A comparative examination of rearing parameters and layer production performance for brown egg-type pullets grown for either free-range or cage production

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Primary Audience: Free-Range Producers, Commercial Egg Producers

SUMMARY

Within the last 10 yr, the US egg industry has grown significantly in the use of alternative systems of cage-free and free-range egg production to satisfy consumer demands. Despite the increasing popularity among consumers of alternative management methods, very few studies have been conducted in the United States with the objective of comparing rearing parameters and production performance in alternative systems with those of conventional caged housing. Present knowledge regarding pullet growth records and how alternative production methods influence egg productivity and egg quality is severely limited or is based on research conducted in the late 1940s and early 1950s. Thus, it is imperative that pullet-rearing parameters of current strains, as well as their egg production performance, be assessed in alternative management systems, such as a free-range environment, and that they be compared with those of birds in a traditional caged environment. On the basis of the egg production performance measured in this study, caged hens had better overall egg production and quality characteristics compared with free-range hens, including improved FCR, daily egg masses, production of hen-housed and hen-day eggs, and production of grade A eggs; greater Haugh unit ratings; and decreased mortality rates.

Key words: cage, chicken, free-range, growth, production

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DESCRIPTION OF PROBLEM

Alternative production systems, such as cage-free or free-range egg production, have been growing in numbers to satisfy recent changes in consumer demands [1]. Concerns about the impact of using the cage environment on layer hen well-being have been a driving force in this expansion. In response to consumer concerns regarding caged layer welfare, both the commercial egg production sector and small-scale egg producers use commercial hybrids and standard breeds of chickens, respectively, in flocks ranging in size from 20,000 to 100 hens and produce eggs in both cage-free and free-range settings. One of the predominant issues with this transition in production management methods is that the current knowledge base of how alternative production methods influence egg performance and quality characteristics is limited to publica-

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tions written in the late 1940s and early 1950s [2–4]. This information was collected with specific breeds and not with modern lines of poultry that have been selected for very high rates of egg production.

In the early 1900s, when smaller, highly diversified farms were commonplace in the United States, free-range poultry production of eggs and meat was a standard component of most farms. The poultry operations, which were typically run by the farm wife, provided many household amenities for the farm family and accounted for 2.78% of the livestock income [5, 6].

By the 1930s, more intensive free-range production was prevalent and there was movement within the poultry industry toward more intensive production practices. Farmers were constantly looking for methods to produce eggs by more economical means to better supply the market demands. As the understanding of disease control improved and vaccines were developed, the range productivity increased and further intensification of egg production was possible. The egg production sector continued to confine hens, which culminated in highly intensive cage operations by the early 1950s [2]. Cages protected the hens from the environment, predation, external and internal parasites, and disease. However, possibly because of the increasing generational distance of the public from animal agricultural production, consumers have voiced concerns related to the use of the cage environment for egg production [7].

In 2008, California passed legislation (Division 20, Chapter 13.8 of the California Health and Safety Code) that implemented strict regulations for the confinement of layer hens and other production animals. In response to the passing of this legislation, the California commercial egg industry is heavily expanding the production of eggs in alternative production systems. It is likely that other states may also pass similar legislation, which would further expand the production of eggs in alternative production systems.

Alternative production studies on current layer strains in controlled settings relevant to US egg producers are severely limited. Therefore, an examination of alternative husbandry practices in the context of the current knowledge base would provide beneficial information on pullet rearing and hen production performance. This research takes into account the current knowledge base to determine how husbandry practices translate to modern strains of laying hens under free-range and cage rearing systems with respect to pullet-rearing parameters and egg production performance during a single egg production cycle.

MATERIALS AND METHODS

Pullet Rearing

Examination of pullet-rearing parameters and egg production performance in this study was conducted in accordance with the 37th North Carolina Layer Performance and Management Test [8]. Animal husbandry in this study was performed according to the 1999 agricultural guide standards of the Federation of Animal Science Societies [9] and approved in accordance with North Carolina State University Institutional Animal Care and Use Committee regulations. Fertile eggs for the Hy-Line Brown Layers used in this study were received at the Piedmont Research Station (Salisbury, NC). The eggs were set and hatched concurrently, at which time the chicks were sexed to remove the males by color sexing and were vaccinated for Marek's disease, and the chicks for the range portion were pinioned. Pinioning involved the surgical removal of the metacarpals of a bird, the point on the wing where the primary flight feathers originate. The procedure was accomplished using a hot blade and a bar apparatus mounted in a Lyons trimmer [10]. One wing (i.e., left or right) was extended and a cut was made through the joint at the intracarpal ligament between the radius and ulna and the first phalanx of the third and fourth digit. Simultaneously, the hot blade cauterized all cuts, which stopped any bleeding, enabling the birds to recover much faster. The pain and distress associated with this procedure at 1 d of age is similar to that of beak trimming, which was done on all birds at 6 to 10 d. Beak trimming began at 6 d of age using a Lyons Precision beak trimmer with a 7/64-in. guide hole [10]. The trim was a block cut with an approximate blade temperature of 1,100°F (dull red). Beak trimming was completed in less than 3 d. Pullets were not retrimmed at any point in the rearing period.

