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# Egg quality traits as affected by selection for feed efficiency of egg production and feeding regimen in Sinai Bedouin fowl

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**Abstract:***Current experiment conducted at Research farm of Poultry and Fish production Department, Menoufia University, Egypt. The study aimed to assess the effect of selection for feed efficiency under different feeding regimens (free (i.e. once) at 08:00 am and twice (50%:50%) at 08:00 am and 03:00 pm) in local Egyptian chickens Saini Bedouin fowl on egg quality traits (EQT). Experiment continued for three successive generations and EQT were measured, recorded and statistically analyzed for all genetic groups (1284 fresh eggs were used). Results indicated that, both selection ($P \leq 0.05$) and feeding regimen ($P \leq 0.01$) increased egg weight significantly. Eggs laid by selected birds were heavier (41.22 and 46.05 g) than those produced by control lines birds (40.16 and 42.40 g) under free and twice feeding, respectively.Moreover, external, shell and internal quality traits didn't affected significantly by selection for feed efficiency except egg width and yolk weight. Egg length, width, shell, albumen and yolk weight significantly differed according to feeding regimen effect. Additionally, significant interaction effect was detected between lines (selection) and feeding regimen for albumin height, albumin % and yolk weight, interaction between generations with feeding regimens was statistically significant in most investigated traits.Phenotypically, feed efficiency (as a selection criterion) weakly correlated with external, egg-shell and internal EQT (ranged between -0.001 for yolk weight and 0.107 for yolk height). Moreover, egg weight highly correlated with most studied EQT (0.119 for yolk index to 1.00 for number of pores in egg-shell).*

*Selected birds actually responded to selection (as % of control) as follow: 1.0, -1.6, 0.16 and 12.07 % versus 8.5, 3.39, 3.36 and -28.0 % under free and twice feeding regimens, respectively for external EQT (egg weight, egg length, egg width and breakage force, respectively); egg shell quality traits negatively affected (-8.09, -24.37 and -4.04%) under free feeding regimen comparing with-5.88, 0.60 and 4.28%under twice feeding for wet-shell %, dry shell % and average shell thickness, respectively;internal quality traits (albumen height, albumen weight%, Haugh units and yolk weight%) responded to selection as -7.23, -5.97, -5.11 and 6.35% under free feeding, these responses were 1.61, 8.25, -1.01 and -8.17% under twice feeding comparing with control lines. Birds subjected to twice feeding a day better corresponded to selection and achieved higher improvement in different EQT comparing with birds fed freely (once) after two generation of selection. Results of the current study revealed that, egg quality traits could be improved in local chickens utilizing selection for feed efficiency alongside with applying twice a day feeding regimen.*

**Key words:***Egg quality, feed efficiency, feeding regimen, Sinai Bedouin fowl*

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## I. Introduction

Eggs, the cheapest source of high quality animal protein for human nutrition. Worldwide egg production reached more than 68 million tons annually [1]. This high demand could be attributed to their use as a human food with high nutrients plus using of eggs in many industries [2].Breeding programs in layers resulted in valuable improvement in egg production, but, its objectives are being complicated [3]. However, recently, there are many strategies aimed to increase egg production in poultry industry [4]. In the past, layer breeders companies focused on selection for high egg production and low body weight as indicators of feed efficiency due to the strong correlations between these two traits with feed efficiency [5]. Nowadays, more attention paid to different feed efficiency estimation methods (as a direct selection criteria) to be incorporated in selection programs directly. Yet, the main goal for breeding companies in egg production industry is to produce high number of sealable eggs (per time unit) with acceptable egg weight range and good quality characteristics [3].

Recently, local breeds/strains have a huge importance and need to be fully characterized by producers due to their unique features [6].Sinai chickens considered as one of valuable animal genetic resources in Egypt which mainly kept by Bedouin people in Sinai Peninsula for their meat and egg production. Eggs must be characterized by high quality externally and internally. Egg quality plays the main role (economically) of both table and hatching eggs production process to preserve high quality food stuffs or optimum environment for the embryo [3,7,8], consequently, profitability. The lower egg quality the most negatively affected contamination of other eggs and the most negatively affect consumer's health [3,9] and chick quality.

There are multiple factors that affect quality of eggs including: 1) genetic factors: quality traits of eggs differed from one breed/strain to other [7,8,10,11] and, by crossing due to heterotic effects [12].2) non-genetic factors: environmental (housing climate and season, mainly temperature and humidity); nutritional (including feed quality, feeding regimen, feed additives and components), age, hygiene status and management factors [7,11,13,14] and egg handling.There are many factors that affect egg composition such as breed, egg weight, age of layers and season, method of estimation of egg components [15].

The objective of the recent work is to study the effect of selection for feed efficiency (FE) of egg production under two different regimens of feeding on egg quality traits (EQT) and to determine the phenotypic correlations between these traits in Sinai fowl as a local chicken strain in Egypt.

## II. Materials And Methods:

Current study held at Research Poultry Farm of the Faculty of Agriculture, Menoufia University, ShebinEl-kom, Egypt. Records of 584 Sinai Bedouin fowl hens' represent 4 genetic groups (selected – 2 lines + control – 2 lines) have been recorded in the current experiment. Data were collected for three successive generations: base, first and second generations applying selection for egg production feed efficiency under tow different feeding regimens (free and twice feeding). Flock history and selection procedure have been detailed by Soltan et al., [16] and Soltan et al., [17]. The objective of the recent work to study the effect of selection for feed efficiency ofegg production on studied external and internal egg quality traits and to determine the phenotypic correlations between these quality traits in Sinai fowl as a local chicken breed.

Egg production data were collected for all experimental lines.After reaching sexual maturity by 10 days three fresh eggs have been sampled continuouslyfrom each hen (cage)and have been used to study egg quality traits: external and internal.Total number of 1284 eggs (from 428 hens) representing all investigated lines were used. All studied groups were kept in open housed farm and have been reared at the same environmental and hygienic conditions. During the first 16 weeks of age all birds allowed to reach water and feed freely (ad labium), composition of brooding diet represented in Table (1). After that, pullets were transferred to layer house and kept in individual numbered battery cages according to their line and feeding regimen, and the diet replaced by layer ration as shown in Table (1).

