

THE LAYING HOUSE PERFORMANCE
OF CHICKENS BROODED AND REARED
ON FLOORS AND IN CAGES

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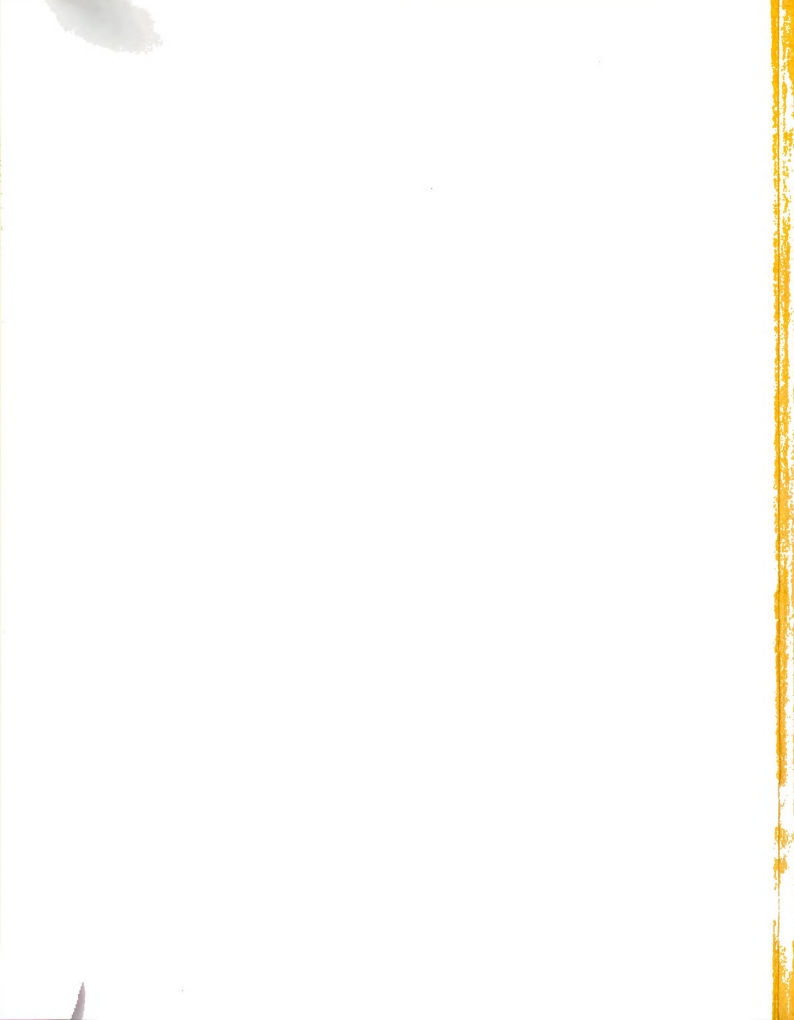
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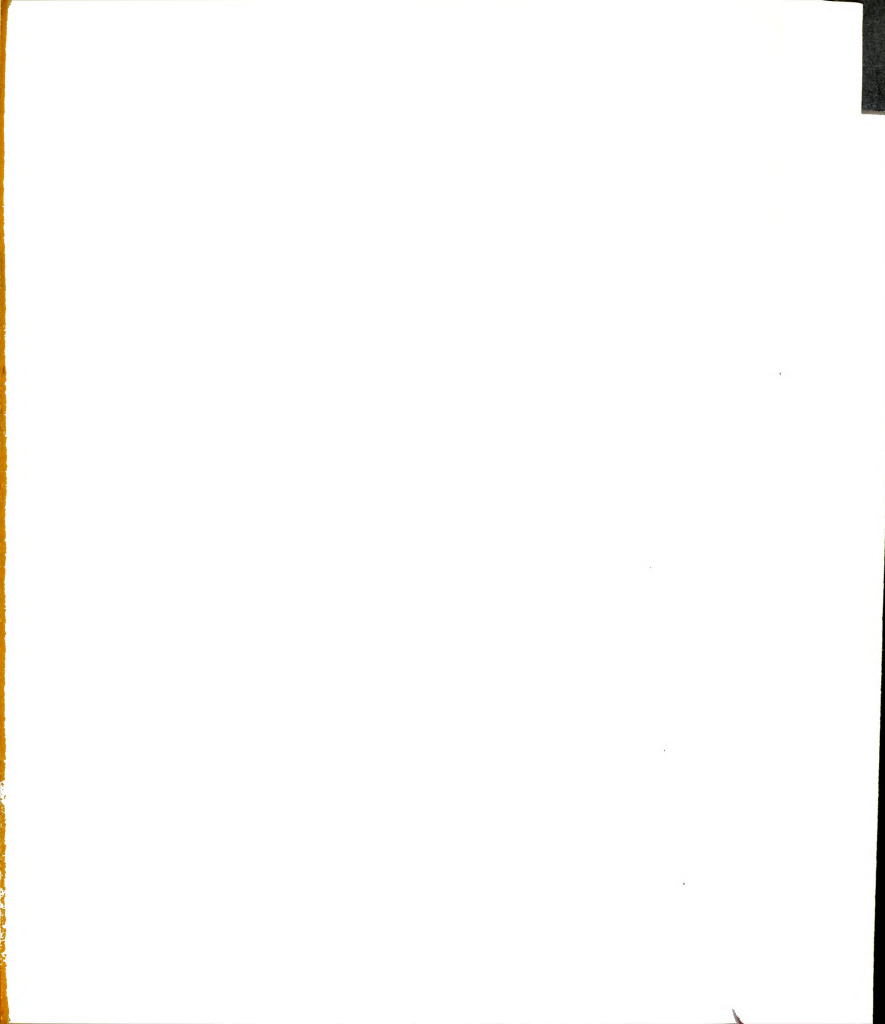
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ABSTRACT

THE LAYING HOUSE PERFORMANCE OF CHICKENS BROODED AND REARED ON FLOORS AND IN CAGES

By

Howard Edwin Wildey

There is a lack of information on the relationship of management and nutritional aspects of caged pullet rearing to economic egg production. It was therefore of interest to evaluate the subsequent performance of pullets reared under four methods: in cages without a coccidiostat in the diet, in cages for the same period with a coccidiostat in the diet, on litter to seven weeks of age and then in cages to 20 weeks of age, and on litter to 20 weeks of age. Five levels of phosphorus were factorially combined with the four rearing methods (20 factorial combinations). Pullets grown in these combinations were compared for mean body weight at 20 weeks of age and for production in single bird density laying cages.

Day-old commercial White Leghorn type pullets were used in this experiment. No debeaking was done. The pullets reared on the floor were significantly lighter in body weight and consumed significantly less feed than pullets reared in cages or in the floor-cage rearing methods.



Mortality percentages by rearing method were 1.33 (cages-no coccidiostat), 2.00 (cages-coccidiostat), 5.33 (floor-cage combination) and 6.66 (floor). There were significant differences among the rearing methods in mortality. No significant differences in body weight at 20 weeks of age due to diet treatments were found.

The same diet was fed to the birds in all treatment combinations during the production phase. No significant differences in performance were found among the treatment combinations during the production phase regarding egg production, egg weight, Haugh Unit or shell thickness values.

Experiment 2 was conducted to test the effect of rearing density, i.e., 10, 20, 30 or 40 chicks (density levels 1 through 4, respectively) per 24 inches wide x 22 inches deep x 16 inches high cage, on performance during the subsequent production phase.

A total of 330 White Leghorn type day-old pullets were separated into three weight class intervals that differed in weight by three grams. Equal numbers of chicks from each weight class were wing-banded for each rearing density to be tested. Feeder space per chick for rearing densities 1 through 4 was 2.5, 1.2, 0.8 and 0.6, respectively. At seven weeks of age, one-half of the pullets were transferred to identical cages, thus

doubling feeder and cage floor space for the remainder of the period to 20 weeks of age.

Fifty-four pullets from each rearing density level were selected equally from the three weight classes. Eighteen pullets were housed at one bird per cage in 8 inch x 16 inch cages and the remaining 36 were placed in the same size cages at two birds per cage. All pullets received the same laying diet. Records of production were obtained from 22 weeks of age through six 28-day production periods.

At 20 weeks of age the pullets reared at density 4 were significantly lighter than those reared at the other densities and had consumed significantly less feed. The pullets reared at density 1 consumed significantly more feed than did the pullets in the other treatment levels.

No significant differences were found among the means of number of eggs laid by pullets surviving the six 28-day production periods at either one or two birds per cage laying density. However, there were significant differences in hen-day production where the pullets were housed at two birds per cage; whereas no significant differences were found where they were housed individually. The pullets reared at density levels 3 and 4 had significantly lower hen-day production than those reared at



levels 1 and 2. In the first production period, the pullets reared at density levels 3 and 4 and subsequently housed at one bird per cage laid significantly larger eggs than those that had been reared at density levels 1 and 2; however no significant differences were found for this trait when data from the first three production periods were analyzed. No significant differences were found for this factor when the pullets were housed at two birds per cage.



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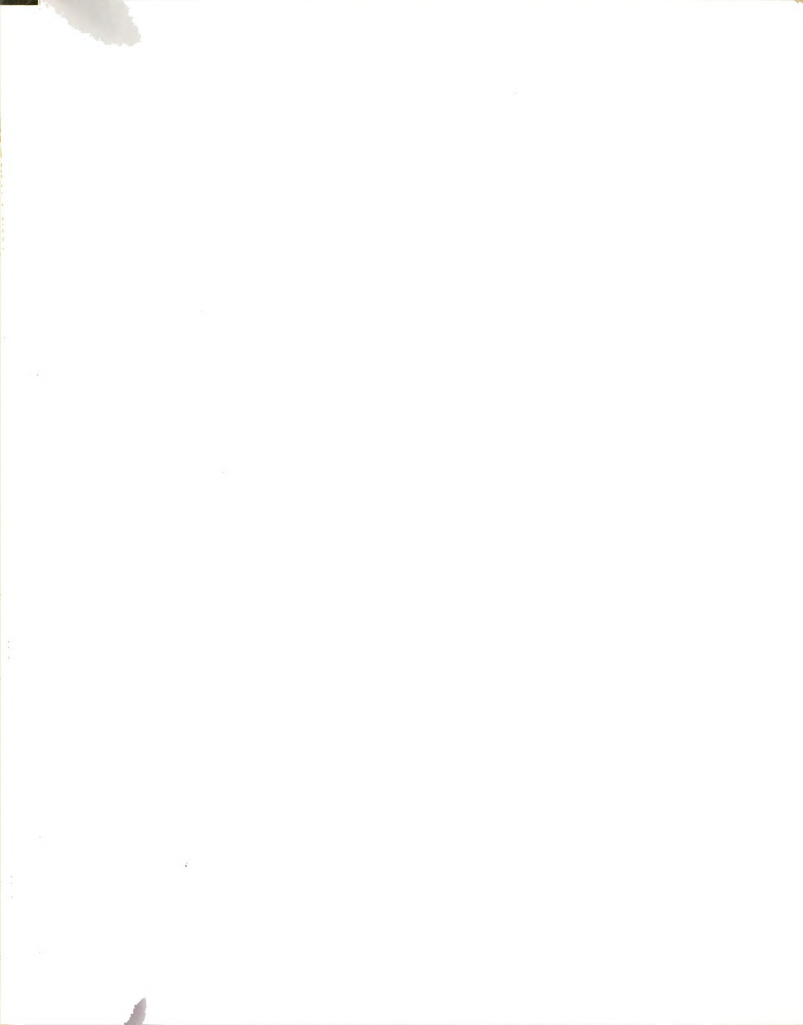
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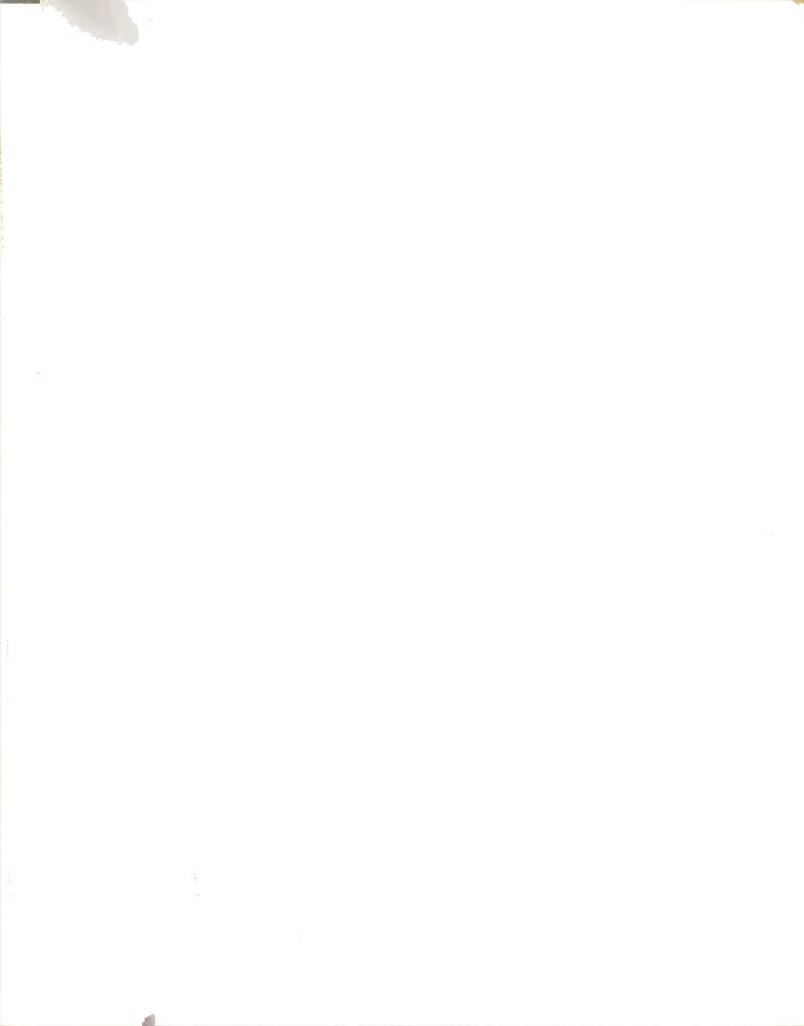


