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Comparative Study of Egg Quality Traits of Sasso Chicken Breed under Different Management Systems and Phenotypic Correlation of Egg Parameters in Ethiopia

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

This study was conducted to evaluate the egg quality traits of Sasso chicken breed under different managements. For the experiment 160 fresh eggs form differently managed Sasso chickens (100 from on-station and 60 from on-farm) were randomly taken. The fresh eggs collected from farmers in Yirgalem were brought to Hawassa University poultry farm for quality measurement and the eggs collected from poultry farm of College of Agriculture in Hawassa University were separately determined. The recorded data was analyzed using SAS (ver. 9.4). Management system difference has a significant influence on more than half of studied external traits such as egg weight, egg length, egg width, shell thickness and egg surface area. The Sasso chickens managed under intensive system had significantly ($p<0.05$) higher mean egg weight (59.0g), egg length (57.5mm),

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egg width (42.2mm) and egg surface area (84.7mm2) than the same chicken breed reared under farmers management system. There was a significant difference in albumen weight, albumen height, yolk height, albumen ratio, yolk index, yolk albumen ratio and Hough unit for the eggs collected from the Sasso chickens under different management system. Egg weight has a highly significant and strong positive (p<.0001) phenotypic correlation with egg surface area (0.99), egg length (0.65), egg width (0.72) and shell weight (0.52). Albumen weight has significant correlation with all the studied internal egg quality parameters. It has the negative correlation with yolk ratio (-0.14) and yolk albumen ratio (-0.69). There was a variation for egg quality traits of Sasso chicken in different management systems where the on-station management system is better.

Keywords: Egg quality; Ethiopia; management systems; Sasso.

1. INTRODUCTION

"The poultry population in Ethiopia is estimated to be 60.04 million, from which 88.5% indigenous, 6.25% cross and 5.25% exotic breeds" [1]. "Different exotic chicken breeds have been disseminated for Ethiopian farmers in rural, urban and Peri-urban areas to improve the egg and meat production in the country" [2]. "Mostly dual purpose and layer chicken breeds were distributed in the last 2 decades and among the dual-purpose breeds of chicken, Sasso is one of the chicken breeds found in Ethiopia" [3].

"Poultry production in the world now a day is expanding and developing during the last few decades. Advances in genetics, nutrition and husbandry have contributed to substantial improvement in poultry productivity which resulted in high consumption of poultry meat and eggs globally" [4].

"Egg quality parameters expresses that the characteristics of an egg which influence its acceptability by consuming community. Chicken eggs are providing balanced source of nutrients for human and it is nutritious, economical and easily prepares food" [5,3]. "The quality of egg could be categories internal and external quality of egg. External factors including cleanliness, freshness, and egg weight and shell quality are important in consumer's acceptability of shelled eggs. The internal quality of eggs including yolk weight, albumin weight, yolk color, albumin height, yolk height and Hugh unit and it decline as soon as they are laid by hens. Feeding and management of hens have a significant impact on internal egg quality, egg handling and storage practices and influence the acceptability of the quality of eggs by consumers" [6,7]. "Production of good shell and internal quality of eggs have significant economic viability of the egg industry. External and internal characteristic of eggs are prerequisite for safety, soundness and wholesomeness of the eggs. The breed and age of hen is the most vital production factors affecting the quality of eggs. The egg production cycle of layers allowed extending from 68 weeks to 90 weeks of age through genetic improvement" [8].

"External and internal egg quality traits are the determinant factors for the embryonic development of an egg and latter for the viability of the new hatched chick" [9,10]. "Moreover, some egg quality traits like eggshell thickness and strength are very important to handle the egg during transportation from time of laying up to consumption" [9]. "Other egg quality traits like yolk color have valuable influence on the egg market" [11,12]. "For this reason, valuable egg quality traits are very important reproductive parameter in chicken production industry and breeding strategies" [13]. According to Tadesse et al. [14], "most of such internal and external egg quality parameters are subjected to the level of chicken management and egg handling techniques". "Egg storage technique and storage duration influences most of egg quality parameters such as albumen and yolk height" [15,12,16].

2. MATERIALS AND METHODS

2.1 Experiment Sites

The study was conducted at Hawassa University poultry farm on the eggs collected from Sasso breed managed under intensive system and on the eggs collected from the same chicken breed managed under farmers' management system in Yigalem district. The study farms were selected based on the existence of same aged Sasso chicken breed on-station (intensive) and on-farm (extensive) and their source was same (Dore

Bafena poultry farm). Experimental chickens were fed on different diets. The chickens managed in Hawassa University poultry farm were feeding on concentrated feeds whereas those managed under farmers extensively in Yirgalem district were scavenging with some supplementation of any available feeds.

