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Research Article

Evaluation of Egg Quality Traits of Sasso T44 and Potchefstroom Koekoek Genotypes of Chicken Kept Under Farmers' Management Conditions

[1]Tariku Beyene, [1]Zemene Worku, [1]Solomon Demeke, [1,2]Ashenafi Miresa

[1]College of Agriculture and Veterinary Medicine, Jimma University, Jimma, Ethiopia
[2]College of Agriculture and Natural Resource, Mekdela Amba University, Mekdela Amba, Ethiopia

Abstract

Background and Objective: Understanding egg quality traits of exotic chicken kept under farmers' management condition is very important for improving genetic performance and overall production obtained from both egg and hens. This study was conducted to compare two chicken ecotypes (highland and midland) and two chicken genotypes (Sasso T44 and Potchefstroom Koekoek) in Dedo district of Jimma Zone, Ethiopia in terms of internal and external egg quality traits and to determine the possible relationships among these traits. **Materials and Methods:** A total of 100 eggs were collected and their some internal and external egg quality traits were evaluated. Two-way ANOVA was used to compare the ecotypes and genotypes and Pearson Correlation analysis was used to determine relationships among the traits. **Results:** Two ecotypes were significantly different ($p<0.05$) in terms of egg weight, egg length and shell ratio. There was significant difference ($p<0.05$) between the two chicken genotypes in terms of all external egg quality traits except shell thickness. The interaction of ecotypes and genotypes shows a non-significant effect ($p>0.05$) on all external egg traits except egg length ($p<0.05$). Albumin weight, yolk height and yolk diameters were significantly ($p<0.05$) affected by chicken ecotypes. All internal egg quality traits were significantly influenced ($p<0.05$) by chicken genotypes. The difference in egg quality traits of chicken genotypes and ecotypes suggested that there is a need for modifying genetic, feeding system and environmental factors for improving the performance of these exotic chickens. **Conclusion:** Sasso T44 is superior in most of egg quality parameters and raising Sasso T44 genotype might be recommended for smallholder farmers.

Key words: Egg quality, egg traits, exotic chicken, phenotypic correlation, farmers' management

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Corresponding Author: Ashenafi Miresa, College of Agriculture and Veterinary Medicine, Jimma University, Jimma, Ethiopia
College of Agriculture and Natural Resource, Mekdela Amba University, Mekdela Amba, Ethiopia

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Chicken production has significant socio-economic benefits and plays a key role in family income and nutrition in developing countries. They are an important source of human food, profitable business, a tool for improving family income and means of poverty alleviation[1]. In 2020, global contribution of chicken to animal source protein production was reported to have attained 40%, with a significant increase occurring in developing countries[2]. The current Ethiopian chicken population is estimated to be about 57 million[3]. About 78.85, 12.02 and 9.11% of the country's total chicken population was reported to be indigenous, hybrid and exotic respectively[3]. The indigenous chickens are distributed over a wide range of agro-ecologies and reared under a traditional scavenging management system, characterized by small flock sizes and low input and output, occasional flock devastation by disease outbreaks and informal market system[4]. The production potential of indigenous chicken, the demand of egg and chicken meat of Ethiopian populations cannot be satisfied[5], indicating that there is strong need to improve the egg production performance of the indigenous chickens. In the past, development initiatives of village chickens in Ethiopia placed special emphasis on genetic improvement through the introduction of exotic genotypes of chickens, to be used either on their own or for crossbreeding with the indigenous chickens. Sasso T44 and Potchefstroom Koekoek (PK) genotypes are among the exotic chicken recently introduced into Ethiopia to improve chicken production and productivity[6].

Egg qualities have gained great relevance in egg production process and directly affect consumers' preferences[7,8]. Understanding the egg quality characteristics has a paramount role to improve chicken productivity and meet the increasing demand of chicken products as well as minimize the rate of loss during commercial processing[8,9]. According to Kul and Seker[10], about 8% of eggs produced were broken during transport from farms to consumers and the numbers of egg cracked are a serious economic loss for both producers and distributors. In order to maintain the egg quality and avoid problems of preservation and marketing, it is important to give attention to internal and external egg characteristics. Evaluation of egg quality traits of some indigenous, crossbreeds and exotic chicken breeds have been conducted in some parts of Ethiopia[11-13].

Furthermore, carcass characteristics evaluation, incubation and brooding practices, marketing and price determinant factors, constraint and opportunities, breeding practices, objective and farmer's trait preference of village chicken production under natural breeding environment had also been studied in South-Western Ethiopia and Jimma zone[4,14-16]. However, no research on evaluation and phenotypic correlation between internal and external egg quality traits of Sasso T44 and PK chicken breeds kept under farmers' management conditions had been conducted in Dedo district of Jimma zone. This being a case, this study was conducted to evaluate egg quality traits and phenotypic correlation between external and internal egg quality traits of Sasso T44 and PK Breeds of chicken kept under farmers' management conditions Dedo district of Jimma zone.

MATERIALS AND METHODS

Description of study area: The study was conducted in Dedo district of Jimma Zone of Oromia Regional State of Ethiopia in 2022. The geographical location of the district is 7°13'39'' North latitudes and 36°43'12'' East longitudes. The altitude of the district ranges between 1035 and 3048 m above sea level. The climate condition of the district include of 32.6% cool, 49.2% subtropical and 18.2% tropical agro-climates. The annual rainfall of the districts ranges from 1300-1700 mm while the annual temperature ranges from 11.5-26.3°C.