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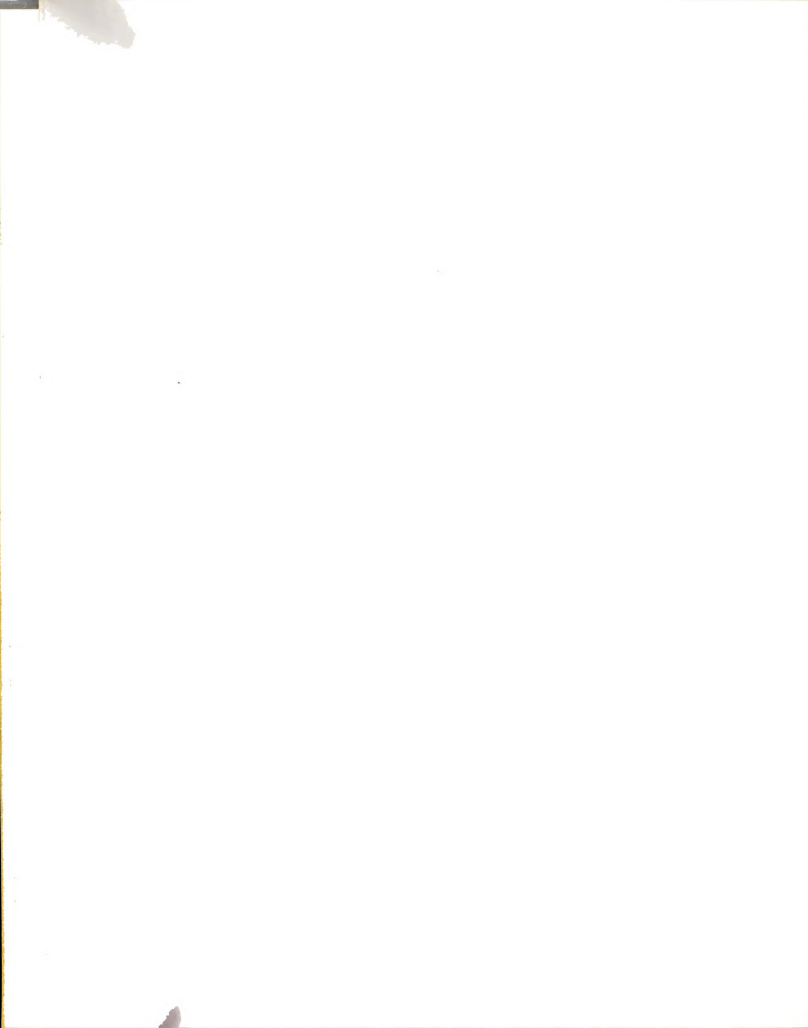


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INTRODUCTION

The rapid development of fewer but larger and more specialized egg production units has emphasized the need for efficiency in pullet production. Egg producers have found themselves in a highly competitive business where efficiency is one of the keys to survival. Consequently, they are receptive to innovations that lead to a reduction in costs of production. An innovation is an idea perceived as new by the individual (Rogers, 1962). An important economic factor in the production of market eggs is the replacement pullet, her production cost, and her performance regarding egg numbers, egg size and interior egg quality, shell quality and livability.

The use of wire floors and wire floor cages for growing replacement pullets is not new. Poultry researchers have used battery brooders for years and, although batteries are not used extensively in commercial poultry operations because of poor labor efficiency, some growers still use them to start chicks and poults for a brief period. In intensive production areas of California where extensive change in management technology tends to be more readily accepted than in other production regions, the practice

of rearing chickens on wire has been in use for several decades (Bell, 1967).

The use of caged rearing procedures for producing pullets appears to be a natural procedure as commercial poultrymen move toward environmental control and increased house density. Rearing and housing methods have been areas of important concern in the poultry industry for many years and are considered vitally related to the cost of producing market eggs. However, range and confinement methods of rearing pullets have been used extensively in most production areas until the last few years. Recently, the development of cage brooding and/or rearing systems has received a great deal of attention. Some experimental work comparing range with confinement pullets, and range and confinement pullets with colony cage reared birds has been reported in the literature. However, except for field trials, reports in the literature show little work comparing the egg production of birds grown in cages from day old to 20 weeks with that of birds grown in combination floor and cage rearing systems and/or with that of birds grown on the floor by conventional confinement rearing procedures.

It has been generally appraised that cage rearing is more expensive than conventional systems of floor rearing, yet Bell (1967) reported that both floor and

wire rearing is practiced in Riverside County, California, where six and one-half million layers on 225 farms were kept in cages. His 1965 survey showed that 67 percent of the commercial poultrymen in that locality maintained their birds on wire through rearing and production. In this survey, 12 percent of the poultrymen brooded the birds on the floor and moved them to wire cages when they were eight weeks of age and 13 percent of these producers reared their birds on the floor to 18-20 weeks of age. Bell (1967) reported further that in some instances where poultrymen had built new floor rearing facilities in the hope of raising a better pullet, they were forced to convert to cage and wire rearing to overcome severe disease problems. His observations suggest that disease problems associated with intensification may be better controlled when replacement pullets are grown on wire or in cages. Since healthy, productive replacement pullets are essential for financial success in commercial egg production, many producers feel that cage rearing is worth the extra \$0.50 (Bell, 1967) or \$0.73 (Brown, 1969) per bird initial investment cost required for cage rearing. If we assume that the extra cost of cage rearing facilities is \$0.50 per bird above that of conventional floor rearing, and that this cost is spread over 50 birds, the extra cost of the cage system is one cent per replacement pullet.

This may be a minor additional expense if uncertainty is generally eliminated from the replacement pullet growing enterprise and risk is reduced to a manageable proportion of pullet production cost.

Claybaugh (1966) reported that growing pullets on wire is not without problems. He observed that management, rations, and feeding must be developed to produce the best pullet possible under this regime. He stated further that the action of progressive producers in important production areas indicate a definite trend toward cage rearing. The advantages and disadvantages claimed for this system of pullet rearing seem to be based on little more than field observations. Flegal et al. (1966) have listed these possible advantages and disadvantages as follows:

Advantages

1. Elimination of losses due to crowding and smothering.
2. Elimination of coccidiosis and intestinal parasites.
3. Birds are accustomed to cages when moved to laying cages.
4. Dust is reduced and this helps reduce respiratory problems.
5. The cage system affords better working conditions.
6. Feed consumption is reduced when properly controlled.
7. There is increased efficiency in the use of labor, capital and housing.

8. Fuel costs are reduced.
9. Flocks are more uniform in size and appearance.
10. The cost of litter is eliminated.
11. There is better control of management factors.
12. The overall cost of producing pullets is reduced.

Disadvantages

1. Birds reared in cages should not be sold for floor layer operations because they lack immunity to coccidia.
2. Pullets often have a poorer appearance to prospective customers.
3. A higher total investment in production facilities is required.
4. Management systems must be changed.
5. Temperature and ventilation are more critical.
6. Cannibalism can be a serious problem.
7. During certain periods, the labor requirements are extremely high.

Description of Brooding and Rearing Systems in General Use

1. Floor brooding is generally a one-step process in which the chick is started in a brooder house and kept there until she is 16 to 22 weeks of age, and then moved into laying quarters; cages or a litter operation.

2. Litter floor brooding to wire or cage combinations: In this system, the chicks are usually grown from

day-old to six to 10 weeks of age in a conventional floor house and then are moved to either wire or cages to be grown until maturity. While on the floor, $2/3$ to $3/4$ of a square foot of floor space per bird is allowed.

3. In some instances chicks are started on wire floors at day-old and grown to maturity under the same conditions. The floor space allowed with this system may be less than the one square foot per bird that is generally allowed for a floor operation. Hovers are generally used as the heat source.

4. A wire floor to cage system may be used. In this system, the chicks are started on wire at day-old and grown to six to 10 weeks of age with about $1/2$ square foot of floor space per bird. At six to 10 weeks of age the birds are moved into rearing cages.

5. Two cage rearing systems are being used currently. In one type the birds are raised in cages in the same house from day-old to 20 weeks of age. This is done in either of two ways: (1) two sets of cages are used, one for starting and one for growing, or (2) one set of cages is used to start the birds and they are continued in the same cages to 20 weeks of age. This latter system of cage rearing has the advantage over other wire systems in that birds are not moved to another house during the brooding and growing period. Further, it

results in saving the labor costs of moving and also it eliminates the stress on the birds due to moving and a change in environment. The birds are fed by the use of an auger cart or mechanical feeder and water is provided by a continuous flow or cup water system. A disadvantage is that the heating system is used for only six weeks out of the 20 week growing period.

In the second cage rearing system, chicks are grown from day-old to six to eight weeks of age in starter cages at which time they are moved to grower cages where they remain until they are 20 weeks of age. As with the first system, mechanical feeders and automatic water systems are generally used. This system allows for a more continuous use of the starting cages and the associated heating system. Under this system, three cage rearing houses are required if the starting cage house is to be used to capacity.

REVIEW OF LITERATURE

Good pullets are considered to be absolutely essential for the economic success of an egg production unit. This fact has led to considerable research to test the effect of rearing methods and procedures on subsequent production. Stevenson and Bryant (1944), Heuser et al. (1945), Johnson and Davidson (1957), Taylor et al. (1957), Bailey et al. (1959b), Pepper et al. (1959), and Winter (1957) found no significant differences between the laying house performance of pullets reared on range and those grown in floor pens in confinement. Kinder and Yoes (1956), Winter and Schlamb (1948) and Tomhave (1960) found that range reared pullets laid at a higher rate than those reared in confined floor pens. Tomhave (1960) found that New Hampshire pullets grown on range not only laid more eggs, but that the eggs were larger and hatched more chicks that had better livability than was the case for confinement floor reared birds of the same breed.

Pearl and Surface (1914) have shown that either weight or bulk may be used as a measure of size in fresh eggs. Jull (1952) presented the factors in pullet rearing and layer management that affect egg size and

quality. He stated that certain environmental and physiological factors affect egg weights. Pullets fed diets relatively low in protein and that are hatched during the winter tend to lay smaller eggs than those fed higher protein diets and are hatched during the spring and the month of September. High summer temperatures tend to reduce both egg size and shell quality.

Early sexual maturity, according to Jull (1952), is important in securing high first year egg production records. However, the lack of persistency makes for the greatest difference in total egg record. Late sexual maturity makes for the least difference in total egg record (Hays, 1944). Researchers have observed that egg weight is determined by the size of the yolk and oviduct (Asmundson, 1931) and it has been demonstrated that the weights of the other egg components are greater as the size of the oviduct increases (Asmundson and Jervis, 1933).

Earliness of sexual maturity is economically desirable when associated with reasonably good egg size. It is obvious that the earlier in life a pullet commences laying, the sooner it produces some income for its owner. The work of Hays (1933), Funk (1935) and Callenbach (1934) confirmed a positive relationship between egg weight and body weight of the pullet at the start of egg production.



Ideally, a pullet should be reared so that sexual maturity is delayed until it has adequate body size to lay an acceptable percentage of medium or larger size eggs (23 ounces per dozen or more). Wolford (1964) summarized the recent research on the subject of delayed sexual maturity in replacement pullets. He stated that either the use of controlled light period or restricted feed programs is effective in delaying sexual maturity of replacement pullets, but controlled lighting seems to have a greater degree of influence on rate of maturity than does restricted feeding. Restricted lighting programs differ according to housing conditions used. Two light control programs are available to delay the sexual maturity of replacement pullets: (1) a restricted light program to be used in conjunction with windowless houses; and (2) a decreasing light program to be used in houses with windows. The program for windowless houses consists of rearing birds under 12 hours of light until they are 8 to 10 weeks of age. The birds are then given 6 to 9 hours of light until they are 20 to 22 weeks of age. It is used throughout the year. In the program for houses with windows a decrease in length of the daily light period is applied at periodic intervals through the rearing phase. The producer using this system first determines the total number of natural daylight hours (sunup

to sundown) at the time that the birds will be 22 weeks of age. Then to this figure 7 hours are added. The resulting sum is the amount of light required during the first week of the rearing period. After the first week, the daily light period is decreased 20 minutes per week until the birds are 22 weeks of age. The programs recommended by various breeding firms may vary somewhat from these recommendations but the principles involved remain the same.

The advantage of restricted light over natural daylight for growing pullets is that sexual maturity can be delayed one to three weeks with the controlled system. The disadvantage of a restricted light program is that it requires a completely darkened building. This practically makes an environmentally controlled house a necessity with the additional cost of insulation and ventilation. This is not too serious since economic production of pullets in most regions requires this type of housing. A time clock controls the length of light period automatically.