2.2 Egg Collection

A total of 160 fresh eggs (100 from on-station and 60 from on-farm) were taken to determine external and internal egg quality traits. The hens in both sites were at same age but managed under different production systems (Hawassa University poultry farm-intensive and Yirgalem-extensive). The fresh eggs collected from farmers were brought to Hawassa University poultry farm for quality measurement, and the eggs collected from poultry farm of College of Hawassa University were separately determined for internal and external egg traits.

2.3 Egg Quality Determination

Each egg was individually weighed using sensitive weighing balance. Egg width and egg length were measured using digital caliper. After external quality trait measurement, the eggs were broken on a smooth glass platform (previously calibrated) and the albumen and yolk weights, lengths, and heights (albumen weight (AW), albumen length (AL), albumen height (AH), yolk weight (YW), yolk length (YL) and yolk height (YH) were determined using a digital caliper. Afterward, the shells were cleaned and kept in egg tray for drying at room temperature. Finally, after 2 days, shell weight (SW) and shell thickness (ST) were measured. Albumen and yolk height (mm) was determined using tripod micrometer. Yolk colour was measured using colour fan of 1–15 leveled colour fans. Egg shape index was computed by dividing egg width with egg length. Haugh unit was calculated according to Haugh [17] by fitting the average albumen height and egg weight in to the following the equation: 100×log [albumen height+7.57− 1.7 (egg weight 0.37)].

Measured egg quality characteristics data were used to calculate some external and internal egg quality characteristics. These calculated characteristics were estimated using equations obtained from Alkan et al. [18] and Debnath and Ghosh [19].

External

$$\text{ESI}\ (\%) = \frac{\text{EG}}{\text{EL}} * 100$$

$$\text{SR}\ (\%) = \frac{\text{SW}}{\text{EW}} * 100$$

$$\text{ESA}\ (\text{cm}^2) = 3.9782 * \text{EW}^{0.75056}$$

$$\text{USSW}\ (\text{mg/cm2}) = \frac{\text{SW}}{\text{ESA}}$$

Internal

$$\text{AR}\ (\%) = \frac{\text{AW}}{\text{EW}} * 100$$

$$\text{YR}\ (\%) = \frac{\text{YW}}{\text{EW}} * 100$$

$$\text{YI}\ (\%) = \frac{\text{YH}}{\text{YD}} * 100$$

$$\text{YA R}\ (\%) = \frac{\text{YW}}{\text{AW}} * 100$$

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

Where:
ESI = Egg Shell Index; EG = Egg Width; SR = Shell Ratio; SW = Shell Weight; EW = Egg Weight; ESA = Egg Surface Area; USSW = Unit Surface Shell Weight; AW = Albumen Weight; AR = Albumen Ratio; YR = Yolk Ratio; YI = Yolk Index; Y: A R = Yolk Albumen Ratio; HU = Haugh Unit.

2.4 Statistical Analysis

Data were analyzed using SAS (Ver. 9.4). Statistical analysis system (SAS) was used to carry out descriptive statistics on quantitative variables between the studies sites (on-farm and on-station). Data was analyzed by using the following statistical model:

$$Y_i = \boldsymbol{\mu} + F_i + e_i$$

Y_i = overall observations of dependent variables of i^{th} chickens; μ = overall mean of variables; F_i = effect due of i^{th} farming (i= on-station, on-farm) of i^{th} chicken; ei = random error term.

Table 1. Description of the pearson correlation coefficient

Correlation coefficient r)	Interpretation of r
-1.00	Perfect negative correlation: ("A major X, minor Y", proportionally. It means, every time X increases a unit, Y always decreases a constant amount). This also applies "A minor X, greater Y"3
-0.90	Very strong negative correlation
-0.75	Considerable negative correlation
-0.50	Medium negative correlation
-0.25	Weak negative correlation
-0.10	Very weak negative correlation
0.00	There is no correlation between the variables
+0.10	Very weak positive correlation
+0.25	Weak positive correlation
+0.50	Medium positive correlation
+0.75	Considerable positive correlation
+0.90	Very strong positive correlation
+1.00	Perfect positive correlation: ("A major X, greater Y" or "a minor X, minor Y", proportionally, every time X increases, Y always increases a constant amount)

Hernández et al. [35]; - or +: Direction of the correlation, 1.00: Magnitude of the correlation. 3 X: Independent variable, Y: Dependent variable

3. RESULTS

Least Square Mean for external egg parameters is presented in Table 2. Management system difference has a significant influence on egg weight, egg length, egg width, shell thickness and egg surface area.

