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Comparative Study of Production and Reproductive Performance of Various Strains of Chicken Parent Layers Raised in Floor Pens

Dawud Ibrahim*[1,2], Gebeyehu Goshu[2], Wondmeneh Esatu[1], Gashahun Bino[3], and Tesfaye Abebe[3]

[1]*Ethiopian Institute of Agricultural Research/Debre Zeit Agricultural Research Center, Debre Zeit, Ethiopia.*
[2]*Addis Ababa University, College of Veterinary Medicine and Agriculture, Debre Zeit, Ethiopia.*
[3]*Hawassa University, Research and Technology Transfer, Hawassa, Ethiopia.*

አህፅሮት

ጥናቱ የሚያተኩረው አምስት ወላጅ ዶሮዎች በአውሮፓ የተዳቀሉ እና አንድ ከሀገር ውስጥ ለንፅፅር ተወስደው ለምርትና እና ምርታማነት በኢትዮጵያ ሁኔታ ተገመገሙ፡፡ ወላጅ ዶሮዎቹም ዶሚናንት ቀይ፣ ዶሚናንት ሰሴክስ፣ ኮኮክ፣ ሎህማን ብራውን እና ሎህማን ጥምር ነበሩ፡፡ ስራው የተሰራው በአንድ ክፍል በወል ላይ ሲሆን፣ አነኚህ ዶሮዎቸ የተገመገሙበት መስፈርት፡ በምግብ አወሳሰድ፣ በክብደት፣ በዕንቁላል ምርት፣ በዕንቁላል ይዘት፣ በዕንቁላል መዳበር፣ በዕንቁላል መፈልፈል እና በሌሎችም ከነባራዊ ሁኔታ ጋር ተላምዶ መኖር ወይም መሞት ነበር፡፡ በአጠቃላይ ለዚህ ስራ 600 ሴት እና 75 ወንድ ወላጅ ዶሮዎች በሶስት ጊዜ ድግግሞሽ በዝርያ በአንድ ቤት ውስጥ በcompletely randomized design መሰረት ተሰራጩ፡፡ ይህ ስራ ከፍተኛ የሆነ በዝርያ፣ በዕድሜ እና በሁለቱም ማለትም በዝርያና ዕድሜ ላይ ልዩነቶች የታየው በአመጋገብ፣ በክብደት፣ በዕንቁላል ምርት፣ በዕንቁላል ይዘት፣ በዕንቁላል መዳበር፣ በዕንቁላል መፈልፈል እና በሌሎችም መመዘኛ ነበር፡፡ በዚህ ሙከራ በአማካይ ከፍተኛ የሴት ክብደት በዶሚናንት ቀይ፣ በመቀጠልም በዶሚናንት ሰሴክስ እና በኮኮክ ላይ ተመዝግቧል፡፡ ዝቅተኛ ክብደት ደግሞ በሎህማን ብራውን እና በሎህማን ጥምር ላይ ነበረ፡፡ በወንዶች ላይ ደግሞ በሎህማን ጥምር ላይ ከፍተኛ ክብደት ሲመዘገብ በመቀጠል ደግሞ በዶሚናንት ቀይ፣ በኮኮክ፣ ዶሚናንት ሰሴክስ ሲሆን፣ ዝቅተኛ ክብደት ደግሞ በሎህማን ብራውን ተመዝግቧል፡፡ ይህ በሎህማን ጥምር ወንድ ወላጅ ዶሮ ላይ የታየው ከፍተኛ ክብደት የስጋ ዶሮ ደም ስላለበት ሲሆን ለሌሎቹ ከዝቅተኛ ክብደት ግን ከሎህማን ጥምር ጋር ሲነፃፀር የተመዘገበበት ምክንያት መደበኛ የዕንቁላል ጣይ ዶሮ ደም ስላላቸው ነበር፡፡ በአማካይ ከፍተኛ የዕለታዊ የምግብ አወሳሰድ የተመዘገበው በዶሚናንት ቀይ እና ዶሚናንት ሰሴክስ በተለይ ከ17 እስከ 24 እና ከ25 እስከ 32 የሳምንት ዕድሜ ክልል ሲሆን በመቀጠልም በኮኮክ ላይ ተመዝግቧል፡፡ ነገር ግን በሎህማን ብራውን እና በሎህማን ጥምር ላይ ዝቅተኛ የዕለታዊ የምግብ አወሳሰድ ተመዝቧል፡፡ በአማካይ ከፍተኛ የዕንቁላል ምርት በሎህማን ብራውን እና በሎህማን ጥምር ላይ ሲታይ በመቀጠል ከፍተኛ ምርት የተመዘገበው በዶሚናንት ቀይ፣ ዶሚናንት ሰሴክስ እና በኮኮክ ላይ ነበር፡፡ በአማካይ ከፍተኛ የዕንቁላል የመዳበር እና የመፈልፈል በኢንኩቤተር ከታቀፈው ዕንቁላል የተመዘገበው በዶሚናንት ቀይ፣ ዶሚናንት ሰሴክስ፣ በኮኮክ እና በሎህማን ብራውን በመቀጠልም የዕንቁላል የመዳበር እና የመፈልፈል በኢንኩቤተር ከታቀፈው ዕንቁላል ሲታይ ዝቅተኛው ሆኖ የተመዘገበው በሎህማን ጥምር ላይ ነበር፡፡ ይህ ዝቅተኛ የመዳበር እና የመፈልፈል በኢንኩቤተር ከታቀፈው ዕንቁላል በሎህማን ጥምር ላይ የታየው ሙከራው በተካሄደበት ወቅት በሙሉ ነበር፡፡ በአጠቃላይ በዚህ በደቡብ ኢትዮጲያ ክልል ላይ በተካሄደው የምርምር ሙከራ ጊዜ በተወሰደው የመገምገሚያ መስፈርት ማለትም በአመጋገብ፣ በክብደት፣ በዕንቁላል ምርት፣ በዕንቁላል ይዘት፣ በዕንቁላል መዳበር፣ በዕንቁላል መፈልፈል እና በሌሎችም መሰረት ከከፍተኛ ወደ ዝቅተኛ ምርትና ምርታማነት ሲቀመጡ፡ ሎህማን ብራውን፣ ኮኮክ፣ ዶሚናንት ቀይ፣ ዶሚናንት ሰሴክስ እና ሎህማን ጥምር ነበሩ፡፡