A restricted feeding program requires a great deal of work and effort on the part of the pullet grower, according to Wolford (1964). Ringrose (1958) has prepared a feeding guide which showed the pounds of feed that should be allowed for 100 birds at various ages in weeks throughout the pullet growing period. High fiber feeding



programs are also used to restrict nutrient intake (Wolford, 1964 and Taylor et al., 1957).

The size of pullets grown under any rearing regime is important because pullet body size at the beginning of lay may affect egg size. Until recently, the general procedure was to rear replacement pullets in floor pens in confinement at a density of one square foot of floor space per bird from day-old to 20 weeks of age.

Hartung (1955), Brooks et al. (1957), Heishman et al. (1952) and Moreng et al. (1961) found that increasing population density beyond a certain point reduced the average size of chicken broilers. However, Siegel and Coles (1958) observed little if any effect on the body weight, feed efficiency or livability of broilers grown at densities ranging from one-half to one and one-half square feet of floor space per bird.

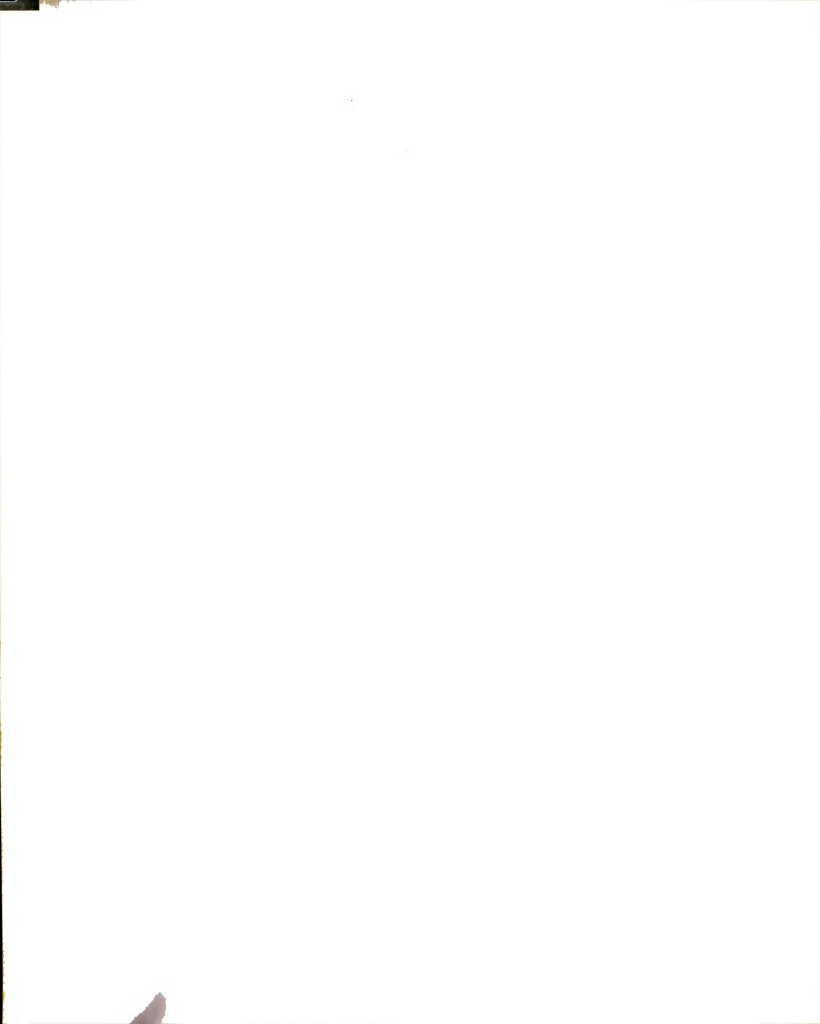
Magruder and Nelson (1961) reared White Leghorn pullets under two feeding regimes, restricted and full-fed, and supplied six hours of light daily from three to 21 weeks of age. When subsequently housed in an all slat floor, mechanized, high density laying house, there was little difference between the two groups as to total production. However, the pullets fed a restricted diet laid a significantly higher percentage of large eggs which also tended to have a higher albumen quality.

Ernst and Coleman (1966) used Coturnix quail to determine the feasibility of using quail as a substitute for chickens and turkeys in environmental studies. These researchers found that when quail were reared at densities of 4 or 17 birds per square foot from hatching to onset of egg production, and were then placed in individual cages for 100 days, the egg production was not significantly different.

The trend in poultry management has been toward denser populations in growing and production poultry. Kimber (1941), Hoffman and Tomhave (1945), Nordskog (1959), Siegel (1959) and Fox and Clayton (1960) found that, in laying hens, egg production per bird decreased as floor space per bird was decreased. Champion et al. (1962) found no difference in egg production between birds housed in floor pens at 1.25 or 2 square feet per bird during the laying period.

Wolford and Coleman (1960) found that when Beltsville Small White or Broad Breasted Bronze turkeys were kept at high population densities, egg production per unit of floor space increased but fertility in naturally-mated turkeys decreased.

Though the majority of new commercial layer operations have birds housed in laying cages, this is a rather recent development and research on laying cages



versus floor type operations has produced varied results. Parker and Rodgers (1954) found no consistent differences in egg production or mortality in tests which compared the performance of layers in floor pens, individual cages and colony cages. Gowe (1955) obtained better production from floor housed birds but had lower mortality in cage housed birds. Hill et al. (1957), Miller and Quisenberry (1959) and Bailey et al. (1959a) obtained higher egg production from cage housed birds. Bailey et al. (1959a) found that cage housed birds laid heavier eggs and had heavier body weights. Miller and Quisenberry (1959) observed lower mortality in the cage housed birds than in those housed in floor pens.

Champion and Zindel (1968) evaluated the performance of pullets housed in (1) individually in 8 inch cages, (2) two birds to a cage in 8 inch cages, (3) three birds to a cage in 12 inch cages, (4) four birds to a cage in 16 inch cages, and (5) six birds to a cage in 24 inch cages. All cages were 16 inches deep. They found no great differences in average random sample body weights at 500 days of age or in 400th day average egg weight. They concluded, from their data, that income per unit of cage space can be maximized by using multiple cage units in preference to caging layers individually. The poultryman's ability to control cannibalism was suggested as



being the determining factor as to whether individual or multiple cages are used.

Only limited research data are available dealing with the rearing of replacement pullets on wire or in cages. A number of articles based upon survey data have been published in the poultry press. Shupe and Quisenberry (1961) reported the first research data that involved subsequent production tests of cage-reared birds. However, their work involved rearing in cages only during the latter part of the growing period. In their trial, pullets were reared on the floor for 14 weeks in conventional, confinement pens. At 14 weeks, the pullets were equally divided among floor pens, range and colony cages, either 25 or 35 pullets per 3 1/2 x 8 foot colony cage. Equal numbers of cages had slat and wire floors. During the subsequent rearing period, significant differences in body weight were observed. The colony cage reared birds were heaviest in body weight and consumed the most feed. The range reared birds were significantly heavier in body weight than those reared in floor pens. Rearing mortality was highest for birds in the colony cages and lowest for those in the floor pens. Pullets from each rearing environment were subsequently housed in colony laying cages. During the production period no significant differences in average body weight, egg production, egg weight, feed



efficiency or mortality attributable to the different rearing treatments were found.

Magruder and Nelson (1968) compared three rearing regimes: (1) floor confinement, (2) floor confinement and cage combination, and (3) cage rearing from day-old to 20 weeks of age. Comparisons were made for body weight, feed consumed, feed conversion and mortality as well as for subsequent production. They found that the three rearing systems produced pullets of about the same body weight at 20 weeks. Rearing mortality was lowest for the floor rearing system (0.83 percent). The cage reared birds consumed the most feed (1.98 kgs.) but the floor-cage combination and cage rearing systems had the highest mortality (3.72 percent each).

Bell (1969) reported the results of four field trials to measure the effect of crowding pullets in 24 x 24 inch cages in commercial controlled environment brooder and growing houses. In the first trial, chicks were placed in cages at the rate of 6, 8, 10, 12, 14, 16, 18 and 20 per cage at one day of age. Dead birds were replaced throughout the trial with equal numbers of banded pullets of the same age. Each cage had 24 inches of mechanical feeder space. The pullets were weighed at 6, 10, 12 and 16 weeks of age. Debeaking was done at 13 1/2 weeks of age. It was found that the average body weight

at each age tended to go down as density was increased. At 10 weeks of age, the birds in the 8-bird cage were closest to the breeder's goal for body weight. At 12 weeks of age, birds in both the 8 and 10-bird cages were closest to the breeder's goal of 2.3 pounds or 1.044 kgs. average body weight. Though greater densities resulted in lower weights, this researcher observed that some grower managers might require fewer pullets per cage to reach the optimum weight while others might achieve this weight with somewhat higher density. No significant differences were found in variability of body weights or in mortality among the density levels.

A second trial in the same house was conducted using densities of 8, 10, 12, 14 and 16 birds per cage. Two White Leghorn strains were used. Statistical analyses of weights taken at 6, 12 and 16 weeks of age indicated a definite relationship between body weight and density but the difference was most apparent at 16 weeks of age. A comparison of 12 week weights indicated that identical results would have been obtained with either strain.

In trial 3, densities of 6, 8 or 10 pullets in 24 x 24 inch cages were used for the growing period between 7 1/2 and 15 1/2 weeks of age. The birds were not debeaked in this trial. Besides density, feeder

space levels of 1, 2, 2.4, 3 and 4 inches per bird were compared. A back-to-back double deck cage arrangement was used and feeding was done by a mechanical feeder. Weights were taken only at 15 1/2 weeks of age, at which time the pullets were moved. Though body weights tended to decrease as cage density increased, no real differences were observed except for interaction of feeder space and cage density. The birds in the lowest density cages provided with four inches of feeder space per bird weighed significantly more than the birds in the highest density cages provided with only one linear inch of feeder space per pullet. All other combinations showed essentially no difference in body size.

Trial 4 repeated the experimental conditions of trial 3 except that the growing period extended from 7 to 18 weeks of age. The results of this test showed no significant differences in body weights of birds due to density or feeder space treatments even though body weights tended to decrease with decreased feeder spaces. Bell (1969) stated that "within sensible ranges, these differences are so slight that they would be extremely difficult to pick up under commercial conditions".

Massey and Noles (1968) studied the performance of pullets caged in groups with body weights either within a one-fourth pound range or at random. The results



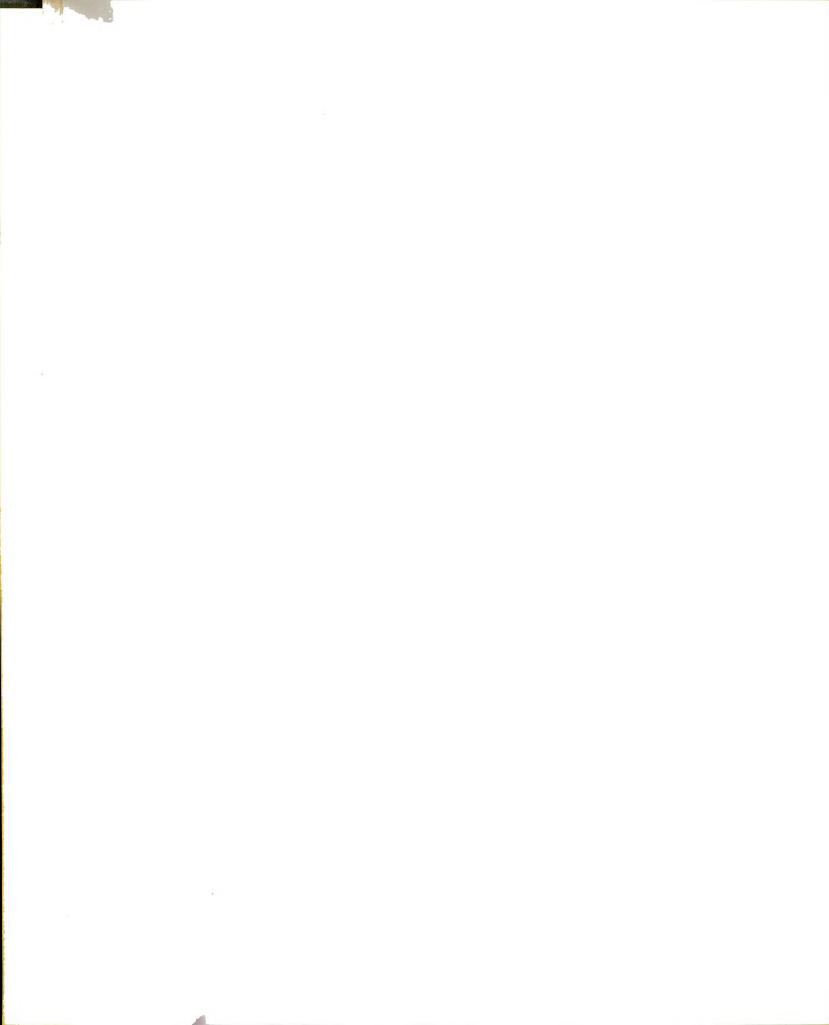
indicated that separation of White Leghorn pullets by weight is not economical. Lighter weight birds housed at weights below 1.25 kgs. (2.75 pounds) matured at a later date and laid fewer eggs than heavier birds.

Almquist (1954) in a review of applicable research regarding the phosphorus needs of chicks concluded that the readily available phosphorus requirements for the chick to four weeks of age suggests a minimum of 0.45 percent, in the presence of ample amounts of vitamin D. After this age, he concluded that the requirement may drop to 0.35 percent for the period up to 10 weeks.

