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Laying Performance of Pearl Gray Guinea Fowl Hens as Affected by Caging Density

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ABSTRACT The caging density required for optimal egg production by various avian species and varieties is highly variable. Even so, little is known of the required cage density for optimum performance of the laying guinea fowl (*Numida meleagris*). The objective of this study was to assess the effect of varying cage densities on production performance of pearl gray guinea fowl laying hens. In 3 replicates, 270 pearl gray guinea hens [28 wk of age (WOA)] were weighed individually and randomly assigned to laying cages at densities of 1, 2, and 3 birds/cage, equivalent to 1,394, 697, and 465 cm^2/bird, respectively. During the experiment, all birds received a 16-h lighting regimen and were fed the same diet, comprising 2,800 kcal of ME/kg of diet and 16% CP (28 to 59 WOA) and 2,800 kcal of ME/kg of diet and 14% CP (60 to 76 WOA). Feed and water were provided for ad libitum consumption. Experimental birds were observed for feed consumption (FC), hen-day egg production (HDEP), egg weight, egg mass (EM), feed conversion ratio, internal egg quality, and shell thickness at the end of each 28-d lay period for 11 consecutive periods. Mean FC and HDEP decreased significantly with increases in cage density, such that 1,394 > 697 > 465 cm^2/bird. Mean EM was also higher ($P < 0.05$) for birds reared in cages at 1,394 cm^2/bird than those reared in cages at 697 and 465 cm^2/bird (24.8, 17.4, and 14 g/hen per d, respectively). Feed conversion, HDEP, and EM were negatively correlated with cage density ($P < 0.05$). Mean feed conversion ratio and percentage of mortality were also lower in birds reared in cages at 1,394 cm^2/bird than in other treatment groups. Therefore, laying guinea fowl hens exhibited superior performance when raised at a density of 1 bird/cage (1,394 cm^2/bird) than those reared at densities of 2 and 3 birds/cage (697 and 465 cm^2/bird, respectively).

Key words: guinea fowl hen, cage density, egg production, egg quality

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INTRODUCTION

The guinea fowl is gradually finding its share of the US market because of the increasing demand for specialty poultry products, such as table eggs, and the changing demographics of the US population (Nahashon et al., 2004). Although efforts are under way to promote guinea eggs as a specialty and an alternative to chicken table eggs in the United States, there is a ready market for guinea fowl and guinea fowl products in Africa and European countries such as France, Belgium, and Italy. Indeed, guinea fowl production has already been proven to be profitable in several countries, including Canada, France, and Italy (Embury, 1998). There is, therefore, great potential for guinea fowl production as a profitable enterprise, especially for table eggs in the United States and other parts of the world. Lacking, however, are management practices, such as optimum cage density that would increase productivity, improve the well-being, and minimize production costs of the guinea fowl.

Within the poultry egg industry, high-density cage-layer systems are attractive to commercial egg producers because of the potential for reducing housing, equipment, and labor costs. There has been considerable effort in evaluating the effect of cage density on hen performance (Anderson et al., 1989; Hester et al., 1996). Okpokho et al. (1987) reported that higher densities appear to decrease performance characteristics such as livability, egg mass, and BW of laying birds. It has also been suggested that some birds have a greater ability to adapt to high-density environments than others (Anderson et al., 2004). However, Craig (1992) suggested that at least some of the differences in behavior observed among different strains of birds under the same environmental conditions must be a result of their genetic makeup.

Al-Rawi and Craig (1975) reported that exposing chickens to high-density and multiple-bird cages might not have detrimental physiological effects on an individual bird's welfare. However, behavioral patterns may change significantly after hens are placed in cages, suggesting a process of adaptation to changes in management practices and physical and social environments (Anderson et al.,

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1989). This adaptation process ultimately lowers the number of negative social interactions among hens, which may reduce stress and enhance welfare. Using 2 commercial strains, Hy-Line W-36 and DeKalb XL, Anderson et al. (2004) observed no significant interactions between strain, density, and age of birds. However, cage density affected the percentage of hen-day egg production (**HDEP**), which was greater for hens provided a density of 482 cm^2/bird than for hens provided a density of 361 cm^2/bird. Cage density has also been reported to influence egg weight (**EW**) and feed consumption (**FC**; Adams and Craig, 1985; Cheng et al., 1991; Lee and Moss, 1995).

