EGG PRODUCTION AND QUALITY TRAITS OF SASSO-RIR, NORMAL FEATHERED LOCAL AND THEIR F1 CROSS CHICKENS MANAGED UNDER ON-STATION CONDITION IN SOUTHERN ETHIOPIA †

[PRODUCCIÓN DE HUEVO Y CARACTERÍSTICAS DE CALIDAD DE SASSO-RIR, AVES LOCALES DE PLUMAJE NORMAL Y SUS CRUZAS F1 MANEJADAS EN CONDICIONES CONTROLADAS EN EL SUR DE ETIOPÍA]

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SUMMARY

Background. Poultry production is a tool for livelihood improvement and poverty alleviation in the developing countries. Indigenous chickens are numerous but lower in egg production performance than exotic chickens in Ethiopia. **Objective**. To compare egg yield, feed conversion ratio (FCR), mortality, and egg quality traits of Normal feathered local (LL), Sasso-RIR (SRSR) and their F1-cross (LSR) chickens under on-station conditions. **Methodology**. Data on egg production, feed intake and mortality were collected for 33 weeks whereas egg quality was assessed at 6, 9 and 12 months of age at poultry farm of Hawassa University. The experiment was laid out with Completely Randomized Design with four replications. **Results.** Next to SRSR chickens, LSR performed higher than LL chickens in terms of egg number per hen (96.8), egg weight (46.9 g/egg), daily feed intake (102 g/hen), body weight (1882 g/hen), albumen height (5.97 mm), albumen weight (27.2 g/egg) and albumen weight ratio (56.8). FCR was best, intermediate and worst for SRSR (4.19), LL (4.57), and LSR (5.20) chickens, respectively. Higher egg weight (52.9 g), yolk weight (18.3 g), albumen weight (28.9 g), and yolk weight ratio (35.1) were obtained from eggs of older hens whereas higher albumen weight ratio (59.4) and shell weight ratio (11.0) were obtained from eggs of younger hens. For LL chickens, the lowest values of egg weight, egg length, yolk color, albumen weight, albumen weight ratio were obtained at older ages whereas the lowest value of yolk weight ratio was obtained at younger ages. **Implications.** The results of the present study contribute in knowing the effects of cross-breeding of LL chicken with SRSR chicken on egg yield and quality. **Conclusions.** The exotic blood of Sasso-RIR chicken had played a significant role in upgrading most of the economically important egg production and quality traits. However, the influence of genotype on some egg quality traits depends on laying age of hen.
Key words: chicken genotype; egg quality; egg production; hen age; mortality

RESUMEN

Antecedentes. La producción avícola es una herramienta para mejorar los medios de vida y aliviar la pobreza en los países en desarrollo. Los pollos autóctonos son numerosos, pero tienen un rendimiento de producción de huevos inferior al de los pollos exóticos en Etiopía. **Objetivo.** Comparar el rendimiento de huevos, la tasa de conversión alimenticia (FCR), la mortalidad y los rasgos de calidad de los huevos de pollos locales con plumas normales (LL), Sasso-RIR (SRSR) y su cruza F1 (LSR) en condiciones de la estación. **Metodología.** Los datos sobre la producción de huevos, el consumo de alimento y la mortalidad se recopilaron durante 33 semanas, mientras que la calidad del huevo se evaluó a los 6, 9 y 12 meses de edad en la granja avícola de la Universidad de Hawassa. El experimento se diseñó con un diseño completamente aleatorio con cuatro repeticiones. **Resultados.** Junto a los pollos SRSR, el LSR tuvo un mejor desempeño que los pollos LL en términos de número de huevos por gallina (96.8), peso del huevo

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(46.9 g / huevo), ingesta diaria de alimento (102 g / gallina), peso corporal (1882 g / gallina), altura de la albúmina (5.97 mm), peso de la albúmina (27.2 g / huevo) y relación de peso de la albúmina (56.8). La FCR fue mejor, intermedia y peor para los pollos SRSR (4.19), LL (4.57) y LSR (5.20), respectivamente. Mayor peso del huevo (52.9 g), peso de la yema (18.3 g), peso de la albúmina (28.9 g) y relación de peso de la yema (35.1) se obtuvieron de los huevos de gallinas más viejas, mientras que la relación de peso de la albúmina (59.4) y el peso de la cáscara (11.0) fueron más altos se obtuvieron de huevos de gallinas más jóvenes. Para los pollos LL, los valores más bajos de peso del huevo, longitud del huevo, color de la yema, peso de la albúmina, relación de peso de la albúmina se obtuvieron a edades más avanzadas, mientras que el valor más bajo de la relación de peso de la yema se obtuvo a edades más tempranas. **Implicaciones.** Los resultados del presente estudio contribuyen a conocer los efectos del cruzamiento de pollos LL con pollos SRSR sobre el rendimiento y la calidad del huevo. **Conclusiones.** La sangre exótica de pollo Sasso-RIR había jugado un papel importante en la mejora de la mayoría de las características de calidad y producción de huevos económicamente importantes. Sin embargo, la influencia del genotipo en algunos rasgos de la calidad del huevo depende de la edad de la gallina ponedora.

