THE EFFECTS OF TYPE OF REARING DIET, CAGE SHAPE, AND TYPE OF CAGE SIDE PARTITION ON THE PRODUCTIVITY AND WELL-BEING OF LAYERS

by

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TABLE OF CONTENTS

LIST OF TABLES

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INTRODUCTION

Housing systems have changed from when commercial layers were kept on litter. Intensive management systems, such as housing birds in cages, have attracted most commercial producers because of their emphasis on reducing investment costs. This has led to some management problems brought about by high density stocking rates in cages such as lower egg production, increased mortality, and concerns about bird well-being.

Traditionally cage layers have been housed in deep cages with the long dimension of the cage perpendicular to the feed trough. Bell (1972) saw the advantages of a cage system with the long side of the cage running parallel to the feed trough. Subsequent studies have shown that the advantages of this cage system are increased feed consumption, egg production and quality, and favorable behavioral responses. Another innovation in cage design adopted by some European cage manufacturers is fully mechanized cage systems with solid metal or plastic rather than wire partitions between adjacent cages. Its effects on general production parameters of layers have not been fully investigated.

Pullet body weight and its relationship to egg size is of prime importance to the producer. Conventional rearing diets for pullets have been to reduce the protein levels (step-down) as the birds grow. But Leeson and Summers (1979) found that increasing protein levels (step-up) as the birds aged reduced feed costs and controlled body weight better than step-down protein diets.

The objective of this study was to investigate the effects of rearing diets, cage shape, and type of cage side partition on productivity and well-being of layers.

REVIEW OF LITERATURE

Rearing Diets

One of the first published papers on restricted protein levels during the growing period was by Lillie and Denton (1966). Their experiment involved protein levels of 21, 16, and 12% fed at different ages during the growing period under a feed restriction scheme. They postulated that protein levels could be lowered from 21 to 16% from 0 to 8 weeks and from 16 to 12% from 8 through 20 weeks without any adverse effect during the laying period. Sexual maturity was delayed 4 days for those fed the restricted protein diets. In a subsequent study (1967) they reported that birds fed a higher protein regimen in the growing stage had significantly higher egg production than birds fed lower protein diets.

Wright et al. (1968) studied the effects of short term feeding of egg type pullets low protein levels of 10 and 16% during the growing stage. When strain 1 birds were fed a low protein diet from 8 to 18 weeks, they had increased age (5 days) at first egg, slightly higher egg production rates, and improved feed efficiency. In strain 2, egg production was delayed, resulting in inferior egg production rates and feed conversion.

Christmas et al. (1974) fed protein diets of either 9.07 or 15.35% from 8 to 18 weeks. From 18 to 21 weeks all birds received 15.35% protein diets. Low protein diets reduced pullet cost, delayed sexual maturity, delayed production peak, increased egg size at 50% egg production, and improved levels of production near the end of the laying period. However birds on the low protein diet were lighter in body weight at the end of the growing cycle, had lower total egg production, and higher mortality in the laying house.

Significant interactions between breeds and the level of dietary protein fed from 0 to 8 weeks were reported by Balnave (1974). Egg production, total egg weight, feed conversion efficiency, and mean egg weight of brown-medium breed hens were better when starter diets contained 16 vs. 19% protein. The lighter breed hens had better egg production, total egg weight, and feed conversion, but lower mean egg weight when given 19% protein. Feed intake, weight gain, and feed conversion efficiency were better when 19% protein was fed during the 8 to 20 week period. Poorer feed conversion efficiency of birds fed 19% protein during 0 to 8 weeks was observed.

In a dietary self-selection of protein and energy in White Leghorn pullets, Summers and Leeson (1978) reported that protein intake was positively correlated with age. Dietary equivalents of 11.4, 11.3, 17.0, 18.9, and 19.3% crude protein during the 4 to 8, 8 to 11, 11 to 14, 14 to 17, and 17 to 20 week growth periods were determined. They postulated that the protein requirement was related to a relatively slow initial growth rate and to the development of the reproductive organs around 12 to 14 weeks of age. Although birds were smaller at housing under this scheme they were more sexually mature. In a subsequent study, Leeson and Summers (1979) reported that birds fed a step-up protein diet were significantly smaller at 20 weeks of age and consumed less feed while producing a comparable number of smaller sized eggs than control birds. They concluded that pullets can be reared on step-up protein diets as a means of controlling body weight. Their step-up protein diets consisted of 12% crude protein (CP) and 3080 kcal/kg of metabolizable energy (ME) from 0 to 12 weeks, 16% CP and 2974 ME from 12-16 weeks, and 19% CP and 2972 ME from 16-20 weeks. The control diets consisted of 18% CP and 3049 ME from 0-8 weeks, 15% CP and 2992 ME from 8-12 weeks, and 13% CP and 2952 ME from 12-20 weeks.

Kim and McGinnis (1976), in an experiment studying the effect of dietary protein levels of 12 and 15% from 12-20 weeks, found that pullets fed 15% protein grower diets were 15 and 14 g heavier per bird at 20 and 32 weeks of age, respectively. Pullets fed the higher protein diet laid 1.8% more eggs on a hen-day basis. Birds fed 15% protein levels reached production at an earlier age.

In comparing the effects of step-down and step-up protein grower diets, Leeson and Summers (1980) found that birds on a step-up protein regimen were smaller in body size at point of lay. This was associated with reduced quantities of fat deposition. They observed that these differences were maintained through early egg production. Leeson and Summers (1981) fed broiler breeder pullets 12, 16, and 19% step-up protein diets from 0-12, 13-16, and 17-20 weeks respectively. The control birds received a regular feeding program based on a restricted feeding schedule. Up to 8 weeks of age, the step-up protein fed birds were smaller in body size than controls, however from 8 through 20 weeks birds on the reverse protein diets were significantly heavier. In a subsequent study, Leeson and Summers (1984) reported that birds fed a step-up protein diet were smaller at 16 weeks and produced fewer eggs that were significantly smaller than birds reared on step-down protein diets, suggesting that the reverse protein diets are not advisable when early induced maturity is desired.

Doran et al. (1983) compared the effects of a low and high energy ration step-up protein and step-down grower rations on pullet growth and laying performance. Birds subjected to the step-up protein diets at 6 weeks of age were 17% lighter and at 12 weeks were 22.4% lighter than those reared on conventional diets. Energy level had no significant effect on weight, feed consumption, or mortality. They reported that hens on the step-up protein regimen reached 50% egg production 2 days earlier. Mortality during the production period was significantly lower (2.64%) for those fed the step-up protein diets. No significant differences were found for egg production, although birds on the step-up protein grower diets had a higher hen-day egg production.

Cage Shape and Density

The concept of using reverse shape cages was introduced by Bell (1972). He reported birds housed in 45.7 x 30.5-cm cages had significantly ($P<.05$) less mortality, laid significantly more eggs with fewer cracks, and had better feed conversion than those in 30.5 x 40.6-cm cages. No difference was noted for total feed consumption.

Lee and Bolton (1976) analyzed performance of medium and light weight hens in deep (40.5 x 46.0-cm) and shallow (61.0 x 30.5-cm) cages. Significant differences in egg production of the medium weight and light weight hens were found between 18-30, 31-42, and 43-60 weeks, respectively. Cage shape had no effect on mortality. Hens of both strains housed in shallow cages consumed 4% less feed. Among the reasons postulated for this was less feed spillage due to increased trough space, less need to acquire feed or water, and less heat loss and energy requirement from a better feather cover. The incidence of hair-line cracked, cracked, and broken eggs was lower in shallow cages due to shorter distance of eggs to roll to the collecting area.

Given equal floor areas per bird, Hughes and Black (1976) found that birds in shallow cages (45.7 x 30.5-cm) produced more eggs from 30-70 weeks than those in deep (30.5 x 45.7-cm) cages. The mean proportion of birds feeding at any given time was significantly higher in shallow cages than deep cages (48.3 vs. 44.8%). In comparing performance of Red x Rock Sex-linked females in shallow (45.7 x 30.5-cm) and deep (30.5 x 45.7-cm) cages, Muir (1976) found birds in shallow cages had increased body weights at 40 and 72 weeks, indicating less competition for feed. A subsequent trial indicated significantly higher egg production rates and feed efficiency in birds housed in shallow cages than those in deep cages. Swanson and Bell (1977) reported improved egg production, feed efficiency, and egg income over feed cost with birds housed three per cage in shallow (45.7 x 30.5-cm) cages than those in deep (30.5 x 45.7-cm) cages. Performance parameters were lower in both cage shapes with four birds per cage. No effect of cage density or shape on egg size, shell quality and Haugh units was reported.

