

*Full Length Research Paper*

# Comparative study on some egg quality traits of exotic chickens in different production systems in East Shewa, Ethiopia

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A total of 227 eggs were collected during summer 2013 from Isa Brown (IB), Bovan Brown (BB) and Potchefstroom Koekoek (PK) chickens for comparative study of internal and external egg quality traits under intensive and village production systems in East Shewa, Ethiopia. The data collected was analyzed using SPSS and significant differences in egg quality traits were compared using post hoc multiple comparisons. Average egg weight, Haugh Unit, shell thickness, yolk colour, albumen weight, yolk percent and yolk to albumin ratio of IB showed a significant difference ( $p < 0.05$ ) under intensive and village production systems. BB showed a statistical significant difference ( $p < 0.05$ ) for egg weight, yolk height, albumen height, yolk colour, Haugh Unit, shell thickness, yolk percent and albumen percent under intensive and village production systems. Further, average yolk height, yolk weight, yolk color, yolk percent and yolk to albumen ratio of PK revealed a significant difference under village and intensive production systems. The study revealed that even though the differences were observed in egg quality traits under intensive and extensive system, eggs produced from village were also found to be good quality.

**Key words:** Egg quality traits, exotic chicken, intensive and village production system.

## INTRODUCTION

Worldwide, 80% of the total chicken populations are found in village poultry production system (Alabi et al., 2006), indicating the importance of village chicken production for the development rural economy. In Ethiopia, total poultry population at country level is estimated to be 50.38 million and with regard to breed, 96.9, 0.54 and 2.56% were reported to be indigenous, hybrid and exotic chickens, respectively (CSA, 2013). From the total population of chicken, 99% are raised under the traditional backyard system of management,

while 1% is under intensive management system (Solomon, 2007). The poultry sector can be characterized into village or backyard, small scale and large scale commercial poultry production system (Dawit et al., 2008).

Embryo development is dependent on the egg quality traits such as egg weight, yolk and albumen weights, genetic line and age of the hen (Onagbesan et al., 2007), besides egg weight is one of the important phenotypic traits that influence egg quality and reproductive fitness of

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the chicken (Islam et al., 2001; Farooq et al., 2001). Eggshell thickness is an important trait for hatchability; in which hatchable egg thickness lies between 0.33 and 0.35 mm and few eggs with a shell thickness less than 0.27 mm will hatch (Khan et al., 2004). In addition, marketability of eggs entirely depends on eggshell thickness and strength, as poor eggshell quality results in millions of dollars of loss in USA (Roland, 1988). Even though, it is subjective and varies from country to country, yolk color remains to be key a factor for consumer acceptability (Okeudo et al., 2003). Further, the egg is probably the food item most frequently involved in outbreaks of foodborne infections with *Salmonella species* as ethiological agent (Gast et al., 2005; Gantois et al., 2009). Several factors affect penetration of the egg by *Salmonella species*, but the common factors includes the quality of eggshell, albumen and yolk (Messens et al., 2004).

With the aim of improving poultry productivity exotic chickens such as Isa Brown (IB), Bovan Brown (BB) and Potchefstroom Koekoek (PK) were distributed to smallholder farmers in Ada'a and Lume districts of East Shewa Zone, Ethiopia (Tadesse et al., 2013). In the layer reference for more than 30 years everywhere in the world, IB is the most efficient layer in the poultry industry producing many high quality eggs and adapts itself to all climates and environments (ISA, 2010). The PK was bred from crosses between the Black Australorp and the White Leghorn in South Africa and is one of the most promising breeds. It is also second to White Leghorn, Fayoumi in terms of hen-housed egg production per hen and hatchability, respectively (Grobbelaar et al., 2010).

Despite the benefits of quality eggs, common surveys and previous research works conducted by Tadelles et al. (2003), Moges et al. (2010) and Mengesha et al. (2011) indicated village poultry farmers have low awareness to sort eggs for different purposes such as for hatching, marketing and home consumption purposes. Hence a considerable portion of eggs will be lost because of indiscriminate use of eggs rather than sorting eggs for different purposes. The egg quality could be affected by the production system among others. Thus, comparison between eggs from village and intensive production system would help researchers to suggest possible intervention options to improve quality of eggs in different production systems. Thus, the present study was designed with the objective to compare egg quality traits of three exotic chickens under intensive and village poultry production systems in East Shewa Zone of Oromiya, Ethiopia.

