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By

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ABSTRACT

THE EFFECT OF CAGE SHAPE AND BIRD DENSITY ON PERFORMANCE OF RECYCLED HENS

By

Talal H. Hussein

Recycled White Leghorn hens, 17 months old, were housed in conventional 12" x 16" (30.48 x 40.64 cm.) cages and reverse 16" x 12" (40.64 x 30.48 cm.) cages at three or four bird density.

Egg production was significantly ($P < 0.01$) affected by bird density in favor of three birds per cage. Significantly ($P < 0.05$) heavier eggs with higher shell weight were obtained from birds housed in conventional cages.

Feed consumption was significantly ($P < 0.05$) more for birds kept at low density than for birds kept at high density.

Mortality was significantly ($P < 0.01$) higher among birds housed in reverse cages at four bird density than it was among those housed at three bird density.

Body weight gain was significantly ($P < 0.01$) higher for birds housed in conventional cages over the whole experimental period.

To My Country

and

My Family

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INTRODUCTION

The practice of forced molting in laying hens is a technique used to cause hens to stop laying and take a rest. This process overcomes some of the shortcomings of older birds to be used for further egg production.

The intent of this research was not to study the area of force molting per se, but rather the effect of housing force molted birds in different types of cages at different bird densities on their subsequent performance.

The use of cages in the poultry industry has been developed in an attempt to utilize vertical space, thus, with the same number of birds a house can be reduced in size and some economy be realized.

Since the optimum number of layers to house in a given type of cage is a very controversial subject in the poultry industry, numerous studies have been done to investigate the effect of cage size and number of birds per cage on performance of caged hens.

There is still no consistent results to show the definite cage size and number of birds per cage at which crowding becomes economically very impractical.

Recently, the idea of using reverse or shallow cages has entered the cage size debate. These cages are designed to be wider but shallower, from front to back, so that the possibility of insufficient feed intake will be reduced and, thus, egg production will be improved.

Results of many researches have shown better laying performance from birds housed in reverse or shallow cages as compared to that of those housed in conventional or deep cages.

To gain additional information concerning the type of cage and bird density, an experiment was conducted at Michigan State University, Poultry Science Department Research and Teaching Center. Birds used in this test were 17-month-old Shaver strain White Leghorns. They had produced an average of 242 eggs per hen housed with a livability of 94% over a 12-month production period prior to being force molted.

To force molt the birds, feed, water and light were concurrently restricted. Feed restriction continued for the first week, water restriction continued for the first two days and light restriction continued for the first two weeks.

The main objective of this investigation was to determine the effect of cage shape, deep 12" x 16" (30.48 x 40.64 cm.) and shallow 16" x 12" (40.64 x 30.48 cm.), and bird density, three and four birds per cage, on egg production, egg quality, feed utilization, mortality and body weight gain of recycled hens.

LITERATURE REVIEW

The practice of force molting to improve egg production, egg quality, and shell quality has gained more popularity in the last ten years.

Force molting can be done at any time of the year by anyone of several methods and techniques.

The conventional method is to restrict the feed and/or water and keep the birds in the dark for 2-3 weeks. Using Enheptin (2 amino -5 nitro thiozol) at 1% in the ration gave better results from standpoints of egg production, body weight loss, and mortality than did the feed and water intake restriction (Robblee and Clandinin, 1954). The use of zinc-oxide in the ration is one of the latest methods developed to induce forced molting (Creger, 1976). In this method, zinc-oxide is added to the ration at a level of 25,000 ppm for one week and then reduced to 50 ppm which is the regular amount of zinc in the layer ration. Better results were obtained by the zinc-oxide method than the conventional method. A reduction in death losses, less feather shedding, rapid production cessation and a faster return to egg production were observed when compared to the conventional force molting method.

Hamm and Welter (1965) performed an early forced molt upon birds at nine months of laying age and noted a higher percentage of egg production after molt than prior to molting.

Berg and Bearse (1947) reported an improvement in egg weight and shell thickness following the molting process of yearling White Leghorn hens. Hill (1966) conducted an experiment for the purpose of comparing performance of pullets, force molted hens, and nonforced molted hens. In ten-28-day periods, results showed superior egg weights for molted hens over the other two groups.

Hansen (1960) and Len et al. (1964) reported an improvement in shell thickness of eggs laid in the post molt period.

Mati and Shrivastava (1974) investigated the effect of force molting upon egg production, egg properties and hatchability in breeding hens. Forced molting resulted in an increase in egg production, hatchability and improved egg size.

Early in the 1930's a trend toward housing layers in cages resulted from an effort to use the vertical space of poultry houses.

The first recorded use of laying cages in this country was in 1924 by D. C. Kennard at the Ohio Agricultural Experiment Station. The cages he used were thirty inches square (76.20 cm^2) (McNiece, 1959). Two years later, tests were started with individual layers in 18" (45.72 cm.) cages. Interest in cages developed because there was a feeling that pullet performance improved with a subsequent saving in production cost.

Cages have advantages over litter floor systems. Summarized are the advantages of cages over litter floor pens (Thompson, 1939 and Claybaugh, 1966).

1. Lower investment cost per bird; the use of vertical space will reduce building size, thus some economy will be realized
2. Less expenses for medication; pullets in cages offer the opportunity to provide a more ideal disease free environment

3. Dust level can be reduced
4. Culling the nonproductive birds is easier
5. Improve body weight and egg size
6. More systematic and orderly management
7. Elimination of crowding losses and regular replacement and handling is simpler
8. Restriction of the feed is easier.

The following are the more serious disadvantages of the cages scheme (Thompson, 1939 and Claybaugh, 1966).

1. Higher initial monetary investment of cage equipment and higher cost of depreciation
2. The ration should be tailored for cage confined birds
3. Fly control could be more difficult in open housing
4. Extra labor for moving birds
5. Cannibalism may occur quicker than on the floor
6. Manure is handled as pure manure

Accordingly, a lot of research has been done to compare layer performance in cages versus floor systems.

Morgan (1954) compared two groups of White Leghorns. One group was distributed in 10" x 18" (25.4 x 45.7 cm.) cages and the other group was housed in a wood floor pen. The hens in cages laid slightly better (183 eggs) than those on the floor (167 eggs). Feed conversion per dozen eggs was 4.71 lbs. for caged birds and 4.99 lbs. for floor housed birds. He also found that body weight gain was less for the floor birds than for caged birds. Shupe and Quisenberry (1961) studied the performance of birds housed in floor pens, individual cages, and colony cages. Their results indicated that egg production of individually caged birds was higher than that of either colony caged or floor birds. They also reported better feed efficiency and less mortality in individual caged birds than in those kept on the floor or in colony cages.

Berry (1952) obtained better egg production from caged birds than from floor birds. Parker and Rodgers (1957) reported that egg production was essentially equal with little advantage for birds in the floor housing system when compared with those in individual or colony cages.

On the other hand, some workers have reported better performance for birds kept on the floor than for cage housed birds. Lowry et al. (1956), in four years of experiments, found that the egg production rate for floor birds was 15 eggs per bird more than for their full sisters housed in individual cages. They also found, however, that caged birds showed significantly lower mortality and produced heavier eggs (2.5 gms.) than did floor birds.

Bailey et al. (1959) found that caged birds outproduced floor housed birds by 1.3 percent. Likewise, Shupe and Quisenberry (1961) found that individually caged birds outproduced floor birds by 9.3 percent. Both groups of workers reported heavier eggs and body weights, less mortality, and better feed efficiency for caged birds than for floor housed birds.

At Pennsylvania State University, birds in one-bird cages, two-bird cages, three-bird cages, and twenty-bird cages were compared to birds on conventional litter floors and birds on slatted floors (Michalson, 1964). In this test, egg production tended to be lower from birds in cages than from birds in floor houses. In addition, the mortality was higher for caged birds than for those in floor systems. Froning and Funk (1958) found that birds housed on litter floor produced 2.4 percent more eggs than those kept in cages, but caged birds laid larger eggs with slightly thicker shells than did floor birds.

Logan (1965) demonstrated that floor housed birds produced 10 eggs more per year than caged birds, but the egg weights were greater and incidence of blood spots higher for caged birds. Mortality was greater among floor birds than it was in caged birds.

Johnson (1961) conducted two studies that compared performance of chickens in cages, on a slatted floor, and on a litter floor. He found no difference in egg production between birds housed individually in cages and those on a litter floor. However, there was a significant difference in egg production between single caged birds and slatted floor housed birds in favor of those housed individually in cages. He also found that caged birds were heavier and their eggs weighed more, than slatted or litter floor birds. Mortality was higher during both studies in the slatted floor birds than in either of the other two groups.

In general, comparing caged and floor birds has given results which are inclusive and sometimes contradictory. In an attempt to explain these discrepancies, Gowe (1956) stated that "some strains of S.C. White Leghorns were better adapted to cages than other strains."

From the literature reviewed, there would, perhaps, be general agreement that somewhat higher egg production can be obtained from floor layers than cage layers, whereas heavier eggs can be obtained from caged layers.

Since the rush to cages began, several studies have compared the effect of cage size and bird density on performance of caged layers. The following review will be dealing with layer's performance in different type of cages and different densities.

Egg Production: A plethora of work has been done comparing egg production in different size cages and/or at different bird densities. Sicer (1964), in one trial, compared layer performance of three or four birds in 12" x 18" (30.48 x 45.72 cm.) cages. He found that, in five months, birds at the four-bird density produced seven eggs less per bird than birds at the three-bird density. Bramhall (1966) also reported more egg production (+4.9%) for birds at three-bird density than for birds at four-bird density in 12" x 18" (30.48 x 45.72 cm.) cages. Adams and Jackson (1970) investigated the effect of bird density on egg production efficiency. Two or four birds were placed in 12" x 18" (30.48 x 45.72 cm.) cages. Six egg production strains were used. The same all mash ration and same debeaking procedures were utilized for all birds in the experiment. The results showed that the average hen-housed production for birds at the two-bird density was 60.75 percent compared to 50.1 percent for birds at four-bird density. These results concurred with the observations made by Logan (1965) and Wilson et al. (1967) who reported that crowding the birds reduced the rate of lay.

Bell and Little (1966), in an experiment in which birds were assigned as two, three, or four birds in 12" x 18" (30.48 x 45.72 cm.) cages, found that hen-day production was inversely proportional to the bird density in that size cage.

Bell (1964) compared three versus four hens per 12" x 18"

(30.48 x 45.72 cm.) cage. The average hen-day production was 64 percent for birds at the three-bird density while it was 61.7 percent for birds at the four-bird density. On the other hand, Wayman et al. (1969) found no significant depression in egg production as bird density increased from two to four in 12" x 18" (30.48 x 45.72 cm.) cages. Rooney et al. (1965) obtained 66.5 percent production from three hens compared to 67.6 percent from two hens in 12" x 18" (30.48 x 45.72 cm.) cages. They also compared three versus four birds in 12" x 18" (30.48 x 45.72 cm.) cages through a period of 48 weeks and again hen-housed production was in favor of low-bird density.