Very little information has been published by researchers who compared the egg production of pullets reared on diets which contained varied levels of phosphorus. However, Temperton et al. (1965a) observed that pullets reared to 18 weeks of age on diets which contained no feed stuffs of animal origin and without phosphorus supplementation showed no significant differences in egg production during the subsequent laying stage from that of similar pullets fed growing diets that contained animal protein and added phosphorus as recommended by the National Research Council of America (1960).

These same researchers, Temperton, et al. (1965b), in another test fed pullets diets which contained 0.46 and 0.14 percent available phosphorus, respectively, during

the period from day-old to 8 weeks and 0.40 and 0.12 percent available phosphorus, respectively, from 8 weeks of age to 18 weeks of age. They reported that there were no significant differences in mortality, growth, feed consumption, nor in feed efficiency between birds fed the basal growing diet composed of feed stuffs of plant origin and birds fed a diet supplemented with inorganic phosphorus. These researchers found no advantage when the starter diet was supplemented to give 0.81 percent total phosphorus, 0.35 percent inorganic phosphorus and 0.49 percent available phosphorus. Similarly, they observed no effect when the growing diet was supplemented to provide levels of total phosphorus that ranged from 0.49 to 0.73 percent; inorganic phosphorus from 0.09 to 0.34 percent; and available phosphorus from 0.20 to 0.5 percent. However, bone ash was reduced in the pullets grown on the unsupplemented diets.

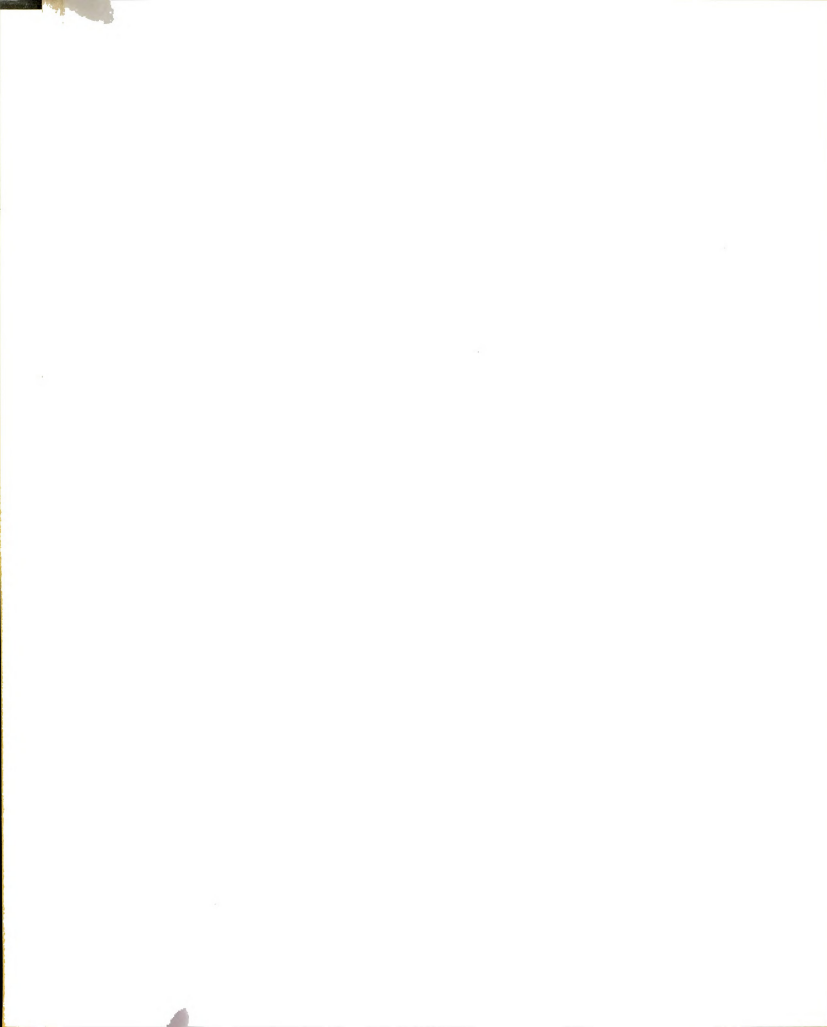


OBJECTIVES

Experiment 1

The objectives of this experiment were:

1. To compare four replacement pullet rearing conditions, 1 through 4, listed below with respect to (A) effect on body weight at 7 and 20 weeks of age, total feed consumption and mortality and (B) effect on subsequent production for six 28-day production periods in single bird cages, number of days to 50 percent production, laying mortality, egg weight and quality dimensions in Haugh Units (Haugh, 1937, and Haver et al., 1964), and shell thickness--
 - (1) pullets reared in cages from day-old to 20 weeks of age and fed a diet which contained no coccidiostat from day-old to 14 weeks of age;
 - (2) pullets reared in cages from day-old to 20 weeks of age and fed a diet which contained a coccidiostat from day-old to 14 weeks of age;
 - (3) pullets reared on the floor from day-old to 7 weeks of age, in cages from 7 weeks of age to 20 weeks of age, and fed a diet which contained a coccidiostat from day-old to 14 weeks of age;



- (4) pullets reared on the floor from day-old to 20 weeks of age and fed a diet which contained a coccidiostat from day-old to 14 weeks of age.
2. To compare the effect of five levels of available phosphorus, 1 through 5, i.e., (1) 0.16, (2) 0.31, (3) 0.46, (4) 0.61, and (5) 0.77 percent, in diets fed to replacement pullets from day-old to 20 weeks of age with respect to the criteria stated in objective 1.
3. To compare the effect of four rearing conditions and five levels of available phosphorus combinations in diets fed to replacement pullets for the criteria listed in objective 1.

Experiment 2

The objective of this experiment was: to compare four replacement pullet cage rearing density levels, 1 through 4, listed below with respect to (A) effect on body weight at 7 and 20 weeks of age, total feed consumption and mortality and (B) effect on subsequent production for six 28-day production periods when housed at single and two birds per cage densities--

- (1) pullets reared in cages at a density of 10 birds per cage (day-old to 7 weeks of age) and 5 birds per cage (7 weeks to 20 weeks of age);

- (2) pullets reared in cages at a density of 20 birds per cage (day-old to 7 weeks of age) and 10 birds per cage (7 weeks to 20 weeks of age);
- (3) pullets reared in cages at a density of 30 birds per cage (day-old to 7 weeks of age) and 15 birds per cage (7 weeks to 20 weeks of age);
- (4) pullets reared in cages at a density of 40 birds per cage (day-old to 7 weeks of age) and 20 birds per cage (7 weeks to 20 weeks of age).



HYPOTHESES

Experiment 1

- (1) H: There is no difference among rearing conditions with respect to their effect on body weight, egg production and egg quality.
- (2) H: There is no difference among diets with respect to their effect on body weight, egg production and egg quality.
- (3) H: Rearing conditions and diet are independent with respect to their effect on body weight, egg production and egg quality.

Experiment 2

- (1) H: There is no difference among rearing density treatments with respect to their effect on body weight, egg production and egg quality.
- (2) H: There is no difference among laying density treatments with respect to egg production and quality.
- (3) H: Rearing density and laying density treatments are independent with respect to their effect on egg production and egg quality.

MATERIALS AND METHODS

Experiment 1

Procedure

A total of 1,767 commercial White Leghorn-type pullet chicks was divided into five weight classes numbered 1 to 5: 35 to 36, 37 to 38, 39 to 40, 41 to 42 and 43 to 44 grams, respectively. Chicks with body weights beyond these limits were discarded. The chicks were dubbed at the hatchery but no debeaking was done throughout this series of trials. A total of 1,500 pullets was selected and banded. Four chicks from each weight class were selected at random, wing-banded and combined to make up replicates consisting of 20 pullets each. Two birds from each weight class were randomly designated to be retained for the 7 to 20 week rearing period, one of which was randomly designated for the subsequent production test.

Five levels of phosphorus and four rearing systems were factorially combined for a total of 20 treatment combinations. Three replicates of 20 birds each were assigned to each treatment combination. The available

phosphorus levels were: 0.16, 0.31, 0.46, 0.61 and 0.77 percent. The phosphorus levels were designated Diet 1 through 5, respectively. Composition of the rearing diets used in this experiment is shown in Tables 1, 2 and 3. The rearing systems compared were: (1) in rearing cages from day-old to 20 weeks of age and fed a diet without a coccidiostat; (2) in rearing cages from day-old to 20 weeks of age and fed a diet with a coccidiostat; (3) floor brooding from day-old to 7 weeks of age and then rearing cages to 20 weeks of age and fed a diet with a coccidiostat; (4) floor brooding and rearing from day-old to 20 weeks of age and fed a diet with a coccidiostat. The coccidiostat was fed to the birds according to the manufacturer's recommendations.¹ Each treatment replicate group started in cages at day-old was assigned at random to one of 30 cages. The cage size used was 24 inches wide, 22 inches deep and 16 inches high, with a one inch x one inch wire grid permanent bottom. A removable false bottom, one-half inch x one inch wire grid, was used for the first seven weeks, after which it was removed. A 24 inch feed trough was provided at the front of each cage. The height of the trough was adjusted as needed to allow chicks access to feed.

¹Amprol Plus, manufactured by Merck and Company, Inc., Rahway, New Jersey.

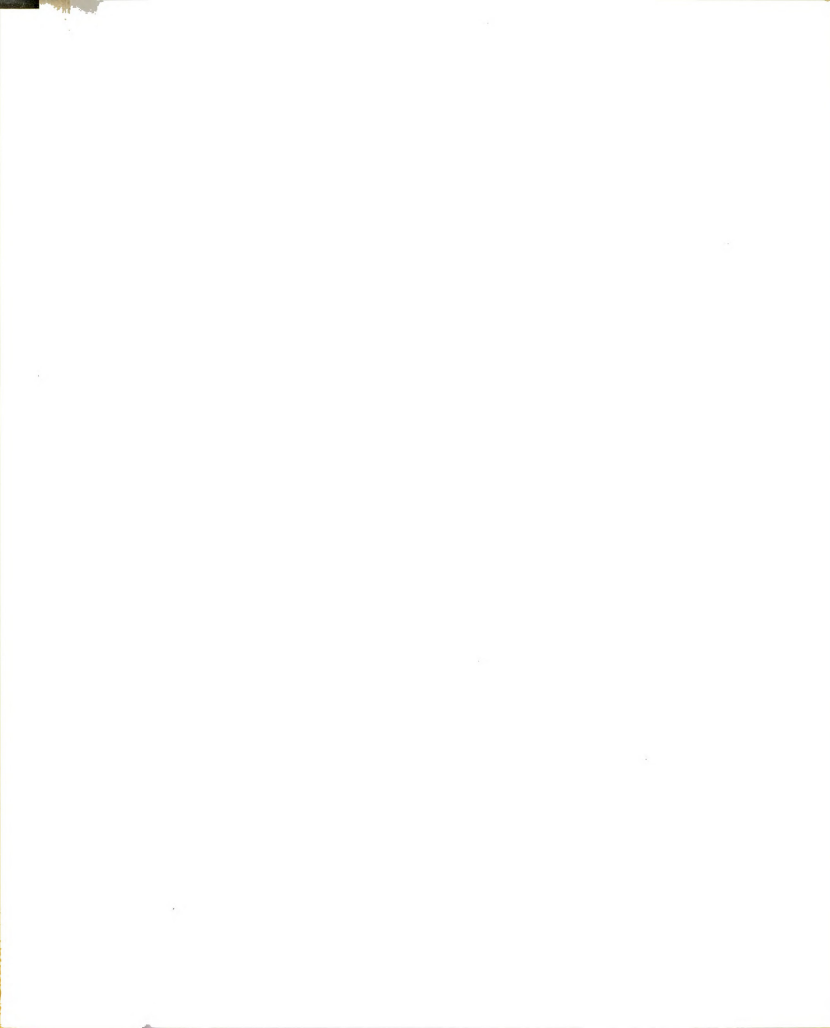


Table 1. Starting and growing diets fed to replacement pullets from day-old to 7 weeks of age, Experiment 1.

Diet number:	1	2	3	4	5
	%	%	%	%	%
Corn, yellow	53.67	53.00	52.30	51.60	50.88
Soybean meal (50%)	28.03	28.15	28.30	28.45	28.60
Oats	7.50	7.50	7.50	7.50	7.50
Alfalfa meal (17%)	2.50	2.50	2.50	2.50	2.50
Dist. dried sol., corn (27%)	2.00	2.00	2.00	2.00	2.00
Fish meal (60%)	1.50	1.50	1.50	1.50	1.50
Whey, dried (12%)	1.50	1.50	1.50	1.50	1.50
Tallow, stabilized	.50	.70	.90	1.10	1.30
Methionine hydroxy analog	.05	.05	.05	.05	.05
Limestone	2.10	1.60	1.10	.60	.12
Dical. phos., 26% Ca., 18% P.	None	.85	1.70	2.55	3.40
Salt	.40	.40	.40	.40	.40
NOPCOSOL M5 Vit. Min. Premix	.25	.25	.25	.25	.25
Calculated analysis:					
Crude protein	20.00	20.00	20.00	20.00	20.00
Fat	3.09	3.28	3.45	3.63	3.79
Fiber	5.17	5.17	5.16	5.15	5.13
Calcium	1.007	1.004	1.002	1.000	1.004
Phosphorus:					
Total	.411	.563	.716	.868	1.020
Available	.160	.312	.465	.618	.771
Energy, productive	928	928	927	927	926

Table 2. Growing diets fed to replacement pullets from 7 to 14 weeks of age, Experiment 1.