Abstract

*Five Parent Stocks (**PS**) bred by European companies, and one local PS, were evaluated for their production and reproductive performance under typical conditions in Ethiopia. The PSs were Dominant red Barred (**DR**), Dominant Sussex (**DS**), Koekoek (**KK**), Lohmann Brown (**LB**) Lohmann-Dual (**LD**), and reared in floor pens up to 60 weeks of age, were evaluated for feed intake, body* *weight, egg production, egg quality, fertility, hatchability, and mortality. A total of 600 females and 75 males were kept in three replicated pens per strain and distributed in a house using completely randomized design. There were significant (P<0.05) effects of strain, age and strain by age interactions at all stages of the laying phases in terms of feed intake, fertility, hatchability, body weight of females and males, and egg production. Significantly, highest average female body weight was recorded in DR, followed by DS and KK. The lowest average female body weights were recorded in LD and LB at all ages of the laying phases. Among the average male body weight of LD was significantly higher than other strains, followed by DR, KK and DS, the lowest average male body weights were recorded in LB during laying phase. This (LD) superiority was from the dwarf (homozygous dw/dw) meat-type line of LD. The other male strains were from the layer-types and hence lowest in body weight during the laying stages compared to that of LD male. Significantly higher average daily feed intakes were recorded in DR and DS than other PS in week 17 to 24 and 25 to 32, followed by the KK, while the lower average feed intakes were recorded in LB and LD. The average egg production of LB and LD were significantly higher than the rest, followed by KK, DS and DR. DR, DS, KK and LB were higher in egg fertility and hatchability per set eggs, followed by LD. The present result clearly indicated that the LD was poor in fertility (%) and hatchability (%) per set eggs at all stages of the laying phases. Therefore, LB, KK, DR, DS and LD were ranked 1 to 5, respectively, top to lowest in feed consumption, body weight, egg production, and reproductive performance when raised in floor pens management in Southern part of Ethiopia.*

Introduction

Animal production in general and chicken production in particular plays important socio-economic roles in developing countries (Alders, 2004; Kondombo, 2005). Family poultry contributes to good human nutrition by providing food (eggs and meat) with high quality nutrients and micronutrients. The small income and savings provided by the sale of poultry products is especially important for women, enabling them to better cope with urgent needs and reducing economic vulnerability (FAO, 2014).

Chickens are widely kept in Ethiopia (Halima et al., 2006), with total population estimated to be about 60 million of which 90.8%, 4.4% and 4.8% were reported to be indigenous, exotic and hybrid, respectively (CSA, 2017). In the past 20-25 years, there has been a shift to industrial production with an increase in small and medium-scale producers that have been established to exploit mainly urban markets. But the expansion of the commercial chickens' production is limited by the shortage of adequate local supply of high performing chicken stocks. Efforts are currently being made to alleviate this problem by introducing, evaluating and identifying suitable high-performing exotic strains that can adapt and perform in intensive and extensive management conditions in Ethiopia. Global primary straining companies tend to promote the strains that are used in developed countries, mostly originated in temperate climates, claiming that they are suitable for all environments (Robert, 2013). Hence, enhancing production and productivity of the chickens in the country by testing such stocks along with the associated technologies like husbandry; feeding and health care packages are to speed up poultry development activities.