Cunningham and Ostrander (1982) evaluated the effect of strain and cage shape and density on performance and fearfulness of White Leghorn (**WL**) layers. They reported that increasing bird density from 4 to 5 birds/cage (484 and 387 cm^2/bird, respectively) resulted in reduced egg production, increased mortality, reduced BW gains, and reduced feed usage and conversion. Other studies (Ouart and Adams, 1982b) also indicated that feed consumption of Single Comb WL hens was significantly affected by bird density, such that hens housed 2 birds/cage (45.7 cm of feeder space) ate 10.5 g more per hen per d than those housed 3 birds/cage (25.4 cm of feeder space). Moreover, the maximum number of birds feeding simultaneously was significantly affected by feeder space, bird density, and level of feeding. In other studies, Carey (1987) reported reduced feed intake and 18-wk BW at greater bird densities from 311 to 222 cm^2/bird when feeder and drinker space were reduced with greater bird numbers. However, Anderson and Adams (1992) observed no effect of pullet density on 18-wk BW when WL pullets were subjected to cage densities of 221, 249, 277, and 304 cm^2/bird.

Although considerable work has focused on the effect of cage density on performance of pullets and laying chickens, little research has addressed the effect of varying cage densities on performance of laying guinea fowl. Therefore, the objective of this study was to assess the effect of varying cage densities on the performance of the pearl gray guinea fowl layers. Cage density was adjusted by varying the number of pullets per cage, which also modified cage, feeder, and drinker spaces.

MATERIALS AND METHODS

Birds and Management

One-day-old pearl gray guinea keets were obtained from a commercial source (Ideal Poultry Breeding Farms Inc., Cameron, TX). Birds were weighed individually and randomly assigned to electrically heated, thermostatically controlled Petersime battery brooders (Petersime Incubator Co., Gettysburg, OH) equipped with raised wire floors from hatch to 4 wk of age (**WOA**). The battery cages measured 99 × 66 × 26 cm and each housed about 20 birds. The brooder temperature was maintained at 32.2°C for the first week and was reduced gradually by 2.8°C every week until 23.9°C; from this point on, no artificial heating was provided to the birds. At 5 WOA, the keets were transferred into growing batteries, which were not supplied with supplemental heating. However, room temperature was maintained at 21.1°C. The growing batteries measured 163 × 69 × 33 cm and housed 15 birds from 5 to 8 WOA. Ventilation within the growing cages was maintained by thermostatically controlled exhaust fans. Timer fans were used to maintain air quality in the poultry houses throughout the study period. Birds were then transferred to floor pens in which they were raised from 9 to 28 WOA. Three floor pens measuring 452 × 274 × 213 cm were partitioned into 5 smaller pens (255 × 274 × 213 cm). Each of the 5 pens housed about 50 birds, providing approximately 1,397 cm^2/bird of cage space. This is almost equivalent to 1,394 cm^2/bird, the maximum cage space provided to the experimental birds in laying cages at 28 to 76 WOA. This also provided uniform floor space and feeder space to the birds before cage assignments at 28 WOA. At 28 WOA, 270 pearl gray guinea hens were individually weighed and randomly assigned to laying cages (30.5 × 45.7 × 45.7 cm) at densities of 1, 2, and 3 birds/cage, equivalent to cage-space allowances of 1,394, 697, and 465 cm^2/bird, respectively. The feeder space for the 3 cage-space allowances was 30.50, 15.25, and 10.17 cm/bird, respectively. Cage density was adjusted by varying the number of pullets per cage, and each treatment (cage density) was replicated 3 times (Table 1). All birds received 23, 8, and 16 h of constant lighting from hatch to 10, 11 to 22, and 23 to 76 WOA, respectively. Birds were fed the diets presented in Table 2. These diets comprising 3,000 kcal of ME/kg of diet and 24% CP (0 to 4 WOA), 3,100 kcal of ME/kg of diet and 21% CP (5 to 8 WOA), 3,000 kcal of ME/kg of diet and 18% CP (9 to 22 WOA), 2,900 kcal of ME/kg of diet and 17% CP (23 to 27 WOA), 2,800 kcal of ME/kg of diet and 16% CP (28 to 59 WOA), and 2,800 kcal of ME/kg of diet and 14% CP (60 to 76 WOA). The diets were fed in mash form, and both feed and water were provided for ad libitum consumption. Feed was supplied in troughs placed in front of each cage, and water was delivered in plastic-cup waterers, each fitted with a nipple. Feeder space per bird was 16, 8, and 5.3 cm for cage densities of 1, 2, and 3 birds/cage. Experimental birds were observed for FC, HDEP, EW, egg mass (**EM**), feed conversion ratio (**FCR**), internal egg quality (**IEQ**), shell thickness (**ST**), and BW at the end of each 28-d lay period for 11 consecutive periods. Fifteen birds from each treatment were identified, and the same birds were weighed at the end of each 28-d period. Eggs were collected for 5 consecutive days to the end of each 28-d period and were used in determining EW, IEQ, and ST. The eggs were weighed individually and broken on a glass break-out stand with a reflective mirror to detect blood spots on the underside of the egg. Albumen heights were measured using a micrometer (B.C. Ames Co., Waltham, MA), the incidence of blood spots was recorded, and Haugh units were calculated using the formula described by Roush (1981). Eggshell thickness was determined using a caliper (B.C. Ames Co.). Two measurements from the midpoint of the opposite

