Productive traits in hybrid hens with Fayoumi maternal genotype

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ABSTRACT: The productive performance during the first laying cycle of two experimental F_1 populations of laying hens with Fayoumi maternal genotype and either Rhode Island Red or White Leghorn paternal genotype was evaluated. The Egyptian Fayoumi breed characterized by a low body weight was used to explore its usefulness as a parent stock to diminish maintenance costs of the progeny by reducing its mean body weight. Productive traits at sexual maturity, body weight and egg weight dynamics, form and shape of the egg, feed efficiency for egg production and major egg components were studied. No clear advantage of either of the two hybrids with Fayoumi genotype was evinced. The expectations of enhancing feed efficiency were not accomplished. Although F_1 hens were lighter than both paternal lines, their voluntary feed consumption equaled that of the heaviest birds. This fact could be explained in terms of a behavioural response to environmental temperature as these birds, with a natural resistance to hot climates, showed a higher daily intake relative to their body weight when reared during the winter season in a temperate zone.

Key words: Body weight, crossbreeding, egg traits, Fayoumi, feed efficiency, laying hens

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Desempeño productivo en gallinas híbridas con genotipo materno Fayoumi

RESUMEN: Se evaluó el desempeño productivo de dos híbridos simples de gallinas ponedoras con genotipo materno Fayoumi y genotipo paterno Rhode Island Red o White Leghorn, durante su primer ciclo de postura. La raza Fayoumi de origen egipcio, caracterizada por su bajo peso corporal de naturaleza poligénica, se utilizó con el fin de estudiar la posibilidad de su incorporación como raza parental en la producción de híbridos locales de menor peso corporal promedio y, por ende, menor costo de mantenimiento y menor consumo de alimento. Estas poblaciones experimentales se caracterizaron en término de los caracteres productivos a la madurez sexual, el patrón de aumento de peso corporal y de aumento de peso del huevo, el largo, el ancho y la forma de los huevos, el consumo voluntario de alimento, la eficiencia de conversión en huevos y los componentes mayores del huevo. Ninguno de los dos híbridos mostró una clara ventaja en términos productivos. Si bien las aves F_1 fueron más livianas que los dos genotipos paternos, su consumo voluntario no se diferenció del expresado por las aves más pesadas. Este hecho podría atribuirse a una respuesta en su comportamiento frente a la temperatura ambiente, ya que estas aves, con una resistencia natural a las altas temperaturas, muestran un mayor consumo de alimento relativo a su peso corporal cuando se mantienen durante el invierno en una región templada.

Palabras clave: Caracteres del huevo, cruzamientos, eficiencia de conversión, Fayoumi, gallinas ponedoras, peso corporal

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Introduction

The Argentine government has developed a national program of social assistance that includes, among other strategies, the distribution of laying hens to low resource families. This policy is intended to enhance their nutritional status by producing eggs for self-consumption. These hens are produced in a public institution (EEA INTA Pergamino) by crossing local strains of Rhode Island Red (R) as sire line, and Rhode Island White or Barred Plymouth Rock as dam lines, thus generating two autosexing hybrids. The distribution of one-day-old female chicks to these families is followed-up by technical and educational assistance to ensure the success of this policy.

To test other genetic alternatives that might reduce the feeding costs of the program, a new set of experimental crosses including Fayoumi (F) hens was proposed. The Egyptian Fayoumi breed is characterized by a low body weight; genetic resistance to hot climates, Marek disease (Nordskog and Philips, 1960) and Coccidiosis (Hamet and Mérat, 1982); and eggs of high shell strength and high proportion of yolk content (Amer, 1972). Thus, it was deemed a good option to explore the use of F as a parent stock with the aim of diminishing maintenance costs by reducing mean body weight of the progeny. In a first step, F hens were crossed either with R or White Leghorn (L) as sire lines to produce a pair of two-way hybrids. In a second step, these F_1 hybrids will be used as dam lines to produce three-way hybrids by crossing them with the third breed that is not represented in the maternal genotype. The objective of the present paper was to evaluate the productive performance during the first laying cycle of two F_1 populations of layers in which F was used as the maternal genotype.