**Table (1):** Composition of the experimental rations.

| Ingredients | Starter ration | Layer ration |
|---|---|---|
| Ground yellow corn | 57 | 65 |
| Soybean meal | 37 | 27 |
| Limestone | 1.8 | 2.5 |
| Salt | 0.5 | 0.5 |
| di-calcium phosphate | 2 | 2.35 |
| Bone meal | 1.35 | 2.3 |
| Methionine | 0.1 | 0.1 |
| Vitamin and mineral premix %* | 0.25 | 0.25 |
| Total kg | 100 | 100 |
| Crude protein | 21.1 | 17.4 |
| ME/kg. kal. | 2734.6 | 2779.6 |

* Pfizer premix provided per kilo gram of diets:-
10000 IU Vit. A, 2000 IU Vit. $D_3$, 2 mg Vit. E, 3 mg Vit. $B_3$, 3 mg Vit. $B_2$, 10 mg pantothenic, 250 mg choline, 25 mg Fe, 10 mg Mg, 2 mg Cu, 1.2 mg I and 0.2 mg Co.

Collection of eggs done one time a day, fresh laid eggs was labeled according to their line group and kept under room conditions until egg quality traits were measured during 24 hour after collection. External egg quality traits including: egg weight (EW), egg length (EL), egg width (EWi), shell weight (wet WSW and dry DSW), breaking force (BF), shell thickness at three regions: sharp end, equator and blunt end of the egg have been measured, and the average value of egg shell thickness (AST) was calculated; internal egg quality traits including: albumen height (AH), albumen weight (AW), yolk height (YH), yolk diameter (YD), yolk weight (YW) and yolk color (YC), have been measured using appropriate instrument (digital scale ± 0.01g for weighing, three legged micrometer for height measuring, force gauge for breaking force, digital Verniercaliper for dimensions ± 0.01mm, Roche fanyolk color and micrometer for thickness – including membranes). All of above traits were measured carefully; identified eggs firstly weighed, then dimensions and breaking force measured. Egg broken on clean glass table; albumen and yolk heightwere recorded; diameter of yolk measured; albumen and yolk have been separated carefully into Petri dishes and weighed individually. Egg-shell was washed under water to clean any contacted albumen, thereafter dried in air and wet-shell weight recorded, then shell left at room temperature for 24hours to determine the dry weight of shell.

Depending on the previous measurements the following quality traits have been calculated:

1) $Egg\ shape\ index\ (ESI) = (egg\ width\ /\ egg\ length) \times 100$ ……….………..…..…..($Carter\ and\ Jones$ [18])
2) $Number\ of\ pores\ in\ eggshell\ (NP) = 304 \times (egg\ weight)^{0.767}$ ………..…..…($Rahn\ and\ Paganelli$ [19])
3) $Egg\ volume\ (cm^3)(EV) = (0.6057 - 0.0018 \times egg\ width) \times (egg\ length) \times (egg\ width)^2$
……………………………………($Narushin$ [20])
4) $$Egg\ specific\ gravity\ (ESG) = \left(\frac{\left(\frac{egg\ shape\ index}{100}\right) + 0.2872}{1.0088}\right)$$
…….($Yannakopoulos\ and\ Tserveni - Gousi$ [21])
5) $$Shell\ surface\ area\ (cm^2)(SSA) = \frac{(3.155 - 0.0136 \times egg\ length + 0.0115 \times egg\ width) \times (egg\ length \times egg\ width)}{100}$$
………………..($Narushin$ [20])
6) $Unit\ surface\ shell\ weight\ \left(\frac{g}{cm^2}\right)(USSW) = (shell\ surface\ area\ /\ wet\ shell\ weight)$
……………($Alkan\ et.al.$ [22])
7) $Haugh\ units\ (HU) = 100 \times (Log_{10}(albumen\ height - (1.7 \times egg\ weight^{0.37}) + 7.57)$
………….………($Haugh$ [23])
8) $Yolk\ index\ (YI) = (yolk\ height/yolk\ diameter) \times 100$ …………………………..….……….……($Funk$ [24])

Data collected were statistically analyzedusingIBM SPSS Statistics for Windows [25], program version (21.0)utilizing following model:

$$Y_{ijkl} = \mu + G_i + L_j + FR_k + (G \times L)_{ij} + (G \times FR)_{ik} + (L \times FR)_{jk} + (G \times L \times FR)_{ijk} + e_{ijkl}$$

Where:
$Y_{ijkl}$ = The observation on $l^{th}$bird.
$\mu$ = The overall mean.
$G_i$ = The fixed effect of $i^{th}$ generation.
$L_j$ = The fixed effect of $j^{th}$ line within the $i^{th}$ generation.
$FR_k$ = The fixed effect of the $k^{th}$ feeding regime.
$(G \times L)_{ij}$ = The interaction between $i^{th}$ generation and $j^{th}$ line.
$(G \times FR)_{ik}$ = The interaction between $i^{th}$ generation and $k^{th}$ feeding regime.
$(L \times FR)_{jk}$ = The interaction between $j^{th}$ line and $k^{th}$ feeding regime.
$(G \times L \times FR)_{ijk}$ = The interaction between $i^{th}$ generation and $j^{th}$ line and $k^{th}$ feeding regime.
$e_{ijkl}$ = The random error assumed to be normally distributed with zero mean and variances $\sigma_e^2$

The phenotypic correlations and its significances between studied egg quality traits were determined by Pearson correlation analysis procedure integrated in IPM SPSS computer program version 21.0. The realized correlated responses in studied traits due to selection underdifferent feeding regimens were calculated as follow:
9) $Realized\ correlated\ response = (S_n - C_n) - (S_0 - C_0)$ ……………($Chen\ and\ Tixier - Boichard$ [26])
Where: $S_n$ and $S_0$ represent the mean of the selected line in calculation (n) and base (0) generations, respectively. and $C_n$ and $C_0$ represent the corresponding means of control line.

