THE EFFECT OF POULTRY HOUSING SYSTEMS ON EGG PRODUCTION AND EGG QUALITY

SILAS MOZES MUROTHO

A THESIS SUBMITTED IN PARTIAL FULFILLMENT FOR THE DEGREE OF MASTER OF SCIENCE IN ANIMAL PRODUCTION IN THE FACULTY OF AGRICULTURE UNIVERSITY OF NAIROBI

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

SILAS MOZES MUROTHO

This thesis has been submitted for examination with our approval as University Supervisors.

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Dedicated to my wife Evelyn, and my daughters

Aileen and Bertha.

ABSTRACT

A study lasting six months was conducted to determine the effect of housing systems on poultry egg production and egg quality. It was found necessary to embark on the subject because often poultry producers have a preference for one housing system or the other without sufficient experimental support.

The design was completely randomised with three treatments, replicated four times. The treatments were deep litter, wire floor and cage systems. 216 brown egg laying type of birds "Ross Browns" were used at 72 layers per treatment. They were fed a commercial layers mash *ad libitum*.

Egg production, egg size, internal egg spots, egg cleanliness, egg shell thickness, feed efficiency, live-weight gains and mortality were recorded during the study. Collection, weighing, candling, and grading of eggs were done everyday. Measurement of egg shell thickness was done once a week from the 11th to the 16th week of the study period. Weighing of the birds was done at the beginning and end of the experimental period.

Results showed that caged birds were superior ($P < 0.05$) to those in other systems in egg production, egg size and feed efficiency, and only to birds on wire

floor system in liveweight gains. Hens on deep litter system demonstrated a significant superiority ($P < 0.05$) to those in other systems in production of thicker shelled eggs and the lowest percentage of eggs with internal spots. Birds on the wire floor system produced the cleanest ($P < 0.05$) eggs. Differences in liveweight gains between layers on deep litter and those on wire floor systems were not significant ($P > 0.05$).

It was concluded that the cage system could be the most favoured. However it could successfully be substituted by the deep litter system. The wire floor system could not be recommended as it demonstrated inferiority in almost all the characters measured. It was also concluded that with proper management housing systems have no effect on mortality of birds.

1.0 INTRODUCTION

Poultry products are among the most abundant sources of animal protein for all classes of people in Africa. In terms of food conversion poultry eggs rank with cow's milk in being the most economically produced animal protein, and in terms of biological value poultry products rank highest (Leitch and Godden, 1941).

In the tropics poultry are kept either for the supply of animal protein to the family in rural areas or for the supply of protein to the urban workers and other concentrations of money-earning communities. Thus the need to increase the supply of poultry products to cater for the ever expanding populations is much more felt now than ever before.

In order to increase production of poultry and their products elaborate methods of management must be undertaken including the provision of well ventilated clean housing and balanced diets. The birds should be provided with a comfortable environment so that they achieve their maximum genetic potential for production because, with the right kind of stock and suitable housing and food supply, production of eggs is likely to be in direct proportion to the comfort of the birds.

Experiments on different types of poultry houses started around 1900 and continued for more than 25 years till the cumulative practical data gradually resulted into a few common recommendations on the type of housing systems poultry producers should adopt. Thus there are now three intensive systems of poultry housing namely: deep litter, wire floor, and cage systems (Card and Nesheim, 1966).

Currently commercial poultry producers retain a preference for one housing system or the other without sufficient experimental support. Reports on the effect of housing systems on poultry production have been contradictory. Ensminger (1971) reported that birds on deep litter feel comfortable but there is usually a high incidence of bacterial diseases. There is better control of diseases in the wire floor system but the birds appear nervous. In cages, birds have a high feed conversion efficiency but they suffer from fly infestation because it is difficult to control flies in this system.

With respect to egg production Wegner (1970), Mel'nick and Poplavskii (1974), Sharma (1974), and Oluyemi and Roberts (1975) reported that caged birds always performed better than those on deep litter. While Kosin (1962), Querner and Tuller (1966), Christmas et al., (1974), and Bhagwat and Craig (1975) found that birds on deep litter produced more eggs than those in cages. However De Portal (1966), Weinreich and Willeke (1972) and Thomason et al., (1972) reported no significant differences in egg production between caged birds and those on deep litter system. Most of the previous researchers, for unknown reasons, never included the wire floor system in their studies.

1.1 Objective of the study

The present study was designed to compare the effect of the three housing systems, namely: deep litter, wire floor and the cage system, on the performance of laying birds with respect to a number of production characters: the main ones being egg laying intensity, general egg quality, feed conversion efficiency, liveweight gains and mortality. It is hoped that results obtained will help in providing further information on the suitability of the three different housing systems in a tropical situation.

2.0 LITERATURE REVIEW

Housing of poultry for egg or meat production is important as a means of keeping environmental conditions under the control of the operator. It also helps to ensure maximum use of feed energy for productive purposes rather than overcoming the effects of unfavourable weather.

Production goals in egg production are:

a) Production of at least 240 eggs per hen per year.

b) Feed conversion of less than 2.04 kg per dozen eggs.

c) A laying house mortality of less than 10 percent per year.

d) Production of 95 percent or more marketable eggs.

e) Production of 75 percent or more large grade eggs.

f) Production of on farm egg breakage of less than 2 percent.

These goals are usually affected by the housing systems adopted (Ensminger, 1971). Research has shown that egg production rate, egg size, egg shell thickness, blood spots in eggs, feed efficiency, liveweight gains, and mortality are all affected by housing systems.

2.1 Egg production rate

Egg production refers to the total number of eggs produced irrespective of quality. The effect of housing systems on egg production has received wide attention in recent years. Alvier (1941), using sixty ducks in single cages and sixty on deep litter, over a period of one year, found that caged birds laid more eggs than those on deep litter (171 eggs versus 117 eggs). He concluded that the difference in egg production between the two management systems was that ducks on deep litter system wasted much energy in activities like fighting and moving about.

Comparing the performance of layers in cage and deep litter systems in an experiment lasting one year, Bailey et al., (1958) reported that egg production was higher by 1.3 percent in cages than on deep litter. Earlier, Quisenberry (1954) (cited by Miller and Quisenberry, 1958) demonstrated that caged birds produced on average, 7.35 percent more eggs over those produced by birds on deep litter.

In a study lasting over a period of one year on the effect of housing systems on egg production Keen and Mowbray, (1969) concluded that rate of hen-housed egg production between deep litter housed hens and caged ones differed by 1.29 percent in favour of caged birds. Similar results were obtained by Kolodziej et al., (1970) who observed that egg production was 2.9 percent higher for caged pullets than those on deep litter.

Working with Black Australorp hens for 48 weeks Spurling and Spurling (1971) reported that egg production was higher in caged birds than that of birds on deep litter or restricted range. Also results from five years of laying tests showed that caged hens were significantly superior to those on deep litter in egg production (Hagger et al., 1974). Kaparkaleis et al., (1974) showed that average egg production per bird per year was 256.6 in cages and 238.7 on deep litter. The superiority of the cage system over the deep litter was also proved by experimental results reported by Oluyemi and Roberts (1975).

Contrary to the above findings Gowe (1955, 1956) studying the performance of seven White Leghorn strains as affected by housing systems, found that on average the birds laid thirty eggs per bird less in cages than in deep litter pens. Lowry et al., (1956), experimenting on birds housed in individual cages and on deep litter for four years, reported that deep litter birds were superior in egg production over caged ones. Results obtained by Querner and Tuller (1966), after one year of data collection, also showed that birds on deep litter produced more eggs than caged layers.

Ahmedov et al., (1968) also worked on the effect of housing systems on performance of laying pullets for one year. Their results showed that under the same environmental conditions egg production per battery hen was 3 to 5 percent lower than per deep litter hen. In a 12 month experiment with White Leghorn, White Cornish, and White Plymouth Rock breeds, Chand et al., (1974) reported that egg production was significantly higher for birds on deep litter than for caged hens. Similar results were observed by Christmas et al., (1974) and Bhagwat and Craig (1975).

Using White Leghorns for 45 weeks Francis and Robertson (1962) found no significant differences in egg production between caged birds and those on deep litter. De Portal (1966) tested the performance of light and heavy breeds of layers managed on deep litter and in individual cages. He also found that there were no significant differences in egg production between caged layers and those on deep litter. Thomason et al., (1972) observed that for the first twelve weeks, egg production of large white Turkeys was higher in cages than on deep litter, and after the 12th week, the trend reversed favouring Turkeys on deep litter system. In the final analysis, after 24 weeks, there were no significant differences in egg production between the two groups. That there were no significant differences in egg production between caged layers and those on deep litter was also reported by Wegner (1970), Weinrich and Willeke (1972), Giannakopoulos (1974), Yeldan and Gurocak (1974), and Chand and Razdan (1976).

Thus as far as egg production is concerned no particular housing system seems to have any definite advantage over the other.

2.2 Egg size

Egg size refers to the average weight of an egg usually expressed in grams. It is normally affected by the energy and protein levels in a feed. A reduction of these will result in reduced egg size. Thus any system which interferes with feed intake by the birds will cause a reduction in egg size.

Alvier, (1941) compared the performance of ducks in cages and others on deep litter. At the end of twelve months results showed that egg size was 62.24 grams for eggs from the cage system and 60.7 grams for eggs from the deep litter system. The reduced egg size on the litter was generally due to loss of energy by the ducks through running around and fighting.

Bailey et al., (1958) reported that average egg weight was significantly higher for caged birds than for those kept on deep litter at 56.1 grams and 55.1 grams respectively. Keen and Mowbray (1969) observed that mean egg weight per dozen eggs indicated a 1.2 percent advantage in favour of cages at mean egg weights of 59.38 grams versus 58.64 grams.

Data collected by Kolodziej et al., (1970) demonstrated that egg size was 3.02 percent higher ($P< 0.01$) for eggs from caged birds than those from deep litter hens. In the study conducted by Giannakopoulos (1974) results showed that average egg size in cages was

59.9 grams and on deep litter it was 58.8 grams. Results obtained by Kaparkaleis et al., (1974) indicated that egg size was 62 grams for eggs from caged birds and 60.2 grams for deep litter layers. That caged birds laid heavier eggs than those on deep litter was also reported by Lowry et al., (1956), Wegner (1970), Hagger et al., (1974) Kotiash et al., (1974), Christmas et al., (1974); Petrovic et al., (1974); and Oluyemi and Roberts (1975).