Data collection: A total of 100 fresh eggs (50 from each genotype) were purchased and transported to Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) to evaluate egg quality traits of chicken ecotypes and genotypes. Soon after arrival, each egg was individually weighed using sensitive digital balance. Length (mm) and width (mm) of the eggs were measured with Electronic digital caliper. Egg shape index (SI) was calculated according to the following formula as cited by Anderson *et al.*[17]:

$$\text{Shape index (\%)} = \frac{\text{Egg width}}{\text{Egg length}} \times 100$$

Eggshell thickness was measured at three regions (large, middle and small end) using a micrometer gauge and the mean values was considered. After taking the external measures of the egg sizes, measures of the internal constituents were obtained by precisely 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 also precisely separated from the albumen and placed in a petri dish for weighing. Concurrently, the related albumen was also placed on another petri dish and weighed. Both petri dishes used in weighing the egg contents had been initially weighed and the difference in the weights of the petri dish after and before the egg constituents was taken as the weight of the egg constituents. After each weighing, the petri dishes were washed in clean water and wiped dry before next weighing. The yolk and albumin height measurements were taken using a Tripod Micrometer.

The shell weight with membrane was obtained by precisely placing the opened part in the shell and weighing on the electronic scale. Egg yolk/albumin (Y/A) ratio was calculated by dividing the yolk weight by the albumen weight[18]. Eggshell color of each egg was determined by visual observation while yolk color was measured with a Roche yolk color fan scale (ranged 1-15) (Roche scale). The following internal egg quality traits were calculated as described by Singh and Panda[19]:

$$\text{Shell}(\%) = \frac{\text{Shell width}}{\text{Egg weight}} \times 100$$

$$\text{Yolk}(\%) = \frac{\text{Yolk weight}}{\text{Egg weight}} \times 100$$

$$\text{Albumen}(\%) = \frac{\text{Albumen weight}}{\text{Egg weight}} \times 100$$

$$\text{Yolk index}(\%) = \frac{\text{Yolk height}}{\text{Yolk diameter}} \times 100$$

Hough unit (albumin height corrected for egg weight) is a measure of the internal quality of an egg by relating the height of thick albumen and egg weight[20]. The higher the Hough unit, the better the quality of the egg (fresher, higher quality eggs have thicker whites) is and it was determined using the following formula developed by Haugh[20].

$$\text{Haugh unit (HU)} = 100 \text{ Xlog } (\text{AH} - 1.7 \text{ EW}^{0.37} + 7.6)$$

Where:

HU = Hough unit
AH = Albumen height (mm)
EW = Egg weight (g)

Statistical analysis: The effect of ecotypes (2 levels: midland and highland) and genotypes (2 levels Sasso T44 and PK) on external and internal egg quality traits were determined using two-way analysis of variance. Shapiro-Wilk test was used to analyze the normality of the residuals of all variables evaluated using SPSS statistical software (SPSS 26.0). Tukey's multiple range tests was used to compare significant differences among means. Correlation analysis of egg characteristics was obtained with Pearson product-moment correlation coefficients (PCC) using SPSS 26.0 computer package program. $p<0.05$ and $p<0.01$ were considered significant and highly significant, respectively. The model used for the two-way analysis was:

$$Y_{ijk} = \mu + E_i + G_j + E_i \times G_j + \varepsilon_{ijk}$$

Where:

Y_{ijk} = Observed k variable in the i^{th} ecotypes and j^{th} genotype
μ = Overall mean of the observed variables,
E_i = Effect of ith ecotypes (I = highland and midland)
G_j = Effect of jth genotype (j = Sasso T44 and PK chicken)
$E_i \times G_j$ = Effect of interaction between ith ecotypes and jth genotypes
ε_{ijk} = Random residual error

RESULTS

Descriptive statistics: Table 1 shows the descriptive statistics obtained from the data on external and internal characteristics. The average egg weight, egg width, egg length, shell weight, shell thickens, shell ratio and shape index were 58.85 g, 46.64 mm, 54.35 mm, 5.89 g, 0.27 mm, 11.10% and 76.85%, respectively. In addition, the average albumin height, albumin ratio, albumin weight, yolk height, yolk weight, yolk color, yolk ratio, yolk diameters and haugh unit were 4.18 mm, 59.06%, 31.28 g, 15.24 mm, 16.23 g, 9.20 RYCF, 40.72%, 30.76%, 37.81 mm and 63.23, respectively.

External egg quality traits: Significant difference ($p<0.05$) was observed among the two chicken ecotypes in terms of egg weight, egg length and shell ratio, however, there was no significant difference ($p>0.05$) among egg width, shell weight, shell thickness and shape index (Table 2). Significantly higher mean values of egg weight and egg length were obtained from midland chicken ecotypes, whereas higher mean value of shell ratio and egg shape index was obtained from highland chicken ecotypes. Irrespective of chicken genotypes, there was a significant ($p<0.05$) effect of genotypes on all external egg quality traits except shell thickness ($p>0.05$). The mean value of all external egg quality traits, except shell thickness in Sasso T44 was higher than PK genotypes. The interaction of ecotypes and genotypes shows a non-significant effect ($p>0.05$) on all external egg quality traits except egg length ($p<0.05$).