The chicks were equally divided between 2 pullet-rearing facilities. The cage brooding and rearing system consisted of 6 replicates. Each replicate was composed of 4 cages filled with 13 brown-egg-laying pullets [13 per 24 × 26 in. (61 × 66 cm) cage] on the day of hatch, totaling 52 chicks per quad-deck cage system in an environmentally controlled house. All chicks were brooded in the same cage during the entire 16-wk rearing phase, with a floor space allowance of 48 in.^{2} (309.7 cm^2), 1.8 in. (4.6 cm) of feeder space/bird, and a nipple drinker-to-bird ratio of 1:6.5. Paper was placed on the cage floor for the first 7 d within each of the replicate cages and was removed at the time of beak trimming. This represented 312 birds started in cages.

The second group of chicks was reared in accordance with free-range standards as practiced by specialty egg producers. They were brooded in an environmentally controlled floor brooder-grower facility consisting of a single room divided into individual 32 × 72 in. (81.3 × 182.9 cm) pens with 34 in. (86.4 cm) of linear feeder space, 6 nipple drinkers, and linear roosting space of 32 in. (81.3 cm). Each of the 17 pens (replicate) was filled with 15 brown-egg-laying pullets on the day of hatch, for a rearing allowance of approximately 929 cm^2/pullet, 2.3 in. (5.7 cm) of feeder space, a nipple drinker-to-bird ratio of 1:2.5, and bird roosting space of 0.8 in. (2.1 cm). This represented a total of 255 pullets that were moved to the range units.

The pullets for the range facilities were moved to the range house and paddock at 12 wk of age. Pullets had access to feed, nipple waterers, and roosts to gain familiarity with their environment and to facilitate nest box usage. All other rearing procedures and vaccinations were the same as for their cage-reared flock mates. The general description of the range forage would be a typical hay mixture for North Carolina consisting of both warm- and cool-season forages. These paddocks were an established bermudagrass and fescue grass mix and clover. Based on a sample soil analysis of the paddock, the soil in the range paddock had a high cation exchange capacity, occupied by calcium at 996.8 ppm.

The free-range pullets were placed in a range hut with slatted floors that provided 143.9 in.^{2}/pullet (929 cm^2/pullet), 5.1 in. (13 cm) of roosting space/pullet, and 1 nest/8 hens. Dimensions of the nest boxes were as follows: an opening of 9.5 × 7 in. (24.1 × 17.8 cm), a width of 10 in. (25.4 cm), a height of 14.5 in. (36.8 cm), and a depth of 12 in. (30.5 cm). The range hut was naturally lit during daylight hours, and supplemental light was provided via a powered battery and solar cell to achieve a 16L:8D lighting program that was identical to that of the caged hens. A supplemental propane heater for winter conditions was provided to maintain an interior temperature above 7.2°C (45°F), which is the lower level of the thermal neutral zone of chickens, where body temperature will be maintained via an increase in feed intake. The supplemental propane heater was programmed to turn on when the interior temperature of the range hut reached 50°F. The pullets had access to the outdoors at all times via continuously opened popholes, but they appeared to return to the range hut during the dark for roosting and protection. Husbandry, lighting, and supplemental feed were allocated on the same basis as flock mates in cages to minimize the variables between flock mates. Range density was based on a 500 hen/acre (500 hen/0.405 ha) static equivalency of 8.04 m^2/hen (12,462.0 in.^{2}/hen). The range pens were 21.3 × 21.3 m (70 × 70 ft) and were enclosed by a 1.8-m (6-ft) fence, with the lower chain link section being 1.2 m (4 ft). Pullets were fed ad libitum by hand daily with starter feed containing amprolium, a coccidiostat [11], during the initial brooding period to achieve the breeder recommended BW at each weigh interval. This was followed by grower and developer diets [8]. Pullets were moved onto the next rearing diet at the point of achieving target BW goals or after a prescribed time interval. The expected feed transition intervals were as follows: starter, 0 to 6 wk; grower, 6 to 12 wk; developer, 12 to 15 wk; and prelay diet, 15 to 16 wk. The prelay diet was provided no earlier than the last week in the rearing facility through the interim before reaching the threshold day length of 14 h. Feed consumption and BW were monitored every other week beginning at 2 wk of age. All mortality was recorded daily, but mortality attributed to the removal of males (sex slips, i.e., males that were inadvertently sexed as females at hatch) and accidental deaths from a replicate were excluded. Pullet vaccination schedules were identical between the rearing treatments.