Attempts to improve the chicken productivity in Ethiopia through the introduction of high performing Commercial Parent Stock (PS) layers were very limited. Despite interests of Ethiopian chicken farmers, the production and reproduction performance of imported strains under different management conditions were not investigated. For years, the Debre Zeit Agricultural Research Center was evaluating only a single imported strain (layers, broilers, or dual purpose) at a time, concluding that this single strain is accepted or not based on the results observed on-station and on-farm conditions, without valid comparisons to alternative strains. In contrast, the present study is the first one in Ethiopia to evaluate several imported and local strains in the same trial. In light of these facts, the objective of this study was to evaluate feed consumption, body weight, and reproductive performance of five Parent Stock (PS) layers raised in floor pens.

Materials and Methods

Study site

The study was carried out under station conditions at Hawassa University (HU) in South Nations, Nationalities, and People Regional State (SNNPR), Hawassa, Ethiopia. Hawassa, 273km south of Ethiopia's capital city Addis Ababa, is geographically situated at latitude and longitude of 7°3′N 38°28′E with average altitude of about 1708 meters above sea level. Hawassa area is known for its poultry production (CSA, 2013). Temperature of the area ranges from maximum of 29°C to minimum of 12°C and humidity ranges 70%to 80% (Agro-Meteorology Department data).

Parent stock layers

Day old chickens (DOC) of five Parent Stock (PS) layers were imported from primary breeding companies of Europe known as Avian Influenza (AI)-free by Ministry of Livestock and Fisheries Development (MoLFD). The PSs were Lohmann Brown Classic (LB) and Lohmann-Dual (LD) from Lohmann Tierzucht (Germany), Dominant Sussex D104 (DS) and Dominant red Barred D922 (DR) from Dominant CZ (Czech Republic). The Potchefstroom Koekoek (KK) was used as a reference as it has been used in Ethiopia for more than 10 years.

Sex differentiation

The two PS layers (LB and DR) were color sexable; the females were brown ("gold") and the males were white ("silver") at hatch. In case of DR, the female chick was red completely and the male DOC shows white spot on the head, wing, and back. KK day old chicks had white spot on the head of male and full black color of female. The DS was sexed by feather development at DOC. In LD sex differentiation of DOC was not possible because all DOCs were entirely white.

Health management

The birds were vaccinated against Marek's, New castle disease (**NCD**), Gumboro, Fowl Typhoid, and Fowl Pox at the appropriate age as recommended by veterinarians. In addition, the Ox tetracycline plus (**OTC** plus) was given when necessary. Standard vaccination and medication were strictly adhered to and strict sanitary measures followed during the experimental period.

They were vaccinated against common diseases indicated in the vaccination programs, like Marek's, New castle disease (NCD), Gumboro, Fowl Typhoid, and Fowl Pox at the appropriate age as recommended by veterinarians. In addition, the Ox tetracycline plus (OTC plus) was given when necessary. Strict sanitary measures were followed during the experimental period.

Housing and management

The females and males of each Parent stock (PS) were raised in a separate pen under station conditions till 16 weeks of age at Debre Zeit Agricultural Research Center (DZARC). A total of 600 female and 75 male parents from the five strains were transferred to the poultry research farm at Hawassa University's poultry farm (HU).

The house was partitioned into fifteen (15) pens to accommodate 3 replicates per strain (40 females and 5 males per pen). At the beginning of week 17, all chickens were weighed and randomly allotted to pens filled with deep litter in a completely randomized design (CRD). Extra pen was left for the isolation of sick birds. The experimental house was open-sided with deep litter of 15cm of tef straw on concrete floor. Standard lighting program based on the age of the birds, stocking density of 7 birds per m^2 were applied based on the recommendation of the breeder's companies.

Feeding management

Standard layer ration was fed with a diet purchased from local feed mill containing 17.9% CP, 2784.8 kcal/kg ME). Each of the experimental breeds' requirements is shown in Table 1. Feeders and waterer was placed in the house/per pen according to the recommendations of each breeder's manual. Water was given *ad-libitum* to all chickens in the experiments without recording the amount consumed.

Table 1: Crude protein (CP) and energy recommendations by the breeder's companies content in the feed, by strain and age*.

Strain	Age	% CP	Energy kcal/kg ME	Source
DR and DS	17 to 39	17	2750	Dominant CZ, 2016.
	> 40	15.5	2700	
LB, LD and KK	17 to 45	18.7	2800	Lohmann, 2016; Wondmeneh *et al*., 2011.
	> 46	17.95	2725	

* DR = Dominant Red Barred D922; DS = Dominant Sussex D104; KK = Potchefstroom Koekoek; LB = Lohmann Brown Classic and LD = Lohmann Dual. ; CP = Crude Protein

