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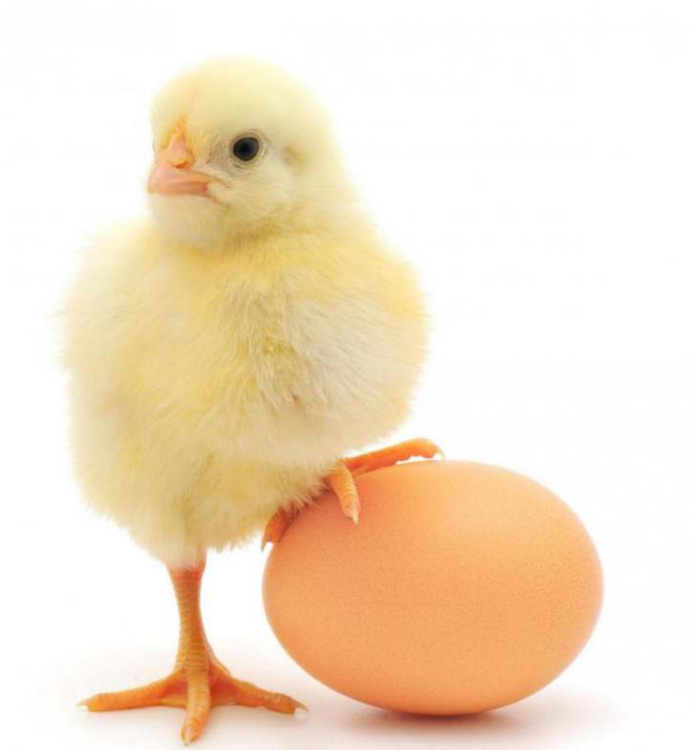

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Effect of Rearing Dietary Regimen, Feeder Space and Density on Egg Production, Quality and Size Distribution in Two Strains of Brown Egg Layers

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Abstract: Step-Up Protein (SUP) rearing regimens can reduce Feed Consumption (FC) and Body Weight (BW), while still resulting in pullets with equal or superior egg production and egg mass to pullets grown on a Step-Down Protein (SDP) program. Egg weight has been reduced due to SUP programs, presumably due to the reduced BW at sexual maturity. Because BW is reduced by SUP regimens and a slight lowering of FC, BW and EW may be economically advantageous. Therefore, the objective of this experiment was to evaluate the impact of SUP regimens on brown-egg layer rearing program on subsequent productivity and the effect of feeder space and density on performance. Two brown-egg strains, Hy-Line Brown (HB) and the H and N “Brown Nick” (BN) were grown on three different dietary regimens, i.e. a "normal" SDP regimen, a SUP regimen: low energy starter for 9 wk (SUP9) and a SUP regimen: low energy starter for 12 wk (SUP12). The SUP9 and SUP12 feeding regimens resulted in significantly lower BW and feed conversion and shorter sternum length, than the SDP regimen. Egg production was not significantly different among the 3 regimens, but feed conversion was lower while livability was highest in the SUP12 reared hens. Feeder space of 13.6 cm resulted in poorer feed conversion for the SUP12 reared hens. Density per hen of 482 cm^2 resulted in significantly improved egg production characteristics, such as 37 more eggs per hen and an 8.1% improvement in flock livability. Only density affected egg income and feed costs and in both egg income and feed costs were higher in hens kept at 482 cm^2 were \$2.39 and \$0.21, respectively. Rearing pullets did not result in a reduced economic return in the laying period, where providing hens a lower density environment increased the per hen income.

Key words: Brown egg strains, dietary regimens, step-up protein, step-down protein

INTRODUCTION

The use of step-down protein feeding regimens in the growing period for production pullets is a common practice for the egg industry. With these regimens the pullet growers are trying to get optimal growth for the lowest possible feed cost (Leeson, 1986; Anderson *et al*., 1995; Anderson, 2010). Researchers have shown that reducing dietary protein during the growing period from 18-12% at 16 wk of age had reduced body weight with no effect on subsequent egg production (Blaylock, 1956; Berg and Bearse, 1958; Lillie and Denton, 1966; Connor and Burton, 1971; Kim and McGinnis, 1976; Christmas *et al*., 1982). In a study comparing 6 different Step-Down Programs (SDP) for dietary protein, Douglas *et al*. (1985) determined that 18 to 20 wk body weights were significantly reduced at a level of 15% dietary protein or less. However, body weight differences vanished by 28 wk of age and none of the dietary growing regimes affected egg production, egg weight, or feed conversion.

