COMPARISONS BETWEEN PULLETS HOUSED IN CAGES, ON A SLATTED FLOOR AND ON A LITTER FLOOR

Thesis for the Degree of Ph. D.

MICHIGAN STATE UNIVERSITY

Hugh Swaney Johnson

1961

This is to certify that the

thesis entitled

COMPARISONS BETWEEN PULLETS
HOUSED IN CAGES, ON A SLATTED
FLOOR AND ON A LITTER FLOOR

presented by

Hugh Swaney Johnson

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Poultry Science

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Date Feb. 22, 1962

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ABSTRACT

COMPARISONS BETWEEN PULLETS HOUSED IN CAGES, ON A SLATTED FLOOR AND ON A LITTER FLOOR

by Hugh Swaney Johnson

In recent years there has been considerable interest in keeping laying hens in cages and on slatted floors. Many persons and organizations have unduly glamorized and distributed misinformation about these two methods of laying house management due to the lack of scientific evidence. Therefore, this study was made to ascertain information pertaining to the comparative efficiencies of cages and slatted-floor management for the more severe climate of the area selected.

This study was composed of two separate experiments. The first trial, during 1959-1960, measured laying house performances for 305 days, and the second experiment extended for 334 days during 1960-1961. The same strain of pullets was used for making comparisons between laying birds in cages, on a slatted floor and on a litter floor. Factors measured included: (1) egg production, (2) laying house mortality, (3) body weight, (4) feed consumption,

(5) egg size, (6) albumen quality (Haugh scores), (7) shell thickness, and (8) blood and meat spots.

In the first study (1959-1960) the pullets were housed in three adjacent pens which each contained 464-square feet of floor area. One-hundred-and-twenty birds were placed in each pen with the cage birds being put in individual cages which were 8-inches wide and 16-inches deep. A commercial pelleted cage layer feed with a minimum guaranteed analysis of 16.5 percent protein was fed all groups both years. No culling was practiced and only dead birds were removed from any of the pens.

During the second study (1960-1961) the number of birds in each pen was increased to 200. In the cage room, one bird was placed in each of 40 cages and two pullets were put in each of 80 cages. These were the same cages that had been used the previous year. Dead birds were replaced with stock which was unused at the beginning of this trial. On three consecutive days of every month eggs from each pen were weighed and the albumen quality, shell thickness, and blood and meat spots recorded.

For both of these studies, the cage layers produced a total of 62,151 eggs, those on the litter floor laid 61,940 and the slatted-floor group produced 56,239 eggs.

During the second year of this work, the pullets in individual cages laid at a rate of 63.13 percent while those housed two per cage produced at a rate of 60.99 percent. These latter two figures are based on the total number of birds in cages. A statistically significant difference in egg production was obtained both years between cage and slatted-floor birds. Also a significant difference was observed the first year between litter-floor birds and those on the slatted floor.

Mortality was higher during both studies on the slatted floor than it was among the other two groups. The percentage of deaths was lower in single-bird cages than in two-bird cages.

The weight of birds in cages was greater at the end of the laying period than for those birds maintained on either a litter floor or slatted floor.

Larger eggs were laid by the cage birds than by either of the other two groups. Both studies revealed this difference to be significant at the one-percent level.

Interior egg quality, measured in terms of Haugh units, was practically the same among all groups.

The cage layers produced eggs with slightly thicker shells than those produced by the other two groups.

Blood spots and also meat spots were detected most often in the eggs produced in cages. A significant difference was noted in the incidence of blood spots between the cage eggs and those produced by slatted-floor birds.

COMPARISONS BETWEEN PULLETS HOUSED

IN CAGES, ON A SLATTED FLOOR

AND ON A LITTER FLOOR

By

Hugh Swaney Johnson

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Poultry Science

1961

ACKNOWLEDGEMENT

Deepest appreciation is expressed to Dr. H. C. Zindel, Head, Poultry Science Department, who supervised this study in addition to directing the author's graduate program.

Thanks is also due Drs. Henry Larzelere, Merle Esmay and Theo Coleman for their helpful suggestions and constructive review of this thesis.

The writer is indebted beyond words to his wife, Carolyn, for her encouragement, understanding, sacrifice and patience during the period of his graduate program. The endless hours she spent on the clerical portion of this report deserves special praise.

Also sincere gratitude is extended to Dr. William Baten of the Agricultural Experiment Station for his advice and direction in planning the statistical portion of this analysis. In addition, a note of thanks is offered Dr. L. R. Champion for his helpful assistance after the retirement of Dr. Baten.

Finally, without the fullest cooperation of the poultry plant employees and other personnel in the Poultry Science Department, this thesis would not have become a reality.

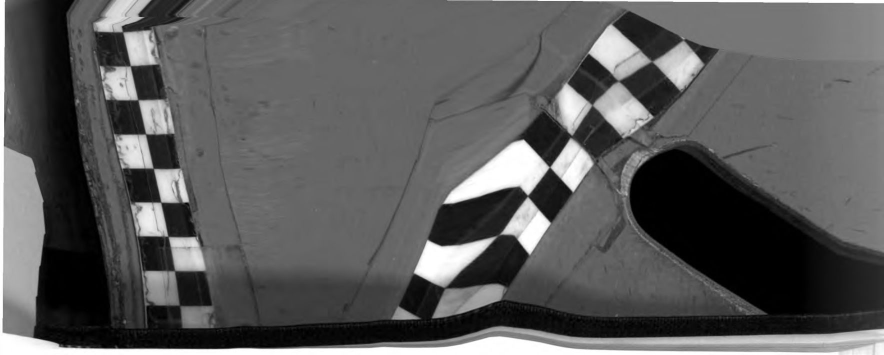
TABLE OF CONTENTS

LIST OF TABLES

Table | Page

Table | Page

LIST OF FIGURES



LIST OF APPENDICES

INTRODUCTION

In recent years, there has been considerable interest in keeping laying stock in cages and on raised floors made of wood slats or laths, commonly called slatted floors. Along with this interest, there has been a considerable number of questions asked. The most prevalent question being--"How does egg production compare between birds housed in cages, on a slatted floor and under litter-floor management?"

Personal opinions and observations have been used to influence producers and prospective producers to use cages or slatted floors in their poultry operation. Only in limited instances has experimental evidence been presented comparing these two methods to the conventional litter-floor type of management.

At the same time, poultry department staff members from colleges and universities have been uncertain whether or not to recommend these innovations due to the lack of scientific evidence. This hesitation has prompted many individuals and organizations to unduly glamorize and distribute misleading information about cages and slatted floors.

The idea of keeping laying hens in cages probably originated at the Ohio Agricultural Station in 1924 when Professor D. C. Kennard began a series of tests with wire cages holding four birds each (Hartman and King, 1956). In 1926, Kennard initiated tests with single-bird cages 18-inches square. He discovered that chickens kept in cages laid well and produced strong shelled eggs with practically no loss from breakage, that the mortality seemed to be less, that roosts and nests were not needed, and that the wire floors did not make the feet of the birds sore.

At the beginning of the thirties, various manufacturers throughout the United States put out individual cages arranged in three decks. Interest remained high for a few years and it was estimated that by 1935 a quarter of a million such cages were sold in southern California (Hartman and King, 1956). However, ventilation troubles, high initial cost and the extra labor required for their operation caused many of them to be discarded.

Immediately preceding World War II, a large number of cage plants were established in southern California. The war period brought further expansion to a virtual standstill but immediately after the war interest in cages revived

and reached boom proportions. L. D. Sanborn, farm advisor in Los Angles county, estimated in 1949 that 20 percent of all the layers in his county were in cages (Hartman and King, 1956). In this same county, it has been estimated that 90 percent of all farms starting egg production since 1945 have been of the individual or wire-cage type (King, 1952). Many of the nearby counties showed this same phenomenal expansion.

During the time the cage method was becoming established in southern California, other producers along the Pacific Coast and in the Southwest were becoming interested. In 1950, D. F. King at the Alabama station began experimenting with cages. His work popularized them throughout much of the South as well as in other areas.

Some of the most commonly cited reasons for the preference of cages over litter floors include (Paris and Byers, 1957, and McNiece, 1959):

1. Elimination of competition between birds
2. Increased feed efficiency
3. Lower mortality
4. Increased egg production
5. Regular replacements make it possible to operate at full capacity

6. Elimination of cannibalism and pickouts

7. Less trouble with diseases and parasites

Equally important are the disadvantages of cages when compared with litter floors. The following are most often enumerated (Paris and Byers, 1957, and McNiece, 1959):

1. High initial investment

2. More dirty eggs may result

3. Increased fly problem

4. Difficulties arising from having different ages of replacement pullets on hand

5. Possibly more blood spots

6. Problem of keeping cages full

Maintaining layers on a slatted surface and in a restricted area or on limited floor space is not new. The system has been popular in sections of the Orient for centuries. Professor C. Bice at the University of Hawaii brought the system of slatted floors into commercial prominence in the 1930's (Skinner and Adams, 1958). His objective was to get the birds off the damp ground and thereby eliminate some of the parasites, mold and disease problems.

The present popularity of slatted floors seems to be based on one or more of the following assumptions (anonymous, 1959):

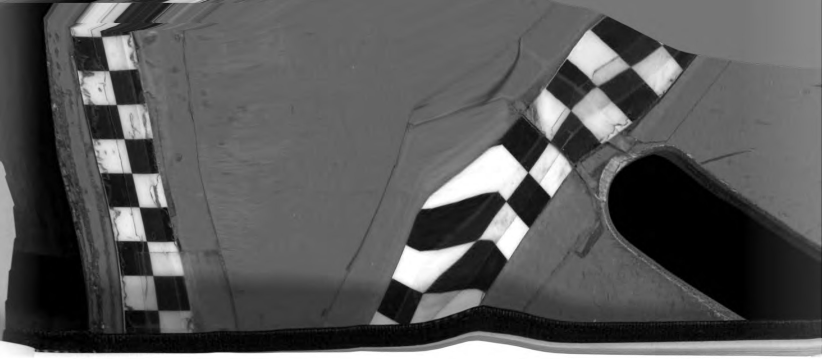
1. More birds are kept on a given amount of floor space and this in turn reduces the housing cost per dozen eggs produced
2. Eliminates litter expense
3. More efficient use of labor because of the concentration of birds and suitability to mechanization
4. Decreased parasite problems
5. Longer life of feeders and waterers
6. No dust problem

Once again the so-called disadvantages should be noted as well. These include (anonymous, 1959):

1. Initial cost is high and just as many birds can be housed by other means
2. Ceiling heights in existing houses may make the system impractical
3. Birds are inclined to be more cannibalistic
4. Unless completely mechanized, cleaning may require additional labor
5. Floor eggs are frequently a problem
6. Flies may become a problem in the summer unless pit cleaners are used
7. Possibly less production per hen

Expansion of the cage and slatted-floor systems has continued in some areas, but the dearth of factual material relating to them, particularly comparing them to the floor method, leaves many questions unanswered. Therefore, this study was undertaken and is based on the following null hypotheses.

1. There are no significant differences in egg production between pullets housed in cages, on a slatted floor and on a litter floor.
2. There are no significant differences in egg size distribution between the three systems of laying-house management.
3. There are no significant differences in the physical condition of the birds housed in cages, on a slatted floor and on a litter floor.
4. There are no significant differences between the egg quality factors of shell thickness and interior quality between the various systems of management.



REVIEW OF LITERATURE

A general tightening of the agricultural economy in recent years has resulted from higher production costs and decreasing margins per unit. It is therefore imperative that each farmer and poultryman scrutinize the effects of his management practices on production and attempt to make the proper managerial decisions accordingly.

Although this experiment was not designed as a cost study per se, any system that reduces such things as feed consumption and laying house mortality, and increases egg production, must be considered a means for lowering production costs and thus increasing income. These factors have been involved in some of the claims made by the proponents of the various methods of laying house management as they are compared one with another. To shed more light on such statements the following comparisons were made between cages, slatted floors and litter floors: (1) egg production, (2) egg weight, (3) albumen quality, (4) blood spots, (5) shell thickness, (6) feed consumption, (7) laying house mortality, and (8) body weight.

Because little information is available comparing all three of these management methods, this review will be

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divided into two parts. The first section will compare cages with conventional litter floors and the second part will compare slatted floors with litter floors.

Comparisons Between Cages and Litter Floors

Egg production. A great deal of work has been done on egg production comparisons between birds maintained on a litter floor and in cages, but in general, results have been contradictory as to whether floor or cage birds laid more eggs.

Composite data from two different random sample tests conducted in California during 1959-1960 showed that floor birds laid an average of 270 eggs and cage layers 248. These production figures were based on the number of pullets housed and cover the entire 553 days of the tests (U.S.D.A., 1961).

Timmons et al. (1961) compared equal numbers of Rhode Island Reds and Single Comb White Leghorns in cages and on the floor. They found that Leghorn pullets did better in cages than the Rhode Island Reds, but in both cases, the floor birds laid at a higher rate than those in cages over a period of 335 days.

Carlson and Strangeland (1960), using Single Comb White Leghorns and feed containing three different protein levels with and without antibiotics, reported that over a six-month period hens in floor pens laid at a superior rate to those in cages.

In another antibiotic study, Sanford (1959) found that floor birds laid significantly more eggs than those in cages. The feeds of the various groups contained (1) no antibiotic, (2) a single source of antibiotic, and (3) combinations of antibiotics.

Two research reports from Missouri also showed floor birds to be superior to those in cages. Froning and Funk (1958) reported average production on a hen-day basis for the floor birds to be 237 eggs while their full-sisters in cages laid 224 eggs. All birds were fed an all-mash ration containing 16-percent protein and 860 Calories of productive energy. Funk _et al_. (1958) obtained data on egg production for a three-year period and found that birds housed on a litter floor laid at an average rate of 65.0 percent while those in cages produced at 62.6 percent.

Lowry _et al_. (1956), comparing full-sisters in cages and on the floor during a four-year period, found the floor

birds superior each year. Only two of these years, however, was the difference statistically significant.

In a test involving seven strains of White Leghorns, Gowe (1955) reported that on a survivor basis, pullets on the floor laid 209 eggs while those in cages laid 179. Both groups were fed the same all-mash ration during the 500-day test period.

On the other hand, a number of workers have found that cage layers excelled in production. Some of the early work by Berry (1946) showed a clear superiority for cages. He found during a 10-year period that caged White Leghorns produced more each year than corresponding birds in floor pens.

Texas researchers also reported better performance from cages. Miller and Quisenberry (1959), studying 328 birds in cages and 383 on the floor, found through 224 days of production that cage layers, on a hen-day basis, laid 8.6 percent more than those on the floor. Three egg production strains were used in this experiment. That same year Bailey et al. (1959) reported egg production of caged housed birds to be 1.3 percent higher than those on litter. In this experiment, 873 birds representing four different egg production strains were compared over a period of 308 days of egg production.

At the South Dakota station, Bonzer and Morgan (1958) measured the performance records of 180 pullets during four months of lay. Their data showed the cage birds to be superiod by at least five-percent production in each of the months studied.

Robertson (1956), and Robertson and Branding (1957) at the Red Rose Research Center found that cage layers excelled floor birds during each of three laying seasons. The first year, 1954-1955, cage birds averaged 66-percent production during a 10-month laying period. A floor flock of the same strain and fed the same ration averaged 58-percent lay over an 11-month period. During the 1955-1956 laying year another strain of White Leghorns was used. Production for the cage group was 76 percent and for the floor group 72 percent. The third year two different protein levels were fed. However, in both cases, the cage birds exceeded their rivals on the floor.

In a South Carolina experiment, two groups of 48 White Leghorns were compared for a period of 40 weeks (Morgan, 1954). The hens in cages averaged 183 eggs while those on the floor tallied 167.

Gutteridge <u>et al</u>. (1944) found that Barred Plymouth Rock pullets in cages laid better than those on a litter

floor. They reported the differences to be statistically significant at the five-percent level.

Another researcher, Thompson (1939), concluded from four years practical experience in the management of laying hens in cages that, "There was no evidence that the individual caging of the fowls either increased or decreased the egg yield."

Egg weight. The relationship between egg weight and type of laying house management has been studied by a number of investigators. Generally caged layers have been observed to lay larger eggs than birds on a litter floor. Lowry et al. (1956) reported April egg weights over a four-year period to consistently favor birds in cages. In each of the years, the difference was statistically significant at the one-percent level.

Bailey et al. (1959), and Froning and Funk (1958) also found statistical differences at the one-percent level favoring cage layers. In the work by Bailey et al. (1959), the larger egg size in cage housed birds was consistent in all four strains studied.

In three years work at Missouri, Funk et al. (1958) observed that birds in cages laid slightly, but significantly,

larger eggs than their sisters on the floor.

Cage layers laid significantly larger eggs than pullets housed on the floor, according to Sanford (1959), in an experiment in which he fed no antibiotics, a single source of antibiotics and a combination of antibiotics.

Mellor et al. (1957), comparing four strains of laying hens, reported that eggs produced by birds in cages were slightly heavier than eggs produced by the same strain held on the floor. In this case, they also observed slight differences existed among strains.