Lee et al. (1978), studying energy intake of laying hens found that hens in shallow cages produced 10.3 more eggs/bird, had fewer damaged eggs, 3.8% greater egg mass, and consumed 2.7% less feed than those in deep cages.

Two types of shallow cages (40 x 25 x 45-cm) and (30 x 25 x 45-cm) with their corresponding exact reverse deep cages were studied by Baiao and Campos (1979). Egg production (hen-day basis) was significantly higher in shallow cages than deep cages. The birds in smaller cages had better production and feed conversion, but lower livability than those in larger cages.

Bell et al. (1979) analyzed the economic implications of different combinations of cage shape and colony size. Cage depth varied from 30.5 to 45.7-cm and cage width from 30.5 to 61 cm. Feeder space and floor space per bird were positively correlated with egg income over feed cost. Birds in shallow cages yielded significantly higher monetary returns at the same floor space allowance per bird than those in deep cages.

Using a factorial designed experiment, Robinson (1979) used wire cages of variable widths and depths to study cage depth, feeder space, floor area, colony size, and cannibalism control measures on two SCWL strains. Results indicated that feeding space had more of an impact on laying performance than did colony size or floor space. No influence of cage depth or width on proportion of cracked eggs was noted.

Cunningham and Ostrander (1981) housed 4, 5, 6, and 5, 6, 7 birds per cage in deep (38.1 x 50-cm) and shallow (60.9 x 35.5-cm) cages, respectively. Pullets in deep cages had lower egg production than birds in shallow cages. Birds in shallow cages consumed more feed and had heavier body weights due to more feeder space. Eggs from birds in shallow cages were significantly ($P<.05$) heavier and had more egg mass as a result of increased nutrient intake and larger body size of birds. Increasing the population density resulted in reduced egg production, body weight, feed usage, egg mass, and undergrades in both types of cage configurations. The effects of social rank and cage shape on behavioral and performance traits of White Leghorn layers housed four per cage in deep (38.1 x 50-cm) and shallow (60.9 x 31.8-cm) cages were evaluated by Cunningham (1981). No significant differences were obtained for rate of egg production, although birds in shallow cages laid heavier eggs, which was attributed to higher feed intake by these birds. In a subsequent study, Cunningham (1982a) analyzed layer performance in deep and shallow cages with birds either full-fed or control-fed. Full-fed birds in shallow cages consumed more feed and had heavier body weights at 48 weeks than control-fed shallow caged birds or full-fed birds in deep cages. Rate of egg production, egg weight, and egg mass were significantly higher for birds full-fed in shallow cages than those in either of the other treatments.

Carey (1982) studied the effects of cage shape and feeding behavior on four commercial SCWL strains. Hens in deep (30.5 x 45.7-cm) cages produced significantly more eggs from 40 to 68 weeks, with higher feed consumption and feed conversion values (0.38 vs. 0.35 g egg/g feed) than birds in shallow cages (45.7 x 30.5-cm). In the second experiment, birds in shallow cages (45.7 x 30.5-cm) cages produced numerically more eggs than those in deep cages. Birds in the shallow cages consumed significantly less feed with superior feed conversion (0.40 vs. 0.38 g egg/g feed).

Cunningham (1982b) observed that hens in shallow cages (60.9 x 31.8-cm or 60.9 x 35.5-cm) had significantly higher egg production, better weight gain, heavier ending body weights, higher egg weights and egg mass, higher number of eggs grading large or extra large than those in deep cages (38.1 x 50.1-cm). Feed conversion and feed usage were significantly affected by cage type, birds in shallow cages consuming more feed with poorer feed conversion. Significant strain differences for egg production, feed consumption, feed conversion, egg mass, large eggs and undergrades between two strains of White Leghorn pullets housed four and five birds in deep and shallow cages were reported by Cunningham and Ostrander (1982). Birds in shallow cages had significantly higher egg production (76 vs. 73%), heavier average body weights, and consumed 1.8 kg more feed per bird than birds in deep cages. Increasing bird density resulted in reduced egg production, increased mortality, reduced body weight gains, and reduced feed usage and feed conversion figures.

Ouart and Adams (1982), studying the effects of cage design and densities of three or four birds per cage on production and well-being of two strains of SCWL, reported that hens housed three per cage had significantly higher rates of lay than those housed four per cage. Decreasing population size and increasing floor space per hen increased hen-day (3.4%) and hen-housed (3.5%) egg production. Mortality, feed consumption, and feed conversion were not significantly affected by cage shape, density, or strain. Birds housed three per cage produced fewer body checks and cracks (4.5 vs. 7.1%) than those housed four per cage.

Based on a summary of published reports on cage shape and density, Adams and Craig (1985) reported cage shape had a significant ($P<.05$) effect on egg production with hens in shallow cages laying an average of 5.8 more eggs on a hen-housed basis than those in exactly reversed deep cages. As bird density per cage was increased; mortality was increased, feed conversion was depressed, and egg production rates were lowered.

Martin et al. (1976) housed two to seven hens at densities of 580 to 310 cm^2 in cages ranging from 25.5 x 30.5-cm to 61 x 51-cm. Severe depression of economic criteria was noted at densities lower than 454 cm^2 per bird. Within the range of 312-454 cm^2 per bird, mortality increased 1.2%, hen-day egg production decreased by 75%, feed consumption increased 14.8 g per dozen eggs, and eggs per pullet housed decreased 4.7. Hens in deep cages produced 9.2 eggs more than those in shallow cages.

Hill (1977) provided space allowances of 310, 387, and 464 cm^2 per bird in groups of 3, 6, and 12 birds. He concluded that a space allowance of 310 cm^2 adversely affected egg production. A negative linear response was obtained between group size and egg production. As floor space diminished body weights decreased (2.06 vs. 1.84 kg), resulting to poorer feed conversion (2.73 vs. 2.85 kg feed/kg eggs). As group size increased mortality increased significantly (26.2 vs 10.7%).

Populations of 3, 6, and 12 birds at 310, 387, and 464 cm^2 of space, housed in deep and shallow cages were studied by Hill and Hunt (1978). No significant differences for cage shape were observed for egg production. Birds in shallow cages had significantly higher egg weights (60.3 vs. 59.6 g) and ending body weights (1.76 vs 1.72 kg) than those in deep cages because of higher feed consumption per bird (47.3 vs. 45.6 kg) with a lower feed conversion (2.55 vs. 2.66 kg feed/kg eggs). An adverse effect of increasing bird density was noted for mortality, egg weight, body weight, feed per bird, and feed conversion. Birds in deep cages were as profitable as those in shallow cages due to superior feed conversion.

Martin et al (1980) housed five strains of layers at three or four birds in deep (30.5 x 40.6-cm) and shallow (40.6 x 30.5-cm) cages in light and air-controlled houses. Birds in shallow cages showed significantly higher feed consumption, more feed per dozen eggs, lower percentage of grade B eggs during the last 14 weeks, higher final body weight, and lower Haugh units than birds in deep cages. Nonsignificant effects of shallow cages included 0.8 fewer eggs per bird housed, 1% higher mortality and lower income over feed and chick cost. Reducing cage space from 416 to 312 cm^2 included 11.5 fewer eggs per bird, lower feed consumption, lower egg grade, and lower income over feed cost.

Dorminey and Arscott (1971) conducted three studies in which White Leghorn hens were housed 4, 6, 8, and 10 per 61 x 61-cm cage, 1,2, and 3 per 30.5 x 45.7-cm cage, or 4 per 30.5 x 45.7-cm cage. No significant decreases in hen-day and hen-housed egg production were observed as bird density increased. Density had a nonsignificant effect on feed consumption, mortality, egg weight, and cracked and shell-less eggs, although there was a tendency for one hen per cage to produce more shell-less eggs than two or three hens per cage.

Evaluating dietary energy concentration on performance of heavy egg-type hens housed at 1320, 660, 440 cm^2 of floor area per hen, Carew et al. (1976) found that increasing hen density caused a significant ($P<.01$) reduction in final overall body weight. As number of hens per cage increased, energy and protein intake diminished, which was postulated as the cause of reduced egg production. Mortality increased as density per cage was increased. Egg weights and quality were not affected by hen density.