## III. Results And Discussion:

Data in Table, 2 represent external egg quality traits that have been investigated in recent research. Results revealed that, after two generations of selection for FE under two different feeding regimens, egg weightsat maturity increased(41.22 and 46.05 g) in selected lines comparing with (40.16 and 42.40 g) control lines (under free and twice feeding, respectively). Slightly higher egg weights were recorded 45.8 – 46.33 g [4] in Sinai Bedouin fowl. Current results are fully agreed with those obtained by Rizk et al., [4] regarding externalEQT.Twice feeding increased EW comparing with once a day feeding in broiler breeders' hens [13,14]. The increase of EW could be due to the availability of nutrients all over the day [13], but they argued that, this improvement of egg weight didn't affected the percentages of different egg components. In local Egyptian Dokki-4 chicken strain decrease in egg weight have been detected due to selection for egg number (-0.42 g after 2 generations), this could be attributed to negative genetic correlation reported for egg number with egg weight (-0.13) as reported by Younis et al., [28].

Table (2): External egg quality traits for Sinai chickens according to line, feeding regimen and generation effect (Mean ± SE)

| Line | Feeding Regimen | G | Egg weight (g) | Egg length (mm) | Egg width (mm) | Egg shape index % | Breakage force (kg/cm$^2$) | Number of pores in egg shell | Egg volume (cm$^3$) | Specific gravity (g/cm$^3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| Selected | Free | Base | 41.35 ±0.75 | 50.90 ±0.57 | 38.77 ±0.22 | 76.33 ±0.75 | 1.94 ±0.21 | 5278 ±75 | 45.90 ±0.88 | 1.04 ±.007 |
| | | First | 42.98 ±0.80 | 50.67 ±0.53 | 39.30 ±0.26 | 77.79 ±0.56 | 3.71 ±0.20 | 5431 ±78 | 47.21 ±1.04 | 1.06 ±.006 |
| | | Second | 41.22 ±0.75 | 50.50 ±0.50 | 38.66 ±0.24 | 76.71 ±0.34 | 2.74 ±0.19 | 5260 ±73 | 45.54 ±1.03 | 1.05 ±.003 |
| | Twice | Base | 44.97 ±0.71 | 52.31 ±0.37 | 39.67 ±0.22 | 75.89 ±0.54 | 3.33 ±0.27 | 5629 ±68 | 49.33 ±0.74 | 1.04 ±.005 |
| | | First | 44.11 ±0.72 | 51.35 ±0.46 | 39.49 ±0.23 | 77.06 ±0.52 | 3.16 ±0.22 | 5543 ±70 | 48.15 ±0.87 | 1.05 ±.005 |
| | | Second | 46.05 ±0.51 | 53.78 ±0.40 | 39.99 ±0.15 | 74.50 ±0.47 | 3.29 ±0.22 | 5733 ±50 | 51.58 ±0.65 | 1.02 ±.005 |
| | Total | Base | 43.20 ±0.58 | 51.62 ±0.35 | 39.23 ±0.17 | 76.11 ±0.45 | 2.65 ±0.20 | 5457 ±56 | 47.66 ±0.62 | 1.04 ±.005 |
| | | First | 43.51 ±0.54 | 50.99 ±0.35 | 39.39 ±0.18 | 77.45 ±0.39 | 3.45 ±0.15 | 5483 ±53 | 47.65 ±0.69 | 1.05 ±.004 |
| | | Second | 43.59 ±0.52 | 52.11 ±0.36 | 39.31 ±0.16 | 75.63 ±0.31 | 3.01 ±0.15 | 5492 ±50 | 48.50 ±0.68 | 1.03 ±.003 |
| Control | Free | Base | 40.84 ±1.10 | 50.68 ±0.53 | 38.63 ±0.35 | 76.29 ±0.86 | 2.06 ±0.19 | 5228 ±108 | 45.35 ±1.07 | 1.04 ±.009 |
| | | First | 41.74 ±0.79 | 51.18 ±0.45 | 39.04 ±0.26 | 76.42 ±0.49 | 3.84 ±0.21 | 5311 ±76 | 47.00 ±0.99 | 1.04 ±.005 |
| | | Second | 40.16 ±0.91 | 51.13 ±0.51 | 38.46 ±0.26 | 75.30 ±0.40 | 2.55 ±0.19 | 5157 ±89 | 45.50 ±1.07 | 1.03 ±.004 |
| | Twice | Base | 44.94 ±1.19 | 52.37 ±0.82 | 39.77 ±0.34 | 76.10 ±1.16 | 2.41 ±0.49 | 5625 ±115 | 49.65 ±1.25 | 1.04 ±.012 |
| | | First | 42.66 ±0.66 | 50.85 ±0.34 | 39.06 ±0.22 | 76.88 ±0.32 | 2.63 ±0.16 | 5403 ±64 | 46.65 ±0.80 | 1.05 ±.003 |
| | | Second | 42.40 ±1.02 | 52.12 ±0.78 | 38.79 ±0.29 | 74.67 ±0.62 | 3.30 ±0.28 | 5376 ±98 | 47.31 ±1.40 | 1.02 ±.006 |
| | Total | Base | 42.80 ±0.90 | 51.49 ±0.50 | 39.18 ±0.27 | 76.20 ±0.70 | 2.23 ±0.25 | 5418 ±88 | 47.41 ±0.92 | 1.04 ±.007 |
| | | First | 42.20 ±0.51 | 51.01 ±0.28 | 39.05 ±0.17 | 76.65 ±0.29 | 3.24 ±0.14 | 5357 ±50 | 46.83 ±0.63 | 1.04 ±.003 |
| | | Second | 41.28 ±0.69 | 51.63 ±0.46 | 38.62 ±0.19 | 74.99 ±0.37 | 2.92 ±0.18 | 5267 ±67 | 46.40 ±0.88 | 1.03 ±.004 |
| Significances of different studied factors | | | | | | | | | | |
| | L | | * | NS | * | NS | NS | * | NS | NS |
| | G | | NS | * | NS | ** | ** | NS | NS | ** |
| | FR | | ** | ** | ** | NS | NS | ** | ** | NS |
| | L×G | | NS | NS | NS | NS | NS | NS | NS | NS |
| | L×FR | | NS | NS | NS | NS | NS | NS | NS | NS |
| | G×FR | | * | * | * | NS | ** | * | * | NS |
| | L×G×FR | | NS | NS | NS | NS | NS | NS | NS | NS |

L = line; G = generation; FR = feeding regimen; L×G, L×FR, G×FR and L×G×FR = different interaction effects; * significant; ** highly significant; NS non-significant.