Table 1. Treatments used in evaluating optimum cage density for pearl gray guinea fowl layers

Treatment	Housing method	Cage size (cm)	No. of birds/cage	Cage floor area/bird (cm^2)	Feed space (cm)	No. of birds/reps[1]	No. of reps[1]	No. of birds/ treatment
1	Raised wire floor cages	30.5 × 45.7	1	1,394	30.50	15	3	45
2	Raised wire floor cages	30.5 × 45.7	2	697	15.25	30	3	90
3	Raised wire floor cages	30.5 × 45.7	3	465	10.17	45	3	135

[1]Reps = replications.

ends of the longitudinal sections of the egg, and 1 measurement each from the large and small ends of the egg were obtained. Mortality was recorded as it occurred.

Statistical Analysis

Percentage data (HDEP) were transformed into arc sine coefficients before analysis. Data were subjected to ANOVA using the GLM procedure of SAS (SAS Institute, 2002), with cage density as a treatment effect. All variables were analyzed as repeated measurements, with the exception of mortality. Correlation analyses between treatment effects and performance variables were also computed using the GLM procedures. The statistical model used for egg production, FC, FCR, EW, egg mass, IEQ, ST, BW gains, and mortality was

$$Y_{ijk} = \mu + M_i + R_{ij} + \gamma_{ijk},$$

where Y_{ijk} = response variables from each individual replication, μ = the overall mean; M_i = the effect of cage density; R_{ij} = the interexperimental unit (replications) error term; and γ_{ijk} = the intraexperimental unit error term. Least significant difference comparisons were made among treatment means for main effects when there was a significant *F*-value.

Differences in mortality among dietary treatments were analyzed using the χ^2 method. Significance is implied ($P < 0.05$) unless stated otherwise.

RESULTS AND DISCUSSION

The mean FC, HDEP, EW, EM, FCR, IEQ, ST, BW, and percentage of mortality of pearl gray guinea fowl layers reared in varying caging densities are presented in Figures 1 through 9, respectively. Interactions between cage density and time (28-d study periods) were not significant. Throughout the experiment, mean FC decreased proportionately with increases in cage density, such that birds at a cage density of 1,394 cm^2/bird consumed about 8 to 18 and 33 to 36% more feed ($P < 0.05$) than those in cage densities of 697 and 465 cm^2/bird, respectively

Table 2. Composition of experimental diets

	Age, wk					
Ingredients and analyses (%)	0 to 4	5 to 8	9 to 22	23 to 27	28 to 59	60 to 76
Corn, yellow no. 2 (8% CP)	45.00	49.42	67.82	64.55	63.24	69.58
Soybean meal (48% CP)	42.70	37.30	22.60	24.50	22.50	17.30
Alfalfa meal (17% CP)	1.00	1.00	1.00	1.00	1.00	1.00
Meat and bone meal (50% CP)	3.00	3.00	3.00	0.00	0.00	0.00
Poultry-blended fat	5.80	6.70	3.10	2.30	2.10	1.00
Dicalcium phosphate (18% P, 22% Ca)	0.90	1.00	1.10	2.00	2.20	2.20
Limestone flour (38.8% Ca)	0.90	0.90	0.75	5.00	8.30	8.30
Salt	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin-mineral premix[1]	0.25	0.25	0.25	0.25	0.25	0.25
DL-Met[2] (98%)	0.15	0.13	0.08	0.10	0.11	0.07
Calculated levels (%)						
ME, kcal/kg of diet	3,000	3,100	3,100	2,900	2,800	2,800
CP	24	21	18	17	16	14
Ca	1.0	1.00	0.95	2.50	3.75	3.75
Total P	0.72	0.72	0.70	0.71	0.73	0.73
Available P	0.48	0.48	0.47	0.48	0.52	0.51
Met	0.53	0.48	0.39	0.37	0.35	0.30
Met + Cys	0.92	0.85	0.68	0.66	0.62	0.54
Lys	1.46	1.31	0.92	0.89	0.83	0.69
Crude fat	7.68	8.60	5.92	4.79	4.54	3.74
Analyzed levels (%)						
CP	23.93	20.87	17.91	16.85	15.89	13.95
Crude fat	7.22	8.41	5.63	4.51	4.26	3.49

[1]The following was provided per kilogram of diet: retinyl acetate, 3,500 IU; cholecalciferol, 1,000 ICU; DL-α-tocopheryl acetate, 4.5 IU; menadione sodium bisulfite complex, 2.8 mg; vitamin B_{12}, 5.0 mg; riboflavin, 2.5 mg; pantothenic acid, 4.0 mg; niacin, 15.0 mg; choline, 172 mg; folic acid, 230 mg; ethoxyquin, 56.7 mg; manganese, 65 mg; I, 1 mg; Fe, 54.8 mg; Cu, 6 mg; Zn, 55 mg; and Se, 0.3 mg.