Table 1: Descriptive statistics of egg quality traits of Sasso T44 and PK chicken

Characteristics	Grand mean	SEM	Minimum	Maximum	CV
External egg quality traits					
Egg weight (g)	58.85	0.46	51.93	53.76	8.72
Egg width (mm)	46.64	0.21	41.25	42.06	5.14
Egg length (mm)	54.35	0.24	53.87	54.83	4.42
Shell weight (g)	5.89	0.06	5.78	6.02	10.23
Shell thickness (mm)	0.27	0.00	0.26	0.28	13.78
Shell ratio (%)	11.10	0.14	10.83	11.37	12.28
Shape index (%)	76.85	0.51	75.83	77.86	6.68
Internal egg quality traits					
Albumin height (mm)	4.18	0.07	4.03	4.34	18.43
Albumin ratio (%)	59.06	0.62	57.83	60.29	10.50
Albumin weight (g)	31.28	0.42	30.45	32.12	13.48
Yolk height (mm)	15.24	0.11	15.03	15.45	6.93
Yolk weight (g)	16.23	0.19	15.85	16.61	11.82
Yolk color (RYCF)	9.20	0.13	8.94	9.45	13.99
Yolk index (%)	40.72	0.49	39.47	41.69	12.06
Yolk ratio (%)	30.76	0.30	30.16	31.36	9.88
Yolk diameters (mm)	37.81	0.37	37.06	38.56	9.96
Haugh unit	63.23	0.82	61.59	64.87	13.05

SEM: Standard error of mean, CV: Coefficient of variation

Table 2: Effect of agro-ecology and breed on external egg quality traits (Mean±SE)

AEZ	Breed	Egg weight (g)	Egg width (mm)	Egg length (mm)	Shell weight (g)	Shell thickness (mm)	Shell ratio (%)	Shape index (%)
HH	Sasso	56.07±0.92	41.92±0.43	56.52±0.48	6.19±0.12	0.27±0.01	11.01±0.27	74.38±1.03
	PK	45.61±0.92	40.52±0.43	50.64±0.48	5.47±0.12	0.27±0.01	12.01±0.27	80.09±1.03
ML	Sasso	58.58±0.92	42.52±0.43	56.76±0.48	5.63±0.12	0.27±0.01	10.39±0.27	74.49±1.03
	PK	51.14±0.92	41.60±0.43	53.48±0.48	5.64±0.12	0.27±0.01	11.00±0.27	77.92±1.03
Source of variations								
AEZ		<0.0001	0.0528	0.0018	0.2561	1.0000	0.0037	0.4505
Breed		<0.0001	0.0080	<0.0001	<0.0001	1.0000	0.0040	<0.0001
AEZxB		0.1060	0.5766	0.0081	0.8300	1.0000	0.4847	0.1775

AEZ: Agro-ecological zone, HH: Highland, ML: Midland, PK: Potchefstroom Koekoek

Internal egg quality traits: Among the internal egg quality traits evaluated in the current study, albumin weight, yolk height and yolk diameters were significantly (p<0.05) affected by ecotypes. Significantly higher mean values of albumin weight, yolk height and yolk diameters were recorded from midland chicken ecotypes. On the other hand, all internal egg quality traits were significantly influenced (p<0.05) by chicken genotypes (either Sasso T44 or PK) except yolk height, yolk diameters and yolk index (Table 3). According to the result obtained from the current study, Sasso T44 chicken genotypes have significantly higher internal egg quality traits compared to PK chicken genotypes. Among the internal egg traits tested, only albumin height and yolk weight were significantly (p<0.05) affected by the interaction of ecotypes and genotypes of chicken.

Phenotypic correlations among external egg quality traits: Table 4 shows the phenotypic correlations between external egg quality traits of exotic chicken in the study area. Moreover, significant correlations between egg quality traits were found in the two agro-ecological zones. Egg weight was positively and strongly (p<0.01, highly significant) correlated with egg length (r = 0.839) and shell weight (r = 0.633) and negatively and strongly (p<0.01) correlated with shell ratio (r = -0.589) and shape index (r = -0.538) in highland agro-ecological zones. In midland agro-ecological zone egg weight was positively and strongly (p<0.01) correlated with egg length (r = 0.785) and shell weight (r = 0.710) and negatively and strongly correlated with shape index (r = -0.373). At highland chicken ecotypes, only egg width was strongly and negatively correlated with shape index (r = -0.538). On the other hand at midland ecotypes, egg widths were strongly and positively (p<0.01) correlated with shape index (r = 0.600) and shell weight (r = 0.303), whereas negative significant correlation (p<0.05) was observed between egg width and shell thickness (r = -0.294).