Palabras clave: genotipo de pollo; calidad del huevo; producción de huevos; edad de gallina; mortalidad

INTRODUCTION

Poultry is an important source of animal food and a profitable venture, and eventually a tool for livelihood improvement and poverty alleviation in the developing countries (Dolberg, 2007). In Ethiopia, the total chicken population is estimated at 59.42 million head composed of 50.91, 4.35, and 4.16 million indigenous, hybrid and exotic breeds, respectively (CSA, 2018). In addition to numerous availability, indigenous chicken are known to possess desirable characteristics such as thermo-tolerance, resistance to some diseases, good egg and meat flavour, presence of hard egg shells, high fertility and hatchability as well as high dressing percentage. However, production performances such as egg production, growth rate, and sexual maturity, etc. of indigenous chickens is low in comparison to exotic chicken in Ethiopia (Nigussie *et al*., 2010).

One of the chicken development initiatives in Ethiopia has been by Ethio-chicken plc. with a focus on Sasso-RIR breed. It distributes chicken of this breed to rural and urban households so that it is crossing with the local chicken ecotypes. Sasso-RIR chicken was previously rated the best for egg production and the second best breed in terms of body weight compared to Kuroiler, Koekoek and improved Horro chickens under on-station condition (Tadelle, 2018). Habtie (2019) also reported that Sasso-RIR chicken was the best for egg production compared to Kuroiler, Koekoek and Sasso chickens under on-farm conditions in northern Ethiopia.

Therefore, crossbreeding between indigenous stock and exotic commercial chickens, would take advantage of productive merits which have already been accumulated through selection in the exotic chickens as well as merits for hardiness which have been endowed in indigenous chickens through decades of natural selection (Rajkumar *et al*., 2011). Normal feathered local chicken comprises about 98 % of the total local chicken population in Ethiopia (Nigussie *et al*., 2010). However, no attempt has been made to assess the egg production performances and egg quality traits of the normal feathered local chicken and also the introduced commercial dual purpose chicken (Sasso-RIR), and their F1-crosses. Consequently, the combining abilities with respect to beneficial traits of both genotypes such as egg production performances and egg quality traits need to be evaluated. Hence, the objective of this study was to evaluate egg production, egg quality, feed efficiency, and survival of Sasso-RIR, normal feathered local chicken and their F1-cross chickens under on-station management condition.

MATERIALS AND METHODS

Description of study site

The experiment was carried out at Poultry Farm of School of Animal and Range Sciences, College of Agriculture, Hawassa University, Hawassa. Hawassa is located at 273 km South of Addis Ababa, Ethiopia, at 7°4°N latitude and 38°31°E longitude at an altitude of 1650 m above sea level. The area has a bimodal rainfall that ranges between 674 and 1365 mm annually. The mean temperature ranges between 13.5 ^{0}C and 27.6^{0}C (NMA-Hawassa Branch Directorate, 2012).

Sources of chicken genotypes

The Sasso-RIR chicks of 45-day old were purchased from agents of Ethio-chicken poultry breeding farms in Hawassa. The eggs of normal feathered local chicken were purchased from individual rural households in Bolosso-Sore and Humbo districts of Wolaita zone of southern Ethiopia and hatched at Hawassa Agricultural Research Center and then brooded and reared at Hawassa University, College of Agriculture.

Mating plan of chicken

Mating plan was arranged at 18 weeks of age naturally by putting a cock and a hen together in a separate pen. Mating of Sasso-RIR cock with Sasso-RIR hen, normal feathered local chicken cock with normal feathered local chicken hen, and normal feathered local chicken cock with Sasso-RIR hen was made to produce Sasso-RIR (SRSR), normal feathered local chicken (LL) and their F1- crosses (LSR) chickens, respectively. A total of 10 males and 60 females were mated to produce each of SRSR and LSR genotypes whereas 19 males and 114 females were mated to produce LL genotype.

Hatching and management of chicken

Eggs were collected for each genotype and hatched at the Poultry Farm of the School of Animal and Range Sciences. After 14-days of brooding, 150 unsexed chicks of each genotype were randomly selected and further replicated in to five pens in a grower house consisting of 30 chicks each in a completely randomized design (CRD). The chickens were reared in a deep litter housing system until 18 weeks of age. Then, chickens in five pens were combined together and female chickens of each genotype were randomly distributed to 4 pens (10 hens per pen) under CRD. The pens were partitioned with mesh wire in an open deep litter layer house with concrete floors covered with wood shavings and kept the hens until 52 weeks of age under a standard housing space with natural lighting. The poultry house equipped with all the necessary chicken rearing facilities and the room and equipment were cleaned and disinfected with 37 % formalin before two weeks of transferring the pullet.

Table 1. Chemical composition of commercial dual purpose chicken feeds used in the study.

Nutrient composition	Age (weeks)			
	0 − 3	4 − 7	8–17	> 17
Crude protein, %	20.9	18.5	15.5	16.0
Crude fiber, %	4.50	5.80	8.00	7.00
Crude fat, %	3.00	5.00	5.00	5.00
Calcium, %	1.15	0.90	0.80	3.55
Phosphorus, %	0.55	0.49	0.43	1.85
ME (kcal/kg)	3035	2950	2750	2800

Water and feeds were offered on *ad lib* basis. All genotypes were fed the same standard commercial dual purpose chicken feed as per the recommended feeding schedules by the manufacturer (Alema Koudijs Feed Plc, Debrezeit, Ethiopia) (Table 1). All chickens were vaccinated against Newcastle, Marek's and infectious bursal diseases as per the recommended vaccination schedules of the manufacturer. Coccidiostat (Amprolium 20% powder) was also administered as indicated by the manufacturer.