Contrary to the above findings Querner and Tuller (1966) reported that eggs laid by birds on deep litter had a higher total egg mass than those from caged birds. Gowe (1955); De Portal, (1966), Thomason et al., (1972); Yeldan and Gurocak (1974), and Sharma (1974) found no significant differences in egg size between eggs produced by caged birds and those from deep litter hens. Thus the effect of housing systems on egg size has also not been conclusive.

2.3 Shell thickness

It is gnerally believed that measurement of egg shell thickness can give useful information in relation to the liability of an egg to crack, and possibly also in relation to hatchability (Tyler and Geake, 1961). However, Potts and Washburn, (1973) reported that thinner shells were not necessarily weaker than thicker shells. The reason given was that factors affecting the strength of egg shells are heredity, age, health, season, production rate, diet and environment. But in the absence of equipment for measuring egg shell strength, thickness can be used to determine shell strength.

There has been very little experimental work on the effect of housing systems on egg shell thickness. Hagger et al., (1974) reported that caged birds were significantly superior to birds on deep litter in the production of thicker shelled eggs. Similar results were obtained by Kotiash et al., (1974).

Contradictory results were reported by Starchikov and Dogadaev (1974). Their results showed that all shell characters were better in eggs produced by birds kept on deep litter than those produced by caged layers. Kolodziej et al., (1970) found out that there were 14 percent more cracked eggs in cages than in deep litter pens.

Testing seasonal variation in quality of eggs laid by caged hens and their sisters in deep litter, Froning and Funk (1957) found no significant differences in egg shell thickness and in general egg quality. Data collected by Sharma (1974) also supported these findings.

Thus the little information available on the effect of housing systems on egg shell thickness is also not conclusive.

2.4 Blood spots

The occurrence of blood spots in eggs is a problem which causes great losses in marketable eggs as well as unfavourable reactions from consumers.

It is commonly assumed that 1-6 percent of chicken eggs randomly selected will contain blood spots (Waldroup and Harms, 1961). It is known that blood spots are due to the rupturing of blood vessels in the follicle wall or they are due to haemorrhages that occur before ovulation (Taylor 1949, cited by Waldroup and Harms, 1961).

Blood spots of all sizes may occur in as high as 20 percent of all eggs produced. The extent of their occurence is influenced by differences in heredity, nutrition, age, season, management, and stress (Pope et al., 1960). The tendency of fowls to produce blood spots has a relatively high heritability of 80 percent. However, vitamin A deficiency can increase blood spots incidence as will high levels of protein (Phelps, 1977). Results from the experiments Phelps (1977) conducted showed that hens fed a diet containing 18 percent protein laid about 10 percent of the eggs with blood spots, but birds receiving only 13 percent protein diet produced only 7.2 percent of the eggs with blood spots. In a second trial a 14 percent protein diet produced 50 percent more blood spotted eggs than the 12 percent protein diet. He also reported that exercise may have an effect since a group of birds laid significantly less eggs with blood spots when on range than when caged although the diet was the same.

Jeffrey and Pino (1943) compared blood spots incidence in eggs produced by caged and deep litter birds. Their work showed caged birds to have produced eggs with a lower incidence of blood spots than the birds in deep litter pens.

Jeffrey (1945) reported results contrary to his earlier findings when he worked with Rhode Island Red layers housed in deep litter and in cages. He found out that caged birds produced eggs with a higher percentage of blood spots than did the birds on deep litter. Similar results were also obtained by Lowry et al., (1956), Froning and Funk, (1957), and Grotts (1956) cited by Froning and Funk (1957).

However results from the experiment conducted by Sharma (1974) demonstrated no significant difference in blood or meat spots in eggs from caged birds and from those on deep litter.

Thus not much work has been done on the effect of housing systems on blood spots incidence in eggs.

2.5 Food conversion efficiency

Food conversion efficiency is the maximum use of a given amount of feed per unit of animal product produced. With respect to egg production it is normally the amount of feed consumed per given weight of eggs produced. In poultry production it is generally affected by the system of management employed.

Miller (1956) cited by Bailey *et al*., (1958) reported that caged birds had a better feed efficiency than those kept on deep litter. Results obtained by Bailey *et al*., (1958) showed that birds on deep litter system required 66.2 grams of feed more than that required by caged hens to produce 454 grams of eggs. It was also shown that to produce a dozen eggs layers on deep litter system needed 53.57 grams of feed more than that used by caged hens. Earlier, Quisenberry (1954) cited by Bailey *et al*., (1958) had reported that caged birds produced an average of 24 more eggs per 45.4 kg of feed as compared to layers on deep litter. Studies conducted by Kolodziej *et al*., (1970) demonstrated that consumption of feed per kilogram of eggs laid was 15.5 percent lower in cages than on deep litter. Results of an experiment carried out by Giannakopoulos (1974) showed that to produce a dozen eggs, hens in cages needed 1.881 kg of feed and birds on deep litter needed 1.897 kg of feed. That caged birds utilized feed more efficiently than layers on deep litter was also reported by Wegner (1970); Hagger *et al*., (1974) and Christmas *et al*. (1974).

Contradictory results were obtained by Querner and Tuller (1966) who reported that layers on deep litter were superior to caged birds in all production characters. Confirming these findings, Sharma, (1974) found out that to produce a kilogram of eggs, caged birds needed 6.83 kg of feed and deep litter layers needed only 4.74 kg of feed. However, it has also been reported by several other workers that there are no significant differences in feed conversion efficiency between caged and deep litter hens (De Portal, 1966, Keen and Mowbray 1969, Yeldan and Gurocak, 1974 and Oluyemi and Roberts 1975).

2.6 Liveweight gain

Although the main concern of the farmer is the number of eggs of good quality produced, liveweight gains of the layers are also important. They give an indication on how well the birds are kept, and the heavier birds fetch more money at culling time. The effect of housing systems on liveweight gains of layers has been studied by very few workers.

Gowe, (1956) reported that liveweight gains were higher in caged birds than those on deep litter. Results of the study carried out by Bailey *et al.*, (1958) showed that average body weight of caged birds was 116.4 grams heavier than that of hens on deep litter. Keen and Mowbray (1969) reported that the mean body weight gain was 376.82 grams for caged hens and 263.32 grams for those on deep litter. Giannakopoulos (1974) found that at 74 weeks of age, caged birds weighed 9.7 percent more than the deep litter ones.

However, it was also reported by other workers that there were no significant differences in liveweight gains between caged birds and those on deep litter (De Portal, 1966; Querner and Tuller, 1966, and Hagger *et al.*, 1974). Thus as far as liveweight gains in layers are concerned the cage system is generally reported to be slightly better than the deep litter system.

2.7 Mortality

Mortality of birds in any type of poultry production indicates a direct financial loss to the poultry producer. This is why almost all researchers, who worked on the effect of housing systems on poultry production, included mortality as one of the evaluation criteria.

Results from the experiment conducted by Alvier (1941) showed that mortality was 5 percent in cages as compared to 10 percent on deep litter. These findings were supported by Gowe (1955) whose results demonstrated that mortality rate was 24 percent among birds on deep litter and 19 percent for caged layers. Earlier on Quisenberry, (1954) reported caged birds to have exhibited a 2.4 percent lower average mortality than deep litter birds. Results obtained by Sharma (1974) showed that mortality was 8 percent in the deep litter system and 4 percent in the cage system. Giannakopoulos (1974) found that 75.56 percent of the layers in cages survived while 72 percent had survived on deep litter system. Kaparkaleis et al., (1974) reported that mortality was 1.8 percent for caged birds and 2.9 percent for those on deep litter. That caged pullets showed significantly lower mortality than those kept on deep litter was also reported by Lowry et al., (1956), and Querner and Tuller, (1966).

However, contradictory results were reported by Kolodziej et al., (1970), Wegner (1970) and Christmas et al. (1974). All these workers reported that mortality was higher in cages than on deep litter. Other researchers reported that housing systems did not affect mortality of the birds (Parker and Rodgers, 1954; Gowe, 1956, Bailey et al., 1958, Keen and Mowbray, 1969, Petrovic et al., 1974, Hagger et al., 1974, and Yeldan and Gurocak, 1974). Therefore information on mortality as affected by housing systems has not been very conclusive.

2.8 General evaluation of the systems

2.8.1 The deep litter

This system has the advantage of being more flexible than the other systems. It is also reported that birds housed under this system feel comfortable. Maintenance costs are low. But there is a high risk of bacterial diseases and internal parasites. There is a tendency of collecting dirty eggs, and culling of the low producers is difficult (Ensminger, 1971).

2.8.2 The wire floor

In this system there is better control of bacterial diseases and internal parasites. But there is usually high humidity in the houses, birds appear nervous, feather pecking is high, and there is a high rate of egg breakages (Ensminger, 1971).

2.8.3 The cage system

This system accommodates more birds per given floor area than the other systems. The system also eliminates bacterial diseases and internal parasites. The problem associated with it are that capital requirement is high, removal of manure is difficult, and there is high labour requirement (Ensminger, 1971).

From the literature cited there is no clear cut advantage for one system or the other as results are generally contradictory. All the researchers quoted excluded the wire floor system in their studies so it is felt that comparisons made were not complete. Again most of them did not include a wide selection of production characters.

3.0 MATERIALS AND METHODS

The experiment was carried out at the Poultry Unit of the University of Nairobi, Kabete. It lasted six months from 25th March to 8th September 1981. A summary of weather records during the experimental period is shown in Appendix A.1. Brown egg-laying type of birds 'the Ross Brown' were used. Records from the supplier indicated that the birds were reared on deep litter up to the age of sixteen weeks when they were purchased for the study and assigned to treatments.

3.1 Materials

Feed, building materials and vaccine used in the experiment were purchased locally. Houses, measuring equipment, and buckets were provided by the University. Birds were purchased from B.A.T. Company Limited, Nairobi.

3.2 Housing

Housing systems used in the study were single wire cages, wire floored pens, and deep litter pens. All these were housed in existing poultry shelters which are 25.5 x 8.1 meters and orientated in East-West direction. The sides of the shelters consisted of 0.8 meter high walls and 5 cm x 5 cm mesh wires extending two meters from the walls to the eves thus permitting straight through ventilation.

