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Egg Quality Characteritics and Phenotypic Correlations in Three Algerian Native Chicken Populations and One Exotic Strain

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ABSTRACT

This study aimed to assess and compare egg quality traits among three indigenous Algerian chicken genotypes [Naked Neck (NN), Crested (Cr), and Normal Feathered (NF), and a commercial exotic strain (CS)], focusing on the genetic influence on morphological, physicochemical properties, and fatty acid composition. A total of 400 eggs, with 100 eggs from each genotype, were analyzed. The CS hens produced significantly heavier eggs with a higher shape index, as well as greater eggshell weight and albumen content. Yolk weight was similar across all indigenous genotypes and the CS group, but the Yolk:Albumen ratio was significantly higher in NF (0.64) hens compared to NN (0.60) and Cr (0.63) counterparts. The edible matter percentage was lower in indigenous genotypes compared to CS, while pH values varied, with NN eggs having the highest albumen pH and CS having the lowest yolk pH. The fatty acid composition varied significantly among genotypes. Eggs from the Cr group exhibited higher levels of MUFA, particularly oleic acid, while NN hens demonstrated the highest linoleic acid and PUFA. The NF genotype had a more favorable *n-6*to *n-3* ratio compared to the Exotic strain.Naked Neck and Normal Feathered chickens offer distinct advantages in fatty acid profiles and yolk-to-albumen ratios, highlighting their potential for improving egg nutritional value. These findings underscore the importance of indigenous breeds in enhancing the quality and nutritional benefits of poultry products.
Keywords: egg quality, fatty acid, genetic, indigenous chickens

INTRODUCTION

According to FAO estimates, by 2050, the food needs of the world's population will increase by 70% (FAO, 2009). Demand for poultry meat and eggs is expected to continue increasing due to population growth and rising individual consumption. Poultry production plays a vital role in human nutrition and food security, contributing to poverty alleviation, income generation, and the creation of employment opportunities. Eggs are substantial sources of proteins and several essential nutrients (Ruxton *et al.,* 2010). The protein quality of eggs is considered high in relation to other foods (Eddin *et al.,* 2019). Moreover, different studies have reported that eggs have antioxidant properties (Yousr and Howell, 2015) and that the daily consumption of eggs can facilitate weight loss in a hypocaloric diet (Vander Wal *et al.,*2008). Quality of the breeding eggs has an overall significance on economic breeding (Tserveni-Goussi *et al.,*2011). Improvements in egg production over the years have significantly reduced its cost, making it an affordable source of animal proteins and lipids (Nys and Sauveur, 2004). Egg quality criteria evolve in response to the changing demands of consumers and the food industry, requiring breeders to combine high production levels with superior quality to meet market expectations (Romé and Le Roy, 2016). Determination of egg quality is a requirement for both edible eggs and for the production of hatching eggs (Çiftsüren and Akkol, 2018)**.** Egg qualities comprise internal attributes such as yolk weight, yolk color, percentage of yolk, albumen height, haugh unit, and external characteristics including egg weight, eggshell weight, eggshell color, eggshell strength, eggshell index, and eggshell thickness (Zhang *et al.,* 2023)**.** Previous studies showed that egg quality characteristics such us egg weight, proportions of shell, yolk and albumen and nutrient composition can considerably affect hatchability, embryonic mortality, hatching weights, the growing embryo during incubation, chick performance, and post-hatch feed conversion of broilers (Shanawany, 1987; İpek and Sözcü, 2013; Liswaniso *et al.,* 2021).

Native chicken breeds represent great value to the majority of consumers, particularly in the rural sector of the most developing and underdeveloped countries (Fathi *et al.,* 2022). Their meat and eggs are favored by most rural communities and are also popular among urban populations (Zouaoui *et al.,* 2023). The low egg productivity of local chicken breeds in traditional farming systems is largely influenced by genetic factors and suboptimal rearing conditions. As a result, these local strains are generally excluded from modern poultry production (Moussa *et al.,* 2010). Nonetheless, the implementation of a genetic improvement program, alongside improved management practices, has the potential to substantially enhance both egg-laying performance and egg quality in these breeds. To achieve this, rigorous performance evaluations under controlled conditions are necessary, as current data on these genotypes remains limited (Adamou *et al.,* 2022). Several chicken breeds in Algeria are well adapted to the local environmental conditions. However, few studies have investigated the egg quality traits of these indigenous chicken populations (Moula *et al.,* 2012; Dahloum *et al.,* 2015; Dahloum *et al.,* 2024). Taking these facts into consideration, this study aims to address the research gap by comparing the egg quality traits of three indigenous chicken phenotypes with those of a commercial strain. This comparison is crucial for evaluating the physical and nutritional characteristics of local chicken populations.