Material and Methods

Birds. Data were collected on females of R, L and F random bred experimental lines, sampled from the respective populations maintained at the Facultad de Ciencias Veterinarias, Universidad Nacional de Rosario, Argentina. Two F_1 crosses, with maternal F genotype and either R (R x F) or L (L x F) as sire genotypes, were produced via artificial insemination. Chicks from the five genetic groups were obtained from only one hatch in Spring (October) and were reared intermingled on the floor. Birds were fed a standard starter ration (21% crude protein; CP) from hatch to 56 days of age, standard developing ration (18 -19% CP) from 57 to 140 days of age, and a standard laying ration (16% CP) beginning at 141 days of age. At 18 weeks of age, 18 birds randomly sampled from each genetic group were moved to the laying house and individually caged. The lighting program used was one with an evenly decreasing day length from 24 hours the first week to 13 hours at 18 weeks of age. Day length was then increased by 30 minutes per week up to the limit of 17 hours per day.

Productive traits at sexual maturity. Sexual maturity, defined as age at first egg, body weight at first egg, weight of the first egg, weight of the first 10 eggs, and number of days required for laying the first 10 eggs were determined for all birds. The last trait was used as an indicator of the regularity of initial egg production.

Body weight and egg weight. Individual body weight was registered weekly to the nearest 50 g from 18 to 36 weeks of age. All the eggs laid in the same period were identified and weighed the evening of the same day to the nearest 0.l g. Body weight and egg weight of each individual were expressed as a function of time using the model (W = A = B rt) proposed by Weatherup ad Foster (1980), where A = asymptotic body weight or egg weight; B = range in body weight or egg weight from t = 0 to the asymptote; and r = the rate at which the respective asymptotic weight is approached (r = 1). The same model was used for fitting both dependent variables because, on the one hand it is a reparameterization of Brody's growth function (Brody, 1945); on the other hand, it adequately describes how egg weight increases with age in layers (Shalev and Pasternak, 1993). A nonlinear estimation procedure (GraphPad Prism Software, Version 2.0) based on Marquardt's algorithm (Marquardt, 1963) was used to fit the experimental weight-age data. Goodness of fit was evaluated by the coefficient of multiple determination (R2), and also judged by the significance of the tests performed to verify the random distribution of the residuals. For statistical analysis, A and r values were treated as metric traits.

Egg shape, major components and feed efficiency of production. Egg shape values were estimated by the ratio between egg width and length (Lerner, 1964), both measured to the nearest 0.1 mm using a steel caliper. Measures were taken on ten eggs of each genetic group randomly chosen at 43 weeks of age.

Ten eggs of the hens of each genetic group were chosen at random at 43 weeks of age. Individual eggs were weighed, then broken and whites and yolks carefully separated manually. Most of the albumen was discarded upon initial separation from the yolk; further separation of the adhering albumen was made by carefully rolling the yolk several times on a paper towel. The egg shells (including membranes) and yolks were weighed separately with an accuracy to the nearest 0.1 g. Albumen weight was taken as egg weight minus the sum of fresh yolk weight plus fresh shell weight. Using the individual weight of each egg and its components, percent yolk, percent albumen, and yolk:albumen ratio were calculated.

Feed efficiency for egg production was calculated as the ratio between egg mass and food consumption, both registered from 40 to 44 weeks of age.

Statistical analysis. Data were analysed by a one-way analysis of variance using the following linear model: $Yij = \mu + \alpha i + eij$. Where: yij is the j^{th} observation in the i^{th} genetic group, μ is the population mean, αi is the fixed effect of the i^{th} genotype ($i = 1,...5$) and eij is the random effect term. Differences between group means were evaluated by Duncan's multiple range test (Sokal and Rohlf, 1969).

Results and Discussion

Productive traits at sexual maturity. Table 1 shows the mean values for age at first egg (AFE) and several associated traits. L hens laid their first egg later than the other genotypes which is a particular feature of this experimental line previously described (Dottavio *et al.*, 1995). No differences was seen between F and R hens in AFE. Relative to L and R, both F_1 hybrids reduced age at sexual maturity and laid leggs of low weight; also (R x F) exhibited an irregular initial production, with values for days to lay first ten eggs (DTE) of 29.9 ± 4.15. This behaviour of (R x F) hens might be explained as losses of potential eggs due to internal laying. These losses may result from a disparity between the age when hens attain the ability to ovulate and the age when they are able to complete egg formation (Koops and Grossman, 1992), perhaps as a consequence of the extremely different adult weights of the parental lines used in this cross. Considering the fate of these layers, negative heterosis for AFE appears to be an important productive feature, despite the low egg weight at the beginning of the cycle. This response, in a reproductive character closely connected with fitness, could be explained in terms of a reversal effect, of hybrid vigour in the crosses, to inbreeding depression in the closed parental populations.