Feather Condition and Nervousness

Adams et al. (1978), using a feather condition chart consisting of photographs of various stages of feather loss in the backs and wings of chicken, observed no significant differences in feather condition at 40 weeks between two experimental strains of SCWL breeders housed at two male:female ratios. However birds from smaller flock sizes had significantly better feather cover. Pullets housed in cages at 12 weeks had significantly poorer feather scores than those housed at 18 weeks.

Hughes and Black (1976), using a 0-6 scoring system where 6 indicated complete denudation and 1 complete feathering, evaluated at 54 and 70 weeks of age the feathering of light-hybrid SCWL housed in deep (40.5 x 45.7-cm or 30.5 x 45.7-cm) and shallow (61 x 30.5-cm or 45.7 x 30.5-cm) cages. Feather pecking was more extensive in deep cages at 54 weeks and approached significance ($P<.05$) at 70 weeks. Group size had no significant effect on feather damage. Incidence of feather damage of medium weight strains of layers housed four per cage was 1.46 + or - 0.08 in shallow (61 x 30.5-cm) cages and 1.81 + or - 0.08 in conventional (30.5 x45.7-cm) cages at 74 weeks (Hughes and Black, 1977). Feather cover on the wings, tail, back, underside, and neck of SCWL hens housed 3, 6, and 12 per cage in deep or shallow cages was rated by Hill and Hunt (1978) where a score of 1=0-33%, 2=34-66%, and 3=67-100% loss of feathering. Feather wear was attributed to rubbing against other birds and the wire partitions. Less space and increased populations caused increased feather wear. Birds in deep cages had significantly more back feather wear as a result of scrambling over each other to reach the feed trough than those in shallow cages. Ouart and Adams (1982) measured feather coat damage of two strains of SCWL housed under different cage designs and densities by the Adams' et al. (1978) method. Birds housed four per cage were significantly more nervous and had poorer feathering than birds housed three per cage. Cage shape had no effect on nervous score. Significant strain differences for nervous response were noted. Average feather scores were not significantly affected by cage shape. Significant differences between scores for nervousness and feathering due to bird density and strain suggested a basis for feather damage-nervousness relationships supporting the hypothesis that pain contributes to nervousness of mature layers.

Measuring feathering score by the Adams' et al. (1978) procedure, VanSkike and Adams (1983) recorded scores in two ways: 1) three birds in a cage were observed simultaneously and the average collective feather score measured (CFS), and 2) birds in each cage were scored individually and individual scores averaged (IFS). Cage shape significantly affected IFS, hens in reverse cages having higher feather scores (7.60 vs. 7.28) than those in conventional cages. Lack of significant average feather scores between cage shapes by the CFS method suggested that IFS was a more sensitive measure. Time required for birds to return to feeding after exposure to a noise stimulus was used as a measure of fearfulness. Cage shape did not significantly affect latency to feeding. A trend for the first and second bird in deep cages to return to feeding sooner than those in shallow cages suggested a stronger drive to eat in deep cages. Longer time for simultaneous feeding of three birds in deep cages reflected competition for space at the trough. Nervousness, as determined by a method suggested by Hughes and Black (1974) and modified by Sefton (1976), indicated birds were significantly more nervous with decreasing space and increasing population size.

Sefton (1976) measured the fearful response at 60 and 64 weeks of 10 matings of SCWL in 3-sized cages. Responses were observed by an observer moving a pencil back and forth in front of each cage for 60 sec. Birds which pecked at the pencil during this time were given a score of 0. Remaining birds were scored on their position at the end of a 60 sec period. Birds facing the front of the cage were scored 1, those facing the side 2, those facing the back 3, and those in flight 4. Level of fearfulness was influenced more by number of cagemates than by floor area. An average negative correlation of -0.47 between fear and productivity was observed for 9 of 10 matings. Two of three cage sizes gave negative estimates of estimates of correlation between fear and production.

Fearful responses of eight genetic stocks derived from a common foundation stock were observed at 35, 48, and 61 weeks of age by Kujiyat et al. (1984). Age did not affect latency to feeding, however a group x round interaction for latency to feeding reached significance ($P<.01$). A moderate correlation existed between latency to feeding and duration of tonic immobility. Habituation to the metronome as a fear inducing object within the test group was evident. Direct or indirect exposure shortened latency to return to feeding. Feather scores were affected by age as older hens were less well-feathered.

Hansen (1976) observed that population size increases the incidence of nervousness in caged birds. He postulated that pain was a factor in the transition from nervousness to hysteria, characterized by broken feathers and torn backs.

Fearful behavior of caged hens of two genetic stocks was evaluated by Craig et al. (1982). Fear responses, measured by latencies to feeding were induced by striking the cage or exposing the birds to a metronome after being deprived of feed for 15 hours. Strain differences were evident for nervous score, duration of fearful behavior, and feather loss. Intra-strain analysis indicated that fearful behavior was associated with number of hens per cage but was independent of a neighbor's behavior. Nervous and fearful behavior were significantly associated with greater feather loss.

MATERIALS AND METHODS

Day-old pullet chicks of the Hisex (1) and Babcock (2) strains were hatched on January 21, 1983. The chicks were wingbanded and vaccinated for Newcastle, Marek's and infectious bronchitis diseases. An equal number of chicks were randomly assigned to each brooding-rearing pen. The strains were reared separately with no more than 120 birds per pen. An equal number of pens on each side of a curtain-sided brooding-rearing house were assigned either the experimental step-up protein diets or the KSU step-down protein diets.

Pullets on the step-up protein diets were fed 12% crude protein from 0 through 12 weeks, 16% from 13 through 16 weeks, and 18% from 17 through 18 weeks. Pullets on the step-down protein diets were fed 20%, 18%, and 16% crude protein from 0 through 8, 9 through 12, and 13 through 18 weeks, respectively. Feeding was ad libitum. Composition and analyses of the diets are shown in Appendix, A-1 through A-7.

Chicks were beak trimmed at 1 week of age and retrimmed at 18 weeks. Pullets were reared in photoperiods decreasing from 21 hours the first week to 14 (natural daylength) hours by 18 weeks.

At 18 weeks of age, a random sample of pullets were weighed prior to housing in laying cages and at 68 weeks of age the survivors were weighed to determine weight gain.

The pullets were housed in a curtain-sided, naturally ventilated cage house. Part of the birds were housed three or four per cage, depending on treatment, in either an inside row of double-deck deep cages (30.5 x 45.7-cm) or an adjacent row of double-deck shallow cages (45.7 x 30.5-cm). The remaining birds were housed three per cage in two outside rows containing an equal number of single-deck deep (25.4 x 45.7-cm) and shallow (45.7 x 25.4-cm) cages. The pullets were randomly assigned to one of eight treatments in the inside rows and one of four in the outside rows. Treatments in the inside rows were assigned on the basis of strain, number of birds per cage, and type of cage side partition (solid metal or wire). Treatments for the outside rows were assigned on the basis of cage side partition (solid metal or wire) and strain. Table 1 shows treatment assignments.

Table 1. Treatment assignments in double and single-deck cages

Double-deck cages

Cage side partition	Strain code	Number of birds	Number of replicates	Total birds
Wire	1	3	18	54
Wire	2	3	18	54
Solid metal	1	3	18	54
Solid metal	2	3	18	54
Wire	1	4	18	72
Wire	2	4	18	72
Solid metal	1	4	18	72
Solid metal	2	4	18	72

Single-deck cages

Cage side partition	Strain code	Number of replicates	Total birds
Wire	1	32	96
Wire	2	32	96
Solid metal	1	32	96
Solid metal	2	32	96

The wire partitions consisted of 2.6 by 5.1-cm wire while the solid metal partitions were constructed of 10 gauge metal fastened to the wire sides of the cages by metal rivets. Birds were randomly assigned to each treatment combination. Floor area per bird was 464 and 348 cm^2 in three and four bird cages, respectively, in the double-deck inside rows and 386 cm^2 in the three bird cages in the single-deck outside rows. Egg production was measured by recording all eggs produced 3 days per week and converting to 7 day values. All eggs collected the last 3 days of each 28-day period were weighed and graded according to USDA grades. Data were summarized at 28-day intervals from 18 to 66 weeks. The KSU 17% protein ration was fed ad libitum during the laying period. The photoperiod was 16 hours.