Strong positive correlation (p<0.01) was found between egg length and shell weight (r = 0.537 and r = 0.655) at highland and midland chicken ecotypes respectively. However, strong negative correlation (p<0.01) was found

Table 3: Effect of agro-ecology, breed and their interactions on internal egg quality traits (Mean±SD)

AEZ	Breed	Albumin height (mm)	Albumin ratio (%)	Albumin weight (g)	Yolk height (mm)	Yolk weight (g)	Yolk color (RYCF)	Yolk ratio (%)	Yolk diameter (mm)	Yolk index (%)	HU
HH	Sasso	4.29±0.15	59.67±1.24	33.38±0.84	15.14±0.21	17.32±0.38	9.56±0.26	30.66±0.61	37.88±0.75	40.58±0.98	63.51±1.65
	PK	3.98±0.15	58.15±1.24	26.54±0.84	14.69±0.21	14.54±0.38	9.04±0.26	31.72±0.61	35.12±0.75	42.26±0.98	62.11±1.65
ML	Sasso	4.78±0.15	61.26±1.24	35.97±0.84	15.53±0.21	16.81±0.38	9.64±0.26	28.66±0.61	39.20±0.75	39.78±0.98	66.98±1.65
	PK	3.68±0.15	57.16±1.24	29.24±0.84	15.59±0.21	16.25±0.38	8.56±0.26	32.01±0.61	39.04±0.75	40.26±0.98	60.32±1.65
Source of variations											
AEZ		0.5270	0.8097	0.0022	0.0027	0.1200	0.4391	0.1614	0.0008	0.1571	0.6128
Breed		<0.0001	0.0256	<0.0001	0.3608	<0.0001	0.0025	0.0005	0.0556	0.2734	0.0164
AEZxB		0.0114	0.3016	0.9440	0.2250	0.0046	0.2794	0.0633	0.0876	0.5449	0.1148

AEZ: Agro-ecological zone, HH: Highland, ML: Midland, PK: Potchefstroom Koekoek and HU: Haugh unit

between egg length and shell ratio (r = -0.435) and shape index (r = -0.709) at highland ecotypes. At midland ecotypes, egg length was strongly and negatively (p<0.01) correlated with shape index (r = -0.614). Shell weight was significantly and negatively correlated with shape index (r = -0.341 at highland and r = -0.300 at midland ecotypes).

Phenotypic correlations among internal egg quality traits: Table 5 shows the phenotypic correlations between internal egg quality traits. Among internal egg quality traits, only albumin height was strongly and significantly correlated (p<0.01) with haught unit (r = 0.920) and significantly correlated with albumin weight (r = 0.295) at highland chicken ecotypes. Similarly, at midland ecotypes, albumin height was strongly and significantly correlated (p<0.01) with haught unit (r = 0.879) and significantly correlated with albumin weight (r = 0.313). A strong positive correlation was observed between albumin ratio and albumin weight at highland (r = 0.653) and at midland (r = 0.879) areas. There is non-significant (p>0.05) correlation between albumin ratio and other internal egg quality traits at highland ecotypes, whereas there is negative and strong correlation (p<0.01) between albumin ratio and yolk ratio (r = -0.810) at midland ecotypes. In highland ecotypes, albumin weight was positively and strongly correlated (p<0.01) with yolk weight (r = 0.424) and yolk diameter (r = 0.474). However, in midland chicken ecotypes, albumin weight was positively and strongly correlated (p<0.01) with yolk color (r = 0.396) and negatively and strongly correlated (p<0.01) with yolk ratio (r = -0.761). Strong positive correlations (p<0.01) were found between yolk height and yolk index (r = 0.463 and r = 0.700) at highland and midland ecotypes, respectively.

Yolk weight was positively and strongly correlated with yolk color (r = 0.365), yolk ratio (r = 0.591) and yolk diameter (r = 0.610) at highland as well as positively and strongly correlated with yolk ratio (r = 0.402) and yolk diameter (r = 0.384) at midland ecotypes. Significant positive phenotypic correlations were found between yolk color and yolk diameter (r = 0.353) at highland ecotypes. On the other hand, yolk color was significantly and negatively correlated (p<0.05) with yolk index (r = -0.281) at high land and yolk ratio (r = -0.309) at midland ecotypes. Highly positive significant (p<0.01) phenotypic correlations were found between yolk ratio and yolk diameter (r = 0.411) and significant negative phenotypic correlations (p<0.05) were found between yolk ratio and yolk index (r = -0.347) at highland ecotypes. Significant (p<0.01) strong negative phenotypic correlations were found between yolk diameter and yolk index (r = -0.826 and r = -0.776) at highland and midland ecotypes respectively.

Table 4: Correlations among external egg quality traits from the study area

	EWth	EL	SHW	SHT	SHR	SHI
Highland						
EWt	0.266	0.839**	0.633**	-0.184	-0.589**	-0.538**
EWth		0.211	0.189	-.068	-0.156	-0.538**
EL			0.537**	-0.078	-0.435**	-0.709**
SHW				-0.238	0.098	-0.341*
SHT					0.031	0.009
SHR						0.266
Midland						
EWt	0.355*	0.785**	0.710**	0.008	-0.264	-0.373**
EWth		0.261	0.303*	-0.294*	-0.148	0.600**
EL			0.655**	-0.041	-0.005	-0.614**
SHW				0.206	0.213	-0.300**
SHT					0.107	-0.210
SHR						-0.102

*Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed), EWt: Egg weight, EWth: Egg width, EL: Egg length, SHW: Shell weight, SHT: Shell thickness, SHI: Shape index

