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Research Article

On-Farm Performance Evaluation of Koekoek Layers Chicken in West Arsi Zone of Oromia, Ethiopia

Nebi Husein*, Usman Abdulkedir, Beshir Husein, Tesfa Geleta

Oromia Agricultural Research Institute, Adami Tulu Agricultural Research Center, Poultry Research Team, Batu, Ethiopia

Abstract

This study was conducted with the objective of evaluating the egg production performance and egg quality of Koekoek chicken breed under farmer management conditions with locally formulated rations and determines the economic feasibility. Chickens were managed under a semi-scavenging system and supplemented with a locally formulated diet, except for one household which served as a control (no formulated ration). The ingredients used were maize (35%), soybean (20%), wheat bran (19.5%), noug cake (22%), salt (1.5%), premix (1%), and limestone (1%). Each bird received 90 g of the formulated feed daily. A total of 240 Koekoek chickens (200 pullets and 40 cockerels) were distributed and purposive sampling approach was employed to select 20 smallholder farmers (10 from each district) in collaboration with Development Agents, and Kebele leaders. Results showed that formulated ration feeding improved survival rate and egg production performance. Nagele Arsi had a higher survival rate (95%) compared to Kofele (78%). Egg production per hen per year increased with ration, from 122 to 180 eggs in Kofele and from 183 to 222 eggs in Nagele Arsi. While egg quality parameters (egg length, egg width, and yolk color and shell weight) showed no statistically significant differences, egg weight, albumen weight and shell thickness was improved with formulated ration. Formulated ration improved the economic performance of Koekoek layers under farmer management conditions. Farmers perceived Koekoek chickens as more productive when supplemented, less broody, and resilient to disease and predatory compared to local breeds. The study concludes that locally formulated ration improves egg productivity from 153-201, income and survival of Koekoek layer chickens under smallholder management conditions.

Keywords

Egg, Farmer Management, Koekoek, Semi-scavenging and Supplementary Feed

1. Introduction

Poultry production plays a vital role in improving household income, food security, and nutrition in Ethiopia, particularly under smallholder farming systems where chickens are a major source of animal protein and cash income [23]. Among different poultry species, chickens are the most dominant, accounting for over 96% of the total poultry population in the country, with the majority being indigenous ecotypes managed under traditional systems [6]. Despite their wide distribution and adaptability, indigenous chickens are characterized by low productivity in terms of egg production, growth rate, and maturity age, which constrains their contribution to household livelihoods [15].

*Correspondence: Nebi Husein (nabihusein2008@gmail.com)

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To address these challenges, improved and dual-purpose chicken breeds have been introduced into different agro ecologies of Ethiopia. One such breed is the South African Koekoek chicken, known for its dual-purpose traits, including higher egg production, faster growth rate, and adaptability to semi-scavenging systems [10]. Previous studies have indicated that Koekoek hens can produce 170-200 eggs annually under smallholder conditions, outperforming local ecotypes, while also providing better carcass yield [2, 12].

In Oromia region, particularly in the West Arsi Zone (Kofele and Nagele Arsi Districts), poultry farming is an important livelihood strategy. However, limited research has been conducted to evaluate on-farm performance of Koekoek under farmers' management and varying agro-ecological conditions. Assessing their productivity, survivability, and adaptability at the farm level is essential for informing sustainable poultry development interventions.

Therefore, this study was designed to evaluate the on-farm performances of the Koekoek breed chickens on egg production, Egg quality and survivability under smallholder management conditions through partially supplementation of locally formulated feed and to determine economic feasibility.

2. Materials and Methods

2.1. Descriptions of Study Area

The study was conducted Nagele Arsi and Kofele districts. Nagele Arsi and Kofele have a midland and highland agro-ecologies respectively. Arsi Negelle district is located at 38˚25′ E to 38˚54′ E and 07˚09′ to 07˚41′ N, with altitudes ranging from 1,500 to 3,070m above sea level and characterized with a sub humid agroecology. The mean annual rainfall of the district is 825mm. Kofele is located at latitude and longitude of 7°00′N 38°45′E with an elevation of 2695 meters above sea level.