Egg quality measurement

Egg quality parameters were measured five times on 27, 31, 35, 39 and 45 weeks of age. The temperature and humidity in the egg storage room were kept at an optimum level 12°C to 14°C and 75% to slow down the loss in quality. Data were taken from the stored eggs on the 2nd day after collection. Fifteen normal eggs per treatment (3 eggs per pen) were randomly selected from the egg-laying nest at one time and used for analysis. The external and internal egg quality measurements were obtained by carefully making an opening around the sharp end of the egg, large enough to allow passage of both the albumen and the yolk through it without mixing their contents together. The yolk was carefully separated from the albumen and placed in a petri dish for weighing. Simultaneously, the associated albumen was placed on another petri dish and weighed. After each weighing, the petri dishes were washed in clean water and wiped with dry cloth before next weighing (Veena *et al*., 2015). The egg weight, albumen weight and yolk weight measurement was determined by electric balance. Egg shape (width and length), albumen height measured at the height of the chalazae at midway point between thinner and outer circumference of the white with a spherometer. Yolk height measured at the height of the yolk at the midpoint with a spherometer. Shell thickness was measured at three points of the sharp, equatorial, and blunt region after removal of the shell membrane. This shell thickness was determined using a digital caliper and the mean of the three points was taken as shell thickness. The widely used DSM Yolk Color Fan (formerly Roche Yolk Color Fan) which is 15 scales color index to distinguish the yolk color density determined yolk color. Eggshell color was determined visually as white, brown, light brown or white-creamy eggshell color.

Fertility and hatchability

To determine fertility and hatchability, 27 eggs per pen were collected three times, each for five consecutive days, when the hens were at 30, 36 and 45 weeks of age, and incubated in a petersime (Belgium) Incubator with capacity of 4400 set eggs and 1466 hatching eggs. The total number of set eggs per strain per age, combined over pens and 3 incubations, was 81 (27x3) in 5 strains (DR, DS, KK, LB, KD) (Table 4). At the end of the 18th day of incubation, all eggs were candled and the infertile ones were counted and removed, and all remaining eggs were transferred to hatching baskets. Percent fertility from set eggs per pen was calculated as total set egg – (total number of infertile eggs at candling per pen and total number of infertile eggs at hatch per pen / total number of set eggs per pen times 100). Upon hatch, each day-old-chick DOC was weighed and counted. Mean percent hatchability of set eggs per pen was calculated from the number of DOC divided by the number of set eggs, times 100. Mean percent hatchability of fertile eggs was calculated from the number of DOC divided by the difference between the number of eggs set and the number of eggs found to be infertile at candling and among the number of eggs with no embryo, times 100.

Collected and calculated data

Data were collected during the trial (from Week 17 to Week 60) on daily average feed intake (g/bird/day) of female and male together per pen due to unavailability of sophisticated materials to record the daily average feed intakes of females and males separately and also female and male cannot be kept separately since they are parent stocks. Another data was on weekly body weight (average of 10% of the females and all of males in each pen), weekly number of collected eggs per pen and number of died birds per sex per pen.

Additionally derived data were generated through calculation as follows.

- Weekly % lay = (weekly number of collected eggs per pen / actual number of hens present per pen) X 100;
- Weekly % mortality = (number of died birds per sex per pen / number of birds per pen) X 100;
- Age at 5% Lay (days) = when the pen reaches 5% laying (Wondmeneh *et al.*, 2015);
- Egg production per hen-day = (No. of eggs per day / No. of live birds on the same day) X 100;
- Average % lay at peak of lay = the maximal weekly % lay in each pen;
- Age at peak of lay = the age of maximal weekly % lay in each pen;
- Average number of eggs/hen/44wks = total number of eggs laid during 44 weeks (from week 17 to 60 weeks) / the average number of live hens during these 44 wk;
- Yolk weight ratio (%) = (yolk weight (gm) / egg weight (g)) X 100;
- Albumen weight ratio (%) = (albumen weight (gm) / egg weight (g)) X 100;
- Shell weight ratio = (shell weight (gm) / egg weigh (g)) X 10; and
- Egg shape index = (egg width (mm) / egg length (mm)) X100.

Statistical analysis

The overall trial period of 44 weeks (from the beginning of Week 17 to the end of Week 60) was split to 5 age periods (17-24, 25-32, 33-40, 41-48, and 49-60), each of 8 weeks (except the last period, with 12 weeks).The ANOVA model included strains and age period as main effects and their interaction (strains by age). Thus, the ANOVA was conducted according to the following model: - $y_{ijlk} = \mu + B_i + A_j + X_l + B_iA_j + E_{ijlk}$

where: y_{ijlk} = the y^{th} observed response,

μ = overall mean,

B_i = strain effect,

A_j = age effect,

X_l= covariate of initial body weight at 17 weeks

B_iA_j = strain by age interaction effect,

e_{ijlk} = random error.

Mean separation was determined using Tukey test with 5% probability. The JMP software Version 12 (SAS Institute Inc., 2014) was used to analyze the data.