Data collection

Feed intake, body weight, feed conversion ratio and mortality

Feed offered and refusals were weighed and recorded daily in the morning on pen basis. Average feed intake was then computed by difference by subtracting feed refusal from that of offered. Feed conversion ratio (FCR) was computed by the ratio of average intake to average egg mass yield. The average body weight of laying hens at pen level was measured at 20 weeks of age and then at monthly interval through the study period. Number of death chicken was recorded daily at pen level and mortality percentage was calculated (Kamil *et al*., 2012).

Egg production

The hatch date of chicks and date of first egg laid in each pen were recorded, and total number of day between them was used as age at first egg. The number of eggs and laying hens were recorded daily at pen level from start of lay to the end of the experimental period (33 weeks). Hen-day egg number was calculated as the total sum of the number of eggs produced by the birds at pen level divided by the number of birds alive at the day of egg collection. Daily rate of lay was calculated as the hen-day egg number divided by the total laying period in days. Hen housed egg production (HHEP) was calculated as a ratio of total eggs produced during the laying period to total number of chickens housed at the beginning of the laying period (Kamil *et al*., 2012; Wondmeneh, 2015; Bamidele *et al*., 2019). Average egg weight data was taken every week during experimental period and it was measured by weighing total eggs collected for 7 days at pen level and then dividing this weight by the total number of eggs weighed. Finally, the average of the weekly average egg weights was taken as the egg weight of the respective genotype. Egg mass was calculated by multiplying total egg number collected in replicate per hen (hen-day) during study period by egg weight (Kamil *et al*., 2012).

Egg quality

The quality test of fresh eggs (aged about 24 hours) was performed at 6, 9, and 12 months of hen age. A total of 150 eggs per genotype and 50 eggs per each hens age category were used for quality test. Eggs were collected in the morning, identified and analyzed for the external and internal egg quality parameters. Laboratory tests were performed at the Poultry Laboratory of the School of Animal and Range Sciences, Awassa College of Agriculture, Hawassa University, Ethiopia. The eggs were first numbered and then weighed with an electronic balance to the nearest 0.001 g. Then egg length and width were measured by electronic digital caliper sensitive to 0.001 mm and egg shape index was calculated as a ratio of egg width to egg length multiplied by 100. Next the eggs were broken on to a glass covered table and the albumen and yolk heights were measured using Tripod Micrometer, calibrated in mm whereas yolk width was measured by using an electronic digital caliper. The yolk color was determined using the Roche Colour Fan, a standard colorimetric system ranged from 1 to 16 (1 = very pale to 16 = deep orange). The average grading for egg color made by four different persons by the Roche Color Fan was used. Following this, the yolk was carefully separated from the albumen and weighed. Then, the cleaned egg shells were dried in the open air for 24 hours and weighed together with the shell membrane. Finally, the egg shell thickness was measured from the two ends and middle position of the egg using an electronic digital caliper and the average of the three was used as a trait. The albumen weight was calculated by subtracting yolk weight and dry shell weight from the gross egg weight. Yolk weight ratio (%) was calculated as a ratio of yolk weight to egg weight multiplied by 100. Albumen weight ratio (%) was calculated as a ratio of albumen weight to egg weight multiplied by 100. Shell weight ratio was calculated as a ratio of shell weight to egg weight multiplied by 100 (Khan *et al*., 2004; Anderson *et al*., 2004). Individual Haugh Units (HU) were calculated from the two parameters; height of albumen in mm (AH) and egg weight in g (EW) using the formula:

$$HU=100 \log (AH-1.7\ EW^{0.37} + 7.6)$$ (Haugh, 1937)

Data analysis

Data were subjected to analysis of variance using the General Linear Models (GLM) Procedure of SAS (2014). Means were separated using Duncan's multiple-range test. Treatment differences were considered significant at the *P*<0.05 level. Models used:

ANOVA Model 1 (feed intake, egg production, age at first egg, feed efficiency, body weight and mortality)

$$Y_{ik} = \mu + G_i + e_{ik}$$

Where:
Y_{ik} = the observed k^{th} variable in the i^{th} genotype of chicken
μ = overall mean
G_i= the i^{th} fixed effect of genotype (i = SRSR, LSR, LL)
e_{ik} = random error

ANOVA Model 2 (egg quality traits)

$$Y_{ijk} = \mu + G_i + Aj + Gi*Aj + e_{ijk}$$

Where:
Y_{ijk} = the observed k^{th} variable in the i^{th} genotype and j^{th} age of hen
μ = overall mean
G_i= the i^{th} fixed effect of genotype (i = SRSR, LSR, LL)
Aj = the j^{th} fixed effect of age (j = six, nine, twelve month)
Gi*Aj = effect due to interaction of genotype with hen age
e_{ijk} = random error

RESULT

Egg production and mortality

Table 2 shows the laying performances and mortality. The LL chicken had the lowest (p < 0.05) value in Hen-housed egg number whereas the values were similar (p > 0.05) between SRSR and LSR chickens. The hen-day egg number, egg weight, egg mass, feed intake and final body weight were highest (p < 0.05) for SRSR chicken and lowest (p < 0.05) for LL chicken. The feed efficiency was best, inferior, and in-between for SRSR, LSR and LL chickens, respectively. The age at first egg was longest (p < 0.05) for LL chicken, while it was similar (p > 0.05) for SRSR and LSR chickens. The body weight was almost un-changed and the values were heaviest, intermediate, and lightest for SRSR, LSR and LL chickens, respectively through the study period (Figure 1). The mortality rate was not affected (p > 0.05) by genotype. Hen-day egg number was higher for SRSR than LL chickens through the study period. However, the values were showed a fluctuating trend for LSR chickens. Age at peak of lay was 27 week for LSR and SRSR chickens and 47 week for LL chickens (Figure 2).