Ostrander and Young (1970) concluded that, from the standpoint of egg production, it was more profitable to place four birds per 12" x 18" (30.48 x 45.72 cm.) cage than to place two, three, or five birds per cage. Conversely Bell (1977) reported that three birds per cage resulted in the highest returns and would be the recommended density in 12" x 18" (30.48 x 45.72 cm.) cages. Cook and Dembnicki (1966) assigned one and two birds in 10" x 18" (25.40 x 45.72 cm.) cages and five birds in 20" x 18" (50.8 x 45.72 cm.) cages. Through a 280 day production period, the average hen-housed production was significantly higher for individually housed birds than for other groups.

Lowe and Heywang (1964), using White Leghorn pullets, compared the performance of single and multiple birds in four housing regimes. Individual birds in 8" x 18" (20.32 x 45.72 cm.) cages, two birds in 12" x 18" (30.48 x 45.72 cm.) cages and five birds in 24" x 18" (60.96 x 45.72 cm.) cages were studied. Results indicated that less egg production was obtained as bird density increased. Fox and Clayton (1960), Moore et al. (1965), Mather and Gleaves (1970), and

Dorminey and Arscott (1971) reported that egg production was highly affected by increasing bird density in different types of cages.

According to Walker et al. (1965) and Wilson et al. (1967), two birds performed better in 10" x 18" (25.40 x 45.72 cm.) cages than in 8" x 18" (20.32 x 45.72 cm.) cages. On the other hand, Wilson and his associates reported that individually caged birds laid more eggs per bird than two or three birds did in either type of cages. Rooney et al. (1965) obtained more eggs from housing one bird than two birds in 8" x 18" (20.32 x 45.72 cm.) cages. They also obtained equivalent hen-day production from housing either three or four birds in 16" x 18" (40.64 x 45.72 cm.) cages. The data obtained from two-336 day experiments showed an average hen-housed production of 65, 63, 61 and 51 percent for the four regimes, respectively. Regardless of cage size, lower hen-housed production was obtained as density increased. A significant difference in egg production was observed between birds in one bird cage and those in five birds per cage.

Magruder and Nelson (1966) found that the performance of two birds per cage was superior to that of a single bird in 8" x 16" (20.32 x 40.64 cm.) cages. Aitken et al. (1973) stated that there was a nine percent superiority in egg production of single birds in 8" x 16" (20.32 x 40.64 cm.) cages versus two birds housed in the same type of cages. Japanese researchers also compared different types of cages with different bird densities. Nakazawa et al. (1968), using five cage regimes of individually caged and multi-bird density in different cage sizes, found no significant difference in percentage of eggs produced from birds in the different regimes.

Feldkamp and Adams (1973) demonstrated higher egg production (+8 percent) from small size cages with low-bird density than from large size cages with high-bird density. Champion and Zindel (1968) housed egg type pullets under five cage regimes: Individual birds in 8" x 16" (20.32 x 40.64 cm.) cages; two pullets in 8" x 16" (20.32 x 40.64 cm.) cages; three pullets in 12" x 16" (30.48 x 40.64 cm.) cages; four pullets in 16" x 16" (40.64 x 40.64 cm.) cages; and six pullets in 24" x 16" (60.96 x 40.64 cm.) cages. Hen-housed production for individually caged birds was significantly superior to that of birds in the other treatments.

Shupe and Quisenberry (1961) reported that there was a significant difference in egg production in favor of individual caged birds compared with colony caged birds. Furthermore, from results of several studies, Quisenberry (1968) concluded that placing 2-5 birds in small cages with 350-465 sq. cm. per bird resulted in better performance than from birds in larger cages with similar space per bird.

Marr et al. (1967) reported that "two hens in a 10" x 16" (25.4 x 40.64 cm.) cage had higher performance than birds maintained in colonies of 3, 4, 5, or 6 per cage with comparable space per bird." Roy et al. (1967) found that egg production from 10 birds in colony cages was greater than individually caged birds or 2, 5 and 20 birds per cage with the same floor space per bird (0.625 sq. ft., 228.6 cm.).

Quisenberry (1965) demonstrated that colony cages with more than 10 birds per cage were less desirable than cages with smaller numbers of birds per cage. However, Hann and Harvey (1971) stated that "at a given density a small group of birds gave better economic performance than did the large groups."

There is evidence in the literature indicating that reversing the dimension of conventional layer cages to be wider but shallower resulted in greater egg production. In this respect, Bell (1972) compared the performance of pullets in conventional 12" x 16" (30.48 x 40.64 cm.) cages with that in the reverse, shallow, type of 18" x 12" (45.72 x 30.48 cm.). He used three or four bird density in each type of cage. Regardless of the cage shape, birds at the three bird density had more egg production than those at the four bird density. Comparing the density by shape, birds at three bird density in reverse cages laid 240 eggs on a hen-housed basis while those in the conventional cages, laid 215 eggs. Birds at four bird density in reverse and conventional cages produced 224 and 213 eggs on a hen-housed basis.

To gain further information, Bell (1976) conducted another trial to compare reverse cages 18" x 12" (45.72 x 30.48 cm.) with conventional 12" x 16" (30.48 x 40.64 cm.) and 12" x 18" (30.48 x 45.72 cm.) cages. Three or four birds per cage were used in each type of cage. Data of 24 weeks of egg production revealed better hen-day production for both densities from birds kept in reverse cages than for birds in either type of conventional cages.

To further clarify the situation, Bell (1977) repeated the same test over a production period of 56 weeks. Again, birds in reverse cages had superior egg production over those in conventional cages at the three and four bird density. Martin (1977) indicated that birds in shallow cages produced up to five percent more eggs than those in conventional cages when kept at the same density.

In a test comparing conventional 10" x 18" (24.40 x 45.72 cm.) cages with a density of two birds, conventional 12" x 18" (30.48 x 45.72 cm.) cages with a density of three birds versus shallow cages of 18" x 12" (45.72 x 30.49 cm.) with three birds per cage, Muir and Gerry (1976) found that hens kept in shallow cages laid more eggs than birds in the 12" x 18" cages but not more than the two birds in the conventional 10" x 18" cages.

However, according to recent research published by Canadian workers (Hill and Hunt, 1977), they concluded from their trials that birds in varying populations of 3, 6, and 12 birds with bird densities of 48, 60, and 72 square inches per bird had superior performance in the conventional type cages compared to birds in reverse cages.

From the literature reviewed, one can conclude that the optimum number of birds in a given type of cage is a very controversial subject.

In general, egg production was found to be decreased when birds were crowded in cages. Furthermore, birds in reverse or shallow cages tended to produce more eggs than those in deep or conventional type cages at a given bird density.

Egg Weight: Caged layers have generally produced heavier eggs than floor birds. Based on their work, Lowry et al. (1956), Froning and Funk (1958), Bailey et al. (1959), Johnson (1961), Logan (1965), and Kotaiah et al. (1975), concluded that birds in cages laid heavier eggs than did birds housed on the floor.

The influence of cage size and bird density on egg weights has also been studied.

Coligado and Quisenberry (1967) indicated that larger cages reduced egg size while greater bird density showed no effect on the egg size. Lowe and Heywang (1964) reported that egg size tended to be smaller when bird densities were increased.

Roy et al. (1967) housed layers individually, two, five, ten or twenty birds per cage with the same floor space per bird (.625 sq. ft.), 18.75 cm.^{2}; highest egg weight was obtained from 10 birds density versus lowest weight from individually caged birds. Donald Bell (1977) found an increase in egg weight of 0.51 grams by increasing bird density from one to four birds in 12" x 18" (30.48 x 45.72 cm.) cages.

On the other hand, most research workers showed no significant influence on cage size and bird densities on egg weights.

Walker et al. (1965) compared two types of cages, 8" x 18" (20.32 x 45.72 cm.) and 10" x 18" (25.40 x 45.72 cm.), with two birds per cage. They found no significant differences in egg weights due to cage sizes. Nakazawa et al. (1968) observed no difference in egg weight from birds housed in different cage sizes and bird densities.

Wayman et al. (1969), Adams and Jackson (1970), and Ostrander and Young (1970) indicated that they found no significant effect on egg weights by housing different number of birds, 2, 3, 4, or 5, in 12" x 18" (30.48 x 45.72 cm.) cages. Wilson et al. (1967) reported that housing pullets individually, two, or three per 8" x 18" (20.32 x 45.72 cm.) cage or 10" x 18" (25.40 x 45.72 cm.) cage resulted in no significant difference in weights of eggs produced due to cage size or number of birds per cage. Dorminey and Arscott (1971) also found no statistical difference in egg weights produced from a different number of birds in different cage sizes. Working with one or two birds per cage from seven strains of White Leghorn in 8" x 16" (20.32 x 40.64 cm.) cages, Aitken et al. (1973) found no effect of bird number on egg size. Jensen and Chang (1975) indicated no significant effect on egg weights from placing one or three birds in cages at

25 x 40 centimeters. Champion and Zindel (1968), from a comparison of five cage regimes, found no great differences in egg weight due to different cage size or different number of birds per cage.

In a test concerning reverse and conventional cages, Hill and Hunt (1977) indicated greater egg weight was observed from birds in reverse cages than from those in conventional cages.

Shell Weight, Shell Percent, and Thickness: Since shell quality is an important economic factor, strength of the egg shell and the breaking strength have been studied by correlating shell strength with other characteristics of eggs and their shell. Frank et al. (1964) stated that shell weight and shell thickness are the best estimators of measuring the shell strength. They reported that the relationship between shell weight and the force to crush the shell was 0.72 while the relationship between shell percent and crushing force was 0.82. They also found a high positive correlation between breaking strength and shell thickness. These results were similar to those obtained by Potts and Washburn (1974) and Romanoff (1929).

Morgan (1932) found a correlation coefficient between shell percent and breaking strength of about 50 percent.

Stewart (1936) evaluated the relationship of breaking strength to shell thickness and egg weight. The correlation coefficients of breaking strength with egg weight and with shell thickness were 0.26 and 0.509, respectively.

McNally (1965) demonstrated an increase in the percentage of cracked eggs as the weight of egg shell decreased from 6.0 grams to 3.5 grams.

Tyler and Geake (1964) pointed out that "a decline in shell thickness is not necessarily to be associated with a decline in shell strength for all birds."

Egg shell thickness is also affected by the type of housing conditions in which the birds are kept.

Froning and Funk (1958), Johnson (1961), and Kotaiah et al. (1975) reported that egg shell thickness of eggs produced by caged birds was slightly thicker than that of eggs produced by floor birds.

With respect to cage size and bird density, Wayman et al. (1969) found no significant influence on shell thickness when they crowded four birds into 12" x 18" (30.48 x 45.72 cm.) cages as compared to two birds per cage in the same size cages. Roy et al. (1967) conducted an experiment comparing layer performance in single or colony cages. Results showed no significant housing effect on shell thickness. Muir and Gerry (1976), and Lee and Bolton (1976) investigated the effect of cage shape (reverse versus deep) and bird densities on layer performance. No significant effects of the treatments were observed on shell thickness characteristic. However, Hill and Hunt (1977) reported a thicker egg shell from birds housed in shallow cages than from birds in deep cages.

Cracking and Egg Cleanliness: Since cage eggs can be easily gathered, there is less incidence of cracked eggs and dirty eggs than in floor eggs. However, bird density and cage size might affect the number of cracked eggs and the incidence of dirty eggs.

Bell (1964) reported that three birds in 12" x 18" (30.48 x 45.72 cm.) cages produced 3.62, percent dirty, cracked, and defective eggs. Wayman et al. (1969) also found a slight increase in the percentage of cracked eggs as bird density increased in 12" x 18"

(30.48 x 45.72 cm.) cages.