2.2. Farmers' Selection and Training

Farmers were selected in collaboration with Subject Matter Specialist (SMS), Development Agents (DAs) and Kebele leaders. Purposive sampling was used for farmer selection depending up on their accessibility to main road for ease monitoring and data collection, chicken-keeping practice, ability to manage experimental chickens, interest to build night shelter, willing to accept and necessary management for experimental chickens throughout experimental period and able to give required information.

Training on chicken management like feeding (ration formulation), egg handling, watering, data recording, health care, hygiene and house construction was given for farmers, SMS and DAs at farmer training center. From the trained farmers ten (10) farmers were selected and totally twenty (20) farmers were selected from the two districts. After training the selected farmers constructed separated poultry house from locally available materials. All construction and bedding materials used in poultry house were supplied by farmers. Feeders and watering equipment's were also supplied by farmers. Finally one leader was selected from households to monitor on chicken management and data collection process from each study districts.

2.3. Experimental Feed and Feeding

The experimental chickens were supplemented with the recommended locally formulated ration [18] except one household. One household was used as control (managed the chickens without formulating supplementary feed). The ingredient used were maize 35%, Soybean 20%, wheat bran 19.5%, Noug cake 22%, salt 1.5%, premixes 1% and 1% limestone. The experiment chickens were supplemented with 90g of experimental of feed per day (half was provided in the morning and half was in the afternoon) and others feed ingredients were assumed to be obtained from scavenging. Farmers were managed intensively for four months. During experimental periods chickens were managed under semi-scavenging system.

2.4. Experimental Chicken Management

The experimental chickens were fed on locally formulated experimental diet during growing based on their requirement. Vaccinations were given for experimental chickens against NCD, Gomborro and Fowl Pox. At about five months of age's chickens with uniform performance were selected and distributed to households. In this study a total of 240 (200 females and 40 males) Koekoek layer chickens with the ratio (5F: 1M) were distributed. Each household were received 10 pullets and 2 cockerels.

2.5. Data Collection

Egg laid were collected by households every day and stored properly until counted and recorded by the numerator. After record the farmer used it either for selling or for home consumption. Mortality and disease observed also recorded by numerator and researchers. Eggs quality parameters were determined from fresh and clean 200 eggs (100 eggs from each study sites) and ten (10) eggs collected from each household. Eggs were weighed using an electronic digital balance at 50% egg production. The yolk weight was taken after gently separated the yolk from the albumen and the differences between [egg weight- (shell weight + yolk weight)] were considered as albumen weight. Egg length, egg width and eggshell thickness were measured using electronic digital caliper and Yolk color was determined by adjusting the score of yolk color on color fan from Roche [21].

Hen-Day Egg Production (HDP)

Measures the percentage of hens laying eggs on a given day

$$\text{HDEP (\%)} = (\text{Number of eggs collected per day/Number of hens present on that day}) \times 100$$

Hen-Housed Egg Production (HHP)

Measures egg production based on the original number of hens housed.

HHEP (%)=(Total number of eggs collected during the period/Number of hens housed at the beginning ×Number of days) ×100

Percentage Change in Egg Quality Due to Formulated Ration

Measures the improvement or reduction in egg quality compared with the farmer's practice.

Egg Quality Change (%)=(Value under Formulated Ration−Value under Farmer Practice/Value under Farmer Practice) ×100

Mortality Rate (%)

Measures the proportion of birds that died during the experimental period.

Motalty Rate (%) = (Number of birds died during the experimental al period/Total bird population at the beginning of the experiment) ×100

2.6. Partial Budget Analysis

Partial budget analysis was undertaken by following the procedure outlined by [24] to determine the profitability of Koekoek layer chickens distributed to farmers and managed under on-farm conditions with and without supplementary feeding. The total variable costs (TVC) for the supplementary group were computed based on the prices of locally formulated feed ingredients, namely Maize (4,250 ETB), Soybean (9,000 ETB), Wheat bran (3,600 ETB), Noug cake (5,500 ETB), Limestone (2,100 ETB), Salt (2,200 ETB), and Premixes (12,000 ETB) per quintal. Bedding and house construction materials were 150 and 8000 ETB, respectively and they were from locally available materials. Additionally, medication expenses amounted to 450 ETB and 250 ETB in Kofele and Nagele Arsi districts, respectively.