Table 5: Correlations among internal egg quality traits from the study area

	AR	AW	YH	YW	YC	YR	YD	YI	HU
Highland									
AH	0.209	0.295*	0.164	0.082	0.200	-0.037	-0.015	0.131	0.920**
AR		0.653**	0.190	-0.223	-0.070	-0.260	0.248	-0.035	0.162
AW			0.251	0.424**	0.210	-0.211	0.474**	-0.265	0.108
YH				0.150	0.015	0.101	0.083	0.463**	0.138
YW					0.365**	0.591**	0.610**	-0.515**	-0.121
YC						0.088	0.353*	-0.281*	0.066
YR							0.411**	-0.347*	-0.102
YD								-0.826**	-0.212
YI									0.289*
Midland									
AH	0.234	0.313*	-0.065	0.142	0.193	-0.220	0.070	-0.124	0.879**
AR		0.879**	-0.065	-0.098	0.356*	-0.810**	0.007	-0.054	0.051
AW			-0.072	0.240	0.396**	-0.761**	0.178	-0.183	0.115
YH				0.111	-0.061	0.150	-0.104	0.700**	-0.055
YW					0.110	0.402**	0.384**	-0.216	0.150
YC						-0.309*	0.155	-0.153	0.080
YR							0.074	0.046	-0.020
YD								-0.776**	0.010
YI									-0.072

*Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed), AH: Albumin height, AR: Albumin ratio, AW: Albumin weight, YH: Yolk height, YW: Yolk weight, YC: Yolk color, YR: Yolk ratio, YD: Yolk diameter, YI: Yolk index

Table 6: Phenotypic correlations between internal (rows) and external (columns) egg quality traits of exotic chicken

Traits	EWt	EWth	EL	SHW	SHT	SHR	SHI
AH	0.253*	0.002	0.177	0.072	0.027	-0.285**	-0.162
AR	0.191	0.002	0.165	0.031	0.122	-0.17	-0.147
AW	0.839**	0.267**	0.689**	0.498**	0.008	-0.421**	0.409**
YH	0.124	0.044	0.061	-0.082	-0.019	-0.275**	-0.032
YW	0.664**	0.237*	0.527**	0.308**	-0.194	-0.384**	-0.282**
YC	0.325**	0.051	0.432**	0.254*	-0.032	0.065	-0.325**
YR	-0.346	-0.081	-0.332**	-0.405**	-0.146	0.032	0.236*
YD	0.433**	0.137	0.434**	0.165	-0.066	-0.286**	-0.275**
YI	-0.337	-0.109	-0.351**	-0.206*	0.041	0.110	0.218*
HU	0.063	-0.044	0.022	-0.079	0.046	-0.207*	-0.061

*Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed), AH: Albumin height, AR: Albumin ratio, AW: Albumin weight, YH: Yolk height, YW: Yolk weight, YC: Yolk color, YR: Yolk ratio, YD: Yolk diameter, YI: Yolk index, EWt: Egg weight, EWth: Egg width, EL: Egg length, SHW: Shell weight, SHT: Shell thickness and SHI: Shape index

Phenotypic correlations between internal and external egg quality traits: Phenotypic correlations between internal and external egg quality parameters are shown in Table 6. Highly significant phenotypic correlations ($p<0.01$) were found between albumin weight with egg weight ($r = 0.839$), egg width ($r = 0.267$), egg length ($r = 0.689$), shell weight (r = 0.498) and shape index (r = 0.409). Furthermore, highly significant negative phenotypic correlations were found between albumin weight and shell ratio (r = -0.421) and albumin height and shell ratio (r = -0.285). Highly significant (p<0.01) phenotypic correlations were found between yolk weight with egg weight (r = 0.664), egg length (r = 0.527) and shell weight (r = 0.308) whereas, yolk weight was found to have strong negative phenotypic correlations with shell ratio (r = -0.384) and shape index (r = -0.282). Yolk height was not significantly (p>0.05) correlated with any of the internal egg quality traits except with shell ratio (r = -0.275). Additionally, albumin height was not significantly (p>0.05) correlated with egg width, egg length, shell weight, shell thickness and shape index. Strong positive phenotypic correlations were observed between yolk color and egg weight (r = 0.325) as well as yolk color and egg length (r = 0.432). However strong negative phenotypic correlations were observed between yolk color and shape index (r = -0.325).

Moreover, positive phenotypic correlation (p<0.05) was observed between albumin height and egg weight (r = 0.253) and yolk color and shell (r = 0.254). Yolk ratio was negatively and significantly correlated with egg length (r = -0.332) and shell weight (r = -0.405) and positively correlated with shape index (r = 0.236). Positive and strong phenotypic correlations (p<0.01) was observed between yolk diameters and egg weight (r = 0.433) as well as egg length (r = 0.434). However yolk diameter was strongly and negatively (p<0.01) correlated with shell ratio (r = -0.286) and shape index (r = -0.275). There were non-significant (p>0.05) phenotypic correlations between shell thickness and all internal egg quality traits. Similarly, non-significant (p>0.05) phenotypic correlation was found between haugh unit (HU) and all external egg quality characteristics.