No differences were noted in egg size between cage and floor birds by Timmons et al. (1961) and Gowe (1956).

Albumen quality. Little work has been done comparing albumen quality of eggs produced by the two methods. Funk et al. (1958) reported albumin quality of eggs produced by hens in cages to be slightly higher during seven of nine months studied; however, the difference was not statistically significant. This same trend was observed in the 1959-1960 California random sample tests, in which case the Haugh unit averages were 76 and 77 respectively for floor and cage layers (U.S.D.A., 1961).

On the other hand, Mellor et al. (1957), using 90 hens from each of four strains in cages and a similar number on the floor, found albumen quality to favor the floor system.

Studies by Timmons et al. (1961), Walker and Offord (1958), and Froning and Funk (1958) all indicated no differences in egg quality between cage and floor birds.

Blood and meat spots. Cage layers have generally shown a higher frequency of blood and meat spots than floor birds. Results from the 1959-1960 California random sample tests indicate that eggs laid in cages contained blood spots 9.4 percent of the time compared with 6.2 percent for those laid by the floor group (U.S.D.A., 1961).

In experiments covering a three-year period, Funk et al. (1958) reported that birds in cages produced more eggs containing meat and blood spots than their sisters on the floor.

Lowry et al. (1956) found significantly more eggs with blood spots from caged birds than from those on the floor in results obtained during another three-year test.

Jeffery (1945) reported that 7.0 percent of the eggs produced by Rhode Island Reds kept in cages contained blood spots compared with 5.7 percent for those of the same strain housed on the floor. His data also showed the

percentage of red meat spots was higher for the Rhode Island Reds kept in cages (20.3 percent) as compared with those on the floor (12.6 percent).

Contrary to later results, Jeffrey and Pino (1943) observed a higher incidence of blood spots in eggs laid by hens housed on the floor (11.09 percent) than in eggs laid by caged hens (4.01 percent).

No differences between systems of management as far as blood spots were concerned were reported by Timmons et al. (1961).

Shell thickness. Frequent statements have been made that shell thickness is a problem in cage produced eggs. No available evidence was found to bear this out. In fact, both Funk et al. (1958) and Timmons et al. (1961) found thicker shells on cage eggs. The thickness of the shells deposited by both caged and floor housed hens varied greatly during the year, according to Funk et al. (1958). However, they found the shells of eggs laid by birds in cages were thicker eight out of nine months measurements were made. The difference was not statistically significant, though.

Mellor et al. (1957) and Walker et al. (1958) observed no important differences in shell thickness between the two systems.

Feed efficiency. Most experimental work has shown more efficient feed conversion in cage birds than in floor groups. Bailey et al. (1959) found that cage housed birds required 0.118 pounds less feed to produce a dozen eggs than those on the floor. This difference, although it appears slight, was significant at the one-percent level.

Experimental results in Texas showed cage and floor birds required 4.48 and 4.96 pounds of feed per dozen eggs respectively (Miller et al., 1959). Both groups received a cage layer diet of 18-percent protein during the laying period.

During a six-year study, Robertson (1956) observed that cage pullets required less feed per dozen eggs in each of the six comparisons.

Hill et al. (1957), Berry (1946) and Morgan (1954) also found it took less feed to produce eggs in cages than on the floor. Morgan (1954) compiled data during a 40-week period and reported feed consumption per dozen eggs was 4.71 pounds for the birds in cages and 4.99 pounds for the pullets on the floor.

On the other hand, Timmons et al. (1961) reported feed consumption, measured in pounds per 24 ounce eggs, to be higher for the cage group. Rhode Island Reds and White Leghorns were used in the test and in both instances the additional feed required by the cage birds was statistically significant.

Mortality. Almost all the experimental evidence shows floor birds to have higher mortality, and conversely, cage birds to have better livability. Miller and Quisenberry (1959) compared mortality for the first 224 days of production and found death losses on the floor to be 6.27 percent and in cages 3.35 percent. Their study involved 383 and 328 birds on the floor and in cages respectively.

Robertson (1956) reported that floor birds had a higher rate of mortality in five out of the six years he compared cage and floor layers.

Mortality was highest among birds kept on the floor in each of the four years studied by Lowry et al. (1956). The difference was found to be statistically significant at the one-percent level in two of the years.

Gowe (1955) observed from his work that death losses were higher among birds in floor pens than in cages.

Mortality in the former group was 24 percent and in the latter 19 percent.

Although he noted no trend of any kind in causes of mortality, Gutteridge et al. (1944) found death losses to be highest on the floor (19.5 percent) and lowest in cages (18.6 percent).

Several other researchers (Berry, 1946, and Hill et al., 1957) also reported lower mortality in birds kept in cages than on the floor.

Higher mortality among cage birds was observed by Bailey et al. (1959) and in the 1959-1960 California random sample tests (U.S.D.A., 1961). Mortality in the latter case was 9.5 percent in cages and 7.2 percent on the floor.

Timmons et al. (1961) found the death losses to be higher on the floor for a group of Rhode Island Reds, but observed just the opposite effect among similar groups of White Leghorns.

Body weight. Experimental data indicate heavier body weights in caged birds than in floor birds. Bailey et al. (1959) found the average body weight of caged birds to be 11.64 grams greater than for similar birds on the floor. These

results were obtained after 308 days of egg production and the difference was significant at the one-percent level.

Timmons et al. (1961) reported that both Rhode Island Reds and Single Comb White Leghorns in cages weighed more, after 335 days of egg production, than corresponding groups of birds on the floor.

Morgan (1954) also reported cage layers to be heavier at the end of 40-weeks egg production.

Comparisons Between Slatted and Litter Floors

Egg production. Little work has been done comparing slatted and litter floors. The studies that have been done, however, seem to favor egg production on conventional litter-type floors. Osborn et al. (1959) made a six-month comparison between Leghorn type hens housed on litter at three-square feet per bird and wood-slat floors at one-square foot per bird. The experiment consisted of 360 pullets housed on slats and 127 on litter. Hen-housed egg production was 7.2 percent higher (60.2 percent vs. 53.0 percent) for the hens on litter.

In another test, Godfrey and Butler (1959) compared pullets on a slatted and litter floor with one, one-and-one-half and two-square feet per bird. The test was g

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conducted in 12 pens with six pens being used for each type management. These researchers found over a 12-month period that average production on the litter floor was 66.2 percent while on the slatted floor it was 61.9 percent.

Egg weight. Both Yao (1959), and Godfrey and Butler (1959) report little difference in egg size between the two management methods. Yao (1959) found the average egg size to be 57.2 grams on the slatted floor and 57.4 grams on the litter floor. Godfrey and Butler (1959) took a sample of the eggs laid in June and reported the percentage of large and over to be 82.0 and 80.5 percent respectively for slatted and litter floors.

Albumen quality. The only research on interior egg quality is that by Yao (1959), and Godfrey and Butler (1959). Neither researcher recorded any appreciable difference between the eggs produced on slatted or litter floors. Yao (1959) found the average Haugh unit score to be 73.7 for slatted-floor birds and 73.8 for litter-floor birds.

Blood and meat spots. Once again, too little research has been done on this problem to project any kind of trend.

Osborn et al. (1959) reported the incidence of blood spots to be lower among birds on a slatted floor than on a litter floor--6.8 percent as compared to 10.5 percent. Godfrey and Butler (1959) found the two methods of management to be practically the same as they observed blood spots in 0.5 percent of the slatted-floor birds' eggs and in 0.4 percent of those laid by the birds on litter.

Shell thickness. No research data are available on this particular point.

Feed efficiency. There is no information on feed efficiency comparing birds on slats and litter.

Mortality. The amount of mortality in birds was reported to be higher on slatted floors by both Godfrey and Butler (1959), and Osborn et al. (1959). Death losses among birds on the slatted floor amounted to 14.1 percent and on the litter floor 10.1 percent (Godfrey and Butler, 1959). Osborn et al. (1959) found mortality to be 7.2 and 2.4 percent respectively for birds on slatted and litter floors.

<u>Body weight</u>. The only study on this was by Yao (1959). He reported the mature body weight to be 4.0 pounds for birds on a slatted floor and 4.4 pounds per bird on a litter floor.

PROCEDURE

The first of these two studies commenced October 1, 1959 and lasted until August 1, 1960 for a total of 305 days. The second experiment ran for 334 days from September 1, 1960 to August 1, 1961.

Brooding and Rearing Period

First year. Some of the birds used in the first year of this experiment were raised from day-old chicks at the Michigan State University poultry farm. The others were purchased as 10-week old pullets and were the same commercial strain as the day-old chicks. In both cases, they were purchased from the same hatchery.

The chicks purchased at one day of age were debeaked on arrival and fed a starter feed in crumbled form to eight weeks of age. From eight weeks until housing time they were fed a grower all-mash. Between seven and eight weeks of age the pullets were moved to a grass-legume range and remained there until August 17 at which time they were moved to one of the permanent houses at the poultry farm. From August 18 to September 30 they were fed an all-mash laying mash.

The pullets purchased at 10 weeks of age were only one-day older than those raised as chicks. They, too, were reared on a grass-legume range until housing time and fed in a similar manner.

All the pullets were vaccinated for Newcastle disease, bronchitis and fowl pox and at the time of housing they were debeaked by cauterizing one-half of the upper mandible.

Second year. The same commercial strain of chickens was used the second year as had been used the first. This time, however, they were all purchased as 17-week old started pullets and had been reared in confinement on a farm away from M.S.U. Prior to delivery, they had been vaccinated for Newcastle disease, bronchitis, and fowl pox. At housing time they were all debeaked in the same manner as used the first year.

Description of Pens

The same three adjacent pens were utilized in what is known as the "Commercial House" at the poultry farm for both of these experiments. Each pen measured 23 feet 6 inches by 19 feet 9 inches. Ceiling height was 7 feet 2 inches.

A commercial type slatted floor was erected 14 inches above the concrete floor in one of these pens. The slatted floor came in four-foot square sections and each section was constructed of 1/2-inch by 1 1/2-inch hardwood slats. Dowel rods supported the slats which were spaced seven-eighths of an inch apart. Water was supplied by two automatic cup type waterers.

Stair-step cages manufactured by the Northco Ventilating Company were installed in a second pen. Two-double rows of cages were used with each cage being 8-inches wide and 16-inches deep. The height of each cage in the back was 16 inches and in the front 19 inches. Feed and water troughs were located in front of the cages and extended across the entire series of cages.

Michigan softwood shavings provided the litter in the third pen. An initial layer of approximately three inches was used with additional shavings being added as needed. The watering device consisted of two automatic cup type fountains situated on top of a small wire platform. The same amount of feeder space was furnished in this pen as in the slatted-floor pen. Roosts were located in the litter-floor pen but not in the slatted-floor pen.

Each pen had one outside wall which was well insulated and contained a vapor barrier. Two glass windows were located in each pen and a transparent plastic window material used on the outside to provide double protection. One of the inside walls in each pen faced an enclosed alleyway and the other two walls faced adjoining pens. Therefore, wall exposure in all the pens was exactly the same.

There was a total of 464 square feet of floor area in each pen or 3,328 cubic feet.

Other Environmental Conditions

Exhaust fans with thermostatic controls were located in each pen. All fans were rated at 1500 C.F.M. (cubic feet per minute) against a one-eighth inch static pressure. During the year the thermostat settings were changed from 45° F. to 60° F. depending on outside weather conditions. These adjustments were made in all the pens at the same time.

In cool weather, air was drawn into each pen through four slots in the ceiling located on the opposite side of the room from the fans. Each slot opening was 4-inches by 24-inches. Tempered air was brought into the pens via the attic. In turn, the air was brought into the attic of the

gable roof house through louvers located on the roof. In the summer time, the slots in the ceiling were closed and air was brought into the pens through a screened window in the entry door which opened into the alleyway.

Fourteen hours of light were provided daily during both of these experiments. The lighting arrangement consisted of 300 watts of light in each pen. Two 150-watt bulbs were used in both the slatted floor and litter-floor pens. This same arrangement was not feasible in the cage room as the cages formed an obstruction and would not permit an even distribution of light. Therefore, three outlets with 40-watt bulbs were located nearest the outside wall and three outlets with 60-watt bulbs were installed toward the inside alley wall.

Originally the pens were to have been cleaned out twice yearly, but several water fountain accidents and a maggot infestation in the droppings from the cage birds caused more frequent cleanings. All three pens were always cleaned out at the same time.

Trap nests were used in the slatted floor and litter-floor pens with one nest being provided for each five hens.

Number of Birds Housed

First year. On September 23, 1959, a total of 120 pullets were placed in each pen. Selection was made at random with obvious cull birds being discarded.

Floor space per bird amounted to 3.87 square feet in the litter and slatted-floor pens and 0.89 square feet per bird for those placed in cages. Even though this latter figure seems low, it must be remembered that the same number of birds were put in each of the identical sized pens.

Second year. Two-hundred pullets were housed in each pen on September 1, 1960. The birds were placed in the various pens at random with the culls being removed.

In order to accommodate 200 birds in the cage room, one pullet was placed in each of 40 cages and two in each of 80 cages. Single birds in cages were interspersed to maintain an equal number in the top and bottom tiers of the stair-step cages.

The amount of floor space per pullet was 2.32 square feet on the slatted and litter floor, and 0.89 and 0.45 square feet respectively for those in one and two-bird cages.

Nutrition

The same commercial feed was fed all three groups for the duration of these studies. It was a pelleted 16.5 percent all-mash laying mash with the trade label "Hi-Efficiency Cage Layer."

The composition shown in Table 1 is the formula as it appeared on the feed tag during the 1960-1961 laying season. Two ingredients had been changed slightly from the first year. The amount of soybean meal was increased from 296.26 pounds per ton to 296.38 pounds. Penicillin 10 meanwhile had been reduced from 0.24 pounds to 0.12 pounds per ton. The guaranteed analysis remained the same, though.

A feed sample was taken from every new shipment of feed to check on the guaranteed analysis. The results are shown in Appendix 1. The chemical composition was determined by the Agricultural Chemistry Department at Michigan State University until January 1, 1961. After that time, the feed analysis work was handled by the chemical laboratory of the Michigan Department of Agriculture.

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Characteristics Measured

The following characteristics were measured during one or both of these trials: egg production, mortality, bird weights, feed fed, egg weights, Haugh unit scores, shell thickness, blood spots and pen temperatures.

Egg production. Trap nest records were kept on all birds 5 days a week for the duration of these experiments. No individual records were maintained on Saturdays, Sundays, and legal holidays. Instead, the total number of eggs collected in each pen on those days was recorded. Floor eggs were recorded separately during the week but on week ends and holidays they were lumped into the grand total.

When two birds were kept in a cage the second year of this experiment, egg records were not maintained on each individual, but on the production from the cage.

Mortality. No culling was practiced in either one of these experiments. Only dead birds were removed from the pens and these were sent to the Michigan State University Pathology Laboratory for an autopsy to determine the cause of death.

During the second year of this experiment when a bird died it was replaced by similar stock held for this purpose. This kept the number of birds uniform under each management system. Replacement pullets were housed in a separate litter-floor pen and were the birds left after the various pens had originally been filled. All replacements were made at night to prevent undue social disturbances.

It should be noted that no replacements were made in any of the pens during the first year of this work.

<u>Weights</u>. Each pullet was weighed to the nearest one-tenth of a pound when housed. At the end of the respective test periods all the birds were again individually weighed.

<u>Feed fed</u>. The feed used in this experiment was delivered in 50-pound paper bags. When a bag was brought into a pen it was recorded on a feed card.

<u>Egg quality factors</u>. Records were kept on egg weights, albumen quality, shell thickness, and blood and meat spot incidences.

During the 1959-1960 laying season egg size was measured twice monthly from October through July. All eggs

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laid by the cage birds and those laid in the trap nests by the others were recorded and weighed, to the nearest one-half gram, on the first and third Wednesday of each month. Albumen quality--as measured in Haugh units--was computed on eight different occasions during May, June and July 1960. Once again all trap nested eggs in the case of slatted floor and litter-floor birds, and all eggs laid by the cage birds were collected one day and broken and measured the next day. The shell thickness was measured a total of three times during June and July at the same time the albumen quality was being determined.

The second year of this study, International Business Machine (I.B.M.) cards were used (actual cost $254.36) to record data on egg weight, albumen quality, blood and meat spots, and shell thickness. Three consecutive days every month all the trap nested eggs from the slatted and litter-floor birds and all eggs produced by the pullets in individual cages were marked. After each collection, the eggs were stored in a 45° F. walk-in egg cooler until the next day when they were delivered to Anthony Hall and examined.

Each egg was broken-out on a level glass plate, which was supported by a metal stand. The albumen height was

measured using a tripod micrometer and this figure plus the weight measurement was used to compute Haugh units as a measure of interior quality.

Shell thickness was recorded by a thickness gauge calibrated in thousandths of an inch and both shell membranes were included in the measurement. All measurements were taken while the shell and the membranes were wet.

The incidences of blood and meat spots was noted at the same time albumen height was being measured. Size, color and location of these blood and meat spots in the broken-out egg was observed visually with the aid of mirrors located underneath and behind the glass plate while measuring the albumen height.