Diet number:	1	2	3	4	5
	%	%	%	%	%
Corn, yellow	61.62	60.86	60.17	59.46	58.75
Soybean meal (50%)	19.53	19.69	19.83	19.97	20.12
Oats	10.00	10.00	10.00	10.00	10.00
Alfalfa meal (17%)	2.50	2.50	2.50	2.50	2.50
Dist. dried sol., corn (27%)	1.50	1.50	1.50	1.50	1.50
Fish meal (60%)	1.50	1.50	1.50	1.50	1.50
Tallow, stabilized	.50	.70	.90	1.10	1.30
Limestone	2.06	1.56	1.06	.58	.09
Dical. phos., 26%					
Ca., 18% P.	.14	1.04	1.89	2.74	3.59
Salt	.40	.40	.40	.40	.40
NOPCOSOL M5 Vit.					
Min. Premix	.25	.25	.25	.25	.25
Calculated analysis:					
Crude protein	16.99	17.00	16.99	17.00	17.00
Fat	3.43	3.60	3.78	3.95	4.13
Fiber	5.10	5.09	5.07	5.06	5.05
Calcium	1.000	.999	.996	1.001	1.002
Phosphorus:					
Total	.396	.557	.709	.862	1.014
Available	.166	.327	.480	.633	.786
Energy, productive	956	955	955	954	953



Table 3. Growing diets fed to replacement pullets from 14 to 20 weeks of age, Experiment 1.

Diet number:	1	2	3	4	5
	%	%	%	%	%
Corn, yellow	59.15	58.46	57.77	57.07	56.37
Soybean meal (50%)	11.17	11.31	11.45	11.59	11.73
Wheat middlings, std.	7.50	7.50	7.50	7.50	7.50
Oats	15.00	15.00	15.00	15.00	15.00
Alfalfa meal (17%)	2.50	2.50	2.50	2.50	2.50
Fish meal (60%)	1.50	1.50	1.50	1.50	1.50
Tallow, stabilized	.25	.45	.65	.85	1.05
Limestone	2.13	1.63	1.13	.64	.15
Dical. phos., 26% Ca., 18% P.	.15	1.00	1.85	2.70	3.55
Salt	.40	.40	.40	.40	.40
NOPCOSOL M5 Vit. Min. Premix	.25	.25	.25	.25	.25
Calculated analysis:					
Crude protein	14.50	14.50	14.50	14.50	14.50
Fat	3.45	3.63	3.80	3.98	4.15
Fiber	5.64	5.63	5.62	5.61	5.60
Calcium	1.005	1.002	1.000	1.001	1.002
Phosphorus					
Total	.406	.558	.710	.862	1.014
Available	.169	.326	.475	.628	.781
Energy, productive	923	922	921	921	920

Chicks assigned to floor treatments starting at day-old were assigned to pens 16 feet x 9 feet, 10 inches. Both cage and floor pens were in windowless, insulated, force-ventilated houses. Fan covers were not available, hence, complete light control was not possible.

Heat was provided by one 150 watt, infrared, heat bulb suspended over each cage for the birds on cage treatments. Supplemental room heat was provided in the cage room by a gas brooder and a minimum room temperature of 70° F. (21.3°C.) was maintained for the first 7 weeks. Two 150 watt, infrared, heat bulbs were used for brooding in each floor pen. Linear feeder space per chick at day-old was 2.4 inches and floor space was 2.9 square feet in the floor pens. After seven weeks, when some of the pullets were removed, feeder space was increased to 6.0 inches and floor space to 7.86 square feet per bird. Water was provided in one-gallon fountains for the first three weeks in the floor pens, after which time automatic fountains were used. One Hart cup was used to provide water in each cage. Feeder space for the caged chicks was 1.2 inches per bird. This cage feeder space was increased to 2.4 inches per bird after seven weeks when one-half of the chicks were removed from each cage; those birds randomly designated for rearing to 20 weeks of age in cages and for subsequent production testing were kept in cages.

Continuous lighting, a factor imposed on the trial by the infrared heat lamps, was used from day-old to seven weeks of age. From seven weeks until 14 weeks of age, the day-length was reduced to 14 hours daily. From 14 weeks of age to 20 weeks, the day length was reduced by 1 1/2 hours weekly until a 9 hour daily light period was obtained. Light was provided in each floor pen by one 100 watt, red, incandescent light bulb located in the center of the pen at ceiling height (8 feet). An identical lighting regime was used on birds in the cage room, where the light was supplied by four incandescent 60 watt, red bulbs at ceiling height, located to distribute the light as equally as possible over the rearing cages. The lighting period was controlled by an electric time-clock. A secondary lighting system was provided for use when it was necessary to observe or care for the birds.

The birds were vaccinated for infectious bronchitis and Newcastle disease at various dates via the drinking water. The vaccination program followed was consistent for all birds in the experiment.

The birds were weighed individually at 4, 7, 14 and 20 weeks of age. Feed consumption records were kept and feed was weighed-back at each of these times, thus making possible computation of feed utilization efficiency

for each replicate for the age interval between each weighing. At seven weeks of age, one-half of the pullets in each cage and floor replicate group were discarded leaving 10 pullets in each cage and/or floor replicate or 30 pullets in each diet housing treatment combination.

At 20 weeks of age, the pullets designated at day-old for the production test were transferred to individual 8 inch by 16 inch cages. A total of 15 pullets from five weight classes was caged for each of the 20 diet housing treatment combinations. At 20 weeks of age, the pullets were given 14 hours of light. The daily light period was then increased 15 minutes each week until a maximum light period of 17 hours was obtained. All treatment groups received the same Michigan State University Layer-Breeder Diet throughout the production period.

Individual cage production records were recorded five days per week, starting when the caged pullets were 22 weeks of age. Production records were obtained for six 28-day periods. The pullets were weighed at the end of each 28-day period and feed consumption records were obtained. At this time all the eggs laid for three consecutive days were identified by cage number and date, weighed, broken out and measured for Haugh Unit values and shell thickness. Egg size and quality measurements were recorded for each pullet by cage number.



The rearing data were analyzed by analysis of variance (Snedecor, 1956). Body weights and production data were evaluated at the Computer Laboratory, Michigan State University, using a modified version of the Michigan State University, Agricultural Experiment Station, STAT Series Description No. 13, One-way analysis of variance with unequal number of replications permitted (UNEQ1 ROUTINE) Ruble et al., 1967). The experiment followed a design prepared by Gill (1967). Duncan (1955) Multiple Range Tests for group means were used where equal numbers were observed. The Duncan Multiple Range Tests as modified by Kramer (1956) for unequal numbers of replications were used where unequal numbers of observations were encountered. A Chi-square test was used in the analysis of mortality data (Gill, 1969).

Results

An analysis of variance of 7-week pullet weights, Experiment 1 is shown in Table 4.

The 7-week mean body weight of pullets grown under the four rearing treatments in Experiment 1 are shown in Table 5. The average weights for the four rearing conditions, 1 through 4, were 531.50, 510.18, 527.45 and 528.30 grams, respectively. Pullets grown to 7 weeks of age in cages and fed the diet with a coccidiostat were significantly lighter in body weight ($P < 0.01$) than those grown

Table 4. Analysis of variance of 7-week pullet weight, Experiment 1.

Source of variance	Degrees of freedom	Sum of squares	Mean square	F ratio
Total	599	1,715,097		
Rearing	3	42,115	14,038	10.013**
Diet	4	382,685	95,671	68.239**
Replicates	2	16,380	8,190	5.842**
Weight (class)	4	120,134	30,034	21.422**
R x D	12	27,942	2,328	1.661
R x W	12	291,493	24,291	17.326**
D x W	16	70,057	4,378	3.123**
Error	546	765,291	1,402	

**Significant at the 0.01 level of probability.

Table 5. Seven-week pullet weight by rearing method, Experiment 1.

Rearing method	Mean body weights (gms.) ¹
Cages (day-old to 20 weeks) fed a diet without a coccidiostat	531.50 a
Cages (day-old to 20 weeks) fed a diet with a coccidiostat	510.18 b
Floor (day-old to 7 weeks) fed a diet with a coccidiostat and Cages (7 to 20 weeks) combination	527.45 a
Floor (day-old to 20 weeks) fed a diet with a coccidiostat	528.30 a

¹ Means not followed by a common letter are significantly different ($P < 0.01$) when compared by Duncan Multiple Range test.

under the other rearing regimes. The mean body weight of birds grown under rearing regimes 1, 3 and 4 were not significantly different from each other. At 7 weeks of age, the mean body weights for birds on the five diets, 1 through 5, were 474.5, 532.5, 541.7, 541.2 and 531.7 grams, respectively (Table 6). Pullets fed diet 1 were significantly lighter than birds fed the other four diets.

Table 6. Seven-week pullet weights by diets, Experiment 1.

Diet (available phosphorus level %)		Mean body weights (gms.) ¹
1	(0.16)	474.5 a
2	(0.31)	532.5 b
3	(0.46)	541.7 b
4	(0.61)	541.2 b
5	(0.77)	531.7 b

¹Means not followed by a common letter are significantly different ($P < 0.01$) when compared by Duncan Multiple Range test.

According to initial weight class interval (Table 7), pullets in class 1 (35 to 36 grams) were significantly lighter in body weight than those in classes 2 and 3. The pullets in weight classes 2 and 3 were not

significantly different from each other but were significantly lighter in body weight than those in classes 4 and 5. The mean body weights of pullets in classes 4 and 5 were not significantly different from each other.

Table 7. Seven-week pullet weights by weight classes, Experiment 1.

Weight ranges (grams body weight at day-old)		Mean body weights (gms.) ¹
1	(35 to 36 grams)	500.8 a
2	(37 to 38 grams)	520.4 b
3	(39 to 40 grams)	523.7 b
4	(41 to 42 grams)	534.2 c
5	(42 to 43 grams)	542.7 c

¹Means not followed by a common letter are significantly different ($P < 0.05$) when compared by Duncan Multiple Range test.

The interaction between rearing regime and diet for 7-week mean body weight was not significant (Table 4). However, there were significant differences between weights of pullets in different replicates. The interaction between rearing and initial body weight class interval and between diet and initial weight class interval were highly significant.



The analysis of variance of 20 week body weights, Experiment 1, is shown in Table 8. Rearing and weight class effects significantly affected body weights at 20 weeks, but the effects of replicates and diets were not significant.

Table 8. Analysis of variance of 20-week pullet weights, Experiment 1.

Source of variance	Degrees of freedom	Sum of squares	Mean square	F ratio
Total	581	22,157,833		
Rearing	3	2,078,999	693,000	21.130**
Diet	4	30,721	7,680	.227
Replicates	2	22,767	11,384	.342
Weight (class)	4	1,396,655	349,164	10.646**
Error	568	18,628,691	32,797	

**Significant at the 0.01 level of probability.

The 20-week mean body weights, the average feed consumption per bird and the percent mortality for each treatment group are shown in Table 9. The pullets grown on the floor from day-old to 20 weeks of age were significantly lighter ($P < 0.05$) in body weight than those in the other rearing treatments. The mean body weights for birds on rearing methods, 1 through 4, were 1728, 1601, 1605, and 1474 grams, respectively.

Table 9. Twenty-week pullet weights, feed consumption and mortality, Experiment 1.

Rearing Method	Mean body weights ¹ (gms.)	Feed 0-20 weeks ¹ (kgs.)	Mortality ² (%)
Cages (day-old to 20 weeks without a coccidiostat)	1728 a	7.922 a	1.33
Cages (day-old to 20 weeks with a coccidiostat)	1601 a	7.895 a	2.00
Floor (day-old to 7 weeks) with a coccidiostat and Cages (7 to 20 weeks), (combination)	1605 a	8.099 b	5.33
Floor (day-old to 20 weeks) with a coccidiostat	1474 b	6.991 c	6.66

¹Means under same heading not followed by a common letter are significantly different ($P < 0.05$) when compared by Kramer Modification of Duncan Multiple Range test.

²There were significant differences among the rearing methods in mortality when the data were subjected to a Chi-square test ($P < 0.05$).

The average amount of feed consumed per bird according to rearing methods 1 through 4 were 7.922, 7.895, 8.099 and 6.991 kilograms, respectively. The floor-reared pullets consumed significantly ($P < 0.05$) less feed per bird to 20 weeks of age than did pullets reared under the other treatments. The pullets grown under the combination



of floor and cage rearing required significantly ($P < 0.05$) more feed per bird than did those grown under the other systems. The two cage rearing systems ranked second in the amount of feed used and although the caged pullets fed the diet without a coccidiostat used slightly more feed than those fed the coccidiostat, the difference in feed consumption was not statistically significant. The mortality for rearing regimes, 1 through 4, were 1.33, 2.00, 5.33 and 6.66 percent, respectively. There were significant differences among the rearing methods in mortality when the data were subjected to a Chi-square test ($P < 0.05$).

Twenty-week mean pullet weight, feed consumption per bird, and mortality for birds fed the five diet treatments are shown in Table 10. No significant differences in mean body weight were observed between and among birds on different diet treatments. The pullets fed diet 1 consumed significantly less feed ($P < 0.05$) than those fed diet 2. However, the average amount of feed consumed by pullets on neither of these diets was significantly different from the amount consumed by pullets on the other three diets. The feed consumption per bird, diets 1 through 5, were 7.600, 7.845, 7.736, 7.791 and 7.664 kilograms, respectively.



