 73: 3-11.
20. Lwelamira, J., 2007. Prospects for improving performance among two local chicken ecotypes of Tanzania through selection. PhD thesis, Sokoine University of Agriculture, Morogoro, Tanzania, 204pp. Lwelamira, J., G.C. Kifaro and P.S. Gwakisa 2008.
21. On station and on-farm evaluation of two Tanzania chicken ecotypes for body weights at different ages and for egg production. African J. of Agric. Res., 3 (12): 843-851.
Lwelamira, J., G.C. Kifaro and P.S. Gwakisa, 2009.
22. Genetic parameters for body weights, egg traits and antibody response against Newcastle Disease Virus (NDV) vaccine among two Tanzania chicken ecotypes, Trop. Anim. Health and Prod., 41: 51–59.
23. Magwisha, H.B., A.A. Kassuku, A.A, N.C. Kyvsgaard and A. Permin, 2002. A comparison of the prevalence and burdens of helminth infections in growers and adult free-range chickens. Trop. Anim. Health and Prod., 34 (3): 205 – 214.
24. Maniatis, N and G. E. Pollott, 2002. Genotype by environment interactions in lamb weight and carcass composition traits. Anim. Sci., 75: 3-14.
25. Msoffe, P.M.M., 2003. Diversity among local chicken ecotypes in Tanzania. PhD Thesis. Sokoine University of Agriculture, Morogoro, Tanzania, 223pp.
26. Muchadeyi, F.C., C.B.A. Wollny, H. Eding, S.Weigend, S.M. Makuza and Simianer, H., 2007. Variation in village chicken production systems among agro-ecological zones of Zimbabwe. Trop. Anim. Health and Prod., 39: 453-461.
27. Muchadeyi, F.C., S. Sibanda, N.T. Kusina, J.F. Kusina, J.F. and S.M. Makuza, 2005. Village chicken flock dynamics and contribution of chickens to household livelihoods in smallholder farming area in Zimbabwe. Tropic. Anim. Health and Prod., 37 (4): 333-344
28. Mukherjee, T.K., P. Horst, D.K. Flock and J. Petersen, 1980. Sire x location interactions from progeny tests in different countries. *British Poultry Science* 21: 123-129.
29. Mulder, H.A. and Bijma, P, 2005. Effect of genotype x environment interactions on genetic gain in breeding programs. J. of Anim. Sci., 83: 49-61.
30. N'dri, A.L., N. Sellier, M. Tixier- Boichard, C. Beaumont, S. Mignon- Grasteau, 2007. Genotype by environment interactions in relation to growth traits in slow growing chickens. Gen. Sel. Evol. 39: 513–528
31. Nauta, W.J., 2009. Selective Breeding in Organic Dairy Production. PhD thesis, Wageningen University, The Netherlands. 160pp.
32. Otim, M.O., 2005. Newcastle disease in village poultry: Molecular and phylogenetic studies of the virus and disease epidemiology. PhD thesis. The Royal Veterinary and agricultural University (RVAU), Copenhagen. Denmark. 140pp.
33. Pedersen, C.V., 2002. Productivity of semi-scavenging chickens in Zimbabwe. PhD Thesis. The Royal Veterinary and Agricultural University (RVAU), Copenhagen, Denmark. 133pp
34. Robertson, A., 1959. The sampling variance of the genetic correlation coefficient. Biometrics., 15: 469-485.

35. Rosa dos Anjos, F., 2005. Effect of scavenging feed resource base on prevalence of parasites and performance of chickens in Sussundenga District, Mozambique. M.Sc. Thesis. The Royal Veterinary and Agricultural University (RVAU), Copenhagen, Denmark. 81pp.
36. Statistical Analysis System (SAS). 2000. SAS/STAT Users' Guide, Release 6.12 Edition, SAS Institute Inc, Cary, North Carolina. USA.
37. Sørensen, P., 1977. Genotype- Level of protein interaction for growth rate in broilers. Bri. Poult. Sci., 18:625-632.
38. Sørensen, P., 1999. Interaction between breeds and environments.In: *Poultry as a tool in poverty eradication and promotion of gender equality*. Proceedings of a workshop, held on march, 22-26, 1999, Tune Landboskole, Denmark, pp 145-150.
39. Togashi, K., C.Y. Lin and K. Moribe, 2001. Construction of optimum index to maximize overall response across countries in the presence of Genotype x Environment interaction. J. of Dairy Sci., 84: 1872 – 1883.
40. Tolon, B. and S. Yalcin. 1997. Bone characteristics and body weight of broilers in different husbandry systems. Br. Poult. Sci. 38:132-135.
41. Wollny, C.B.A., J.W. Banda, T.F.T. Mlewah and R.K.D. Phoya, 2002. The lessons of livestock improvement failure: Revising breeding strategies for indigenous Malawi sheep?. In: Proceeding of the seventh World Congress on Genetics Applied to Livestock Production, Vol 3, Montpellier, France, 19 -23 August 2002, pp. 345- 348.