<u>Temperature</u>. The temperature in each pen was recorded by the attendant at 8:00 a.m. and 4:00 p.m. every day. A commercial Fahrenheit thermometer was used in each pen and their agreement was checked periodically.

Thermographs were placed in identical positions in the pens on January 25, 1960 and seven-day readings were recorded until March 7, 1960.

Table 1. Pelleted all-mash laying mash (Farm Bureau)

Ingredients	Percentage	Pounds
Alfalfa meal	2.00	40
Blood meal	1.25	25
Corn	60.00	1200
Dicalcium phosphate	1.75	35
Fat	0.375	7.5
Fish meal	0.50	10
Fish solubles	0.25	5
Limestone	5.81	116.2
Meat scraps	2.50	50
Pulverized oats	10.00	200
Salt	0.44	8.8
Poultry mineral mix	0.05	1
50% soybeam meal	14.819	296.38
Penicillin 10	0.006	0.12
Layer vitamin premix (0.08% soy)	0.25	5
	100.00%	2000

Guaranteed Analysis

Protein	(Min.)	-	16.5%
Fat	(Min.)	-	3.2%
Fiber	(Max.)	-	3.8%
Calcium	(Min.)	-	3.0%
Phosphorus	(Min.)	-	0.6%
Iodine	(Min.)	-	0.0001%
Salt	(Max.)	-	0.5%

RESULTS

Experiment I--1959-1960

Egg production. Individual egg records were started on October 1, 1959 when the birds were 195-days old and were maintained for 305 days until they reached 500 days of age. The total egg production for all pens during this period amounted to 61,729 eggs. Of this total, the litter-floor birds laid 21,506, those in cages 21,369 and the slatted-floor group 18,854 (Table 2).

Production is shown for the various pens on a weekly hen-day basis in Figure 1 and Table 3. The slatted-floor birds consistently trailed the other two groups in production, except at the very beginning and end of the study. The poor production of the slatted-floor birds was especially evident from the sixth to twenty-fourth week or from November to the middle of March. During the entire period of this study, on a hen-day basis, the cage layers produced at a rate of 63.67 percent. This compares with 63.18 percent for the litter-floor birds and 57.79 percent for those on the slatted floor.

An analysis of variance indicated that the difference between these systems of management was statistically c[illegible]

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mc[illegible]

significant at the one-percent level (Table 4). All the birds that died and those that laid less than 50 eggs during the study were discarded before this analysis was made. The latter group was removed because the egg production patterns indicated they either laid a large number of floor eggs or were ill. When a studentized-range test was applied to these data, it was found both cage and litter-floor birds laid significantly more eggs, at the one-percent level, than those birds housed on the slatted floor. There were no statistical differences between the production of cage and litter-floor birds.

The number of eggs laid on the floor by the slatted-floor birds was 2160 and by the litter-floor group 1353 (Table 2) or 16.54 percent and 9.02 percent respectively for the two groups.

<u>Mortality</u>. The mortality was highest among the slatted-floor birds and lowest among the litter-floor group during the 1959-1960 laying season. A total of 29 birds died on the slatted floor (24.17 percent) compared with 22 in cages (18.33 percent) and 20 on the litter floor (16.67 percent). The number of death losses during the various months is given in Table 5.

According to autopsy reports received from the Veterinary Pathology laboratory, the major cause of mortality in all the groups was visceral lymphomatosis (Table 6). Nine birds in cages died from visceral lymphomatosis while seven birds were lost due to this same cause in each of the other two groups. Prolapses and/or pickouts were another important cause of deaths in the slatted-floor pen.

The t-test was used for making a statistical analysis on mortality between the various methods of management. No statistical differences were observed between any of the pens. The calculated t-values are given in Table 7.

Body weight. When the pullets were moved into their permanent quarters on September 23, 1959 they were each individually weighed. The average weight per bird on the litter floor was 3.90 pounds while these housed on the slatted floor averaged 3.83 pounds and the group placed in cages averaged 3.82 pounds. An analysis of variance on initial weights indicated the populations in the three pens were homogeneous (Table 8).

At the end of the study on August 1, 1960 all the live pullets were again weighed. The cage birds were the heaviest and averaged 4.76 pounds each while the slatted-

floor group averaged 4.47 pounds and those on litter averaged 4.27 pounds. The statistical treatment involved the use of an analysis of variance and final weights were found to be significantly different at the one-percent level of significance (Table 9). When a studentized-range test was applied to the results, the cage birds proved to be significantly heavier (one-percent level) than those on either the slatted floor or litter floor. No statistical differences were noted between the latter two groups.

<u>Feed consumption</u>. The total amount of feed consumed in each of the three pens is shown in Table 10.

The greatest consumption of feed took place in the litter-floor pen (9209 pounds) but egg production was also highest in this group of birds. The cage layers ate 9156 pounds and those birds on the slatted floor consumed 9095 pounds. When this was calculated on the pounds of feed per dozen eggs produced, the cage and litter-floor birds required identical amounts of 5.14 pounds. The pullets on the slatted floor required 5.79 pounds per dozen eggs produced.

Egg size. The eggs produced by cage layers were heavier than those laid by either of the other two groups. Average size of the cage eggs, as measured twice monthly during the study, was 61.15 grams. The birds on the slatted floor and litter floor produced eggs which averaged 59.54 grams and 59.13 grams respectively. Average egg size for each of the twenty weigh periods and by pens is shown in Figure 2 and Table 11.

When a weight distribution was made according to U.S.D.A. Standards for Consumer Grades, the number of eggs from cage layers which weighed Large and above totalled 79.22 percent. This compares with 68.21 percent from the litter-floor birds and 67.75 percent from the slatted-floor pullets. A complete distribution of egg sizes as measured by eggs collected three consecutive days monthly, is given in Table 12. This is also shown in Figure 3, except the Jumbo and Extra Large eggs are combined into one group as were the Small and Peewee eggs. They were combined to avoid using very small and disproportionate figures.

For a statistical treatment, the t-test was used for making comparisons between the various groups (Table 13). Eggs laid by the cage birds were found to be significantly

larger, at the one-percent level, than those produced by the litter-floor group. Caged birds also laid significantly larger eggs than the slatted-floor pullets. There was no significant difference in egg size between the litter floor and slatted-floor groups.

<u>Albumen quality</u>. Eggs were broken-out and Haugh unit scores recorded during the spring and summer months of May, June and July. Interior egg quality, as measured in Haugh units, favored the litter-floor birds with an average score of 75.93. The cage birds averaged 74.53 Haugh units and those pullets on the slatted floor averaged 74.25 (Table 14).

An analysis of variance was used as the statistical treatment and a significant difference, at the five-percent level, was observed between pens. The studentized-range test indicated that Haugh unit scores for the litter-floor pullets were significantly better than the eggs from the cage and slatted-floor birds. No difference was evident between the cage and slatted-floor groups (Table 15).

<u>Shell thickness</u>. Slightly thicker shells were found in eggs laid by the cage layers than by either of the other

two pens. The average shell thickness, measured in fractions of an inch, was 0.01337 of an inch for the cage layers. The birds on litter and the slatted floor had shell thicknesses of 0.01289 and 0.01320 of an inch respectively (Table 16).

When an analysis of variance was applied to these data the differences between pens were found to be highly significant (Table 17). The studentized-range test indicated that both the cage and slatted-floor birds had thicker shells than those deposited on the eggs of the litter-floor groups. The difference was at the one-percent level of significance between cages and litter-floor birds and at the five-percent level between slatted floor and litter-floor birds. There was no statistically significant difference between the shell thickness of eggs laid by slatted floor and cage birds.

<u>Pen temperatures</u>. The average monthly temperature varied only slightly between the three pens (Table 18). Over the entire 10-month period, the lowest average monthly temperature was recorded in February at 4:00 p.m. in the slatted-floor pen (45.97° F.). The highest monthly temperature--80.90° F.--was in July at 4:00 p.m. in the litter-floor pen.

The thermograph recordings from January 25 to March 7 indicated this same uniformity of temperatures between the various pens. In general, the thermograph records showed the lowest temperature during a 24-hour period was around 4:00 a.m. or just before the lights went on. The highest daily temperature was reached about 2:00 p.m.

Table 2. Monthly egg production in total numbers of eggs--1959-1960

	Slatted-floor eggs				Litter-floor eggs				Cage eggs		
	Trap-nested	Floor eggs	Week ends	Total	Trap-nested	Floor eggs	Week ends	Total	Trap-nested	Week ends	Total
Oct.,1959	1304	267	683	2254	1284	155	568	2007	1735	722	2457
November	1249	268	632	2149	1497	144	702	2343	1685	734	2419
December	1183	340	673	2196	1591	206	763	2560	1769	785	2554
Jan.,1960	1032	303	752	2087	1425	151	859	2435	1576	874	2450
February	1015	223	519	1757	1382	152	587	2121	1434	559	1993
March	1087	173	451	1711	1358	146	518	2022	1506	531	2037
April	1084	183	557	1824	1353	124	638	2115	1411	610	2021
May	1027	169	573	1769	1367	105	711	2183	1389	634	2023
June	997	149	403	1549	1326	98	511	1935	1306	487	1793
July	919	85	554	1558	1062	72	651	1785	1017	605	1622
Total	10,897	2160	5797	18,854	13,645	1353	6508	21,506	14,828	6541	21,369

Table 3. Weekly percentage egg production based on hen-day basis--1959-1960

Dates		Weeks	Percent production		
			Slatted floor	Litter floor	Cages
October: 1959					
	1-7	1	57.02	48.56	62.14
	8-14	2	58.10	51.14	64.17
	15-21	3	64.05	55.70	69.05
	22-28	4	64.36	60.26	68.21
	29-4	5	60.86	62.38	66.55
November:					
	5-11	6	60.50	65.21	67.62
	12-18	7	58.77	66.91	67.83
	19-25	8	60.68	66.30	67.79
	26-2	9	61.05	68.13	69.09
December:					
	3-9	10	61.17	70.26	70.09
	10-16	11	60.76	74.35	70.48
	17-23	12	60.47	72.30	72.13
	24-30	13	60.32	70.68	72.30
	31-6	14	61.49	70.31	68.96
January: 1960					
	7-13	15	58.02	67.54	69.91
	14-20	16	57.40	68.55	70.92
	21-27	17	62.39	69.30	71.72
	28-3	18	58.04	66.92	66.84
February:					
	4-10	19	57.79	64.79	61.86
	11-17	20	55.54	66.25	62.02
	18-24	21	53.21	64.35	61.85
	25-2	22	52.23	61.19	60.13

Table 3. Continued

Dates		Weeks	Percent production		
			Slatted floor	Litter floor	Cages
March:					
	3-9	23	48.94	60.30	63.49
	10-16	24	49.54	58.53	61.52
	17-23	25	52.60	54.68	61.28
	24-30	26	55.14	57.11	58.61
	31-6	27	51.67	57.53	61.15
April:					
	7-13	28	58.85	62.29	64.62
	14-20	29	60.64	65.12	63.68
	21-27	30	61.20	67.53	62.22
	28-4	31	61.78	66.80	64.44
May:					
	5-11	32	58.97	65.74	64.63
	12-18	33	58.13	67.06	62.55
	19-25	34	56.72	63.62	60.16
	26-1	35	59.34	63.65	60.85
June:					
	2-8	36	57.71	64.56	59.48
	9-15	37	55.28	61.71	57.28
	16-22	38	55.90	62.83	57.01
	23-29	39	53.42	59.78	56.65
	30-6	40	51.48	59.38	54.89
July:					
	7-13	41	56.20	59.10	53.95
	14-20	42	57.77	56.44	53.25
	21-27	43	55.57	54.92	50.36
	28-31	44	53.30	52.00	50.26
Average			57.79	63.18	63.67

Table 4. Analysis of variance and studentized-range test on egg production--1959-1960

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	14,168.74	2	7084.37	8.08**
Error	228,718.59	261	876.32	
Total	242,887.33	263		

** Significant at one-percent level

Studentized-range test[1]

121.37 133.48 139.53

Slatted floor · Litter floor · Cages

One-percent level:

Cages, litter floor > slatted floor

[1]Any two means not overscored by the same line are significantly different, and any two lots overscored by the same line are not significantly different.

Table 5. Total number of death losses by months--1959-1960

Dates	Numbers		
	Slatted floor	Litter floor	Cages
October, 1959	1	1	0
November	2	2	2
December	2	2	3
January, 1960	4	1	3
February	2	1	4
March	2	2	1
April	6	2	0
May	6	3	3
June	3	4	1
July	1	2	5
Total	29	20	22

Table 6. Causes of mortality during the 1959-1960 laying season

Cause	Numbers		
	Slatted floor	Litter floor	Cages
Visceral lymphomatosis	7	7	9
Prolapses and/or pickouts	7	1	-
Hemorrhagic causes	-	3	1
Peritonitis	2	-	2
Impacted oviduct	1	1	1
Visceral gout	1	2	-
Chronic respiratory disease	1	1	-
Tracheitis	-	1	1
Tumors (liver or ovary)	-	-	2
Nephritis	1	1	-
Coccidiosis	-	1	-
Impacted intestine	-	-	1
Air sacculitis	1	-	-
Chronic cholera	-	1	-
Undetermined	8	1	5
Total	29	20	22

Table 7. Statistical analysis of mortality in the various pens by use of the t-test--1959-1960

SLATTED FLOOR and LITTER FLOOR

$$t = \frac{0.2417 - 0.1667}{0.05182}$$

$$= \frac{0.07500}{0.05182}$$

$$t = 1.45 \text{ N.S.}$$

LITTER FLOOR and CAGES

$$t = \frac{0.1833 - 0.1667}{0.04905}$$

$$= \frac{0.0166}{0.04905}$$

$$t = 0.34 \text{ N.S.}$$

SLATTED FLOOR and CAGES

$$t = \frac{0.2417 - 0.1833}{0.05268}$$

$$= \frac{0.05840}{0.05268}$$

$$t = 1.11 \text{ N.S.}$$

Table 8. Analysis of variance on initial weights of pullets as measured on September 23, 1959

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	0.43	2	0.215	0.78 N.S.
Error	97.81	357	0.274	
Total	98.24	359		

Table 9. Analysis of variance on final weights of pullets as measured on August 1, 1960

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	11.82	2	5.91	9.88**
Error	171.11	286	0.598	
Total	182.93	288		

**Significant at one-percent level

<u>Studentized-range test</u>[1]

4.27	4.47	4.76
Litter floor	Slatted floor	Cages

One-percent level:

Cages > slatted floor, litter floor

[1]Any two means not overscored by the same line are significantly different, and any two lots overscored by the same line are not significantly different.

Table 10. Monthly and yearly feed consumption in pounds--1959-1960

Dates	Pounds of feed		
	Slatted floor	Litter floor	Cages
October, 1959	1000	950	1050
November	925	850	950
December	1050	1050	1050
January, 1960	1000	1000	1000
February	950	950	850
March	1000	1050	1000
April	900	950	1050
May	850	900	850
June	700	800	750
July	720	709	606
Total	9095	9209	9156

Table 11. Average egg size in grams as measured twice monthly--1959-1960

Dates			Average egg size (grams)		
			Slatted floor	Litter floor	Cages
October	7	(1959)	51.11	51.50	52.57
	21		53.96	52.33	55.82
November	4		55.12	54.96	57.56
	18		56.18	55.74	59.01
December	2		57.52	57.21	59.48
	16		58.24	57.68	60.81
January	6	(1960)	58.85	57.68	61.23
	20		59.81	58.98	61.21
February	3		60.28	58.39	61.21
	17		61.39	60.54	61.65
March	2		62.74	62.36	63.35
	16		61.68	61.52	63.86
April	6		62.73	62.61	64.08
	20		60.45	59.57	60.40
May	4		63.34	62.69	64.23
	18		62.76	61.73	64.79
June	1		63.44	61.58	64.18
	15		62.45	62.02	64.85
July	6		62.62	63.37	65.12
	20		61.99	62.36	64.48
Average			59.54	59.13	61.15

Table 12. Composite distribution of egg sizes in percentages according to U.S.D.A. Standards for Consumer Grades--1959-1960

Weight classes	Percent		
	Slatted floor	Litter floor	Cages
Jumbo	4.45	2.48	4.61
Extra large	19.09	19.24	28.30
Large	44.21	46.49	46.31
Medium	27.89	24.86	18.87
Small	3.56	6.36	1.84
Peewee	0.79	0.58	0.07

Table 13. A t-test analysis on egg size as measured twice monthly during the 1959-1960 laying season

SLATTED FLOOR and LITTER FLOOR

$$t = \frac{59.64 - 59.27}{\sqrt{0.03606 + 0.02955}}$$

$$= \frac{0.37}{0.2561}$$

$$t = 1.44 \text{ N.S.}$$

LITTER FLOOR and CAGES

$$t = \frac{61.21 - 59.27}{\sqrt{0.02955 + 0.02208}}$$

$$= \frac{1.94}{0.227}$$

$$t = 8.55^{**}$$

** Significant at one-percent level

SLATTED FLOOR and CAGES

$$t = \frac{61.21 - 59.64}{\sqrt{0.02208 + 0.03606}}$$

$$= \frac{1.57}{0.2411}$$

$$t = 6.51^{**}$$

** Significant at one-percent level

Table 14. Average Haugh unit scores[1] as measured on eight different dates in 1960

Dates			Average Haugh units		
			Slatted floor	Litter floor	Cages
May	18	1960	72.88	74.88	72.03
June	1		76.24	77.39	77.20
	15		75.05	78.38	74.96
July	6		81.17	81.34	79.58
	20		69.73	71.16	69.34
	26		70.43	71.59	74.09
	27		74.93	74.44	74.02
	28		73.89	76.26	74.84
Average			74.25	75.93	74.53

[1]Haugh units for U.S.D.A. Egg Quality Standards:

AA - 72 and above

A - 55 to 72

B - 31 to 55

C - 31 and below

Table 15. Analysis of variance and studentized-range test comparing Haugh unit scores--1959-1960

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	625.62	2	312.81	3.87*
Error	94,635.88	1170	80.89	
Total	95,261.50	1172		

* Significant at five-percent level

Studentized-range test[1]

Slatted floor	Cages	Litter floor
74.25	74.53	75.93

Five-percent level

Litter floor > cages, slatted floor

[1]Any two means not overscored by the same line are significantly different, and any two lots overscored by the same line are not significantly different.