In contrast, the farmers groups were provided with low-quality feed below recommended ration per day per hen from household left over and cereal grains, predominantly Maize (4,000 ETB per quintal) and Barley and Wheat (3,800 ETB per quintal). The total revenue (TR) was derived from the sale of eggs, with an average market price of 20 ETB per egg during the experimental period. The net return (NR) was determined using the relationship:

NR = TR-TVC Where NR = Net Return, TR = Total Revenue and TVC = Total Variable Cost.

2.7. Statistical Analysis

All data collected during the experimental period were entered into Microsoft Excel 97-2003. The collected data was analyzed using the descriptive statistics such as mean and percentage.

3. Results and Discussions

3.1. Mortality and Survival Rate

Numbers of chickens distributed to the study districts, survived and died is presented in Table 1. There is a highly significant difference in survival rates among districts ($p < 0.001$), with supplementary feed vs without supplementary feed), and sexes. Chickens in Nagele Arsi district had higher survival rates. The current finding agrees with the report of [7] who observed location and agroecology strongly affect chicken survival in Ethiopia. Layers with supplementary feed generally performed better than those managed without supplementary feed. This line with findings by [4] and [16] who reported that supplementary feeding significantly enhances survival in village chicken production systems. Overall survival rate at Kofele district was 78% and at Nagele Arsi was 95%.

The survival rate of current study was higher than the finding of [19, 20] who reported around 31% mortality rate in Dugda district under farmer's managements. This difference might be due to better hygiene, age of distribution, improved shelter, types of feed supplemented and care provided by the households. The current mortality rate recorded in Nagele Arsi district was similar with report of [11]. The survival rate of the Koekoek breed up to eight weeks of age under a smallholder farmer's condition was 88.3% according to [17] in Sidama zone of Ethiopia.

Table 1. *Numbers of Chickens Distributed and Survived at Nagele Arsi and Kofele districts.*

Districts	Treatments	Sex	Distributed	Survived	Survival rate (%)	Over survival rate (%)	P-value
Kofele	Formulated Ration	F	90	75	83.3	78.3	0.024
		M	18	12	66.7		
	Farmer practice	F	10	6	60		
		M	2	1	50		

Districts	Treatments	Sex	Distributed	Survived	Survival rate (%)	Over survival rate (%)	P-value
Nagele Arsi	Formulated Ration	F	90	87	96.7	95.0	0.013
		M	18	17	94.4		
	Farmer practice	F	10	8	80		
		M	2	2	100		

3.2. Egg Production Performance

Egg production performance of Koekoek breed is presented in the Table 2. In both districts, supplementary feeding increased egg production across all parameters; Hen Day Production (HDP%), Hen House egg Production (HHP%), total eggs and eggs per hen per year. The difference is more pronounced in Nagele Arsi than in Kofele district, with higher performance values and stronger statistical significance. In Kofele district egg production increased from 122 eggs (no supplement) to 180 eggs with supplementation and in Nagele Arsi district egg production was increased from 183-222 due to providing supplementary feed additionally on scavenging. These variations might be due to climate, back yard scavenging feed availability and husbandry practices. The average egg production in Kofele (151 eggs/hen/year) was lower than the findings of [18], who reported 213 ± 12.4 eggs at the Adami Tulu Agricultural Research Center. However, values obtained in Nagele Arsi (203 eggs/hen/year) slightly agree with their results. These variations might be attributed due to differences in agro-ecological conditions, feed quality and overall management practices. Moreover, the current study's results were found in the range reported by [14], who reported 180-240 eggs/hen/year under smallholder management conditions in the Tigray Region. The only exception is the un-supplemented experimental group in Kofele district was below this range.

Table 2. *Egg Production Performance of Koekoek Chicken at Nagele Arsi and Kofele Districts.*

Districts	Treatments	Parameters		Eggs/hen/year	P-Value
		HDP%	HHP%		
Kofele	Formulated ration	49.12	49.33	180	0.037
	Farmer practices	40.81	33.33	122	0.019
Nagele Arsi	Formulated ration	60.34	60.92	222	0.042
	Farmer practices	51.34	50	183	0.011

3.3. Egg Quality Characteristics Performance

The egg quality characteristics of the Koekoek breed under farmers' management conditions are summarized in Table 3. Comparative analysis of egg quality traits between Formulated ration (and Farmer practice feeding groups in Kofele and Nagele Arsi districts revealed variable responses across several parameters. Most of the measured parameters including egg length, egg width, shell weight, and yolk color did not show statistically significant differences ($P > 0.05$). However, Egg weight, albumen weight and yolk weight showed a significant difference in both locations under applied treatments. Egg weight showed statically significant ($p < 0.05$) in both study agro ecology and under both experimental feeds, which recorded (+4.29% in kofele and +3.53% in Nagele Arsi districts). Supplementary feeding enhances nutrient intake, leading to heavier eggs [3, 13]. Additionally, agro-ecological conditions such as climate, forage availability and altitude affect nutrient metabolism and egg formation, resulting in regional variations in egg weight [7, 19].