Table 10. Twenty-week pullet weights, feed consumption and mortality by diet, Experiment 1.

Diet	(Available phosphorus level%)	Mean body weights ¹ (gms.)	Feed 0-20 weeks ¹ (kgs.)	Mortality ² (%)
1	(0.16)	1546 a	7.600 a	3.75
2	(0.31)	1608 a	7.845 b	3.75
3	(0.46)	1579 a	7.736 ab	3.75
4	(0.61)	1578 a	7.791 ab	3.75
5	(0.77)	1578 a	7.664 ab	4.10

¹Means under same heading not followed by a common letter are significantly different ($P < 0.05$) when compared by Kramer Modification of Duncan Multiple Range test.

²Differences in mortality among the rearing methods were not significant ($P > 0.05$) when the data were subjected to a Chi-square test.

Although the observed differences in mean body weight of birds on the different diets were not statistically significant, pullets grown on diet 1 were lightest, averaging 1546 grams. The pullets fed diet 2 had the heaviest average body weight of 1608 grams. Little, if any, difference was observed among birds fed diets 3, 4, and 5, with mean body weights of 1579, 1578 and 1578 grams, respectively. Diet 3 (with 0.46 percent available phosphorus) was formulated to meet the requirements of the National Research Council of America (1964).



The mean body weight of pullets at 20 weeks of age by weight class interval are shown in Table 11. Pullets in class 1 with individual initial weights of 35 or 36 grams had a mean 20-week body weight of 1496 grams and were significantly lighter ($P < 0.05$) than those in any of the other treatment groups. Pullets in classes 2 (37 to 38 grams) and 3 (39 to 40 grams) had mean 20-week body weights of 1579 and 1563 grams, respectively, and while not significantly different from each other, they differed significantly from those in classes 1, 4 and 5. The mean 20-week body weight of pullets in classes 4 (41 to 42 grams) and 5 (43 to 44 grams) were the heaviest at 20 weeks (1628 and 1627 grams, respectively).

Table 11. Twenty-week pullet weights by weight class, Experiment 1.

Initial weight class interval		Mean body weights ¹ (gms.)
1	(35 to 36 grams)	1496 a
2	(37 to 38 grams)	1579 b
3	(39 to 40 grams)	1563 b
4	(41 to 42 grams)	1628 c
5	(43 to 44 grams)	1627 c

¹Means not followed by a common letter are significantly different ($P < 0.05$) when compared by Kramer Modification of Duncan Multiple Range test.

The results of the production phase of Experiment 1 are presented in Tables 12 and 13. Table 12 shows the days of age at 50 percent production, hen-housed and hen-day production, percent mortality and feed efficiency for the four rearing methods tested. Table 13 shows information for the same traits shown in Table 12 by diet.

Pullets grown in cages from day-old to 20 weeks and fed the diet without a coccidiostat reached 50 percent production significantly earlier than those grown under the other systems. The number of days to 50 percent production for the females for rearing methods, 1 through 4, were 163, 167, 168 and 167, respectively. There were no significant differences in hen-housed egg production, hen-day egg production, mortality, nor in feed efficiency among pullets from the four rearing treatment groups. The pullets grown in cages and fed the ration without a coccidiostat had the lowest hen-housed and hen-day egg production (62.4 and 65.1 percent, respectively) as well as the second highest mortality (8 percent). Pullets grown in cages and fed the diet with a coccidiostat (Rearing Method 1) had the highest hen-housed production (66.2 percent) and, along with the floor-reared birds, had the lowest laying house mortality (6.7 percent). The pullets reared under the combination of floor rearing from day-old to 7 weeks and cage rearing from 7 weeks

Table 12. Days of age at 50 percent production, 168 day egg production, mortality and feed efficiency by rearing methods, Experiment 1.

Rearing method	Days to 50% prod. ¹	Egg production (%) ¹ Hen-day	Mortality (%) ²	Feed. eff. ¹ (kgs. feed/doz. eggs)
Cages (0-20 wks without a coccidiostat)	163 a	62.4 a	65.1 a	8.0
Cages (0-20 wks with a coccidiostat)	167 b	66.2a	67.6 a	6.7
Floor (0-7 wks) with a coccidiostat and Cages (7-20 wks) (combination)	168 b	64.3 a	68.5 a	14.7
Floor (0-20 wks) with a coccidiostat	167 b	65.5 a	67.8 a	6.7
				1.91 a
				1.74 a
				1.93 a
				1.96 a

¹Means under same heading not followed by a common letter are significantly different ($P < 0.05$) when compared by Duncan Multiple Range test.

²No significant differences in mortality due to rearing method were found when the data were subjected to a Chi-square test ($P > 0.05$).



Table 13. Days of age at 50 percent production, 168 day egg production, mortality and feed efficiency by diets, Experiment 1.

Diet (during growing period)	Days to 50% prod. ¹	Egg production Hen-housed	Egg production (%) ¹ Hen-day	Mortality (%)	Feed eff. (kgs. feed/ doz. eggs)
1	170 a	62.8 a	66.4 a	13.3	1.98 a
2	166 ab	68.3 a	71.4 a	6.7	1.76 a
3	161 b	63.4 a	69.0 a	13.3	1.86 a
4	166 ab	65.0 a	66.6 a	6.7	1.91 a
5	169 a	63.5 a	64.6 a	6.7	1.91 a

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¹Means not followed by a common letter are significantly different (P < 0.05) when compared by Duncan Multiple Range test.

²No significant differences in mortality due to diet levels were found when the data were subjected to a Chi-square test (P > 0.05).

to 20 weeks, had the highest hen-day production (68.5 percent) and also the highest laying house mortality (14.7 percent). The pullets grown in cages from day-old to 20 weeks of age and fed the diet with a coccidiostat (Rearing Method 2) had the lowest feed conversion ratio (1.74 kilograms of feed). The ratio of feed per dozen eggs for Rearing Methods 1 through 4 were 1.91, 1.74, 1.93, and 1.96 kilograms, respectively.

The number of days to 50 percent production, 168 day hen-housed and hen-day percent production, laying house mortality and feed efficiency by diet treatments are shown in Table 13. The average number of days to 50 percent production for pullets which had been fed diets 1 through 5 were 170, 166, 161, 166 and 169, respectively. Regarding days to 50 percent production, pullets which had been fed diets 1, 2, 4, and 5 were not significantly different from each other but those which had been fed diets 1 and 5 required a significantly longer period than those fed diet 3 to achieve this level of production. However, no significant differences for this trait were observed between the pullets which had been fed diets 2, 3, and 4. Pullets which had been fed diet 2 had the highest hen-housed egg production (68.3 percent). Those which had been fed diet 4 had the second highest hen-housed production (65.0 percent). Hen-housed production for pullets

from diets 3, and 5 was 63.4 and 63.5 percent, respectively. The differences in egg production were not significant. The hen-day production for birds fed diet 1 through 5 was 66.4, 71.4, 69.0, and 64.6 percent, respectively. Laying house mortality for the diet levels 1 through 5 were 13.3, 6.7, 13.3, 6.7, and 6.7, respectively. No significant differences in mortality due to diet level were found when the data were subjected to a Chi-square test ($P > 0.05$). The feed efficiency for the birds on the diets 1 through 5 was 1.98, 1.76, 1.86, 1.91, and 1.91 kilograms, respectively.

Simple correlations made with the use of the computer facilities at Michigan State University indicated that body weights at 20 and at 22 weeks of age were not associated with average performance during the first three months of production. Traits compared were number of eggs, egg size, Haugh Unit and shell thickness values.

Experiment 2

Procedure

The equipment used in Experiment 2 was essentially the same as in Experiment 1; however, only cages were used for rearing during the growing phase. Further, the removable false bottom of the rearing cage was bent to allow more clearance between it and the permanent cage



floor to eliminate the build-up of droppings that had been observed in field testing of the original type cage. This condition, however, had not been a problem in Experiment 1.

The purpose of Experiment 2 was to evaluate the effect of cage density during rearing on the subsequent performance of pullets housed in laying cages at densities of one and two birds per cage during the production period. Pullets were reared from day-old to seven weeks of age at densities, 1 through 4, of 10, 20, 30 and 40 chicks per cage, respectively, thus providing 52.8, 26.4, 17.6 and 13.2 square inches of cage floor area, respectively. At seven weeks of age, one-half of the birds were removed and placed in identical cages, thus doubling the original cage floor area per bird for the balance of the growing period to 20 weeks of age.

White Leghorn-type commercial pullet chicks were separated into three weight class intervals: 35 to 37, 38 to 40, and 41 to 43 grams and designated weight classes 1, 2 and 3, respectively. Equal numbers of chicks from each weight class were wing-banded for each rearing density level. The chicks were not dubbed nor debeaked. Six replicates of 10 birds per rearing cage were allocated to each of the other three densities. A total of 330 chicks was used. The pullets in all treatment groups were fed the diet number 3 feeding regime as shown in Table 1

(day-old to 7 weeks), Table 2 (7-14 weeks) and Table 3 (14-20 weeks). All birds were weighed to the nearest gram and replicate feed consumption records were obtained at 4, 7, 14 and 20 weeks of age. Mortality data were obtained for each density treatment group.

Only one Hart cup for drinking water and the 24 inch feeder trough were permitted per cage regardless of population density. Thus, linear feeder space per chick for the period from day-old to 7 weeks of age was 2.5, 1.2, 0.8 and 0.6 inches for the four rearing density levels, respectively.

When the pullets were weighed at 20 weeks of age, those within each treatment group were separated according to initial body weight class interval. Six pullets from each weight class (a total of 18 pullets from each rearing density) were housed in 18 single bird laying cages; the same cages that had been used in Experiment 1. Twelve pullets from each initial weight class (a total of 36 birds from each rearing treatment) were housed at a density level of two birds per laying cage. Birds from the same initial weight class were caged together.

Starting at 20 weeks of age, all of the pullets selected for the laying test received the same standard Michigan State University Layer-Breeder Mash for the duration of the experiment. Starting at 22 weeks of age, egg

production data were obtained for each cage, five days per week. Egg production, body weight and feed consumption data were obtained for six 28-day production periods.

Analysis of body weight and egg production data were made according to the experimental design prepared for this trial (Gill, 1968). Comparisons of treatment means were made as in Experiment 1.

All dead birds were examined at the Michigan State University Veterinary Diagnostic Laboratory.

Results

Analyses of variance of the 7-week and 20-week body weights (Experiment 2) are shown in Tables 14 and 15, respectively. The 7-week and 20-week mean body weight, feed consumption and mortality are presented in Tables 1 through 4 (which provided 52.8, 26.4, 17.6 and 13.2 square inches of cage floor area) at seven weeks of age were 553, 530, 499 and 479 grams, respectively. Body weight decreased as cage density increased. The pullets reared at density level 4 were significantly smaller than those reared at density levels 1 and 2 but not significantly different in body weight from the birds reared at density level 3 at 7 weeks of age. The pullets reared at density levels 1, 2 and 3 were not significantly different from each other at 7 weeks of age. The mortality for pullets reared at

density levels 1 through 4 were 3.3, 0.0, 3.3 and 7.5, respectively. No significant differences in mortality due to density level were found when the data were subjected to a Chi-square test ($P > 0.05$).

Table 14. Analysis of variance of seven week body weights, Experiment 2.

Source of variance	Degrees of freedom	Sum of squares	Mean square	F ratio
Total	215	1,001,136		
Weight (class)	2	4,798	2,399	0.612
Treatment	3	172,815	57,605	14.689**
Error	210	823,523	3,922	

**Indicates significance at the .01 level.

Note: Only seven week body weights of pullets selected for the subsequent production test were used in this analysis.

Table 15. Analysis of variance of 20-week body weights, Experiment 2.

Source of variance	Degrees of freedom	Sum of squares	Mean square	F ratio
Total	278	7,435,796		
Treatment	3	3,568,685	1,189,562	87.91**
Weight (class)	2	172,978	86,489	6.39**
Error	273	3,694,133	13,532	

**Indicates significance at the .01 level.

The average feed consumption of pullets in density levels 1 through 4 from day-old to 7 weeks of age was 1.689, 1.457, 1.404 and 1.284 kilograms, respectively, Table 16. The pullets in density level 4 were not only smaller than the pullets reared in density levels 1, 2 and 3 but, also, consumed significantly ($P < 0.05$) less feed than the pullets reared in density levels 1 and 2. The feed consumption of the pullets in density levels 2 and 3 did not differ significantly. The pullets in density level 1 consumed significantly ($P < 0.05$) more feed than the pullets brooded in any of the other density levels.

Table 16. Comparison of mean body weights, feed used and mortality for pullets by initial rearing density at seven weeks of age, Experiment 2.

Initial rearing density	Mean body weights (gms.) ¹	Mean feed consumption (kgs.)	Mortality (%) ²
1 (52.8 sq. in./chick 0 to 7 weeks)	553 a	1.689 a	3.3
2 (26.4 sq. in./chick 0 to 7 weeks)	530 a	1.457 b	0.0
3 (17.6 sq. in./chick 0 to 7 weeks)	499 ab	1.404 bc	3.3
4 (13.2 sq. in./chick 0 to 7 weeks)	479 b	1.284 c	7.5

¹Means under same heading not followed by a common letter are significantly different ($P < 0.05$) when compared by Duncan Multiple Range test.

²No significant differences in mortality due to rearing density level were found when the data were subjected to a Chi-square test ($P > 0.05$).

Table 17. Comparison of mean body weights, feed used and mortality for pullets by rearing density at 20 weeks of age, Experiment 2.