The same was found by Ghanem et al., [29] in Mandarah Egyptian local chicken strain. The volume of the egg affected significantly according to variety effect in a study on guinea fowl (4 varieties) by Kgwatalala et al., [30]. Egg volume determined by the length and the width of this egg [31] which already indicate egg weight.

Some external egg quality traits (i.e. egg weight, egg width and number of pores in egg shell) have been significantly ($P \leq 0.05$) affected by either selection for feed efficiency or feeding regimen. Additionally, some other EQT(i.e. egg length and egg volume) weren't affected by selection, but, affected significantly ($P \leq 0.05$) by feeding regimen. Egg shape index, breakage strength and specific gravity traits weren't affected by selection for egg production feed efficiency or by feeding regimen. Generation effect was statistically significant for EL, ESI, BF and SG. Two way interactions (L×G) and (L×FR) didn't affected studied external egg quality traits, while, the interaction effect of G×FR significantly affected studied external quality traits except ESI and SG. Three way interaction (L×G×FR) had no effect on external egg quality traits in the current study. Line (selection) have statistical effects ($P \leq 0.01$) on EQT at 90 days of laying (i.e. ESI, YW%, AW%, SW%, ST and HU) as well as generation, while, interaction between line and generation was not significant [28]. While, in Mandarah chickens, selection for high number of produced eggs didn't affect EQT (ESI, YW%, SW% and YI) [29].

Low positive phenotypic correlation was recorded between feed efficiency and EW, EL, EWi, NP and EV, on the other hand, negative low correlations between feed efficiency and ESI, BF and ESG were detected (Table, 5). Egg weight highly correlated phenotypically with studied external EQT (Table, 5), positively with EL, EWi, BF, NP and EV, while this correlation was negative with ESI and ESG traits. Realized selection responses in external EQT in the current study have been recorded in Table (6). It have been reported that birds subjected to twice feeding a day better corresponded to selection and achieved higher improvement in different external EQT comparing with birds fed freely after two generation of selection. Results revealed that, realized response to selection was 1.0, -1.6, 0.16, 1.8, 12.07, 1.0, 1.12 and 1.33 % comparing with 8.5, 3.39, 3.36, 0.05, -28.0, 6.5, 6.69 and 0.03 % in selected lines under free and twice feeding regimens, respectively for external EQT (EW, El, EWi, ESI, BF, NP, EV and ESG, respectively).

Regarding egg shell quality traits investigated in the current research, means of egg shell traits were presented in Table (3). Shell have a major role in packaging and protecting egg components. Although, the effects of both lines and feeding regimens were not statistically significant, DSW% negatively affected by selection under free feeding and the birds subjected to twice feeding have a good DSW% comparing with those fed once a day. Differences due to line, generation and feeding regimen were not significant in most of studied egg shell quality traits, the same trend was observed concerning interaction effects between L×G and L×G×FR as shown in Table (3). Shell quality didn't affected by twice feeding, however egg weight increased [13]. On the other hand the interaction between G×FR was statistically significant in all traits investigated. Wet shell percentages were 12.52 and 13.26% comparing with 13.37 and 13.45% in selected and control lines under free and twice feeding, respectively. Slightly lower shell ratio were detected with a range between 11.99 and 12.72% in Sinai Bedouin fowl [4]). In Italian local chickens shell ratio recorded 9.5-10% [32]. Shell thickness differed according to breed, ration and house microclimate variations [14].

Phenotypic correlation coefficients between feed efficiency and egg shell quality traits (i.e. WSW, DSW, AST, SSA and USSW) were positive and low with no significances (Table, 5) and ranged between 0.049 (AST) and 0.081 (SSA). Egg weight negatively correlated with AH, ESI, BF and shell % in Italian local chickens [32]. Surface area of an egg highly correlated (0.989) to egg weight [33], so the heavier the egg the larger the surface area. Breaking strength known to be affected by shell percentage, the lower shell/egg ratio the lower breaking force observed [6]. Moreover, the eggs tend to be round (i.e. highest in ESI value) show higher breaking strength [6,34].Realized correlated response in egg shell traits represented in Table (7). Results revealed that, after two generations of selection egg shell quality traits negatively affected (-6.15, -7.71, -8.09, -24.37, -4.04, -1.03 and -6.38 %) under free feeding regimen, while these effect was positive under twice feeding (1.66, 8.09, -5.88, 0.60, 4.28, 6.29 and -4.12 %) except for WSW and USSW positively respond to selection in comparison of control lines for WSW, DSW, WSW%, DSW%, AST, SSA and USSW, respectively.

Results in Table (4) showed the means of studied internal quality traits. Results revealed that, line and generation didn't affect internal quality traits under investigation except the effect of line (selection) on yolk weight. Feeding regimen affected significantly albumin weight, yolk diameter, yolk index and yolk weight but not other studied traits. Interaction effect between L×G was not significant, while interaction between L×FR affected AH, AW, HU, YW and YW% significantly. Additionally, there were some significant effects of G×FR interaction and L×G×FR three way interaction on some internal quality traits (AH, AW and HU). Yolk represented 33.33 – 37.48% in current study of total egg weight. Lower values 26.7 – 28.74% were detected by Rizk et al., [4] in Sinai chickens, however, yolk recorded about 30-35% of egg weight in Italian local chickens till 48 weeks of age [32]. Variability in yolk characteristics may be caused by variation of egg weight or strain [14]. On the other hand, yolk parameters didn't affected by variety of guinea fowl [30], while other external and internal traits significantly affected. They added, egg weight closely related to width and length of an egg, the bigger width and/or length the heavier the weight.