Leeson and Summers (1978) questioned the practice of using step-down protein levels during the growing period for egg-type pullets. Their experiment provided one group of pullets a conventional SDP regime while another was allowed free choice feed of a high energy ration and a protein concentrate in separate feeders in the same pen. The split-diet group consumed increasing levels of protein exactly opposite of what was being provided in SDP pullet feeding programs. The split-diet group had lower body weight, but higher subsequent egg production than conventionally fed pullets. The step-up system was an advantageous means of restricting pullets intake, thereby lowering feed costs, while at the same time producing a better developed bird at sexual maturity.

Subsequently, Leeson and Summers (1979) compared SDP with Step-Up Protein (SUP) regimes with the following percent Crude Protein (CP) and Metabolizable Energy (ME) levels per kcal/kg, i.e. Step-down (0-8 wk - 18% CP, 3049 ME; 9-12 wk - 15% CP, 2992 ME; 13-20 wk - 13% CP, 2952 ME) versus step-up (0-12 wk - 12% CP, 3080 ME; 13-16 wk - 16% CP, 2974 ME; 17-20 wk - 19% CP, 2972 ME). Birds grown on the SUP regime were lighter, consumed less total protein and did not meet their calculated energy requirements in comparison to the birds on the SDP regime. Egg production was comparable, but egg weight reduced in the SUP regimen group. In a second study, Leeson and

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Summers (1984a,b,c) confirmed that SUP regime resulted in lower pullet weight, but did not affect feed consumption or other performance parameters that were observed for the SUP regime groups.

Bish *et al.* (1984) studied several modified step-up protein feeding regimes which included starting all of the step-up groups of birds on an 18% CP pre-starter diet. A step-down protein group was also maintained and was provided the 18% starter diet. The different step-up groups were then placed on a 12% CP diet at 1, 2, or 3 wk of age to start their step-up program. All step-up programs produced pullets with reduced body weight in comparison to those on the step-down program, but the reductions were not as large as those reported by Leeson and Summers (1979). Rate of egg production and egg weight for the step-up groups was only slightly reduced and feed consumption was similar to that for the step-down protein feeding group.

All of the above research on SUP feeding programs was conducted using White Leghorn layers. Whereas, the body weights that were lowered by using lower protein regimes (Leeson, 1986), may be advantageous for rearing brown-egg pullets. In their case it appears to be advantageous to reduce body weight at sexual maturity as described by brown-egg pullet growers for the egg industry who have begun using management to restrict the body weight of pullets during the rearing period (Peters, 1993). As a result the lighter body weights may allow for greater productivity of the hens. The lower body weights can be maintained throughout the subsequent laying period by feed restriction but not without conflicting results. However, if the pullets are lighter this appears to be sustained throughout the production period without having to manage their dietary regimen and the management of the hens would be simpler with fewer production problems. Studies by Robinson *et al.* (1986) and Cheng *et al.* (1991) found that reverse protein regimens produced lighter body weight hens with no significant differences in egg production or weight with comparable feed conversions. The lower feed costs during the rearing period outweighs any advantages of the conventional dietary regimens.

Anderson *et al.* (1995) and Anderson (2010) reported results from SUP regimens in comparison to a standard SDP regime. The SUP high energy regime pullets weighed significantly less than those on the SUP low energy regime, however, both SUP groups weighed less than the SDP pullets. Anderson *et al.* (1995) looked at subsequent performance of hens grown on SUP regimes and found that age 50% production was significantly delayed in both SUP groups, but egg production and livability was significantly improved over the SDP group. Egg weight was lower in both SUP groups, however, due to their increased production, total egg mass was significantly higher from both SUP groups than from hens grown on the SDP regime.

Davami *et al.* (1987) found depressed layer performance when feeder space was reduced. However, Anderson *et al.* (1995) found that feeder space had no effect on sexual maturity, feed consumption or hen-day production. The differences may have been due to the cage shapes of shallow vs deep cages which were used by Davami *et al.* (1987) whereas Anderson used the same cage dimensions with differing feed access. Thogerson *et al.* (2009) found that hen-day production was no different at 5.8 vs 12.2 cm of feeder space/hen, but feed conversion was poorer at 5.8 cm/hen than at 12.2. In addition, egg weights were similar at the upper and lower end of feeder space allowances.