MATERIAL AND METHODS

Egg Quality Analysis

The commercial eggs used in this study were purchased, while the local eggs were collected from a privately-owned farm. These phenotypes were housed separately and subjected to the same commercial diet as the exotic strain. The eggs were cleaned, identified by lot, and transported to the laboratory.

A total of 400 fresh eggs (100 eggs from each phenotype) were analyzed for internal and external quality within 24 hours after laying. The external egg traits recorded were: whole egg weight (EW, g), egg width (EWd, mm) and egg lenght (EL, mm): These values were used for egg shape index calculation [ESI= (EWd/EL x 100)] and eggshell weight (ESW, g). As regards the internal egg quality, the parameters investigated were: albumen weight (AW, g), albumen pH (ApH), yolk weight (YW, g), yolk pH (YpH), and yolk by albumen ratio (Y/A). EW was determined to the nearest 0.01g using electronic scale. EWd, EL and YD were determined using a digital caliper. The eggs showing any macroscopic abnormalities (broken egg, dirty egg, misshaped egg, bloody egg, double-yolk egg) were removed from the analysis. The percentage of edible matter (EM) in the eggs was calculated using the following equation: $EM = (YW + AW) / EW \times 100$ (Gittins and Overfield, 1991; Nys and Sauveur, 2004). The egg weight classification was established according to the Commission Regulation (EC) No 589/2008

Determination Of Egg Fatty Acid Composition

Ten representative eggs from each group, were analyzed twice for their fatty acids (FA) profile, and the percentage of saturated (SFA), monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA). Measurement of the fatty acid profile in the whole edible parts of eggs (albumen + yolk) was determined through gas chromatography analysis after lipid extraction according to Folch et al. (1957).

Statistical Analysis

The main effect of genotype on egg characteristics was analyzed using one-way analyses of variance. Significant differences among means were analyzed by Student-Newman-Keuls multiple range test at $P<0.05$. Computations were by using the General Linear Model (GLM) procedure of SPSS software (IBM, version 20.0).

RESULTS AND DISCUSSION

The total egg weight, width, and shape index of commercial eggs were significantly higher compared to local eggs. Similar finding was reported by Serge et al. (2016), who showed that eggs from improved strains had higher mean values for traits such as egg weight, egg length, egg diameter, shell weight, and shape index than those from local chicken breeds in Burkina Faso. However, the Naked Neck hens produced larger eggs and exhibited a higher shape index compared when compared to normal feathered and crested counterparts.

According to Halbouche et al. (2009), eggs from local chickens contain more yolk and less albumen compared to eggs from selected breeds. Furthermore, the shape index of local eggs was lower than that of commercial strains (73 versus 79), indicating that local eggs are longer and narrower than commercial eggs. As the primary criterion for egg sales is weight, the eggs in this study were categorized based on their weight into several classes (Table 2).

Eggs from the exotic breed are predominantly classified in the first four categories, with the highest proportion falling into Class 3 (44.83%). In contrast, local eggs are mainly classified from Class 3 to Class 6, with varying percentages depending on the phenotype. For Naked Neck chickens, Class 4 dominates (56.86%), while Class 5 is most prevalent for Crested and Normal Feathered groups (60% and 50%, respectively). Notably, the lowest weight category (≤ 45g) was exceptionally found only in eggs from NF genotype, though with a minimal percentage. Egg weight tends to vary with the age of the hen, being lower at the beginning of laying and increasing as the hen ages (Beaumont *et al.*, 2010). The weight typically ranges between 50 and 70 g, with extremes from 45 to 75 g, depending on the hen’s age and commercial breed. Egg weight increases significantly throughout the production year, though this progression and the average egg weight depend largely on the hen’s breed, particularly in relation to its body weight. This increase has been strongly limited by selective breeding in current commercial lines (Travel *et al.*, 2010).

Table 1. Effect of genotype on egg weight, egg length, egg width and egg shape index (Mean ± standard deviation).