Table (3): Egg shell quality traits for Sinai chickens according to line, feeding regimen and generation (Mean ± SE)

| Line | Feeding Regimen | G | Wet-shell weight (g) | Wet-shell weight % | Dry-shell weight (g) | Dry-shell weight % | Sharp-end shell Thickness (mm) | Equator shell thickness (mm) | Blunt shell thickness (mm) | Average shell thickness (mm) | Shell-surface area ($cm^2$) | Unit surface shell weight ($g/cm^2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Selected | Free | Base | 5.38 ±0.15 | 13.07 ±0.40 | 3.59 ±0.16 | 8.68 ±0.35 | .312 ±.012 | .312 ±.012 | .300 ±.012 | .308 ±.011 | 57.41 ±0.77 | .094 ±.003 |
| | | First | 5.73 ±0.19 | 13.21 ±0.28 | 4.09 ±0.20 | 9.30 ±0.33 | .375 ±.015 | .353 ±.014 | .368 ±.017 | .364 ±.015 | 58.19 ±0.86 | .098 ±.003 |
| | | Second | 5.20 ±0.17 | 12.52 ±0.27 | 3.36 ±0.18 | 7.96 ±0.32 | .273 ±.015 | .288 ±.015 | .262 ±.016 | .274 ±.015 | 56.97 ±0.83 | .091 ±.002 |
| | Twice | Base | 5.92 ±0.16 | 13.17 ±0.29 | 4.35 ±0.17 | 9.65 ±0.34 | .361 ±.011 | .351 ±.013 | .361 ±.013 | .358 ±.011 | 60.18 ±0.58 | .098 ±.002 |
| | | First | 5.49 ±0.19 | 12.32 ±0.28 | 3.80 ±0.18 | 8.48 ±0.31 | .333 ±.014 | .324 ±.012 | .317 ±.015 | .325 ±.013 | 59.07 ±0.71 | .092 ±.002 |
| | | Second | 6.12 ±0.13 | 13.26 ±0.20 | 4.56 ±0.15 | 9.81 ±0.25 | .366 ±.012 | .385 ±.011 | .380 ±.013 | .377 ±.011 | 62.02 ±0.53 | .099 ±.002 |
| | Total | Base | 5.66 ±0.12 | 13.12 ±0.24 | 3.98 ±0.13 | 9.17 ±0.25 | .337 ±.009 | .332 ±.009 | .331 ±.010 | .333 ±.009 | 58.82 ±0.52 | .096 ±.002 |
| | | First | 5.62 ±0.14 | 12.79 ±0.20 | 3.95 ±0.13 | 8.91 ±0.23 | .355 ±.011 | .340 ±.010 | .344 ±.012 | .346 ±.010 | 58.60 ±0.56 | .095 ±.002 |
| | | Second | 5.65 ±0.12 | 12.88 ±0.17 | 3.95 ±0.13 | 8.87 ±0.23 | .318 ±.011 | .336 ±.010 | .319 ±.012 | .324 ±.011 | 59.44 ±0.55 | .094 ±.001 |
| Control | Free | Base | 5.25 ±0.25 | 12.84 ±0.45 | 3.46 ±0.17 | 8.43 ±0.28 | .323 ±.016 | .316 ±.017 | .317 ±.018 | .319 ±.015 | 56.98 ±0.87 | .092 ±.004 |
| | | First | 5.39 ±0.21 | 12.74 ±0.32 | 3.93 ±0.19 | 9.23 ±0.32 | .365 ±.016 | .327 ±.016 | .346 ±.017 | .345 ±.016 | 58.18 ±0.79 | .092 ±.003 |
| | | Second | 5.39 ±0.22 | 13.37 ±0.41 | 3.50 ±0.21 | 8.57 ±0.37 | .295 ±.016 | .296 ±.016 | .300 ±.015 | .297 ±.015 | 57.13 ±0.86 | .094 ±.003 |
| | Twice | Base | 5.61 ±0.21 | 12.56 ±0.56 | 3.99 ±0.21 | 8.92 ±0.49 | .319 ±.023 | .328 ±.016 | .317 ±.020 | .322 ±.018 | 60.39 ±1.02 | .093 ±.004 |
| | | First | 5.23 ±0.17 | 12.14 ±0.25 | 3.46 ±0.19 | 7.91 ±0.35 | .297 ±.012 | .292 ±.012 | .278 ±.013 | .289 ±.012 | 57.91 ±0.64 | .089 ±.002 |
| | | Second | 5.71 ±0.21 | 13.45 ±0.36 | 3.89 ±0.24 | 9.02 ±0.42 | .316 ±.018 | .326 ±.019 | .335 ±.018 | .327 ±.018 | 58.55 ±1.14 | .097 ±.003 |
| | Total | Base | 5.42 ±0.16 | 12.71 ±0.35 | 3.71 ±0.14 | 8.66 ±0.27 | .321 ±.014 | .322 ±.011 | .317 ±.013 | .320 ±.011 | 58.61 ±0.75 | .093 ±.003 |
| | | First | 5.31 ±0.13 | 12.44 ±0.20 | 3.69 ±0.14 | 8.57 ±0.25 | .331 ±.011 | .310 ±.010 | .312 ±.011 | .317 ±.010 | 58.05 ±0.51 | .091 ±.002 |
| | | Second | 5.55 ±0.15 | 13.41 ±0.27 | 3.70 ±0.16 | 8.79 ±0.28 | .306 ±.012 | .311 ±.012 | .317 ±.012 | .312 ±.012 | 57.84 ±0.71 | .096 ±.002 |
| Significances of different studied factors | | | | | | | | | | | | |
| | L | | NS | NS | NS | NS | NS | * | NS | NS | NS | NS |
| | G | | NS | * | NS | NS | * | NS | NS | NS | NS | NS |
| | FR | | * | NS | * | NS | NS | NS | NS | NS | ** | NS |
| | L×G | | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| | L×FR | | NS | NS | NS | NS | * | NS | * | * | NS | NS |
| | G×FR | | ** | * | ** | ** | ** | ** | ** | ** | * | * |
| | L×G×FR | | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

L = line; G = generation; FR = feeding regimen; L×G, L×FR, G×FR and L×G×FR = different interaction effects; * significant; ** highly significant; NS non-significant.