Table 16. Average shell thickness in fractions of an inch as measured on three dates in 1960

Dates (1960)	Shell thickness (X0.001 = inches)		
	Slatted floor	Litter floor	Cages
June 15	13.32	12.84	13.58
July 6	12.90	12.85	13.12
July 20	13.33	13.00	13.41
Average	13.20	12.89	13.37

Table 17. Analysis of variance and studentized-range test on shell thickness--1960

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	17.69	2	8.85	7.02**
Error	543.71	433	1.26	
Total	561.40	435		

** Significant at one-percent level

Studentized-range test[1]

12.89	$\overline{13.20 \quad 13.37}$	
Litter floor	Slatted floor	Cages

Five-percent level:

Slatted floor > litter floor

One-percent level:

Cages > litter floor

[1]Any two means not overscored by the same line are significantly different, and any two lots overscored by the same line are not significantly different.

Table 18. Average monthly pen temperatures as recorded daily at 8:00 a.m. and 4:00 p.m. in degrees Fahrenheit--1959-1960

Dates	Slatted floor		Litter floor		Cages	
	8:00 am	4:00 pm	8:00 am	4:00 pm	8:00 am	4:00 pm
<u>1959</u>						
October	53.92	59.65	54.58	59.92	52.71	58.80
November	47.60	49.10	49.20	49.93	47.83	49.17
December	47.45	48.77	48.48	48.61	48.90	48.65
<u>1960</u>						
January	47.26	46.97	47.71	46.68	48.23	47.13
February	46.00	45.97	46.90	46.41	47.45	46.66
March	46.77	48.61	48.10	50.03	48.10	49.52
April	54.70	63.24	55.93	64.20	54.34	61.86
May	61.81	70.35	61.74	71.13	60.35	68.61
June	65.00	75.00	65.60	76.37	65.17	74.30
July	68.10	79.60	69.10	80.90	68.13	78.10

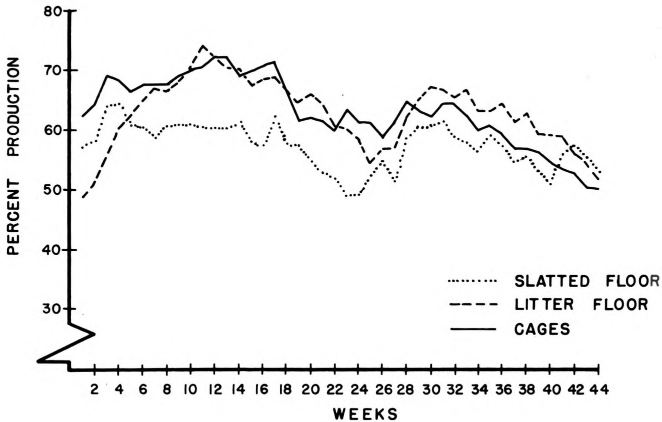

FIGURE I. EGG PRODUCTION IN PERCENT BY WEEKS BASED ON HEN-DAY BASIS FOR BIRDS IN CAGES AND ON SLATTED FLOOR AND LITTER FLOOR — 1959-1960.

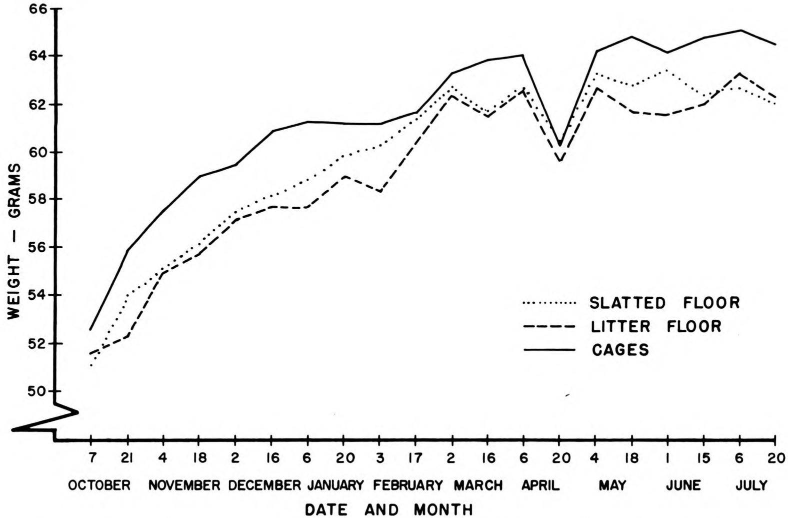

FIGURE 2. AVERAGE EGG SIZE (GRAMS) AS MEASURED TWICE MONTHLY 1959-1960.

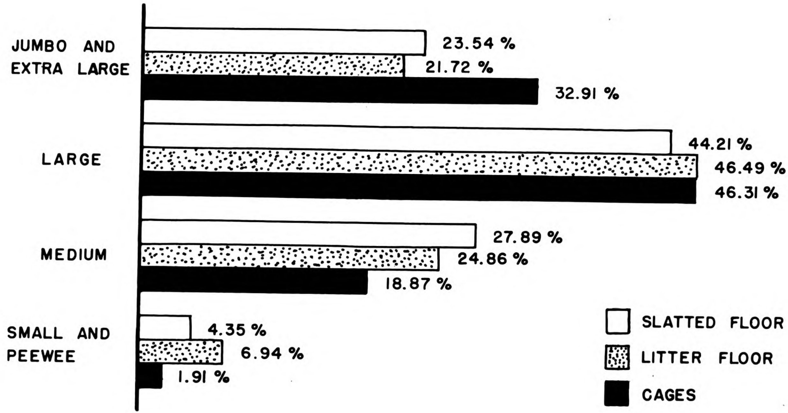

FIGURE 3. COMPOSITE DISTRIBUTION OF EGG SIZE—1959-1960.

Experiment II--1960-1961

Egg production. Total egg production was practically identical on the litter floor and in cages during the second year of this study. Over a 334-day period, the cage birds laid 40,782 eggs and the litter-floor pullets 40,434. Chickens confined on the slatted floor produced a total of 37,385 eggs (Table 19). The respective percentages, based on the total number of birds, for the pullets in cages and on the litter floor and slatted floor were 61.05, 60.53 and 55.97.

The weekly rate of lay is shown in Figure 4 and Table 20. In figuring the percent production, the total number of eggs laid in a 7-day period was used, except during the forty-eighth week when only a five-day period was covered. It can be seen that the birds on the slatted floor trailed the other two groups, almost without exception, during the 48-week laying period. The litter-floor birds hit a slump about the sixteenth week and fell considerably below the cage layers until approximately the twenty-seventh week. This period of time was between December 15 and March 8. On the other hand, the cage birds maintained fairly even production throughout the entire laying period.

A comparison between birds in single and two-bird cages is shown in Figures 5 and 6, and also in Table 21. The percentages used, for the most part, are based on a five-day week as no distinction was made on Saturday or Sunday whether the eggs were laid by birds in one or two-unit cages. The weeks listed in Table 21, therefore, include only a five-day period unless otherwise stated.

Figure 5 illustrates egg production in cages based on the total number of birds. The pullets in two-bird cages trailed the pullets in single-bird cages, on a percentage basis, during much of the study. This was especially evident from the tenth to thirty-eighth week. Over the entire 48-week laying period, the pullets in individual cages laid at a rate of 63.13 percent and those in the two-bird units produced at a rate of 60.99 percent.

Egg production on a hen-day basis for the pullets in one and two-bird cages (63.26 and 61.22 percent, respectively), is shown in Figure 6. The percentages listed are based only on the pullets which originally started in this experiment on September 1, 1960. When a pullet died in a two-bird cage the entire cage was dropped from further consideration as it was not possible, under the conditions of this experiment, to make a distinction between eggs laid

by a particular individual in a two-bird unit. The difference in production is slight, however, whether the results are based on the total number of birds or a hen-day basis.

An analysis of variance indicated there was a statistically significant difference, at the five-percent level, between pens (Table 22). A studentized-range test showed there was a significant difference at the one-percent level favoring cage birds over the slatted-floor pullets. No observable differences were detected between cage and litter-floor birds or between litter floor and slatted-floor pullets. Before computing the analysis of variance, birds that either died or laid less than 40 eggs during the test period were removed from consideration.

Floor eggs were less of a problem the second year of this experiment than they were the first. A total of 2075 eggs were laid on the floor by the litter confined birds and 1817 eggs by those birds on the slatted floor (Table 19). This amounted to 7.28 percent and 6.87 percent respectively, based on the total number of trap nested and floor eggs.

Mortality. The number of deaths during the second year of this experiment was once again highest on the slatted

floor. Mortality amounted to 22.50 percent among the slatted-floor birds compared with 18.50 percent on litter and 13.50 percent in cages. These figures include two replacement birds which died in each of the floor pens and one replacement that died in cages. Including replacements, a total of 45 pullets died on the slatted floor, 37 on the litter floor and 27 in cages (Table 23).

In the cages, three pullets died in the one-bird units or 7.50 percent. Twenty-four birds died in the two-bird cages for a total of 15.00 percent.

The largest number of determined deaths was caused by visceral lymphomatosis and prolapses or pickouts (Table 24). The cause of mortality in many cases was undetermined even though all the birds were given a post-mortem examination in the Veterinary Pathology laboratory.

The t-test was employed to determine statistical differences in mortality between pens (Table 25). No significant differences were obtained between birds on the slatted floor and litter floor or between birds in the litter pen and cages. A significant difference at the five-percent level was observed between the slatted-floor pen and cage birds.

The statistical analysis was carried one step further by comparing birds in single-bird cages with the two-bird units and also with the slatted floor and litter-floor pens. There was a significant difference at the five-percent level favoring pullets in single cages over the litter-floor birds. Pullets in single cages were superior to slatted-floor birds at the one-percent level.

Body weight. The initial weights of the pullets in the various pens were statistically different at the one-percent level of significance (Table 26). When a studentized-range test was applied to these data, it was found that the pullets on the slatted floor were significantly heavier than either of the other two groups. Their average weight was 3.38 pounds compared with 3.26 pounds for those in cages and 3.19 pounds for the litter-floor group. The results of a t-test indicated this same difference (Table 27).

Due to the initial weight differences, little reliance can be placed on final comparisons with the slatted-floor birds. However, an analysis of variance and subsequent studentized-range test on final weights did indicate that cage birds were significantly heavier (one-percent level) than their counterparts on the litter floor. Also, the

cage layers were significantly heavier than the slatted-floor birds even though the latter group was significantly heavier at the start (Table 28).

Average body weights at the end of this experiment were 4.49 pounds for the cage birds, 4.32 pounds for those on the slatted floor and 3.98 pounds for the litter-floor group.

Feed consumption. The largest amount of feed was consumed by the slatted-floor birds. They required 16,979 pounds of commercial mash during the 11-month test period. The cage pullets consumed 16,936 pounds while those on the litter floor required 15,795 pounds (Table 29).

In terms of feed conversion, the highest degree of efficiency was obtained by the litter-housed birds. They required 4.69 pounds for each dozen eggs produced. Cage layers had a feed conversion of 4.98 pounds and those on the slatted floor 5.45 pounds.

Egg size. The eggs produced by the cage birds were heavier than those produced by either of the other two groups of birds. This was the same trend as observed during the first year of this study.

Average weight of the cage produced eggs was 61.02 grams. This represented a sample of 760 eggs produced by pullets in single-unit cages. Only eggs from birds housed in single cages were weighed as individual production records were not maintained for those pullets in two-bird units. Eggs from the slatted-floor birds averaged 59.65 grams and those produced by litter-floor pullets averaged 57.44 grams each (Table 30). A total of 2810 eggs comprised the former group and 3050 the latter. The average egg weights by groups for the various months are pictured graphically in Figure 7. This chart shows, except for October, that eggs from cage birds were the largest. They were followed in size by eggs from the slatted-floor pullets and then those produced by birds on the litter floor.

A distribution of egg size was made according to U.S.D.A. Standards for Consumer Grades (Table 31 and Figure 8). The Jumbo and Extra Large, and Peewee and Small were once again combined in Figure 8 in order to avoid using very small figures. The exact classification, according to the various weight classes, is shown in Table 31.

The t-test was used for making a statistical comparison of egg size between the three systems of laying house management. A significant difference at the one-percent level was

observed between all three management methods. The pullets in cages laid significantly larger eggs than birds on either the slatted floor or litter floor. Also, slatted-floor birds laid significantly larger eggs than those on the litter floor (Table 32).

Egg size comparisons in alternate months of this study using an analysis of variance are shown in Appendix 2.

<u>Albumen quality</u>. Haugh unit scores, used to measure albumen quality, favored the litter-floor birds. The average score for this pen was 79.72 as computed on 3050 eggs during a 10-month period. The cage birds had an average Haugh score of 78.56 and those birds on the slatted floor averaged 78.53. A total of 760 and 2810 eggs respectively comprised the latter two groups. Only eggs from the single-bird cages were used in making these comparisons. Daily and monthly average Haugh unit scores for the three groups of birds are shown in Table 33.

A graphic illustration of average monthly Haugh scores is shown in Figure 9. It can be seen from this illustration that albumen quality declines with season and/or age of birds.

A two-variable analysis of variance was used to compare the Haugh unit scores of the eggs produced in the various

pens. One of the variables was the seasons of the year with October, November and December being considered one season; January through April was another season; and May, June and July comprised the third season. The other variable was management methods or pen differences. To avoid using a very complicated series of formulas for disproportionate numbers, a random selection of 12 Haugh unit scores was made from each pen for each season (Dixon and Massey, 1951). The selection provided material for a proportionate sub-class of numbers. No statistical differences were evident between the pens in this analysis. However, a highly significant different was present in these data between seasons (Table 34).

An analysis of variance on all eggs during alternate months of this study is shown in Appendix 3.

<u>Shell thickness</u>. The pullets in cages laid eggs with thicker shells than birds in either of the other two groups. Average shell thickness for cage layers was 0.01408 of an inch compared with 0.01380 and 0.01364 of an inch respectively for birds on the slatted floor and litter floor. These results coincide with results obtained the first year of this experiment. A complete listing of the average

daily and monthly shell thicknesses are listed in Table 35. The monthly averages are, in turn, graphically presented in Figure 10.

The statistical treatment, a two-variable classification of an analysis of variance, indicated that eggs from cage birds had significantly thicker shells than those deposited on the eggs by birds on the slatted floor or litter floor (Table 36). The seasonal variation was significant at the one-percent level. The same random selection was used for making shell thickness comparisons as had been employed for comparing Haugh scores.

Statistical treatments for shell thicknesses every two months of this experiment are listed in Appendix 4.

<u>Blood and meat spots</u>. The percentage of blood spots was highest in the eggs from cage layers with 3.29 percent. The litter-floor group had blood spots in 1.97 percent of their eggs and the slatted-floor birds produced eggs that contained blood in 1.92 percent of their eggs. A total of 6620 eggs were examined with 3050 of these from the litter-floor group, 2810 from the slatted-floor pen and 760 from cages. These were the same eggs used for making Haugh unit, shell thickness and weight comparisons. The total number

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48

and size of the various blood spots is shown in Table 37.

All spots, both blood and meat, were found in the largest percentage in cage produced eggs. The respective percentages for birds in cages, on a litter floor and on a slatted floor were 13.29, 12.30 and 10.89 percent. The number of meat spots, classified according to small, medium and large, are listed in Table 37.

A t-test was used for making a statistical comparison between management methods relative to the incidences of blood and meat spots. No statistical differences were evident when all spots were considered (Table 38). However, when just blood spots were taken into account a statistical difference at the five-percent level was observed between the slatted-floor birds and those in cages (Table 39).

Pen temperatures. Average monthly temperatures are shown in Table 40. In general, these temperature readings are higher than they were the previous year.

The lowest average monthly temperature during the 1960-1961 laying season was 46.90° F. This was recorded in the slatted-floor pen during March. Readings in the litter-floor pen and cage room averaged 48.23° F. and 48.10° F., respectively during this same time.