3.2.1 Cages

The cages were 39 cm long, 35 cm wide, and 37 cm high giving the recommended 0.1 square metre floor space per bird. There were four rows of cages two on each side of an aisle, one row above the other, and the bottom rows projecting forward thus giving a stair-step effect. The bottom and top rows were 0.5 metres and 1 metre above the floor respectively. Each row contained eighteen cages. The floor of the cages was at a slope to allow eggs to roll down into an egg cradle. Manually operated feeding and watering equipment lined the rows of cages one above the other.

3.2.2 Wire floor

The floor was covered with 2.5 cm x 2 cm plastic coated wire mesh at one metre from the ground to allow droppings to collect beneath the floor. Main pens were temporarily partitioned into four compartments of 1.6 x 3.5 metre floor space using 2.5 cm x 2.5 cm mesh wires supported by timbers. The birds were stocked at 0.31 sq. metre per bird thus each compartment accommodated eighteen layers. Metal laying nests lined one side of the walls, and automatic nipple type waterers lined the other side. Each compartment was provided with a metal bucket feeder hanging in the middle of the pen at 30 cm from the floor.

3.2.3 Deep litter

This consisted of litter (wood shavings) covering the entire floor to a height of 15 centimeters. Partitioning equipment, and floor space per bird were the same as in the wire floored pens.

Floor space per bird in both the deep litter and the wire floor systems is within that recommended by Jull (1951). He recommended 0.25 sq. metre to 0.36 sq. metre per bird for light breeds.

3.3 Experimental Design

The experiment was completely randomized with three treatments namely: deep litter, wire floor and the cage systems replicated four times. There were 72 birds per housing system randomised in four groups of 18 birds each. In the cage system a row of cages was taken as a replicate.

3.4 Management

Houses and all the equipment were thoroughly cleaned and disinfected a week before birds were brought in. Germisol was used ror disinfecting the houses at a concentration of 15 ml to 5 litres of water. During the experimental period nests were cleaned once every week and waterers in the cage system were cleaned every other day. Feeding equipments were cleaned only when dirty. Manure was removed once every week in the cage system and once a month in the wire floor system following the system practiced in the existing Kabete Poultry Unit. Litter was not replaced during the whole experimental period because it is known that well kept litter can stay for one year before being replaced.

3.4.1 Vaccinations

Records from the suppliers of the birds indicated that the birds were vaccinated against Marek's disease at day old and against Newcastle disease at two weeks of age. However, the Newcastle vaccination was repeated at 19 weeks of age using Vaccine 'F' strain (attenuated) produced by Veterinary Research Laboratories, Kabete. The vaccine was administered through a single drop in each nasal opening.

3.4.2 Feed

The birds were fed growers mash up to 21 weeks of age and commercial layers mash during the experimental period. Analysis of the layers mash revealed that it contained 17.11 percent crude protein, 9.94 percent crude fibre and 3.942 kcal per gram gross energy. Feeding was *ad libitum*. Clean drinking water was also available all the time.

3.5 Observations

During the experimental period records were taken on laying intensity, egg size, internal egg spots, egg shell thickness, egg cleanliness, feed efficiency, liveweight gains and mortality.

3.5.1 Egg production data

There were record sheets for each group of birds. Information recorded per day included number of eggs, total egg weight, number of dirty eggs, eggs with internal spots and grade of eggs. Grading was done by using a mannual egg grader. The eggs were classified into rejected (under 42.56 grams), small (42.56 to 46.12 grams), medium (46.12 to 53.20 grams), standard (53.20 to 62.07 grams), and large (over 62.06 grams). The number of cracked eggs were also recorded every day. Egg production data collection followed the method explained by Mowbray (1967).

Hen-housed egg production was calculated by using the formula:

$$\frac{\text{Total number of eggs laid to date}}{\text{Number of hens housed X Number of days from first egg}} \times 100$$

Egg size was calculated by dividing total weight of eggs by the number of eggs. Dirty eggs were identified visually and by rubbing with hands to determine if the dirt was stuck firmly or not. Internal egg spots were identified through candling as described by Phelps (1977).

3.5.2 Egg shell thickness

Egg shell thickness measurements were taken on a weekly basis from the 11th to the 16th week of the experimental period. A total random sample of 120 eggs per treatment were used for the measurement of egg shell thickness. Carter (1974) recommended 30 eggs per treatment to be enough for the measurement of shell thickness. He stated that an increase in sample size above 30 eggs is accompanied by only a small improvement in precision. However, it was decided to increase the sample size in the current study because the treatments were replicated four times. Thus 30 eggs were randomly selected from each replicate.

The method followed in the measurement of shell thickness was that explained by Thomason et al., (1972). A micrometer screw gauge was used to measure the thickness of the shells. The instrument allowed an approximation to 0.001 of an inch, thus the data had to be converted to the metric system. Measurements were taken from pieces of shells taken from both caps and the middle of the egg. Thus mean egg shell thickness corresponding to a treatment was the mean of 360 measurements. Tyler and Geake (1961) reported that the broad and narrow caps of an egg each have a shell thickness greater than most intermediate latitudes. However minimum values may fall in different positions. Thus it was found necessary to take three measurements from each egg as explained above.

3.5.3 Feed conversion efficiency

All the feed given to the groups of birds was weighed separately and at the end of the study feed left in the feeding containers was also weighed. This was done in order to calculate the total amount of feed consumed. Feed conversion was then calculated by dividing total weight of feed per treatment with total weight of eggs.

3.5.4 Liveweight gains

All groups of birds were weighed separately both at the beginning and end of the experimental period. Liveweight gains were then calculated for each treatment.

3.6 Statistical analysis

All the data, except liveweight gains, were subjected to analysis of variance as described by Snedecor and Cochran (1967). The liveweight gains data were subjected to analysis of covariance in order to reduce the effects of variations in initial weights.

For ease of comparison and subsequent statistical analysis data on internal egg spots, dirty eggs, cracked eggs, and grades of eggs were converted into percentages. Thus the percentages had to be transformed by taking their square roots before subjecting them to analysis of variance. This was done so that the transformed data become approximately normally distributed and also to make the means and variances independent, with the resulting variances homogeneous. The method followed was as described by Steel and Torrie (1960).

Tukey's test of significance was used for pairwise comparisons of the treatment means.

4.0 RESULTS

4.1 Egg production

Results on total hen-housed egg production showed that caged birds produced significantly ($P < 0.01$) more eggs than either the birds on deep litter or wire floor systems (Table 1). However the difference in egg production data from the deep litter and wire floor systems was not significant ($P > 0.05$).

Figure 1 shows monthly laying percentages during the study period. It demonstrates that laying percentages in the deep litter system increased upto the third month, dropped slightly in the following two months of the study and then started rising again. In the wire floor system the laying percentages increased up to the fourth month, dropped sharply in the fifth month and increased steadily during the last month of the study. The trend was different in the cage system. Laying percentages in this system increased sharply during the first two months, then continued rising at a lower rate up to the fourth month, remained static for one month, and finally started dropping gradually. By the sixth month of the study caged birds had reached a mean laying percentage of 78.5 percent as compared to 62.5 percent and 63.5 percent for the deep litter and wire floor birds respectively. However overall laying intensities were

Table 1: The effect of poultry housing systems on hen-housed egg production by layers between 21 and 45 weeks of age.

Housing system	Mean number of eggs[1]	Mean hen-housed egg production (%)
Deep litter	1,590.5[a][2]	52.60 [a][2]
Wire floor	1,443.5[a]	47.73[a]
Cages	2,048.5[b]	67.74[b]
Standard error	± 57.9	± 3.10

[1]Treatment means were calculated from four groups of 18 birds each.

[2]Means with a different superscripts are significantly different ($P < 0.01$).

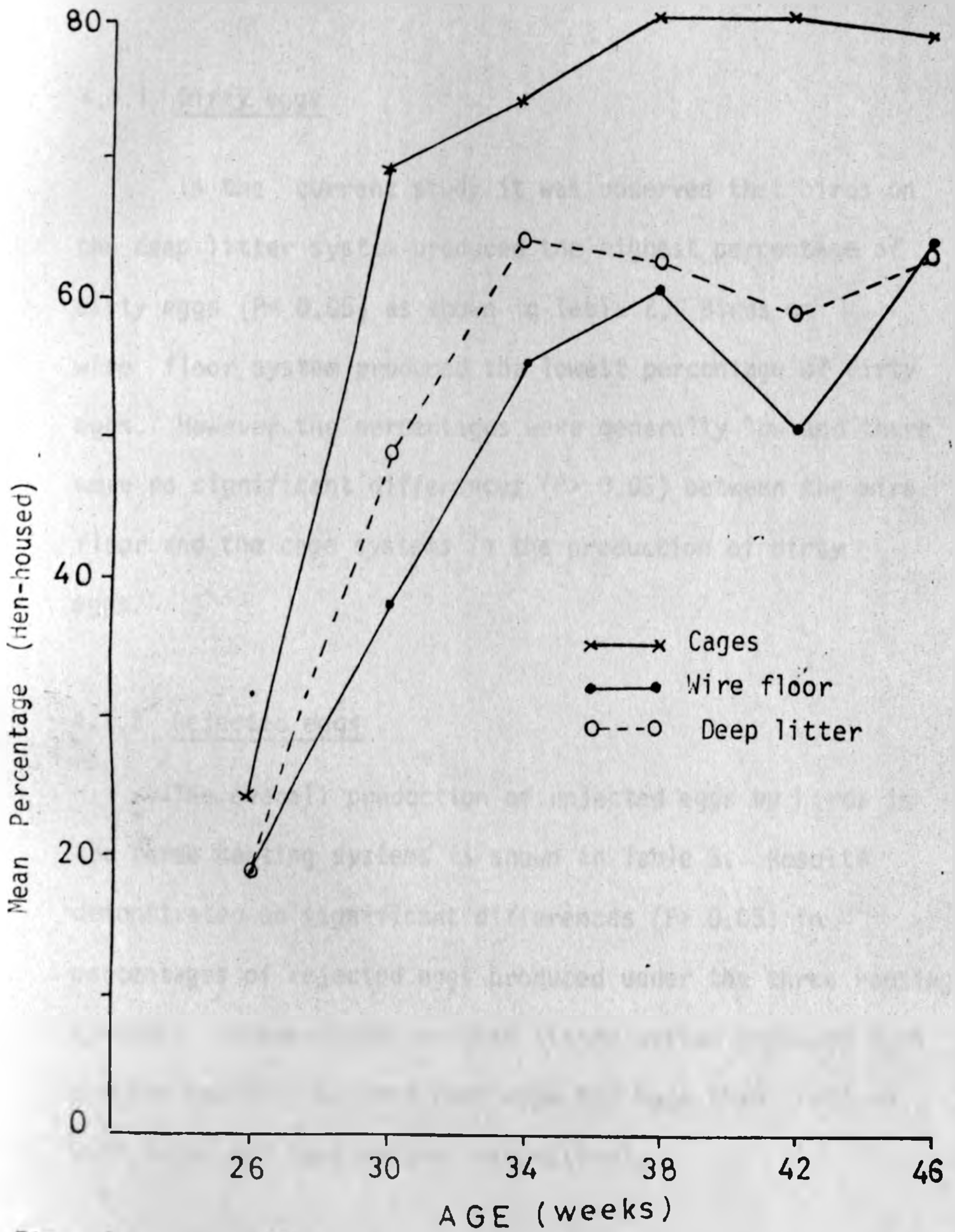

Fig. 1: The effect of poultry housing systems on laying percentages.