In studies by Walker et al. (1965), Roy et al. (1967), Nakazawa et al. (1968), and Dorminey and Arscott (1971) no effect of bird density and cage size on the incidence of cracked eggs was observed.

In trials of reverse and deep cages, Hughes and Black (1976) found that the percentage of cracked eggs produced was significantly less for birds in reverse cages than for those in deep cages. Bell (1972) and Muir and Gerry (1976) indicated that the percentage of cracked eggs produced by birds in shallow cages was about half as great as the percentage produced by birds in conventional cages. Bell (1977) has also studied the effect of reverse or deep cages on layer performance with three or four bird density. He noted that percentage of cracked eggs produced was less for birds in reverse than for those in deep cages. In addition, less cracked eggs were produced by birds at a density of three birds per cage than at four birds per cage.

Lee and Bolton (1976) also reported less cracked eggs from birds housed in reverse cages than from those housed in deep type cages. Conversely, Hill and Hunt (1977) reported a greater number of cracked and broken eggs were obtained from shallow caged birds.

Feed Consumption and Feed Efficiency: Much of the experimental work on the comparisons between caged birds and floor birds has indicated better feed utilization in caged birds than in floor birds (Morgan, 1954; Bailey et al., 1959; and Shupe and Quisenberry, 1961). However, Logan (1965) observed that floor housed birds consumed less feed to produce a dozen eggs than did caged birds. He ascribed this difference in feed consumption to the large size of eggs produced by caged birds.

Concerning cage shape and bird density, Fox and Clayton (1960) found no significant difference in feed utilization from placing birds at three densities of equivalent space per bird. Moore et al. (1965) reported better feed efficiency for two birds than one bird in 8" x 16" (20.32 x 40.64 cm.) cages.

Ruggles et al. (1967), Dorminey and Arscott (1971), and Wilson et al. (1967) indicated that they observed no significant effect of cage shape or bird density on feed consumption. Doran et al. (1967) noted an improvement in feed conversion per dozen eggs from housing one bird in 25.4 x 45.0 cm. cages as compared to housing two birds in cages of that size. Similar results were obtained by Aitken et al. (1973) using 8" x 16" (20.32 x 40.64 cm.) cages.

Cardin et al. (1969) reported a decline in average feed consumption as bird density increased from 3 to 4 to 5 in 12" x 18" (30.48 x 45.72 cm.) cages. Wayman et al. (1969) and Ostrander and Young (1970) found no significant difference in feed efficiency from housing 2, 3, 4, or 5 birds in 12" x 18" (30.48 x 45.72 cm.) cages. Housing individual birds in 8" x 18" (20.32 x 45.72 cm.) or 10" x 18" (25.4 x 45.72 cm.) cages, and five birds in 24" x 18" (60.96 x 45.72 cm.) cages resulted in approximately equivalent feed consumption and feed required per dozen eggs (Lowe and Heywang, 1964). Owings et al. (1967) reported no difference in feed efficiency between two and three birds in 10" x 16" (25.40 x 40.64 cm.) cages. Walker et al. (1965) housed two pullets in 8" x 18" (20.32 x 45.72 cm.) or 10" x 18" (25.40 x 45.72 cm.) cages and found that the amount of feed required per dozen eggs for the two treatments was 3.84 and 3.75 pounds, respectively.

Jensen and Chang (1975) stated that individual pullets consumed more feed per bird than did three birds in 10" x 16" (25.40 x 40.64 cm.) cages.

In tests with shallow cages versus deep cages, Bell (1972, 1976) reported better feed conversion per dozen eggs for birds in the shallow cages than for those in deep cages at both three and four bird densities. Lee and Bolton (1976) found that shallow caged birds of two layer strains consumed 4 percent less feed than deep caged birds without adverse effect on egg production. Likewise, Muir and Gerry (1976) reported better feed utilization for birds in reverse cages than for those in deep cages.

Earlier this year, Bell (1977) from another reverse cage test, reported that birds in reverse cages required less feed per dozen eggs than did those in conventional cages. These results are in agreement with the finding of Martin (1977) who studied various sizes of reverse and deep cages with various bird densities.

Mortality: A number of comparisons of laying hens in cages and on the floor indicated that floor birds had higher mortality (Lowry et al., 1956; Johnson, 1961; Shupe and Quisenberry, 1961; and Logan, 1965). Morgan (1954) found that the mortality rate was about the same for groups of birds kept in cages and on the floor. However, Bailey et al. (1959) and Michalson (1964) noticed higher mortality in caged housed birds than in floor housed birds. Cage size and bird density experiments show that mortality rate increases when birds are crowded. In this respect, Sicer (1964) found a higher mortality rate (+2.5%) for four birds than for three birds in 12" x 18" (30.48 x 45.72 cm.) cages. With the same cage size, Bell (1964) reported that mortality was 8.6 percent more for four birds than for three birds per cage. Bell and Little (1966) indicated that the percentage of mortality increased with the addition of each extra bird when placing two, three, to four birds in 12" x 18" (30.48 x 45.72 cm.) cages. Rooney et al. (1965) pointed out that three or four birds in 16" x 18" (40.64 x 45.72 cm.) cages showed twice the mortality of one or two birds in 8" x 18" (20.32 x 45.72 cm.) cages. Moore et al. (1965) placed 1 or 2 birds in 8" x 16" (20.32 x 40.64 cm.) and 3 or 4 birds in 16" x 16" (40.64 x 40.64 cm.) cages and observed that mortality was significantly affected by size of cage but not by bird density. Conversely, Coligado and Quisenberry (1967), and Fowler and Quisenberry (1969), using different cage sizes, reported that cage size had no significant effect on mortality. Fox and Clayton (1960) also reported no significant effect of bird density on mortality. Doran et al. (1967) stated that livability was five percent more in individually caged birds than at two-bird density in 10" x 18" (25.40 x 45.72 cm.) cages. Other researchers, Cook and Dembnicki (1966), Wilson et al. (1967), Dorminey and Arscott (1971), and Craig and Polley (1977), reported that mortality tended to be increased as bird density increased. Champion and Zindel (1968) indicated that no significant difference was observed when pullets were placed into five cage sizes and/or bird densities. On the other hand, Lowe and Heywang (1964) compared four cage regimes and found that mortality was less for individually caged birds. Individually and colony housed birds showed no significant difference in mortality according to Roy et al. (1967).

With birds in reverse cages of 24" x 12" (60.96 x 30.48 cm.) versus 16" x 18" (40.64 x 45.72 cm.) deep cages with four bird density, Lee and Bolton (1976) did not observe any significant difference in mortality rate. Similar results were reported by Hill and Hunt (1977). Bell (1972, 1976) reported that mortality was less for birds in reverse cages than for those in deep cages at three or four-bird density. Furthermore, Bell (1977) demonstrated that percentage mortality of birds in reverse cages was much less than that for birds in two types of deep cages. Likewise, Muir and Gerry (1976) and Martin (1977) demonstrated better livability of birds in reverse versus conventional cages.

Body Weight Gain: In general, experimental work has shown that birds in cages weigh more than comparable birds on the floor (Morgan, 1954; Bailey et al., 1959 and Johnson, 1961). Reports of cage size and bird density indicate that pounds of weight gain per layer vary with the concentration of layers per cage. Doran et al. (1967) indicated that in 10" x 18" (25.40 x 45.72 cm.) cages individually caged birds were an average of 31.8 grams lighter than birds caged at two birds per cage. Other researchers (Aitken et al., 1973) have reported that body weight gain for individual birds was 130 grams more than the average of two birds in 8" x 16" (20.32 x 40.64 cm.) cages. Similarly, Roy et al. (1967) observed higher body weight gain for individually caged birds than for colony caged birds. However, Craig and Polley (1977) reported significantly higher body weight gain for two cockerels than for individually caged males in 10" x 18" (25.40 x 45.72 cm.) cages.

Wilson et al. (1967) and Cardin et al. (1969) observed that body weight gain declined as bird density increased. Also, in a comparison between single and multiple caged White Leghorns, using four types of cages, Lowe and Heywang (1964) found greater body weight gain for multiple caged layers than for single caged birds.

Coligado and Quisenberry (1967), and Fowler and Quisenberry (1969) stated that body weight gain was increased with larger layer cages. Wayman et al. (1969) and Ostrander and Young (1970) found no significant effects upon gain in weight from placing 2, 3, 4, or 5 S. C. White Leghorns in 12" x 18" (30.48 x 45.72 cm.) cages. Champion and Zindel (1968) also reported no statistical effect upon body weight in relation to bird density.

Birds in reverse cages had greater body weight gain than those in deep cages (Muir and Gerry, 1976). Likewise, Hill and Hunt (1977) reported that body weight gain was significantly greater for shallow caged birds than for deep caged birds.

OBJECTIVES

Recently, the idea of converting deep laying cages to shallow or reverse type cages has become popular. Very little information is available on the effects of reverse cages on the performance of laying hens. Consequently, this study was made in an attempt to compare the effect of two cage shapes, reverse or shallow cages of 16" x 12" (40.64 cm. x 30.48 cm.) and the deep or conventional type cages of 12" x 16" (30.48 cm. x 40.64 cm.), on the performance of molted or recycled hens (using three or four bird density in either type of cage) from the following standpoints:

1. egg production;
2. egg quality, egg breakage, and egg cleanliness;
3. feed consumption and feed efficiency;
4. body weight gain; and
5. mortality.

EXPERIMENTAL PROCEDURE

The experiment was carried out at the Poultry Science Research and Teaching Center, Michigan State University, East Lansing, Michigan 48824. Data were collected during six 28-day periods or for a total of 168 days starting on November 10, 1976 and ending on April 26, 1977. The housing facilities utilized were deep or conventional type cages and reverse or shallow type cages, in a windowless, fan-ventilated 150 feet (45 meter) x 40 feet (12 meter) house with four-triple deck back to back stacked decks cage rows. Each cage row had three columns on either side for a total of six columns per row. Conventional rows of cages were alternated with the reverse rows of cages. Each conventional, deep, column consisted of 72 cages 12 inches (30.48 cm.) wide, from side to side, by 16 inches (40.64 cm.) deep, from front to back. Each reverse, shallow, column contained 54 cages 16 inches (40.64 cm.) wide by 12 inches (30.48 cm.) deep. The height of conventional and reverse cages was 18 inches (45.72 cm.) at the front and 16 inches (40.64 cm.) at the back. Consequently, the floor slope in conventional cages was 1 in 6 inches (2.54 in 15.24 cm.) and in the reverse cages 1 in 8 inches (2.54 in 20.32 cm.).

Feed troughs and continuous water troughs were fastened to the front of the cages. The house was provided with 11 fans of 1725 RPM and thirty-five 100 watt bulbs. A mechanical manure scraper was utilized to remove the manure once a day.

In an attempt to provide a good environment, only the middle columns of each type of cage in the two cage rows in the middle of the house were used for housing the experimental birds. A total of 104 conventional and 104 reverse cages were utilized for the experiments. Cages were thoroughly washed and well cleaned prior to placing birds in them. The roll-out trays of the experimental cages were separated by wires from each other to avoid the rolling of eggs from the tray of one cage to that of another.