Latency to feeding tests, as a measure of nervousness, were conducted at 47 and 61 weeks of age. One-half of the cages in each treatment with no mortalities were selected for observation. Adjacent cages with a common side to a test cage were not observed on the same day as the test cages to decrease the effect of habituation. Feeding trough area of the test cage and one-half of the trough area of adjacent cages were covered with wood and metal covers at 0800 hour and left covered for a minimum of 5 hours. Latency to feeding was conducted by placing a metronome mounted on a wood block in front of the cages 15.2-cm above the feeding trough. The metronome was set at 120 beats per minute, the feeder was uncovered and the individual time it took for each bird to return to feeding was measured. A hen was considered to be feeding if her beak touched the feed. The observer stood in the aisle 1.2-m from the cage.

Feather cover scores were recorded for all hens at 54 and 65 weeks of age. The observer matched feather cover of birds with a series of photographs (Adams et al., 1978). Feather condition was recorded by scoring individuals of a cage and averaging the scores (VanSkike and Adams, 1982). Egg production, egg quality, body weight gain, feathering, and nervous response were treated as main effects in analysis of variance (Snedecor and Cochran 1982). Duncan's Multiple Range test was used to test for differences between specific treatment means that were found to be significantly different by analysis of variance.

RESULTS AND DISCUSSION

Analysis of variance data for initial body weights, age at sexual maturity, egg production, average egg weights, egg quality, body weight gain from 18 to 66 weeks, feather cover scores, and latency to feeding tests are shown in Appendix A-8 through A-16.

EFFECTS OF REARING DIETS

Housing Weights. The means for housing body weights are shown in Table 2 and for age at sexual maturity, egg production, mortality, and body weight gain in Table 3. Pullets on the step-up protein diets had significantly ($P<.001$) lower body weights at housing (18 weeks) than those fed the step-down protein diets (1184 vs. 1282 g). These results agree with those of Leeson and Summers (1979, 1980, 1984) and Doran et al. (1983). But the birds fed both the step-up and step-down protein diets were within the breeders' recommended average target weights. Eighty percent of the pullets of both strains fed the step-up protein diets weighed within + or - 10% of the average body weight for the flock versus 74% for those fed the step-down protein diets.

Table 2. Grower diet effects on body weights at housing

Grower diets	Housing weights[1] (g)
Step-up protein	1184***
Step-down protein	1282

[1] Average body weights measured at 18 weeks of age.
*** $P<.001$

Age At Sexual Maturity. A significant (P<.001) delay in sexual maturity was observed for birds on the step-up protein diets (Table 3) compared to step-down protein fed birds when housed in double-deck (157 vs. 165 days) and single-deck cages (161 vs. 173 days). These results were similarly observed by Doran et al. (1983) and Leeson and Summers (1979, 1980, 1984).

Egg Production and Egg Quality. Although the birds fed the step-up protein diets weighed less and appeared more sexually immature at housing than the step-down protein fed birds, no significant differences were observed for egg production (Table 3) and egg weight and quality (Table 4) of hens in both single- and double-deck cages. Leeson and Summers (1984) observed that birds fed step-up protein diets were significantly lighter at maturity and produced fewer and lighter eggs than birds on step-down protein diets. In an earlier study (1979), they reported that birds on the step-up protein diets produced significantly lighter eggs than birds reared on the step-down protein diets. Doran et al. (1983) found no significant differences in egg production among birds grown on either step-up or step-down protein rearing diets, but step-up protein fed birds produced significantly (P<.05) lighter eggs.

Mortality. None of the parameters tested had a significant effect on mortality rates of hens in both single- and double-deck cages (Table 3). Leeson and Summers (1979, 1984) noted similar results.

Body Weight Gain From 18 to 66 Weeks. Percent body weight gain from housing to end of the experiment (18-66 weeks) was significantly (P<.05) affected by type of rearing diets (Table 3). Birds reared on the step-up protein

Table 3. Grower diet effects on performance of egg-type layers housed in single- or double-deck cages

Grower diet	Age at sexual maturity	Egg production rates		Mortality	Body weight gain[1] (18-66 wk)
		hen-housed	hen-day		
	(days)	(%)		(%)	(%)
Single-deck cages:					
Step-up protein	173***	66.8	72.8	11.4	44.1*
Step-down protein	161	63.7	72.8	16.4	33.9
Double-deck cages:					
Step-up protein	165***	66.3	71.3	11.2	42.1*
Step-down protein	157	65.2	71.3	13.8	36.7

[1] Body weight gain = ((ending body wt - beginning body wt)/ending body wt) x 100.

* $P<.05$; *** $P<.001$

Table 4. Grower diet effects on egg weight and egg quality of egg-type layers housed in single- or double-deck cages

Grower Diets	Egg weight (g)	Egg grades: Grade A Large	Egg grades: Grade A Medium	Egg grades: Grade A Small	Egg grades: Undergrds	Other: Cracks	Other: Loss
		(%)					
Single-deck cages:							
Step-up protein	60.48	62.67	24.26	4.03	6.48	1.03	1.67
Step-down protein	61.23	63.73	23.32	3.89	5.59	1.39.	2.14
Double-deck cages:							
Step-up protein	60.89	61.51	26.32	4.46	5.12	1.75	1.35
Step-down protein	60.84	64.62	24.11	4.00	3.86	1.55	1.70

diets had significantly higher weight gains in both single- and double-deck cages during the laying period than birds on the step-down protein diets. It is postulated that step-up protein fed birds compensated for their lower housing weights during the laying period.

EFFECTS OF CAGE SHAPE AND CAGE SIDE PARTITION

Age At Sexual Maturity. Neither cage shape nor type of cage side partition had significant effects on age at sexual maturity of birds kept in single- or double-deck deep and shallow cages (Table 5 and 6). Strain 1 birds matured significantly earlier than Strain 2 birds in both single-deck (165 vs. 169 days) and double-deck (160 vs. 163 days) cages. Bird density had no significant effect on age at sexual maturity (Table 6).

Egg Production. Egg production rates were measured on a hen-housed and hen-day basis. There was a significant ($P<.001$) trend for hens housed in single-deck shallow cages (45.7 x 25.4-cm) to have higher hen-day rates of lay than those in single-deck deep (25.4 x 45.7-cm) cages (75.9 vs. 69.8%) as shown in Table 5. These results agree with the findings by Cunningham and Ostrander (1981), Bell (1977), Baiao and Campos (1979), and VanSkike and Adams (1982). The birds in double-deck deep (30.5 x 45.7-cm) cages had a higher egg production on a hen-housed basis than those in double-deck shallow cages (45.7 x 30.5-cm) cages, but this difference was not statistically significant (Table 6). Carey (1982) observed that birds in deep cages had higher rates of egg production.

The type of cage side partition (wire or solid metal) had no significant effect on egg production of hens housed in either of the cage sizes (Table 5 and

6). These results confirm the findings of some preliminary work reported by Adams (1983) who indicated no significant differences in egg production for hens housed in cages with either wire or solid wood partitions.

Hens housed three per cage in double-deck deep or shallow cages had significantly higher hen-housed (68.2 vs. 63.3%) or hen-day (73.7 vs. 68.9%) egg production (Table 6) than those housed four per cage. These results agree with previous reports by Ouart and Adams (1982), Martin et al. (1976), and Cunningham and Ostrander (1981 and 1982), indicating that decreasing the population size and increasing floor space per bird benefited egg production.

Strain 1 birds had significantly higher hen-day rates of egg production than Strain 2 birds in both cage sizes.

Mortality. Cage shape and type of cage side partition had no significant effect on mortality of birds housed in single-deck deep or shallow cages (Table 5). A trend was observed for birds in both single- and double-deck shallow cages to have higher mortality rates than those in deep cages. Ouart and Adams (1982) and VanSkike and Adams (1983) observed similar but non-significant trends. However Lee and Bolton (1976), Hill and Hunt (1978), Baiao and Campos (1979), and Robinson (1979) found that mortality was lower in shallow cages.

Birds housed in double-deck shallow cages had significantly ($P<.05$) higher mortality rates than birds in the deep cages (Table 6). Hill and Hunt (1980) noted significantly higher mortality rates for their shallow caged birds compared to hens in deep cages. Similarly Carey et al. (1981) reported that birds housed four per cage in 45.7 x 30.5-cm cages experienced higher losses than birds in 30.5 x 45.7-cm cages.