Result and Discussion

Body weight changes

Body weights (LSM) (g/bird/wk) of female and male chickens of each Parent Stock (PS) at different periods were shown in Table 2. There were significant differences ($P<0.05$) among PS layers in average body weight (g/bird/wk) of female during the laying stages (17 to 60 weeks of age). The result also shows significant difference ($P<0.05$) within age but the strain by age interactions effect on the average female body weight at all stages of the laying phases was not significant ($P>0.05$). Significantly highest ($P<0.05$) average female body weight was recorded in DR, followed by DS and KK. The lowest average female body weights were recorded in LD and LB at all ages of the laying phases. The average weekly female body weight of KK was relatively comparable with the report by Wondmeneh *et al*., (2011), (1873 g/bird/wk). But average weight at 60 weeks of age of LB was lower than 1950g at 50 weeks of age as reported by Singh *et al.* (2009). However, the average weekly females body weight of DR, DS, LD and LB PS layers were lower than the standards reported by the breeding company (2150, 2150, 1894 and 1897 g/bird/wk respectively) during the laying stages. The reasons may be due to the environmental factors as reported by Doni *et al*. (2015) that, temperature more than 28^{0}C, weight gains are lowered. If condition remains for prolonged period, there may be loss in body weight. From the initial to the end of this study the average female body weight records shows that there were big differences among the strains.

There were significant differences ($P<0.05$) among all strains in average body weight (g/bird/wk) of male between (17 to 60 weeks of age). The analysis of the result also showed that there were significant effect ($P<0.05$) among PS layers within age in week but not significantly different ($P>0.05$) among strains and strains by age interaction on the average male body weight at all stages of the laying phases. The average male body weight (g/bird/wk) of LD was significantly higher than other strains, followed by DR, KK and DS, the lowest average male body weights were recorded in LB during studies. This (LD) superiority was from the dwarf (homozygous dw/dw) meat-type line of LD. The other males were from the layer-types and hence lowest in body weight during the laying stages compared to that of LD male. The results were similar to findings reported by Wondmeneh *et al*. (2011) on average body weight (2653g/bird/wk) of male strain KK and with the standards reported by the strainer's company (3583g/bird/wk) of male LD. Reference cannot be found specifically on body weight at later ages of parental male line strains because most of the companies record shows weight recording up to 18 weeks of age only. From this study we found out that, there is a big difference among the PSs in terms of average male body weight at the different growth stages.

Average feed intake

Average feed intake (g/bird/day) of female and male together at different periods for all the five PS layers were presented in Table 2. Significantly higher average daily feed intakes were recorded in DR and DS than other PS in week 17 to 24 and 25 to 32, followed by the KK, while the lower average feed intakes were recorded in LB and LD. This superiority in PS DR and DS may be due to heavy body weight of the PS layers. There was significant difference ($P<0.05$) among the test strains in average feed intakes (g/bird/day) of female and male together during the laying stages (17 to 60 weeks of age). The average feed intake (between 33 to 60 weeks of age) was not significantly different ($P>0.05$) among PS across all the ages. The result also showed a significant difference ($P<0.05$) in average feed intakes (g/bird/day) for both sexes. Among PS within age in week but no significant difference ($P>0.05$) for the strain by age interaction at all stages of the laying phases. The average feed intake of LB, LD, DR, and DS (both female and male) during 17 to 60 weeks of age was comparable with the standards reported by the breeder's company (117, 115, 119 and 119g/bird/day respectively). The daily feed intakes of Lohmann strain was close to a value of 114.5g reported by Singh *et al*. (2009), but that of PS KK was lower than the value of 123 g/bird/day (Wondmeneh *et al*., 2011). Contradict results on feed intake was found as environmental factor like temperature was found to contribute about 97.2% showing that it has the greatest effect on feed intake. Hence, a decrease in rate of feed intake in any poultry farms as reported by Obayelu et al., (2006). The effects higher temperature (above 27°C) on feed consumption was also reported by Talukder et al., (2010).

Table 2: Least square means of female body weight (BW-F), male body weight (BW-M) and average feed intake (AFI) of female and male (together) in five age periods from Week 17 to Week 60 of seven strains*.

Parameters	Age (wk)	Strains				
		DR	DS	KK	LB	LD
BW-F (g)	17	1336.7	1286.3	1233.5	1244.1	1242.0
	28	2166.7^{a}	1970.0^{ab}	1980.0^{ab}	1866.7^{b}	1933.3^{b}
	40	2068.7	1766.7	1736.7	1766.7	1830.0
	60	1930	1938.7	1813.3	1793.3	1863.3
BW-M (g)	17	1943.3^{b}	1740.0^{bc}	1924.0^{b}	1361.0^{c}	3006.7^{a}
	28	3133.3^{ab}	2866.7^{ab}	3300.0^{a}	2566.7^{b}	3566.7^{a}
	40	2631.3	2536.7	2760.0	2440.0	3243.3
	60	3126.7^{b}	3176.7^{ab}	3000.0^{b}	2526.7^{c}	3483.3^{a}
AFI (g/bird/day)	17-24	100.3^{a}	99.9^{a}	98.7^{ab}	93.7^{c}	94.9^{bc}
	25-32	125.4^{a}	122.6^{ab}	116.9^{b}	119.2^{ab}	120.9^{ab}
	33-40	126.1	125.7	122.5	121.5	121.9
	41-48	123.9	126.1	119.3	123.0	120.2
	49-60	128.0	127.9	127.9	128.0	128.0
Total AFI (kg/bird/308 days)	17-60	37.080	37.095	36.207	36.088	36.061

$^{a-c}$Means with different letters within the rows differ significantly by the Tukey test at p<0.05.
* DR = Dominant Red Barred D922; DS = Dominant Sussex D104; KK = Potchefstroom Koekoek; LB = Lohmann Brown Classic and LD = Lohmann Dual.