[2]Degussa Corp., Kennesaw, GA.

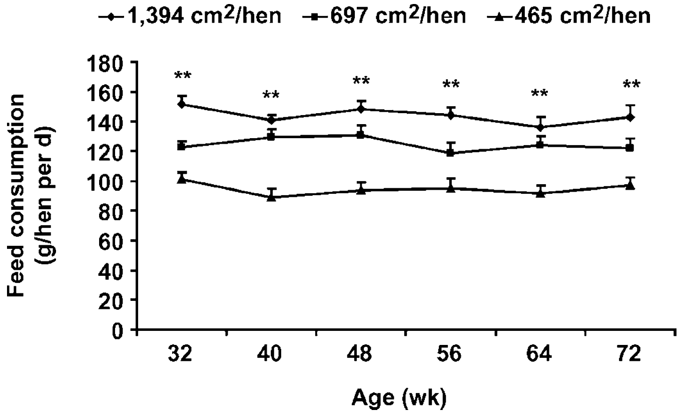

Figure 1. Mean feed consumption of pearl gray guinea fowl hens reared in varying cage densities and feeder spaces during the laying period. At a time point, each bar represents the mean ± SE of 45, 90, and 135 pearl gray guinea fowl hens reared in cage densities of 1,394, 697, and 465 cm^2/bird, respectively. Birds in these cage densities had feeder spaces of 30.5, 15.25, and 10.17 cm/bird, respectively. Double asterisks (**) indicate differences ($P < 0.05$) among the 3 cage-density treatment groups.

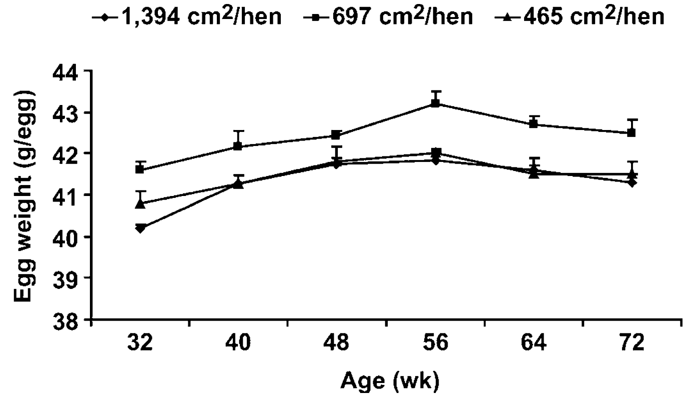

Figure 3. Mean egg weight of pearl gray guinea fowl hens reared in varying cage densities and feeder spaces during the laying period. At a time point, each bar represents the mean ± SE of 45, 90, and 135 pearl gray guinea fowl hens reared in cage densities of 1,394, 697, and 465 cm^2/bird, respectively. Birds in these cage densities had feeder spaces of 30.5, 15.25, and 10.17 cm/bird, respectively. Differences among cage-density treatment groups were not significant ($P > 0.05$).

(Figure 1). Birds reared in 697 cm^2/bird cages also consumed 25% more feed ($P < 0.05$) than those in 465 cm^2/bird cages. Limited feeder space may have contributed to lower FC in birds raised in higher cage densities. Feeder space of 30.50, 15.25, and 10.17 cm/bird was provided for the cage densities of 1, 2, and 3 birds/cage, respectively. According to Ouart and Adams (1982b), Single Comb WL hens with 45.7 cm of feeder space per cage, housed at 3 birds per cage, and receiving 90% full feed had more simultaneous feeding than hens with 25.4 cm of feeder space, housed at 2 birds per cage, and on full feed. Cunningham and Ostrander (1982) and Ouart and Adams (1982a) reported that commercial-strain WL layers raised in cages with limited feeder space consumed less feed than those with more feeder space available. In similar studies, Hester and Wilson (1986) cited evidence that reducing the amount of feeder space available per hen, which resulted in increased competition for feed and water in hens housed 2 or 3 per cage, may have caused a reduction in feed intake, resulting in lower productive efficiency. Anderson et al. (1989) also reported that feeding activity was significantly more frequent in 4-hen cages than in 6-hen cages, and they also suggested that this might have been the result of availability of feeder space to the different hen populations. Hens in the 4-bird cages could feed simultaneously, whereas those in the 6-hen cages had to compete for access to the feeder. This report was consistent with our findings.