The average egg weights recorded in this study are consistent with previous findings reported by [19] and [8], who documented egg weights of 44.28 ± 2.96 g and 47.08 g, respectively, under farmer management conditions. Moreover, the results of the current study are higher than those reported by [5], who reported an average egg weight of 40.30 g for Koekoek chickens raised in and around Mehoni, Southern Tigray Zone, Ethiopia. These comparisons suggested that management practices and agro-ecological differences play a

significant role in determining the egg quality of Koekoek chickens.

Egg width increased slightly in Kofele (+1.64%), but slightly decreased in Nagele Arsi (–0.77%). The overall result indicated statistically non-significant. Egg shape and size are not strongly influenced by feeding type, and might be more genetically determined [22]. Statistically significant difference was observed in shell thickness in both study districts. Shell weight remained constant across both systems and districts, with no significant difference detected. Highly significant difference was observed in albumin weight between the two feeding systems. Improved dietary protein and more nutrient intake were improved internal egg components, particularly albumen [1, 9, 13]. Yolk color was numerically higher in formulated supplementary experimental group. However, differences were not statistically significant, indicating that carotenoid levels in both diets were likely similar. Yolk color is extremely influenced by intake of green forages [9].

Table 3. *Egg Quality Characteristic of Koekoek Chicken at Nagele Arsi and Kofele Districts.*

Parameters	Kofele		Change%	Nagele Arsi		Change%	P-Value
	FR	FP		FR	FP		
Egg weight (g)	47.17	45.23	+4.29%	46.94	45.34	+3.53%	0.039
Egg length (mm)	54.59	53.72	+1.62%	54.54	53.97	+1.07%	0.561
Egg width (mm)	40.30	39.65	+1.64%	40.12	40.43	-0.77%	0.892
Shell thickness (mm)	0.38	0.34	+10.53%	0.40	0.39	+2.56%	0.018
Shell wt (g)	5	5	0%	5	5	0%	0.775
Albumin Wt (g)	33.67	20.70	+62.6%	33.64	31.2	+7.87%	0.0036
yolk Wt (g)	15.83	20	-20.85%	18.9	17.8	+6.18%	0.043
yolk color (1-15)	6.42	6	+10.5%	6.35	6	+8.75%	0.91

g= gram, mm = millimeter, Wt= weight, FR= Formulated Ration, FP = Farmer Practices

3.4. Partial Budget Analysis

Variable costs and growth revenue of Koekoek layers under farmer management condition with Formulated ration and farmer practices are presented in Table 4. The economic analysis showed difference was observed in profitability between formulated ration and farmer practices management across both study districts. In Kofele District, the total feed cost was higher for the formulated ration (32,603.5 ETB) compared to the farmer practices (23,904 ETB). A similar trend was observed in Nagele Arsi District, where the formulated ration birds earned higher feed costs (40,050.41 ETB) than the farmer practices (33,956ETB). However, these additional costs were compensated by higher revenues in the formulated ration groups.

In both districts, the total revenue and growth revenue of formulated ration birds were significantly higher. Supplemented with balanced diet flocks in Kofele generated 66,600 ETB compared to 45,000 ETB for farmer practices, while in Nagele Arsi district, the revenue was 95,400 ETB versus 79,200 ETB, respectively. This indicates that feed Formulated ration improved market weight and overall profitability.

The marginal rate of return (MRR) was higher in the formulated ration in both districts, 1.62 in Kofele and 1.97 in Nagele Arsi and also high in Nagele Arsi under farmer practices. These figures show that each additional unit of cost in formulated ration resulted in proportionally higher revenue, especially in Nagele Arsi, where environmental and management conditions likely enhanced feed utilization efficiency. Supplementation with nutritionally balanced rations improved feed conversion efficiency, egg production, and profitability of dual-purpose chickens under smallholder conditions [2].