Trait	Genotype				
	Naked neck	Crested	Normal feathered	Exotic strain	Sig
Egg weight (g)	54.87± 3.86[b]	52.57± 3.68[a]	54.45 ±4.39[ab]	63.95 ±4.59[c]	***
Egg width (cm)	3.93± 0.11[a]	3.92 ±0.18[a]	3.98±0.14[a]	4.14 ±0.22[b]	***

Egg lenght (cm)	5.37± 0.35[a]	5.38 ±0.28[a]	5.46 ±0.28[a]	5.49±0.26[a]	NS
Egg shape index	73.42±4.5[ab]	73.06±5.01[a]	73.08±4.37[a]	75.54±4.44[c]	*

Within a row means are significantly different (* Significance at P < 0.05; *** Significance at P < 0.001; NS: Not significant (P > 0.05).

The commercial eggs exhibited higher values for shell weight, albumen weight, shell percentage, and edible matter compared to the local chicken populations. The yolk ratio in indigenous genotypes were 32.59%, 33.66%, and 34.04% for NN, Cr, and NF hens, respectively. The corresponding albumen ratios were 54.61%, 54.27%, and 53.98%, respectively. In contrast, the commercial strain recorded yolk and albumen contents of 28.9% and 58.09%, respectively. This highlights a distinct pattern, with local breeds showing higher yolk content and a greater yolk-to-albumen ratio compared to commercial strains. These findings are consistent with those reported by Moula (2018). In commercial breeding programs, the yolk weight-to-egg weight ratio is often regarded as a critical parameter, providing valuable insight into the overall "value" of the egg. However, selection for traits such as increased egg weight and enhanced feed efficiency frequently leads to a higher water content in the egg. This is due to the stronger genetic correlation between egg weight and albumen percentage, compared to the correlation between egg weight and yolk percentage (Washburn, 1990). The percentage of edible matter in local eggs was significantly lower, with recorded values of 62.56±3.41% for NN, 62.16±4.93% for Cr, and 63.44±5.60% for NF genotype. These findings stand in contrast to those reported by Serge et al. (2016),who reported a higher percentage of edible matter in local breed eggs (89.81%) compared to commercial layers (88.17%). The percentage of edible matter is a critical parameter in the egg production industry, as both local and commercial eggs are assessed based on their yield efficiency. Regarding pH values, the yolk exhibited slightly acidic values, ranging from 5 to 6, whereas the albumen consistently showed basic pH values, between 8 and 9, across all eggs analyzed. These findings align with data from Serge et al. (2016) in Burkina Faso. The differences in pH between yolk and albumen were statistically significant between local and commercial eggs, emphasizing the role of pH as a key indicator of egg quality. Mertens et al. (2010) further highlighted the importance of albumen pH, suggesting that it serves as a more accurate measure of egg freshness than albumen height. The albumen pH typically starts between 7.6 and 7.9 in freshly laid eggs and increases to around 9 as the egg ages.

Phenotypic Correlation Between Internal and External Traits

Pairwise correlations between internal and external egg characteristics are presented in Table 4. Egg weight was positively correlated with EL and EWd, AW, YW, ESW, and EM. However, EW was negatively associated with Yolk proportion and the Y:A ratio. Similar findings were reported by

Dahloum et al. (2015). Albumen weight showed a positive correlation with ESW (+0.493;P<0.001), but a negative correlation with yolk proportion (–0.503; P<0.001) and the Y:A ratio (–0.642; P<0.001). The strongest correlation was observed between EW and yolk ratio, along with the Y:A ratio (+0.893; P<0.001). Furthermore, eggshell proportion exhibited a negative correlation with the yolk ratio (-0.17; P<0.01) but demonstrated no significant correlation with albumen proportion (-0.109; P>0.05). These results stand in contrast to those reported by Dahloum et al. (2015). Overall, the positive correlations observed between EW and specific egg traits, particularly AW, indicate that the quality of eggs from local chickens may be improved through a well-designed breeding program. Similar results have been reported in previous studies (Udoh *et al.,* 2012; Sreenivas *et al.,* 2013; Zita *et al.,* 2013).