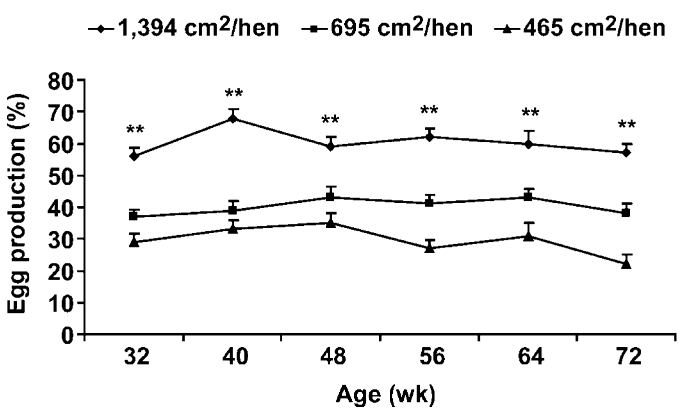

Figure 2. Percentage of hen-day egg production of pearl gray guinea fowl hens reared in varying cage densities and feeder spaces during the laying period. At a time point, each bar represents the mean ± SE of 45, 90, and 135 pearl gray guinea fowl hens reared in cage densities of 1,394, 697, and 465 cm^2/bird, respectively. Birds in these cage densities had feeder spaces of 30.5, 15.25, and 10.17 cm/bird, respectively. Double asterisks (**) indicate differences ($P < 0.05$) among cage-density treatment groups.

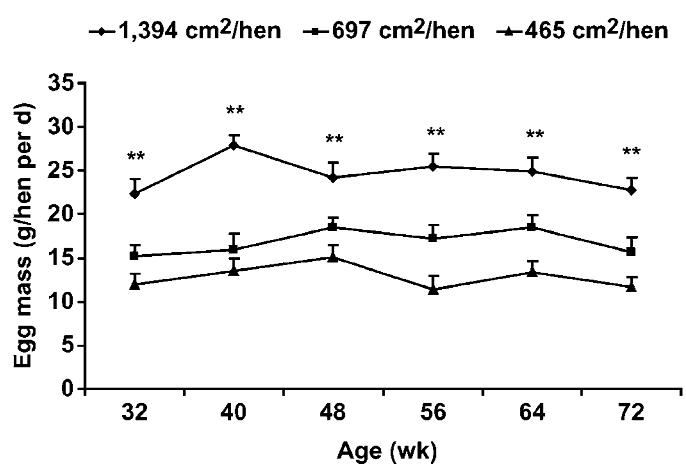

Figure 4. Mean egg mass of pearl gray guinea fowl hens reared in varying cage densities and feeder spaces during the laying period. At a time point, each bar represents the mean ± SE of 45, 90, and 135 pearl gray guinea fowl hens reared in cage densities of 1,394, 697, and 465 cm^2/bird, respectively. Birds in these cage densities had feeder spaces of 30.5, 15.25, and 10.17 cm/bird, respectively. Double asterisks (**) indicate differences ($P < 0.05$) between birds in a cage density of 1,394 cm^2/bird and those in cage densities of 697 and 465 cm^2/bird, which were not different ($P > 0.05$).

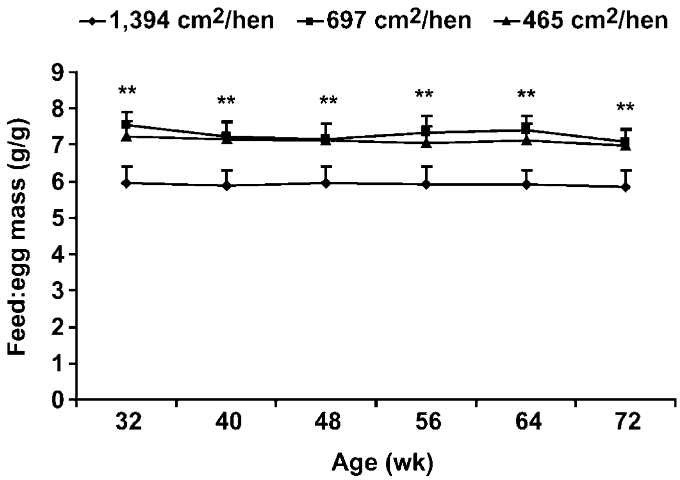

Figure 5. Feed conversion ratio of pearl gray guinea fowl hens reared in varying cage densities and feeder spaces during the laying period. At a time point, each bar represents the mean ± SE of 45, 90, and 135 pearl gray guinea fowl hens reared in cage densities of 1,394, 697, and 465 cm^2/bird, respectively. Birds in these cage densities had feeder spaces of 30.5, 15.25, and 10.17 cm/bird, respectively. Double asterisks (**) indicate differences ($P < 0.05$) between birds in a cage density of 1,394 cm^2/bird and those in cage densities of 697 and 465 cm^2/bird, which were not different ($P > 0.05$).