In a review of research studies from 1971-1983 Adams and Craig (1985) showed that when hens were provided greater floor space productivity improved, feed intake increased and mortality declined. Anderson (1996) supported these findings showing that by providing more floor area per hen from 310 cm^2 to 482 cm^2 feed intake increased, hen-housed eggs were higher, with greater hen-day production. This was consistent between both White and Brown egg layers (Anderson, 1996). Bell and Weaver (2002) examined multiple studies and determined that reducing the floor space in laying hens decreases the productivity in both white and brown egg layers. Production decreases by 10 and 14 eggs per hen in white and brown egg strains, respectively when floor area is decreased from 465 cm^2 to 349 cm^2.

Therefore, the objectives of this research were to compare the reproductive performance of two different commercial brown-egg layer strains grown using three different dietary regimens, i.e. SDP regime, SUP regime with a low energy starter fed for 9 wks and SUP regime with a low energy starter fed for 12 wks, when housed at two laying densities and two feeder spaces.

MATERIALS AND METHODS

Hatching eggs from two commercial brown-egg layer strains (H and N Brown Nick and Hy-Line Brown) were obtained and hatched at the Piedmont Research Station at Salisbury, NC, USA. The chicks were brooded and grown in an environmental control facility of triple-deck brood-grow cages. The treatment groups consisted of a traditional SDP regimen, a SUP regimen: low energy starter for 9 wk (SUP9) and a SUP regimen: low energy starter for 12 wk (SUP12). The rearing program for the pullets was described by Anderson (2010). Briefly, three different dietary regimens resulting in a 2 x 3 factorial design were used. The regimens were a standard Step-Down Protein Regimen (SDP) comprised of a 20% CP Starter, 0 to 6 wk, 18% CP Grower 1, 7 to 12 wk and 16% CP Grower 2, 13 to 18 wk; a step-up protein regimen (SUP9) comprised of a 12% CP Starter, 0 to 9 wk, 16% CP Grower 2, 10 to 16 wk and 18% CP Grower 1, 16 to

17 wk and a step-up protein regimen (SUP12) comprised of a 12% CP Starter, 0 to 12 wk, 16% CP Grower 2, 13 to 16 wk and 18% CP Grower 1, 16 to 17 wk. The pullets were moved at 17 wks of age to environmental control laying house containing 4 banks of 3 tier stair-step cages. Each tier was designated as a block for a total of 12 blocks with 6 reps each of 61 cm and 81 cm cages in each block. The 6 rearing treatment combinations were randomly assigned with each treatment represented in both densities in each block. Hens which were housed at a density of 361 cm^2 provided 4 cages, 6 hens/cage for a total of 24 hens/replicate while hens housed at 482 cm^2 had 3 cages, 6 hens/cage for a total of 18 hens/replicate. A sub-study was conducted using blocks 1 and 8 to determine if feeder space had an effect on layer productivity. Feeder space was maintained at 10.2 cm/bird for all 81 cm cages and all rearing treatments in those blocks. Feeder space was restricted by blocking off 20 cm of the cage front with 2.54 by 5.1 cm welded wire screen used to block the opening on the 81 cm cage to 61 cm. In this manner differences in production were attributed to either density or feeder space. Observations during the production period included egg production, egg weight, egg quality, egg income, feed consumption, feed cost, mortality and body weight. The individual bird scores were combined to provide a mean feather score for each replicate.

Data from the laying periods were analyzed using the General Linear Model Program (GLM) by SAS7 (SAS Institute, 2000-2004) using the replicate means. Production data from the feeder space study was analyzed as three treatment groups. Treatments consisted of; 361 cm^2 and 10.2 cm of feeder space per hen; 482 cm^2 and 10.2 cm of feeder space per hen and 482 cm^2 and 13.6 cm of feeder space per hen. Analysis of treatment differences was accomplished using orthogonal contrast statements to isolate the effects of feeder space independent of density. Data are reported as the least square mean estimates for each parameter. Where significant main effects occurred, the significance of the differences present was tested using Duncan's new multiple range test (Steel and Torrie, 1960). Percent Mortality was converted to Arc Sine prior to analysis. Feed costs were calculated from the actual feed costs incurred during the course of the experiment from the mill where the feed was purchased. Egg incomes were based on three year regional price averages of the eggs in relation to the size categories into which they were classified by computer weighing.