67.74, 52.6 and 47.73 percent in the cage, deep litter, and wire floor systems respectively. Thus they were 15.15 and 20.01 percent higher in cages than on deep litter and wire floor systems.

4.1.1 Dirty eggs

In the current study it was observed that birds on the deep litter system produced the highest percentage of dirty eggs ($P < 0.05$) as shown in Table 2. Birds on wire floor system produced the lowest percentage of dirty eggs. However the percentages were generally low and there were no significant differences ($P > 0.05$) between the wire floor and the cage systems in the production of dirty eggs.

4.1.2 Rejected eggs

The overall production of rejected eggs by birds in the three housing systems is shown in Table 3. Results demonstrated no significant differences ($P > 0.05$) in percentages of rejected eggs produced under the three housing systems. However birds on deep litter system produced 0.06 percent and 0.12 percent more rejected eggs than birds on wire floor and cage systems respectively.

Table 2: The effect of poultry housing systems on production of dirty eggs (percentages)

Housing system	Mean percentage
Deep litter	1.51[a][1]
Wire floor	0.67[b]
Cages	0.79[b]
Standard error	± 0.04

[1]Means with different superscripts were found on a transformed scale to be significantly different (P< 0.05) by Tukey's test.

Table 3: The effect of poultry housing systems on the production of rejected, small, medium, standard, large and extra-large eggs (percentages)

Grade of eggs (Mean percentage)[1]	Housing systems: Deep litter	Wire floor	Cages	S.E.
Rejected	0.66[a][2]	0.60[a]	0.54[a]	± 0.04
Small	1.70[a]	1.59[a]	1.26[a]	± 0.07
Medium	19.27[a]	18.17[a]	8.53[b]	± 0.11
Standard	63.48[a]	59.99[a]	53.88[b]	± 0.07
Large and extra large	15.64[a]	20.39[b]	36.57[c]	± 0.12

[1]Group means are from the transformed scale i.e. square roots of original percentages.

[2]Means in a row with different superscripts are significantly different (P< 0.05)

4.1.3 Small eggs

Results on production of small eggs by layers in the three housing systems are also shown in Table 3. Caged birds produced 0.44 percent and 0.33 percent less small eggs than hens on deep litter and wire floor systems respectively. However differences among the systems were not significant (P> 0.05).

4.1.4 Medium size eggs

Analysis of variance on percentages of medium size eggs showed that birds on deep litter produced significantly (P< 0.01) a higher mean percentage than caged birds. Layers on wire floor system also produced significantly (P< 0.01) a higher mean percentage than caged birds. However there were no significant differences (P> 0.05) in the production of medium size eggs between hens on deep litter and those on wire floor system. Table 3 shows that caged birds produced 10.74 percent and 10.18 percent less medium size eggs than those produced by layers on deep litter and wire floor systems respectively.

Figure 2 demonstrates that by the end of the first month of the study, when birds were 26 weeks old, 38.64 percent of the eggs produced by caged layers were of medium grade while 60.05 percent and 60.21 percent of the eggs produced by birds on deep litter and wire floor systems

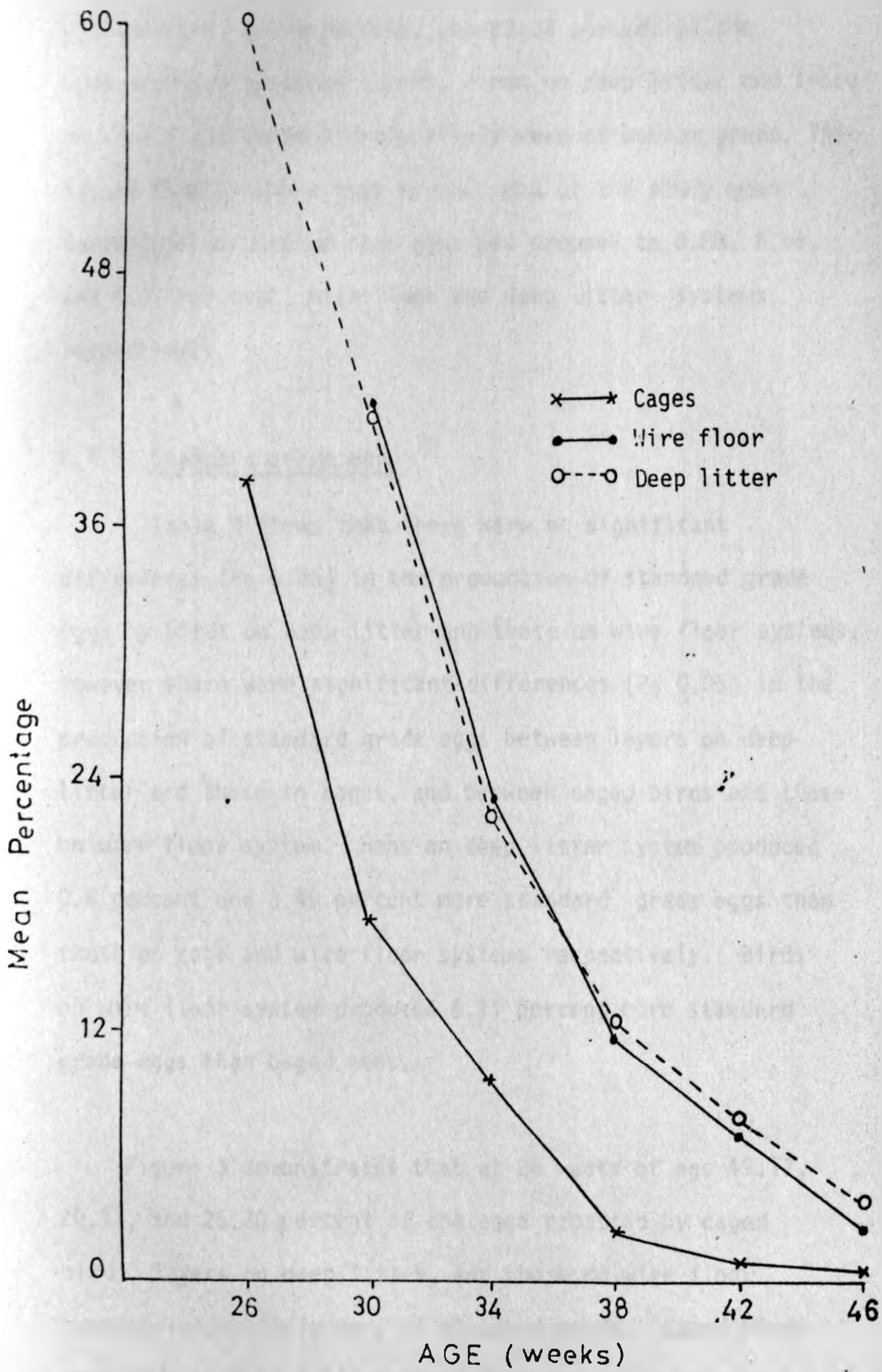

Fig. 2: The effect of poultry housing systems on production of medium size eggs.

respectively were of medium grade. At 34 weeks of age 9.57 percent, 22.68 percent, and 23.36 percent of the eggs produced by caged layers, birds on deep litter and those on wire floor systems respectively were of medium grade. The figure finally shows that by the end of the study mean percentages of medium size eggs had dropped to 0.88, 2.96, and 4.35 for cage, wire floor and deep litter systems respectively.

4.1.5 Standard grade eggs

Table 3 shows that there were no significant differences ($P > 0.05$) in the production of standard grade eggs by birds on deep litter and those on wire floor systems. However there were significant differences ($P < 0.05$) in the production of standard grade eggs between layers on deep litter and those in cages, and between caged birds and those on wire floor system. Hens on deep litter system produced 9.6 percent and 3.49 percent more standard grade eggs than those on cage and wire floor systems respectively. Birds on wire floor system produced 6.11 percent more standard grade eggs than caged hens.