Highest monthly temperatures were recorded at 4:00 p.m. in the month of July. The average readings were 82.45° F. in the litter-floor pen, 81.90° F. in the slatted-floor pen and 79.74° F. in the cage room.

Table 19. Monthly egg production in total numbers of eggs--1960-1961

Date	Slatted-floor eggs					Litter-floor eggs					Cage eggs			
	Trap nested	Floor eggs	Week ends	Replace-ments	Total	Trap nested	Floor eggs	Week ends	Replace-ments	Total	Single cages	Double cages	Week ends	Total
1960														
Sept.	1142	203	468	9	1822	1224	165	455	8	1852	174	1064	393	1631
Oct.	2296	312	1204	28	3840	2622	218	1342	20	4202	482	2190	1234	3906
Nov.	2391	211	941	50	3593	2936	278	1151	48	4413	644	2377	1125	4146
Dec.	2173	173	1120	64	3530	2400	204	1280	90	3974	628	2253	1362	4243
1961														
Jan.	2031	154	1131	134	3450	1934	177	1074	128	3313	595	2066	1294	3955
Feb.	1600	129	765	191	2685	1867	151	863	181	3062	567	1978	990	3535
Mar.	2406	157	988	315	3866	2470	192	1012	251	3925	640	2267	1004	3911
Apr.	2145	140	1184	322	3791	2075	177	1322	315	3889	567	2023	1271	3861
May	2266	132	975	415	3788	2442	198	1046	416	4102	607	2347	1007	3961
June	2041	136	905	366	3448	2204	193	1025	417	3839	533	2223	1010	3766
July	1830	70	1259	413	3572	1967	122	1375	399	3863	472	2048	1347	3867
Tl.	22,321	1817	10,940	2307	37,385	24,141	2075	11,945	2273	40,434	5909	22,836	12,037	40,782

Table 20. Weekly egg production in percent based on total number of birds--1960-1961

Dates	Weeks	Percent egg production		
		Slatted floor	Litter floor	Cages
September, 1960:				
1-7	1	11.71	9.64	9.71
8-14	2	21.79	21.57	20.00
15-21	3	37.93	36.57	30.86
22-28	4	45.86	48.14	40.64
29-5	5	51.21	55.79	53.93
October:				
6-12	6	62.36	61.86	58.86
13-19	7	64.00	70.86	65.71
20-26	8	65.86	73.07	66.79
27-2	9	61.21	76.57	68.57
November:				
3-9	10	63.07	71.93	69.00
10-16	11	57.86	73.43	70.07
17-23	12	57.29	74.21	67.36
24-30	13	60.93	74.00	70.14
December:				
1-7	14	61.43	71.71	71.57
8-14	15	59.79	72.29	70.43
15-21	16	55.07	61.29	68.50
22-28	17	52.71	55.86	64.71
29-4	18	54.21	54.36	65.00
January, 1961:				
5-11	19	57.64	52.79	63.57
12-18	20	54.57	54.57	63.50
19-25	21	57.00	54.14	63.50
26-1	22	52.50	51.00	64.07
February:				
2-8	23	44.50	50.00	62.79
9-15	24	42.07	52.71	63.21
16-22	25	49.43	55.43	63.43
23-1	26	58.07	61.43	62.50

Table 20. Continued

Dates		Weeks	Percent egg production		
			Slatted floor	Litter floor	Cages
March:					
	2-8	27	62.21	64.29	64.79
	9-15	28	62.50	66.00	64.29
	16-22	29	62.36	63.86	61.57
	23-29	30	62.07	61.79	62.14
	30-5	31	62.64	61.07	62.64
April:					
	6-12	32	62.50	63.36	63.93
	13-19	33	64.50	62.71	65.50
	20-26	34	64.21	67.79	65.21
	27-3	35	62.21	68.07	65.93
May:					
	4-10	36	61.50	67.93	65.29
	11-17	37	61.07	65.93	61.79
	18-24	38	60.14	65.14	62.36
	25-31	39	60.93	64.86	63.93
June:					
	1-7	40	57.79	66.14	65.93
	8-14	41	56.57	62.64	62.86
	15-21	42	57.00	64.50	62.79
	22-28	43	57.86	63.07	59.93
	29-5	44	57.86	61.29	61.50
July:					
	6-12	45	59.57	61.57	63.50
	13-19	46	56.43	62.64	62.29
	20-26	47	55.36	63.57	62.07
	27-31	48	60.20	62.60	62.10
Average			55.97	60.53	61.05

Table 21. Weekly egg production in percent for single and two-bird cages based on total number of birds and hen-day basis--1960-1961

Dates		Weeks	Percent egg production			
			Total birds		Hen-day basis	
			Single birds	Two birds	Single birds	Two birds
1960						
Sept.	* 1-7	1	1.88	14.38	1.88	14.38
	8-14	2	9.50	23.50	9.50	23.50
	15-21	3	22.00	33.25	22.00	33.25
	22-28	4	36.00	42.50	36.00	42.50
	29-5	5	45.50	58.00	45.50	58.00
Oct.	6-12	6	52.50	62.13	52.50	62.19
	13-19	7	65.50	65.63	65.50	65.31
	20-26	8	58.00	68.00	58.00	67.48
	27-2	9	67.50	69.00	67.50	69.35
Nov.	3-9	10	68.50	68.00	68.50	68.57
	10-16	11	70.00	67.88	70.00	68.44
	17-23	12	75.00	65.38	75.00	65.58
	24-30	13	78.50	69.13	78.50	68.85
Dec.	1-7	14	76.50	70.00	76.50	70.66
	8-14	15	79.50	68.75	79.50	69.74
	15-21	16	71.50	66.75	71.50	67.50
	*22-28	17	70.63	62.97	70.63	63.29
	*29-4	18	71.88	64.69	71.88	64.70
1961						
Jan.	5-11	19	73.00	60.63	73.00	60.95
	12-18	20	72.00	60.88	72.00	61.76
	19-25	21	68.50	60.63	68.50	61.62
	26-1	22	70.00	63.00	70.00	64.59
Feb.	2-8	23	69.50	60.88	69.54	61.35
	9-15	24	71.50	61.38	70.77	62.13
	16-22	25	71.50	62.50	71.28	63.40
	23-1	26	71.00	61.50	71.28	62.64

Table 21. Continued

Dates		Weeks	Percent egg production			
			Total birds		Hen-day basis	
			Single birds	Two birds	Single birds	Two birds
March	2-8	27	73.00	63.25	72.82	63.33
	9-15	28	74.00	61.75	74.36	62.08
	16-22	29	65.00	60.75	65.13	61.17
	23-29	30	67.50	61.25	68.21	60.79
	30-5	31	67.50	61.88	67.69	62.57
April	6-12	32	74.50	62.50	74.87	62.61
	13-19	33	71.50	63.13	72.31	64.09
	20-26	34	69.00	64.50	69.23	66.72
	27-3	35	72.50	66.00	72.82	66.30
May	4-10	36	66.50	64.38	66.67	64.53
	11-17	37	62.00	61.25	61.54	62.50
	18-24	38	67.00	62.00	67.18	62.26
	25-31	39	63.50	65.13	64.10	66.35
June	1-7	40	68.50	66.25	68.21	67.46
	8-14	41	62.00	62.25	61.54	62.90
	15-21	42	55.50	63.25	55.90	64.03
	22-28	43	59.00	60.88	58.46	62.26
	*29-5	44	58.75	64.06	59.62	64.52
July	6-12	45	56.00	65.25	56.92	66.45
	13-19	46	59.00	63.00	60.10	63.77
	20-26	47	58.00	63.13	59.47	63.44
	**27-31	48	62.50	64.38	65.49	67.13
Average			63.13	60.99	63.26	61.22

* 4-day week

** 3-day week

Table 22. Analysis of variance and studentized-range test on egg production during the 1960-1961 laying season

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	5,447.15	2	2723.58	3.49*
Error	256,508.09	329	779.66	
Total	261,955.24	331		

* Significant at five-percent level

Studentized-range test[1]

137.81 143.19 150.68

Slatted floor — Litter floor — Cages

One-percent level:

Cages > slatted floor

[1]Any two means not overscored by the same line are significantly different, and any two lots overscored by the same line are not significantly different.

Table 23. Total number of deaths by months--1960-1961

Dates	Numbers		
	Slatted floor	Litter floor	Cages
September, 1960	1	1	0
October	2	2	3
November	1	3	1
December	2	4	3
January, 1961	11	4	0
February	5	4	3
March	4*	5	4
April	5	4*	3
May	2*	1	2
June	6	6*	2
July	6	3	6*
Total	45	37	27

* Total includes one replacement bird.

Table 24. Causes of mortality during the 1960-1961 laying season

Cause	Numbers		
	Slatted floor	Litter floor	Cages
Visceral lymphomatosis	6	6	2
Prolapses and/or pickouts	6	3	5
Peritonitis	3	6	4
Hepatitis	4	2	1
Nephritis	2	1	2
Chronic respiratory disease	1	3	-
Impacted oviduct	2	2	-
Tracheitis	2	1	-
Ascariasis	1	1	-
Air sac infection	1	1	-
Catarrhal enteritis	1	-	-
Erythrol lymphomatosis	-	-	1
Tumors	-	-	1
Enteritis	1	-	-
Undetermined	15	11	11
Total	45	37	27

Table 25. A t-test comparison between the various pens relative to mortality during 1960-1961

SLATTED FLOOR and LITTER FLOOR	LITTER FLOOR and SINGLE-BIRD CAGES
$t = \frac{0.2250 - 0.1850}{0.04032}$	$t = \frac{0.1850 - 0.0750}{0.04988}$
$= \frac{0.04000}{0.04032}$	$= \frac{0.11000}{0.04988}$
t = 0.99 N.S.	t = 2.21*
LITTER FLOOR and CAGES	SLATTED FLOOR and SINGLE-BIRD CAGES
$t = \frac{0.1850 - 0.1350}{0.03658}$	$t = \frac{0.2250 - 0.0750}{0.05105}$
$= \frac{0.05000}{0.03658}$	$= \frac{0.15000}{0.05105}$
t = 1.37 N.S.	t = 2.94**
SLATTED FLOOR and CAGES	SINGLE-BIRD CAGES and TWO-BIRD CAGES
$t = \frac{0.2250 - 0.1350}{0.03815}$	$t = \frac{0.1500 - 0.0750}{0.05031}$
$= \frac{0.09000}{0.03815}$	$= \frac{0.0750}{0.05031}$
t = 2.36*	t = 1.49 N.S.
*Significant at five-percent level	**Significant at one-percent level

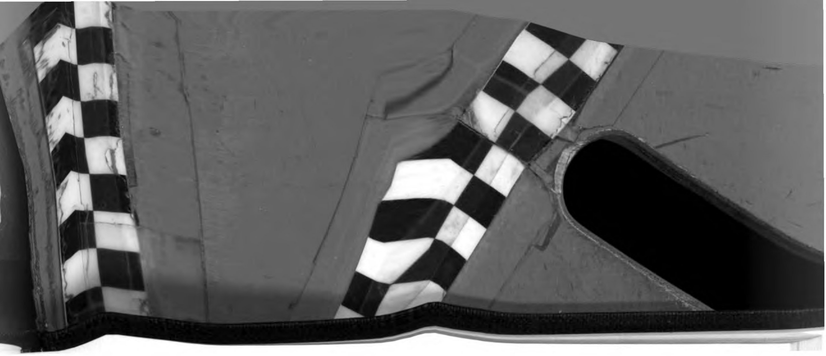

Table 26. Analysis of variance and studentized-range test on initial weights of pullets as measured on September 1, 1960

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	3.71	2	1.86	14.3 **
Error	78.99	597	0.13	
Total	82.70	599		

** Significant at one-percent level

Studentized-range test[1]

$\overline{3.19 \qquad 3.26}$ $\qquad 3.38$

Litter floor	Cages	Slatted floor

One-percent level:

Slatted floor > cages, litter floor

[1]Any two means not overscored by the same line are significantly different, and any two lots overscored by the same line are not significantly different.

Table 27. Comparison between initial weights of pullets on September 1, 1960 using the t-test--1960-1961

SLATTED FLOOR and LITTER FLOOR

$$t = \frac{3.38 - 3.19}{\sqrt{0.0007475 + 0.0006111}}$$

$$= \frac{0.19}{\sqrt{0.001358}}$$

$$= \frac{0.19}{0.0368}$$

$$t = 5.16^{**}$$

LITTER FLOOR and CAGES

$$t = \frac{3.25 - 3.19}{\sqrt{0.0006111 + 0.0007563}}$$

$$= \frac{0.06}{\sqrt{0.001367}}$$

$$= \frac{0.06}{0.0370}$$

$$t = 1.62 \text{ N.S.}$$

SLATTED FLOOR and CAGES

$$t = \frac{3.38 - 3.25}{\sqrt{0.0007475 + 0.0007563}}$$

$$= \frac{0.13}{\sqrt{0.001504}}$$

$$= \frac{0.13}{0.0388}$$

$$t = 3.35^{**}$$

**Significant at one-percent level

Table 28. Analysis of variance and studentized-range test on final weights of birds as measured on August 1, 1961

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	23.17	2	11.59	27.60 **
Error	206.56	493	0.42	
Total	229.73	495		

** Significant at one-percent level

Studentized-range test[1]

3.98	4.32	4.49
Litter floor	Slatted floor	Cages

Five-percent level:

Cages > slatted floor

One-percent level:

Cages > slatted floor

[1]Any two means not overscored by the same line are significantly different, and any two lots overscored by the same line are not significantly different.

Table 29. Monthly and yearly feed consumption in pounds--1960-1961

Dates	Pounds of feed		
	Slatted floor	Litter floor	Cages
September, 1960	1125	1148	1214
October	1550	1400	1450
November	1450	1500	1550
December	1550	1500	1600
January, 1961	1600	1350	1650
February	1500	1450	1450
March	1800	1550	1800
April	1800	1750	1800
May	1650	1500	1550
June	1500	1400	1500
July	1454	1247	1372
Total	16,979	15,795	16,936

Table 30. Average egg size in grams as measured 3-consecutive days monthly during a 10-month period--1960-1961

Dates			Average egg size (grams)		
			Slatted floor	Litter floor	Cages
October	17	(1960)	53.42	50.49	51.21
	18		53.26	50.13	52.42
	19		52.62	51.02	51.63
Average			53.07	50.55	51.79
November	14		55.28	53.90	56.10
	15		55.81	53.83	56.47
	16		55.40	54.03	57.02
Average			55.50	53.92	56.52
December	19		58.15	56.24	60.20
	20		57.14	56.01	60.45
	21		58.08	55.49	59.81
Average			57.79	55.93	60.20
January	16	(1961)	60.27	57.23	61.20
	17		59.33	57.89	61.90
	18		58.81	57.63	61.73
Average			59.47	57.58	61.60
February					
	13		60.47	59.02	61.25
	14		60.11	58.44	62.00
	15		59.84	59.40	62.80
Average			60.10	58.95	62.06
March	20		62.31	61.01	63.96
	21		62.45	60.19	63.48
	22		61.66	60.36	64.26
Average			62.14	60.52	63.94
April	17		62.98	61.13	64.83
	18		63.54	60.77	64.16
	19		63.53	60.99	64.17
Average			63.36	60.96	64.35

Table 30. Continued

Dates		Average egg size (grams)		
		Slatted floor	Litter floor	Cages
May	15	61.82	60.44	63.34
	16	61.94	60.69	64.46
	17	62.07	60.21	64.50
Average		61.95	60.44	64.12
June	19	62.56	60.07	63.05
	20	62.87	59.81	64.58
	21	62.75	60.20	63.88
Average		62.72	60.03	63.85
July	24	61.46	58.89	62.69
	25	60.47	59.09	62.39
	26	62.12	60.06	62.71
Average		61.40	59.34	62.60
Grand average		59.65	57.44	61.02

Table 31. Composite distribution of egg sizes in percentages according to U.S.D.A. Standards for Consumer Grades--1960-1961

Weight classes	Percent		
	Slatted floor	Litter floor	Cages
Jumbo	3.17	1.61	1.32
Extra Large	20.71	11.93	33.68
Large	45.34	41.87	44.21
Medium	26.98	35.48	18.03
Small	3.77	8.72	2.50
Peewee	0.04	0.39	0.26

Table 32. A t-test analysis comparing egg size as measured 3-consecutive days monthly during a 10-month period--1960-1961

SLATTED FLOOR and LITTER FLOOR

$$t = \frac{59.76 - 57.72}{\sqrt{0.01140 + 0.01278}}$$

$$= \frac{2.0400}{0.1555}$$

$$t = 13.12^{**}$$

LITTER FLOOR and CAGES

$$t = \frac{61.06 - 57.72}{\sqrt{0.03859 + 0.01278}}$$

$$= \frac{3.3400}{0.2267}$$

$$t = 14.73^{**}$$

SLATTED FLOOR and CAGES

$$t = \frac{61.06 - 59.76}{\sqrt{0.03859 + 0.01140}}$$

$$= \frac{1.3000}{0.2236}$$

$$t = 5.81^{**}$$

** Significant at one-percent level

Table 33. Average Haugh unit scores for each date and month during the 1960-1961 laying season