Five thousand, two hundred and ninety-two Shaver strain Leghorn type hens were moved into the house on October 22, 1976. They were 17-months old and considered to be "spent" hens. All the hens had been vaccinated against Newcastle, bronchitis, epidemic tremors and fowl pox during the growing period. They had produced an average of 242 eggs per hen housed with a mortality of six percent over a 12-month period.

At housing time, 728 of the 5,292 birds were randomly distributed in the 208 experimental cages into four treatments as follows: In the conventional cages three birds per cage in the first 26 cages of the column (treatment 1, rep. 1) and four birds per cage in the last 26 cages of the same conventional cage column (treatment 2, rep. 1); and in the backing column, four birds per cage in the first 26 cages (treatment 2, rep. 2) and three birds per cage in the last 26 cages of the column (treatment 1, rep. 2). Since the conventional column was 72 cages long, the rest of the cages were occupied, for the purpose of keeping the poultry house warm during the experimental period, by birds not included in the test. In the reverse cages, birds were assigned in the same way as in the conventional cages, except that there were no extra cages in the middle part of the column. The birds in the reverse cages represented treatment 3 with two replicates (reverse cages with three bird density). An empty cage was left between the beginning of or at the end of each replicate and the adjacent cages to prevent consumption of nonweighed feed by the experimental birds. The distribution of the treatments is shown in Figure 1.

To force molt the birds, feed, water and light were concurrently restricted. Feed restriction continued for the first week, water restriction continued for the first two days and light restriction continued for the first two weeks.

Six days after the force molting process began, egg production had dropped to almost zero. On November 10, 1976, all birds were allowed feed ad libitum, continuous water and 14 hours of continuous light.

The experimental hens were individually weighed at 7:00 a.m. to the nearest 25 grams using a hanging scale and the mean body weight was calculated as the arithmetic mean of the number of birds in each cage. The weights of the birds were considered to be the initial body weights of the recycled birds. "Extra" birds with the same order of treatment allocations were weighed and saved for replacing experimental birds that died.

When full feeding was resumed, birds were fed ad libitum an all mash laying ration for two weeks and then an all pellet laying ration throughout the entire experimental period. The composition of the feed is given in Appendix Table 1. All birds were exposed to 14 hours of light per day throughout the experimental period. Temperature was recorded in Fahrenheit at 8:00 a.m. and 3:00 p.m. every day.

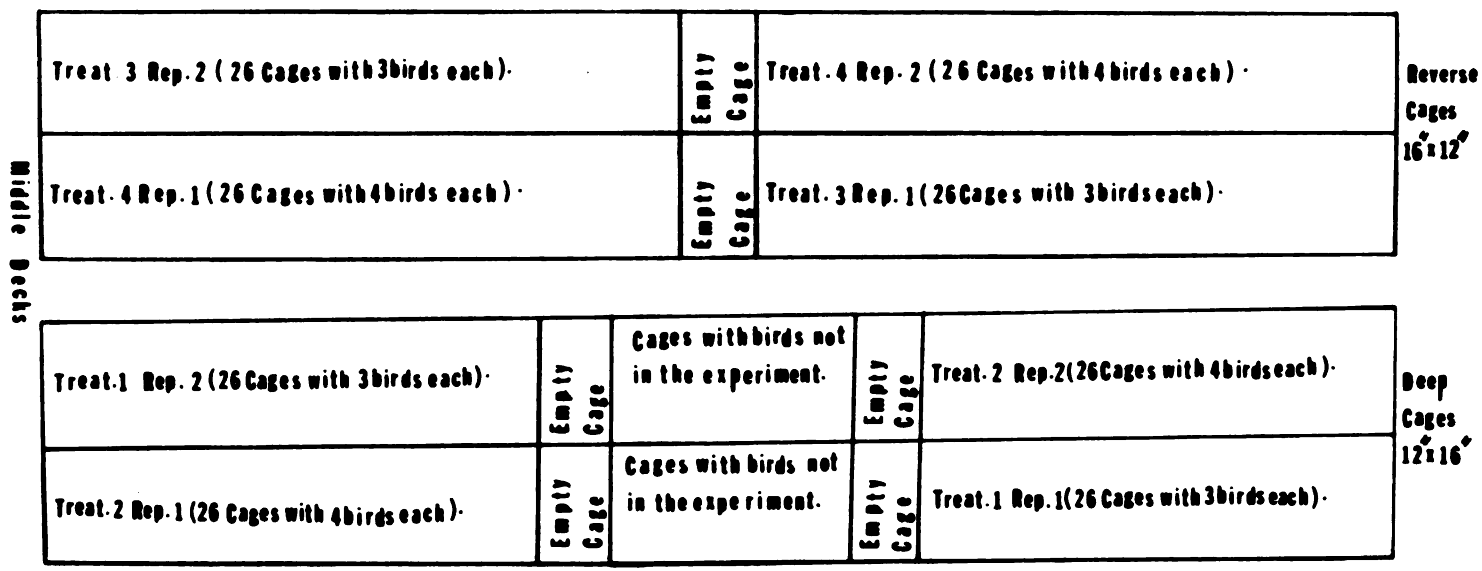

Figure 1. Allocation of Experimental Treatments.

Average monthly temperatures are shown in Appendix Table 2.

The house floor and the aisles were swept out everyday.

In this study, the following traits were measured during the course of the experiment.

1. Egg Production - Egg production was recorded daily for six 28-day periods beginning on November 24, 1976, when the first few eggs were obtained post-molt. Eggs were collected by hand daily between 3:00 and 5:00 p.m. and recorded on a hen-cage production basis.

2. Egg Cleanliness and Egg Breakage - The effects of cage shape and bird density on the incidence of dirty and/or cracked eggs were evaluated every day during egg collection, by a thorough visual inspection of all that day's eggs from the birds in each cage for each replicate treatment group. Egg cleanliness was classified as clean, soiled, moderately soiled, or slightly soiled according to U.S.D.A. standards (U.S.D.A. Egg Grading Manual, 1969). Description of shell cleanliness categories is presented in Appendix Table 4.

3. Egg Weights and Egg Size - The eggs used for this part of the study were collected from each replicate group from alternate cages on a two day-a-week basis during the six 28-day periods. Eggs were weighed to the nearest 0.01 gram by using a Mettler electrical scale.[1] From the egg weights, sizes of the eggs were derived and classified into five weight classes according to U.S.D.A. Standards (U.S.D.A. Egg Grading Manual, 1969). The weights of eggs from which egg sizes were derived is presented in Appendix Table 3.

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[1]Mettler Instrument Corp. (E.H. Sargent and Co.), Hightstown, N.J. 08520.

4. Shell Weights and Shell Thickness - The same eggs used for egg weight and size studies were used for determining the shell weight and shell thickness. Eggs to be measured were cracked open at their widest area by using a lab spatula, the contents were washed out, and the shells were air dried at room temperature for at least 24 hours before weight and thickness were measured. The egg shell weights were determined to the nearest 0.01 gram by the Mettler electrical scale. Shell thickness was accurately measured by means of a calibrated micrometer[2] to the nearest 0.01 mm. Two measurements were taken in the area of the equatorial zone of each dry shell, with the two-shell membranes intact, and thickness was considered to be the average of the two measurements. The percentage of egg as shell and shell membranes were calculated from the dried shell weight and egg weight.

5. Feed Consumption - At the beginning of each production period, the feed given to each treatment replicate group was weighed to the nearest 0.01 kilogram. Each day, feed was distributed by hand immediately after egg collection. The remaining feed in the troughs and the storage can of each replicate was weighed back at the end of each 28-day period. The data and the number of eggs produced were subsequently used to determine the amount of feed, in grams, required per dozen eggs and feed consumed per hen per day in each replicate group by periods.

6. Mortality - Mortality was recorded seven days per week and calculated as a percent of total birds housed for each treatment at the beginning of the experiment. No culling was practiced during the

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[2]Federal Products Corp. (a subsidiary Esterline Corp.), 114 Eddy St., Providence, Rhode Island 02901.

test period.

For each bird which died, a postmortem examination was made by the Department of Pathology to determine the cause of death.

To keep the available space per bird constant in each cage where mortality occurred, "extra" birds from the same type of cage with the same bird density were used as replacements.

7. Body Weight Gain - Initial body weight per bird from each cage was recorded on the same day birds were returned to full feed after one week of feed restriction (November 10, 1976). At the end of the experiment (April 26, 1977), individual body weights were measured to the nearest 25 grams. Then, average body weight per bird per cage was calculated and the weight gain in grams was determined for each bird.

The "extra" birds which had been saved for dead bird replacement were numbered and weighed. When an experimental bird died, an "extra" bird weighing approximately the same was used as a replacement.

Experimental Design and Statistical Analysis: The design of the experiment employed was as outlined by Gill (1978, in press) using one-way analysis and split-plot design with replicates.

Since the first production period included about two weeks of recovery from the molting process with few eggs produced, data from the other two weeks of the period were analyzed separately from the other five periods using one-way analysis. The split plot design was used to analyze the data of all traits studied, except the mortality trait which was analyzed by a contingency table for the five 28-day periods combined.

Orthogonal contrasts and Benferroni t-test were used to determine the specific effects of treatments.

Percentage data for cracked eggs and soiled eggs were transformed to arcsine prior to conducting the analysis of variance. Statistical analyses were run using the analysis of variance (ANOVA) program of Michigan State University, STAT 4 System, Statistical package available on the Control Data Corporation (CDC) 6500 computer at Michigan State University. Subsequently, statistical effects of cage shape, bird density, periods, and interaction of treatments that showed significant differences were specified by the analysis of variance program.

A three-factor model (plus replicates) for balanced data was used for all traits, with cage size, bird density, and periods assumed to be fixed, and replicate locations random and assumed not to interact with treatments.

The following model indicates the effects of each variable.

$$Yijlm = M + Ci + Dj + Pk + Rp + CKij + Cpik + Dpjk + CDpijk + Eijklm.$$

M = General Mean; Ci = Effect of cage shape (i = 1,2);

Dj = Effect of bird density (j = 1,2); Pk = Effect of period (p = 2,3,. . .,6);

Rp = Random effect of replicate (p = 1,2).

Dual symbols stand for two and three factor interactions and Eijklm = Random variation.

RESULTS AND DISCUSSION

For each type of cage size, deep or shallow, fifty-two cages (two replicates) with three birds per cage and the same number of cages with four birds per cage were used.

Data were obtained on a group basis (a group consisted of all birds in an individual cage) and then converted, by average, to individual bird performance for all traits.

Since the first production period represented only two weeks of production, post-molting period, analysis of variance was applied on the data of this period separately. The data of the other five 28-day periods were subjected to the analysis of variance, so that the time effect on the bird's performance was determined.

Egg Production: Egg production records were started on November 24, 1976 when the first few eggs were laid post-molting recovery period. The percentage of hen-housed egg production for the six 28-day periods is shown in Table 1.

During the entire period of this experiment, 168 days, total egg production from hens kept in deep and shallow cages was 28,246 and 29,112 eggs, respectively. Birds housed at three-bird density in deep cages laid 12,456 eggs and those in shallow cages laid 13,368 eggs.

Analysis of variance revealed that egg production over the whole experimental period was significantly ($P < 0.01$) affected by bird density and period of time (Appendix Tables 5 and 6).