The Sasso chickens managed under intensive system had significantly ($p<0.05$) higher mean egg weight (59.0g), egg length (57.5mm), egg width (42.2mm) and egg surface area (84.7mm^2) than the same chicken breed reared under farmers management system. However, shell thickness (0.29) was measured significantly less thicker for eggs collected from the chickens managed under intensive system.

However, there was no significant influence ($p>0.05$) of management condition on shell weight, egg shape index and shell ratio.

Least square mean for internal egg parameters is presented in Table 3. There was a significant difference in albumen weight, albumen height, yolk height, albumen ratio, yolk index, yolk albumen ratio and Hough unit for the eggs collected from the Sasso chickens under different management system.

Most of the internal egg quality traits have significantly higher for eggs collected from the Sasso chicken breed in on-station management condition. Albumen weight (33.8g), albumen height (5.51mm), yolk height (16.6mm), albumen ratio (57.8%), yolk index (39.9%) and Hough unit (71.8%) were measured significantly higher for the eggs collected from chicken reared under intensive management system; but yolk albumen ratio was exhibited higher for the eggs collected from on-farm management systems.

Table 2. On-farm and on-station external egg quality of Sasso chicken breed

Parameters	Management system				p-value
	On-farm		On-station		
	LSM	SE	LSM	SE	
Egg weight (g)	55.2^a	0.77	59.0^b	0.61	0.0002
Egg length (mm)	55.1^a	0.38	57.5^b	0.30	<.0001
Egg width (mm)	40.7^a	0.21	42.2^b	0.17	<.0001
Shell weight (g)	4.71	0.09	4.90	0.07	0.1300
Shell thickness	0.31^b	0.005	0.29^a	0.004	0.0381
Egg shape index (%)	74.0	0.50	73.5	0.40	0.4230
Shell ratio (%)	8.54	0.15	8.35	0.12	0.3332
ESA (mm^2)	80.7^a	0.84	84.7^b	0.67	0.0003

ESA = egg surface area, LSM = Least Square mean, SE = Standard error, superscripts "a" and "b" at the same row are indicating the traits significantly varied between management systems, mm = millimeter, % = percentage, g = gram

Table 3. On-farm and on-station internal egg quality of Sasso chicken breed

Parameters	Management system				P-value
	On-farm		On-station		
	LSM	SE	LSM	SE	
Albumen weight	29.8^{a}	0.59	33.8^{b}	0.46	<.0001
Albumen height	4.73^{a}	0.17	5.51^{b}	0.14	0.0004
Yolk weight	18.7	0.31	19.5	0.24	0.0576
Yolk height	15.5^{a}	0.21	16.6^{b}	0.17	<.0001
Yolk diameter	42.3	0.39	43.2	0.31	0.0832
Yolk color	9.76	0.28	9.52	0.22	0.4949
Albumen ratio	54.0^{a}	0.97	57.8^{b}	0.77	0.0024
Yolk ratio	34.0	0.61	33.4	0.41	0.4783
Yolk index	36.7^{a}	0.63	39.2^{b}	0.50	0.0026
Yolk Albumen ratio	63.9^{b}	1.39	58.7^{a}	1.10	0.0070
HU	67.1^{a}	1.48	71.8^{b}	1.17	0.0122

HU = Hough unit, LSM = Least square mean, different superscript at the same row indicates the significant difference

Fig. 1. Pictures during egg breaking

3.1 Correlation of External Egg Quality Traits

Table 3 shows the correlations between external egg characteristics of Sasso chickens. Egg weight has a highly significant and strong positive (p<.0001) correlation with egg surface area (0.99), egg length (0.65), egg width (0.72) and shell weight (0.52). Unlike wise, egg weight has a significant (p<0.05) and negative correlation with shell ratio (-0.22). Egg weight has no significant (p>0.05) correlation with shell thickness and egg shape index.

Egg length has a highly significant (p<.0001) phenotypic correlation with egg width (0.44), shell weight (0.48) and egg surface area (0.65) positively, however, with egg shape index (-0.70) negatively (Table 4).

Egg width is another trait of internal egg quality that has been measured which had highly significant positive correlation with shell weight (0.42), egg shape index (0.33) and egg surface area (0.72). Unlike wise, egg width has no significant correlation with shell thickness and shell ratio.