RESULTS

Strain: Hen-day and hen-housed egg production were similar for both strains (Table 1). Feed consumption was not different between the strains, but, the BN hens had greater ($p<0.0001$) daily egg mass by 1.3 g which resulted in better ($p<0.0001$) feed conversion by 0.016 g egg per g feed. Livability was higher ($p<0.001$) for the HB than for the BN hens. The eggs produced by the BN hens weighed significantly ($p<0.0001$) more than the eggs produced by the HB hens by 1.4 g (Table 2). This resulted in a shift in egg size distribution in Table 2, showing a corresponding increase ($p<0.0001$) in percent in extra large in the BN and a significant

Table 1: Effect of strain, rearing regimen, feeder space and density on brown egg layer performance and livability

	HD Prod (%)	HH Eggs	Daily egg mass (g)	Feed Cons (kg/100/day)	Feed Conv (g egg/g feed)	Livability (%)
Strain (S)						
Hy-Line Brown	77.8	285.0	49.6	12.3	0.391	89.5***
H and N "Brown Nick"	78.2	278.0	50.9****	12.2	0.406****	83.3
SE	0.3	3.0	0.2	0.1	0.002	1.3
Rearing (R)						
SDP	78.2	276.0	50.6	12.3	0.402[a]	82.8[b]
SUP9	78.1	284.0	50.2	12.2	0.401[a]	87.1[ab]
SUP12	77.8	286.0	50.1	12.2	0.392[b]	89.3[a]
SE	0.4	4.0	0.3	0.1	0.003	1.6
Feeder Space (F)						
10.2 cm	79.9	300.0	51.4	12.0	0.428**	89.4
13.6 cm	79.0	297.0	51.0	12.5*	0.411	88.5
SE	0.6	6.0	0.5	0.1	0.004	2.6
Density (D)						
361 cm^2	76.8	263.0	49.3	12.1	0.397	82.4
482 cm^2	79.3****	300.0****	51.2****	12.4****	0.400	90.5****
SE	0.3	3.0	0.2	0.07	0.002	1.3
S x R	N.S	N.S	N.S	N.S	*	N.S
S x F	N.S	N.S	N.S	N.S	N.S	N.S
S x D	N.S	N.S	N.S	N.S	N.S	N.S

[ab]Superscripts within the column and main effect division are significantly different ($p<0.05$). *$p<0.05$, **$p<0.01$, ***$p<0.001$, ****$p<0.0001$

Table 2: Effect of strain, rearing regimen, feeder space and density on brown egg layer egg weight and egg size distribution

	Egg Wt (g)	X Large (%)	Large (%)	Medium (%)	Small (%)	Pee Wee (%)
Strain (S)						
Hy-Line Brown	63.6	57.8	27.7****	12.9****	1.3	0.3
H and N “Brown Nick”	65.0****	65.1****	22.9	10.6	1.1	0.3
SE	0.2	0.9	0.7	0.4	0.1	0.1
Rearing (R)						
SDP	64.6	63.6	23.7	11.2	1.2	0.3
SUP9	64.2	60.8	25.6	12.3	1.1	0.3
SUP12	64.1	60.0	26.6	11.8	1.3	0.4
SE	0.2	1.1	0.9	0.4	0.1	0.1
Feeder Space (F)						
10.2 cm	64.0	59.7	24.7	12.8	1.4	0.4
13.6 cm	64.3	60.8	25.8	11.5	1.2	0.4
SE	0.3	1.8	1.3	0.7	0.2	0.1
Density (D)						
361 cm^2	64.1	60.4	26.1	12.0	1.3	0.3
482 cm^2	64.4	62.5	24.5	11.5	1.1	0.4
SE	0.14	0.9	0.7	0.4	0.1	0.1
S x R	N.S	N.S	N.S	N.S	N.S	N.S
S x F	N.S	N.S	N.S	N.S	N.S	N.S
S x D	N.S	N.S	N.S	N.S	N.S	N.S

[ab]Superscripts within the column and main effect division are significantly different (p<0.05). *p<0.05, **p<0.01, ***p<0.001, ****p<0.0001

Table 3: Effect of strain, rearing regimen, feeder space and density on brown egg layer USDA Grades, egg income and feed costs