## MATERIALS AND METHODS

### Management of chickens

Under village production system, more than 90% of farmers provided separate housing for their chicken in Lume and Ada'a districts. Chickens scavenge feed materials such as kitchen

wastes, insects, worms and agricultural leftovers. Maize and wheat were provided three times a day (morning, noon and evening) in addition to the normal scavenging by 95% farmers in both districts. Similarly, water was provided as free access by more than 96% of the farmers in both districts. Under intensive system, the housing management was based on semi-opened deep litter system, fed on commercial balanced ration and with standard feeder and watering facility in both private and government poultry farms sampled.

### Egg sample collection and evaluation

From village production system, a total of 137 fresh eggs (57 from IB, 56 from BB and 24 from PK) were collected from adult laying hens from six Peasant Associations (PA's) (Momoshoki, Byobiskie and Jogogudedo) in Lume and (Denkaka, Kurkuradenbi and Godino) in Ada'a districts for egg quality evaluation. Further, under intensive production system a total of 90 freshly laid eggs from three breeds (30 from each) were collected from two privately owned farms for IB and BB and from a government owned intensive farm for PK. A total 227 eggs were collected from both production systems for evaluation of internal and external egg quality traits at Debre Zeit Agricultural Research Institute (DZARC) laboratory.

### Data collection

External egg quality traits such as egg weight were measured using digital balance (g) and shell thickness (mm) using an electronic Digital Caliper (Mitutoyo, Japan). The shell thickness was measured at three different points in the equatorial shell and the calculated average of the three was taken as a trait. To determine the internal egg quality traits, eggs were broken onto a flat surface. The thick albumen height (AH) was measured at its widest part at a position half way between the yolk and the outer margin. Yolk height was measured using Tripod Micrometer (TSS, England). The yolks were carefully separated from the albumen. Albumen and yolk weight were determined by weighing with electronic sensitive balance (Sartorius, Germany) separately. The yolk colour was determined using the Roche Colour Fan (Printed in Switzerland); a standard colorimetric system ranged from 1 to 15. Individual Haugh Units (HU) were calculated from the two parameters; height of albumen (AH) and egg weight (EW) using the formula:

$$HU=100\log(AH-1.7EW^{0.37}+7.6)$$

Where HU=Haugh Unit, AH=Albumen height and EW=Egg weight (Haugh, 1937).

The albumen ratio (AR) and the yolk ratios (YR) were calculated as follows:

$$\text{Yolk percent}=(\text{weight of yolk}/\text{weight of whole egg}) \times 100$$

$$\text{Albumen percent}=(\text{weight of albumen}/\text{weight of the whole egg}) \times 100.$$

### Data management and analysis

The data were entered into Microsoft Excel spreadsheet and analyzed using SPSS (Version, 17). To examine the significant differences among egg quality traits, post hoc multiple comparisons were done using means generated from one-way ANOVA.

## RESULTS AND DISCUSSION

### Egg weight

It is one of the important phenotypic traits that influence

**Table 1.** External egg quality traits of exotic chickens under different production systems in East Shewa, Ethiopia.

Traits	Management system used	Egg quality traits		
		Isa Brown, N=87 (Mean±SD)	Bovan Brown, N=86 (Mean±SD)	Koekoek, N=54 (Mean±SD)
Egg weight (g)	Intensive	64.78±3.81 <sup>a</sup>	63.46±4.14 <sup>a</sup>	47.79±4.43
	Village	58.92±7.16 <sup>b</sup>	59.32±4.78 <sup>b</sup>	47.53±4.72
Shell thickness (mm)	Intensive	0.34±0.03 <sup>a</sup>	0.35±0.03 <sup>a</sup>	0.29±0.03
	Village	0.31±0.05 <sup>b</sup>	0.33±0.04 <sup>b</sup>	0.29±0.03

<sup>a-b</sup> means with different superscript in the same column were differ significantly (P<0.05).

egg quality and reproductive fitness of the chicken parents (Islam et al., 2001). The analysis for average egg weight (g) revealed that (64.78, 58.9), (63.46, 59.32) and (47.79, 47.53) under intensive and village production systems for IB, BB and PK layer chickens, respectively (Table 1). Average egg weight of IB and BB under intensive system was significantly higher than under village production system ( $p<0.05$ ), such difference is not a surprise since IB and BB are commercial strains developed for egg weight improvement (Hocking et al., 2003). However, there was no significant difference for PK under intensive and village production systems; this could indicate that PK breed could perform comparatively under village production systems, as it is also an indigenous African chicken (Grobbelaar et al., 2010).