DISCUSSION

External egg quality traits: Significant variations were observed among the exotic chicken ecotypes in egg weight, egg length and shell ratio. Midland chicken ecotype produced egg with significantly higher mean value than highland chicken ecotypes. The significant variation in some external egg quality traits of the chicken implies the existence of genetic and environmental variations[21]. Irrespective of chicken genotypes, significant variations were found between the exotic chicken in all studied egg quality traits except shell thickness. The findings indicated that the egg weight, egg width and egg length of the Sasso T44 genotypes from both agro-ecological zones was significantly (p<0.05) higher than PK genotypes. Sasso T44 had heavier eggs than that of PK chickens which may have been attributed to the genotype, feed, housing and difference between the two ecotypes.

The egg weight, egg length and egg width for exotic chicken reared in the studied district was similar with the finding of Melesse *et al.*[15] who reported egg weight (53.8±4.9), egg length (5.50±4.2) and egg width (3.92±2.6) from Sidama Zone. Similarly, Mengsite *et al.*[22] reported egg weight (65.57±5.26), egg length (4.52±2.33) and egg width (5.84±2.83) from North Showa Zone, Ethiopia. On the other hand shell ratio of PK genotypes from midland and highland area was significantly (p<0.05) higher than Sasso T44 chicken. Shell weight of SassoT44 chicken was significantly higher compared to PK from highland areas. Exotic chicken (PK and Sasso T44) reared in midland had better egg length and egg weight than those reared in highland areas. The results obtained from the current study indicated that the external egg quality traits of the both genotypes studied were influenced by the ecotypes, which could be attributed to the quality and quantity of feed available and environmental temperature. According to Şekeroğlu *et al.*[23], feeds from lowland areas usually have low protein and high fiber contents compared to the feeds from highlands. Unlike ruminant animals, chickens are unable to utilize poor-quality feeds with higher crude fiber, which in turn can influence their growth and egg production[24,25].

The variation in egg length, egg width and egg weight can be associated with genotypes of the chicken, the shell thickness is closely associated with calcium and phosphorus from the feeds chicken consume[26]. The weights of the eggs are also correlated with the age of the birds[27,28]. The egg weight of exotic chickens (Sasso T44 and PK) is optimum for the ecotypes and it is also expected that chickens born from these eggs are strong and have a higher weight[29]. The shell thickness of chickens from both genotypes and across the two studied agro-ecological zone was not significantly different. The shell thickness of exotic chicken from the current study (0.27±0.01) was similar to the finding of Melesse *et al*[15] who reported (0.275±0.02) from the Boricha district Sidama zone, Southern Ethiopia and higher than the finding of Olawumi and Christiana[30] who reported (0.09±0.01) for Coturnix Quails reared under intensive housing system. The variations between the mean value of some external egg quality traits obtained in this study and the previous findings might be due to difference in breed, age, nutrition regimes, health condition, altitude and management practices.

Internal egg quality traits: The internal egg quality traits are influenced by the quantity and quality of feed, storage condition, then strain, age, induced molt and disease[31,32]. The internal egg quality traits calculated from the current study were Albumin height, albumin ratio, albumin weight, yolk height, yolk weight, yolk color, yolk index, yolk ratio, yolk diameters and haugh unit (Table 1). Significant variations were observed among the two exotic chicken genotypes in all studied internal egg quality traits except yolk height, yolk diameter and yolk index. Exotic chicken from midland ecotypes significantly higher albumin weight, yolk height and yolk diameter. The average albumin height (4.18±0.07) of exotic chicken in the current studied district was lower than the finding of Inca *et al.*[8] who reported 7.10±0.07 mm for 85-week old age of laying hens and Markos *et al.*[9] who reported 5.65 mm for indigenous chicken ecotypes kept under farmers condition. In comparable with our finding, Demissu[33], who reported 4.48±0.07 mm from Western Ethiopia. The lower albumin height as compared with the current result have been reported by Molla[4] who reported 2.87 from Gomma wereda and Melesse *et al.*[25] 2.10 from indigenous chicken. The variation in albumin height is correlated with the freshness of the eggs and might be influenced by several non-genetic factors[4].

The mean albumin ratio recorded from exotic chicken of the present study (59.06±0.62) was in close agreement with values reported (61.81±0.16) by Inca *et al.*[8] for 85-week old age of laying hens but higher than the finding of Bekele *et al.*[11] who reported that the mean value of albumin ratio was 52.2 in Southern Ethiopia. Albumin weight of Sasso T44 and PK chicken in the study district was in agreement with the finding of Rajkumar *et al.*[34] who reported 34.24 g under tropical climate of India. However, Inca *et al.*[8] reported the higher albumin weight for 85-week old age of laying hens and Solomon *et al.*[35] reported lower albumin weight for local chicken ecotypes in Fogera district, Ethiopia. The consumed amount of protein content in the chicken feed could influence the albumin content of the egg[36]. The average yolk weight observed in this study (16.23±0.19 g) was in close agreement with value reported by Solomon *et al.*[35] for local scavenging chicken eggs in central Ethiopia (16.3 g) but higher than the value reported by Molla[4] (15.0 g) for extensively managed Ethiopian local chickens. Similarly the lower yolk weight (12.2-14.3 g) was reported by Gebresilisase[37] for Tswana chicken strains managed under intensive management system. The yolk width also varied across the studied agro-ecological zones but there is a non-significant difference between Sasso T44 and PK genotypes of exotic chicken. The yolk width (diameter) of exotic chicken reared in the study area was higher the observation of Melesse *et al.*[25] from Amhara region and Alewi *et al.*[24] from Guraghe zone.