Table 1. Treatment Means ± Standard Deviation for Percentage of Egg Production by Six 28-Day Periods.

Periods	Percent of Egg Production			
	Conventional Cages		Shallow Cages	
	3 Birds/Cage	4 Birds/Cage	3 Birds/Cage	4 Birds/Cage
1	6.53± 6.45	4.55± 4.29	7.17± 6.75	4.46± 4.17
2	49.77±14.29	42.69±12.86	52.50±15.33	46.57±12.15
3	62.98±16.05	59.07±15.61	64.61±13.72	56.34±11.86
4	59.96±14.36	56.04±13.86	64.47±13.16	56.39±12.05
5	55.24±16.69	55.07±14.34	60.19±16.04	54.34±17.07
6	50.69±16.24	53.71±13.77	57.12±17.02	52.22±17.96
Ave.*	55.73	53.32	59.78	53.17

*Averages do not include Period 1.

Increasing the number of birds in the deep and shallow cages from three to four birds reduced the egg production by 4.15 percent. These results confirm the general trend of the observations of other workers who have compared three and four birds per cage (Sicer, 1964; Rooney et al., 1965; Bramhall, 1966; and Bell, 1977). Cage shape had no significant ($P > 0.05$) effect on egg production despite the fact that the trend was in favor of birds housed in reverse cages over those kept in the deep type cages. Birds in reverse cages laid 1.67 percent more eggs than those housed in the deep cages.

These results are in agreement with the findings of many investigators (Bell, 1972; Muir and Gerry, 1976; and Martin, 1977).

The results of the time effect study show that the number of eggs produced was increased from the onset of egg production until the third 28-day period and then tended to gradually decrease. The density x period interaction showed a significant ($P < 0.05$) effect on egg production but none of the other interactions were significant for the whole experimental period.

Orthogonal contrasts and the Benforroni t-test were applied to the data.

Despite interaction of bird density and periods of time, it is the total production difference due to bird density, 4.54 percent, that is of primary importance.

The average difference in egg production percentage, in favor of three-bird density, was 6.51, 6.10. 6.00, 3.01 and 0.95 over the five 28-day successive periods, with significant interaction suggesting that the differences in the early periods were indeed larger than those at the end.

Egg Weight: A total of 6,629 eggs were evaluated for egg weights and other egg characteristics during the course of the experiment. Of this total, 3,289 eggs were from birds housed in the deep cages and 3,340 eggs from those housed in the shallow cages.

The egg weights were measured once a week from birds in each cage of each replicate. The distribution of egg size throughout the experimental period is shown in Figure 2. Jumbo and extra large eggs were combined into one group. Since very few peewee eggs were produced, these were added to the small egg group. Average egg weights for the four treatments are presented in Table 2.

Analysis of variance of egg weights from the first production period and the other five 28-day periods was conducted. There was no evidence of a significant effect ($P > 0.05$) of cage shape and bird density on egg weights during the first period (Appendix Table 8). On

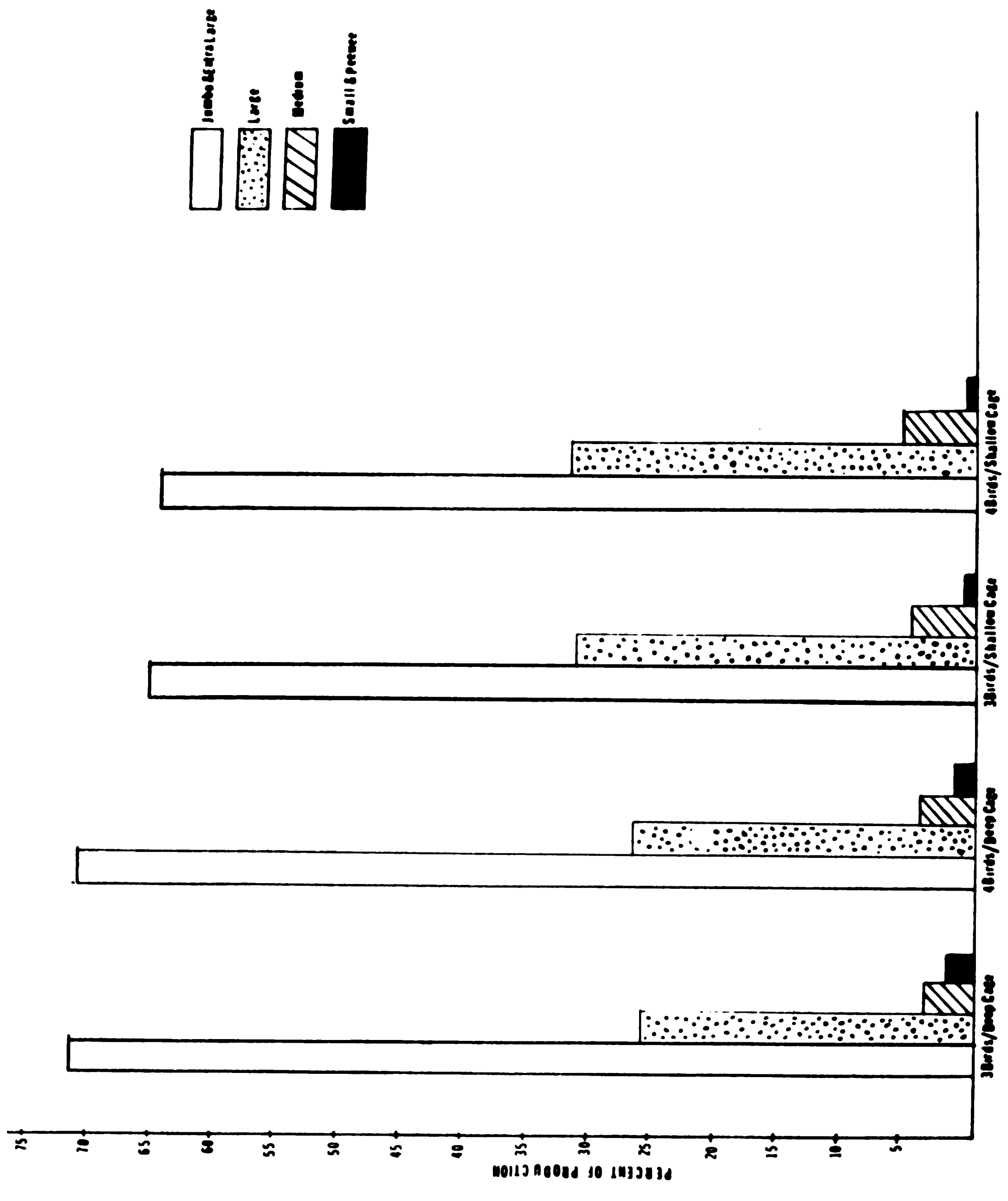

FIGURE 2. COMPOSITE DISTRIBUTION OF EGG SIZES

Table 2. Treatment Means ± Standard Deviation for Egg Weights in Grams by Six 28-Day Periods.

Periods	Grams Egg Weight			
	Conventional Cages		Shallow Cages	
	3 Birds/Cage	4 Birds/Cage	3 Birds/Cage	4 Birds/Cage
1	62.63±3.98	65.20±5.12	62.56± 2.43	62.06± 4.02
2	67.87±4.58	65.51±9.83	64.42±10.51	65.37± 5.01
3	66.20±8.83	66.32±8.88	66.69± 2.90	66.89± 2.50
4	66.49±5.23	65.68±5.59	65.35± 3.27	63.89± 9.47
5	67.49±4.09	66.87±3.27	66.54± 3.91	65.89± 3.43
6	66.99±3.83	67.08±3.61	66.73± 4.16	63.77±13.18
Ave.	66.28	66.11	65.38	64.65

the other hand, data of the five 28-day periods indicated that egg weights were significantly ($P < 0.05$) affected by cage shape (Appendix Table 7). Birds housed in conventional cages laid heavier eggs (1.18 gms.) than did birds kept in the reverse cages. Bird density showed no adverse effect on egg weights. In addition, egg weights were not drastically reduced by periods of production.

These results are in contrast to those of Lee and Bolton (1976) who found no differences in egg weights from birds, 42-70 weeks of age, housed in shallow and deep cages, and also to those results reported by Hill and Hunt (1977) who obtained heavier eggs from birds housed in shallow cages.

Concerning bird density, results in this study agree with the observations of Wayman et al. (1969), Wilson et al. (1967), Aitken et al. (1973) and Adams and Jackson (1970) who found no significant difference in egg weight due to different bird densities in different cage sizes, but not with those of Bell (1977) who noticed an increase in egg weights when bird density was increased.

Shell Weight and Shell Percentage: Shell weight and shell percentage, for a total of 6,629 eggs during the course of the experiment, were studied.

Average shell weight and shell percentage for the four treatments over the six 28-day periods are presented in Table 3 and 4. Analysis of variance indicated that birds housed in deep cages laid eggs with significantly ($P < 0.05$) heavier shells (+0.14 gms.) than those laid by the birds housed in shallow cages (Appendix Table 9). Periods of time had a significant ($P < 0.05$) influence on shell weights. Eggs laid during the first three periods had slightly heavier shells than those laid during the last three periods. Shape x density x period interaction showed a significant ($P < 0.05$) effect on shell weight. The reason for this has not been elucidated.

Table 3. Treatment Means ± Standard Deviation for Egg Shell Weights by Six 28-Day Periods.

Periods	Shell Weights in Grams			
	Conventional Cages		Shallow Cages	
	3 Birds/Cage	4 Birds/Cage	3 Birds/Cage	4 Birds/Cage
1	5.54 ± 0.41	4.85 ± 0.35	5.34 ± 0.42	5.55 ± 0.42
2	6.10 ± 0.61	5.90 ± 0.98	5.94 ± 0.99	6.06 ± 0.51
3	6.25 ± 0.46	6.27 ± 0.33	6.15 ± 0.42	6.23 ± 0.46
4	6.24 ± 0.38	6.32 ± 0.77	6.15 ± 0.35	6.03 ± 0.90
5	6.15 ± 0.55	6.09 ± 0.45	6.05 ± 0.48	5.99 ± 0.41
6	6.10 ± 0.51	6.12 ± 0.35	6.01 ± 0.44	5.73 ± 1.21
Ave.	6.06	5.93	5.94	5.93

Table 4. Treatment Means ± Standard Deviation for Shell Percentage by Six 28-Day Periods.

Periods	Percentage of Shell			
	Conventional Cages		Shallow Cages	
	3 Birds/Cage	4 Birds/Cage	3 Birds/Cage	4 Birds/Cage
1	8.84± 0.40	9.00± 0.58	9.54±0.55	8.95±0.39
2	9.00± 0.71	8.85± 1.46	9.12±1.90	9.29±0.78
3	10.95±12.11	10.90±11.56	9.23±0.55	9.32±0.64
4	9.41± 0.58	9.62± 0.69	9.41±0.45	9.26±1.35
5	9.11± 0.61	9.10± 0.44	9.09±0.50	9.10±0.48
6	9.11± 0.63	9.14± 0.41	9.01±0.62	8.64±1.79
Ave.	9.40	9.44	9.07	9.09

Shell weights of the small number of eggs laid in the first period were not statistically ($P > 0.05$) influenced by cage shape or bird density (Appendix Table 10), while shell percentage was significantly ($P < 0.01$) affected by bird density during that period (Appendix Table 12). Birds housed at the four bird density produced eggs with higher shell percentage, +0.28, than those eggs laid from birds housed at three-bird density. Data of the other five 28-day periods showed that shell percentage was significantly ($P < 0.05$) affected by period of time, but not by cage shape, bird density or interaction (Appendix Table 11).