Table (4): Internal egg quality traits for Sinai chickens according to line, feeding regimen and generation (Mean ± SE)

| Line | Feeding Regimen | G | Albumen height (mm) | Albumen weight (g) | Albumen weight % | Haugh Units | Yolk height (mm) | Yolk diameter (mm) | Yolk index % | Yolk color | Yolk weight (g) | Yolk weight % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Selected | Free | Base | 5.05 ±0.14 | 20.66 ±0.51 | 49.93 ±0.74 | 76.69 ±1.02 | 14.20 ±0.21 | 37.20 ±0.40 | 38.22 ±0.60 | 6.18 ±0.21 | 15.18 ±0.37 | 36.56 ±0.71 |
| | | First | 5.21 ±0.18 | 22.39 ±0.65 | 51.59 ±0.67 | 76.85 ±1.05 | 14.52 ±0.23 | 37.54 ±0.49 | 38.70 ±0.35 | 5.74 ±0.22 | 14.71 ±0.17 | 34.68 ±0.61 |
| | | Second | 4.58 ±0.22 | 20.03 ±0.65 | 48.17 ±0.86 | 72.28 ±1.46 | 14.03 ±0.22 | 36.81 ±0.54 | 38.12 ±0.29 | 4.98 ±0.31 | 15.33 ±0.30 | 37.48 ±0.74 |
| | Twice | Base | 5.34 ±0.18 | 23.46 ±0.51 | 52.11 ±0.56 | 77.19 ±1.16 | 14.63 ±0.19 | 38.37 ±0.35 | 38.18 ±0.54 | 5.61 ±0.27 | 15.40 ±0.27 | 34.31 ±0.49 |
| | | First | 5.04 ±0.22 | 23.07 ±0.70 | 51.78 ±0.89 | 74.67 ±1.41 | 14.46 ±0.25 | 37.68 ±0.44 | 38.40 ±0.53 | 5.78 ±0.29 | 15.04 ±0.24 | 34.64 ±0.89 |
| | | Second | 5.76 ±0.17 | 24.29 ±0.44 | 52.60 ±0.51 | 79.49 ±1.02 | 14.75 ±0.17 | 39.43 ±0.36 | 37.44 ±0.33 | 6.51 ±0.22 | 15.61 ±0.19 | 34.02 ±0.44 |
| | Total | Base | 5.19 ±0.12 | 22.09 ±0.42 | 51.04 ±0.48 | 76.95 ±0.77 | 14.42 ±0.14 | 37.80 ±0.28 | 38.20 ±0.40 | 5.89 ±0.18 | 15.30 ±0.23 | 35.41 ±0.45 |
| | | First | 5.13 ±0.14 | 22.71 ±0.48 | 51.68 ±0.55 | 75.83 ±0.87 | 14.50 ±0.17 | 37.61 ±0.33 | 38.56 ±0.31 | 5.76 ±0.18 | 14.86 ±0.14 | 34.66 ±0.53 |
| | | Second | 5.16 ±0.15 | 22.12 ±0.45 | 50.34 ±0.55 | 75.81 ±0.96 | 14.38 ±0.15 | 38.09 ±0.35 | 37.79 ±0.22 | 5.73 ±0.21 | 15.47 ±0.18 | 35.78 ±0.47 |
| Control | Free | Base | 5.59 ±0.23 | 20.76 ±0.77 | 50.82 ±1.23 | 80.72 ±1.56 | 14.35 ±0.20 | 36.42 ±0.67 | 39.50 ±0.74 | 6.00 ±0.33 | 14.25 ±0.66 | 35.22 ±1.34 |
| | | First | 5.20 ±0.19 | 21.82 ±0.62 | 51.90 ±0.63 | 77.26 ±1.09 | 14.34 ±0.24 | 37.43 ±0.45 | 38.27 ±0.33 | 5.85 ±0.24 | 14.45 ±0.21 | 35.01 ±0.65 |
| | | Second | 5.53 ±0.20 | 21.02 ±0.64 | 52.19 ±0.67 | 80.41 ±1.22 | 14.18 ±0.27 | 37.13 ±0.60 | 38.25 ±0.60 | 5.98 ±0.27 | 13.60 ±0.37 | 33.98 ±0.71 |
| | Twice | Base | 4.69 ±0.23 | 23.98 ±1.31 | 53.07 ±1.91 | 72.23 ±1.78 | 14.51 ±0.35 | 39.20 ±0.51 | 37.03 ±0.86 | 5.36 ±0.34 | 14.86 ±0.24 | 33.33 ±1.67 |
| | | First | 4.95 ±0.19 | 21.32 ±0.61 | 49.53 ±0.69 | 74.87 ±1.23 | 14.07 ±0.23 | 37.20 ±0.39 | 37.84 ±0.50 | 5.80 ±0.27 | 15.71 ±0.15 | 37.27 ±0.68 |
| | | Second | 5.03 ±0.28 | 21.17 ±0.88 | 49.47 ±1.11 | 75.29 ±1.88 | 14.44 ±0.26 | 37.67 ±0.65 | 38.39 ±0.46 | 5.67 ±0.38 | 15.13 ±0.39 | 35.97 ±0.98 |
| | Total | Base | 5.16 ±0.18 | 22.30 ±0.80 | 51.89 ±1.11 | 76.66 ±1.46 | 14.42 ±0.19 | 37.75 ±0.51 | 38.32 ±0.61 | 5.70 ±0.24 | 14.54 ±0.44 | 34.32 ±1.06 |
| | | First | 5.08 ±0.13 | 21.57 ±0.43 | 50.72 ±0.48 | 76.07 ±0.83 | 14.20 ±0.17 | 37.31 ±0.29 | 38.05 ±0.30 | 5.82 ±0.18 | 15.08 ±0.14 | 36.14 ±0.48 |
| | | Second | 5.28 ±0.17 | 21.10 ±0.54 | 50.83 ±0.66 | 77.85 ±1.16 | 14.31 ±0.19 | 37.40 ±0.44 | 38.32 ±0.38 | 5.82 ±0.23 | 14.36 ±0.28 | 34.98 ±0.61 |
| Significances of different studied factors | | | | | | | | | | | | |
| | L | | NS | NS | NS | NS | NS | NS | NS | NS | ** | NS |
| | G | | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| | FR | | NS | ** | NS | NS | NS | ** | * | NS | ** | NS |
| | L×G | | NS | NS | NS | NS | NS | NS | NS | NS | ** | * |
| | L×FR | | ** | NS | ** | ** | NS | NS | NS | NS | * | ** |
| | G×FR | | NS | * | * | NS | NS | * | NS | NS | NS | * |
| | L×G×FR | | * | NS | * | ** | NS | NS | NS | * | NS | NS |

L = line; G = generation; FR = feeding regimen; L×G, L×FR, G×FR and L×G×FR = different interaction effects; * significant; ** highly significant; NS non-significant.