Figure 3 demonstrates that at 26 weeks of age 49.17, 20.11, and 25.20 percent of the eggs produced by caged birds, layers on deep litter, and those on wire floor systems respectively were of standard grade. Caged birds reached a peak of 67.43 percent standard grade eggs at

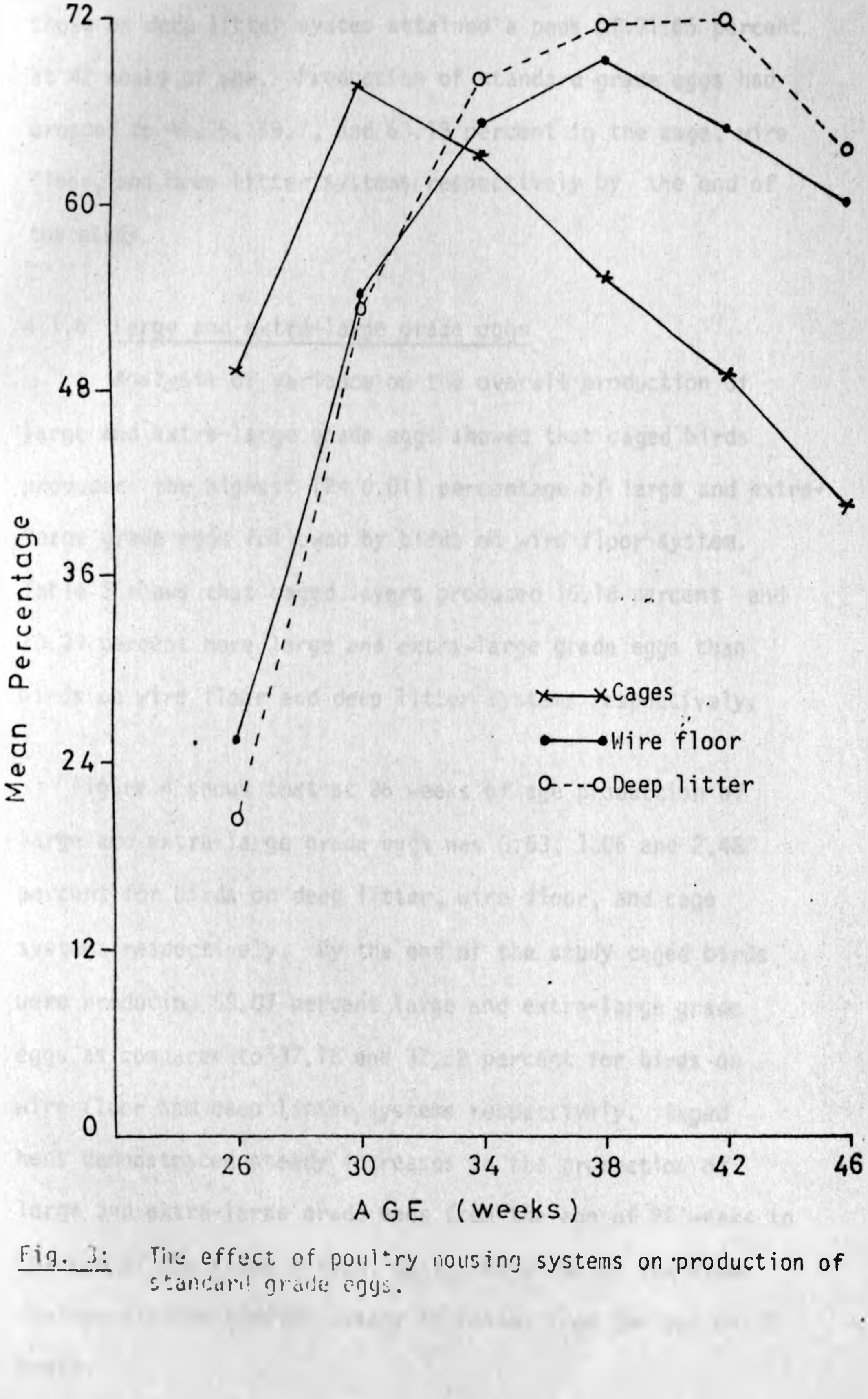

Fig. 3: The effect of poultry housing systems on production of standard grade eggs.

30 weeks of age. Birds on wire floor system reached a peak of 68.9 percent standard grade eggs at 38 weeks of age, and those on deep litter system attained a peak of 71.65 percent at 42 weeks of age. Production of standard grade eggs had dropped to 40.05, 59.7, and 63.13 percent in the cage, wire floor, and deep litter systems respectively by the end of the study.

4.1.6 Large and extra-large grade eggs

Analysis of variance on the overall production of large and extra-large grade eggs showed that caged birds produced the highest ($P < 0.01$) percentage of large and extra-large grade eggs followed by birds on wire floor system. Table 3 shows that caged layers produced 16.18 percent and 20.39 percent more large and extra-large grade eggs than birds on wire floor and deep litter systems respectively.

Figure 4 shows that at 26 weeks of age production of large and extra-large grade eggs was 0.53, 1.06 and 2.48 percent for birds on deep litter, wire floor, and cage systems respectively. By the end of the study caged birds were producing 59.07 percent large and extra-large grade eggs as compared to 37.18 and 32.52 percent for birds on wire floor and deep litter systems respectively. Caged hens demonstrated steady increases in the production of large and extra-large grade eggs from the age of 26 weeks to the end of the study period, while the birds in the other systems started showing steady increases from the age of 30 weeks.

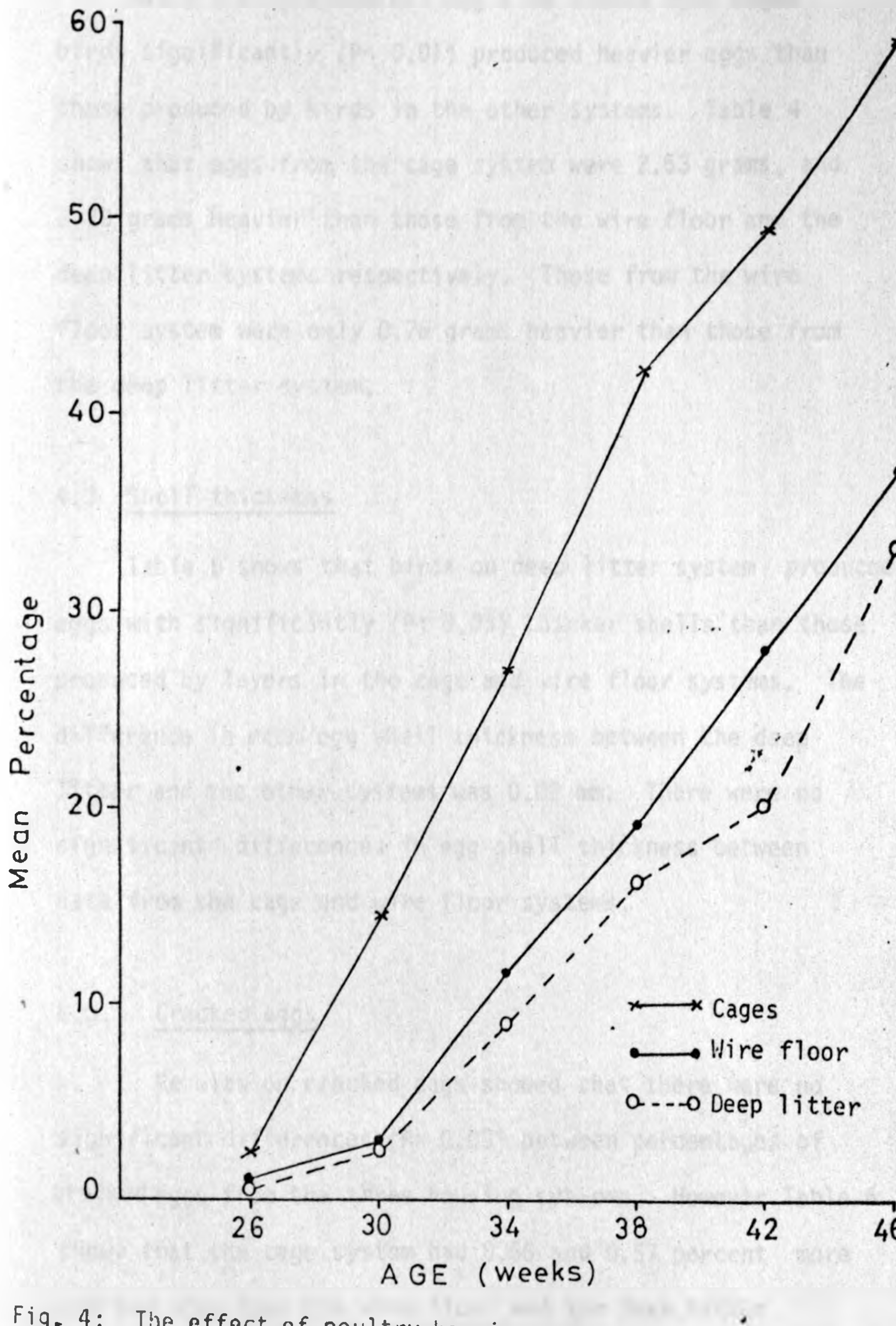

Fig. 4: The effect of poultry housing systems on the production of large grade eggs.

4.2 Overall egg size

Results on the overall egg size showed that caged birds significantly ($P < 0.01$) produced heavier eggs than those produced by birds in the other systems. Table 4 shows that eggs from the cage system were 2.53 grams, and 3.29 grams heavier than those from the wire floor and the deep litter systems respectively. Those from the wire floor system were only 0.76 grams heavier than those from the deep litter system.

4.3 Shell thickness

Table 5 shows that birds on deep litter system produced eggs with significantly ($P < 0.05$) thicker shells than those produced by layers in the cage and wire floor systems. The difference in mean egg shell thickness between the deep litter and the other systems was 0.02 mm. There were no significant differences in egg shell thickness between data from the cage and wire floor systems.

4.3.1 Cracked eggs

Results on cracked eggs showed that there were no significant differences ($P > 0.05$) between percentages of cracked eggs from the three housing systems. However Table 6 shows that the cage system had 0.56 and 0.57 percent more cracked eggs than the wire floor and the deep litter systems respectively.

Table 4: The effect of poultry housing systems on egg size (grams)

Housing system	Mean egg size[1]
Deep litter	55.89[a][2]
Wire floor	56.65[a]
Cages	59.18[b]
Standard error	± 0.23

[1]Means are per group of birds.

[2]Means with different superscripts are significantly different ($P < 0.05$).

Table 5: The effect of poultry housing systems on egg shell thickness (mm).

Housing system	Mean shell thickness[1] (mm)
Deep litter	0.35[a][2]
Wire floor	0.33[b]
Cages	0.33[b]
Standard error	±0.003

[1]Means were calculated from 120 eggs.

[2]Means with different superscripts are significantly different ($P < 0.05$).

Table 6: The effect of poultry housing systems on the production of cracked eggs (percentages)

Housing system	Mean percentage[1]
Deep litter	1.58[a][2]
Wire floor	1.59[a]
Cages	2.15[a]
Standard error	± 0.09

[1]Group means are from the transformed scale i.e. square roots of original percentages.

[2]Means with the same superscripts are not significantly different ($P > 0.05$).