Egg quality characteristics

Table 3 shows egg quality traits. The SRSR chicken had the highest (p < 0.05) whereas the LL chicken had the lowest (p < 0.05) values of egg and shell weights. The value of egg length was lowest for LL chicken. The values of shell thickness, egg width and egg shape index were not affected ($p > 0.05$) by genotype. The value of egg length was increased ($p < 0.05$) whereas the value of shell thickness showed a decreasing trend with increased hens age. The SRSR hens had the highest ($p < 0.05$) values in yolk weight, albumen weight, yolk height, albumen height,

Table 2. Laying performances and mortality of three genotypes of chicken tested on-station.

	Genotypes				
Parameters	SRSR	LSR	LL	Mean	SEM
33-week egg number per hen (HH)	101[a]	82.0[a]	57.9[b]	80.1	6.07
33-week egg number per hen (HD)	126[a]	96.8[b]	75.6[c]	99.4	6.66
Daily rate of lay per hen	0.55[a]	0.42[b]	0.33[c]	0.43	0.03
33-week average egg weight, g/egg	50.9[a]	46.9[b]	44.4[c]	47.4	0.82
33-week egg mass, kg/hen	6.41[a]	4.53[b]	3.36[c]	4.77	0.40
Daily egg mass, g	27.7[a]	19.6[b]	14.5[c]	20.6	1.72
33-week feed intake, kg/ hen	26.7[a]	23.5[b]	15.3[c]	21.9	1.46
Daily feed intake, g/ hen	116[a]	102[b]	66.2[c]	94.5	6.32
Feed conversion ratio (g feed/ g egg mass)	4.19[b]	5.20[a]	4.57[ab]	4.67	0.18
Age at first egg, day	142[b]	144[b]	157[a]	147	2.38
Body weight at 52 weeks of age, g/ hen	2362[a]	1882[b]	1449[c]	1898	128
Mortality (18 - to 52- weeks of age), %	25.0	20.3	31.8	25.7	2.54

[a, b, c] Means with the same letter within rows are not significantly different ($P>0.05$); SEM= standard error of the mean; HH = hen housed; HD = hen day; g = gram; kg = kilogram

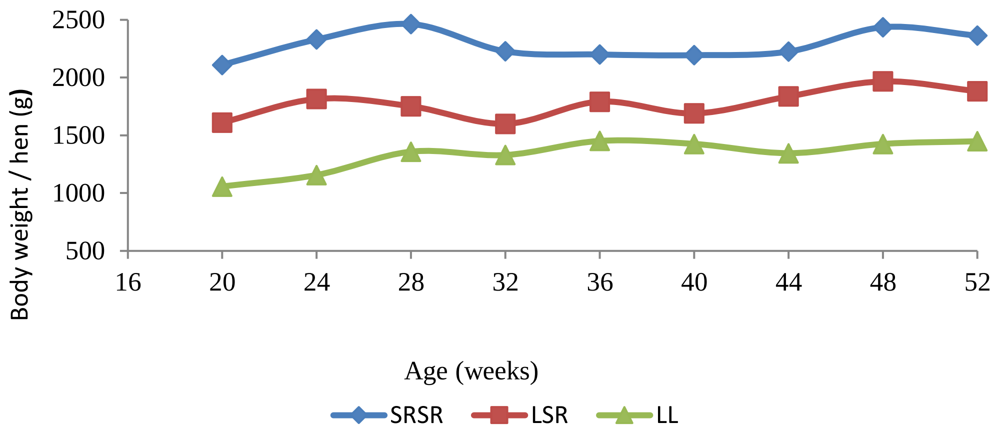

Figure 1. Body weight of three genotypes of hens at different ages.

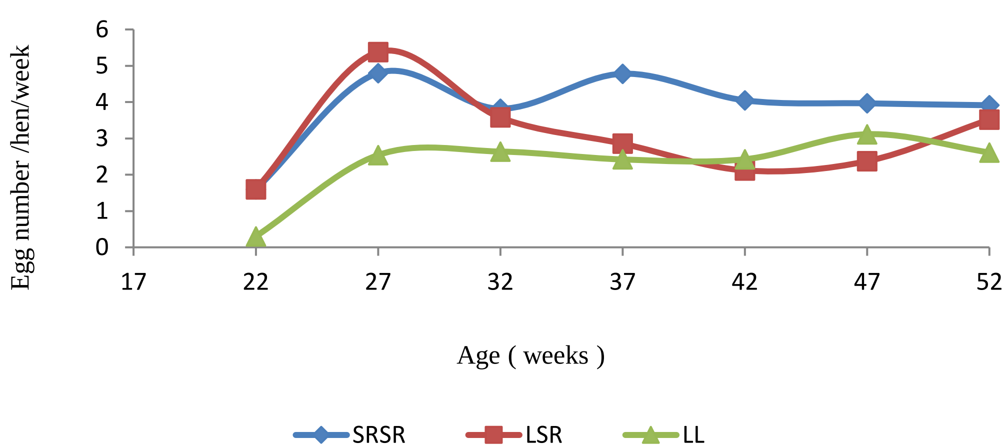

Figure 2. Egg production of three genotypes of hens at different ages.

yolk width and albumen weight ratio. The LL hens had the highest ($p < 0.05$) value in yolk weight ratio. The SRSR hens had the lowest ($p < 0.05$) values in yolk weight ratio and shell weight ratio. The LL hens had the lowest ($p < 0.05$) values in albumen weight, albumen height, yolk color score, and albumen weight ratio. The values of albumen height, yolk width, yolk weight and shell weight ratio of LSR hens were comparable ($p > 0.05$) with LL hens. The yolk height, yolk color score, yolk weight, albumen weight, and yolk weight ratio were increased ($p < 0.05$) with hens age. On the other hand, the values of albumen weight ratio and shell weight ratio were decreased ($p < 0.05$) with hens age. Albumen height and Haugh unit were highest ($p < 0.05$) at 6 months of hens age.