Birds in double-deck cages with solid metal partitions experienced

Table 5. Age at sexual maturity, egg production rates, mortality, and body weight gains of two strains of SCWL housed in single-deck deep (25.4 x 45.7-cm) or exactly reverse cages

	Age at sexual maturity	Egg production rates Hen-housed	Egg production rates Hen-day	Mortality	Body weight gain[1] (18-66 wk)
	(days)	(%)	(%)	(%)	(%)
Cage shape:					
Deep	169	63.7	69.8***	11	38
Shallow	166	66.7	75.9	16	39
Cage side:					
Wire	166	65.8	72.7	12	34
Solid metal	168	64.6	73.0	15	43
Strain:					
1	165*	63.0*	74.7**	20***	37
2	169	67.5	71.0	7	40

[1] Body weight gain = ((ending body wt - beginning body wt)/ending body wt) x 100.

* P<.05; ** P<.01; *** P<.001

Table 6. Age at sexual maturity, egg production rates, mortality, and body weight gain of two strains of SCWL housed in double-deck deep (30.5 x 45.7-cm) or exactly reverse cages

	Age at sexual maturity	Egg production rates		Mortality	Body weight gain[1]
		Hen-housed	Hen-day		
	(days)	(%)		(%)	(%)
Cage shape:					
Deep	162	67.0	70.8	8*	41
Shallow	160	64.5	71.8	16	37
Cage side:					
Wire	161	66.4	71.1	9*	36**
Solid metal	161	65.1	71.5	15	42
Density:					
3 birds	163	68.2**	73.7***	10	35*
4 birds	160	63.3	68.9	14	43
Strain:					
1	160***	65.7	73.2***	16**	36*
2	163	65.8	69.4	8	42

[1] Body weight gain = ((ending body wt - beginning body wt)/ending body wt) x 100.

* $P<.05$; ** $P<.01$; *** $P<.0001$

higher (P<.05) mortality rates than birds kept in cages with wire partitions (15 vs. 9%). Preliminary studies by Adams (1983) noted similar trends between birds in cages with wire and solid wood partitions (5.7 vs. 9.4%). A high incidence of birds catching their toes between the solid metal wall and the wire of the cage floor was observed which could have resulted in death due to blood loss or inability to reach the feeder.

Strain 1 birds showed significantly higher mortality than Strain 2 birds in both cage systems.

A significant (P<.05) type of cage side partition by bird density interaction for mortality was observed in double-deck cages (Table 7). Birds housed four per cage with solid metal sides had significantly (P<.05) higher mortality rates (20%) than those housed four per cage with wire sides (8%), under the conditions of this experiment. The increased mortality in four birds cages with solid metal sides furthers the concept that crowding which reduces movement increases the possibility of birds catching their toes between the metal partition and the wire floor.

Table 7. Cage side partition by density interaction for mortality rate in double-deck cages

Cage side x density	Mortality
	(%)
Solid metal x 4 birds/cage	20^{a}[1]
Wire x 3 birds/cage	11^{b}
Solid metal x 3 birds/cage	10^{b}
Wire x 4 birds/cage	8^{b}

[1]Means with different superscipts differ significantly (P<.05).

Body Weight Gain From 18 To 66 Weeks. No significant differences were observed for the effects of cage shape on weight gain in both cage systems (Table 5 and 6). These results agree with Ouart and Adams (1982) and VanSkike and Adams (1983). However Cunningham and Ostrander (1980, 1982) and Hill and Hunt (1980) reported that birds in shallow cages experienced higher weight gains than those in deep cages.

Birds in double-deck cages with solid metal side partitions gained significantly (P<.01) more weight than birds in cages with wire partitions (42 vs. 36%). A similar but non-significant trend was observed for birds in single-deck cages.

Birds housed four per double-deck cage gained significantly (P<.05) more weight than birds housed three per cage. These results differ from those of Ouart and Adams (1982), Cunningham and Ostrander (1982), and Cunningham (1982) who reported that higher weight gains were observed in cages with lower bird densities.

Strain 2 birds housed in double-deck cages gained significantly (P<.05) more weight than Strain 1 birds, but not in single-deck cages.

Egg Weight. Data in Tables 8 and 9 show that cage shape and type of cage side partition had no significant effects on average egg weight of birds housed in either single- or double deck cages. These results agree with those of Bell (1977), Muir and Gerry (1976), VanSkike and Adams (1983), Ouart and Adams (1982), and Cunningham and Ostrander (1982), who found no significant differences in egg weight of birds housed in deep or shallow cages.

Density in double-deck cages had no significant effect on average egg weight. This agrees with the findings by Cunningham and Ostrander (1982), Ouart and Adams (1982), and Cunningham (1982). However Roush et al. (1984) found that

Table 8. Egg weight and egg quality data of two strains of SCWL housed in single-deck deep (25.4 x 45.7-cm) or exactly reverse cages

	Egg weight (g)	Egg grades				Other	
		Grade A					
		Large	Medium	Small	Undergrds	Cracks	Loss
				(%)			
Cage Shape:							
Deep	61.25	63.70	23.54	3.40	5.90	1.35	2.21
Shallow	60.46	62.70	24.04	4.51	6.16	1.08	1.60
Cage Side:							
Wire	61.15	64.15	22.39	3.77	5.55	1.69*	2.50*
Solid metal	60.56	62.25	25.19	4.14	6.52	0.73	1.31
Strain:							
1	60.79	61.81	23.66	4.46	6.75	1.22	2.24
2	60.92	64.59	23.92	3.45	5.32	1.21	1.57

* P<.05

Table 9. Egg weight and egg quality data of two srains of SCWL layers housed in double-deck deep (30.5 x 45.7-cm) or exactly reverse cages

	Egg weight (g)	Egg grades					
		Grade A				Other	
		Large	Medium	Small	Undergrds	Cracks	Loss
					(%)		
Cage Shape:							
Deep	61.03	62.81	25.30	4.17	4.39	1.56	1.77
Shallow	60.70	63.31	25.19	4.29	4.59	1.74	1.28
Cage side:							
Wire	60.91	62.44	26.13	4.17	4.54	1.74	1.34
Solid metal	60.82	63.68	24.29	4.28	4.44	1.56	1.71
Density:							
3 birds	60.89	62.59	25.43	3.22*	5.37	1.69	1.85
4 birds	60.84	63.53	24.99	5.24	3.61	1.61	1.20
Strain:							
1	61.23	62.14	24.13	4.15	6.10**	2.34**	1.58
2	60.49	63.98	26.29	4.31	2.88	0.96	1.57

* $P<.05$; ** $P<.01$

egg weight tended to increase as area per bird decreased and Cunnningham and Ostrander (1981) found that egg weight decreased as density in deep cages was increased.

A significant ($P<.05$) cage shape by strain interaction was observed in double-level cages (Table 10). Strain 1 birds housed in deep cages laid heavier eggs (61.85 g) than Strain 1 birds in shallow cages (60.61 g).

Table 10. Cage shape by strain interaction for egg weight of birds housed in double-deck cages

Cage shape x strain	Egg weight
	(g)
Deep x strain 1	61.85[a1]
Shallow x strain 2	60.78[ab]
Shallow x strain 1	60.61[b]
Deep x strain 2	60.20[b]

[1]Means with different superscripts differ significantly ($P<.05$).

Egg Quality. Cage shape and type of cage side partition for birds in double-deck cages had no significant effects on percentages of various sizes of Grade A, undergrades, cracked, and loss eggs (Table 9). Our cage shape results agree with those of Carey (1982), Swanson and Bell (1977), Ouart and Adams (1982), VanSkike and Adams (1983), and Cunningham and Ostrander (1981). However Cunningham and Ostrander (1982) reported that birds in shallow cages produced larger eggs than those in deep cages.

A significant cage shape by cage side partition interaction was noted for eggs classified as Loss (Table 11). Birds kept in double-deck deep cages with solid metal partitions produced more loss eggs (2.61%) than those in shallow cages with solid metal partitions (0.82%). Increased bird movement and birds climbing over each other at the front of the cage resulting in pain and nervousness increased the incidence of loss eggs in deep cages.