Pullet vaccination schedules and the lighting schedule for the pullet controlled-environment facility and range rearing are outlined in the Single Production Cycle Report of the 37th North Carolina Layer Performance and Management Test [8].

Single-Cycle Egg Production Performance

Single-cycle production records commenced on October 3, 2007 (at 17 wk of age), when range populations were equilibrated to study levels and the cage pullets were moved to the lay facility. The lay facility is outlined in the Single Production Cycle Report of the 37th North Carolina Layer Performance and Management Test [8] and consisted of 4 caged replicate flocks of 72 hens housed in 12 cages, with each cage containing 6 hens at a density of 64 $in.^2$/hen (412.9 cm^2/hen). Production data were collected through the end of a single cycle of production at 8 wk of age on December 30, 2008 (574 d). Production data were summarized for 3 range replicate flocks of 75 hens and 4 caged replicate flocks of 72 hens. Production parameters for feed conversion rates (grams of egg produced per gram of feed consumed), feed consumption rates (kilograms/100 hens per day), daily egg masses (average daily production of egg mass in grams/hen per day), hen-housed (**HH**) eggs (total number of eggs produced divided by the number of birds housed at 119 d) [12], hen-day (**HD**) eggs (average daily number of eggs produced/100 hens per day) [12], total mortality rates (recorded daily; obvious accidental mortalities were not included), and egg quality (graded according to USDA standards for egg quality [13]) were recorded.

Statistical Analysis

All data were subjected to ANOVA using the GLM procedure [14], with the main effects of period and rearing environment. Separate analyses were conducted for mortality and flock uniformity. Mean differences were separated via the PDIFF option of the GLM procedure of SAS.

RESULTS AND DISCUSSION

Pullet Age

There were significant effects of pullet age on BW, BW gain, feed conversion, and daily feed consumption. These differences were due to the growth of the pullet and the increasing feed capacity of the pullet as it aged. The rate of BW gain reached a plateau at 8 wk of age and then declined through 16 wk of age. Feed efficiency was greatest at 4 to 6 wk of age, after which the G:F ratio declined through 16 wk of age. The results shown in Table 1 related to growth are consistent with previous work on pullet growth [8]. This pattern is consistent regardless of the rearing environment.

Pullet Rearing Environment

The pullets reared in cages were significantly heavier (by 93 g; $P < 0.0001$) than their free-range counterparts. This lighter BW of free-range pullets may be the result of an increase in activity levels associated with foraging behavior. This is supported by the lower BW gain of pullets maintained on the free range from 12 wk of age. Total supplemental feed consumption was reduced by 0.79 kg/bird when the pullets were reared on the free range, which represented a 13.3% reduction in supplemental feed consumption by the free-range birds (Table 1). This reduction in feed consumption was most likely due to the replacement of the feed with foraged materials, although intake of food materials from foraging could not be accurately measured. However, based on the forage analysis from the paddocks and presumed 13.3% forage consumption [12], the pullets reared on the free range would have consumed approximately 79 g of protein from the forage. If this was the case, then total protein consumption would have been comparable for the free-range and cage-reared groups. With the increased foraging, the use of feed for activity rather than growth would help explain the resulting reduction in BW. Pullets reared on the free range consumed less formulated feed and thus had lighter BW than their cage-reared counterparts.