Dates			Average Haugh unit score		
			Slatted floor	Litter floor	Cages
October	17	(1960)	83.59	86.70	89.05
	18		85.51	86.98	90.80
	19		86.89	86.71	88.50
Average			85.43	86.80	89.44
November	14		82.24	83.45	82.31
	15		81.30	81.18	81.24
	16		84.31	81.17	81.96
Average			82.69	81.93	81.84
December	19		82.37	84.40	81.74
	20		85.17	83.45	81.76
	21		80.66	83.18	81.67
Average			82.73	83.71	81.73
January	16	(1961)	80.17	80.13	79.80
	17		80.65	80.88	81.52
	18		78.08	82.96	78.84
Average			79.70	81.33	79.94
February	13		80.47	79.00	79.42
	14		73.38	78.19	74.08
	15		75.04	75.51	77.03
Average			75.91	77.55	76.89
March	20		80.74	77.19	76.82
	21		76.72	80.07	75.80
	22		76.34	78.54	76.56
Average			77.94	78.61	76.45
April	17		78.21	77.69	77.17
	18		78.24	79.83	76.48
	19		77.51	78.09	75.00
Average			77.99	78.52	76.18

Table 33. Continued

Dates		Average Haugh unit score		
		Slatted floor	Litter floor	Cages
May	15	74.03	74.62	71.77
	16	73.39	75.49	73.58
	17	73.65	74.56	76.14
Average		73.68	74.88	73.81
June	19	72.66	75.26	70.77
	20	74.42	75.06	74.00
	21	73.68	74.34	73.06
Average		73.57	74.90	72.61
July	24	75.33	76.60	73.50
	25	75.23	76.15	75.55
	26	69.84	72.23	75.24
Average		73.27	75.04	74.72
Grand average		78.53	79.72	78.56

Table 34. Analysis of variance for a random selection of Haugh unit scores measured during the 1960-1961 laying season

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	99.18	2	49.59	0.73 N.S.
Seasons	3161.45	2	1580.73	23.19 **
Interaction	154.42	4	38.61	
Error	6865.02	99	69.34	
New error	7019.44	103	68.15	
Total	10280.07	107		

** Significant at one-percent level

Table 35. Average shell thickness in fractions of an inch as measured during the 1960-1961 laying season

Dates			Shell thickness (x0.001 = inches)		
			Slatted floor	Litter floor	Cages
October	17	(1960)	14.07	14.18	14.87
	18		14.45	14.40	14.74
	19		14.43	14.72	14.54
Average			14.33	14.43	14.69
November	14		14.17	14.32	14.76
	15		14.20	14.14	15.17
	16		13.85	14.50	14.88
Average			14.06	14.32	14.94
December	19		14.18	13.91	14.15
	20		13.81	13.45	13.95
	21		13.98	13.35	13.79
Average			13.99	13.59	13.98
January	16	(1961)	13.75	13.57	14.17
	17		13.70	13.53	13.82
	18		13.80	13.37	14.31
Average			13.75	13.49	14.12
February	13		14.07	13.68	14.00
	14		14.18	13.64	13.98
	15		13.89	13.77	14.25
Average			14.04	13.70	14.09
March	20		13.87	13.40	14.20
	21		13.85	13.67	14.18
	22		13.83	13.43	14.26
Average			13.85	13.50	14.21
April	17		14.19	13.83	14.35
	18		14.05	13.72	14.12
	19		13.81	13.73	13.81
Average			14.02	13.76	14.08

Table 35. Continued

Dates		Shell thickness (x0.001 = inches)		
		Slatted floor	Litter floor	Cages
May	15	13.29	13.03	13.55
	16	13.16	13.19	13.63
	17	13.74	13.24	13.95
Average		13.40	13.16	13.71
June	19	13.15	12.97	13.14
	20	13.51	13.11	13.79
	21	13.39	13.16	13.19
Average		13.34	13.08	13.40
July	24	13.09	12.82	13.06
	25	12.96	12.81	13.14
	26	13.22	12.83	13.64
Average		13.09	12.82	13.27
Grand average		13.80	13.64	14.08

Table 36. Analysis of variance and studentized-range test for a random selection of egg shell thicknesses measured during the 1960-1961 laying season

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	7.40	2	3.70	3.43*
Seasons	15.59	2	7.80	7.22**
Interaction	7.91	4	1.98	
Error	103.31	99	1.04	
New error	111.22	103	1.08	
Total	134.21	107		

*Significant at five-percent level

**Significant at one-percent level

Studentized-range test[1]

13.58	14.14
Slatted floor Litter floor	Cages

One-percent level:

Cages > slatted floor, litter floor

[1]Any two means not overscored by the same line are significantly different, and any two lots overscored by the same line are not significantly different.

Table 37. Number and size of blood and meat spots detected in broken-out eggs for 3-consecutive days monthly during a 10-month period--1960-1961

Type and size of spots	Number		
	Slatted floor	Litter floor	Cages
Blood spots:			
Large[1]	23	16	9
Medium[2]	11	17	7
Small[3]	20	27	9
Total	54	60	25
Meat spots:			
Large[1]	62	80	9
Medium[2]	96	117	31
Small[3]	94	118	36
Total	252	315	76
Grand total:	306	375	101

[1] Over 1/8th of an inch

[2] Between 1/16th and 1/8th of an inch

[3] Less than 1/16th of an inch

Table 38. A t-test analysis of all blood and meat spots detected in broken-out eggs--1960-1961

SLATTED FLOOR and LITTER FLOOR

$$t = \frac{0.1230 - 0.1089}{0.00836}$$

$$= \frac{0.01410}{0.00836}$$

$$t = 1.69 \text{ N.S.}$$

LITTER FLOOR and CAGES

$$t = \frac{0.1329 - 0.1230}{0.01367}$$

$$= \frac{0.00990}{0.01367}$$

$$t = 0.72 \text{ N.S.}$$

SLATTED FLOOR and CAGES

$$t = \frac{0.1329 - 0.1089}{0.01364}$$

$$= \frac{0.0240}{0.01364}$$

$$t = 1.76 \text{ N.S.}$$

Table 39. A t-test analysis of all blood spots detected in broken-out eggs--1960-1961

SLATTED FLOOR and LITTER FLOOR

$$t = \frac{0.0197 - 0.0192}{0.00361}$$

$$= \frac{0.0005}{0.00361}$$

$$t = 0.14 \text{ N.S.}$$

LITTER FLOOR and CAGES

$$t = \frac{0.0329 - 0.0197}{0.00694}$$

$$= \frac{0.0132}{0.00694}$$

$$t = 1.90 \text{ N.S.}$$

SLATTED FLOOR and CAGES

$$t = \frac{0.0329 - 0.0192}{0.00697}$$

$$= \frac{0.0137}{0.00697}$$

$$t = 1.97^{*}$$

*Significant at five-percent level

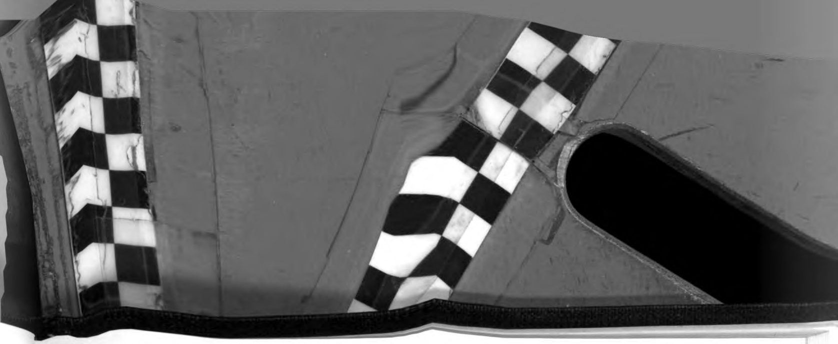

Table 40. Average monthly pen temperatures as recorded in degrees Fahrenheit daily at 8:00 a.m. and 4:00 p.m.--1960-1961

Dates	Slatted floor		Litter floor		Cages	
	8:00 a.m.	4:00 p.m.	8:00 a.m.	4:00 p.m.	8:00 a.m.	4:00 p.m.
September, 1960	64.93	72.72	65.93	75.97	64.50	74.34
October	56.84	65.23	57.81	66.48	54.35	62.77
November	54.33	57.70	54.57	57.73	55.80	57.10
December	50.77	51.03	51.42	51.71	52.74	52.65
January, 1961	51.61	52.32	53.52	54.32	52.87	50.39
February	47.11	51.04	48.93	52.15	47.86	50.93
March	46.90	55.45	48.23	56.94	48.10	55.61
April	49.90	57.50	51.47	60.47	50.53	59.07
May	57.48	72.42	58.90	72.81	57.03	68.42
June	65.43	78.33	67.47	79.57	65.10	76.37
July	71.19	81.90	72.45	82.45	70.58	79.74

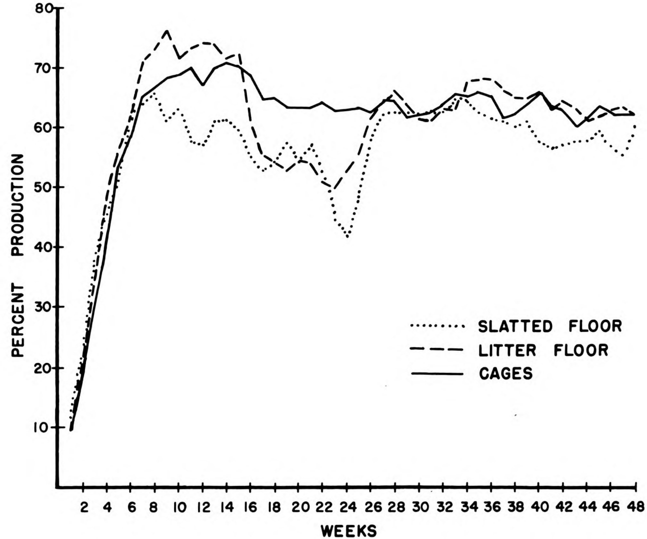

FIGURE 4. EGG PRODUCTION IN PERCENT BY WEEKS BASED ON TOTAL NUMBER OF BIRDS IN CAGES AND ON A SLATTED FLOOR AND LITTER FLOOR — 1960-1961.

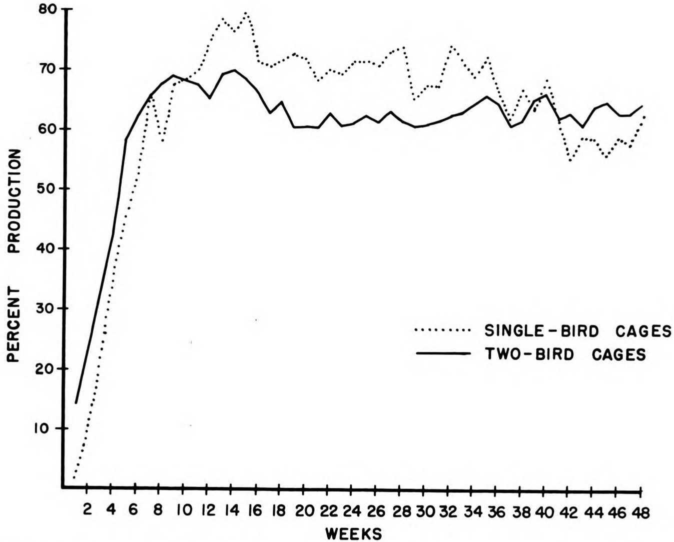

FIGURE 5. EGG PRODUCTION IN PERCENT BY WEEKS BASED ON TOTAL NUMBER OF BIRDS IN SINGLE AND TWO-BIRD CAGES — 1960—1961.

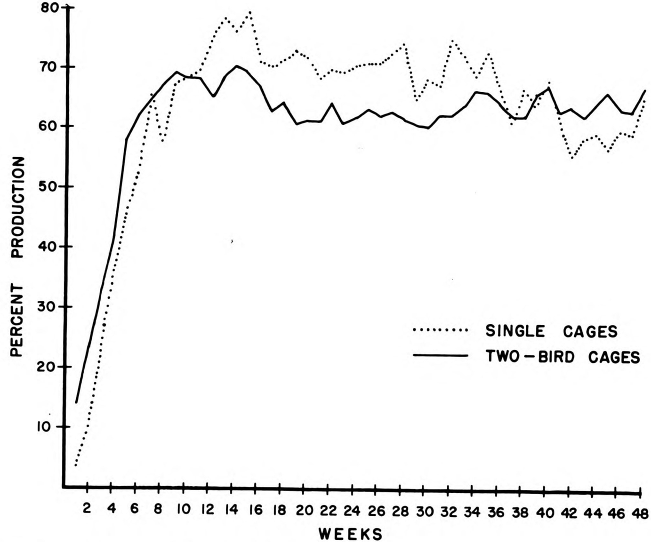

FIGURE 6. EGG PRODUCTION IN PERCENT BY WEEKS BASED ON HEN-DAY BASIS FOR BIRDS IN SINGLE AND TWO-BIRD CAGES — 1960-1961.

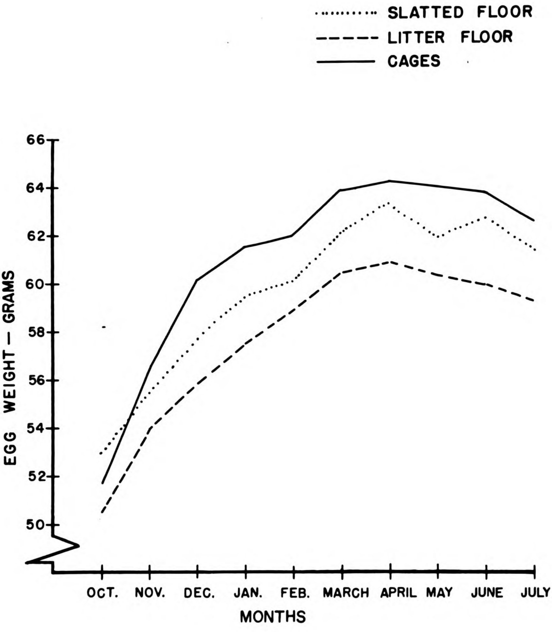

FIGURE 7. AVERAGE EGG SIZE (GRAMS) AS MEASURED 3-CONSECUTIVE DAYS MONTHLY — 1960 – 1961.

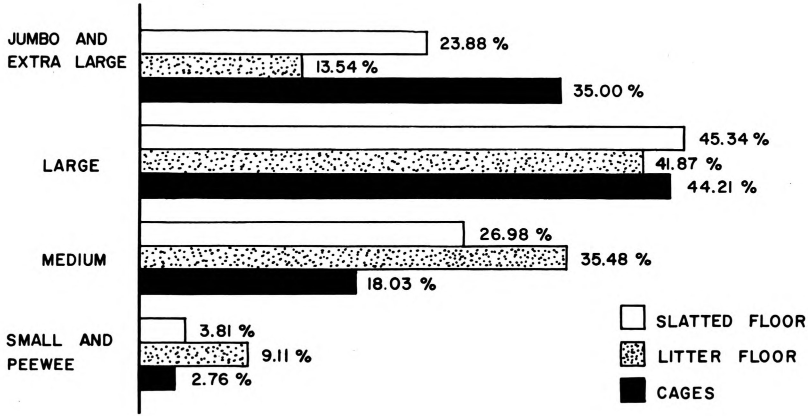

FIGURE 8. COMPOSITE DISTRIBUTION OF EGG SIZE — 1960-1961.

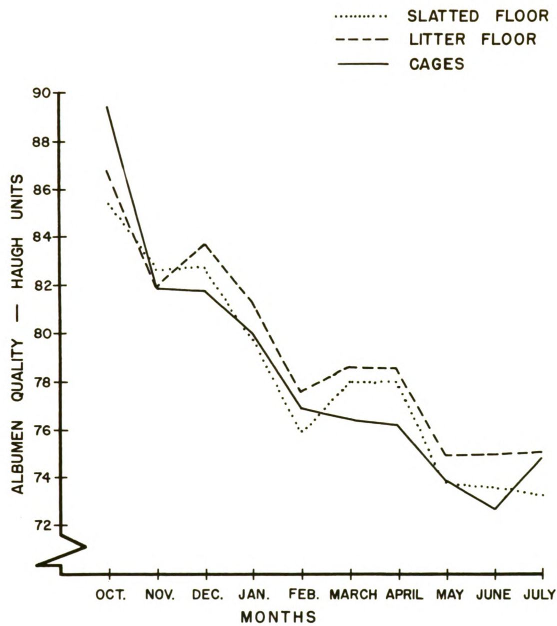

FIGURE 9. AVERAGE ALBUMEN QUALITY (HAUGH UNITS) AS MEASURED 3-CONSECUTIVE DAYS MONTHLY — 1960-1961.