### Shell thickness

The analysis for egg shell thickness revealed that (0.34, 0.31), (0.35, 0.33) and (0.29, 0.29) mm for IB, BB and PK under intensive and village production systems, respectively (Table 1).

The average egg shell thickness of IB and BB under intensive production system was significantly higher ( $p<0.05$ ) than under village production systems ( $P<0.05$ ) and agreed with the reports of Tulin and Ahmet (2009) and Dorji (2013). However, the average egg shell thickness of PK did not differ significantly under intensive and village production system.

### Yolk height

The analysis for yolk height (mm) revealed that (17.81, 17.35), (18.57, 18.11) and (17.59, 18.80) for IB, BB and PK under intensive and village production systems, respectively. Similar average yolk height was reported for IB under village production system by Tadesse et al. (2013). The average yolk height of BB was a significantly higher ( $p<0.05$ ) in intensive than under village production system. However, the average yolk value of PK under village production system significantly higher ( $p<0.05$ )

than intensive production system. In the present study, the yolk height recorded under intensive and village production was comparable to those reported in intensive system in northern Ethiopia by Niraj et al. (2014), but significantly higher than the report of Aberra et al. (2013) in different agro-ecology of Ethiopia for indigenous chickens under village production system.

### Albumen height

The mean albumen heights were (6.17, 6.34), (9.51, 6.92) and (5.53, 5.54) g for IB, BB and PK under intensive and village production systems, respectively (Table 2). The mean albumen height of BB under intensive system was significantly higher under village production system ( $p<0.05$ ). However, albumen height of IB and PK breeds did not differ significantly in intensive and village production systems. Under village production system, comparable average albumen height was reported by Tadesse et al. (2013) for IB and PK breeds in East Shewa, Ethiopia. But, the present average albumen height recorded was significantly lower than the report of Niraj et al. (2014) under intensive management in northern Ethiopia.

### Yolk weight

As presented in Table 2, there was no significant statistical difference in yolk weight for IB and BB; this is in agreement with the report of Tulin and Ahmet (2009) for eggs collected under village production system. The mean yolk weight recorded in the present study was comparable to the report of Tadesse et al. (2013), but significantly lower than the report of Niraj et al. (2014) under intensive management for Rohde Island Red breed. Further, in the current study, the average yolk weight of PK recorded under village was significantly higher ( $p<0.05$ ) than intensive production system; this might suggest the capability of PK to perform well for better yolk weight at village level (Grobbelaar et al., 2010).

**Table 2.** Internal egg quality traits of exotic chickens under different production systems in East Shewa, Ethiopia.

Traits	Management system used	Egg quality traits		
		Isa Brown, N=87 (Mean±SD)	Bovan Brown, N=86 (Mean±SD)	Koekoek, N=54 (Mean±SD)
Yolk height (mm)	Intensive	17.81±0.79	18.57±0.33 <sup>a</sup>	17.59±0.89 <sup>a</sup>
	Village	17.35±1.42	18.11±0.91 <sup>b</sup>	17.80±0.83 <sup>b</sup>
Albumen height (mm)	Intensive	6.17±1.08	9.51±1.37 <sup>a</sup>	5.53±1.33
	Village	6.34±1.81	6.92±1.62 <sup>b</sup>	5.54±1.35
Yolk weight (g)	Intensive	16.69±1.83	15.39±1.28	14.54±1.14 <sup>a</sup>
	Village	16.14±1.89	15.97±1.77	15.94±3.50 <sup>b</sup>
Yolk color (ranges 1-15)	Intensive	6.13±1.55 <sup>a</sup>	6.10±1.73 <sup>a</sup>	10.3±0.13 <sup>a</sup>
	Village	9.78±3.19 <sup>b</sup>	7.77±3.15 <sup>b</sup>	10.72±1.97 <sup>b</sup>
Albumen weight (g)	Intensive	37.23±4.37 <sup>a</sup>	35.98±4.28	26.07±2.69
	Village	33.19±5.89 <sup>b</sup>	34.54±5.67	25.14±2.65
Haugh Unit	Intensive	85.34±4.72 <sup>a</sup>	87.45±6.35 <sup>a</sup>	78.38±8.58
	Village	77.56±12.96 <sup>b</sup>	79.26±9.90 <sup>b</sup>	77.26±8.97
Yolk percent	Intensive	25.44±2.89 <sup>a</sup>	24.45±2.05 <sup>a</sup>	30.55±2.42 <sup>a</sup>
	Village	27.79±4.26 <sup>b</sup>	26.63±3.29 <sup>b</sup>	33.22±4.88 <sup>b</sup>
Albumen percent	Intensive	56.48±3.95	56.85±3.55 <sup>a</sup>	54.66±3.04
	Village	56.28±6.21	57.05±5.23 <sup>b</sup>	53.07±4.84
Yolk:Albumen ratio	Intensive	0.45±0.07 <sup>a</sup>	0.43±0.06	0.56±0.07 <sup>a</sup>
	Village	0.50±0.11 <sup>b</sup>	0.47±0.09	0.64±0.13 <sup>b</sup>