Bodyweight and egg weight dynamics. Although not shown, there was good agreement between the observed body weights or egg weights as a function of time and the theoretical points of the curves fitted for each hen. Convergence was reached in all cases with R2 values ranging from 0.799 to 0.997 for body weight data and from 0.849 to 0.995 for egg weight data. Deviations from the model proposed were not significant. Growth curve parameters for body weight and egg weight are shown in Tables 2 and 3, respectively. R hens were heavier while F and (L x F) birds were

Table 1. Productive traits (mean ± standard error) at sexual maturity.

Trait[1]	Genotype[2]				
	Leghorn	(L x F)	Fayoumi	(R x F)	Rhode I. Red
AFE (days)	187.1 ± 2.3^{a}	153.1 ± 2.3^{b}	165.4 ± 1.7^{c}	151.5 ± 1.9^{b}	167.6 ± 2.7^{c}
WFE (g)	$1\,596.0 \pm 33.6^{a}$	$1\,281.0 \pm 32.1^{b}$	$1\,019.0 \pm 20.1^{c}$	$1\,433.0 \pm 27.6^{d}$	$2\,145.0 \pm 35.8^{e}$
FEW (g)	42.5 ± 0.88^{a}	36.7 ± 1.42^{b}	29.9 ± 0.58^{c}	36.3 ± 0.57^{b}	44.5 ± 1.62^{a}
TEW (g)	45.5 ± 0.54^{a}	41.3 ± 0.94^{b}	31.9 ± 0.65^{c}	41.1 ± 0.96^{b}	49.6 ± 0.88^{d}
DTE (days)	17.8 ± 1.33^{ac}	18.9 ± 2.03^{ac}	21.1 ± 1.71^{a}	29.9 ± 4.15^{b}	15.1 ± 0.66^{c}

[1] AFE (age at first egg) - WFE (body weight at first egg) - FEW (first egg weight) - TEW (first ten eggs weight) - DTE (number of days for laying the first ten eggs).

[2] Eighteen birds per genotype.

[a, b, c, d, e] Values with different superscript differ ($P < 0.05$).

Table 2. Nonlinear estimates (mean ± standard error) of Weatherup and Foster equation parameters for individual bodyweight - age data.

Variable[1]	Genotype[2]				
	Leghorn	(LxF)	Fayoumi	(R x F)	Rhode I. Red
A	$1\,744 \pm 51^{a}$	$1\,537 \pm 34^{b}$	$1\,171 \pm 28^{c}$	$1\,607 \pm 33^{ab}$	$2\,761.6 \pm 54^{d}$
B	672 ± 42^{a}	398 ± 27^{b}	339 ± 28^{b}	295 ± 34^{b}	$1\,107 \pm 50^{c}$
r	0.854 ± 0.012^{a}	0.893 ± 0.011^{ac}	0.785 ± 0.013^{b}	0.798 ± 0.018^{b}	0.915 ± 0.008^{c}

[1] A = asymptotic body weight; B = range in body weight from time zero to the asymptote; r = rate at which the asymptotic weight is approached ($r < 1$).

[2] Eighteen birds per genotype.

Table 3. Nonlinear estimates (mean ± standard error) of Weatherup and Foster equation parameters for individual egg weight - age data.

Variable[1]	Genotype[2]				
	Leghorn	(L x F)	Fayoumi	(R x F)	Rhode I. Red
A	57.13 ± 0.97^{a}	56.22 ± 0.63^{a}	48.49 ± 0.54^{b}	55.94 ± 0.52^{a}	66.89 ± 0.51^{c}
B	15.33 ± 0.86^{a}	17.45 ± 0.72^{ab}	17.45 ± 0.43^{ab}	17.53 ± 0.59^{b}	21.54 ± 0.83^{c}
r	0.890 ± 0.004^{ab}	0.895 ± 0.007^{ab}	0.898 ± 0.004^{a}	0.891 ± 0.005^{ab}	0.874 ± 0.006^{b}

[1] A = asymptotic egg weight; B = range in egg weight from time zero to the asymptote; r = rate at which the asymptotic weight is approached ($r < 1$).

[2] Eighteen birds per genotype.

[a, b, c, d] Values with different superscript differ ($P < 0.05$).

lighter than the same genotypes used by Mérat *et al.* (1983) and Benabdeljelil and Mérat (1994). (L x F) hybrids tended to behave like the paternal line. Although (R x F) hybrids were always heavier than F hens and lighter than R hens, a noticeable skewness towards maternal (F) line weights was evident (Figure 1). Despite their lower body weight during the laying cycle, (L x F) hens laid eggs as heavy as those of L (dominant deviation), while an additive behaviour was observed in (R x F). Both hybrids reached the same asymptotic body size and did not differ in mean egg weight during this period (Figure 2). In the parental populations asymptotic body weight (A) and maturing rate for body weight (r) showed the widely recognized negative relationship (> A, meaning > mature weight; and > r, meaning < maturing rate). This patter was disrupted in hybrids, as they did not differ in mean A values but showed a statistically significant difference in maturing rate, suggesting an independent genetic determination for those parameters which largely determine the shape of the growth curve.