Yolk pigmentation is due to the presence of xanthophylls in the feed chicken consumes but is not influenced by breed[25]. The scavenging chickens usually have a deeper egg yolk due to they obtain pigments from the plant parts they consume. Yolk pigmentation also depends on factors that inhibit liver function and subsequent lipid metabolism of birds[38]. The mean yolk color of Sasso T44 and PK chicken were in agreement with the findings of Bekele *et al.*[39] who reported the yolk color (9.24±1.67) from southern Ethiopia and Tadesse[40] who reported (9.36±9.36) from East Shewa. The mean yolk weight of exotic chicken in the current study was in line with the finding of Bekele *et al.*[39] who reported (16.80±2.0) from southern Ethiopia. The variations in the varied yolk color and yolk weight are influenced by the diet and genotypes of the chicken. The average yolk height in this study was lower than the value reported for indigenous chicken managed under extensive production system[24,25,37]. Similarly the average yolk ratio recorded from the current study (30.76±0.30) (Table 1) was higher than the value (24.64±0.13) reported by Inca *et al.*[8] for 85-week egg laying hens. The results further indicated that Sasso T44 chickens have better egg quality traits compared to PK genotypes. In terms of the ecotypes, chicken from the midland area shows better internal and external egg quality parameters. The egg weights of Sasso T44 hens were the heaviest indicating that these genotypes could be best suited for the studied district.

The average Haugh unit (63.23) recorded in this study was in lower than the values reported (79.1) by Tadesse *et al.*[41] for extensively managed PK chicken breed in Ada'a and Lume districts as well the value reported (107.98) by Simeon Olawumi[30] for Coturnix Quails reared under intensive housing system. Additionally, Yonas *et al.*[13] reported higher mean value of haugh unit (87.04) from exotic chickens reared in Yirgalem and Hawassa towns, Ethiopia. In agreement with the suggestion of Melesse *et al.*[25], the observed variations on haugh unit of the egg might be due to different factors such as feed quality and quantity, management practices, temperature (altitude) and breeds of chicken. The mean value of yolk index (40.72±0.49) obtained in this study was in close agreement with the value (40.2±3.9 for Sasso T44 and 42.9±7.3 for PK) reported by Melesse *et al.*[15] but higher than the value (36.88±0.12) reported by Inca *et al.*[8] for 85-week old egg laying hens.

Phenotypic correlations among external egg quality characteristics: Phenotypic correlations between external egg quality characteristics of exotic chicken in the study area (Table 4). Furthermore, significant correlations between egg quality traits were found in the two chicken ecotypes and genotypes. The magnitude and directions of the relationships between the egg quality traits varied with chicken ecotypes and genotypes. Most of the relationships were similar in other exotic chicken reported in the literature.

The significant positive correlation between egg length and shell weight; significant negative correlations between egg length and shell ratio observed in this exotic chicken are consistent with the previous study[8,42,43]. Similarly, egg weight was positively and strongly correlated with egg length and shell weight, whereas egg weight was negatively and strongly correlated with shell ratio (Table 4). In line with the present finding, Bernacki *et al.*[44] also reported a significant week and negative phenotypic correlation between egg weight and shell ratio (r = – 0.170). This discrepancy might be due to the genotypes of birds and other external factors that affect egg quality. Correlations between egg length and shell ratio indicate that the larger the egg, the lower the shell quality. Alkan *et al.*[45] reported that an increase in egg length affects shell quality negatively because egg size does not increase linearly with shell percentage.

According to the result recorded from this study there is non-significant (p>0.05) correlation between egg width with egg weight (r = 0.266), egg length (r = 0.211) and shell weight (r = 0.189) in highland chicken ecotypes. In contradict with this study many studies reported that there is strong positive correlation between egg width and egg length[9,46,47]. On the other hand in midland chicken ecotypes, there is a significant (p<0.05) and positive correlation between egg width and egg weight (r = 0.355) and shell weight (0.303). This result is in contradiction with the finding of Inca *et al.*[8] who reported a strong and positive correlation between egg width with egg weight (r = 0.84), egg length and shell weight (r = 0.26) from 85-week old laying hens.

Phenotypic correlations among internal egg quality characteristics: Albumin weight was positively and strongly (p<0.01) correlated with albumin ratio (r = 0.653), yolk weight (r = 0.424) and yolk diameter (r = 0.474) in highland agro-ecological zones. Contrary to this result, the finding of Olawumi and Ogunlade[42] indicated that albumen weight has non-significant (p>0.05) phenotypic correlations with albumen height, albumen width, yolk weight, yolk height and yolk width. Yolk color was significantly (p<0.01) correlated with yolk weight (r = 0.365) and yolk diameter (r = 0.353). A strong positive correlation was observed between albumin weight and albumin ratio (r = 0.879) whereas a strong negative correlation was observed between yolk ratio (r = -0.761) in the midland chicken ecotypes. The phenotypic correlations between yolk weight and other yolk characteristics (yolk color, yolk ratio and yolk diameter) are inconsistent with the results reported by previous researchers. For instance, Inca *et al.*[8] reported positive phenotypic correlations between yolk height and yolk index (0.65) and yolk height and yolk ratio (0.23). Ojo *et al.*[48] reported strong positive phenotypic correlations between yolk weight and yolk height (0.64). In addition, Alkan *et al.*[47] reported positive phenotypic correlations between yolk ratio and yolk to albumin ratio (0.98). The strong negative correlation between albumin ratio and yolk ratio (r = -0.810) in midland suggests that direct selection for albumin ratio improvement may result in a decrease in the yolk ratio of the chicken. In both agro-ecological zones, all in all, yolk height has the most non-significant (p>0.01) correlations with other traits. The result from this finding was in line with the finding of Markos *et al.*[9].