<sup>a-b</sup> means with different superscript in the same column were differ significantly (P<0.05).

### Yolk color

In the present study, the yolk color of eggs collected from IB, BB and PK under village production system had a deep yellow colour (~8 to 12) than that of collected under intensive system (~6 to 10) (Table 2), indicating yolk colour is a function of feed not breeds (Demeke, 2004). Village chicken roaming near the backyard could get enough the xanthophyl (plant pigment) content of the diet consumed, which determines the yolk colour (Silversides and Scott 2006). Green grass during scavenging might be responsible for carotenoid deposits in the yolk, which improves the yolk color. Ethiopian consumers have a strong preference for eggs with deep yellow yolk colour. Very small sized eggs from the scavenging local chicken with deep yellow yolk colour fetch much higher prices compared to larger eggs of improved strains with pale yolk (Tadelle et al., 2003).

### Albumen weight

Albumen weight had more closely associated with egg weight than yolk weight (Harms and Hussein, 1993). The analysis for albumen weight (g) revealed that (37.23, 33.19), (35.98, 34.54) and (26.07, 25.14) for IB, BB and

PK under intensive and village production system, respectively (Table 2). In the current study, the average albumen weight of IB under intensive system was significantly higher than under village production system (P<0.05). However, albumen weight of BB and PK did not differ under intensive and village production system. The current albumen weight recorded under village and intensive system for IB and BB was higher than the report of Niraj et al. (2014) in Ethiopia and comparable with the report of Kabir et al. (2014) in Nigeria under intensive management.

### Haugh Unit

The Haugh Unit (HU) is calculated from the height of the inner thick albumen and the weight of an egg and it is considered to be a typical measure of albumen quality (Haugh, 1937). In the present study, the average HU value were (85.34, 77.56), (87.45, 79.26) and (78.38, 77.26) for IB, BB and PK under intensive and village production system, respectively (Table 2). It is generally accepted that the higher the HU value, the better the quality of the eggs. Study has shown in UK that there is consumer resistant to purchase eggs which have HU's below 60 and the minimum acceptable level of 70 HU on

regular documented tests (TSS, 1999). The average HU of IB and BB under intensive production was significantly higher than that in under village production system ( $p < 0.05$ ). The average HU recorded for IB and BB in the current study was significantly higher than the report of Niraj et al. (2014) under intensive management for Rohde Island Red and Bovans white breeds in northern Ethiopia. The current finding disagreed with Tulin and Ahmet (2009) and Dorji (2013), who reported no significant difference in HU for eggs collected from village and intensive production systems.

### Albumen and yolk percent

The results of albumen and yolk percent are presented in Table 2. The mean yolk percent were (25.44, 27.79), (24.45, 26.63) and (30.55, 33.22) for IB, BB and PK under intensive and village production systems, respectively (Table 2). In the present study, the yolk percent of IB, BB and PK under village production system was significantly higher than under intensive system ( $p < 0.05$ ) and this was in agreement with the finding of Dorji (2013). As presented in Table 2, the albumen percent were (56.48, 56.28), (56.85, 57.05) and (54.66, 53.07) for IB, BB and PK under intensive and village production systems, respectively. In the current study, the albumen percent of IB, BB, and PK did not differ significantly under intensive and village production system and this was disagreed with the comparative egg quality study of Dorji (2013) in under intensive and village production systems.

### Yolk to albumen ratio

The yolk albumen ratio in the present study revealed that (0.45, 0.50), (0.43, 0.47) and (0.56, 0.64) for IB, BB and PK under intensive and village production systems, respectively (Table 2). The yolk to albumen ratio of IB and PK under village production system was a significantly higher than under intensive production system ( $p < 0.05$ ), while the yolk : albumen ratio of BB did not differ significantly. It was reported that there was a small positive relationship between egg weight and yolk albumen ratio was found (Harms and Hussein, 1993). Higher yolk to albumen ratio is an attribute to differences more in proportion of albumen than in proportion of yolk (Suk and Park, 2001). However, the yolk albumen ratio of IB in both production systems in the present study was significantly higher than the report Suk and Park (2001) and Harms and Hussein (1993) under intensive management.