4.4 Internal egg spots

Results on internal egg spots are given in Table 7. Analysis of variance showed that birds on wire floor system produced significantly (P< 0.01) the highest mean percentage of eggs with internal spots, while birds on deep litter system produced the least mean percentage of eggs with internal spots. There were significant (P< 0.01) differences between percentages of eggs with internal spots from the cage and the wire floor systems, the cage and the deep litter systems, and from the deep litter and the wire floor systems.

Figure 5 demonstrates that internal egg spots percentages in all systems were increasing up to when the birds reached 34 weeks of age and then started dropping. Sharp increases were observed from 30 weeks to 34 weeks of age. From the age of 34 weeks to 38 weeks internal egg spots percentages dropped sharply in both the wire floor and the cage systems, while the deep litter system demonstrated only a slight drop. From 38 weeks of age to the end of the study period the internal egg spots percentages decreased at a higher rate in the deep litter system than in either the cage or the wire floor system. Percentages of eggs with internal spots throughout the experimental period ranged from 9.26 to 20.59 percent; 16.45 to 37.82 percent; and 6.61 to 39.83 percent for the deep litter, wire floor, and cage systems respectively.

Table 7: The effect of poultry housing systems on internal egg spots incidence (percentages)

Housing system	Mean percentage[1]
Deep litter	13.40[a] [2]
Wire floor	23.57[b]
Cages	22.68[c]
Standard error	± 0.09

[1]Group means are from the transformed scale i.e. square roots of original percentages.

[2]Means with different superscripts are significantly different ($P < 0.05$).

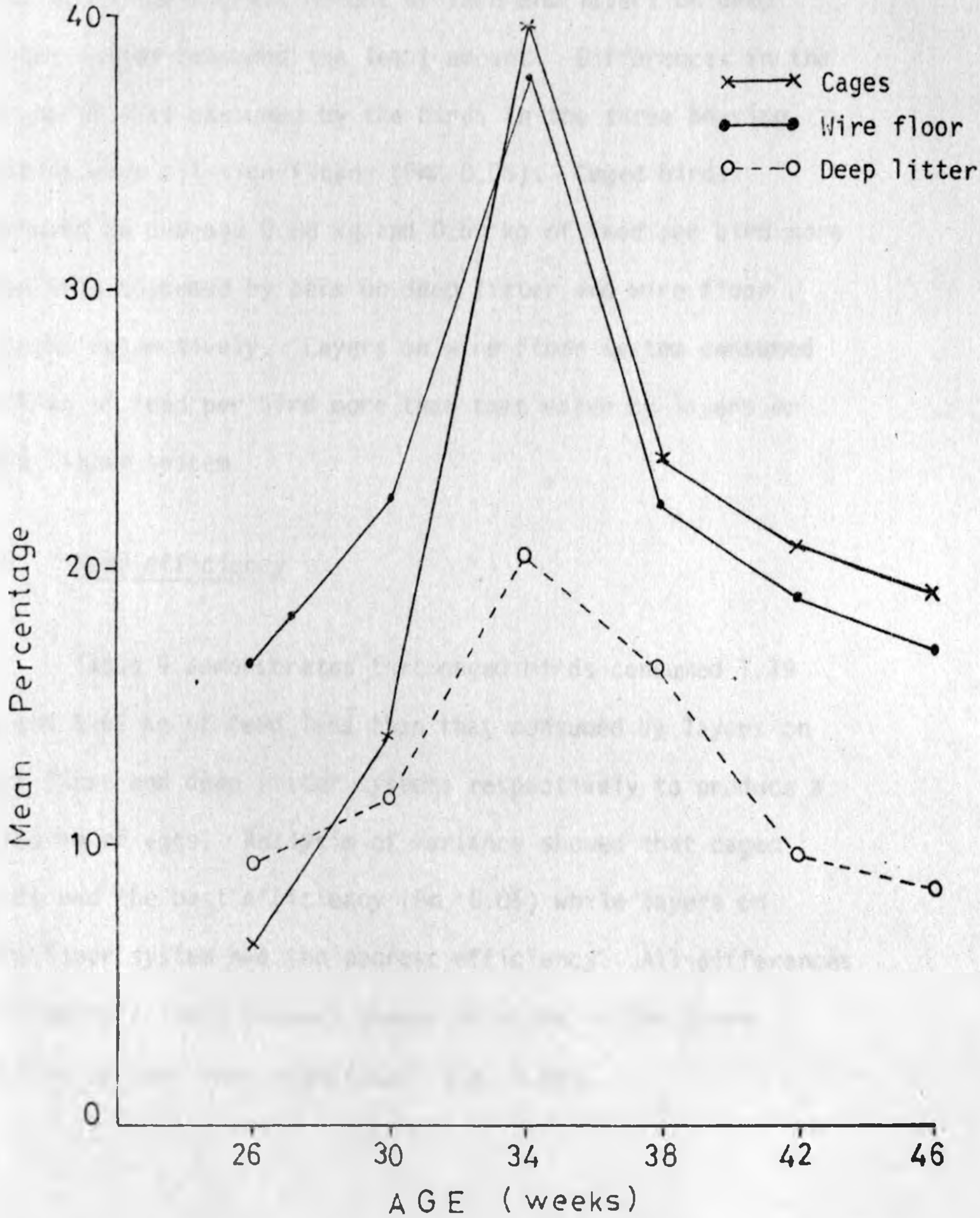

Fig. 5: The effect of poultry housing systems on production of eggs with internal spots.

4.5 Feed consumption

Table 8 shows that caged birds consumed significantly ($P < 0.05$) the highest amount of feed and layers on deep litter system consumed the least amount. Differences in the amount of feed consumed by the birds in the three housing systems were all significant ($P < 0.05$). Caged birds consumed on average 0.88 kg and 0.63 kg of feed per bird more than that consumed by hens on deep litter and wire floor systems respectively. Layers on wire floor system consumed 0.25 kg of feed per bird more than that eaten by layers on deep litter system.

4.6 Feed efficiency

Table 9 demonstrates that caged birds consumed 1.19 kg and 0.62 kg of feed less than that consumed by layers on wire floor and deep litter systems respectively to produce a kilogram of eggs. Analysis of variance showed that caged birds had the best efficiency ($P < 0.05$) while layers on wire floor system had the poorest efficiency. All differences in feed efficiency between groups of birds in the three housing systems were significant ($P < 0.05$).

Table 8: The effect of poultry housing systems on feed consumption by layers between 21 and 45 weeks of age (kg).

Housing system	Mean feed consumption[1]
Deep litter	5.16[a] [2]
Wire floor	5.41[b]
Cages	6.04[c]
Standard error	± 0.14

[1] Means of feed consumption are per bird.

[2] Means with different superscripts are significantly different ($P < 0.05$).

Table 9: The effect of poultry housing systems on feed efficiency (kg feed/kg eggs)

Housing system	Mean feed efficiency[1]
Deep litter	4.21[a][2]
Wire floor	4.78[b]
Cages	3.59[c]
Standard error	± 0.12

[1]Means are per group of birds.

[2]Means with different superscripts are significantly different ($P < 0.05$).

4.7 Liveweight gains

Analysis of variance on liveweight gains showed that caged birds significantly ($P < 0.05$) achieved a higher mean liveweight gain than layers on wire floor system. However there were no significant differences ($P > 0.05$) in liveweight gains between caged hens and those on deep litter system, and between layers on wire floor and those on deep litter systems. Analysis of covariance demonstrated that there were no significant variations ($P > 0.05$) in initial liveweights of the different groups of birds. Table 10 shows that caged layers achieved 2.92 kg and 3.55 kg mean group liveweight gains more than hens on deep litter and wire floor systems respectively. Mean liveweight gain for birds on deep litter system was only 0.63 kg higher than that for hens on wire floor system.

Table 10: The effect of poultry housing systems on liveweight gains (kg).

Housing system	Mean liveweight gains[1]
Deep litter	6.27^{ab}[2]
Wire floor	5.64^{b}
Cages	9.19^{a}
Standard error	± 0.53

[1]Mean liveweight gains are per group of birds.

[2]Means with different superscripts are significantly different ($P < 0.05$).

5. DISCUSSION

The overall hen-housed egg production percentages of 67.74, 52.60, and 47.73 for caged birds, layers on deep litter and those on wire floor systems respectively are typical of the tropics. In Nigeria, Modebe and Hill (1960) recorded egg production percentages of 38.9 in cages and 35.5 on range system. Ademosun and Kalango (1972) recorded hen-housed egg production rates of 57.1 percent in cages and 54.4 percent on deep litter system. In Uganda Trail (1963) recorded 62.4, 51.5, 50.9, 42.9 and 63.1 percent for White Leghorn x Rhode Island Red, Rhode Island Red, Light Sussex, Black Australorp, and Light Sussex x Rhode Island Red strains respectively under the cage system.

There were significant differences in hen-housed egg production between caged birds and either layers on deep litter or those on wire floor system. However, differences in egg production between birds on deep litter and those on wire floor system were not significant. Thus the study demonstrated superiority, in egg production, of the cage system over the other systems.

Physical restriction causes a differential rate of freedom from social conflict in favour of the birds in cages. Thus restricting layers in cages limits wasteful dissipation of nutrients in moving about, and therefore makes more of them available for productive functions. This could be the reason for the observed low laying intensity of layers on the deep litter and those on the wire floor systems as compared to the caged birds.

Monthly laying percentages showed that in both the deep litter and the wire floor systems there was a drop during the fourth and the fifth months of the study period but in the cage system no drop was observed. Weather records (Appendix A.1) revealed that average minimum temperatures reached 11.2^{o}C and 10.2^{o}C for the fourth and fifth months of the experimental period respectively. This could have caused the drop in egg production in the wire floor and deep litter systems. This is consistent with reports by Clark and Amin (1964) who stated that thermal stress for layers as caused by temperatures below 14^{o}C (55^{o}F) was as critical as high temperatures of 23.75^{o}C to 42.5^{o}C (70-100^{o}F). Caged birds were not affected by changes in weather possibly because they were continuously subjected to drafts and got aclimatised while changes in floor and wall temperatures in the wire floor and deep litter systems caused some thermal stress to the birds.