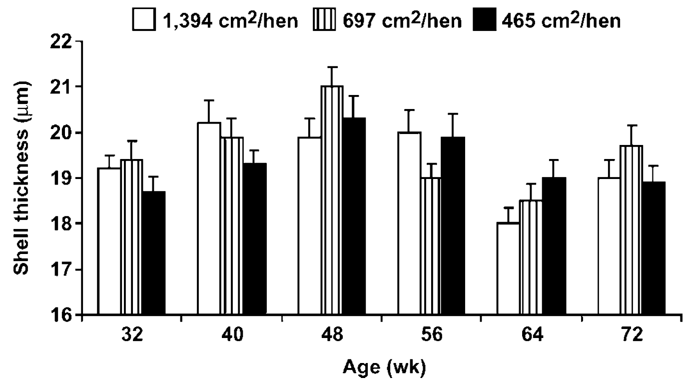

Figure 7. Shell thickness of pearl gray guinea fowl hens reared in varying cage densities and feeder spaces during the laying period. At a time point, each bar represents the mean ± SE of 45, 90, and 135 pearl gray guinea fowl hens reared in cage densities of 1,394, 697, and 465 cm^2/bird, respectively. Birds in these cage densities had feeder spaces of 30.5, 15.25, and 10.17 cm/bird, respectively. Differences among cage-density treatment groups were not significant ($P > 0.05$).

The percentage of HDEP was improved significantly and proportionately with decreases in cage density (Figure 2). The mean HDEP of pearl gray guinea fowl hens provided with 1,394 cm^2/bird of cage space was 33 to 42 and 40 to 61% higher than that of birds reared in 697 and 465 cm^2/bird cages, respectively. Birds reared in cages providing 697 cm^2/bird also exhibited significantly higher ($P < 0.05$) HDEP than those reared in 465 cm^2/bird cages. The reduced feeder space available per hen in each individual cage, coupled with increased competition for feed and water in birds reared in 697 and 465 cm^2/bird cages, may have caused the reduction in feed intake, which led to a decline in HDEP. These observations are further supported by the negative correlations between cage density and both FC and HDEP (Table 3). Previous studies (Hester and Wilson, 1986) evaluating the performance of WL hens in response to cage density have also shown that birds housed at a density of 1,031 cm^2/bird produced significantly more eggs on a hen-day basis than hens reared at 516 or 344 cm^2/bird. Birds reared at 344 cm^2/bird also produced significantly fewer hen-day eggs than those at 516 cm^2 of floor space per bird. Feldkamp and Adams (1973) observed a similar trend in commercial strains of WL-type pullets. They reported that birds housed at high density laid at lower rates (3.9% hen-day, 3.7% hen-housed basis) than those housed at low density. Earlier, Grover et al. (1972) and Carey and Kuo (1995) also suggested that greater bird density depressed egg production. Adams and Craig (1985) reviewed research on the effect of cage density on layer performance and concluded that HDEP declined as bird density increased. More recently, Anderson et al. (2004) reported that cage

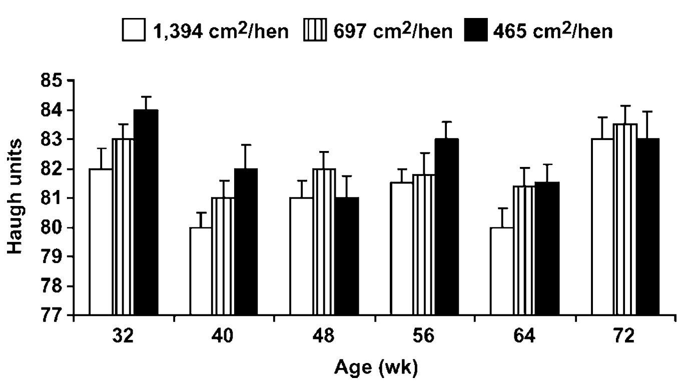

Figure 6. Internal egg quality of pearl gray guinea fowl hens reared in varying cage densities and feeder spaces during the laying period. At a time point, each bar represents the mean ± SE of 45, 90, and 135 pearl gray guinea fowl hens reared in cage densities of 1,394, 697, and 465 cm^2/bird, respectively. Birds in these cage densities had feeder spaces of 30.5, 15.25, and 10.17 cm/bird, respectively. Differences among cage-density treatment groups were not significant ($P > 0.05$).