Egg production performance

Average egg production performances (% in wks) during laying phase (17 to 60 weeks of age) for the five strains are shown in Table 3. The average egg production of LB and LD were significantly higher than the rest, followed by KK, DS and DR. There was significant difference (P<0.05) among strains in average weekly egg production (% in wks) during the laying phase (17 to 60 weeks of age). The result also shows significant effect (P<0.05) of strains within age in week but not significant difference (P>0.05) in strain x age interaction on average egg production performances (% in wks) at all stages of the laying phases. The average egg production of DS and DR were lower than the standard production given by the breeding company (81.2and 81.2%/wk respectively) but the average egg production of LB, LD and KK strains were similar with the standards of 87.0 and 82.5% /in wk, respectively, given by the breeders 57.0 to 63.7 % wks reported by Wondmeneh *et al*. (2011) and 60.4% by Grobbelaar *et al*. (2010). Compared to other strains LD and LB performed well in egg production but DS and DR had irregular and lower egg production performance. The difference between the results obtained during this investigation and the results obtained by breeders' company and other studies could be attributed to genotype-environment interactions. The environment where the strains were developed might be different with the testing environment of the current study.

Reproductive performance

The reproductive performance of the test strains is presented in Tables 3 and 4. There was a significant difference (P<0.05) among parent layers in all reproductive traits except in average age at first eggs drop (days), age at 5% eggs, and average age at peak lay (days).

The result on performance of KK obtained in the current study was not comparable with the report of Wondmeneh *et al*., (2011) in average age at first egg drops (147 days) and 5% egg production or in reaching sexual maturity. On the contrary, findings are comparable to the sexual maturity or production of first egg drops found by Grobbelaar *et al*., (2010) who stated that the sexual maturity for the Potchefstroom Koekoek was 138.5 days. The performance of DR, DS, LB and LD layers were comparable to the standards reported by the breeders' manual (140, 140, 133and 133 days, respectively). LD and LB layers were top in average peak percent of lay (% in wks), followed by DB, DS and KK parent layers. KK was comparable in average age at peak of lay (days) and in average peak percent of lay (252 days and 72.4% in wks respectively) to what had been reported by Wondmeneh *et a*l., (2011) for the same strain. In terms of average weekly peak percent lay, LB and LD were comparable but not with the standards provided by the breeders (94 & 91) % in wks and 175 & 189 days). DR and DS PS layers were not comparable in terms of average age at peak of lay (days) and average peak percent of lay (% in wks) with the standards reported by the breeder's company (203 and 203 days and 92 and 92 % in wk, respectively). LD and LB were the highest in egg production-hen-day (%) and average number of eggs/hen/43wks, followed by PS layers of DB, DS and KK. In this study, we found that % hen-day egg production of LB was lower than reports (87.5%) by Singh *et al*. (2009).

DR, DS, KK and LB were higher in egg fertility and hatchability per set eggs, followed by LD. The present result clearly indicated that the LD was poor in fertility (%) and hatchability (%) per set eggs at all stages of the laying phases. These lowest records were come from the meat-type male line of LD. KK had the highest and PS LD was the lowest, while other PS layers (DR, DS and LB) were intermediate in hatchability per fertile egg during the evaluation periods. PS KK was comparable in egg fertility (%), hatchability (%) per set of eggs and hatchability (%) per fertile eggs with the report of Wondmeneh *et al*., (2011). The performance of the other strains was not comparable with the standards reported by the strainer's company. The result of this study on effects of PS strain on fertility was in contradiction with the findings of Olawumi and Salako, (2011) who reported no significant effect of strain on fertility in Barred Plymouth Rock and White Plymouth Rock but similar results were reported for the effects of strain on hatchability). Islam *et al*., (2002) reported that strain had little effect on hatchability (%) per fertile eggs which contradict with our findings. Our findings on fertility, hatchability per fertile eggs and hatchability per set of eggs was lower than the reports of Islam *et al*., (2002) on strains of Barred Plymouth Rock, White Leghorn, Rhode Island Red and White Rock for fertility (88.8, 94.8, 88.3 and 92.2, respectively), hatchability (%) per fertile eggs (88.6, 90.2, 88.4 and 91.9, respectively) and hatchability per set of eggs (81.3, 86.1, 79.6 and 84.9, respectively). There was no significant difference in DOC weight (g/bird) among strains but there were significant difference (P<0.05) among PS layers in weight of set eggs (g) for average of the three incubations (Table 5).

Table 3: Least square means of age at first egg and at 5% Lay, egg production (% lay in wks), % Lay hen-day and hen-housed, age at peak of lay, peak % Lay, total number of eggs/hen of five strains*.