	Grade A (%)	Grade B (%)	Checks (%)	Loss (%)	Egg Inc ($/hen)	Feed cost ($/hen)
Strain (S)						
Hy-Line Brown	95.8	1.7	2.2	0.3	17.97	7.86**
H and N “Brown Nick”	95.8	2.2*	1.8	0.3	17.59	7.65
SE	0.2	0.1	0.1	0.1	0.21	0.05
Rearing (R)						
SDP	95.8	1.9	2.0	0.3	17.40	7.76
SUP9	95.8	1.9	2.0	0.2	17.93	7.77
SUP12	95.8	1.8	2.0	0.4	18.01	7.73
SE	0.2	0.2	0.2	0.1	0.25	0.06
Feeder space (F)						
10.2 cm	96.0	2.0	1.6	0.5	18.71	7.52
13.6 cm	95.8	2.2	1.6	0.4	18.64	7.79
SE	0.4	0.3	0.2	0.2	0.39	0.11
Density (D)						
361 cm^2	95.6	1.9	2.2*	0.3	16.59	7.65
482 cm^2	96.0	1.9	1.8	0.3	18.98****	7.86**
SE	0.2	0.1	0.1	0.5	0.21	0.05
S x R	N.S	N.S	N.S	N.S	N.S	*
S x F	N.S	N.S	N.S	N.S	N.S	N.S
S x D	N.S	N.S	N.S	N.S	N.S	N.S

[ab]Superscripts within the column and main effect division are significantly different (p<0.05). *p<0.05, **p<0.01, ***p<0.001, ****p<0.0001

(p<0.0001) decrease in large and medium size egg numbers for the HB hens. The percentage of Small and Pee Wee eggs were not affected by strain. Only the percentage of B grade eggs was lower (p<0.05) in the HB hens by 0.5 % than the BN hens that had 2.2 percent Grade B. Feed cost were higher (p<0.01) for the HB over the BN hens by $0.21. There were no significant differences between the strains for egg income (Table 3).

Rearing dietary regimens: The rearing regimens did not impact subsequent productivity, daily egg mass or feed consumption. It was found that the SDP and SUP9 had similar feed conversion of 0.402 and 0.401 g of egg/g feed, respectively while the SUP12 reared hens had lower (p<0.05) conversion at 0.392 g egg/g feed (Table 1). Livability was greatest (p<0.05) in the SUP12 at 89.3% than hens reared on the SDP regimen of 82.8%, the hens reared on the SUP9 regimen had intermediate livability. As shown in Table 2, none of the rearing dietary regimens affected egg weight or egg size distribution or egg grades, egg income or feed cost (Table 3). There was a significant interaction of strain by rearing diet regimen Fig. 1. The HB hens consumed less feed in the

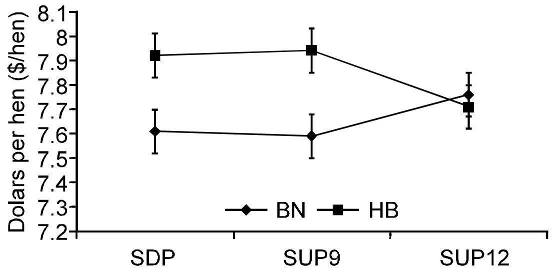

Fig. 1: Interaction of strain by rearing dietary regimen on feed cost

production period than the BN hens. This indicates that the strains responded differently to the SUP12 which restricts protein consumption in the rearing period.

Feeder space: In the laying house feeder space of 13.6 cm per hen significantly ($p<0.05$) increased feed consumption by 0.5 kg/100 hens (Table 1) this reduced feed conversion by 0.017 g egg per g feed over the hens which were provided 10.2 cm of feeder space. The remaining production parameters or egg size distribution and egg quality shown in Table 2 and 3 were not affected by the feeder space per hen. In addition, feed cost and egg income were not affected by the feeder space allocation. There were no interactions associated with feeder space.

Cage density: The hens housed at 482 cm^2 had higher ($p<0.0001$) production parameters than those housed at 361 cm^2 in all performance categories except feed conversion in this case there was no difference between the densities (Table 1). Livability of hens was improved by 8.1% in the hens housed at 482 cm^2. Density had no impact on egg weights or egg size distribution as shown in Table 2, but the percent checked eggs was higher ($p<0.05$) in the hens housed at 361 than at 482 cm^2 at 2.2 and 1.8%, respectively. Since all of the production parameters were higher in the hens housed at 482 cm^2 the total egg income per hen was $2.39 higher ($p<0.0001$) and feed costs were $0.21 higher than the hens housed at 361 cm^2 (Table 3).