Table 3. Least squares means of genotype and hen age effect on egg quality traits of chicken tested on station.

	Hens age (A), month			Genotype (G)				*p*-value	
Parameters	6	9	12	SRSR	LSR	LL	SEM	A	G
External egg quality traits									
Egg weight (EWt), g	44.6[c]	49.6[b]	52.1[a]	52.9[a]	48.0[b]	45.5[c]	0.28	<.0001	<.0001
Shell weight (SWt), g	4.89	5.01	4.95	5.20[a]	4.96[b]	4.68[c]	0.03	0.2653	<.0001
Shell thickness (ST), mm	0.37[a]	0.31[b]	0.30[b]	0.34	0.33	0.33	0.01	<.0001	0.1569
Egg length (EL), mm	51.1[c]	53.6[b]	55.2[a]	54.2[a]	53.8[a]	52.0[b]	0.15	<.0001	<.0001
Egg width (EW), mm	38.9	40.1	42.2	42.6	39.4	39.1	0.76	0.1859	0.1148
Egg shape index (ESI), %	76.0	74.9	76.9	79.0	73.4	75.5	1.50	0.8636	0.3042
Shell weight ratio (SWR), %	11.0[a]	10.1[b]	9.50[c]	9.80[b]	10.3[a]	10.3[a]	0.07	<.0001	0.0022
Internal egg quality traits									
Yolk height (YH), mm	17.3[c]	17.7[b]	18.2[a]	18.2[a]	17.5[b]	17.4[b]	0.06	<.0001	<.0001
Albumen height (AH), mm	6.23[a]	5.84[b]	5.94[b]	6.37[a]	5.97[b]	5.67[c]	0.06	0.0114	<.0001
Yolk width (YW), mm	36.0[c]	40.8[a]	40.1[b]	39.3[a]	38.8[b]	38.8[b]	0.13	<.0001	0.0243
Yolk color (YC), score	7.60[c]	8.65[b]	9.48[a]	8.70[a]	8.69[a]	8.34[b]	0.09	<.0001	0.0356
Yolk weight (YWt), g	13.2[c]	16.6[b]	18.3[a]	16.8[a]	15.8[b]	15.5[b]	0.13	<.0001	<.0001
Albumen weight (AWt), g	26.5[c]	28.0[b]	28.9[a]	30.9[a]	27.2[b]	25.3[c]	0.18	<.0001	<.0001
Haugh unit (HU)	83.4[a]	78.7[b]	78.5[b]	81.1	80.2	79.3	0.65	<.0001	0.1306
Yolk weight ratio (YWR), %	29.6[c]	33.5[b]	35.1[a]	31.8[c]	32.9[b]	34.1[a]	0.18	<.0001	<.0001
Albumen weight ratio (AWR), %	59.4[a]	56.4[b]	55.4[c]	58.4[a]	56.8[b]	55.6[c]	0.20	<.0001	<.0001

[a,b, c] Row means within group with different superscript letters differ significantly at $p< 0.05$; SEM= standard error of the mean.

Table 4. Least squares means of interaction effects (genotype x hen age) on external egg quality traits of chickens tested on station.

		External egg quality traits*						
		EWt (g)	SWt (g)	ST (mm)	EL (mm)	EW (mm)	ESI (%)	SWR (%)
Hens age	**Genotype**							
6 month	SRSR	48.0[a]	5.09	0.39	51.8	40.0	77.4	10.6
	LSR	43.2[b]	4.84	0.36	51.1	38.2	74.9	11.2
	LL	42.6[b]	4.72	0.38	50.6	38.2	75.7	11.1
	SEM	0.52	0.09	0.01	0.26	0.19	0.46	0.2
9 month	SRSR	53.9[a]	5.24[a]	0.30	54.7[a]	40.7	74.5	9.70
	LSR	48.8[b]	5.07[ab]	0.31	54.2[a]	39.9	73.8	10.4
	LL	46.2[b]	4.72[b]	0.31	51.9[b]	39.6	76.5	10.2
	SEM	0.61	0.09	0.01	0.40	0.26	0.62	0.15
12 month	SRSR	56.8[a]	5.28[a]	0.32	56.2[a]	47.1	85.1	9.30
	LSR	51.9[b]	4.96[ab]	0.30	56.0[a]	40.0	71.5	9.60
	LL	47.6[c]	4.61[b]	0.29	53.3[b]	39.6	74.2	9.70
	SEM	0.58	0.07	0.01	0.31	0.16	0.33	0.16
p-value		0.0081	0.4704	0.0811	0.0149	0.5471	0.5415	0.4643

[a,b, c] Column means among genotypes within age group with different superscript letters differ significantly at $p< 0.05$; SEM= standard error of the mean; *Abbreviations are defined in Table 3.

Table 5. Least squares means of interaction effects (genotype x hen age) on internal egg quality traits of chickens tested on station.