Table 11. Cage shape by type of cage side partition interaction for eggs classified as loss in double-deck cages

Cage shape x cage side partition	Loss
	(%)
Deep x solid metal	2.61[a1]
Shallow x wire	1.73[ab]
Deep x wire	0.94[b]
Shallow x solid metal	0.82[b]

[1] Means with different superscripts differ significantly (P<.01).

Significantly (P<.05) more eggs classified as loss (2.50 vs. 1.31%) and cracks (1.69 vs. 0.73%) were produced by birds in single-deck cages with wire partitions than solid metal partitions (Table 8). The presence of solid side partitions preventing visual contact between neighbors may have decreased bird movement resulting in a lower incidence of cracked and loss eggs.

Birds housed four per double-deck cage produced significantly (P<.05) more small eggs than birds housed three per cage (5.24 vs. 3.22%), as shown in Table 9. However Cunningham (1982) found no significant differences in egg quality when birds were housed at different densities. Ouart and Adams (1982) and Cunningham and Ostrander (1982) found that more undergrade eggs were produced at higher densities.

Strain 1 birds housed in double-deck cages produced significantly (P<.01) more eggs classified as cracks (2.34 vs. 0.96%) and undergrades (6.10 vs.

2.88%) than Strain 2 birds (Table 9). No significant effects of strain on percentages of various sizes of Grade A, cracked, and loss eggs was observed in single-deck cages.

Feather Condition. Average feather scores per cage were determined by averaging the individual scores of each bird in a cage at 54 and 65 weeks of age. Data in Table 12 show that birds in single-deck shallow cages had significantly ($P<.05$) better feather cover scores than those in single-deck deep cages (5.8 vs. 5.4). These results agree with the findings by Hughes and Black (1976, 1977), Hill and Hunt (1978), and VanSkike and Adams (1982) indicating that shallow caged birds had better feather covering than those in deep cages.

Birds housed four per double-deck cage had significantly ($P<.001$) lower feather cover scores than hens housed three per cage (4.6 vs. 5.4) as shown in Table 13. Decreased floor space increased the possibility of birds stepping over each other causing feather abrasion against the partitions of the cages. These results agree with those of Hill and Hunt (1979) and Ouart and Adams (1982).

Type of cage side partition had no significant effect on feather cover although it was observed that birds in double-deck cages with solid metal partitions had better feather scores (Table 13).

A significant ($P<.01$) cage side partition by density interaction was observed (Table 14). Birds housed at lower densities in either wire or solid sided cages had better feather cover than birds housed at higher densities. The presence of wire partitions in high density environments increased feather loss through abrasion against the sides.

Latency To Feed As A Nervous Response. Latency to feeding as a measure of fear response from exposure to a novel stimulus (Craig et al., 1982) was used. Data in Table 12 shows that birds in deep cages resumed feeding significantly ($P<.05$) earlier than those in shallow cages (50 vs. 23 sec). The metronome was positioned in the middle of the cage making it possible for birds in shallow cages to feed at the edges of the cage more easily than in deep cages. In spite of this, birds in deep cages resumed feeding earlier indicating that the need to satisfy their hunger drive was a greater need than fear of the observer or stimulus (VanSkike and Adams, 1982).

A significant ($P<.05$) cage shape by cage side partition interaction was observed for birds housed in single-deck cages (Table 15) at 47 weeks. Hens in shallow cages with solid metal partitions returned to feed later (190 sec) than those in deep cages with solid metal partitions (81 sec). This supports the idea that the hunger drive was a greater need.

No significant differences were observed for the average time for birds to return to feed in double-deck cages (Table 13). It was observed that density had no significant effect on time to return to feeding during tests at 47 and 61 weeks. However Hill and Hunt (1978) and Sefton (1976) found that birds were more nervous as density increased.

There was a trend for birds to return to feed earlier during the second test (61 weeks) in both the single- and double-deck cages. It is postulated that the birds may have become adapted to the stimulus.

Table 12. Feather scores and latency to feeding of birds housed in single-deck cages

	Feather score[1]	Latency to feed 47 wk	Latency to feed 61 wk
		(sec)	
Cage shape:			
Deep	5.4*	114	23*
Shallow	5.8	134	50
Cage side:			
Wire	5.6	125	28
Solid metal	5.5	123	40
Strain:			
1	5.2***	97	35
2	5.9	158	33

[1] Higher feather scores denote less feather damage.

* $P<.05$; *** $P<.001$

Table 13. Feather score and latency to feeding of birds housed in double-deck cages

	Feather score[1]	Latency to feed 47 wk	61 wk
		(sec)	
Cage shape:			
Deep	5.1	100	45
Shallow	4.9	89	27
Cage side:			
Wire	4.9	87	33
Solid metal	5.1	102	37
Density:			
3 hens/cage	5.4***	75	26
4 hens/cage	4.6	117	47
Strain:			
1	5.0	91	29
2	5.6	97	42

[1] Higher feather score denote less feather damage.

*** P<.001

Table 14. Type of cage side partition by density interaction effect on feathering in double-deck cages

Cage side partition x density	Feather score[1]
Wire x 3 birds/cage	5.5[a2]
Solid metal x 3 birds/cage	5.3[ab]
Solid metal x 4 birds/cage	4.9[b]
Wire x 4 birds/cage	4.3[c]

1 Higher feather score denote less feather damage.
2 Means with different superscripts differ significantly ($P<.01$).

Table 15. Cage shape by cage side partition interaction at 47 weeks in single-deck cages for latency to feeding

Cage shape x side partition interaction	Latency to feeding
	(sec)
Shallow x solid metal	190[a1]
Deep x wire	165[ab]
Shallow x wire	97[ab]
Deep x solid metal	81 [b]

1 Means with different superscripts differ significantly ($P<.05$).

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APPENDIX

Table A-1. KSU 20% protein chick starter ration (fed from 0 to 8 weeks)

Ingredients	Amount per 45.4 kg (100 lb)
Corn, yellow, ground	13.62
Sorghum grain, ground	13.62
Soybean oil meal, 44% protein	12.26
Alfalfa meal, 17% protein	2.27
Fish meal, 60% protein	1.36
Fermentation solubles	0.91
Ground limestone	0.68
Dicalcium phosphate	0.45
Salt	0.23
Added per 45.4 kg:	
Trace mineral mix	23 g
Vitamin A (10,000 USP units/g)	10
Vitamin D_3 (15,000 ICU/g)	5
B-Complex vitamin mix	46
Vitamin B_{12} (12 mg/kg)	10
Antibiotic supplement	16
D-L Methionine	23
Coccidiostat	23
<u>Calculated Analysis</u>	
Crude protein (%)	20.11
Metabolizable energy (kcal/kg)	2834
Calcium (%)	1.13
Phosphorus (%)	0.63
Methionine (%)	0.35

Table A-2. KSU 18% protein chick grower ration (fed from 8 to 12 weeks)

Ingredients	Amount per 45.4 kg (100 lb)
Corn, yellow, ground	11.58
Sorghum grain, ground	11.35
Soybean oil meal, 44% protein	6.56
Alfalfa meal, 17% protein	2.27
Fish solubles	0.91
Oats, ground	4.54
Wheat standard middlings	4.54
Meat and bone scraps, 50% protein	2.52
Ground limestone	0.45
Dicalcium phosphate	0.45
Salt	0.23
Added per 45.4 kg:	
Trace mineral mix	23 g
Vitamin A (10,000 USP units/g)	10
Vitamin D_3(15,000 ICU/gm)	5
B-Complex vitamin mix	23
Vitamin B_{12} (12 mg/kg)	10
Antibiotic supplement	23
D-L Methionine	23
Coccidiostat	23
Choline Chloride, 25% mix	80
Calculated Analysis	
Crude protein (%)	18.46
Metabolizable energy (kcal/kg)	2692
Calcium (%)	1.25
Phosphorus (%)	0.83
Methionine (%)	0.28

Table A-3. KSU 16% protein chick grower ration (fed from 12 to 18 weeks)

Ingredients	Amount per 45.4 kg (100 lb)
Corn, yellow, ground	13.62
Sorgum grain, ground	15.89
Oats, ground	2.27
Alfalfa meal, 17% protein	3.41
Soybean oil meal, 44% protein	9.10
Ground limestone	0.45
Dicalcium phosphate	0.45
Salt	0.23
Added per 45.4 kg:	
Trace mineral mix	23 g
Vitamin A (10,000 USP units/g)	5
Vitamin D_3 (15,000 ICU/g)	4
B-Complex vitamin mix	10
Vitamin B_{12} (12 mg/kg)	10
Antibiotic supplement	23
Methionine	23
Coccidiostat	23
<u>Calculated Analysis</u>	
Crude protein (%)	16.43
Metabolizable energy (kcal/kg)	2884
Calcium (%)	0.76
Phosphorus (%)	0.53
Methionine (%)	0.26