Parameter	Strain				
	DR	DS	KK	LB	LD
Age at first eggs drop (days)	140.0	137.7	140.0	135.3	137.7
Age at 5%lay (days)	147.0	144.7	147.0	142.3	147.0
Age at peak lay (days)	263.7	296.3	256.7	298.7	280.0
Peak lay (percent)	79.0[b]	77.8[b]	77.6[b]	93.3[a]	95.5[a]
Egg production-17-24 wks (percent)	14.3	13.7	14.8	18.1	16.9
Egg production-25-32 wks (percent)	60.1[bc]	50.5[c]	66.1[abc]	79.5[a]	76.6[ab]
Egg production-33-40wks (percent)	74.8[bc]	72.0[c]	73.5[c]	87.1[ab]	90.4[a]
Egg production-41-48wks (percent)	62.5	70.9	68.9	89.3	88.7
Egg production-49-60wks (percent)	58.3[bc]	60.6[abc]	54.6[c]	81.7[a]	78.4[ab]
Egg production-17-60 wks (hen-day)	54.4[b]	55.3[b]	55.5[b]	72.2[a]	70.9[a]
Total number of eggs/hen/44wks	166.1[b]	169.6[b]	170.8[b]	221.8[a]	217.8[a]

[a–c]Means with different letters within rows differ significantly by the Tukey test at p<0.05.
* DR = Dominant Red Barred D922; DS = Dominant Sussex D104; KK = Potchefstroom Koekoek; LB = Lohmann Brown Classic and LD = Lohmann Dual.

Table 4: Total eggs set /strain/age and least square means of, % fertility, % hatchability of fertile eggs and of set eggs, weight of set eggs, body weight of day-old chicks and number of DOC/hen five strains* .

Parameter	Age (wk)	Strain				
		DR	DS	KK	LB	LD
Total eggs set/strain/age**		81	81	81	81	81
Fertility (%) of set eggs	30-31	83.3[a]	83.3[a]	84.4[a]	70.0[b]	30.0[c]
	36-37	87.0[a]	77.8[ab]	85.2[a]	76.9[ab]	38.0[c]
	45-46	70.0[a]	63.3[ab]	71.1[a]	77.8[a]	17.8[c]
Hatchability (%) of set eggs	30-31	71.1[a]	67.8[ab]	77.8[a]	55.6[b]	23.3[d]
	36-37	80.6[a]	63.9[bc]	73.1[ab]	62.0[bc]	32.4[d]
	45-46	35.5[bc]	12.2[c]	44.4[ab]	55.5[a]	2.2[d]
Hatchability (%) of fertile eggs	30-31	85.0[ab]	81.2[b]	92.1[a]	76.1[c]	53.8[d]
	36-37	92.5	82.0	85.8	78.6	80.4
	45-46	45.1[b]	38.6[c]	57.9[ab]	68.5[a]	8.33[d]
Average weight of set eggs (g),		62.7[a]	58.4[ab]	53.0[c]	56.3[bc]	55.0[bc]
Average weight of day-old chicks (g)		38.1	34.4	32.3	35.3	31.9

[a–c]Means with different letters within rows differ significantly by the Tukey test at p<0.05.
* DR = Dominant Red Barred D922; DS = Dominant Sussex D104; KK = Potchefstroom Koekoek; LB = Lohmann Brown Classic and LD = Lohmann Dual.** Set eggs were collected for incubation 3 times, on Weeks 30-31, 36-37, and 45-46.

Egg quality

DS and KK had white-creamy eggshell color, while LB and LD had brown egg shell color. Shell color of DR, DS, and KK were light brown to brown and not similar with the description of the breeders' manual and Grobbelaar *et al*. (2010), while for the other layers egg shell color was brown, which was in agreement with the breeders'. There were significant difference (P<0.05) among the test strains in terms of egg weight (g), albumen weight (g), egg shape (width in cm & length in cm). However, there were no significant differences (P>0.05) among layers in average yolk weight (g), shell weight (g), yolk weight ratio (%), albumen weight ratio (%), shell weight ratio (%), egg shape index, average shell thickness (mm), yolk color (color fun), yolk height (mm), albumen height (mm) at 27, 31, 35, 39 and 45 weeks of age among PS strains studied for internal and external egg quality parameters (Table, 5). Islam *et al*. (2002) reported that genetic variation had little effect on egg weight in contrary to our findings. The average shell thickness, albumen height, albumen weight, (0.29 mm, 5.53 mm, and 26.07g, respectively) of KK was not comparable reports of Desalew *et al*., (2015) but similar in terms of average yolk height, yolk color, yolk weight, (17.59 mm,10.3 and 14.54g, respectively) reports of Khan et al., (2004). For best result of hatchability, egg shell thickness should be between 0.33 and 0.35 mm and few eggs with a shell thickness of less than 0.27mm will hatch which was similar our findings. It was found out that DR had the highest egg weight (g) while KK had the lowest weight, while the other PS layers of DS, LB and LD were intermediate in egg weight (g). DR, DS and KK were comparable in egg weight (g) with the standards reported by the breeders' manual and findings of Wondmeneh *et al*., (2011) (61.5, 61.5. 51.9g, respectively) but for PS KK heavier (55.7g) (Grobbelaar, 2008) and lighter (47.79g) (Desalew *et al*., 2015) were reported. The egg weights of LB, and LD were not comparable with the standards of the breeding company (63.3, 63.2, and 62g respectively). Jana et al., (2014) also found (60.1g) heavier (60.05g) egg weight than our findings for Lohmann strains. Similar egg weights to what has been found in the current study for PS DS and DR was reported by Islam et al., (2002) with the strains of Barred Plymouth Rock, White Leghorn, Rhode Island Red and White Rock (58.04g, 59.48g, 58.18g and 58.3g respectively). Eggs from PS DR had significantly the highest albumen weight (g) while eggs from PS KK had the lowest albumen weight. PS layers of DS, LB and LD were intermediate in albumen weight at 26, 30, 36, 40 and 44 weeks of age. Jana et al., (2014) have reported 36.6g of albumen weight for Lohmann strains which is higher than our findings but similar findings in yolk weight (16.24g).