However, birds housed in deep cages laid eggs with higher shell percentage (+0.34) than those laid by birds kept in shallow cages.

A comparison between the deep and shallow cages, for three or four bird density, by using orthogonal contrasts and Benforroni t-test indicated that shell percentage was significantly ($P < 0.05$) higher

(+1.65) for eggs produced by birds housed in deep cages as compared to those produced by birds housed in shallow cages only during the third production period.

When this test, orthogonal, was employed on shell weight, results showed no significant ($P > 0.05$) effect of cage shape on shell weight for a given bird density in each production period.

Shell Thickness: Averages of egg shell thickness by six 28-day periods are given in Table 5.

Table 5. Treatment Means ± Standard Deviation for Shell Thickness by Six 28-Day Periods.

Periods	Shell Thickness in mm.			
	Conventional Cages		Shallow Cages	
	3 Birds/Cage	4 Birds/Cage	3 Birds/Cage	4 Birds/Cage
1	0.36 ± 0.02	0.37 ± 0.01	0.35 ± 0.02	0.37 ± 0.02
2	0.39 ± 0.03	0.37 ± 0.06	0.37 ± 0.06	0.39 ± 0.03
3	0.39 ± 0.03	0.39 ± 0.01	0.38 ± 0.02	0.39 ± 0.02
4	0.39 ± 0.02	0.39 ± 0.04	0.39 ± 0.02	0.38 ± 0.07
5	0.38 ± 0.03	0.38 ± 0.02	0.39 ± 0.02	0.38 ± 0.02
6	0.38 ± 0.03	0.38 ± 0.02	0.38 ± 0.02	0.36 ± 0.08
Ave.	0.382	0.380	0.377	0.378

Data from the first production period showed a significant ($P < 0.01$) effect of cage shape and bird density on shell thickness (Appendix Table 14). Thinner shells (-0.01 mm.) were obtained from birds housed in shallow cage than from those in deep cages. On the other hand, birds housed at the three-bird density in deep cages laid eggs with slightly thicker shells than did birds at four-bird density.

However, hens housed in shallow cages at the four-bird density laid eggs with thicker shells than did birds at the three-bird density.

Analysis of variance of the data for the last five periods, indicated that shell thickness was significantly ($P < 0.01$) influenced by period of time (Appendix Table 13). Accordingly, shell thickness got a little thicker as time went on and then tended to drop off gradually again. Reasons for a significant ($P < 0.01$)shape-density period interaction are not apparent. Cage size, bird density, and all other interactions were nonsignificant.

Test of orthogonal contrasts indicated that no one type of cage was better than the other in its effect on egg shell thickness.

The observations of this study are in accord with the results reported by Muir and Gerry (1976), and Lee and Bolton (1976) who found that cage shape, deep and shallow, had no effect on shell thickness. However, the results are contradictory to the findings of Hill and Hunt (1977) who reported that shell thickness of eggs produced by birds kept in shallow cages was significantly greater than that of those produced by birds kept in deep cages.

In regard to bird density, the results of this trial essentially agree with those of Wayman et al. (1969) and Roy et al. (1967) who indicated that crowding the birds in cages produced no significant effect on shell thickness.

Egg Breakage and Cleanliness: The incidences of cracked and dirty eggs have been demonstrated to be influenced primarily by bird density and time effect. The daily inspection of egg condition, as well as the statistical analysis, produced no evidence to indicate that cage shape had any appreciable influence on egg cleanliness or number of cracks. Although, the bottoms of deep and shallow cages had different slopes, it is apparent that the rolling of the eggs down the greater inclined wire bottoms of the reverse cages did not cause an increase in egg breakage. The percentage of cracked and soiled eggs by the six periods for the four treatments are shown in Tables 6 and 7.

Analysis of variance revealed that egg cleanliness was not statistically ($P > 0.05$) affected by cage shape or bird density (Appendix Table 16) during the first period, while it was significantly ($P < 0.05$) affected by bird density, period of time, and density x period interaction during the other five production periods (Appendix Table 15).

Table 6. Treatment Means ± Standard Deviation for Percentage of Cracked Eggs by Six 28-Day Periods.

Periods	Percentage of Cracked Eggs			
	Conventional Cages		Shallow Cages	
	3 Birds/Cage	4 Birds/Cage	3 Birds/Cage	4 Birds/Cage
1	0.12 ± .87	0.65 ± 4.71	4.01 ± 22.02	1.04 ± 5.43
2	0.89 ± 1.70	0.88 ± 1.20	1.15 ± 1.69	2.06 ± 1.96
3	1.08 ± 1.55	0.90 ± 1.33	0.56 ± 1.00	1.45 ± 2.00
4	1.50 ± 2.06	1.37 ± 1.43	1.60 ± 2.21	1.53 ± 1.67
5	1.43 ± 2.10	1.86 ± 2.47	1.80 ± 2.45	2.13 ± 2.95
6	1.05 ± 1.67	3.14 ± 9.22	1.37 ± 1.98	1.52 ± 2.07
Ave.	1.01	1.47	1.75	1.62

Table 7. Treatment Means ± Standard Deviation for Percentage of Soiled Eggs by Six 28-Day Periods.

Periods	Percentage of Soiled Eggs			
	Conventional Cages		Shallow Cages	
	3 Birds/Cage	4 Birds/Cage	3 Birds/Cage	4 Birds/Cage
1	1.63 ± 7.24	0.32 ± 2.31	0.30 ± 1.55	0.71 ± 2.92
2	1.77 ± 3.01	4.20 ± 4.61	2.03 ± 2.18	5.35 ± 4.62
3	2.52 ± 3.70	5.37 ± 4.34	1.55 ± 2.12	5.09 ± 4.70
4	2.10 ± 2.97	4.36 ± 3.60	1.87 ± 2.96	4.77 ± 3.46
5	1.67 ± 3.00	3.83 ± 3.94	1.30 ± 2.39	4.53 ± 4.23
6	1.86 ± 2.53	2.67 ± 2.65	1.27 ± 2.02	3.44 ± 2.54
Ave.	1.93	3.46	1.39	3.98

Eggs from birds caged at the lower density were cleaner (+2.61%) than those eggs from birds caged at the higher density. Concerning the time effects, the number of soiled eggs, produced from the birds in deep and shallow cages, increased during the third and fourth period and then reduced during the last two periods. This might have been due to the same fluctuation in egg production over the experimental period. It was also found that the differences of number of soiled eggs over production periods were higher for birds housed at four-bird density than those for birds housed at three-bird density.

The number of cracked eggs from birds housed at four-bird density was significantly ($P < 0.05$) higher than that from birds housed at three bird density and it was significantly ($P < .05$) affected by period of time (Appendix Table 17). The least number of cracked eggs, for all experimental birds, was observed during the third production period.

A significant ($P < 0.05$) shape x density x period interaction was observed for the number of cracked eggs.

Analysis of the data of the first production period showed no significant ($P > 0.05$) effect of cage shape or bird density on the number of cracked eggs (Appendix Table 18).

In general, results of this test confirm the results of Wayman et al. (1969), who found a slight increase in the percentage of cracked eggs as bird density increased in 12" x 18" (30.48 x 45.72 cm.) cages, but do not agree with those results reported by Bell (1972) and Muir and Gerry (1976) which stated that less cracked eggs were obtained from birds housed in shallow cages than from those housed in deep cages.

Severity of soiled eggs as a percentage of the total eggs produced during the 168 day period is presented in Table 8.

Table 8. Egg Cleanliness and Severity of Soiled Eggs over a 168-Day Period According to U.S.D.A. Standards for Consumer Grades.

Egg Cleanliness	Conventional Cages		Shallow Cages	
	3 Birds/Cage	4 Birds/Cage	3 Birds/Cage	4 Birds/Cage
	%	%	%	%
Clean Eggs	98.7	96.54	98.61	96.02
Slightly Soiled	0.69	1.15	0.40	1.10
Moderately Soiled	0.62	0.43	0.37	0.97
Dirty	0.62	1.88	0.62	1.91

<u>Feed Consumption and Efficiency</u>: The feed consumption data were based on the average of daily feed intake per bird in grams (Table 9). An examination of the data, over all periods, shows that each hen at the three-bird density in deep cages ate 8.77 grams more, per day, than

her counterpart housed at four-bird density. Likewise, in shallow cages, feed consumed per hen per day was 9.89 grams more in the low density cages than in the high density cages.

Table 9. Treatment Means ± Standard Deviation for Daily Feed Consumption in Grams by Six 28-Day Periods.

Periods	Grams of Feed Per Bird Per Day			
	Conventional Cages		Shallow Cages	
	3 Birds/Cage	4 Birds/Cage	3 Birds/Cage	4 Birds/Cage
1	128.71 ± 0.58	95.62 ± 2.65	121.83 ± 5.65	95.08 ± 0.98
2	103.85 ± 1.13	99.60 ± 2.70	103.78 ± 1.33	98.91 ± 0.43
3	113.59 ± 4.06	106.68 ± 5.51	111.53 ± 2.06	107.13 ± 2.50
4	116.28 ± 1.69	110.29 ± 5.96	120.62 ± 3.21	110.48 ± 0.16
5	110.43 ± 3.29	108.88 ± 1.19	115.59 ± 1.98	107.27 ± 4.07
6	107.67 ± 0.49	106.81 ± 1.37	108.45 ± 4.60	103.56 ± 4.78
Ave.	113.42	104.65	113.63	103.74

These variations in daily feed consumption were found to be statistically significant ($P < 0.05$) (Appendix Tables 19 and 20).

The only possible explanation for this discrepancy in feed consumption is to ascribe it to the higher amount of feeder space per bird, for birds at three-bird density, which reduced the possibility of low feed intake and, thus, a higher rate of egg production per bird was obtained than at the four-bird density.

In this study, time had a marked effect on feed consumption. This was significantly ($P < 0.01$) exhibited with the birds housed in deep cages as well as in shallow cages. It is noticeable that feed consumption per bird was proportional to egg production.

Data indicated that birds housed at three birds per cage performed better from the standpoint of feed utilization than did those housed at four-bird density (Table 10). On the other hand, hens housed in shallow cages required less feed (-84.65 gms.) to produce a dozen eggs than did those housed in deep cages. However, the analysis of variance did not reveal any significant ($P > 0.05$) effect of cage shape or bird density on feed conversion per dozen eggs (Appendix Table 21). Feed conversion per dozen eggs was significantly ($P < 0.01$) affected by periods of time. This might have been due to the decline in egg production during the experimental periods.

Table 10. Treatment Means ± Standard Deviation for Feed Conversion (Grams) per Dozen Eggs by Five 28-Day Periods.