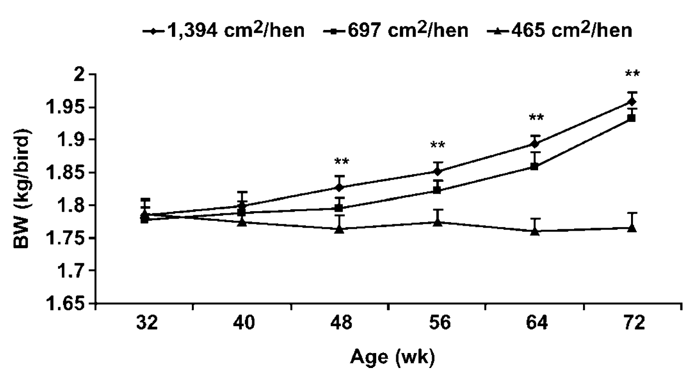

Figure 8. Body weight of pearl gray guinea fowl hens reared in varying cage densities and feeder spaces during the laying period. At a time point, each bar represents the mean ± SE of 45, 90, and 135 pearl gray guinea fowl hens reared in cage densities of 1,394, 697, and 465 cm^2/bird, respectively. Birds in these cage densities had feeder spaces of 30.5, 15.25, and 10.17 cm/bird, respectively. Double asterisks (**) indicate differences ($P < 0.05$) among birds in cage densities of 1,394, 697, and 465 cm^2/bird and their respective feeder spaces.

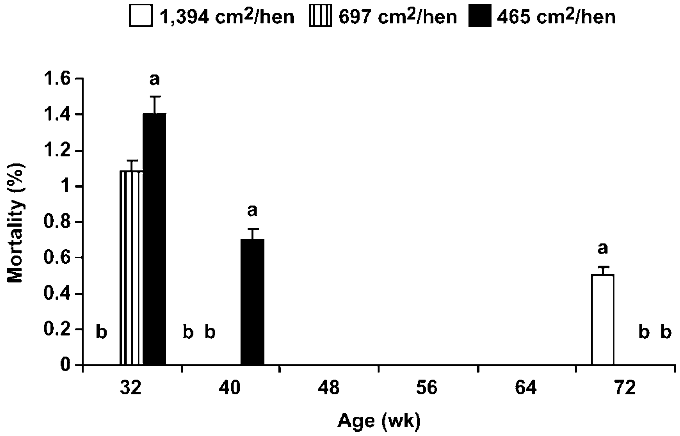

Figure 9. Mortality of pearl gray guinea fowl hens reared in varying cage densities and feeder spaces during the laying period. At a time point, each bar represents the mean ± SE of 45, 90, and 135 pearl gray guinea fowl hens reared in cage densities of 1,394, 697, and 465 cm^2/bird, respectively. Birds in these cage densities had feeder spaces of 30.5, 15.25, and 10.17 cm/bird, respectively. Letters (a,b) indicate differences ($P < 0.05$) among cage-density treatment groups.

density affected the HDEP of Hy-Line W-36 and DeKalb XL commercial egg strains. They reported greater a percentage of HDEP for hens caged at 482 cm^2/bird (82.3%) than for hens caged at 361 cm^2/bird (77.4%).

Mean differences in EW (Figure 3), IEQ (Figure 6), and ST (Figure 7) among pearl gray guinea hens reared in 1,394, 697, and 465 cm^2/bird of cage space were not significant. In other studies that were in agreement with these observations, Grover et al. (1972) and Cunningham (1982) reported that the effect of cage density on EW was not detected in heavy-type chickens. Later studies (Brake and Peebles, 1992) also showed no effects of caging density on the EW of caged WL layers. However, throughout the study period, EM (Figure 4) was significantly higher ($P < 0.05$) in birds reared in cages providing 1,394 cm^2/bird than those reared on 697 and 465 cm^2/bird cages (22 to 27 g/hen per d vs. 15 to 18 and 12 to 15 g/bird per d, respectively). Consistent with these observations, Anderson et al. (2004) also reported that hens housed at lower densities (482 cm^2/bird) produced higher daily EM than those at higher densities (361 cm^2/bird). The lower EM in birds reared in higher density cages may be due to depressed HDEP and FC. The present study, as well as the reports of Craig et al. (1986), indicates that high-density cages also create a stressful environment that is not conducive for optimum performance of laying birds.

Mean FCR were about 17 to 21% lower in guinea fowl hens reared in cages allowing 1,394 cm^2/bird when compared with those raised in 697 and 465 cm^2/bird cages (Figure 5). The lower FCR of birds in 1,394 cm^2/bird cages may be the result of adequate daily FC (Figure 1) coupled with higher HDEP when compared with birds in other cage densities (Figure 2). Differences in FCR of birds reared in 697 and 465 cm^2/bird cages were not significant. In previous studies, bird density effects on FC and FCR were not detected in heavy-type chickens when bird density was increased to 2 and 3 birds per cage (Grover et al., 1972).

The higher BW of birds reared in 1,394 and 697 cm^2/bird cages than those reared in 465 cm^2/bird cages (Figure 8) may be the result of adequate feeder space; hence, higher feed and energy consumption. In other studies using the Single Comb WL layer, Ouart and Adams (1982b) reported that increasing feeder space in shallow cages from 30.5 to 50.8 cm significantly increased BW gain. Similar observations were made by Cunningham and Ostrander (1982) that increasing bird density reduced the BW of caged WL layers.