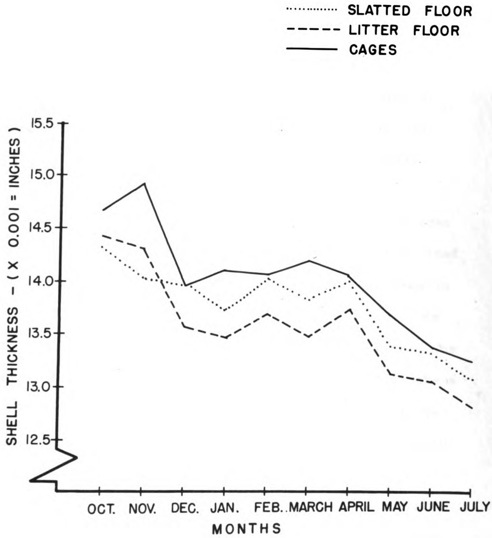

FIGURE 10. AVERAGE SHELL THICKNESS AS MEASURED 3-CONSECUTIVE DAYS MONTHLY—1960-1961.

DISCUSSION

Total egg production was greater for birds confined to a litter floor and in cages than it was for pullets maintained on a completely slatted floor. The birds on the slatted floor trailed the other two groups in total number of eggs laid both years of this study. These variations were statistically significant.

Lower egg production from the slatted-floor birds can not be attributed to such factors as strain of birds, feed or temperature, because these conditions were the same in all pens. Other reasons would have to be explored. One possible theory would be social order or competition. The existence of social organization within flocks of chickens has been known since Schjelderup-Ebbe's (1922) investigations. More recently Guhl (1953) has reviewed thoroughly the available knowledge concerning social behavior in the fowl. He found significant correlations between social rank and egg production, and also between number of eggs produced and the frequency of feeding. In earlier work, Guhl and Allee (1944) observed that individuals in socially unstable flocks laid fewer eggs than their fellows did as members of socially organized control flocks. Guhl (1957) also reported that management practices which favor the development of a high level of toleration within the flock result in greater production.

Indications that a stress factor or social unbalance was prevalent among the slatted-floor birds is evidenced by the large number of floor eggs and death losses in this pen. This problem was especially noticeable the first year when the slatted-floor group laid 16.54 percent floor eggs. Godfrey and Butler (1959) also reported a larger number of floor eggs from slatted-floor birds than from birds on a litter floor.

Mortality was greater both years in the slatted-floor pen than it was in cages or on the litter floor. This in itself could not be considered a stress factor, but rather the result of greater stress. It was during the second year of this experiment that birds in the three pens were affected in varying degrees with coryza. This was most evident in the litter floor and slatted-floor pens from about December 1, 1960 to February 15, 1961. The cage birds did not appear to be bothered as much as the other two groups, nor did their egg production suffer as drastically. A considerable drop in production was noticed in also reported that management practices which favor the development of a high level of toleration within the flock result in greater production.

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A somewhat similar problem was reported by Lowry et al. (1956) when Newcastle disease broke out in one of their experiments in which cage birds were being compared with birds on a litter floor. The disease resulted in the floor birds going out of production at once followed by a return to normal production in about three weeks. The disease spread through the cage birds more slowly, and these birds never dropped completely out of production.

Floor space was reduced from 3.87 to 2.32 square feet per bird from the first to the second year of this experiment in the litter floor and slatted-floor pens. This may account for the slight reduction in rate of lay between the two years. Most researchers have found a small drop in production when floor space has been reduced within these limits. Fox and Clayton (1960), for example, reported a drop of only one-percent production when floor area was reduced from 3 to 2 square feet per bird. Nordskog (1959) also found that egg production dropped one-percent when floor space per bird was reduced from 3.5 to 2.5 square feet.

The birds in single or individual cages out-performed those in double or two-bird cages during the 1960-1961 the two floor pens during this period (Figure 4). No treatment or medication was given to any of the birds.

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The birds in single or individual cages out-performed those in double or two-bird cages during the 1960-1961 laying season. Single cages were also found to be superior to multiple cage units by U.S.D.A. researchers (1960). In their tests, they compared production in both 8 and 10-inch wide single-bird cages and 12-inch cages with two birds per unit. The pullets confined to an 8-inch cage produced 231 eggs per bird while those in 10-inch wide units laid 232 eggs during a 336-day laying period. In the two-bird units each pullet laid an average of 226 eggs. Hill et al. (1957) reported identical production in 8 and 10-inch wide individual cages.

The same commercial strain of chickens was used in both of these experiments in all pens. Controversy exists whether certain breeds and strains will do better in cages than others. For example, Gowe (1956) and Francis (1957) suggest that some strains within the Leghorn breed can adapt to laying battery cages better than others. On the other hand, King (1952) reports from his work in Alabama that any breed or strain that will do well in the production of eggs under litter-floor management will also do well when kept in cages. In England, Blount (1951) is of the opinion that Rhode Island Reds are superior in laying batteries to other breeds and that "light breeds as a whole are not well suited to hen batteries."

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Mortality during the 1960-1961 laying season was higher in two-bird cages than in the single-bird units. Similar results were reported by the U.S.D.A. (1960) in which they found deaths among chickens in two-bird units to be 16 percent compared with 12 and 13 percent respectively for single birds in 8 and 10-inch wide cages. Hill et al. (1957) found mortality in 8-inch individual cages to be two percent higher than in 10-inch single cages. Some researchers have found cage fatigue to be a problem among cage layers (Couch, 1955, and Francis, 1957). In these two studies, however, not a single case of so-called cage fatigue was observed.

Temperatures in the various pens were slightly higher during the 1960-1961 laying season than they were during the 1959-1960 period. This was probably due to the additional 80 birds in each pen during the second season.

The daily temperature in these three pens approached the summer high much more closely than the winter low. The lowest recorded outside temperature during the first experiment was on March 11, 1960 when a temperature of -5° F. was recorded. The lowest temperature in each of the three pens on that date was 45° F., 46° F. and 47° F. respectively for the litter floor, slatted floor and cage room. That same laying season, the highest recorded

outside temperature was 90° F. on July 22, 1960. High temperatures that day in each pen were 89° F. in the litter-floor pen, 88° F. in the slatted-floor pen, and 84° F. in the cage room. All outside temperatures were those reported by the U. S. Weather Bureau in Lansing.

During the second laying season the lowest outside temperature was -10° F. on January 25 and February 2, 1961. The inside low on February 2 was 49° F. in the slatted-floor pen. Low readings in the other pens on that date were 51° F. and 53° F. for the litter floor and cage rooms, respectively. The highest official outside temperature during the second season was 93° F. on September 8, 1960. Both the slatted floor and litter-floor pens recorded a high of 93° F. on that day, and the temperature reached 90° F. in the cage room. Average monthly outside temperatures for both years of this study as reported by the weather station at Lansing are shown in Table 41.

The optimum temperatures for egg production have been reported by a number of workers. Warren _et al_. (1950) found that a constant temperature of 65° F. with uniform humidity and day length was more favorable for egg production than was the uncontrolled environment. Wilson _et al_. (1957) reported that within the range of 48° F.

to 85° F. egg production was not reduced by variations in temperature. Single Comb White Leghorns in individual cages were used in the latter study. From the standpoint of economy in production, Ota (1956) has suggested that a house temperature of 45° F. seems preferable during the coldest winter months.

Heavier body weights of the cage confined pullets at the end of both experiments seem to be substantiated by other research workers. Bailey et al. (1959), Timmons et al. (1961) and Morgan (1954) all found cage layers to be heavier at the end of the laying period than their companions on the floor. Some of the commonly cited reasons for this difference are the continuous access to feed, less competition and reduced activity.

Feed consumption, measured in pounds required to produce a dozen eggs, was the same for birds on litter and in cages during the first year, but the second year feed consumption per dozen eggs favored the litter-floor birds. This latter observation was rather unusual in view of the fact that more efficient feed conversion per dozen eggs for cage layers has been reported by Bailey et al. (1959), Miller et al. (1959), Robertson (1956), Hill et al. (1957), Berry (1946) and Morgan (1954). Several explanations are

plausible. First, the pounds of feed per dozen eggs ratio does not take into account egg size. In both experiments, the cage birds produced eggs which were significantly larger than those laid by the birds on litter floor. Secondly, the cage layers were significantly heavier than the birds on the floor and it has been reported that larger chickens require more feed to produce the same number of eggs as lighter birds (Schaible, 1957).

There is no biological explanation as to why the cage birds laid significantly larger eggs than their companions on the floor during both years of this study. However, it might be postulated that egg size is associated with bird activity and the cage birds were decidedly less active than those on the litter floor and slatted floor. In the literature, larger eggs in cages than on litter floor have been reported by many--Lowry _et al_. (1956), Bailey _et al_. (1959), Froning and Funk (1958), Funk _et al_. (1958), Sanford (1959) and Mellor _et al_. (1957).

During the first year of this study, egg size dropped sharply among all groups on April 20 (Figure 2). There may be many possible causes for this, but the most noticeable one seems to be temperature. According to official plausible. First, the pounds of feed per dozen eggs ratio does not take into account egg size. In both experiments, the cage birds produced eggs which were significantly larger than th[illegible] litter floor. Secondly, the cage layers were significantly heavier than the [illegible] and it has been reported that [illegible] to produce the same [illegible] (Schaible, 1957).

There is no biological explanation [illegible] the cage birds laid significantly larger eggs than their companions on the floor during both years of this study. However, it might be postulated that egg size is associated with bird activity and the cage birds were apparently less active than those on the litter floor and slatted floor. In the literature, larger eggs in cages than on litter floor have been reported by many--Lowry *et al.* (1956), Bailey *et al.* (1959), Froning and Funk (1958), Funk *et al.* (1958), Sanford (1959) and Mellor *et al.* (1959).

During the first year of this study, egg size dropped sharply among all groups on April 30 (Figure 2). There may be many possible causes for this, but the most noticeable one seems to be temperature. According to official

U.S. Weather Bureau data, the average daily temperatures in Lansing varied from eleven degrees below normal to eighteen degrees above normal between April 6 and 20 (U.S. Department of Commerce, 1960). On April 10, for example, a low of 21° F. was recorded and on April 13 a high of 78° F. reported. The pen temperatures during this same period varied from 46° F. to 76° F.

Although Haugh unit scores were higher in the litter-floor pens during both years of this study, a statistical difference was observed only in the first year. There is no biological reason to explain this difference in albumen quality (Haugh scores) between pens. However, caution should be exercised in comparing the Haugh unit scores as, on the average, the eggs in all pens graded AA according to U.S.D.A. Egg Quality Standards.

Shells were observed to be significantly thicker for the cage birds than for either of the other two groups. There does not appear to be any ready explanation for this even though Timmons _et al_. (1961) and Funk _et al_. (1958) both found shells on cage eggs to be thicker than those produced by birds on litter floor. It might be postulated that birds in cages do not have access to their droppings or litter material. As a result, they are relatively free from any

contaminated material that might interfer with calcium assimilation in the bowel. Another theory that might be advanced is that this difference may have been due to membrane thickness as both the shell and shell membrane were measured. In this case, the difference would be attributed to protein assimilation rather than calcium.

More blood and meat spots were observed in the eggs laid by cage birds than by either of the other two groups. No biological reason is evident for this although similar results have been observed by a number of researchers, including Funk _et al_. (1958), Lowry _et al_. (1956) and Jeffery (1945).

The equipment depreciation cost per dozen eggs produced was figured during the 1959-1960 laying season. This cost amounted to 2.4 cents per dozen for eggs produced on the slatted floor and 2.0 and 1.7 cents per dozen, respectively, for those laid by the birds on the litter floor and in single cages. A complete breakdown of these costs is shown in Appendix V.

The purpose of this study was to test the following null hypotheses:

1. There are no significant differences in egg production between pullets housed in cages, on a slatted

contaminated material that might [illegible] assimilation in the bowel. [illegible] advanced is that this difference [illegible] membrane thickness as [illegible] were measured. In [illegible] attributed to [illegible]

More blood and [illegible] laid by cage birds [illegible] No biological reas[illegible] results have been [illegible] including Funk et al. [illegible] Jeffery (1945).

The equipment [illegible] duced was figured [illegible] This cost amounted [illegible] duced on the slatted [illegible] dozen, respectively [illegible] litter floor and in single cages. [illegible] of these costs is shown in Appendix [illegible]

The purpose of this [illegible] was to [illegible] the following null hypotheses:

1. There are no significant differences in egg production between pullets housed in cages, on a slatted

floor and on a litter floor.

During both studies, the cage layers produced significantly more eggs than the birds on the slatted floor. Also, the pullets on the litter floor laid significantly more eggs during the first experiment than those birds on the slatted floor. Therefore, this null hypothesis is rejected.

2. There are no significant differences in egg size distribution between the three systems of laying house management.

The birds in single cages laid significantly heavier eggs both years than either the slatted floor or litter-floor birds. During the second experiment, the birds on the slatted floor produced significantly heavier eggs than those laid by the litter-floor group. Therefore, this null hypothesis is rejected.

3. There are no significant differences in the physical condition of the birds housed in cages, on a slatted floor and on a litter floor.

The cage layers were significantly heavier at the end of both tests than either of the other two groups of birds. Therefore, this null hypothesis is rejected.

4. There are no significant differences between the egg quality factors of shell thickness and interior quality

between the various systems of management.

Significantly thicker shells were found on the eggs produced by cage layers both years than by those laid by the slatted floor and litter-floor birds. During the first year of this work, interior egg quality, measured in Haugh units, was significantly better in the eggs produced by the litter-floor birds than by either of the other two groups. Therefore, this null hypothesis is rejected.

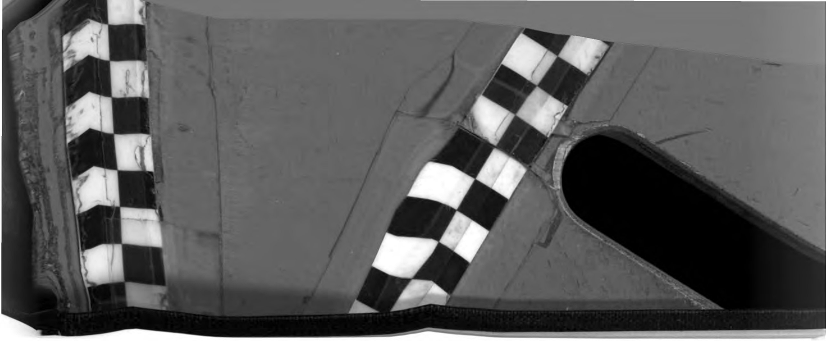

Table 41. Average monthly temperatures in degrees Fahrenheit as recorded at the Lansing, Michigan Weather Station

1959-1960		1960-1961	
Dates	Monthly average (F.)	Dates	Monthly average (F.)
		September, 1960	64.0
October, 1959	48.7	October	50.0
November	32.7	November	41.2
December	32.7	December	22.8
January, 1960	26.0	January, 1961	19.9
February	23.0	February	27.7
March	22.0	March	37.0
April	48.7	April	41.8
May	56.4	May	52.9
June	63.8	June	64.8
July	67.8	July	69.8

Source: U. S. Department of Commerce, Weather Bureau.

CONCLUSIONS, RECOMMENDATIONS AND SUGGESTIONS FOR FUTURE STUDIES

Two studies were conducted using the same commercial strain of egg producing chickens in cages, on a slatted floor and on a litter floor. A total of 1069 birds were used in these experiments with 360 pullets, in groups of 120 each, being used during the 1959-1960 trial, and 600, in groups of 200 each, plus 109 replacements, used during the 1960-1961 laying season.

The following conclusions are based on the material presented herein, and are applicable only to the experimental fowl used and under the experimental conditions which prevailed at the time of this study.

1. During these two studies, the cage layers, including both single and two-bird units, produced a total of 62,151 eggs; litter floor birds laid 61,940 eggs, and; the slatted floor group produced 56,239 eggs. There were no statistically significant differences in egg production between birds housed in single cages or on the litter floor. Egg production from layers in single cages was significantly better, at the one-percent level, than from birds on the slatted floor during both studies. In addition, the birds on the

CONCLUSIONS, RECOMMENDATIONS AND SUGGESTIONS FOR FUTURE STUDY

Two studies were con[illegible] strain of egg production [illegible] floor and on a litter [illegible] used in these exp[illegible] 120 each, being [illegible] in groups of 200 [illegible] the 1960-1961 la[illegible]

The following [illegible] presented herein, [illegible] mental fowl used [illegible] which prevailed at [illegible]

1. During these [illegible] including both single and [illegible] 151 eggs; litter floor [illegible] slatted floor group produced [illegible] statistically significant differences [illegible] birds housed in single cages [illegible] egg production from layers in single cages was significantly better at the one-percent level than from those on the slatted floor during both studies. In addition, the birds on the

litter floor laid significantly more eggs than those pullets on the slatted floor during the first experiment.

2. Both years, the birds in single cages laid significantly larger eggs than those produced by either the slatted floor or litter-floor pullets. During the second trial, the slatted-floor birds laid significantly larger eggs than the litter-floor birds.

3. The birds confined to cages during both of these trials were significantly heavier at the end of the laying season than either of the other two groups of pullets.

4. The greatest number of deaths occurred among the slatted-floor birds. Only during the second year, however, was a significant difference observed between any of the pens. At that time, the number of death losses among the slatted-floor pullets was significantly greater than for the cage birds.