Periods	Grams of Feed Per Dozen Eggs			
	Conventional Cages		Shallow Cages	
	3 Birds/Cage	4 Birds/Cage	3 Birds/Cage	4 Birds/Cage
2	2527.25±331.07	2802.42±128.29	2375.30±105.90	2549.75± 60.85
3	2164.40± 8.26	2173.76±120.37	2074.01± 84.46	2285.19±152.78
4	2327.90± 72.86	2365.18± 81.41	2248.95±102.86	2351.60± 43.87
5	2399.35± 28.46	2374.15± 71.44	2306.94± 85.96	2376.04±146.94
6	2552.68±144.94	2387.05± 73.82	2279.79± 46.85	2380.09± 8.50
Ave.	2394.32	2420.51	2257.00	2388.53

Birds housed at three-bird density in deep and shallow cages, consumed less feed (-78.87 gms.) than those housed at the four-bird density to produce one dozen eggs over the whole experimental period. Since the onset of egg production was at the middle of the first production period, no analysis of variance was applied on feed conversion during that period.

The results obtained in this study substantially agree with those of Bell (1972), Lee and Bolton (1976), Martin (1977) and Muir and Gerry (1976) who found better feed utilization for birds in reverse cages than for those in deep cages.

Mortality: Mortality of birds in the experiment varied considerably. Differences in mortality were significant ($P < 0.01$) between the two-bird densities in the reverse cages, but not in the conventional cages (Appendix Table 22).

Comparing the mortality of the birds in the two types of cages, results of the statistical analysis indicated that the type of cage was not important when bird density was three birds per cage but that it was important when bird density was four birds per cage.

The mortality rate for birds housed at the four-bird density in shallow cages was significantly ($P < 0.05$) higher than in birds at this density in deep cages. In this study, no birds died in shallow cages when birds were housed at the three-bird density during the whole experimental period. The actual causes of mortality and the number of dead birds by periods are given in Tables 11 and 12.

Table 11. Total Number of Death Losses by Six 28-Day Periods.

Periods	Number of Birds Died			
	Conventional Cages		Shallow Cages	
	3 Birds/Cage	4 Birds/Cage	3 Birds/Cage	4 Birds/Cage
1	1	1	0	3
2	1	1	0	1
3	0	1	0	2
4	0	1	0	7
5	0	1	0	0
6	0	0	0	1
Total	2	5	0	14

Table 12. Causes of Mortality for Recycled Birds Housed in Conventional and Reverse Cages at Three or Four-Bird Density Over a 168-Day Period.

Diseases	Number of Birds Died			
	Conventional Cages		Shallow Cages	
	3 Birds/ Cage	4 Birds/ Cage	3 Birds/ Cage	4 Birds/ Cage
Starvation	--	2	--	2
Pickouts	1	--	--	1
Pertonitis	--	--	--	4
Visceral gout	1	1	--	2
Impacted oviduct	--	--	--	2
Round Heart	--	--	--	1
Septicemia	--	--	--	1
Air sac infection	--	1	--	--
Adeno carcinoma of ovary	--	--	--	1
Undetermined	--	1	--	--
Total	2	5	0	14

Since only two birds died in the low density cages versus nineteen dead birds in high density cages, it is obvious that the mortality loss was increased by increasing the number of birds per cage. Mortality of birds in deep and shallow cages, at the three-bird density, corresponds very closely to the mortality data reported by Muir and Gerry (1976), Bell (1977), and Martin (1977) who demonstrated better livability of birds in shallow cages than in deep cages.

Body Weight Gain: The mean values of body weight gain, post molting process, during the entire experimental period are shown in Table 13. Body weight gain per layer varied with the concentration of birds per cage. Birds housed in deep cages at three-bird density gained more weight (+38.78 gms.) than those housed at four-bird density. Similarly, in the shallow cages, birds housed at three-bird density gained slightly more (+9.00 gms.) than those housed at four-bird density. However, analysis of variance indicated that bird density did not show any significant ($P > 0.05$) effect on body weight gain while cage shape had a highly significant ($P < 0.01$) influence on weight gain (Appendix Table 23).

Table 13. Mean Body Weight Gain (Grams) ± Standard Deviation for Recycled Birds Housed in Conventional Cages and Reverse Cages at Three or Four-Bird Density Over a 168-Day Period.

Body Weight Gain			
Conventional Cages		Shallow Cages	
3 Birds/Cage	4 Birds/Cage	3 Birds/Cage	4 Birds/Cage
594.08 ± 155.45	555.29 ± 148.41	486.54 ± 174.76	477.64 ± 120.85

Birds housed in the deep cages gained 574.68 grams per bird while those housed in shallow cages gained 482.09 grams during the entire course of the experiment. These results contradict those reported by Muir and Gerry (1976) and Hill and Hunt (1977) who found that body weight gain was greater for birds housed in shallow cages than for those housed in deep cages. However, as far as the bird density is concerned, the results of this trial are in agreement with those of Wilson et al. (1967) and Cardin et al. (1969) who observed greater body weight gain with less bird density in a cage.

SUMMARY AND CONCLUSIONS

Recycled 17-month-old Shaver strain Leghorn type hens were housed in deep 12" x 16" (30.48 x 40.64 cm.) cages and in shallow 16" x 12" (40.64 x 30.48 cm.) cages at three and four-bird density in each type of cage.

Hen-housed egg production, in percent, was 55.73 and 53.32 over the last five 28-day periods, post molting process, for birds housed in deep cages at three and four birds per cage, respectively. In shallow cages, the percentage of egg production was 59.78 and 53.17 for birds housed at low and high bird density, respectively. There was no significant ($P > 0.05$) effect of cage shape on hen-housed percentage egg production over the entire experimental period. However, the differences in egg production between birds housed at three and four-bird density were statistically ($P < 0.01$) significant in both housing regimes.

Egg weights were significantly ($P < 0.05$) higher for eggs from birds in deep cages than for those from birds in shallow cages. Birds in deep cages produced eggs with an average weight of 64.83 grams while those in shallow cages produced eggs with an average weight of 63.3 grams over the six 28-day periods. Significant effect due to bird density on egg weight was detected. Shell weight was significantly ($P < 0.05$) higher and shells were slightly thicker for eggs produced from hens kept in deep cages than for those produced from hens in shallow cages. Periods of time had a significant effect on shell weight, shell percentage and shell thickness in that relatively lower values for these traits were recorded at the end of the experiment than at the beginning.

The number of cracked and soiled eggs was significantly ($P < 0.05$) affected by bird density and period of time. Birds housed at three-bird density had 3.0 percent less cracked and soiled eggs than those housed at four-bird density in both types of cages.

Average feed consumption per hen per day for birds housed at three and four-bird density in deep cages was 113.42 and 104.65 grams, respectively, while it was 113.63 and 103.74 grams for birds in shallow cages at three and four-bird density, respectively. Accordingly, a significant ($P < 0.05$) influence of bird density on feed consumption was observed. The data on feed consumption did not reveal any significant effect of cage shape but the period of time had a significant ($P < 0.05$) influence on the feed consumption. Feed conversion ratio to a dozen eggs was significantly ($P < 0.01$) affected by period of time. It was found that birds housed at low density required less feed (-78.87 gms.) to produce one dozen eggs than did birds kept at the high density.

Mortality, in shallow cages, was significantly ($P < 0.01$) higher (+3.9%) among birds housed at four-bird density than among those housed at three-bird density. However, bird density, in deep cages, had no significant effect on mortality rate. The total death losses, in shallow cages, for the low and high bird density were zero and fourteen birds during the entire experimental period, respectively. In deep cages, death losses were two and five birds for birds housed at three and four birds per cage, respectively.

The body weight gain was found to be significantly ($P < 0.01$) affected by cage shape but not by bird density. Birds housed in deep cages gained 574.68 grams while those in shallow cages gained 482.09 grams during the entire course of the experiment.

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APPENDIX

Appendix Table 1. Composition of the Experimental Diet in Percent (Hamilton Farm Bureau).

Ingredients	Percent
Corn, ground	68.95
Soybean Meal, 49%	16.50
Alfalfa, 17%	2.00
Meat and Bone Meal, 50%	3.00
Limestone, ground	7.00
Dicalciumphosphate	1.25
Methionine, DL	0.05
Salt	0.25
Fat, A-U	0.50
Layer Premix	0.50
Total	100.00
Calculated Analysis	**Percent**
Crude Protein	16.00
Fat	3.54
Fiber	2.95
Calcium	3.30
Phosphorus	0.48
Metabolizable Energy, Kcal/lb.	13.11

Appendix Table 2. Average Monthly House Temperature as Recorded Daily at 8:00 a.m. and 3:00 p.m.

Dates	8:00 a.m.		3:00 p.m.	
	^0F	^0C	^0F	^0C
Nov. 1976	61.87	16.60	64.63	18.13
Dec. 1976	58.13	14.52	60.29	15.72
Jan. 1977	53.23	11.80	54.55	12.53
Feb. 1977	56.57	13.65	59.32	15.18
March 1977	62.23	16.80	67.19	19.55
April 1977	59.07	15.04	68.81	20.45

Appendix Table 3. Weight Classes of Egg Sizes in Grams According to U.S.D.A. Standards for Consumer Grades.

Size Class	Minimum Net Weight Per Dozen in Ounce	Range Weight Per Egg in Gram
Jumbo	30	70.95--above
Extra Large	27	63.86--70.94
Large	24	56.76--63.85
Medium	21	49.67--56.75
Small	18	42.57--49.66
Peewee	15	42.56--less

Appendix Table 4. Classification of Shell Cleanliness According to U.S.D.A. Description.

Classes	Shell Condition
Clean	Clean appearance
Slightly stained	Free from adhering dirt but scattered stains on 1/16 of the shell surface
Moderate stains	Free from adhering dirt but scattered stains on 1/4 of the shell surface
Dirty	Unbroken shell, adhering dirt, foreign material covering more than 1/4 of shell surface

Appendix Table 5. Analysis of Variance of Egg Production by Shape of Cage, Bird Density and 4 Week Periods.

Source of Variation	Degree of Freedom	Sum of Square	Mean Square	F Statistic	Prob. of Type I Error (Fα)
Shape	1	990.368451	990.368451	1.4	
Density	1	5288.597368	5288.597368	7.479	<.01(6.76)*
Shape x Density	1	1142.154128	1142.154128	1.615	
Error 1	204	144263.4973	707.173866		
Period	4	21670.0399	5417.509337	55.293	<.01(3.34)**
Shape x Period	4	447.936867	111.984217	1.143	
Density x Period	4	1231.987137	307.996788	3.144	<.05(2.38)*
Shape x Density x Period	4	581.791833	145.447961	1.485	
Error 2	816	79949.7117	97.977586		

* Significant

** Highly significant

Appendix Table 6. Analysis of Variance of Egg Production by Shape of Cage and Bird Density for the First Production Period.

Source of Variation	Degree of Freedom	Sum of Square	Mean Square	F Statistic	F.01
Shape	1	4.0068	4.0068	.130	
Density	1	284.2511	284.2511	9.253	6.76*
Shape x Density	1	6.8656	6.8656	.224	
Experimental Error	204	6267.1888	30.7215		

*Significant

Appendix Table 7. Analysis of Variance of Egg Weight by Shape of Cage, Bird Density and 4 Week Periods.