Form and shape of the egg. Data representing egg length, width, and shape are presented in Table 4. F hens produced eggs that tended to be less elongated than those of L. Although F eggs were thinner and shorter than R eggs, both genotypes laid eggs with a similar shape. This is partly in agreement with the findings of Amer (1972) who stated that F eggs are more spherical than L and R eggs. F_1 hybrids did not differ in egg dimensions. Their eggs were similar in width to L eggs, intermediate in length to both parental genotypes, and with a rounded final shape not different from F eggs.

Feed efficiency for egg production. Table 5 shows mean values for feed efficiency and other related traits. Mean daily voluntary intake was similar in L and F hens. A positive heterotic effect on intake was evident in both hybrids, which constituted a detrimental response in terms of efficiency of feed conversion. However (L x F) hens were not statistically less efficient than L hens because of their advantage in egg mass production. The present figures for feed efficiency of the (L x F) cross fall within the values reported by Benabdeljelil and Mérat (1995), while the (R x F) hybrids were less efficient than those tested by Mérat *et al.* (1983) as a consequence of their higher feed intake.

Major egg components. The whole egg is a summation of its different components so a study of those components

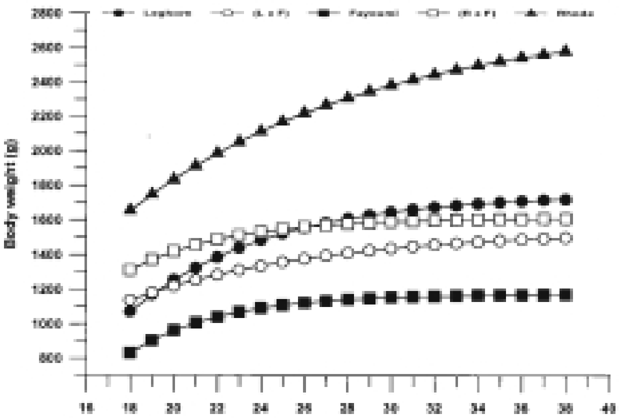

Figure 1. Mean body weight-age curves of five genotypes of layers.

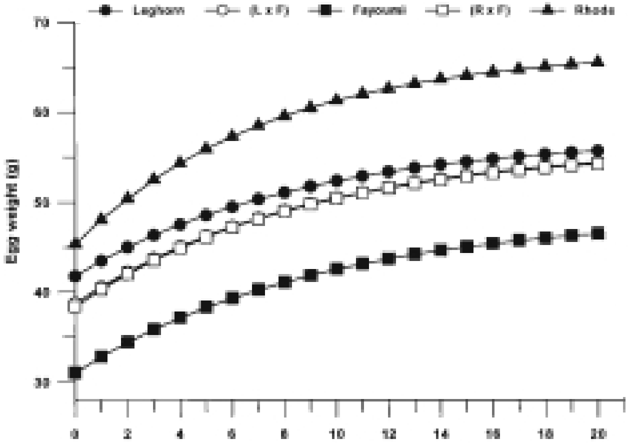

Figure 2. Mean egg weight-age curves of five genotypes of layers during their first laying cycle.

Table 4. Egg shape and egg dimensions (mean ± standard error) at 43 weeks of age.

Egg trait[1]	Genotype[2]				
	Leghorn	(L x F)	Fayoumi	(R x F)	Rhode I. Red
Width (mm)	40.9 ± 0.31^{a}	41.6 ± 0.31^{a}	39.6 ± 0.16^{b}	41.6 ± 0.17^{a}	44.9 ± 0.14^{c}
Length (mm)	57.9 ± 0.57^{ad}	56.2 ± 0.41^{b}	52.6 ± 0.441^{c}	56.3 ± 0.27^{ab}	58.4 ± 0.25^{d}
Shape2	70.7 ± 1.01^{a}	73.9 ± 0.88^{b}	74.3 ± 0.66^{bc}	74.0 ± 0.38^{b}	76.9 ± 0.38^{c}

[1] Ten eggs per genotype.

[2] Ratio between width and length x 100.

[a, b, c, d] Values with different superscript differ ($P < 0.05$).

Table 5. Feed efficiency for egg production and associated traits (mean ± standard error) in the first laying cycle.