Initial rearing density	Mean body weights (gms.) ¹	Mean feed consumption (kgs.)	Mortality ^{2,3} (%)
1 (52.8 sq. in./chick 0 to 7 weeks)	1,512 a	8.989 a	10.00
2 (26.4 sq. in./chick 0 to 7 weeks)	1,472 ab	8.080 b	6.67
3 (17.6 sq. in./chick 0 to 7 weeks)	1,432 b	8.165 b	15.55
4 (13.2 sq. in./chick 0 to 7 weeks)	1,321 c	7.421 b	16.67

¹Means under same heading not followed by a common letter are significantly different ($P < 0.05$) when compared by Kramer Modification of Duncan Multiple Range test.

²No significant differences in mortality due to rearing density level were found when the data were subjected to a Chi-square test ($P > 0.05$).

³Marek's Disease and Leukosis were diagnosed as the cause of 100 percent of the mortality during the production period.

At 20 weeks of age, the mean body weights for birds at the density levels 1 through 4 were 1.512, 1.472, 1.432 and 1.321 kilograms, respectively. As shown, feed consumption increased as density levels decreased. The quantities of feed consumed by the pullets in density treatments 1 through 4 were 8.989, 8.080, 8.165 and 7.421 kilograms, respectively. However, only the pullets in density level 1 consumed significantly more feed than the



pullets in the other treatment groups. The feed consumption of pullets at density levels 2, 3 and 4 did not differ significantly.

The mortality by level (1 through 4) was 10.0, 6.67, 15.55 and 16.67 percent, respectively, but the differences were not significant. The pullets in cages with 30 and 40 chicks, density levels 3 and 4, respectively, had the highest mortality. Marek's Disease and leukosis were diagnosed as the cause of 59.1 percent of the rearing mortality from day-old to 20 weeks of age.

Data obtained during the subsequent production period of pullets reared at density levels 1 through 4, housed in single bird cages, are presented in Table 18. The average egg production (survivors) and hen-day production data were evaluated by analysis of variance. There were no significant differences found. The number of days to 50 percent production as calculated on a group basis for the pullets in density levels 1 through 4 was 178, 175, 175 and 173 days, respectively. The pullets reared at density level 4 reached 50 percent production slightly before (5 days) those reared at other levels. The pullets reared at the lowest density required the longest period of time to reach 50 percent production. The mean number of eggs for pullets surviving the six 28-day production periods was 79.1, 82.2, 83.0 and 79.4 for the density levels

Table 18. Effect of population density during rearing (0 to 20 weeks of age) on subsequent performance when housed in single bird cages, Experiment 2.

Initial rearing density	Production (1 bird/cage)				
	Number of days to 50% production	Mean number of eggs (survivors) ¹	Hen-housed (%)	Mean hen-day (%) ¹	Mortality ^{2,3} (%)
1(52.8 sq. in./chick 0 to 7 weeks)	178	79.1 a	55.1	60.3 a	22.2
2(26.4 sq. in./chick 0 to 7 weeks)	175	82.2 a	62.1	65.2 a	16.7
3(17.6 sq. in./chick 0 to 7 weeks)	175	83.0 a	59.8	61.6 a	16.7
4(13.2 sq. in./chick 0 to 7 weeks)	173	79.4 a	56.1	62.5 a	22.2

¹Means under same heading not followed by a common letter are significantly different ($P < 0.05$) when compared by Kramer Modification of Duncan Multiple Range test.

²No significant differences in mortality due to rearing density level were found when the data were subjected to a Chi-square test ($P > 0.05$).

³Marek's Disease and leukosis were diagnosed as the cause of 100 percent of the mortality during the production period.

1 through 4, respectively. Hen-day production percentages were 60.3, 65.2, 61.6 and 62.5, respectively. The mortality of the pullets by density level 1 through 4 was 22.2, 16.7, 16.7 and 22.2, respectively. No significant differences in mortality due to rearing density level were found when the data were subjected to a Chi-square test ($P > 0.05$). Marek's Disease and leukosis were diagnosed in all cases of mortality from the birds caged individually.

Production data for the pullets housed at a density of two birds per cage are shown in Table 19. The number of days to 50 percent production by density levels, 1 through 4, was 173, 182, 182 and 179, respectively. The birds reared at the lowest density reached 50 percent production somewhat sooner than the pullets grown at the higher density levels. However, pullets reared at the densities tested reached 50 percent production at about the same time irrespective of rearing density. The mean number of eggs laid per pullet, by density levels 1 through 4, was 80.0, 80.0, 80.8 and 68.9, respectively. The pullets reared at the highest density level laid the fewest eggs. The hen-day production for the birds in density levels 1 through 4 was 65.5, 66.2, 54.6 and 55.4 percent, respectively. The egg production of the pullets reared at the relatively higher densities (3 and 4) was significantly lower than that of those reared at levels 1 and 2. The

Table 19. Effect of population density during rearing (0 to 20 weeks of age) on subsequent performance when housed at two birds per cage density, Experiment 2.

Initial rearing density	Number of days to 50% production	Production (2 birds/cage)			
		Mean number of eggs (survivors) ¹	Hen-housed (%)	Mean hen-day (%) ¹	Mortality ^{2,3} (%)
1(52.8 sq. in./chick 0 to 7 weeks)	173	80.0 a	55.1	65.5 a	23.5
2(26.4 sq. in./chick 0 to 7 weeks)	182	80.0 a	64.0	66.2 a	11.1
3(17.6 sq. in./chick 0 to 7 weeks)	182	80.8 a	49.5	54.6 b	25.7
4(13.2 sq. in./chick 0 to 7 weeks)	179	68.9 a	47.9	55.4 b	25.0

¹Means under same heading not followed by a common letter are significantly different ($P < 0.05$) when compared by Kramer Modification of Duncan Multiple Range test.

²No significant differences in mortality due to rearing density level were found when the data were subjected to a Chi-square test ($P > 0.05$).

³Marek's Disease and leukosis were diagnosed as the cause of 73 percent of the mortality during the production period.



hen-housed production reflects the effect of mortality on production--55.1, 64.0, 49.5 and 47.9 percent for density levels 1 through 4, respectively. The mortality of the birds in the four density groups was 23.5, 11.1, 25.7 and 25.0 percent, respectively. However, no significant differences in mortality due to density level were found when the data were subjected to a Chi-square test ($P > 0.05$). Marek's Disease and leukosis were diagnosed in 73 percent of the pullets that died in two bird density cages.

Table 20 shows the hen-day percent production by initial weight class interval for pullets housed in single bird cages. Table 21 shows the data for those females housed two birds per cage. The mean hen-day production of the pullets housed in single bird cages for weight class 1 (35 to 37 grams), 2 (38 to 40 grams) and 3 (41 to 43 grams) was 52.0, 70.6 and 65.6 percent, respectively. The pullets in weight class 1 had significantly lower hen-day production than those in the other classes tested. The hen-day percentages for pullets housed at two birds per cage for initial weight class intervals 1, 2, and 3 were 55.4, 64.6 and 62.4, respectively. Although the pullets in class 1 had lower production than those in the other two classes, the differences were not significant.

Table 20. Comparison of percent hen-day production of pullets housed in single bird cages by weight class, Experiment 2.

Production	Weight Class Interval (gms.)		
	1	2	3
	(35 to 37)	(38 to 40)	(41 to 43)
Hen day (percent) ¹	52.0 a	70.6 b	65.6 b

¹Means not followed by a common letter are significantly different ($P < 0.05$) when compared by Kramer Modification of Duncan Multiple Range test.

Table 21. Comparison of percent hen-day production of pullets housed at a density of two birds per cage by weight class, Experiment 2.

Production	Weight Class Interval (gms.)		
	1	2	3
	(35 to 37)	(38 to 40)	(41 to 43)
Hen day (percent) ¹	55.4 a	64.6 a	62.4 a

¹Means not followed by a common letter are significantly different ($P < 0.05$) when compared by Kramer Modification of Duncan Multiple Range test.

Tables 22 and 23 show data regarding egg weight, Haugh Unit and shell thickness values for pullets housed at one and two birds per cage, respectively, according to rearing density. The mean weights of eggs laid by pullets housed one bird to a cage for pullets from rearing



Table 22. Effect of population density during rearing (0 to 20 weeks of age) on subsequent egg weight and production quality criteria, of pullets housed at one bird per cage, Experiment 2.

Initial rearing density	Mean egg weight (gms) ¹	Mean Haugh Unit value ¹	Shell thickness (millimeters) ¹
(52.8 sq. in./chick 0 to 7 weeks)	48.4 a	88.0 a	.337 a
(26.4 sq. in./chick 0 to 7 weeks)	46.6 a	89.1 a	.325 a
(17.6 sq. in./chick 0 to 7 weeks)	50.2 b	90.1 a	.320 a
(13.2 sq. in./chick 0 to 7 weeks)	50.3 b	89.8 a	.325 a

¹Means under same heading not followed by a common letter are significantly different ($P < 0.05$) when compared by Kramer Modification of Duncan Multiple Range test.

Table 23. Effect of population density during rearing (0 to 20 weeks of age) on subsequent egg weight and production quality criteria, of pullets housed at two birds per cage, Experiment 2.

Initial rearing density	Mean egg weight (gms) ¹	Mean Haugh Unit value ¹	Shell thickness (millimeters) ¹
(52.8 sq. in./chick 0 to 7 weeks)	48.5 a	90.1 a	.320 a
(26.4 sq. in./chick 0 to 7 weeks)	48.8 a	89.2 a	.337 b
(17.6 sq. in./chick 0 to 7 weeks)	50.1 a	89.4 a	.325 a
(13.2 sq. in./chick 0 to 7 weeks)	49.5 a	88.4 a	.320 a

¹Means under same heading not followed by a common letter are significantly different ($P < 0.05$) when compared by Kramer Modification of Duncan Multiple Range test.

densities 1 through 4 were 48.4, 46.6, 50.2 and 50.3 grams, respectively. The pullets reared at the two highest density levels laid eggs that were significantly larger than the eggs laid by pullets reared at density levels 1 and 2. There was little, if any, difference in the size of eggs from pullets reared at density levels 3 and 4. The mean average weight of eggs laid by pullets reared at density level 2 was lowest among all treatment groups but was not significantly different from eggs laid by the pullets in density level 1. However, no significant differences were found among density treatment means for egg weight when the data from the first three production periods were analyzed (Table 24).

Mean Haugh Unit values (a measure of interior egg quality) for eggs laid by pullets from density levels 1 through 4 were 88.0, 89.1, 90.1 and 89.8, respectively. There were no significant differences in Haugh Unit values of eggs from pullets reared at density levels 1 through 4, housed at one bird per cage.

Shell thickness values (an indication of shell strength, Stewart, 1936), for eggs laid by pullets from rearing density levels 1 through 4 were 0.337, 0.325, 0.320 and 0.325 millimeters, respectively. An analysis of variance showed no significant differences among shell thickness means.



Table 24. Effect of population density during rearing (0 to 20 weeks of age) on subsequent egg weight and production quality criteria (average of trait data for first three production periods) for all pullets housed.

Initial rearing density	Mean egg weight (gms) ¹	Mean Haugh Unit value ¹	Shell thickness (millimeters) ¹
1 (52.8 sq. in./chick 0 to 7 weeks)	56.1 a	86.3 a	.328 a
2 (26.4 sq. in./chick 0 to 7 weeks)	55.3 a	86.1 a	.325 a
3 (17.6 sq. in./chick 0 to 7 weeks)	56.0 a	87.0 a	.325 a
4 (13.2 sq. in./chick 0 to 7 weeks)	57.1 a	88.3 a	.325 a

¹Means under same heading not followed by a common letter are significantly different ($P < 0.05$) when compared by Kramer Modification of Duncan Multiple Range test.

The data in Table 23 include mean egg weights for pullets from density levels 1 through 4 as follows: 48.5, 48.8, 50.1 and 49.5 grams. The mean Haugh Unit values for eggs laid by pullets from the four rearing densities in the same order were 90.1, 89.2, 89.4 and 88.4. Analyses of variance showed no significant differences among means regarding either egg weights or Haugh Units. The shell thickness means for eggs laid by pullets from density levels 1 through 4 were 0.320, 0.337, 0.325 and 0.320 millimeters, respectively. The shell thickness of eggs from pullets reared at density 2 (26.4 sq. in. per chick)



was significantly greater than the thickness values for pullets from the other rearing density treatment levels at the end of the first production period. However, no significant differences were found among density treatment means for shell thickness when the data from the first three production periods were analyzed (Table 24).

Feed efficiency data for the production period are given in Table 25 by rearing density level and housing cage density. Feed efficiency by rearing densities 1 through 4

Table 25. Production feed efficiency (kilograms of feed per dozen eggs) by rearing density and housing cage density, Experiment 2.

Initial rearing density	Feed efficiency ¹	
	1 bird/cage (kgs)	2 birds/cage (kgs)
1 (52.8 sq. in./chick 0 to 7 weeks of age)	2.01	1.93
2 (26.4 sq. in./chick 0 to 7 weeks of age)	1.84	1.89
3 (17.6 sq. in./chick 0 to 7 weeks of age)	1.87	2.05
4 (13.2 sq. in./chick 0 to 7 weeks of age)	2.07	2.11

¹Differences in feed efficiency among the rearing densities were not significantly different ($P > 0.05$).

was 2.01, 1.84, 1.87 and 2.07 kilograms, respectively, for pullets housed at one bird per cage. Feed efficiency by rearing densities 1 through 4 for pullets housed at two birds per cage was 1.93, 1.89, 2.05 and 2.11, respectively. Differences in feed efficiency of pullets among rearing densities were not significantly different whether the birds were housed at one or two birds per cage.