Table (5): Phenotypic correlations between studied external and internal egg quality traits.

| Trait | EW | EL | EWi | ESI | BF | NP | EV | ESG | WSW | DSW | AST | SSA | USSW | AH | AW | HU | YH | YD | YI | YC | YW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Feed Efficiency | 0.069 | 0.097 | 0.058 | -0.092 | -0.024 | 0.071 | 0.075 | -0.093 | 0.07 | 0.069 | 0.049 | 0.081 | 0.062 | 0.054 | 0.073 | 0.058 | 0.107 | 0.065 | 0.081 | 0.084 | -0.001 |
| Egg weight | 1 | .839** | .954** | -.330** | .261** | 1.000** | .967** | -.330** | .793** | .814** | .742** | .959** | .510** | .700** | .922** | .552** | .760** | .843** | .119* | .669** | .357** |
| Egg length | | 1 | .747** | -.771** | 0.043 | .839** | .915** | -.770** | .591** | .620** | .542** | .935** | .256** | .612** | .771** | .495** | .627** | .786** | 0.003 | .607** | .372** |
| Egg width | | | 1 | -.159** | .243** | .954** | .950** | -.159** | .755** | .783** | .712** | .934** | .473** | .697** | .892** | .561** | .736** | .798** | .129** | .663** | .325** |
| Egg shape index | | | | 1 | .161** | -.331** | -.451** | 1.000** | -.148** | -.165** | -.115* | -.499** | 0.088 | -.242** | -.289** | -.198** | -.223** | -.382** | .101* | -.253** | -.240** |
| Breakage force | | | | | 1 | .258** | .178** | .161** | .419** | .557** | .603** | .158** | .437** | .215** | .249** | .177** | .324** | .213** | .202** | .109* | -0.012 |
| Number of pores in egg shell | | | | | | 1 | .967** | -.331** | .792** | .813** | .740** | .959** | .510** | .699** | .921** | .551** | .759** | .842** | .118* | .668** | .358** |
| Egg volume | | | | | | | 1 | -.450** | .735** | .766** | .689** | .998** | .410** | .710** | .898** | .572** | .742** | .851** | 0.082 | .688** | .371** |
| Specific gravity | | | | | | | | 1 | -.148** | -.165** | -.115* | -.499** | 0.087 | -.242** | -.288** | -.198** | -.222** | -.381** | .101* | -.252** | -.240** |
| Wet-shell weight | | | | | | | | | 1 | .865** | .767** | .721** | .916** | .656** | .696** | .549** | .746** | .689** | .270** | .574** | .196** |
| Dry-shell weight | | | | | | | | | | 1 | .908** | .752** | .720** | .608** | .755** | .499** | .692** | .741** | .134** | .611** | .210** |
| Average shell thickness | | | | | | | | | | | 1 | .672** | .633** | .598** | .700** | .506** | .694** | .694** | .187** | .535** | .188** |
| Shell-surface area | | | | | | | | | | | | 1 | .391** | .702** | .889** | .566** | .731** | .847** | 0.073 | .680** | .374** |
| Unit surface shell weight | | | | | | | | | | | | | 1 | .473** | .429** | .411** | .574** | .445** | .306** | .389** | 0.034 |
| Albumen height | | | | | | | | | | | | | | 1 | .734** | .976** | .718** | .612** | .326** | .748** | 0.079 |
| Albumen weight | | | | | | | | | | | | | | | 1 | .622** | .684** | .782** | 0.084 | .634** | 0.012 |
| Haugh Units | | | | | | | | | | | | | | | | 1 | .625** | .490** | .335** | .697** | -0.019 |
| Yolk height | | | | | | | | | | | | | | | | | 1 | .713** | .602** | .575** | .296** |
| Yolk diameter | | | | | | | | | | | | | | | | | | 1 | -.127** | .547** | .312** |
| Yolk index | | | | | | | | | | | | | | | | | | | 1 | .198** | 0.055 |
| Yolk color | | | | | | | | | | | | | | | | | | | | 1 | .241** |

EW = Egg weight; EL= Egg length; EWi= Egg width; ESI= Egg shape index; BF= Breaking force; NP= Number of pores in egg shell; EV= Egg volume; ESG= Egg specific gravity; WSW= Wet shell weight; DSW= Dry shell weight; AST= Average shell thickness; SSA= Shell surface area; USSW= Unit surface shell weight; AH= Albumen height; AW= Albumen weight; HU= Haugh Units; YH= Yolk height; YD= Yolk diameter; YI= Yolk index; YC= Yolk color; YW= Yolk weight

The higher the Haugh units the higher the albumin quality.Haugh units and yolk index didn't affected significantly by genotype [6].Taherkhani et al., 2010 found that twice a day feeding didn't affect yolk percentage.

Feed efficiency of egg production weakly positively correlated with studied internal traits as range of 0.054 to 0.107 except yolk weight negatively correlated to feed efficiency (-0.001) as shown in Table (5).Actual correlated response in internal egg quality traits have been recorded in Table (8). Results indicated that, after two generations of selection for egg production feed efficiency, internal quality traits (AH, AW, AW%, HU, YD and YC) decreased in birds subjected to free feeding regimen except YH, YI, YW and YW% have been increased due to selection for feed efficiency. Moreover, the studied internal egg quality traits positively affected by selection in birds fed twice daily except HU, YI, YW and YW% compared by control lines.Haugh units affected by multiple factors, like breed, storage duration and temperature, feed and hygiene status of layers [28]. Control line birds laid eggs with higher value of HU in Dokki-4 Egyptian local strain compared with selected hen for egg production [28]. Regardless of feeding regimen selection for egg production feed efficiency: positively affected external egg quality traits excluding BF; negatively affected egg shell quality traits except SSA; increased some internal quality traits values AW, AW%, YH, YD and YW; and decreased AH, HU, YI, YC and YW% internal quality traits values. On the other hand, selection for high egg production in local Egyptian chicken strain (Dokki-4) had a significant positive effect on egg quality traits (ST, SW%, YW% and HU) as compared by control line [28]. Results of current investigation highlighted valuable information about EQT in Sinai chickens as pure Egyptian breed and itscompromisingfuturity in breeding and conservation plans of local strains of chickens.