Significant variations were also observed in the internal egg quality traits of exotic chickens kept in the study district. The positive correlation between albumin weight and albumin ratio (r = 0.653) in highland and (r = 0.879) in midland chicken ecotypes is in close agreement with previous reports that showed a positive correlation between albumin weight and albumin ratio (r = 0.91) in the 85-week-old laying hens reported by Inca *et al.*[8]. On the other hand, the positive correlations between albumen weight and yolk weight (r = 0.424) in highland exotic chickens are in line with the finding of Kgwatalala *et al.*[43]. This implies that selection for improvement in albumen weight might lead to improvement in the total edible portion of the egg. The present study showed strong negative correlations between albumin ratio and yolk ratio (r = -0.810) in midland ecotypes which is in agreement with the report of Markos *et al.*[9] (r = 0.86) and Inca *et al.*[8] (r = 0.71). Haugh unit is a good indicator of albumin quality, a very low Haugh unit in exotic chicken of the current study showed a poor albumen quality. The result of a strong positive correlation between Haugh unit and albumen height is different from those of Alkan *et al.*[45], who reported weak negative phenotypic correlations.

Phenotypic correlations between internal and external egg quality traits: Egg weight was positively and significantly (p<0.01) correlated with albumin weight, yolk weight and yolk color and yolk diameter (r = 0.839, r = 0.664, r = 0.325 and r = 0.433, respectively). However, egg weight has a positive but weak correlation with albumin ratio and yolk height. This result is in agreement with the finding of Agaviezor *et al.*[49], Bernacki *et al.*[44] and Shafey *et al.*[50] who reported that egg weight has positive significant ($p<0.001$) phenotypic correlations with albumen weight and height, yolk weight and height, shell weight and Haugh unit score. On the other hand, the finding of Okon *et al.*[51] reported a non-significant phenotypic correlation between egg weight and internal egg components. This implies that the weight of exotic chicken (Sasso T44 and PK) egg can be predicted by the size of its major components, which are albumen, yolk and shell. On the other hand, egg width was positively and significantly ($p<0.01$) correlated with albumin weight ($r = 0.267$). This result was similar to the finding of Okon *et al.*[51] which indicated that egg width has a strong positive correlation with albumin weight ($r = 0.348$).

Phenotypic correlations of egg length with albumin weight, yolk weight and yolk color and yolk diameter indicated that an increase in egg sizes affects considerably on those internal egg quality traits. Olawumi and Ogunlade[42] reported medium positive phenotypic correlation (0.64) between egg length and albumin weights. On the other hand, the same authors reported a non-significant phenotypic correlation between both egg height and width with any of the interior egg quality traits. For instance, negative phenotypic correlations (-0.29) between egg length and shell ratio[52] as well as weak negative phenotypic correlations (-0.49) between egg length and albumin height[53] were observed. According to Inca *et al.*[8], egg size (due to the age of hen) has more impact on albumin quality traits than yolk quality traits. Considerable positive phenotypic correlations between shell weight with albumin weight (0.498) and yolk weight (0.308) observed in the current study were in line with the finding of Markos *et al.*[9] who reported the positive phenotypic correlations between shell weight with albumin weight ($r = 0.48$) and yolk weight ($r = 0.53$).

Shell thickness has no significant ($p>0.05$) positive and negative correlation with all internal egg quality parameters. Shell ratio have significant ($p<0.01$) strong and negative correlation with albumin height, albumin weight, yolk weight and yolk diameters. This finding is in line with the result of Inca *et al.*[8] who reported a negative and weak correlation between shell ratios with other internal egg quality traits of laying hens. It is possible to determine and compare eggs of different sizes by knowing the measurements of their interior contents[42]. Eggs with greater proportions of albumen and yolk will no doubt give a higher value of egg weight in contrast to the ones with a lower proportion of egg components[54]. Extensive and or back-yard chicken production system and uncontrolled mating system under farm condition results mixture of chicken breeds which affect the purity of collected eggs. Further comparative on-station and on-farm evaluation of the Koekoek and Sasso T44 considering production performance and egg and carcass qualities.

CONCLUSION

The egg weight and most of the egg quality traits of Sasso T44 chicken was generally higher than that of PK genotypes. And some of the internal and external egg quality traits recorded form exotic chicken from midland area was higher compared to highland ecotypes. The difference observed in internal and external egg quality traits between chicken ecotypes and genotypes can be ascribed to altitude, genotypes and their interactions. Sasso T44 genotypes might be recommended for smallholder farmers as Sasso T44 is superior in most of egg quality parameters. Additionally, customizing genetic, feeding system as well as environmental factors is crucial for improving the performance of these exotic chickens.

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