Trait	Genotype[1]				
	Leghorn	(L x F)	Fayoumi	(R x F)	Rhode I. Red
Body weight (g)	1 707 ± 55^{a}	1 524 ± 35^{b}	1 140 ± 27^{c}	1 521 ± 26^{b}	2 562 ± 58^{d}
Daily intake (g)	107 ± 5^{a}	141 ± 8^{b}	111 ± 5^{a}	155 ± 12^{b}	152 ± 4^{b}
Egg mass (g/day)	37.3 ± 3.5^{a}	40.1 ± 2.5^{a}	22.8 ± 2.6^{b}	38.6 ± 1.8^{a}	50.2 ± 1.3^{c}
Feed efficiency[2]	0.350 ± 0.033^{a}	0.287 ± 0.018^{ab}	0.207 ± 0.024^{b}	0.268 ± 0.021^{b}	0.329 ± 0.008^{a}

[1] Eighteen birds per genotype.

[2] Egg mass/daily intake.

$^{a,\ b,\ c,\ d}$Values with different superscript differ ($P < 0.05$).

Table 6. Proportions of egg major components (mean ± standard error) at 45 weeks of age.

Egg Component	Genotype[1]				
	Leghorn	(L x F)	Fayoumi	(R x F)	Rhode I. Red
Shell (%)	11.3 ± 0.16^{a}	11.5 ± 0.16^{a}	11.1 ± 0.21^{a}	12.3 ± 0.24^{b}	10.4 ± 0.13^{c}
Yolk (Y) %	28.9 ± 0.42^{a}	29.1 ± 0.50^{a}	31.8 ± 0.31^{a}	28.8 ± 0.41^{a}	28.1 ± 0.37^{a}
Albumen (A) (%)	58.7 ± 0.49^{ac}	59.4 ± 0.41^{a}	57.1 ± 0.57^{ab}	59.5 ± 0.49^{a}	61.6 ± 0.45^{c}
Y:A ratio	0.486 ± 0.011^{ac}	0.491 ± 0.012^{a}	0.558 ± 0.011^{b}	0.485 ± 0.009^{ac}	0.456 ± 0.009^{c}

[1] Ten eggs per genotype.

$^{a,\ b,\ c,\ d}$Values with different superscript differ ($P < 0.05$).

should throw some light on the causes of variations among eggs of various genotypes. Proportional egg components by genotype at 45 weeks of age, are presented in Table 6. As expected, F birds showed the highest yolk and the lowest albumen percentages. As F hens are smaller in size than hens from the other two parental genotypes, they have smaller and narrower oviducts, which would secrete less albumen than L and R hens (Amer, 1972). Because of the much greater energetic cost of depositing lipid (yolk) than albumen, there should be a negative association between feed efficiency and the proportion of yolk in the egg (Pym, 1990). This was evident for F hens which showed the highest yolk:albumen ratio and the lowest feed efficiency (Table 5). Sturkie (1965) proposed that egg shape is partly determined by the amount of albumen secreted by the magnum, a statement not corroborated by these data, which demonstrated that genotypes with significant differences in albumen content may differ (F vs. L) or not (F vs. R) in egg shape. F_1 hybrids showed Y:A ratios lower than F, and similar to their paternal lines.

In general terms, the results herein described show that hybrids with L genotype tend to behave more as the paternal line, while the performance of F_1 hens with R genotype is skewed towards the maternal values. As a consequence, both hybrid combinations showed very similar figures for body weight and bodyweight-related productive traits, despite the clear differences in body weight between the two paternal genotypes. No clear advantage of either hybrid with F genotype was evinced. The expectation of enhancing feed efficiency by lowering bodyweight and thereby reducing maintenance requirements was not realized. Although F_1 birds were lighter than L and particularly than R hens, their voluntary feed consumption equaled that of the heaviest birds and was reflected in low feed efficiency. The latter could be at least partially explained in terms of a behavioural response to environmental temperature, as these birds with a natural resistance to hot climates showed a higher daily intake relative to their bodyweights when reared during the winter season in a temperate zone.

In the next step of this research project, the productive performance of a three-way cross using (R x F) females and L males will be evaluated with the same objectives as for the F_1 hybrids. Theoretically the three-way cross has an advantage over other alternative crosses using these same genotypes. First, the hybrid combination with R paternal genotypes to be used as the dam line can be color sexed at hatching, due to the sex-linked segregation of the silver and gold alleles, the males being black barred silver and the females black barred gold; and second, as L cocks are homozygous for the dominant white mutation, the phenotype of the three way cross will be uniformly white.

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