The livability between the cage-reared and free-range birds did not differ significantly ($P > 0.05$; Table 2). No difference in flock uniformity of ±15% of the mean BW was observed between the free-range and cage-reared pullets when the BW distribution of 100 pullets was examined within the 2 groups. The rearing environment does have an impact on 16-wk BW, with the free-range pullets being lighter. With this lighter

Table 1. Effect of pullet age and rearing environment on pullet BW, BW gain, feed conversion, and total feed consumption during the 16-wk rearing phase

Source of variation	Pullet BW, g	BW gain, g	FE, g of BW/g of feed	Feed consumed/d, g of feed/bird per day	Total feed, kg/bird
Pullet age, wk					
2	114.7[g]	76.6[f]	0.38[b]	14.5[g]	
4	260.7[f]	145.9[e]	0.43[a]	24.5[f]	
6	466.8[e]	205.9[bc]	0.37[b]	39.8[e]	
8	676.0[d]	209.2[b]	0.30[c]	49.6[d]	
10	863.6[c]	187.7[c]	0.21[d]	65.5[b]	
12	1,028.8[b]	165.0[d]	0.16[e]	74.3[a]	
16	1,279.9[a]	253.7[a]	0.14[e]	62.7[c]	
Pooled SEM	12.0	6.6	0.01	0.8	
Rearing environment					
Cage	1,326†	184.8***	0.28	52.9*	5.92†
Range	1,233	170.6	0.29	45.8	5.13
Pooled SEM	7	3.3	<0.01	0.4	0.07
Interaction					
Pullet age × housing	NS	0.0001	NS	0.0001	NA[1]

[a–g]Means with unlike superscripts differ significantly.

[1]NA = not applicable.

*$P \leq 0.05$, ***$P \leq 0.001$, and †$P \leq 0.0001$.

BW, subsequent egg production and egg size distribution might be negatively affected.

Single-Cycle Egg Production Performance

Based on production data summarized during a single production cycle (17 to 82 wk) for Hy-Line Brown layer hens (Table 3) in 3 free-range replicate flocks of 75 hens and 4 caged replicate flocks of 72 hens, caged birds had significantly higher ($P < 0.05$) FCR and significantly higher ($P < 0.01$) daily egg masses compared with their free-range flock mates. Caged birds also produced significantly greater numbers of HH ($P < 0.001$) and HD ($P < 0.0001$) eggs compared with free-range hens. Additionally, total mortality was significantly higher ($P < 0.0001$) in free-range hens, primarily because of predation. In addition to predation, cannibalism contributed to increased mortality on the range; however, it was difficult to differentiate between incidences of predation and cannibalism. Caged hens produced a significantly greater ($P < 0.05$) number of grade A eggs (Table 4), whereas free-range hens produced a significantly greater ($P < 0.0001$) number of grade B eggs. The increased production of grade B eggs by the range hens was likely due to shell staining associated with fecal soiling of the shell. No overall difference was observed in the number of egg "checks" (as defined in the Egg Grading Manual [13]) or losses between the 2 groups (Table 4). Additionally, no significant differences in the distribution of egg weights or sizes (Table 5) were observed between the 2 groups. With respect to egg quality (Table 6), caged hens had significantly greater Haugh unit (**HU**; $P < 0.001$) ratings than did free-range hens, whereas free-range hens had a significantly greater eggshell strength (kg; $P < 0.001$) than did caged hens. No significant differences in vitelline membrane strength (g) were observed between the 2 groups.

The egg production performance measured in this study indicated that caged hens had better overall egg production and quality characteristics compared with free-range hens, based on increased FCR, daily egg masses, production

Table 2. Effect of rearing environment on livability and flock uniformity

Source of variation	Livability, %	Flock uniformity, ±15% of mean
Rearing environment		
Cage	99.5	97.8
Range	99.6	96.0
Pooled SEM	0.5	2.0

Table 3. Effect of housing method on single-cycle egg production performance parameters

Source of variation	Feed consumption, kg/100 hens per day	FE, g of egg produced/g of feed	Daily egg mass, g	Hen-housed eggs, no. of eggs	Hen-day grade eggs, % of egg production	Mortality rate, no. of hens
Housing						
Cage	10.3	0.51*	52.5**	357***	81.9†	8.9†
Range	10.1	0.49	49.4	304	77.7	28.4
Pooled SEM	0.20	0.0075	0.51	7.85	0.54	2.62

$^*P \leq 0.05$, $^{**}P \leq 0.01$, $^{***}P \leq 0.001$, and $^{\dagger}P \leq 0.0001$.

of HH and HD eggs, and production of grade A eggs; greater HU ratings; and decreased mortality rates. Improvements in the overall egg production performance of caged hens may be largely attributed to their consumption of a balanced, fortified diet and their ability to partition a greater percentage of the nutrients they consume to egg production because of the cage environment. Despite their consumption of a similar amount of supplemental feed (Table 3), free-range hens experienced a reduction in nutrient partitioning devoted to egg production because of the increased demands for nutrients necessary to support increased foraging and other associated behaviors specific to the range environment. The feed consumption of free-range hens and supplemental nutrients from the materials they foraged did not compensate for the added needs of the range system. The forages consumed from the range paddock were nutritionally consistent across the summer and winter seasons, containing on average 16.6% CP [14]. With this nutrient composition of the forages, the total energy intake would have been reduced and hens would not have been able to increase the volume of feed consumed to overcome a 7% reduction in dietary energy associated with supplemental forage [15].