The three housing systems fulfill the basic functions of protecting the birds from adverse weather conditions mainly rain fall and direct sunlight. However Bond (1967) and Siegel (1968) reported that microclimate differences exist between the systems. In case of caged birds, they are probably better ventilated due to their elevation off the floor. Thus they are not affected much by gradual changes in temperatures. This could explain why there was no drop in egg production in the cage system during the two cold months.

The results on hen-housed egg production agreed with those reported by Alvier (1941), Quisenberry (1954), Bailey et al., (1958), Keen and Mowbray (1969), Kolodziej et al., (1970), Spurling (1971), Hagger et al., (1974), Kaparkaleis et al., (1974), and Oluyemi and Roberts (1975). However they were contrary to observations reported by Gowe (1955, 1956), Lowry et al., (1956), Querner and Tuller (1966), Ahmedov et al., (1968), Chand et al., (1974), Christmas et al., (1974), and Bhagwat and Craig (1975), who found the deep litter system to be superior to the cage system in egg production. The results were also at variance with those reported by Weinreich and Willeke (1972), Francis and Robertson (1962), De Portal (1966), Thomason et al., (1972); Wegner (1970), Giannakopoulos, (1974), Yeldan and Gurocak (1974) and Chand and Razdan (1976). These workers found no significant differences in egg production of birds in cages and those on deep litter system. These differences are probably due to the environment, and type of birds used.

Total feed consumption results showed that caged birds consumed the highest amount of feed and layers on deep litter consumed the least amount at 143 grams, 127 grams, and 123 grams per bird per day for caged birds, those on wire floor, and layers on deep litter systems, respectively. These feed consumption figures are higher than those reported by Moran et al., (1970), Davidson and Boyne (1970) and Scott et al., (1971) who reported 120 grams, 110 grams and 111 grams of feed per bird per day respectively, They were however lower than those reported by Hulan and Nikolaiczuk (1971).

That caged birds consumed more feed than those in other systems was also reported by Logan (1964). However, the results were contrary to those reported by Keen and Mowbray (1969), Christmas et al., (1974) and Petrovic et al., (1974) who found birds on deep litter system to have consumed more feed than those in cages. Differences in amount of feed consumed could be due to strain of birds, stocking density, and management system followed.

Birds on deep litter consumed the least amount of feed probably due to additional nutrients they might have been picking up from the litter. Pecking and other activities could explain why birds on wire floor system consumed less feed than that consumed by caged layers.

Results on feed efficiency showed wide variations with caged birds demonstrating the highest efficiency and birds on wire floor system showing the lowest feed efficiency. Data on feed efficiency of 3.59 kg feed/kg eggs, 4.21 kg feed/kg eggs, and 4.78 kg feed/kg eggs were better than those reported by Sharma (1974) who recorded 6.83 kg feed/kg eggs in the cage system, and 4.74 kg feed/kg eggs in the deep litter system.

Findings in this study are consistent with the observations reported by Miller (1956), Bailey et al., (1958), Quisenberry (1954), Kolodziej et al., (1970), Wegner (1970), Giannakopoulos (1974), Hagger et al., (1974) and Christmas et al., (1974). The observations were however contrary to those reported by De Portal (1966); Querner and Tuller (1966), Keen and Mowbray (1969), Sharma (1974), Yeldan and Gurocack (1974), and Oluyemi and Roberts (1975).

The study demonstrated that caged birds laid the heaviest eggs and birds on deep litter laid the lightest eggs. Data showed that there was a direct relationship between amount of feed consumed and egg size. It was observed that caged birds produced significantly the highest percentages of eggs in the large and extra large grades while birds on deep litter produced the highest percentages of medium and standard grade eggs. Differences on egg size between the deep litter and wire floor systems were not significant.

The results on egg size confirmed those reported by Alvier (1941), Bailey et al., (1958), Lowry et al., (1956), Kolodziej et al., (1970), Wegner (1970), Giannakopoulos (1974), Kaparkaleis et al., (1974), Hagger et al., (1974), Kotiash et al., (1974), Christmas et al., (1974), Petrovic et al., (1974), and Oluyemi and Roberts (1975). However they were inconsistent with those reported by Querner and Tuller (1966), Gowe (1955), De Portal (1966), Thomason et al., (1972), Yeldan and Gurocak (1974), and Sharma (1974).

The study also demonstrated that despite the high feed consumption by the caged birds there were no significant differences on liveweight gains between hens on deep litter system and those in cages. However differences between caged birds and those on wire floor system were significant, and between birds on deep litter and those on wire floor were not significant. Generally liveweight gains in all housing systems were low. This could be typical of the type of birds used.

The observations on liveweight gains in the current study agree with those reported by De Portal (1966), Querner and Tuller (1966), and Hagger et al., (1974). They were contrary to those reported by Gowe (1956), Bailey et al., (1958), Keen and Mowbray (1969) and Giannakopoulos (1974).

Results on egg shell thickness showed that birds on deep litter system produced eggs with thicker shells than those produced by birds in the other systems. A possible reason for the difference could be that the birds on deep litter system could have been picking up additional nutrients, mainly minerals, from the litter.

The findings were similar to those found by De Jong (1963), Starchikov and Dogadaev (1974). They were inconsistent with those reported by Froning and Funk (1957), Hagger et al., (1974) and Kotiash et al., (1974). Since the feed was the same in all systems, differences could only be attributed to the housing systems.

Housing systems had no effect on egg breakages and the study showed that there was no direct relationship between egg shell thickness and egg breakages. It could be due to the fact that egg shell thickness never dropped below 0.33 mm (Table A.10) because Brant et al., (1953) observed that egg breakage increased rapidly when egg shell thickness dropped below 0.33 mm.

Results on internal egg spots showed that birds on wire floor system produced the highest percentages of eggs with internal spots followed closely by caged birds. Given the fact that breed, feed, age, and season were the same, differences might be due to the housing system and stress. It was observed that birds in the wire floor system were the most nervous because they were always trying to runout once the doors were opened. The deep litter system might have provided a more natural environment to the birds. Thus stress could have induced more rupturing of blood vessels in the follicle walls which is responsible for occurrence of internal egg spots.

Percentages of eggs with internal spots were generally higher than expected in all the housing systems. Waldroup and Harms (1961) reported that 1 to 6 percent of randomly selected eggs usually contained blood spots. Pope et al.,

(1960) reported that blood spots of all sizes may occur in as high as 20 percent of all eggs produced. However, the high percentages in the current study could be due to lack of distinction between blood and meat spots. Nutrient composition of the feed could have also contributed to the high incidence of internal egg spots. Phelps (1977) reported that birds fed on an 18 percent protein diet laid 10 percent of the eggs with blood spots. Those fed with a 13 percent protein diet laid only 7.2 percent of the eggs with blood spots. The feed used in the current study had 17.1 percent protein. Phelps (1977) further reported that exercise could also affect the production of eggs with blood spots. But in the current study there was a very wide variation in the production of eggs with internal spots between birds on deep litter and those on wire floor systems despite being equally active.

The findings on internal egg spots in the current study were similar to those reported by Jeffrey (1945), Grotts (1956), Lowry _et al._, (1956), and Froning and Funk (1957) These researchers found out that caged birds produced eggs with a higher percentage of blood spots than did birds on deep litter. This was however contrary to the findings of Jeffrey and Pino (1943) who reported that caged birds produced eggs with a lower incidence of blood spots than birds on deep litter, while Sharma (1974), demonstrated no significant difference in blood spots in eggs from caged birds and those on deep litter. Thus the deep litter system seems to have an overall advantage over the other systems with respect to the incidence of internal egg spots.

It was also observed that birds on deep litter produced significantly a higher percentage of dirty eggs than either those on wire floor system or in cages. This was as expected because some layers laid eggs on the litter and not in the nests. However the highest percentage of dirty eggs was 1.5 percent and the eggs could be cleaned easily. The results agreed with reports by Ensminger (1971).

Only one bird died in the wire floor system due to cannibalism. This indicated that housing systems had no effect on mortality. Generally it is expected that more deaths should occur in the deep litter system due to transmission of bacterial diseases and internal parasites. However, the study demonstrated that with proper vaccinations and good management, disease and internal parasite control in the deep litter system is as effective as in the other systems.

The results on mortality were consistent with those observed by,among others, Keen and Mowbray (1969) and Yeldan and Gurocak (1974) who reported insignificantly different mortality levels of 10% versus 10%, and 12.50% versus 8.33%, for deep litter and caged birds respectively. They were however inconsistent with those reported by Gowe (1955), Sharma (1974) and Christmas et al., (1974) who observed significantly different levels of 24% versus 19%, 8% versus 4%, and 28% versus 24.44%, for deep litter and caged birds respectively.

6. CONCLUSION

The study showed that birds in the cage system were superior to those in the other systems in egg production, egg size and feed efficiency. Observations on liveweight gains were inconclusive because caged birds demonstrated superiority only to those on wire floor system. Layers under the deep litter system were superior to those in the other systems in producing the lowest percentages of eggs with internal spots, production of thicker shelled eggs, and the consumption of the least amount of feed. Birds on wire floor system only demonstrated superiority to those in the other systems in the production of clean eggs.

Housing systems had no effect on bird mortality and production of cracked eggs. This could mean that with proper management the poultry producer should not base choice of housing system on these two evaluation criteria.

Generally results obtained in the study demonstrated that the cage system could be the most favoured. However, the high internal egg spots incidence in the cage system could make the poultry producers prefer the deep litter system.

6.1 SCOPE FOR FURTHER STUDY

Time factor did not allow the study to be carried out for more than six months. Therefore it is suggested that in the event of a repetition of a similar study, the experimental period should be longer. By the end of the current study it was observed that egg production had started dropping in the cage system while it was improving in the other systems. Thus if the experimental period was extended, probably the results could be different.

Jenkins and Tyler (1960) reported that egg shell thickness increased with time, and McDaniel et al., (1978) reported that shell quality declined with age. All this supports the necessity of extending the experimental period. It is also suggested that both egg shell thickness and shell strength should be measured in future similar experiments because Potts and Washburn (1973) stated that thinner shells are not necessarily weaker than thicker shells. Shell strength could not be measured in the current study because of lack of equipment.

Conclusions and recommendations made after the study are not representative of East African conditions because the experiment was conducted only at one location. It is therefore suggested that future similar studies should be replicated at different locations with different climates in order to make results representative of East African conditions. It is also suggested to use almost all the most common available egg laying types of poultry in East Africa. It is possible that one type may perform better under a particular housing system than the other given the possible existence of genotype x environment interaction in poultry.