Table 4. Phenotypic correlations among external egg quality characteristics of Sasso

Traits	EW	EL	EG	SW	ST	ESI	SR	ESA
EW	1	0.64739 <.0001	0.72289 <.0001	0.51669 <.0001	0.10595 0.1810	-0.10871 0.1698	-0.22041 0.0050	0.99987 <.0001
EL		1	0.44352 <.0001	0.48302 <.0001	0.04751 0.5495	-0.70028 <.0001	0.02405 0.7620	0.64812 <.0001
EG			1	0.41593 <.0001	-0.04313 0.5870	0.32585 <.0001	-0.10455 0.1869	0.72262 <.0001
SW				1	0.36544 <.0001	-0.17509 0.0263	0.71477 <.0001	0.51477 <.0001
ST					1	-0.08240 0.2987	0.31377 <.0001	0.10502 0.1849
ESI						1	-0.10415 0.1886	-0.10967 0.1661
SR							1	-0.22293 0.0045
ESA								1

EW = egg weight, EL = egg length, EG = egg width, SW = shell weight, ST = shell thickness, ESI = egg shape index, SR = shell ratio, ESA = egg surface area

Table 5. Phenotypic correlations among internal egg quality characteristics of Sasso breed

Traits	AW	AH	YW	YH	YD	AR	YR	YI	YAR	HU
AW	1	0.44 <.0001	0.30 0.0002	0.43 <.0001	0.28 0.0003	0.71 <.0001	-0.14 0.0849	0.19 0.0175	-0.69 <.0001	0.30 <.0001
AH		1	0.13 0.0991	0.659 <.0001	0.12 0.1368	0.399 <.0001	0.020 0.8043	0.472 <.0001	-0.298 0.0001	0.956 <.0001
YW			1	0.158 0.0455	0.626 <.0001	0.052 0.5090	0.655 <.0001	-0.214 0.0065	0.463 <.0001	0.041 0.6062
YH				1	0.008 0.9166	0.30 0.0002	-0.414 0.6018	0.818 <.0001	-0.225 0.0041	0.571 <.0001
YD					1	0.077 0.3316	0.337 <.0001	-0.561 <.0001	0.201 0.0106	0.048 0.5453
AR						1	0.239 0.0023	0.181 0.0215	-0.616 <.0001	0.436 <.0001
YR							1	-0.220 0.0050	0.60 <.0001	0.134 0.0896
YI								1	-0.283 0.0003	0.439 <.0001
YAR									1	-0.240 0.0021
HU										1

AW= albumen weight, AH=albumen height, YW=yolk weight, YH=yolk height, YD=yolk diameter, AR=albumin ratio, YR=yolk ratio, YI=yolk index, YAR=yolk albumen ratio, HU=Hough unit

Table 6. Phenotypic correlations between external and internal egg quality characteristics of Sasso breed

Traits	EW	EL	EG	SW	ST	ESI	SR	ESA
AW	0.529	0.332	0.423	0.283	-0.074	-0.025	-0.103	0.528
	<.0001	<.0001	<.0001	0.0003	0.3562	0.7565	0.1936	<.0001
AH	0.144	0.07103	0.188	0.019	-0.197	0.067	-0.082	0.142
	0.0682	0.3706	0.0169	0.8106	0.0124	0.4013	0.2994	0.0726
YW	0.360	0.246	0.301	0.269	0.080	-0.018	0.028	0.361
	<.0001	0.0017	0.0001	0.0006	0.3162	0.8186	0.7250	<.0001
YH	0.266	0.212	0.339	0.190	-0.238	0.051	0.018	0.262
	0.0007	0.0071	<.0001	0.0155	0.0024	0.5212	0.8166	0.0008
YD	0.314	0.244	0.331	0.170	0.062	0.007	-0.062	0.316
	<.0001	0.0018	<.0001	0.0309	0.4329	0.9306	0.4359	<.0001
AR	-0.216	-0.146	-0.111	-0.095	-0.159	0.054	0.071	-0.217
	0.0060	0.0648	0.1664	0.2303	0.0433	0.4948	0.3721	0.0058
YR	-0.461	-0.292	-0.282	-0.145	-0.013	0.085	0.225	-0.461
	<.0001	0.0002	0.0003	0.0670	0.8724	0.2813	0.0042	<.0001
YI	0.046	0.040	0.095	0.065	-0.232	0.035	0.051	0.042
	0.5646	0.6124	0.2331	0.4102	0.0030	0.6550	0.5176	0.5937
YAR	-0.201	-0.118	-0.134	-0.035	0.123	0.032	0.130	-0.201
	0.0104	0.1357	0.0909	0.6602	0.1208	0.6914	0.0998	0.0107
HU	-0.109	-0.103	-0.003	-0.110	-0.230	0.097	-0.026	-0.111
	0.1682	0.1940	0.9694	0.1638	0.0034	0.2187	0.7456	0.1600

3.2 Phenotypic Correlations Among Internal Egg Characteristics

Phenotypic correlations among internal egg characteristics are presented in Table 5. Albumen weight has significant correlation with all the studied internal egg quality parameters. It has the negative correlation with yolk ratio (-0.14) and yolk albumen ratio (-0.69).