Table 5: Least square means of egg weight, yolk weight, albumen weight, shell weight, egg width and length, shell thickness, yolk color, yolk height, albumen height and others at 27, 31, 35, 39 and 45 weeks of five (strains) *.

Parameter	Strain				
	DR	DS	KK	LB	LD
Egg weight (g)	62.7^{a}	58.4^{ab}	53.0^{c}	56.3^{bc}	55.0^{bc}
Yolk weight (g)	18.2	18.0	16.3	16.5	16.8
Albumen weight (g)	36.2^{a}	32.2^{ab}	29.7^{b}	32.4^{ab}	31.7^{ab}
Shell weight (g)	8.33	8.13	7.01	7.47	6.55
Yolk weight ratio (%)	29.1	31.0	30.0	29.4	30.6
Albumen weight ratio (%)	57.7	54.9	56.2	57.4	57.7
Shell weight ratio (%)	13.2	14.4	13.3	13.3	11.8
Width (mm)	43.9^{a}	42.3^{ab}	41.3^{b}	42.0^{b}	41.7^{b}
Length (mm)	57.3^{a}	55.8^{a}	52.9^{b}	53.8^{b}	53.5^{b}
Egg shape index	76.7	75.8	78.1	78.2	78.0
Av. shell thickness (mm)	0.33	0.34	0.34	0.36	0.37
Yolk color (color fun)	10.7	9.2	9.6	10.0	9.2
Yolk height (mm)	18.0	17.8	17.9	17.7	17.9
Albumen height (mm)	7.99	7.49	7.18	7.69	8.30

$^{a–c}$Means with different letters within the rows differ significantly by the Tukey test at $p<0.05$.
* DR = Dominant Red Barred D922; DS = Dominant Sussex D104; KK = Potchefstroom Koekoek; LB = Lohmann Brown Classic and LD = Lohmann Dual.

Mortality

The average female and male mortality (% in wks) of the layers during laying period (17 to 60 weeks) is presented in Table 6. The highest average female mortality was recorded in DR, followed by KK, DS and LD, while the lowest average female mortality was recorded in LB PS layers. Lowe average male mortality was recorded in all the five PS layers. Lowest mortality results were found in both sexes in most of the PS layers as compared to the standards reported by the strainer's company, except highest mortality rate in DR PS. For PS the Grobbelaar et al., (2010) which indicates higher than our findings, reported layer KK 22.2 % of mortality for both sexes. There was significant difference (P<0.05) among strains in average female mortality (%/wks) rate during the laying stages. The study also showed that there were significant differences (P<0.05) on average female mortality at the different ages in week but not significantly different (P>0.05) among PS layers in PS X age interaction. For male mortality (% in wks) significant difference (P<0.05) was shown only for the age in week in all stages of the laying phases.

Table 6: Least square means of average female and male mortality in five age periods from 17 to 60 weeks of five (strains) *

Parameter		Strain				
		DR	DS	KK	LB	LD
MT (%/ wk)	F	0.14^{a}	0.05^{ab}	0.08^{ab}	0.03^{b}	0.05^{ab}
	M	0.03	0.01	0.01	0.05	0.03

[a–b]Means with different letters within the rows differ significantly by the Tukey test at p<0.05.* DR = Dominant Red Barred D922; DS = Dominant Sussex D104; KK = Potchefstroom Koekoek; LB = Lohmann Brown Classic and LD = Lohmann Dual.

Conclusion

From this study we can conclude that Parent Stock (PS) layers LB, KK and DR performed best in most of the productive traits, followed by DS and LD at all ages of the laying phases. The performances of all the Parent Stock layers at Hawassa University are more or less comparable with the performance standards indicated by the breeding companies. Thus the Parent Stocks of LB, KK, DR, DS, and LD can be recommended, in their respective order, to the beneficiaries in Ethiopia under similar conditions.

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