Table 2 : Egg weight classification

Class	Egg weight (g)	Naked neck	Crested	Normal feathered	Exotic strain
1	> 70	-	-	-	13.79
2	65- 70	-	-	-	20.69
3	60- 65	3.92	3.33	10	44.83
4	55- 60	56.86	18.33	26.66	20.69
5	50 – 55	21.57	60	50	-
6	45- 50	17.65	18.33	11.66	-
7	≤ 45	-	-	1.66	-

Fatty Acid Analysis

It is known that autochthonous animal breeds accumulate more fat in meat, milk or eggs (Stanišic *et al.,* 2015), which could be the main reason for the higher fat and dry-matter contents determined in eggs from indigenous chickens. The fatty acid composition across the different genotypes of chickens reveals significant distinctions that reflect both genetic variation and the influence of specific major genes such as Naked Neck, Crested, and Normal Feathered. Palmitic acid content is highest in the exotic strain (23.50%) and Naked Neck chickens (23.10%), with significantly lower values observed in Normal Feathered (20.17%), and Crested (21.00%) genotypes, indicating a trend where the commercial breed shows increased saturated fatty acid (SFA) levels. Stearic acid follows a similar pattern, with the highest levels in Crested and exotic strains, showing that these genotypes may contribute to a higher proportion of SFAs. Monounsaturated fatty acids, particularly oleic acid are more abundant in the Crested and exotic hens, both exhibiting values over 38%, whereas Naked Neck and Normal Feathered genotypes showed slightly lower contents. This suggests that Crested chickens might have a slight advantage in MUFA accumulation compared to their local counterparts.

Table 3. Effect of genotype on eggshell weight and internal egg quality traits (mean ± standard deviation).

	Genotype				
Trait	Naked neck	Crested	Normal feathered	Exotic strain	Sig
Eggshell weight, g	6.35 ±0.8^{b}	5.66 ±0.99^{a}	5.67±0.95^{a}	7.23±0.77^{c}	***
Eggshell ratio, %	11.60 ±1.45^{b}	10.81±1.98^{ab}	10.43 ±1.66^{a}	11.34 ± 1.34^{b}	***
Albumen weight, g	29.97± 2.78^{a}	28.51±3.53^{a}	29.4±3.59^{a}	37.09±3.37^{b}	***
Albumen ratio, %	54.61±3.06^{a}	54.27±6.21^{a}	53.98±4.88^{a}	58.09±4.78^{b}	***
Yolk weight, g	17.91± 2.21	17.63± 2.51	18.54±3.08	18.48±2.39	NS
Yolk ratio, %	32.59±2.75^{b}	33.66±5.19^{b}	34.04±4.98^{b}	28.9±3.11^{a}	***
Y: A	0.6± 0.08^{b}	0.63±0.18^{b}	0.64±0.12^{b}	0.5±0.9^{a}	***
EM (%)	62.56±3.41^{a}	62.16±4.93^{a}	63.44±5.6^{a}	65.98±3.5^{b}	***
A pH	9.02± 0.38^{a}	8.6± 0.34^{a}	9.28± 2.24^{a}	8.73±0.20^{a}	*
Y pH	6.44± 0.19^{b}	6.41± 0.41^{b}	6.46± 0.41^{b}	6.2± 0.12^{a}	**

Within a row, means are significantly different (* Significance at P < 0.05; ** Significance at P<0.01; ***Significance at P<0.001; NS: Not significant P> 0.05)

Table 4: Pearson correlations between egg quality traits (n=400).

	EW	EL	EWd	AW	YW	ESW	ESI	A%	Y%	ES%	Y/A	EM
EW	1	0.270**	0.399**	0.817**	0.390**	0.529**	0.064	0.180**	-0.343**	-0.090	-0.300**	0.492**
EL		1	0.193**	0.254**	0.118	0.067	-0.69**	0.118	-0.085	-0.121	-0.116	0.174**
EWd			1	0.483**	0.109	0.463**	0.571**	0.330**	-0.164*	0.244**	-0.219**	0.329**
AW				1	0.087	0.493**	0.138*	0.710**	-0.503**	-0.001	-0.642**	0.520**
YW					1	0.010	-0.017	-0.302**	0.726**	-0.251**	0.653**	0.806**
ESW						1	0.278**	0.199**	-0.367**	0.794**	-0.286**	0.138*
ESI							1	0.139*	-0.046	0.276**	-0.059	0.095
A%								1	-0.421**	0.109	-0.728**	0.306**
Y%									1	-0.174**	0.893**	.477**
ES%										1	-0.112	-0.173**
Y/A											1	0.230**
EM												1

EW: Total egg weight; EL: Egg lenght; EWd: egg width; AW: albumen weight; YW: Yolk weight; ESW: eggshell weight; ESI: egg shape index; A%: Albumen ratio; Y%: Yolk ratio; ES%: eggshell ratio; Y/A: yolk to albumen ratio; EM: Edible matter. (* Significance at P<0.05; ** Significance at P<0.01).