DISCUSSION

Strain: Feed consumption and hen-day production were not significantly different for either of the strains in this experiment. However, feed conversion, egg mass per hen-day, egg weight and subsequent egg size distribution were improved for the BN hens. These production parameters as well as mortality, support the findings of Maurice *et al.* (1982) that strains differ significantly during the laying period. Due to the higher egg weights of the BN hens they produced 0.5% more grade B eggs than the HB hens. The HB hens had significantly higher feed costs by $0.21 than the BN hens with no significant differences in egg income. However, if this is examined closely there is a net income difference of $0.17 between the two strains. Producer needs related to egg size and other management criteria will dictate the strains used in the operation.

Rearing dietary regimens: In this study there were no corresponding reductions that occurred in feed consumption or HD production. These results are similar to the findings of Leeson and Summers (1979) and subsequent work by Maurice *et al.* (1982), Doran *et al.* (1983), Robinson *et al.* (1986) and Cheng *et al.* (1991) shows that the rearing dietary regimen did not affect hens. However, Anderson *et al.* (1995) showed that SUPLES and SUPHES regimens did result in production differences which detracted from the SUP regimes. The regimes in this study did not result in production differences in feed consumption, HD production and egg mass from the SUP9 or SUP12 reared hens. This indicates that feeding low protein starter diets that may result in comparable production and net income during the production period. Since protein consumption was reduced in both SUP9 and SUP12 over the SDP regimes return per hen could be enhanced since the cost of the pullets would be lower (Anderson, 2010). These SUP dietary regimes may be an alternative rearing technique in regions where high protein feed stuffs are limited in availability or high cost.

Feeder space: Laying house feeder space in this study had no effect on HD production capability of the hens which is contrary to the findings of Davami *et al.* (1987). The difference may be due to the different cage shapes between the experiments. In this trial the cages were 81 cm in width while those in Davami *et al.* (1987) were 60 cm wide. This shallow shape in this study would allow easier access to the feeder than the deep shape. However, daily egg mass produced and mortality were similar for both the 10.2 and 13.6 cm feeder space allowances. Feed conversion was reduced as the feeder space increased from 10.2 to 13.6 as a possible result of play activity at the feeder trough. The egg size, size distribution and egg quality as well as feed cost and egg income all of which did not change regardless of the feeder space allocated to the hens which supports the findings of Anderson *et al.* (1995).

Cage density: Cage density of 361 cm^2 reduced the performance of the laying hens in this study. Anderson *et al.* (1995); Davami *et al.* (1987); Adams and Craig (1985) and Cunningham and Ostrander (1981) had similar findings indicating that severe restriction of floor area should be avoided if possible. Even at the relatively moderate densities of 361 cm^2 and 482 cm^2 used in this study the production criteria were negatively affected. The hens kept at 482 cm^2 produced more eggs that were heavier, with a greater percentage of extra large and fewer medium eggs than the hens kept at 361 cm^2 which is contrary to Cunningham (1982). He found no differences in egg weights or grade out for hens at comparable densities of 323 to 484 cm^2 per hen. These differences may be due to the utilization of shallow cages as part of the density treatment groups. The other egg size components were not affected for the hens at either density. Egg quality was shifted by +0.4% checked eggs in the 482 cm^2 density group. However, both the egg income and feed cost were increased in the 482 cm^2 density group by $2.39 and $0.21, respectively.

Balance between the economic return and the cost of the lower densities should be established in order to provide the best environment for the hens. The key to utilization of any management system in the poultry industry is the economic return on investment. Hens housed at 482 cm^2 vs those at 361 cm^2 resulted in a $2.18 advantage in net income for the hens housed at the lower density. However, fixed costs remain the same regardless of the population in the house.

The apparent differences shown in this study appear to relate primarily to strain differences and housing density. This study indicates that a SUP low protein low energy starter diets could be used as part of the rearing dietary regimen with reduced body weights without negative carry-over effects into the laying period. It appears that a reduction in pullet weight at 18 wk of approximately 100 g will not reduce feed conversion or egg weight of the hens as shown by Anderson (2010). Further development of the SUP regimens could result in lower pullet body weights and feed costs with comparable laying production as birds reared on conventional programs. Cage densities above the 361 cm^2 per bird will result in enhance performance of the hens and with the welfare needs of the layer industry, dictates a lower density to improve consumer perceptions of the egg industry. The use of lower densities may be one way to improve welfare with a minimal impact on net income of the companies. Feeder space did not affect the overall production of the hens in this experiment with the exception of feed efficiency. However, if the feeder space per hen would have been below 8 cm per bird then negative effects may have been found in the egg size and quality data.

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