		Internal egg quality traits*								
		YH (mm)	AH (mm)	YW (mm)	YC (score)	YWt (g)	AWt (g)	HU	YWR (%)	AWR (%)
Hens age	**Genotype**									
6 month	SRSR	17.5	6.40	36.6	7.47	14.0[a]	28.9[a]	83.1	29.2	60.2
	LSR	17.0	6.23	35.7	7.49	12.9[ab]	25.5[b]	83.8	29.9	58.9
	LL	17.3	6.07	35.6	7.85	12.6[b]	25.3[b]	83.3	29.6	59.3
	SEM	0.14	0.15	0.23	0.20	0.20	0.38	0.83	0.33	0.56
9 month	SRSR	18.3[a]	6.39[a]	41.0	8.84	17.2	31.5[a]	80.9	31.9[b]	58.4[a]
	LSR	17.5[b]	5.72[ab]	40.4	8.80	16.2	27.5[b]	78.0	33.2[b]	56.4[ab]
	LL	17.2[b]	5.40[b]	41.0	8.31	16.4	25.1[c]	77.2	35.5[a]	54.3[b]
	SEM	0.16	0.17	0.26	0.22	0.25	0.41	0.99	0.41	0.46
12 month	SRSR	18.8[a]	6.32[a]	40.3	9.80[a]	19.1[a]	32.4[a]	79.5	33.6[b]	57.1[a]
	LSR	18.0[b]	5.96[ab]	40.2	9.79[a]	18.2[ab]	28.7[b]	78.6	35.1[b]	55.4[ab]
	LL	17.7[b]	5.54[b]	39.7	8.84[b]	17.4[b]	25.6[c]	77.4	36.6[a]	53.8[b]
	SEM	0.15	0.17	0.30	0.17	0.27	0.40	1.04	0.40	0.42
p-value		0.0139	0.3377	0.1098	0.0042	0.2445	0.0002	0.4251	0.0003	0.0135

[a,b, c] Column means among genotypes within age group with different superscript letters differ significantly at $p < 0.05$; SEM= standard error of the mean; *Abbreviations are defined in Table 3.

Table 4 and Table 5 show genotype by hen age interaction effect on external and internal egg quality traits, respectively. The significant ($P<0.05$) influences of genotype by hens age interaction were observed on the values of egg length, egg weight, yolk height, yolk color score, albumen weight, yolk weight ratio and albumen weight ratio. For LL chicken, the values of egg weight, egg length, yolk color score, albumen weight, and albumen weight ratio were lowest whereas the value of yolk weight ratio was highest at older ages.

DISCUSSION

Egg production and mortality

The significant effects of genotype on laying performances in present study suggest that genetic differences exist between the genotypes in these traits .The age at first egg for LL chicken was comparable with Halima (2007), who reported 150 days for local chickens under on-station conditions in Northern Ethiopia. However, lower and higher values were reported by several authors. For example, Bamidele *et al*. (2019) reported about 122 days for Nigerian local chickens under station conditions. In contrast, Tadelle *et al*. (2003) reported 204 days of age at first egg for Ethiopian local chickens under farmers' conditions. The values of age at first egg were similar between SRSR and LSR and were in line with the values reported for exotic chicken in Ethiopia. For example, Dawud *et al*. (2018) reported 140 days for Dominant Red Barred D922 and Potchefstroom Koekoek chickens under on-station conditions. However, lower values reported by Bamidele *et al*. (2019), who observed that it was 120, 130 and 133 days for Kuroiler, Noiler and Sasso chickens, respectively in Nigeria under station conditions. Inconsistent with the current study, Dawud *et al*. (2018) reported that the age at peak of lay was in the range of 37 weeks for Potchefstroom Koekoek to 43 weeks for Lohmann Brown Classic chickens under on-station conditions in Ethiopia. The variations in age at first egg and peak of lay among chickens in the various studies may be due to genotype, environment or genotype by environment interactions effect (Wondmeneh, 2015; Bamidele *et al*., 2019).

Our results concerning egg number, egg weight and mass are in good agreement with a previous report by Rizzi and Chiericato (2005), who observed that commercial hybrids outperforms local birds in terms of egg number and egg mass. The annual hen-day egg number of Sasso-RIR was in good agreement with Tadelle (2018), who reported that the value was 208 eggs/hen for the same chicken in Ethiopia under on-station conditions. The annual egg number for LL chicken was higher than the values of 85‒95 reported for Ethiopian local chickens under on-station conditions (Duguma, 2009). The finding that LSR chicken was inferior than SRSR chicken but better than LL chicken in egg number, egg weigh and mass confirms previously reported findings by Aberra *et al*. (2005) and Ahmad *et al*. (2019), who reported that the overall performance of the crosses was better than either the local or the exotic parents under similar management condition. The values of egg weight from LL and LSR hens was in the rage of 30 − 50 g reported for eggs from African village chicken (Gueye, 2000). However, the values of egg weights obtained in this study were higher than the values of 39– 42 g reported for Ethiopian local chickens (Duguma, 2009) and lower than the values of 55.8 g reported for Sasso-RIR chickens in Ethiopia (Habtie, 2019). In general, the difference among egg number, egg weight, and mass in the various studies may be due to the influence of age of hen, genotype, rearing system, genotype by rearing system interactions (Kamil *et al*., 2012; Wondmeneh, 2015).