With respect to the effect of BW on caged layer performance, it has been shown that the nutritional composition of the diet of a hen is a better indicator of future egg productivity than the BW of the hen [12]. The forage available to free-range hens in this study did not provide hens with the high-protein, low-fiber nutrient composition necessary to support the same level of production as caged hens receiving a balanced, fortified diet.

In addition to differences in diet and BW, free-range hens may experience higher degrees of stress than caged flock mates as a result of uncontrolled environmental factors that cause range hens to produce fewer eggs than caged hens. Additional factors that may have negatively affected egg production in free-range hens include the reappointment of nutrients to facilitate increased activity levels in the range, maintenance of body temperature in cold weather, and decline in feed intake in hot weather. Hens housed in caged environments may yield better egg production because of lower stress levels in their highly regulated environment.

Free-range hens did exhibit improved performance in one area of egg quality, shell strength. The increased shell strengths detected in free-range eggs may be attributed to increased levels of calcium consumed by these hens from the soil. On the basis of soil analysis of the range paddocks, calcium levels were 996.8 ppm in the paddock soils, and there would have been significant mineral recycling in the hens because of coprophagy.

Table 4. Effect of housing method on single-cycle egg production distribution of egg grades, checks, and losses

Source of variation	Grade A eggs, %	Grade B eggs, %	Checks, %	Losses, %
Housing				
Cage	90.0**	5.9	4.0	0.11
Range	85.9	11.5†	2.4	0.22
Pooled SEM	1.26	0.71	3.2	0.15

$^{**}P \leq 0.01$ and $^{\dagger}P \leq 0.0001$.

Table 5. Effect of housing method on single-cycle distribution of egg weights and sizes

Source of variation	Egg weight, g	Egg size, %			
		Extra large	Large	Medium	Small
Housing					
Cage	63.7	79.7	14.7	5.1	0.35
Range	63.5	77.1	16.7	6.0	0.23
Pooled SEM	0.45	2.30	1.84	0.59	0.23

Overall, caged hens produce at an optimal level compared with free-range flock mates, thereby implying that cage management systems have an economic advantage and possibly that caged hens have improved physiological welfare (lower stress). Studies analyzing the economic impact of implementing alternative management systems also support these findings [16]. According to California data, shifts from conventional cages to cage-free housing would likely result in farm-level cost increases of approximately 40% per dozen eggs, although data on other alternative management methods, such as free-range, furnished-cage, and pasture-based production systems, is limited [17, 18]. Further studies are needed to determine the economic costs of using a free-range management system. Ultimately, egg producers must determine which housing method(s) are most economically viable and beneficial to layer production performance and egg quality while promoting optimal welfare and low stress exposure.

CONCLUSIONS AND APPLICATIONS

1. Although pullet age significantly affected pullet BW, BW gain, FE, and daily feed consumption, these differences were not due to the rearing environment of the pullets.
2. Pullets reared in the free-range environment were significantly lighter in BW than their caged counterparts, potentially because of increased activity levels associated with foraging behavior in the free-range hens. The use of feed for activity rather than growth resulting from the increased foraging would help explain the resulting reduction in BW.
3. Caged hens had better overall egg production and quality characteristics compared with free-range hens, based on increased FCR, daily egg masses, production of HH and HD eggs, and production of grade A eggs; greater HU ratings; and decreased mortality rates.
4. Improvements in the overall egg production performance of caged hens may largely be due to their consumption of a balanced, fortified diet and their ability to partition a greater percentage of the nutrients they consume to egg production owing to the cage environment.
5. Free-range hens experienced a reduction in nutrient partitioning devoted to egg production because of the increased demands for nutrients necessary to support increased foraging and other associated behaviors specific to the range environment.

Table 6. Effect of housing method on single-cycle production egg quality parameters

Source of variation	Haugh units	Shell strength, kg/cm^2	Vitelline membrane strength, g/mm^2
Housing			
Cage	88.7***	4.1	2.16
Range	83.4	4.4***	2.26
Pooled SEM	0.5	0.1	0.05

***$P \leq 0.001$.

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