Source of Variation	Degree of Freedom	Sum of Square	Mean Square	F Statistic	F.05
Shape	1	312.3939	312.3939	3.886	3.87*
Density	1	145.9325	145.9325	1.815	
Shape x Density	1	0.2846242	0.2846242	0.003	
Error 1	204	16396.07	80.37288		
Period	4	248.4441	62.111029	1.857	
Shape x Period	4	196.5722	49.14306	1.470	
Density x Period	4	76.54108	19.13527	0.572	
Shape x Density x Period	4	269.1673	67.291837	2.013	
Error 2	816	27280.15	33.431553		

*Significant

Appendix Table 8. Analysis of Variance of Egg Weight by Shape of Cage and Bird Density for the First Production Period.

Source or Variation	Degree of Freedom	Sum of Square	Mean Square	F Statistic	F.05
Shape	1	29.69781	29.69781	1.934	
Density	1	10.38461	10.38461	0.676	
Shape x Density	1	29.28242	29.28242	1.908	
Error	46	706.04631	15.34883		

Appendix Table 9. Analysis of Variance of Shell Weight by Shape of Cage, Bird Density and 4 Week Periods.

Source or Variation	Degree of Freedom	Sum of Square	Mean Square	F Statistic	Prob. of Type I Error (Fα)
Shape	1	3.745298	3.745298	4.326	<.05(3.89)*
Density	1	0.401663	0.401663	0.464	
Shape x Density	1	0.32656	0.032656	0.038	
Error 1	204	176.6235	176.6235		
Period	4	9.340404	2.335101	8.525	<.01(3.34)*
Shape x Period	4	1.925783	0.481446	1.756	
Density x Period	4	0.842893	0.210723	0.769	
Shape x Density x Period	4	2.980985	0.745246	2.721	<.05(2.38)*
Error	816	223.5219	0.273924		

*Significant

Appendix Table 10. Analysis of Variance of Shell Weight by Shape of Cage and Bird Density for the First Production Period.

Source of Variation	Degree of Freedom	Sum of Square	Mean Square	F Statistic	F.05
Shape	1	0.73562	0.73562	0.039	
Density	1	0.81845	0.81845	0.029	
Shape x Density	1	0.03631	0.03631	0.638	
Error	46	7.45764	0.16212		

Appendix Table 11. Analysis of Variance of Shell Percentage by Shape of Cage, Bird Density and 4 Week Periods.

Source of Variation	Degree of Freedom	Sum of Square	Mean Square	F Statistic	F.05
Shape	1	35.354641	35.354641	2.317	
Density	1	0.137821	0.137821	0.009	
Shape x Density	1	0.191115	0.191115	0.0125	
Error 1	204	3112.8902	15.259265		
Period	4	176.2524	44.063107	3.001	2.38*
Shape x Period	4	115.9808	28.995210	1.975	
Density x Period	4	1.481446	0.370361	0.025	
Shape x Density x Period	4	5.161072	1.290268	0.088	
Error 2	816	11981.10			

*Significant

Appendix Table 12. Analysis of Variance of Shell Percentage by Shape of Cage and Bird Density for the First Production Period.

Source of Variation	Degree of Freedom	Sum of Square	Mean Square	F Statistic	F.05
Shape	1	0.40644	0.40644	1.706	
Density	1	1.05491	1.05491	4.429	4.05*
Shape x Density	1	0.18691	0.18691	0.785	
Error	46	10.95674	0.23819		

*Significant

Appendix Table 13. Analysis of Variance of Shell Thickness by Shape of Cage, Bird Density, and 4 Week Periods.

Source of Variation	Degree of Freedom	Sum of Square	Mean Square	F Statistic	F.01
Shape	1	0.0030036	0.0030036	1.196	
Density	1	0.00035396	0.00035396	0.141	
Shape x Density	1	0.00004805	0.00004805	0.019	
Error 1	204	0.51220378	0.00251080		
Period	4	0.01679315	0.00419829	4.546	3.34*
Shape x Period	4	0.00388916	0.00097229	1.053	
Density x Period	4	0.00209072	0.0005226	0.566	
Shape x Density x Period	4	0.01528375	0.0038209	4.137	3.34*
Error 2	816	0.75362714	0.00092356		

*Significant

Appendix Table 14. Analysis of Variance of Shell Thickness by Shape of Cage and Bird Density for the First Production Period.

Source or Variation	Degree of Freedom	Sum of Square	Mean Square	F Statistic	F.05
Shape	1	0.00133	0.00133	4.631	4.05*
Density	1	0.00153	0.00153	5.329	4.05*
Shape x Density	1	0.00004	0.00004	0.1336	
Error	46	0.01321	0.00029		

*Significant

Appendix Table 15. Analysis of Variance of Soiled Eggs by Shape of Cage, Bird Density and 4 Week Periods.

Source of Variation	Degree of Freedom	Sum of Square	Mean Square	F Statistic	Prob. of Type I Error (Fα)
Shape	1	1.8718	1.8718	0.0684	
Density	1	1721.4253	1721.4253	62.887	<.01(6.72)**
Shape x Density	1	56.6459	56.6459	2.0694	
Error 1	204	5584.1180	27.3731		
Period	4	221.6298	55.4075	7.250	<.05(2.38)*
Shape x Period	4	45.7807	11.4452	1.497	
Density x Period	4	87.1892	21.7973	2.851	<.05(2.38)*
Shape x Density x Period	4	4.4621	1.1155	0.1459	
Error 2	816	62.369516	7.6433		

*Significant

**Highly Significant

Appendix Table 16. Analysis of Variance of Soiled Eggs by Shape of Cage and Bird Density for the First Production Period.

Source of Variation	Degree of Freedom	Sum of Square	Mean Square	F Statistic	F.05
Shape	1	12.5315	12.5315	0.683	
Density	1	11.5975	11.5975	0.632	
Shape x Density	1	40.1047	40.1047	2.187	
Error	204	3741.0666	18.3386		

Appendix Table 17. Analysis of Variance of Cracked Eggs by Shape of Cage, Bird Density and 4 Week Periods.

Source of Variation	Degree of Freedom	Sum of Square	Mean Square	F Statistic	F.05
Shape	1	2.2578	2.2578	0.233	
Density	1	53.3038	53.3038	5.488	3.89*
Shape x Density	1	0.0353	0.00353	0.0036	
Error 1	204	1981.2676	9.721		
Period	4	103.5652	25.8913	3.113	2.38*
Shape x Period	4	56.8464	14.2116	1.701	
Density x Period	4	43.9913	10.9978	1.322	
Shape x Density x Period	4	81.3646	20.3412	2.45	2.38*
Error 2	816	6786.6958	8.3170		

*Significant

Appendix Table 18. Analysis of Variance of Cracked Eggs by Shape of Cage and Bird Density for the First Production Period.

Source of Variation	Degree of Freedom	Sum of Square	Mean Square	F Statistic	F.05
Shape	1	237.3197	237.3197	1.7665	
Density	1	76.8681	76.8681	0.5722	
Shape x Density	1	159.0840	159.0840	1.1842	
Error	204	27406.03	134.3433		

Appendix Table 19. Analysis of Variance of Daily Feed Consumption Per Bird by Shape of Cage, Bird Density and 4 Week Periods.

Source of Variation	Degree of Freedom	Sum of Square	Mean Square	F Statistic	Prob. of Type I Error (Fα)
Shape	1	1.100077	1.100077	0.0498	
Density	1	273.112717	273.112717	12.358	<.05(7.71)*
Shape x Density	1	16.857462	16.857462	0.763	
Error 1	4	88.402143	22.100536		
Period	4	744.539452	186.134859	27.831	<.01(4.77)**
Shape x Period	4	20.070727	5.017679	0.750	
Density x Period	4	28.483903	7.120969	1.065	
Shape x Density x Period	4	26.072054	6.518010	0.975	
Error 2	16	107.008176	6.688011		

*Significant

**Highly significant

Appendix Table 20. Analysis of Variance of Feed Consumption per Bird by Shape of Cage and Bird Density for the First Production Period.

Source of Variation	Degree of Freedom	Sum of Square	Mean Square	F-Stat.	F.01
Shape	1	27.527245	27.527245	2.735	
Density	1	1790.397959	1790.397959	177.868	21.20**
Shape x Density	1	20.064260	20.064260	1.993	
Error	4	40.263597	10.065906		

**Highly significant

Appendix Table 21. Analysis of Variance of Feed Conversion by Shape of Cage, Bird Density and 4 Week Periods.

Source of Variation	Degree of Freedom	Sum of Square	Mean Square	F Statistic	F.01
Shape	1	71651.174	71651.174	1.723	
Density	1	62200.452	62200.452	1.496	
Shape x Density	1	27740.517	27740.517	0.667	
Error 1	4	166326.795	41581.693		
Period	4	630196.319	157549.079	23.586	4.77**
Shape x Period	4	57962.283	14490.570	2.169	
Density x Period	4	76088.471	19022.115	2.848	
Shape x Density x Period	4	39638.523	9909.631	1.484	
Error 2	16	106878.155	6679.886		

**Highly significant

Appendix Table 22. Analysis of Contingency Tables for Mortality by Shape of Cage and Bird Density for 168-Day Period.

I. Effect of placing 3 or 4 birds in 12" x 16" deep cages:

	Total Housed	Died	Lived
3 Birds/Cage	156	2	154
4 Birds/Cage	208	5	203
	364	7	357

Ho: proportion of dead birds are same for 3 or 4 birds per cage.

$Eij = yi \cdot y \cdot j/n$

$E11 = (357)(156) \quad 364 = 153$

$E12 = (357)(208) \quad 364 = 204$

$E21 = (7)(208) \quad 364 = 4$

$E22 = (7)(156) \quad 364 = 3$

$q = \sum_{i=i}^{r} \sum_{j=i}^{c} [(Oij - Eij)^2/Eij]$ where $Oij = yij$ observed number in $i\ j$

$q = (154-153)^2/153 + (203-204)^2/204 + (2-3)^2/3 + (5-4)^2/4 = 0.60$

$\chi^2 \alpha, (r-1)(c-1);$

$\alpha = .05$

χ^2 .05, 1, 1, = 3.841

No significant effect of bird density on mortality in deep cages.

II. Effect of placing 3 or 4 birds in 16" x 12" reverse cages.

	Total Housed	Died	Lived
3 Birds/Cage	156	0	156
4 Birds/Cage	208	14	194
Total	364	14	350

$q = 10.92$

χ^2 0.01, 1, 1 = 6.635*

Mortality of birds was significantly ($P < 0.01$) affected by bird density in the reverse type cages.

Appendix Table 22 Continued

III. Comparisons between deep and shallow cages using same number of birds on mortality rates.

A. Three birds per cage

	Ri	Died	Lived
Deep	156	2	154
Shallow	156	0	156
	312	2	310

q = 2.013

χ^2 .05, 1, 1 = 3.841

B. Four birds per cage

	Ri	Died	Lived
Deep	208	5	203
Shallow	208	14	194
Total	416	19	397

q = 4.47; χ^2 .05, 1, 1, = 3.841*

Therefore, with four birds per cage, those housed in shallow cages showed significantly ($P < 0.05$) higher mortality than did birds in deep cages.

*Significant

Appendix Table 23. Analysis of Variance of Body Weight Gain by Shape of Cage and Bird Density.

Source of Variation	Degree of Freedom	Sum of Square	Mean Square	F Statistic	F.001
Shape	1	445773.32	445773.32	19.522	10.80**
Density	1	29549.36	29549.36	1.294	
Shape x Density	1	11612.66	11612.66	0.509	
Error	204	4658164.0	22834.14		

**Highly significant