With respect to polyunsaturated fatty acids (PUFAs), the NN genotype exhibited the highest linoleic acid content, at 17.30%, exceeding that of other local breeds and exotic strains, which points to its potential role in producing more nutritionally beneficial eggs. Interestingly, the NF chickens exhibited a slightly higher α-linolenic acid level (1.18%) compared to NN and Cr genotypes. This trait suggests that NF hens may be more advantageous for producing eggs with higher omega-3 fatty acid content. Our results are in agreement with those of Rizzi and Chiericato (2010) who found differences in egg yolk *n-3* fatty acids from four hen breeds. Regarding the PUFA content, the NN chickens exhibited the highest levels at 21.41%, followed by the Cr group at 20.38%, while the CS had the lowest PUFA content at 13.67%. These findings reinforce the notion that local genotypes generally produce eggs with higher concentrations of essential fatty acids, with the NN genotype particularly distinguished in this respect. In the present study, eggs of the CS had a lower arachidonic acid (C20:4 n-6) content than those from the indigenous hens, which is in agreement with the findings of Bean and Leeson (2003). The *n-6* to *n-3* ratio was most favorable in NF chickens (9.41) reflecting a healthier profile compared to the significantly higher ratio in exotic strains (20.15) which indicates a potential imbalance. These results highlight the nutritional benefits of indigenous layers, particularly the NN and NF genotypes, which demonstrate more favorable fatty acid profiles compared to exotic commercial strains. The major genes are expected to contribute positively to these traits, highlighting their significance for both genetic diversity and nutritional quality in egg production.

Table 5. Major fatty acid composition of eggs according to genotype.

Fatty acid (%)	Naked neck	Crested	Normal feathered	Exotic strain
Palmitic	23.10^{a}	21.00^{c}	20.17^{b}	23.50^{a}
Stearic	8.02^{b}	10.67^{a}	8.34^{c}	10.87^{a}
Palmitoleic	2.92^{a}	1.51^{c}	1.59^{bc}	1.88^{b}
Oleic	36.75^{b}	38.25^{a}	36.89^{b}	39.27^{a}
Linoleic	17.30^{a}	16.62^{b}	14.1^{c}	16.47^{b}
α-Linolenique	1.10^{a}	0.28^{b}	1.18^{a}	0.12^{c}
Arachidonique	2.60^{a}	2.40^{ab}	2.65^{a}	2.27^{b}
Docosahexaenoic	0.51^{c}	1.08^{a}	0.60^{c}	0.81^{b}
Total lipids	25.40^{ab}	25.50 ^{ab}	26.43^{a}	23.71^{c}
Total SFA	31.18^{b}	31.67^{b}	28.51^{c}	34.37^{a}
Total MUFA	39.67^{b}	39.76^{b}	38.48^{c}	41.15^{a}
Total n-6	19.90^{a}	19.02^{a}	16.75^{c}	18.74^{b}
Total n-3	1.61^{a}	1.36^{b}	1.78^{a}	0.93^{c}
Total PUFA	21.41^{a}	20.38^{b}	18.56^{c}	13.67^{d}
n-6: n-3	12.36^{c}	13.98^{b}	9.41^{d}	20.15^{a}

$^{a-c}$Within a row values with no common superscripts indicate significantly different (P<0.05); SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids.

CONCLUSION

Overall, the findings reveal that local chicken breeds. particularly the Naked Neck and Normal Feathered genotypes, produce eggs with enhanced fatty acid profiles, highlighting their value for both genetic diversity and nutritional quality. The significance of major genes. such as those found in the Naked Neck breed, is particularly pronounced in hot climates, where these genetic traits may confer adaptive advantages. Furthermore, these breeds demonstrate considerable potential for application in both industrial and alternative production systems, proving adaptable to a range of environments, including both temperate and tropical climates.

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Author's Declaration

Conflicts of Interest: None.

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