Table A-4. KSU 17% protein layer ration

Ingredients	Amount per 45.4 kg (100 lb)
Corn, yellow, ground	15.06
Sorghum grain, ground	14.98
Alfalfa meal, 17% protein	1.82
Soybean oil meal, 44% protein	7.26
Fish meal, 65% protein	0.91
Pro-Pak, 60% protein	0.91
Meat and bone meal	0.91
Ground limestone	0.45
Dicalcium phosphate	2.72
Salt	0.23
Added per 45.4 kg:	
Trace mineral mix	23 g
Zinpro-40	46
Vitamin A (10,000 USP units/g)	15
Vitamin D_3 15,000 ICU/g)	7
Vitamin E	5
B-Complex vitamin mix	23
Vitamin B_{12} (20 mg/kg)	23
Antibiotic supplement	23
Methionine	23
Choline Chloride	60
<u>Calculated Analysis</u>	
Crude protein (%)	17.00
Metabolizable energy (kcal/kg)	2827
Calcium (%)	3.30
Phosphorus (%)	0.67
Methionine (%)	0.28

Table A-5. KSU 12% step-up protein experimental grower ration (fed from 0 to 12 weeks)

Ingredients	Amount per 45.4 kg (100 lb)
Corn, yellow, ground	17.88
Sorghum grain, ground	17.88
Oats, ground	2.27
Soybean oil meal, 44% protein	5.27
Limestone	0.58
Dicalcium phosphate	1.13
Salt	0.09
Vitamin premix	0.26
Trace mineral mix	0.02
Amprol	0.02
Calculated Analysis	
Crude protein (%)	12.50
Metabolizable energy (kcal/kg)	3071
Calcium (%)	1.09
Phophorus (%)	0.78
Methionine (%)	0.21

Table A-6. KSU 16% step-up protein experimental grower ration (fed from 12 to 16 weeks)

Ingredients	Amount per 45.4 kg (100 lb)
Corn, yellow, ground	13.94
Sorghum grain, ground	13.94
Oats, ground	5.78
Animal Fat	0.45
Soybean oil meal, 44% protein	9.53
D-L Methionine	0.01
Limestone	0.34
Dicalcium phosphate	0.91
Salt	0.23
Vitamin Premix	0.23
Trace mineral mix	0.02
Amprol	0.02
<u>Calculated Analysis</u>	
Crude protein (%)	15.87
Metabolizable Energy (kcal/kg)	3001
Calcium (%)	0.79
Phosphorus (%)	0.72
Methionine (%)	0.27

Table A-7. KSU 18% step-up protein experimental grower ration (fed from 16 to 18 weeks)

Ingredients	Amount per 45.4 kg (100 lb)
Corn, yellow, ground	15.06
Sorghum grain, ground	13.62
Soybean oil meal, 44% protein	13.62
Oats, ground	0.91
Dicalcium phosphate	0.91
Limestone	0.34
Salt	0.23
Vitamin premix	0.23
Trace mineral mix	0.02
D-L Methionine	0.01
Fat	0.45
<u>Calculated Analysis</u>	
Crude protein (%)	18.47
Metabolizable energy (kcal/kg)	2991
Calcium (%)	0.81
Phosphorus (%)	0.75
Methionine (%)	0.31

Table A-8. Analysis of variance for initial housing weights

Source of variation	df	MS
Strain	1	677.05
Ration	1	729711.47***
Strain x Ration	1	39687.78
Error	309	10830.73

***P<0.001

Table A-9. Analysis of variance for egg production, mortality, age at sexual maturity, and feather score of birds housed in single-deck deep or exactly reverse cages

Source of variation	df	Age at sexual maturity (days)	Egg production (%)		Mortality (%)	Feather score
			HH	HD		
		-MS-	-MS-	-MS-	-MS-	-MS-
Shape (S)	1	6.80	302.19	1195.08***	581.12	6.25*
Wall (W)	1	1.37	41.41	2.62	173.86	0.28
S x W	1	0.15	61.45	107.91	331.95	0.05
Strain (ST)	1	10.82	647.95*	432.52**	4794.01***	16.45***
Ration (R)	1	54.45***	51.53	0.15	52.39	1.76
ST x R	1	0.08	243.41	0.76	490.14	0.02
S x ST	1	0.55	62.74	27.63	331.95	0.99
S x R	1	1.03	410.74	80.61	581.12	0.53
W x ST	1	1.26	5.93	1.88	264.11	0.93
W x R	1	0.59	129.56	37.02	623.02	0.76
S x W x R	1	0.85	78.52	140.57	28.37	0.41
S x W x ST	1	0.70	2.84	2.35	125.75	0.04
S x ST x R	1	0.85	409.08	1.14	899.59	1.38
W x ST x R	1	1.37	233.06	0.44	951.59	0.18
Error	113	2.43	144.48	49.85	367.32	1.05

*P<.05, **P<.01, ***P<.001

Table A-10. Analysis of variance for egg production, mortality, age at sexual maturity, and feather score of birds housed in double-deck deep or exactly reverse cages

Source of variation	df	Age at sexual maturity (days)	Egg production (%)		Mortality (%)	Feather score
			HH	HD		
		-MS-	-MS-	-MS-	-MS-	-MS-
Shape (S)	1	1.97	228.31	42.71	1799.5*	1.76
Wall (W)	1	0.06	58.96	9.00	1326.51*	2.54
S x W	1	0.79	3.38	18.00	43.73	0.35
Strain (ST)	1	14.73***	0.41	509.44**	2031.31**	0.16
Ration (R)	1	54.45***	51.53	0.15	52.39	1.76
ST x R	1	3.48	391.89	3.30	83.72	0.43
S x ST	1	0.32	397.42	44.91	309.01	0.21
S x R	1	1.14	9.79	77.09	9.90	0.44
W x ST	1	1.56	101.31	57.08	357.80	0.20
W x R	1	1.24	0.16	46.60	541.10	0.07
S x W x R	1	0.35	<0.01	0.93	4.95	2.22
S x W x ST	1	0.12	18.97	82.49	240.27	1.74
S x ST x R	1	0.14	3.26	97.14	111.98	1.35
W x ST x R	1	1.41	72.84	6.28	394.27	0.36
Density (D)	1	1.84	864.48**	821.28***	396.95	23.59***
S x D	1	0.79	5.67	82.88	121.92	0.03
R x D	1	0.35	104.63	55.63	253.68	3.29
ST x D	1	5.17*	53.29	133.43	97.09	0.29
W x D	1	0.69	413.79	0.70	1432.70*	5.73*
S x R x D	1	3.15	29.21	175.73	176.94	<0.01
S x ST x D	1	1.58	608.72*	52.43	673.30	1.11
S x W x D	1	0.17	0.19	29.50	12.33	0.13
ST x R x D	1	0.02	10.34	25.01	442.65	<0.01
W x ST x D	1	0.26	237.36	<0.01	97.29	2.37
W x R x D	1	0.34	5.67	44.35	962.65	0.47
Error	122	1.24	111.84	49.43	274.63	0.82

*P<.05, **P<.01, ***P<.001

Table A-11. Analysis of variance for egg weight and egg quality of birds housed in single-deck deep or exactly reverse cages

Source of Variation	df	Egg wt (g)	Grades: Grade A: Large	Grades: Grade A: Medium	Grades: Grade A: Small	Grades: Undgr	Other: Cracks	Other: Loss
		-MS-	-MS-	-MS-	-MS-	-MS-	-MS-	-MS-
Shape (S)	1	992.25	16.09	4.05	19.59	1.11	1.16	5.86
Wall (W)	1	552.25	58.15	125.34	2.12	14.97	14.88	22.51*
S x W	1	390.06	22.93	23.65	0.01	17.53	0.05	10.69
Strain (ST)	1	25.00	123.22	1.11	16.52	32.72	<0.01	7.09
Ration (R)	1	900.00	18.01	13.86	0.32	12.76	2.09	3.53
ST x R	1	588.06	29.36	0.60	37.52	96.13	1.09	5.56
S x ST	1	10.56	80.51	65.16	7.41	0.65	0.56	1.46
S x R	1	217.56	5.20	3.28	15.87	1.04	1.23	0.79
W x ST	1	945.56	67.16	126.83	0.92	12.26	0.24	0.44
W x R	1	68.06	85.54	0.12	6.26	3.77	2.32	15.44
S x W x R	1	2916.00*	440.81*	274.82*	39.58	1.33	0.08	1.04
S x W x ST	1	784.00	36.47	4.18	51.57	6.58	3.56	0.89
S x ST x R	1	625.00	9.05	7.19	14.20	0.26	0.51	2.47
W x ST x R	1	256.00	26.15	19.11	0.98	9.84	1.77	0.41
Error	49	576.06	89.52	64.85	11.68	34.70	2.88	5.05