### Conclusion

In the current study, even though the differences were

observed in egg quality traits under intensive and extensive system, eggs collected from the village were also found to be good quality, which are normally perceived as inferior quality by consumers. This could indicate the efforts of farmers to apply improved management in housing, feeding and health management provided by agricultural extension works in the study areas.

### Conflict of Interest

The authors have not declared any conflict of interest.

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### REFERENCES

- Aberra M, Worku Z, Teklegiorgis Y (2013). Assessment of the prevailing handling and quality of eggs from scavenging indigenous chickens reared in different agro-ecological zones of Ethiopia. *J. Environ. Occup. Sci.* 2(1):1-8. doi:10.5455/jeos.20130104091334. <http://dx.doi.org/10.5455/jeos.20130104091334>
- Alabi RA, Esobhawan AO, Aruna MB (2006). Econometric determination of contribution of family poultry to women's in Niger – Delta, Nigeria. *J. Central. Eur. Agric.* 7:753-760.
- CSA (Central Statistical Agency) (2013). Agricultural sample survey. Report on livestock and livestock characteristics 2012/13 report. The Federal Democratic republic of Ethiopia, Private Peasant Holdings. Statistical Bulletin Addis Ababa, Ethiopia, April, 2013. P. 570.
- Dawit A, Tamrat D, Stotaw F, Nzietcheung S, Roy D (2008). Overview and background paper on Ethiopia's poultry sector. Relevance for HPAI Research in Ethiopia. [www.hpai-research.net](http://www.hpai-research.net). Accessed 06 April 2014.
- Demeke S (2004). Egg production performance of local and White Leghorn hens under intensive and rural household conditions in Ethiopia. *Lives. Res. for Rural Dev.* 16:9. Retrieved on May 29, 2012, from <http://www.lrrd.org/lrrd16/2/deme1602.htm>.
- Dorji N (2013). Comparative study of the egg quality of Bhutanese indigenous strains reared under different production systems. *Bang. J. Anim. Sci.* 42(2):175-178. <http://dx.doi.org/10.3329/bjas.v42i2.18507>
- Farooq M, Mian M, Ali M, Durranim F, Asquar A, Muqarrab A (2001). Egg traits of Fayoumi bird under subtropical conditions. *Sarad. J. Agri.* 17:141-145.
- Gantois I, Ducatelle R, Pasmans F, Haesebrouck F, Gast R, Humphrey TJ, Van Immerseel F (2009). Mechanisms of egg contamination by *Salmonella* Enteritidis. *FEMS Microbiol. Rev.* 33:718-738. <http://dx.doi.org/10.1111/j.1574-6976.2008.00161.x> PMID:19207743
- Gast RK, Holt PS, Murase T (2005). Penetration of *Salmonella enteritidis* and *Salmonella* Heidelberg into egg yolks in an in vitro contamination model. *Poult. Sci.* 84:621-625. <http://dx.doi.org/10.1093/ps/84.4.621> PMID:15844820
- Grobbelaar J, Sutherland B, Molalagotla N (2010). Egg production potentials of certain indigenous chicken breeds from South Africa.