Table 4. Partial Budget Analysis of Koekoek Layer Chickens (ETB).

Variable cost	Kofele District		Nagele Arsi District	
	Formulated ration	Farmer practice	Formulated ration	Farmer practice
Total feed	32603.5	23904	40050.41	33956
Bedding materials	150	150	150	150
House construction	8000	8000	8000	8000
Medication	450	450	250	250
Total Variables cost	41203.5	32504	48450.41	42428
Total return	66600	45000	95400	79200
Net return/HHs	25396.5	12496	46949.6	36772
MRR	1.62	1.38	1.97	1.87

3.5. Households' Perception

Farmers highly appreciate Koekoek chickens breed for their exceptional performance and resilience. They are noted for producing larger eggs with stronger shells, which command higher prices in local markets. Their low tendency to brood ensures continuous egg production, while their resistance to common diseases and reduced vulnerability to predators make them easier to manage under smallholder conditions. Overall, Koekoek chickens are perceived as a valuable breed that enhances household nutrition and income.

4. Conclusion and Recommendation

The study indicated a significant difference in survival rates feeding practices. Nagele Arsi district showing higher survival rate and lower as compared to Kofele district. Formulated ration feeding groups performed significantly better under farmer-managed conditions in both study agro-ecologies.

Formulated ration feeding improves egg production performance of the Koekoek breed, across both districts, birds received locally formulated ration increased HDP, HHP, total eggs, and eggs per hen per year. The effect was more observed in Nagele Arsi district, where better agro-ecological and management might have enhanced the impact of supplementation.

The egg quality characteristics of the Koekoek breed under smallholder management showed limited response between feeding. Egg quality including egg length, width, shell weight, and yolk color did not differ significantly between feeding groups, this indicate feed supplementation had minimal impact on these quality parameters. The only traits with significant differences were recorded from egg weight, albumen weight, and yolk weight and shell thickness.

Locally formulated ration improved the economic performance of Koekoek layers under farmer management conditions in both Kofele and Nagele Arsi districts. Although the total variable and feed costs were higher in the supplemented groups, these additional expenses were outweighed by the increase in total and growth revenues. The higher marginal rate of return values in the supplemented groups indicated that feed supplementation is economically viable and profitable. Among the two districts, Nagele Arsi exhibited a relatively better profitability margin, suggesting that local environmental and management conditions favored efficient feed utilization and productivity improvement. Therefore, promoting the Koekoek breed along with locally formulated feed supplementation can play a vital role in enhancing smallholder poultry production and rural livelihoods in Ethiopia.

Abbreviations

DAs Development Agents
ETB Ethiopian Birr
HDP Hen Day Egg Production
HHP Hen House Egg Production
HHs House Holds
MRR Marginal Rate of Return
SMS Subject Matter Specialist

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Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Abudabos, A. M. 2017. Effect of dietary protein level on performance and egg quality of laying hens under high ambient temperature. Journal of Applied Animal Research, 45(1), 205–209.

[2] Aklilu Hailemichael, Berhanu Gebremedhin and Azage Tegegne, 2017. Status and drivers of village poultry production and its efficiency in Ethiopia, NJAS: Wageningen Journal of Life Sciences, 83: 1, 30-38, https://doi.org/10.1016/j.njas.2017.09.003

[3] Alemayehu, T., Bruno, J., and Getachew, F. 2018. Performance of different chicken breeds under farmers' management in Ethiopia. Livestock Research for Rural Development, 30(3).

[4] Alemayehu, T., Getabalew, M., and Abebe, A. 2018. Village chicken production systems in Ethiopia: Characteristics and constraints. International Journal of Livestock Production, 9(3), 37–46.

[5] Atsbaha Hailemariam, Angesom Taye, Haftom Miglas, Challa Edea, Alemayehu Amare, Tadios Habte, Bethelihem Siyum, and Dawd Ibrahim. (2018). Evaluation and Demonstration of Potchefstroom Koekoek Chicken in and Around Mehoni areas of Southern Tigray Zone, Ethiopia. Global Journal of Science Frontier Research: Agriculture and Veterinary, 18(3) Versions.

[6] Central Statistical Agency (CSA). 2021. Agricultural Sample Survey 2020/21. Addis Ababa, Ethiopia.