*P<.05

Table A-12. Analysis of variance for egg weight and egg quality of birds housed in double-deck deep or exactly reverse cages

			Grades				Other	
			Grade A					
Source of Variation	df	Egg wt (g)	Large	Medium	Small	Undgr	Cracks	Loss
		-MS-	-MS-	-MS-	-MS-	-MS-	-MS-	-MS-
Shape (S)	1	229.68	6.43	0.67	0.07	0.79	0.73	5.42
Wall (W)	1	16.72	32.70	73.80	0.36	0.19	0.67	3.01
S x W	1	228.23	338.74	63.73	1.19	12.63	5.82	35.85*
Strain (ST)	1	1163.61	67.13	104.44	1.82	228.32**	42.11**	0.25
Ration (R)	1	1344.08	212.97	105.25	5.64	34.19	0.81	2.53
ST x R	1	623.52	7.94	9.15	3.43	21.01	3.14	3.42
S x ST	1	1752.08*	179.97	401.57*	0.48	11.06	0.14	6.48
S x R	1	201.44	86.21	9.07	17.45	41.09	4.11	1.32
W x ST	1	320.33	97.02	12.09	8.64	3.89	0.64	0.01
W x R	1	15.94	34.66	49.73	14.59	6.71	0.96	0.01
S x W x R	1	48.00	14.33	22.09	0.28	11.35	0.06	1.93
S x W x ST	1	148.16	187.59	5.63	8.54	115.35*	17.40	0.36
S x ST x R	1	59.25	73.56	3.56	7.20	53.70	4.03	1.83
W x ST x R	1	22.23	74.99	15.56	29.10	4.68	0.24	3.24
Density (D)	1	5.55	17.29	4.12	93.79*	66.28	0.12	8.91
S x D	1	192.00	36.13	34.28	1.63	18.11	11.47	5.92
R x D	1	266.02	0.08	23.90	11.68	18.07	3.75	18.39*
ST x D	1	270.75	654.20*	4.27	42.59	192.46**	<0.01	0.93
W x D	1	173.78	59.97	20.61	0.89	23.22	0.12	0.14
S x R x D	1	700.23	108.48	4.36	3.00	68.43	4.43	3.16
S x ST x D	1	642.89	281.48	304.69*	5.30	1.02	5.41	2.36
S x W x D	1	281.94	95.55	2.54	2.46	114.12	<0.01	1.02
ST x R x D	1	213.92	8.14	27.81	3.71	19.63	1.96	5.37
W x ST x D	1	295.02	3.94	44.35	0.28	59.05	7.85	2.99
W x R x D	1	800.33	1.51	22.26	8.72	50.74	6.58	0.28
Error	65	389.11	105.70	65.74	13.99	25.95	5.58	4.51

*P<.05. **P<.01

Table A-13. Analysis of variance for body weight gain (18-66 wk) of birds housed in single-deck cages

Source of variation	df	MS
Shape (S)	1	0.34
Wall (W)	1	545.62
S x W	1	14.67
Strain (ST)	1	57.16
Ration (R)[1/]	1	791.42*
ST x R	1	463.06
S x ST	1	264.55
S x R	1	7.18
W x ST	1	37.23
W x R	1	83.59
S x W x R	1	262.92
S x W x ST	1	605.06
S x ST x R	1	176.98
W x ST x R	1	115.79
Error	16	167.09

[1/] Rearing diets fed from 0-18 weeks, * $P<0.05$

Table A-14. Analysis of variance for body weight gain (18-66 wk) of birds housed in double-deck cages.

Source of variation	df	MS
Shape (S)	1	138.30
Wall (W)	1	434.35**
S x W	1	49.43
Strain (ST)	1	330.02*
Ration (R)	1	301.52*
ST x R	1	0.01
S x ST	1	17.02
S x R	1	6.11
W x ST	1	1.20
W x R	1	14.76
S x W x R	1	134.90
S x W x ST	1	131.58
S x ST x R	1	0.79
W x ST x R	1	267.35*
Density (D)	1	379.40*
S x D	1	142.67
R x D	1	23.20
ST x D	1	0.19
W x D	1	45.24
S x R x D	1	170.12
S x ST x D	1	228.35*
S x W x D	1	< 0.01
ST x R x D	1	< 0.01
W x ST x D	1	62.96
W x R x D	1	146.31
Error	36	54.57

$^{*}P<0.05$, $^{**}P<0.01$

Table A-15. Analysis of variance for latency to feeding of birds housed in double-deck cages

Source of variation	df	Latency to feeding (47 wk) MS	Latency to feeding (61 wk) MS
Shape (S)	1	<0.01	0.73
Wall (W)	1	0.06	0.02
S x W	1	0.79	0.42
Strain (ST)	1	0.01	0.37
S x ST	1	0.34	0.37
W x ST	1	0.35	0.28
S x W x ST	1	1.00	0.01
Density (D)	1	0.59	1.08
S x D	1	0.59	0.87
W x D	1	0.01	0.02
S x W x D	1	1.84*	1.04
ST x D	1	0.06	0.05
S x ST x D	1	0.51	0.03
W x ST x D	1	0.19	0.11
S x W x ST x D	1	0.01	0.83
Error	48	0.34	0.43

*P<0.05

Table A-16. Analysis of variance for latency to feeding of birds housed in single-deck cages

Source of variation	df	Latency to feeding (47 wk) MS	Latency to feeding (61 wk) MS
Shape (S)	1	0.06	1.36
Wall (W)	1	<0.01	0.29
S x W	1	1.13*	0.17
Strain (ST)	1	0.52	0.01
S x ST	1	0.10	0.01
W x ST	1	0.04	0.06
S x W x ST	1	0.63	0.08
Error	45	0.24	0.24

*P<0.05

THE EFFECTS OF REARING DIETS, CAGE SHAPE, AND TYPE OF CAGE SIDE PARTITION ON THE PRODUCTIVITY AND WELL-BEING OF LAYERS

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AN ABSTRACT OF A MASTER'S THESIS

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Two commercial strains of SCWL chicks were fed either step-up or step-down protein diets to 18 weeks. Then they were randomly housed three per cage in single-deck deep (25.4 x 45.7-cm) and its exact reverse cages or three or four per cage in double-deck deep (30.5 x 45.7-cm) and its exact reverse cages. Half of each cage shape combination had either a wire or a solid metal side partition. Rearing diets, cage shape, cage side, and bird density effects on productivity and well-being were analyzed from 18 to 66 weeks.

Pullets on the step-up protein diets had significantly lower ($P<.001$) housing weights (1184 vs. 1282 g), delayed sexual maturity and higher body weight gain from 18 through 66 weeks. No significant effects on egg production and egg quality were observed.

Cage shape and type of cage side partition did not significantly affect egg production, egg size and quality in double-deck cages. Hens in single-deck shallow cages had significantly ($P<.001$) higher rates of lay than those in deep cages (79 vs. 76% HD). Hens in single-deck cages with wire sides had significantly more loss (2.50 vs. 1.31%) and cracked (1.69 vs. 0.73%) eggs. Mortality rates were higher in cages with solid metal sides for single- (15 vs. 12%) and double-deck (15 vs. 9%) cages. Birds in cages with solid metal sides had higher 18-66 weeks body weight gains. Birds in single-level shallow cages had significantly better feather scores (5.8 vs. 5.4) than those in deep cages. Latency to feed, an indication of nervousness, did not differ significantly between treatments.

Birds housed three per cage had significantly higher rates of lay and better feathering than those housed four per cage.

Significant strain differences were observed for egg production, mortality rates, body weight gain, and egg quality.