5. During the first year of this study, albumen quality, measured in Haugh units, was significantly higher in the eggs produced by litter-floor birds than it was in those eggs laid by the slatted floor and cage birds. No differences in Haugh unit scores were evident among any of the groups during the second year of this work.

litter floor laid significantly more eggs than those pullets on the slatted floor during the first egg season.

2. Both years, the birds in single cages laid signifi- cantly larger eggs than those [illegible] slatted floor or litter-floor [illegible] slatted-floor birds laid [illegible] litter-floor birds.

3. The birds [illegible] trials were significantly [illegible] season than either [illegible]

4. The greatest [illegible] among the slatted-floor birds. [illegible] however, was a significant difference [illegible] of the pens. At that time the [illegible] among the slatted-floor pullets was [illegible] than for the cage birds.

5. During the first year of [illegible] study, albumen quality measured in Haugh units, was [illegible] higher in the eggs produced by litter-floor [illegible] than it was in those eggs laid by the slatted floor and cage birds. No dif- ferences in Haugh unit scores were evident among any of the groups during the second year of this work.

6. Both cage and slatted-floor birds produced eggs with significantly thicker shells than litter-floor birds during the first year. The second year, eggs produced by birds in individual cages had significantly thicker shells than either of the other two groups.

7. Blood and meat spots were observed in broken-out eggs only during the second year of this work. No significant differences were observed between any of the pens when both blood and meat spots were considered together. However, when only blood spots were considered, a significant difference, at the five-percent level, favored the slatted-floor birds over the birds in single cages.

Recommendations

Based on the afore-mentioned conclusions, the following recommendations are made to poultrymen considering these three methods of laying house management.

1. In general, the pullets housed in individual cages performed well relative to egg production, low mortality, heavy body weight at the end of the laying season, large egg size and shell thickness.

2. The litter floor birds, on the average, excelled in egg production, feed conversion per dozen eggs produced,

6. Both cage and slatted-floor birds produced eggs with significantly thicker shells than litter-floor birds during the first year. The second year, eggs produced by birds in individual cages had significantly thicker shells than either of the other two groups.

7. Blood and meat spots [illegible] eggs only during the [illegible] ficant differences [illegible] when both blood and meat spots [illegible] However, when only [illegible] a signi- ficant difference, [illegible] favored the slatted-floor birds over [illegible] eggs [illegible].

RECOMMENDATIONS

Based on the afore-mentioned conclusions, the follow- ing recommendations are made [illegible] considering these three methods of laying house management.

1. In general, the pullets housed in individual cages performed well relative to egg production, low mortality, heavy body weight at the end of the laying season, large egg size and shell thickness.

2. The litter floor birds, on the average, excelled in egg production, feed conversion per dozen eggs produced

albumen quality (Haugh scores) and low mortality.

3. Generally, the slatted-floor pullets were found to perform satisfactory relative to shell thickness and low incidences of blood and meat spots. However, this type of laying house management cannot be recommended when compared with cages and a litter floor.

4. The system of two birds per eight-inch wide cages worked satisfactorily and can be recommended based on the results of this study.

5. The daily temperatures in these well insulated and ventilated pans were influenced more by summer heat than they were by the cold in the winter. This affords a distinct advantage to poultrymen in northern climates, such as Michigan, because artificial cooling is a costly proposition.

6. Eggs gathered at regular intervals have about the same interior quality (Haugh unit scores) regardless of the type of laying house management.

7. The debeaking of pullets prior to placing them in the laying house is highly desirable as it reduces the amount of cannibalism in a flock.

8. No matter which system of management is selected, reliable stock must be used in order to obtain satisfactory results.

9. The equipment depreciation cost per dozen eggs produced is approximately the same for the three systems of laying house management.

Suggestions for Future Studies

Some suggestions or problems which might be resolved in future studies of this nature include:

1. Additional experimentation is needed comparing one and two-bird cages, of various sizes, and also colony cages to the conventional litter-floor type of management.

2. Egg production was not affected appreciably by the reduction from 3.87 to 2.32 square feet per bird in the two floor pens between the first and second year. In subsequent studies, the floor space per bird could be reduced even more to determine the effects of floor space on rate of lay by birds on a slatted floor and litter floor.

3. Feed efficiency per dozen eggs produced appears to favor the litter-floor birds over cage layers because the former group required 4.69 pounds of feed per dozen eggs produced and the latter 4.98 pounds during the second year of this work. Both required identical amounts of feed per dozen eggs produced during the first year. Such figures can be misleading, however, as they do not take

9. The equipment depreciation cost per dozen eggs produced is approximately the same for the three systems of laying house management.

Suggestions for [illegible]

Some suggestions [illegible] in future studies of [illegible]

1. Additional [illegible] and two-bird cages [illegible] to the conventional [illegible]

2. Egg production [illegible] reduction from [illegible] per bird in the two floor pens [illegible] sequent studies, the [illegible] should be reduced even more to determine the [illegible] floor [illegible] on rate of lay by birds on a slatted [illegible] floor.

3. Feed efficiency per dozen eggs produced appears to favor the litter-floor birds over cage layers because the former group required 4.6[illegible] pounds of feed per dozen eggs produced and the latter [illegible] pounds during the second year of this work. Both required identical amounts of feed per dozen eggs produced during the first year. Such figures can be misleading, however, as they do not take

into account the size of the eggs produced. In future studies, it would be desirable to compute feed conversion on pounds of eggs produced as this figure would be more accurate.

4. The eggs produced by cage layers were found to have significantly thicker shells than those produced by either of the other two groups of birds. Additional work is needed to determine the cause or causes of this phenomenon.

5. Further studies are needed comparing birds in cages, on a slatted floor and on a litter floor from the beginning of the rearing period through their laying cycle. This would provide information relative to the rearing efficiencies of these various management methods in addition to laying house performance.

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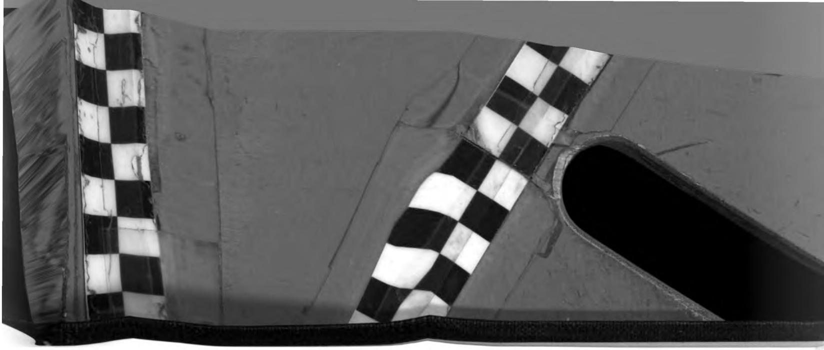

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APPENDIX

Appendix 1. Chemical analysis of pelleted all-mash laying mash (Farm Bureau)[1]

Date	Calcium	Crude fiber	Fat	H_2O	Protein	Phos-phorus
October 10, 1959	2.34	4.26	3.81	10.01	17.50	0.856
November 14	2.57	3.84	6.06	8.43	19.38	0.877
December 6	3.13	4.17	4.51	9.02	24.13	1.33
January 11, 1960	2.50	3.69	3.90	7.64	17.81	1.09
March 31	2.33	3.93	3.65	11.39	22.25	0.854
August 24	2.53	4.75	8.12	11.42	19.56	0.822
September 4	1.53	3.98	3.47	9.45	26.38	1.03
October 11	3.62	4.06	3.77	8.33	23.19	1.11
October 31	3.42	3.84	8.76	9.01	23.13	1.06
November 8	2.63	3.67	3.77	8.46	18.31	0.969
December 1	2.85	3.94	3.72	7.34	22.75	1.09
December 12	3.29	4.28	3.99	7.00	16.81	1.07
December 15	3.12	3.88	4.19	7.65	15.81	1.10
December 27	2.29	3.20	2.79	7.55	29.38	0.871
January 26, 1961	2.30	2.9	3.0	8.4	27.3	0.80
February 20	2.96	3.5	3.6	10.8	17.6	0.74
March 8	2.94	3.5	3.5	8.9	18.3	0.80
March 28	3.14	3.5	3.3	7.0	19.1	0.80
April 11	3.00	3.2	1.7	9.4	18.2	0.68
May 8	2.86	3.1	3.4	9.2	17.9	0.74
June 21	2.76	3.3	3.6	9.3	18.6	0.78
July 3	2.68	2.6	3.7	8.8	17.1	0.80

[1]The chemical analysis of all feed samples were made by and through cooperation of the chemical laboratory of the Michigan Department of Agriculture and the Agricultural Chemistry Department at Michigan State University.

Appendix 2. Analysis of variance and studentized-range test on egg size as computed on alternate months during the 1960-1961 laying season

OCTOBER, 1960:

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	1107.36	2	553.68	25.19**
Error	16989.95	773	21.98	
Total	18097.31	775		

**Significant at one-percent level

Studentized-range test[2]

50.55	51.79	53.07
Litter floor	Cages	Slatted floor

One-percent level:

Slatted floor > cages, litter floor

Cages > litter floor

Appendix 2. Continued

DECEMBER:

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	1319.31	2	659.66	43.60**
Error	10137.22	670	15.13	
Total	11456.53	672		

**Significant at one-percent level

Studentized-range test[2]

55.93	57.79	60.20
Litter floor	Slatted floor	Cages

One-percent level:

Cages > slatted floor, litter floor

Slatted floor > litter floor

Appendix 2. Continued

FEBRUARY, 1961:

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	621.81	2	310.91	17.48**
Error	9911.67	557	17.79	
Total	10533.48	559		

**Significant at one-percent level

Studentized-range test[2]

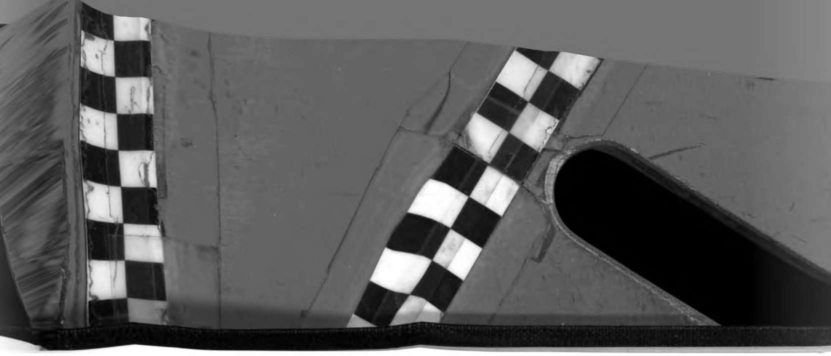
58.95	60.10	62.06
Litter floor	Slatted floor	Cages

Five-percent level:

Slatted floor > litter floor

One-percent level:

Cages > slatted floor, litter floor



Appendix 2. Continued

APRIL:

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	1203.74	2	601.87	27.52**
Error	14978.00	685	21.87	
Total	16181.74	687		

**Significant at one-percent level

<u>Studentized-range test</u>[2]

60.96	63.36	64.35
Litter floor	Slatted floor	Cages

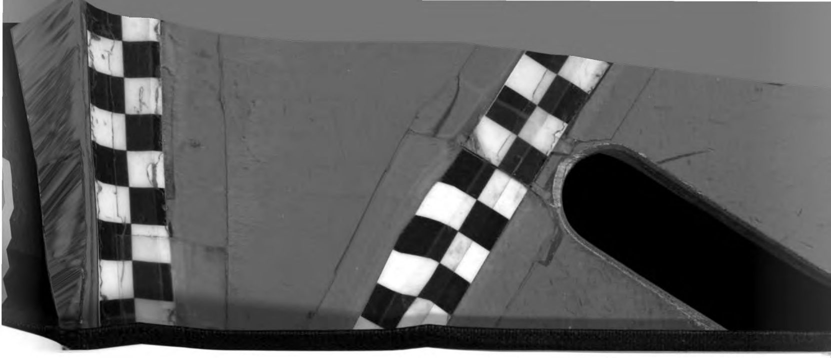
Five-percent level:

Cages > slatted floor

One-percent level:

Cages > litter floor

Slatted floor > litter floor



Appendix 2. Continued

JUNE:

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	1349.46	2	674.73	27.42**
Error	15107.80	614	24.61	
Total	16457.26	616		

**Significant at one-percent level

Studentized-range test[2]

60.03	62.72	63.85
Litter floor	Slatted floor	Cages

Five-percent level:

Cages > slatted floor

One-percent level:

Cages > litter floor

Slatted floor > litter floor

[2]Any two means not overscored by the same line are significantly different, and any two lots overscored by the same line are not significantly different.

Appendix 3. Analysis of variance and studentized-range test on albumen quality (Haugh scores) as computed on alternate months during the 1960-1961 laying season

OCTOBER, 1960:

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	1016.35	2	508.18	10.86**
Error	36157.62	773	46.78	
Total	37173.97	775		

**Significant at one-percent level

Studentized-range test[3]

85.43	86.80	89.44
Slatted floor	Litter floor	Cages

Five-percent level:

Litter floor > slatted floor

One-percent level:

Cages > litter floor, slatted floor

Appendix 3. Continued

DECEMBER:

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	303.76	2	151.88	3.40*
Error	29885.42	670	44.61	
Total	30189.18	672		

*Significant at five-percent level

Studentized-range test[3]

81.73 82.73 83.71

Cages — Slatted floor — Litter floor

One-percent level:

Litter floor > cages

Appendix 3. Continued

FEBRUARY: 1961

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	318.95	2	159.48	2.27 N.S.
Error	39129.11	557	70.25	
Total	39448.06	559		

APRIL:

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	345.22	2	172.61	2.98 N.S.
Error	39704.57	685	57.96	
Total	40049.79	687		

JUNE:

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	389.31	2	194.66	2.96 N.S.
Error	40404.41	614	65.81	
Total	40793.72	616		

[3] Any two means not overscored by the same line are significantly different, and any two lots overscored by the same line are not significantly different.

Appendix 4. Analysis of variance and studentized-range test on shell thickness as computed on alternate months during the 1960-1961 laying season

OCTOBER, 1960:

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	8.17	2	4.09	3.03*
Error	1047.05	773	1.35	
Total	1055.22	775		

*Significant at five-percent level

Studentized-range test[4]

14.33	14.43	14.69
Slatted floor	Litter floor	Cages

Five-percent level:

Cages > litter floor

One-percent level:

Cages > slatted floor

Appendix 4. Continued

DECEMBER:

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	26.59	2	13.30	7.23**
Error	1233.86	670	1.84	
Total	1260.45	672		

**Significant at one-percent level

Studentized-range test[4]

13.59	13.98	13.99
Litter floor	Cages	Slatted floor

One-percent level:

Slatted floor, cages > litter floor

Appendix 4. Continued

FEBRUARY: 1961

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	17.74	2	8.87	6.77**
Error	730.45	557	1.31	
Total	748.19	559		

**Significant at one-percent level

Studentized-range test[4]

13.70	14.04	14.09
Litter floor	Slatted floor	Cage

One-percent level:

Slatted floor, cages > litter floor

Appendix 4. Continued

APRIL:

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	12.36	2	6.18	4.38*
Error	964.41	685	1.41	
Total	976.77	687		

*Significant at five-percent level

Studentized-range test[4]

13.76	$\overline{14.02 \qquad 14.08}$	
Litter floor	Slatted floor	Cages

Five-percent level:

Slatted floor > litter floor

One-percent level:

Cages > litter floor

Appendix 4. Continued

JUNE:

Source of variation	S.S.	D.F.	M.S.	F ratio
Pens	12.00	2	6.00	4.76**
Error	776.32	614	1.26	
Total	788.32	616		

**Significant at one-percent level

Studentized-range test[4]

13.08	$\overline{13.34 \quad 13.40}$	
Litter floor	Slatted floor	Cages

Five-percent level:

Slatted floor > litter floor

One-percent level:

Cages > litter floor

[4] Any two means not overscored by the same line are significantly different, and any two lots overscored by the same line are not significantly different.

Appendix 5. Equipment depreciation cost per dozen eggs produced during the 1959-1960 laying season

Slatted Floor:

1.	Slats and materials - $125.73 @ 5 yrs.	= $25.15
2.	Waterers - $8.73 @ 8 yrs.	= 1.09
3.	Feeders - $53.20 @ 8 yrs.	= 6.65
4.	Nests - $36.00 @ 8 yrs.	= 4.50
	TOTAL	$37.39
	Cost per dozen (1571.2 doz.)	= $0.024

Litter Floor:

1.	Litter - 22 bales @ $25 per ton	= $19.25
2.	Waterers - $8.73 @ 8 yrs.	= 1.09
3.	Feeders - $53.20 @ 8 yrs.	= 6.65
4.	Nests - $36.00 @ 8 yrs.	= 4.50
5.	Roosts - $33.40 @ 8 yrs.	= 4.18
	TOTAL	$35.67
	Cost per dozen (1792.2 doz.)	= $0.020

Cages:

1.	Cages and materials - $247.20 @ 8 yrs.	= $30.90
	TOTAL	$30.90
	Cost per dozen (1780.8 doz.)	= $0.017

ROOM USE ONLY