- Anim. Genet. Resour. 46:25-32.  
<http://dx.doi.org/10.1017/S2078633610000664>
- Harms RH, Hussein SM (1993). Variations in yolk: albumen ratio in hen eggs from commercial flocks. *J. Appl. Poult. Res.* 2:166-170.  
<http://dx.doi.org/10.1093/japr/2.2.166>
- Haugh R (1937). The Haugh unit of measuring egg quality. *US egg Poult. Magazine* 43:552-555.
- Hocking P, Bain M, Channing C, Fleming R, Wilson S (2003). Genetic variation for egg production, egg quality and bone strength in selected and traditional breeds of laying fowl. *Br. Poult. Sci.* 44:365-373.  
<http://dx.doi.org/10.1080/0007166031000085535>  
 PMID:12964619
- ISA (Hendrix Company) (2010). Product performance of Isa Brown Commercial layer.  
<http://www.isapoultry.com/en/Products/Isa/Isa%20Brown.aspx>.
- Islam M, Bulbul S, Seeland G, Islam A (2001). Egg quality of different chicken genotypes in summer and winter. *Pak. J. Biol. Sci.* 4:1411-1414.  
<http://dx.doi.org/10.3923/pjbs.2001.1411.1414>
- Kabir M, Sulaiman RO, Idris RK, Abdu SB, Daudu OM, Yashim SM, Hassan MR, Adamu HY, Eche NM, Olugbemi TS, Adedibu (2014). Effects of Strain, Age and the Interrelationships between External and Internal Qualities of Eggs in Two Strains of Layer Chickens in Northern Guinea Savannah Zone of Nigeria. *Iran. J. Appl. An. Sci.* 4(1):179-184.
- Khan M, Khatun M, Kibria A (2004). Study the quality of eggs of different genotypes of chicken under scavenging system at Bangladesh. *Pak. J. Biol. Sci.* 7(12):2163-2166.  
<http://dx.doi.org/10.3923/pjbs.2004.2163.2166>
- Mengesha M, Tamir B, Dessie T (2011). Village Chicken Constraints and Traditional Management Practices in Jamma District, South Wollo, Ethiopia. *Lives. Res. Rural Dev.* 23:37.  
<http://www.lrrd.org/lrrd23/2/meng23037.htm>.
- Messens W, Dubocage L, Grijspeerd K, Heyndrickx M, Herman L (2004). Growth of Salmonella serovars in hens' egg albumen as affected by storage prior to inoculation. *Food Microbiol.* 21:25-32.  
[http://dx.doi.org/10.1016/S0740-0020\(03\)00045-5](http://dx.doi.org/10.1016/S0740-0020(03)00045-5)
- Moges F, Aberra M, Tadelle D (2010). Assessment of village chicken production system and evaluation of the productive and reproductive performance of local chicken ecotype in Bure district, North West Ethiopia. *Afr. J. Agri. Res.* 5(13):1739-1748.
- Niraj K, Zinabu N, Yohanes T, Etsay K (2014). Evaluation of egg quality traits of Rhode Island Red and Bovans White under Intensive Management in Mekelle, Ethiopia. *IOSR J. Agric. Vet. Sci.* 7(2):71-75.  
<http://dx.doi.org/10.9790/2380-07227175>
- Okeudo N, Onwuchekwa C, Okoli I (2003). Effect of oil treatment and length of storage on the internal quality, organoleptic attributes and microbial profile of chicken eggs. *Trop. Anim. Prod.* 6:63-70.
- Onagbesan O, Bruggeman V, Desmit L, Debonne M., Witters A, Tona K, Everaert N, Decuypere E (2007). Gas exchange during storage and incubation of avian eggs: Effects on embryogenesis, hatchability, chick quality and post-hatch growth. *World's Poult. Sci. J.* 63:557-573.  
<http://dx.doi.org/10.1017/S0043933907001614>
- Roland D (1988). Eggshell problems: Estimates of incidence and economic impact. *Poult. Sci.* 67:1801-1803.  
<http://dx.doi.org/10.3382/ps.0671801>
- Silversides F, Scott T (2001). Effect of storage and layer age on quality of eggs from two lines of hens. *Poult. Sci.* 80:1240-1245.  
<http://dx.doi.org/10.1093/ps/80.8.1240>
- Solomon D (2007). Comparative nutritive value and protein qualities of Atella and industrial brewers grains in poultry ration in Ethiopia. *Livestock Research for rural Development. The International Journal for Research into Sustainable Developing World Agriculture.* CIPAV, Cali, Colombia.
- Suk YO, Park C (2001). Effect of breed and age of hens on the yolk to albumen ratio in two different genetic stocks. *Poult. Sci.* 80:855-858.  
<http://dx.doi.org/10.1093/ps/80.7.855>
- Tadelle D, Kijora C, Peters K, (2003). Indigenous chicken ecotypes in Ethiopia: growth and feed utilization potentials. *Int. J. Poult. Sci.* 2:144-152.  
<http://dx.doi.org/10.3923/ijps.2003.144.152>
- Tadesse D, Harpal S, Ashenafi M, Wondimeneh E, Tadelle D (2013). Study on productive performances and egg quality traits of exotic chickens under village production system in East Shewa, Ethiopia, 11 April, 2013. *Afr. J. Agric. Res.* 8(13):1123-1128.
- TSS (Technical Services and Supplies) (1999). *Technical Services and Supplies, QCD instrument Range Manual.* York, England, Version 2.1- Release 27E7.
- Tulin C, Ahmet K (2009). Comparison of village eggs and commercial eggs in terms of quality. *J. An. Vet. Adv.* 8:2542-2545.