The results concerning feed intake of chicken in this study was in line with reports Wondmeneh (2015), who found that the feed consumption of commercial chicken was highest followed by their F1-cross and indigenous chickens under on-station condition. Moreover, the results concerning FCR in this study were parallel with findings by Wondmeneh (2015), who reported a value of 2.43 for Bovans brown commercial egg layer and 3.33 for crossbred between RIR cock and indigenous improved Horro and the difference was significant ($p < 0.05$). The influence of genotype on body weight of hens in this study was in good agreement with Fassill *et al*. (2010), Bamidele *et al*. (2019) and Kamil *et al*. (2012). The body weights of LL and LSR hens were in the range of 700 – 2100g reported for adult female chicken body weight for African village chicken (Gueye, 2000). However, the final body weight for LSR hens was higher than the values reported for local Kei x Fayoumi cross (1054 g) and local Kei x RIR cross (1227 g) at similar age (Misba and Aberra, 2013) might be due to the genetic superiority of Sasso-RIR chickens in body weight that is a highly heritable trait, and known for its additive genetic response to crossbreeding (Fassill *et al*.,2010; Misba and Aberra, 2013).

In accordance to this study, Udeh *et al*. (2015) reported that the difference of mortality rate among Arbor Acres, Marshall, and Ross chickens was not significant. However, other authors reported that genotype had a significant influence on livability of chickens under on-station condition (Kamil *et al*. 2012; Wondmeneh, 2015). The difference among the mortality rate reported in the various studies may be due to variations in genetics, management conditions, age of birds studied and heat stress (Kamil *et al*. 2012; Bamidele *et al*., 2019). In present study, the genetic influence appears more relevant than others since all genotypes were tested under similar environments. The major environmental factor responsible for mortality of hens in present study was the prevalence of disease (coccidiosis).

External egg quality characteristics

The results concerning egg and shell weights in the current study agree with findings of other studies. For example, several authors reported that exotic chicken produce heavier eggs than local chicken (Silversides and Scott, 2001; Wondmeneh, 2015; Bamidele *et al*., 2019). Moreover, Lishan (2017) and Yonas *et al*. (2019) reported that the genotype of layers significantly affected the weight of egg shell. On the contrary, Dawud *et al*. (2018) reported similar egg shell weight for the eggs from Dominant Red Barred D922, Dominant Sussex D104, Potchefstroom Koekoek, Lohmann Brown Classic and Lohmann Dual chickens under on-station conditions. The increased egg weight and unchanged egg shell weight with increased hen age in present study confirm previous reports by Altunas and Sekeroglu (2007) and Lishan (2017). The values concerning egg shell thickness in present experiment agree with Khan *et al*. (2004), Lishan (2017) and Dawud *et al*. (2018), who reported no significant effect of breed on eggshell thickness. Moreover, Altunas and Sekeroglu (2007) reported that the values of egg shell thickness decline with increase in hens age and which is also in good agreement with present findings. The values for egg shell thickness in the current study was in agreement with Khan *et al*. (2004) who reported that a standard egg shell quality was in the range of 0.33 mm to 0.36 mm. This suggests that the eggs from studied chickens are resistant to forces and withstand manipulating techniques. In present study, the egg shell weight was not affected, egg weight and length were increased and shell thickness was decreased as the hens age increased might be due to an increase in egg weight without an increase in the amount of calcium carbonate deposited in the shells (Nys, 2001).

In accordance to this study, Yonas *et al*. (2019) reported that eggs from local chickens had lower egg length than exotic chickens. Moreover, Lishan (2017) reported that the egg length values for eggs from various chicken breeds showed an increasing trend with hens age. In contrast to the values concerning the egg width in this study, it was reported that genotype had a significant influence on egg width (Dawud *et al*., 2018; Yonas *et al*., 2019). In addition, Lishan (2017) reported an increasing trend of egg width with hen age. However, in line with this study, Lishan (2017) reported that egg shape index values were not different among eggs from different genotypes. In contrast, different egg shape index values among different chicken breeds were reported by Dawud *et al*. (2018). Lishan (2017) observed that the values of egg shape index was unchanged as the age of hen increases is in good agreement with this study. In contrast, van den Brand *et al*. (2004) reported a decrease in egg shape index with increase in hens’ age. The egg shape index values for eggs from LL chicken (75.5 %) and LSR chicken (73.4 %) were within the range classified for normal (standard) egg shape (72 − 76 %), which fits well into pre-made packaging whereas the value of egg shape index for eggs from SRSR (79 %) was classified for round egg shape (> 76 %) which do not fit well in cartons so are much more likely to be broken during shipment than are eggs of normal shape (Altuntas and Sekeroglu, 2007). In general, the variations of egg length, width and egg shape index among chickens in this study were most likely due to genetic factor.

In present study, genotype x age interaction had significant effects on the values of egg weight and egg length. These interactions were caused by the differential responses of the genotypes to hens' age. For example, for egg weight, LSR and LL hens were similar at 6 and 9 months of age, but at 12-months of age, it was lowest for LL hens. Similarly significant effects of genotype × hen age interactions on some external egg quality traits of chicken have been reported (Wondmeneh, 2015; Ahmad *et al*., 2019).