Albumen height (AH) was another parameter that strongly positive and highly significantly correlated with HU (95.6%) and yolk height (65.9%). Albumen height has negative correlation with YAR (-0.298). Highly correlation of Hough unit with albumen height indicates that 95.6% of variation in Hough unit is due to the albumen height quality.

3.3 Correlation among External and Internal Egg Quality Parameters

Egg weight was highly and positively correlated with albumen weight (52.9%) followed by yolk weight (36.0%). Among the internal egg quality parameters, AR, YR and YAR were negatively correlated with egg weight. More than 52% of the albumen weight is dependent on the amount of egg weight and egg surface area of egg. Albumen weight has a negative correlation with shell thickness, egg shape index and shell ratio.

4. DISCUSSION

The difference revealed between the two studied management systems on egg quality parameters could be due to the rearing system and mostly due to insufficient feeding prevailing under on-farm management system that does not support the chickens with adequate levels of nutrition needed to exploit their production potential. This observation concurs with the previous observation of Guni et al. [20] which also showed lower performance of on-farm than on-station management in most egg production traits. Similarly, Champati et al. [21] reported “heavier eggs for intensively reared chickens than for semi-intensive” while Dong et al. [22] and Kucukyılmaz et al. [23] also observed “variation in egg weight for different rearing systems”.

Unlike to the current study, egg weight (64.2g) and shell thickness (0.41mm) for the same breed in Egypt reared under intensive management has reported higher (Mohammed and El-Hamid 2017). The difference could be due to the environmental effect on egg quality parameters.

“The shape index is the ratio between the width and length of the egg, which is a good indicator of uniformity in the size of the eggs. In the present study, the egg shape index was 73.5% (on-station) and 74% on the on-farm that is lower for on-station (75.5%) and almost similar for on-farm (73.9%) as the report of Guni et al. [20] which could be explained by the size and weight of an egg. Normally egg length and width are the determinants of the shape of an egg, which were also higher for on-station eggs (57.05mm and 43mm for egg length and width, respectively) than on-farm (55.9 and 41.3mm for egg length and width, respectively)” [24]. Sokołowicz et al. [25] had “a comparable observation where the egg shape index was found to be higher for birds under deep litter than those from free-range and organic systems”. Similarly, using Red Island Red (RIR) and Fayoumi chicken breeds, Bekele et al [26], found “a higher egg shape index for eggs from the on-station than from on-farm”. On the contrary, Sekeroglu et al. [27], Oke et al. [28], and Champati et al. [21] reported “the effect of rearing system on egg shape indices not to be significant. The shape index in the present study varied from 73.92-75.48%”. This value falls within the range of 72-76% reported by Altuntas and Sekeroglu [29] as “the standard/normal shape. Therefore, both Sasso and Kuroiler chickens had eggs of standard size that fit properly in normal egg trays”. It has been suggested that the eggs with a shape index below 72% are sharp and those above 76% are roundish [29] which increase the possibility of breakages during transportation.

“In this study, the management system significantly ($P<0.05$) affected the shell thickness in favour of on-station. The lower values for on-farm eggs for shell quality traits is most likely to be associated with poor feeding and inadequate Calcium and other trace minerals intake” [30]. Since the on-station birds were provided with a commercial diet, it is anticipated that they had well-balanced minerals required for eggshell formation.

In line with the current study, Dahloum et al. [31] did not find differences in shell weight of eggs from different rearing systems. In addition, Kühn et al. [32] also did not find differences in shell weight of eggs from the litter-floor and free-range systems. Unlike wise, Patel et al. [33] observed “no differences in shell thickness of eggs from deep litter, semi-scavenging and backyard management”. “Inconsistent results might be associated with the interaction of the management system with several factors affecting the traits including nutrition" [34].

5. CONCLUSSION

For most of the egg parameters, the management system exhibits the variation; where the on-station (intensive) management system is better while compared with on-farm (extensive) management system. Under the farmers' management system, chickens could not find the sufficient and quality feed. The variation between studied conditions must be exploited through feed resources and the habit of supplementing.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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