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APPENDIX

Table A.1: A summary of temperature and relative humidity during the study period.

Month	Temperature °C			Relative humidity %		
	Maximum	Minimum	Range	Maximum	Minimum	Range
1	25.1	14.2	11.3-27.5	81.0	53.5	29-98
2	22.7	14.0	11.6-25.9	84.5	62.5	35-98
3	21.7	13.9	11.4-24.2	88.5	73.5	50-98
4	21.5	11.8	8.7-24.8	86.0	59.5	46-97
5	19.5	10.2	7.4-23.2	91.5	72.0	51-100
6	21.7	10.7	8.0-24.9	83.5	58.5	43-98

Table A.2: Statistical analysis of hen-housed egg production data.

	Deep litter	Wire floor	Cages
	1,386	1,449	1,988
	1,629	1,615	2,082
	1,879	1,075	2,144
	1,468	1,635	1,980
Mean	1,590.5	1,443.5	2,048.5
S.E.	± 108.61	± 129.71	± 39.36

Analysis of Variance

Source	df	SS	MS	F
Total	11	1158573.67		
Housing systems	2	796530.67	398265.34	9.9**
Error	9	362043	40227	

**Significant ($P < 0.01$)

S.E. = ± 57.9

C V = 11.84%

Table A.3: Statistical analysis to compare the effect of poultry housing systems on production of dirty eggs (percentages on transformed scale i.e. square roots of original figures)

	Deep litter	Wire floor	Cages
	1.10	0.88	0.87
	1.01	0.87	0.88
	1.45	0.82	0.91
	1.36	0.71	0.89
Mean[1]	1.51	0.67	0.79
S.E.	± 0.10	± 0.04	± 0.01

Analysis of Variance

Source	df	SS	MS	F
Total	11	0.5363		
Housing systems	2	0.3866	0.1933	11.64**
Error	9	0.1497	0.0166	

**Significant ($P < 0.01$)

S.E. = ± 0.44

C.V. = 13.15%

[1]Means are transformed back to original percentages.

Table A.4: Statistical analysis to compare the effect of poultry housing systems on the production of rejected eggs (percentages on transformed scale i.e. square roots of original figures).

	Deep litter	Wire floor	Cages
	0.77	0.75	0.74
	0.89	0.83	0.71
	0.78	0.82	0.77
	0.80	0.71	0.71
Means[1]	0.66	0.60	0.54
S.E.	± 0.03	± 0.03	± 0.01

Analysis of Variance

Source	df	SS	MS	F
Total	11	0.0335		
Housing systems	2	0.0122	0.0061	2.65 NS
Error	9	0.0213	0.0023	

NS = Not significant (P > 0.05)

S.E = ± 0.01

C.V. = 6.23% .

[1]Means are converted back to original percentages.

Table A.5: Statistical analysis to compare the effect of poultry housing systems on production of small eggs (percentages on transformed scale i.e. square roots of original figures).

	Deep litter	Wire floor	Cages
	1.00	1.26	0.92
	1.26	1.36	1.10
	1.59	1.34	1.33
	1.36	1.08	1.14
Means[1]	1.70	1.59	1.26
S.E.	± 0.12	± 0.06	± 0.08

Analysis of Variance

Source	df	SS	MS	F
Total	11	0.3838		
Housing systems	2	0.0709	0.0355	1.02 NS
Error	9	0.3129	0.0348	

NS = Not significant (P < 0.05)

S.E.= ± 0.05

C.V.= 15.16%

[1] Means are transformed back to original percentages.

Table A.6: Statistical analysis to compare the effect of poultry housing systems on production of medium grade eggs (percentages on transformed scale i.e. square roots of original figures).

	Deep litter	Wire floor	Cages
	4.06	4.26	2.49
	4.12	4.75	2.84
	4.89	3.95	3.45
	4.49	4.09	2.90
Means[1]	19.27	18.17	8.53
S.E.	± 0.19	± 0.17	± 0.20

Analysis of Variance

Source	df	SS	MS	F
Total	11	6.5854		
Housing systems	2	5.3059	2.6530	18.66**
Error	9	1.2795	0.1422	

**Significant $(P < 0.01)$

S.E. = ± 0.11

C.V. = 9.77%

[1] Means are converted back to original percentages

Table A.7: Statistical analysis to compare the effect of poultry housing systems on production of standard grade eggs (percentages on transformed scale i.e. square roots of original figures).

	Deep litter	Wire floor	Cages
	8.16	7.82	7.51
	7.94	7.61	7.19
	7.80	7.61	7.69
	7.97	7.94	6.97
Mean[1]	63.48	59.99	53.88
S.E.	± 0.07	± 0.08	± 0.16

Analysis of Variance

Source	df	SS	MS	F
Total	11	1.2665		
Housing systems	2	0.8097	0.4049	7.97*
Error	9	0.4568	0.0508	

*Significant ($P < 0.05$)

S.E. = ± 0.07

C.V. = 2.93%

[1]Means are transformed back to the original percentages.

Table A.8: Statistical analyais to compare the effect of poultry housing systems on production of large and extra-large grade eggs (percentages on transformed scale i.e. square roots of original figures).

	Deep litter	Wire floor	Cages
	4.03	4.41	6.08
	4.32	4.24	6.33
	3.63	5.00	5.25
	3.84	4.41	6.53
Mean[1]	15.64	20.39	36.57
S.E.	± 0.15	± 0.17	±0.28

Analysis of Variance

Source	df	SS	MS	F
Total	11	10.9279		
Housing systems	2	9.3876	4.6938	27.43**
Error	9	1.5403	0.1711	

**Significant (P < 0.C1)

S.E. = ± 0.12

C.V. = 8.55%

[1]Means are transformec back to the original percentages.

Table A.9: Statistical analysis of overall egg size (grams) data

	Deep litter	Wire floor	Cages
	56.28	56.20	59.59
	56.52	55.98	59.58
	55.06	57.06	57.63
	55.69	57.35	59.93
Means	55.89	56.65	59.18
S.E.	± 0.33	± 0.33	± 0.52

Analysis of Variance

Sources	df	SS	MS	F
Total	11	29.6949		
Housing systems	2	23.8145	11.9072	18.22**
Error	9	5.8804	0.6534	

**Significant ($P < 0.01$)

S.E. = ± 0.23

C.V. = 1.41%

Table A.10: Statistical analysis of egg shell thickness (mm) data.

	Deep litter	Wire floor	Cages
	0.35	0.34	0.33
	0.35	0.33	0.33
	0.36	0.33	0.33
	0.35	0.33	0.33
Mean	0.35	0.33	0.33
S.E.	± 0.003	± 0.003	± 0.000

Analysis of variance

Source	df	SS	MS	F
Total	11	0.002		
Housing systems	2	0.001	0.0005	5*
Error	9	0.001	0.0001	

*Significant ($P < 0.05$)

S.E. = ± 0.003

C.V. = 9.3%

Table A.11: Statistical analysis to compare the effect of poultry housing systems on production of cracked eggs (percentages on transformed scale i.e. square roots of original figures)

	Deep litter	Wire floor	Cages
	1.26	1.02	1.21
	1.45	1.09	2.06
	1.09	1.65	1.25
	1.23	1.29	1.35
Means[1]	1.58	1.59	2.15
S.E.	±0.07	±0.14	±0.20

Analysis of Variance

Source	df	SS	MS	F
Total	11	0.8987		
Housing systems	2	0.1149	0.0575	0.66 NS
Error	9	0.7838	0.0871	

NS = Not significant (P > 0.05)

S.E. = ± 0.09

C.V. = 22.19%

[1]Means are transformed back to original percentages.

Table A.12: Statistical analysis to compare the effect of poultry housing systems on the internal egg spots incidence (percentages on transformed scale i.e square roots of original figure).

	Deep litter	Wire floor	Cages
	3.42	4.45	5.00
	3.65	4.89	4.83
	3.45	5.36	4.81
	4.12	4.72	4.41
Mean[1]	13.40	23.57	22.68
S.E.	±0.16	±0.19	±0.12

Analysis of Variance

Source	df	SS	MS	F
Total	11	4.4755		
Housing systems	2	3.5361	1.7681	16.94**
Error	9	0.9394	0.1044	

**Significant ($P < 0.01$)

S.E. = ± 0.09

C.V. = 7.3%

[1]Means are transformed back to original percentages.

Table A.13: Initial liveweight, final liveweights and liveweight gains of groups of layers (kg).

Housing system	Initial weight	Final weight	Liveweight gain
	24.70	30.20	5.50
	23.10	30.40	7.30
Deep litter	25.60	30.60	5.00
	25.00	32.50	7.50
Mean	24.60	30.93	6.27[1]
Standard error	± 0.53	± 0.53	± 0.53
	24.63	30.70	6.07
	24.82	28.70	3.88
Wire floor	25.20	31.20	6.00
	24.10	30.90	6.80
Mean	24.69	30.38	5.64[1]
Standard error	± 0.23	± 0.57	± 0.53
	24.50	31.70	7.20
	26.40	35.60	9.20
Cages	25.70	36.70	11.00
	26.60	35.50	8.90
Mean	25.80	34.88	9.19[1]
Standard error	±0.47	±1.09	±0.53

Analysis of covariance for testing liveweight gains

Source	df	SS	MS	F
Total	11	69.7892		
Covariable	1	33.8715		
Housing systems	2	19.2748	9.6374	4.63*
Error	8	16.6429	2.0804	

*Significant ($P < 0.05$)
S.E. = ± 0.42
C.V. = 4.5%
[1] Adjusted means.

Table 15: Statistical analyais to compare the effect of poultry housing systems on feed efficiency (kg feed/kg eggs)

	Deep litter	Wire floor	Cages
	4.42	4.80	3.55
	3.99	4.36	3.57
	3.81	5.68	3.61
	4.61	4.29	3.63
Mean	4.21	4.78	3.59
S.E.	± 0.19	±0.32	± 0.02

Analysis of Variance

Source	df	SS	MS	F
Total	11	4.4887		
Housing systems	2	2.8454	1.4227	7.79*
Error	9	1.6433	0.1826	

*Significant (P< 0.05)

S.E. = ± 0.12

C.V. = 10.2%