[7] Dana, N., van der Waaij, L. H., Dessie, T., & van Arendonk, J. A. 2010. Production objectives and trait preferences of village poultry producers of Ethiopia: Implications for designing breeding schemes utilizing indigenous chicken genetic resources. Tropical Animal Health and Production, 42, 1519–1529.

[8] Elias Gonta Gobena, 2020. Adaptation and performance evaluation of “Potchefstroom Koekoek” chicken breeds under farmer’s management practice in Debub Ari and Bena-Tsemay districts of South Omo Zone, Ethiopia. Journal of Science and Development, JSD Vol. 8.

[9] Getu, A., Tadesse, D., and Alemayehu, T. 2019. Effect of supplementation on egg quality traits of local chickens under scavenging system in Ethiopia. International Journal of Livestock Production, 10(4), 81–87.

[10] Mtileni, B. J., Muchadeyi, F. C., Maiwashe, A., et al. (2012). Conservation and utilization of indigenous chicken genetic resources in Southern Africa. World’s Poultry Science Journal, 68, 727–748.

[11] Mulualem Ambaw and Mezgeb Werkiy 2021. Demonstration and Performance Evaluation of Dual Purpose "Potchefstroom koekoek" Chickens Under Farmers’ Management Conditions in the High Land Areas of Arsi zone, Oromiya Region. Journal of Economics and Sustainable Development.

[12] Nigussie, H., Dessie, T., Dana, N., and van Arendonk, J. A. M., 2015. Production objectives and trait preferences of village poultry producers of Ethiopia: implications for designing breeding schemes utilizing indigenous chicken genetic resources. Tropical Animal Health and Production, 47, 447–457.

[13] Roberts, J. R., 2004. Factors affecting egg internal quality and egg shell quality in laying hens. Journal of Poultry Science, 41(3), 161–177.

[14] Shumuye Belay, Mehari Resom, Haftom Yemane and Haileslassie Amare., 2018. Production performance evaluation of koekoek chicken under farmer management practice in Tigray region, northern Ethiopia. International Journal of Livestock Production, Vol. 9(9), pp. 232-237.

[15] Tadelle, D., Million, T., Alemu, Y., Peters, K. J. 2003. Village chicken production systems in Ethiopia: 1. Flock characteristics and performance. Livestock Research for Rural Development, 15(1).

[16] Tadesse, H., Esatu, W., Girma, M., 2020. Survival and performance of improved chicken breeds under smallholder management in Ethiopia. Tropical Animal Health and Production, 52, 1295–1303.

[17] Tekalegn Yirgu, Etalem Tesfaye. Alemayehu Amare and Misba Alewi., 2019. On-Farm Evaluation and Demonstration of Dual Purpose Chicken “Potchefstroom koekoek” Technology Packages in Sidama Zone, Ethiopia, World Journal of Agricultural Sciences 15 (5): 317-323.

[18] Tesfa Geleta, Usman Abdulkadir, 2018. Production performance evaluation of Koekoek chickens at Adami Tulu research center. African Journal of Agricultural Research. Vol. 13 (35), pp. 1852-1856.

[19] Tesfa Geleta, 2020. Production Performance of Koekoek Chickens Under Backyard Management Conditions. International Journal of Biomedical Materials Research. Vol. 8, No. 2, pp. 25-28. https://doi.org/10.11648/j.ijbmr.20200802.13

[20] Tesfa, M., 2020. Performance of improved chicken breeds under farmers’ management in the Central Rift Valley of Ethiopia. African Journal of Agricultural Research, 15(3), 344–352.

[21] Vuilleumier, J. P. 1969. The "Roche Yolk Color Fan" An instrument for measuring yolk color. Poultry Science, 48(3), 767–779.

[22] Yassin, H. Hupfer, C. Siering and Schumann, P, 2011. Factors affecting egg quality in different production systems. *Poultry Science Journal*, 90(5), 1207–1215.

[23] Halima, H. (2007). Phenotype and genetic characteristics of indigenous chicken populations in North West Ethiopia. PHD Thesis, submitted to University of Free State, Bloemfontein, South Africa, pp: 186.

[24] Upton, M., 1979. Farm Management in Africa: The principle of production and planning. Oxford University press, Great Britain, 282–98.