Low to moderate records of heritability were noticed by Younis et al., [28] for EQT in Dokki-4 local Egyptian chickens. So, these traits tend to be affected largely by environmental effects (currently, feeding regimen). These findings reflect results of the recent study, that, although analysis of variance showed that selection for FE mostly not affected egg quality traits, birds fed twice a day have the better quality compared with those subjected to free feeding regimen.

## IV. Conclusions

Finally, we came to conclude that, in general, selection for feed efficiency in Sinai Bedouin fowls didn't affected external, shell and internal egg quality traits, however, applying twice feeding regimen enhanced (significantly most of egg quality traits) the whole egg quality in comparison with free (once a day) feeding regimen. Consequently, it is strongly recommended practicing twice feeding regimen in local chickens' production process alongside with any genetic improvement plan.

**Table (6):** Realized correlated response in external egg quality traits for Sinai chickens.

| Feeding regimen | Generation | Egg weight | Egg length | Egg width | Egg shape index | Breakage force | Number of pores in egg shell | Egg volume | Specific gravity |
|---|---|---|---|---|---|---|---|---|---|
| Free | Base | 0.507 | 0.217 | 0.141 | 0.044 | -0.117 | 50 | 0.556 | 0.0002 |
| | First | 0.730 | -0.730 | 0.117 | 1.334 | -0.011 | 69 | -0.346 | 0.0135 |
| | Second | 0.549 | -0.853 | 0.064 | 1.368 | 0.308 | 52 | -0.513 | 0.0137 |
| Twice | Base | 0.031 | -0.059 | -0.105 | -0.213 | 0.917 | 3 | -0.320 | -0.0021 |
| | First | 1.417 | 0.565 | 0.532 | 0.387 | -0.389 | 135 | 1.814 | 0.0039 |
| | Second | 3.620 | 1.719 | 1.304 | 0.040 | -0.926 | 352 | 4.589 | 0.0004 |
| Total | Base | 0.398 | 0.131 | 0.053 | -0.093 | 0.423 | 39 | 0.250 | -0.0010 |
| | First | 0.910 | -0.155 | 0.284 | 0.891 | -0.207 | 86 | 0.574 | 0.0090 |
| | Second | 1.907 | 0.348 | 0.636 | 0.735 | -0.337 | 185 | 1.846 | 0.0073 |

**Table (7):** Realized correlated response in egg-shell quality traits for Sinai chickens.

| Feeding regimen | Generation | Wet-shell weight | Dry-shell weight | Wet-shell weight % | Dry-shell weight % | Average shell thickness | Shell-surface area | Unit surface shell weight |
|---|---|---|---|---|---|---|---|---|
| Free | Base | 0.138 | 0.132 | 0.237 | 0.247 | -0.011 | 0.435 | 0.002 |
| | First | 0.205 | 0.024 | 0.228 | -0.180 | 0.030 | -0.424 | 0.003 |
| | Second | -0.332 | -0.270 | -1.082 | -0.853 | -0.012 | -0.589 | -0.006 |
| Twice | Base | 0.311 | 0.355 | 0.603 | 0.734 | 0.036 | -0.218 | 0.005 |
| | First | -0.047 | -0.011 | -0.417 | -0.168 | 0.000 | 1.376 | -0.003 |
| | Second | 0.095 | 0.315 | -0.791 | 0.055 | 0.014 | 3.683 | -0.004 |
| Total | Base | 0.238 | 0.263 | 0.415 | 0.512 | 0.013 | 0.213 | 0.004 |
| | First | 0.072 | -0.005 | -0.063 | -0.171 | 0.016 | 0.344 | 0.000 |
| | Second | -0.141 | -0.009 | -0.939 | -0.439 | 0.000 | 1.392 | -0.005 |

**Table (8):** Realized correlated response in internal egg quality traits for Sinai chickens.

| Feeding regimen | G | Albumen height | Albumen weight | Albumen weight % | Haugh Units | Yolk height | Yolk diameter | Yolk index | Yolk color | Yolk weight | Yolk weight % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Free | Base | -0.547 | -0.098 | -0.894 | -4.024 | -0.154 | 0.778 | -1.282 | 0.182 | 0.936 | 1.339 |
| | First | 0.559 | 0.667 | 0.585 | 3.613 | 0.339 | -0.660 | 1.710 | -0.283 | -0.679 | -1.674 |
| | Second | -0.400 | -0.889 | -3.118 | -4.112 | 0.006 | -1.102 | 1.154 | -1.186 | 0.793 | 2.161 |
| Twice | Base | 0.644 | -0.521 | -0.956 | 4.965 | 0.123 | -0.838 | 1.151 | 0.245 | 0.538 | 0.984 |
| | First | -0.559 | 2.274 | 3.209 | -5.163 | 0.274 | 1.322 | -0.583 | -0.271 | -1.206 | -3.611 |
| | Second | 0.081 | 3.640 | 4.085 | -0.767 | 0.190 | 2.596 | -2.110 | 0.600 | -0.054 | -2.940 |
| Total | Base | 0.032 | -0.208 | -0.852 | 0.292 | -0.007 | 0.044 | -0.120 | 0.193 | 0.753 | 1.095 |
| | First | 0.021 | 1.349 | 1.818 | -0.531 | 0.300 | 0.253 | 0.627 | -0.258 | -0.969 | -2.575 |
| | Second | -0.155 | 1.231 | 0.366 | -2.332 | 0.083 | 0.647 | -0.417 | -0.288 | 0.351 | -0.289 |

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