DISCUSSION

The results of Experiment 1 of this study were generally consistent with the findings of Shupe and Quisenberry (1961) regarding mean body weight, feed consumption and production of pullets reared on the floor and in cages, but were different as to mortality. Shupe and Quisenberry (1961) found that floor reared birds were significantly lighter in body weight at 22 weeks of age than were pullets which had been reared on the floor to 14 weeks of age and then in colony cages from 14 weeks to 20 weeks of age. The mean body weight of the floor reared birds used in the Texas test was 1,809 grams compared to 1,840 grams for the pullets reared in colony cages. The floor reared pullets consumed an average of 4.404 kilograms of feed compared to 5.321 kilograms for the colony cage reared birds and mortality was significantly higher in the cage reared birds. Shupe and Quisenberry reported that most of the mortality which occurred in the cage reared birds was due to cannibalism. The mean body weight of the floor reared pullets (0 to 20 weeks of age) in Experiment 1 was 1,474 grams compared to 1,728 grams for the pullets reared in cages and fed a diet with a

coccidiostat, 1,601 grams for the pullets reared in cages and fed a diet without a coccidiostat, and 1,605 grams for the floor-cage combination reared birds. The pullets reared on the floor (0 to 20 weeks of age) weighed significantly less than did the pullets reared in cages or in the floor-cage combination.

In Experiment 1, the average feed consumption of pullets (0 to 20 weeks of age) by rearing method 1 through 4, i.e., cages-no coccidiostat, cages-coccidiostat, floor-cage combination and floor rearing method, was 7.922, 7.895, 8.099 and 6.991 kilograms, respectively.

The floor reared pullets consumed significantly less feed than either the cage reared birds or the floor-cage combination reared birds (0 to 20 weeks of age). The floor-cage combination reared pullets consumed significantly more feed from day-old to 20 weeks of age than either the cage reared or floor reared birds. Mortality of pullets reared by methods 1 through 4 was 1.33, 2.00, 5.33 and 6.66 percent, respectively. Differences in mortality of pullets among the rearing methods were significantly different when the data were subjected to a Chi-square test ($P < 0.05$). No cannibalism was observed among the pullets in any of the rearing methods tested in Experiment 1.

Regarding production, the findings of Shupe and Quisenberry (1961) are consistent with the results of Experiment 1 to the extent that there were no significant differences in egg production, egg weight, feed efficiency or mortality among the pullets reared by the methods tested. Shupe and Quisenberry observed that production mortality for floor reared pullets was 13.27 percent compared to 14.29 percent for the colony cage reared birds (14 to 22 weeks of age). In the production phase of Experiment 1, mortality was highest (14.7 percent) in pullets which had been reared by the floor-cage combination method. It was lowest (6.7 and 6.7 percent, respectively) in cage-coccidiostat reared and floor reared pullets.

The results of Experiment 1 were different from the findings of Magruder and Nelson (1968) who compared floor, floor-cage combination and cage rearing of pullets and found that these rearing methods produced pullets of about the same mean body weight (1,430, 1,430 and 1,450 grams, respectively) at 21 weeks of age. In Experiment 1, the pullets reared on the floor were significantly lighter and consumed significantly less feed than the pullets reared in cages (0 to 20 weeks of age) or in the floor-cage combination method. Magruder and Nelson observed that floor reared birds had the lowest rearing

mortality (0.83 percent, compared to 3.72 and 3.75 percent for birds reared in the floor-cage combination and cage rearing methods, respectively). No analysis of mortality data was reported. They found that mean feed consumption (0 to 21 weeks of age) for the floor, floor-cage combination and cage reared birds was 7.50, 7.64 and 7.98 kilograms, respectively, which indicated a trend toward higher feed consumption among cage reared birds compared to floor reared pullets. In Experiment 1, cage reared pullets consumed significantly more feed than did floor reared pullets. During the production phase, Magruder and Nelson found that hen-day production of pullets from the floor, floor-cage and cage rearing methods was 75.7, 74.4 and 74.2 percent, respectively, with little if any difference in feed efficiency. Hen-day production in Experiment 1 for pullets from the cage-no coccidiostat, cage-coccidiostat, floor-cage combination and floor rearing methods was 65.1, 67.6, 68.5 and 67.8 percent, respectively. The differences in hen-day production were not significant. Laying house mortality of pullets from the floor, floor-cage combination and cage rearing methods was 1.8, 1.5 and 1.1 percent, respectively in the Magruder and Nelson (1968) report. No differences in production mortality in Experiment 1 due to rearing methods were found. Magruder and Nelson reported that production feed efficiency (kilograms



of feed per pound of eggs) for the floor, floor-cage combination and floor rearing methods was 1.69, 1.65 and 1.65, respectively, which indicated a slight trend toward higher feed consumption by floor reared birds during the laying period. This trend was also evident in the data from Experiment 1.

The conclusion may be drawn by commercial pullet growers from the data in Experiment 1 that important savings in feed cost can be achieved by growing pullets on the floor. However, pullets reared on the floor appear to compensate for reduced feed consumption during the rearing period by consuming more feed during the production phase than do cage reared birds. It appears from the results of Experiment 1 that floor rearing from day-old to seven weeks of age does not significantly affect 20-week body weight or feed consumption of pullets subsequently reared from seven to 20 weeks of age in cages as compared to the same traits for birds reared in cages from day-old to 20 weeks of age.

The findings in Experiment 1 regarding the effect of available phosphorus levels was consistent with the findings of Temperton et al. (1965a and 1965b). No significant differences in egg weight or egg quality criteria attributable to ration fed during rearing were found.

The data in Experiment 1 regarding body weight of pullets at 20 weeks of age suggest that equal performance may be expected from pullets ranging in mean body weight from 1,474 grams through 1,728 grams. Body weights of pullets at 20 and at 22 weeks of age were not correlated with average performance during the first three months of production. Traits compared were number of eggs, egg size, Haugh Unit and shell thickness values.

The results of Experiment 2 regarding the effect of rearing density were generally consistent with the findings of Bell (1969) in that mean body weight of pullets trended downward as cage population was increased. However, only a general comparison for growth of pullets can be made between the two studies because density-cage floor space relationships and rearing periods were not similar. The California trials demonstrated the effect of crowding and/or limited feeder space during the rearing period on body weight of replacement pullets. A significant difference in body weight was found only where pullets reared at a density of 10 birds per cage with one inch of feeder space per chick were compared with pullets reared at a density of six birds per cage with four inches of feeder space per pullet. These findings would be somewhat comparable to the results obtained in Experiment 2 where feeder space decreased as density was increased

through density levels 1 to 4, i.e., 10, 20, 30 and 40 pullets per cage with corresponding feeder space of 2.5, 1.2, 0.8 and 0.6 inches, respectively, per 24 inches wide x 22 inches deep x 16 inches high cage.

The restrictions on cage space and cage feeder space appear to have resulted in lower mean body weight of pullets in Experiment 2. The mean body weight of pullets reared to 20 weeks of age by density levels 1 through 4 was 1,512, 1,472 and 1,321 grams, respectively. The pullets reared in density 4 were significantly lighter in body weight than the pullets reared in densities 1, 2 and 3. The pullets reared in density 1 consumed significantly more feed during the rearing period (0 to 20 weeks of age) than the pullets reared in densities 2, 3 and 4. Mean feed consumption by pullets in rearing densities 1 through 4 was 8.989, 8.080, 8.165 and 7.421 kilograms, respectively. The data from Experiment 2 suggest a positive relationship between cage floor space, feeder space and body weight at 20 weeks of age. However, differences in mean number of eggs produced by survivors (pullets that survived the six 28-day production periods) by rearing density of pullets housed at either one or two birds per cage were not significant. However, significant differences in hen-day production were found among pullets reared by the density levels tested when the pullets were



housed at two birds per cage but not when they were housed at one bird per cage. Mean hen-day production for pullets reared at levels 1 through 4 was 65.5, 66.2, 54.6 and 47.9 percent, respectively. The pullets reared at density levels 3 and 4 had significantly lower hen-day production than did the pullets reared at density levels 1 and 2. These data suggest that pullets reared at density levels 3 and 4 and subsequently housed at two birds per cage were unable to overcome the limiting effect of high rearing density on hen-day production when housed at two birds per cage. No significant differences in mortality due to rearing density level were found when the pullets were housed at either one or two birds per cage when the data were subjected to a Chi-square test ($P > 0.05$).

The hen-day production by initial weight class intervals 1 through 3 was 52.0, 70.6 and 65.6 percent, respectively, when the pullets were housed in single bird cages. The pullets in weight class 1 (35 to 37 grams) had significantly lower hen-day production than did the pullets in weight classes 2 (38 to 40 grams) or 3 (41 to 43 grams) when housed at one bird per cage but not when housed at 2 birds per cage. Although Experiment 2 was not designed to investigate the effect of initial pullet weight on production, the data suggest that further work to evaluate the effect of this trait on subsequent performance may be worthwhile.

The mean egg weight of pullets reared by density levels 1 through 4 was 48.4, 46.6, 50.2 and 50.3 when the pullets were housed at one bird per cage. The mean egg weight of pullets in densities 1 and 2 was significantly lighter than that of pullets in densities 3 and 4 at one bird per cage laying density but not at two birds per cage. The higher mean egg weight of pullets reared at relatively high densities and housed at one bird per cage suggest that sexual maturity was delayed contributing to larger egg size; however, this was not the case as the birds reared at the highest density levels actually reached sexual maturity as early as those with the greater floor space allowance.

The significantly higher shell thickness value of eggs laid by pullets reared at density level 2 (20 birds per cage, 0 to 7 weeks) and housed at two birds per cage, suggest that this rearing density may be more optimum for this factor than the others tested. However, additional tests seem in order before a definite conclusion can be drawn. No significant differences in shell thickness due to rearing method were found when the pullets were housed at one bird per cage.

It appears, when all factors are considered, that the optimum density for rearing pullets under the conditions of this experiment may be 20 pullets per cage

(26.4 sq in./chick) or slightly higher for the first seven weeks of the growing period. However, further tests should be conducted to carefully define the optimum density. This study was designed to explore a wide range in rearing density levels and the possible relationship of rearing density to subsequent performance. Variations in the effect of water and feeder space may well deserve further study in conjunction with cage density in the determination of the most efficient density level associated with economic production.

SUMMARY

There is a lack of information on the relationship of management and nutritional aspects of caged pullet rearing to economic egg production. It was therefore of interest to evaluate the subsequent performance of pullets reared under four methods: in cages without a coccidiostat in the diet, in cages for the same period with a coccidiostat in the diet, on litter to seven weeks of age and then in cages to 20 weeks of age, and on litter to 20 weeks of age. Five levels of phosphorus were factorially combined with the four rearing methods (20 factorial combinations). Pullets grown in these combinations were compared for mean body weight at 20 weeks of age and for production in single bird density laying cages.

Day-old commercial White Leghorn type pullets were used in this experiment. No debeaking was done. The pullets reared on the floor were significantly lighter in weight and consumed significantly less feed than pullets reared in cages or in the floor-cage rearing methods. Mortality percentages by rearing method were 1.33 (cages-no coccidiostat), 2.00 (cages-coccidiostat), 5.33 (floor-cage combination), and 6.66 (floor). No

significant differences in body weight at 20 weeks of age due to diet treatments were found.

The same diet was fed to the birds in all treatment combinations during the production phase. No significant differences in performance were found among the treatment combinations during the production phase regarding egg production, egg weight, Haugh Unit or shell thickness values.

Experiment 2 was conducted to test the effect of rearing density, i.e., 10, 20, 30, or 40 chicks (density levels 1 through 4, respectively) per 24 inches wide x 22 inches deep x 16 inches high cage, on performance during the subsequent production phase.

A total of 330 White Leghorn type day-old pullets were separated into three weight class intervals that differed in weight by three grams. Equal numbers of chicks from each weight class were wing-banded for each rearing density to be tested. Feeder space per chick for rearing densities 1 through 4 was 2.5, 1.2, 0.8 and 0.6 inches, respectively. At seven weeks of age, one-half of the pullets were transferred to identical cages, thus doubling feeder and cage space for the remainder of the rearing period to 20 weeks of age.

Fifty-four pullets from each rearing density level were selected equally from the three weight classes.

Eighteen pullets were housed at one bird per cage in 8 inch x 16 inch cages and the remaining 36 were placed in the same size cages at two birds per cage. All pullets received the same laying diet. Records of production were obtained from 22 weeks of age through six 28-day production periods.

At 20 weeks of age the pullets reared at density 4 were significantly lighter than those reared at the other densities and had consumed significantly less feed. The pullets reared at density 1 consumed significantly more feed than did the pullets in the other treatment levels.

No significant differences were found among the means of numbers of eggs laid by pullets surviving the six 28-day production periods at either one or two birds per cage laying density. However, there were significant differences in hen-day production where the pullets were housed at two birds per cage; whereas no significant differences were found where they were housed individually. The pullets reared at density levels 3 and 4 had significantly lower hen-day production than those reared at levels 1 and 2. In the first production period, the pullets reared at density levels 3 and 4 and subsequently housed at one bird per cage laid significantly larger eggs than those that had been reared at density levels 1

and 2; however no significant differences were found for this trait when data from the first three production periods were analyzed. No significant differences were found for this factor when the pullets were housed at two birds per cage.

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