At 32 WOA, the percentage of mortality of guinea hens with a cage-space allowance of 1,394 cm^2/bird was significantly lower ($P > 0.05$) than that of birds reared in cages providing 697 and 465 cm^2/bird (Figure 9). However, the percentages of mortality of birds reared in cage densities of 465 and 697 cm^2/bird were not different ($P > 0.05$) at 32 WOA. Earlier studies by Feldkamp and Adams (1973) also revealed no significant differences in mortality between WL hens reared at densities of 330 and 590 cm of cage floor area per bird. Significantly higher ($P < 0.05$) mortality was also experienced among birds in cage densities of 465 and 1,394 cm^2/bird at 40 and 72 WOA, respectively, when compared with other cage densities. Overall, mortality was highest in birds in 465 cm^2/bird cages and least in birds reared in 1,394 cm^2/bird cages. This observation was consistent with earlier reports of Grover et al.

Table 3. Correlation coefficients among performance variables of pearl gray guinea fowl reared in varying cage densities during the laying period

	Feed consumption	Feed conversion ratio	Egg production	Egg weight	Egg mass	Internal egg quality[1]	Shell thickness	BW gain
Cage density	–0.52**	0.22*	–0.46**	0.02	0.44**	0.05	0.04	0.07
Feed consumption	—	0.17*	0.28*	0.07	0.11	0.09	0.05	0.08
Feed conversion ratio	—	—	–0.36*	0.10	–0.18*	0.06	0.04	0.07
Egg production	—	—	—	–0.19*	0.98**	0.21*	–0.35*	0.05
Egg weight	—	—	—	—	0.37*	–0.02	0.11	0.08
Egg mass	—	—	—	—	—	0.13	-0.31*	–0.03
Internal egg quality[1]	—	—	—	—	—	—	0.09	–0.04
Shell thickness	—	—	—	—	—	—	—	0.07

[1]Haugh units.

*$P < 0.05$; **$P < 0.01$.

(1972) and Cunningham and Ostrander (1982) that greater bird density increased mortality of heavy-type chickens and WL layers in wire cages, respectively. In this study, mortality of guinea fowl layers raised in laying cages allowing 465 cm^2/bird was in part due to cannibalism. It is likely that limited feeder space was associated with decreased FC and poor performance; however, there was no evidence to link limited feeder space with mortality. Most birds that died during the experiment seemed to have been gaining weight and were not the poorest production performers. Other possible causes of mortality were not determined. There were no blood spots observed in the eggs evaluated from each cage-density treatment in the present study.

Correlation coefficients among egg production variables of pearl gray guinea fowl are presented in Table 3. Correlations between cage density and FC, HDEP, and EM were negative ($P < 0.01$). As indicated in Figure 1, increasing cage density was associated with a significant decrease in FC, possibly due to limited feeder space. This may have resulted in nutritional deficiencies in higher cage densities that translated into lower HDEP and EM (Figures 2 and 4, respectively). Other negative correlations were observed between FCR and HDEP and EM ($P < 0.05$) and also between ST and both HDEP and EM ($P < 0.05$). The variation in FCR and EM was most dependent on the number of eggs produced; hence, the higher correlations among these variables. Although correlations between EW and ST were positive but not significant, this observation was in agreement with Zhang et al. (2005), who reported positive and significant correlations between EW and eggshell weight. Positive and significant correlations were noted between FC and both FCR and HDEP and also between cage density and FCR. On the other hand, negative correlations were observed between HDEP and EW, whereas EM and IEQ were positively correlated with HDEP. Shell thickness was also negatively correlated with HDEP and EM. Similar findings that strain-cross layers exhibited negative correlations between HDEP and both EW and egg specific gravity were earlier reported by Emsley et al. (1977).

Based on this study, increasing cage density from 1,394 cm^2/bird (1 bird/cage) to 697 cm^2/bird (2 birds/cage) significantly decreased FC, HDEP, EM, and BW of pearl gray guinea fowl laying hens. Mean FCR and the percentage of mortality were higher in birds reared at a cage density of 697 cm^2/bird than those reared at a cage density of 1,394 cm^2/bird. Increasing cage density of the pearl gray guinea fowl layers from 697 cm^2/bird (2 birds/cage) to 465 cm^2/bird (3 birds/cage) further depressed FC, HDEP, and BW and significantly increased mortality of the pearl gray guinea fowl laying hens. The decrease in production performance of guinea fowl hens reared at cage densities of 697 and 465 cm^2/bird reflects differences in FC, possibly because of inadequate feeder space. Therefore, cage space of 1,394 cm^2/bird seems to better sustain the production performance of the pearl gray guinea fowl laying hen compared with 697 and 465 cm^2 of space per laying hen.

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