Internal egg quality characteristics

The values regarding to yolk height, yolk width, and albumen height in this study is in good agreement with Yonas *et al*. (2019), who reported lower yolk height, yolk width, and albumen height values for eggs from local chickens than exotic chickens. The increase of yolk height and fluctuating trend of yolk width with hens' age in this study agree with the values previously reported by Lishan (2017). The value of albumen height for eggs from LL hens is in good agreement with the value reported by Yonas *et al*. (2019), who observed that it was 5.45 mm for eggs from local chicken in Ethiopia. Among the studied chickens, albumen height was highest for eggs from SRSR hens but it was lower than the values recorded for eggs from other exotic chicken breeds. For example, it was 7.55 mm and 8.25 mm for eggs from Sasso and Bovans brown chickens, respectively (Yonas *et al*., 2019). Moreover, it was reported that the range of 10 mm for Koekoek to 11.06 mm for Dominant Red Barred chicken breeds (Lishan, 2017). The differences among the yolk height, albumen height, and yolk width reported in the various studies may be due variations in layer's nutrition, genetics of chicken, environment and housing (Karine *et al*., 2019). In this study, the genetic influence appears more relevant than others since all genotypes were tested under similar environments. In present study, the highest value of albumen height was observed at 6 months of hens age is in line with previous study by Altunas and Sekeroglu (2007), who reported that almost all egg quality traits decline as hens get aged, with the exception of egg weight. The present findings revealed that the values of Haugh unit was not affected by genotype and it agrees with Desalew (2012) but inconsistent with Kamil *et al*.(2012) and Yonas *et al*. (2019). The values of Haugh unit in present study was highest at 6 months of hens' age, and was in good agreement with the findings of Pasquoal *et al*. (2012) who reported that the Haugh units of eggs from Dekalb White hens was 71.3 at 35 weeks of hens age and then it was decreased to 63.1 at 50 weeks of age. The higher the value of the Haugh unit, the better the quality of eggs. According to the United States Department of Agriculture (USDA) eggs are classified as AA (100 to 72), A (71 to 60), B (59 to 30) and C (below 29) (USDA, 2000), and all eggs from all genotypes and ages in the current study are classified as AA.

In the current study the color of egg yolk was influenced by genotype and similar result was also reported by several authors (Desalew, 2012; Kamil *et al*., 2012; Yonas *et al*., 2019). The values of yolk color in present study are below the range of 9.2 to 10.7 reported by Dawud *et al*. (2018) for various chicken breeds under on-station conditions. Apart from genetics, the variation of the values of yolk color was greatly attributed to the presence of xanthophylls in the diet received (Silverside *et al*., 2006). In accordance with this study, Padhi *et al*. (2013) reported that more intense color of yolk was observed at older ages of hen but the reason was unclear.

The highest yolk and albumen weights for eggs from SRSR hens confirm the observations by Aygun and Yetisir (2010), who reported that egg weight positively influences the weight of yolk and albumen. In agreement with present study, yolk weight (Van den Brand *et al*., 2004) and albumen weight (Suk and Park, 2001) have been shown to increase with hens age. This suggest that yolk and albumen weights are positively related with egg weight. In concurrence with our findings, Lishan (2017) reported that the values of yolk, albumen and shell ratios were significant among Dominant Red Barred, Koekoek, Lohmann Brown and Novo Colour breeds of chicken. In contrast to this study, Dawud *et al*. (2018) reported that the values of egg yolk, albumen and shell ratios were not affected by chicken breeds. In line with present study, Danilov (2000) noted that the proportion of yolk ratio increases with hen's age, reaching a plateau by the end of the laying cycle. However, it was reported that lower percentages of albumen (Silversides and Scott, 2001) and shell (Pasquoal *et al*., 2012) for eggs from older birds. A decrease in shell ratio as the hen ages might be due to an increase in egg weight without an increase in the amount of calcium carbonate deposited in the shells (Nys, 2001). A decrease in albumen ratio and an increase in yolk ratio with age indicate that eggs from younger hens may be suitable for a consumer who needs lower yolk proportion. Moreover, eggs from older hens may be more suitable for the product which needs higher yolk proportion.

Our findings showed that genotype x age interaction had significant effects on some internal egg quality traits. These interactions were caused by the differential responses of the genotypes with change in hen age. For example, initially, yolk height did not differ among genotypes. However at 9 and 12 months of age, highest yolk height was found in SRSR eggs. Similar effects of genotype × hen age interactions on some internal egg quality traits of chicken have been reported by Ahmad *et al*. (2019).

CONCLUSIONS

The exotic blood of Sasso-RIR chicken played a significant role in upgrading the egg number, egg weight, egg mass, body weight, age at first egg, HHEP, shell weight, egg length, albumen height, yolk color, albumen weight and albumen weight ratio. On the other hand, indigenous blood of local chicken played a significant role in upgrading the yolk weight ratio, shell weight ratio, and egg shape index (normal) without adverse effect on survival rate, shell thickness, egg width and Haugh unit. The values of feed conversion ratio, yolk height, yolk width, and yolk weight were not improved by cross breeding.

Higher egg weight, egg length, yolk height, yolk color score, yolk weight, albumen weight, and yolk weight ratio were obtained for eggs from older hens whereas higher albumen weight ratio and shell weight ratio were obtained for eggs from younger hens. However, the influences of genotype on the values of egg weight, egg length, yolk height, yolk color, albumen weight, albumen weight ratio, and yolk weight ratio depend on hens age. The eggs from older hens may be more useful for the product which needs more yolk proportion. However, the eggs from younger hens may be suitable for the consumer who needs less yolk proportion.

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Compliance with ethical standards. All applicable international, national, and institutional guidelines for the care and use of animals were followed. Study was reviewed and approved by the School of Animal and Range Sciences, College of Agriculture, Hawassa University.

Conflict of interest. We declare that we have no conflict of interest.

Data availability statement. The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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