EFFECTS OF STOCKING DENSITY AND ENERGY LEVEL OF DIET ON GROWTH AND AGE OF SLAUGHTER OF BROILERS

By

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DECLARATION

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

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

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ABSTRACT

In the studies of stocking densities and growth, the starter chicks showed average total body weight gains of 545.73, 523.33 and 513 grams when housed at 465, 372 and 279 cm^2/chick respectively. In the finisher phase and in week 8 of age, broilers showed weekly body weight gains of 138.18, 236.38 and 142.7 grams per chick when housed at 930, 744 and 558 cm^2/bird respectively.

In the subsequent studies with high energy diets and high stocking densities, the average body weight gain increased by 27.7 percent with an increase in dietary energy level from 2,700 to 3,000 kcal/kg of feed. Body weight gain decreased by 4.9 percent as floor space allowed per bird decreased from 300 to 240 cm^2/chick. In the finisher phase dietary energy levels of 2,930 and 3,200 kcal/kg of feed did not significantly affect average body weight gain. Similarly floor space allowances of 465 and 558 cm^2/bird did not affect average body weight grain. Dietary energy levels significantly affected the overall 0 to 8 weeks average body weight. The broilers on high dietary energy level were 22 percent heavier than broilers on low dietary energy level. A 4 percent decrease in average body weight was observed as floor space allowed per bird decreased from 558 to 465 cm^2/bird. In both studies high stocking densities were associated with more total body weight and body weight gain per unit of floor space.

The high average body weight gain of birds housed at 465 cm^2/chick during the starter phase and 744 cm^2/bird during the finisher phase in the first study were attributed to higher feed utilisation efficiency. In the starter and finisher phases of the second study, the higher body weight gain and total average body weight were due to the higher feed efficiency on the high dietary energy level. The low stocking densities allowed for high feed intake.

These studies show that feed was utilised efficiently at the low and middle stocking densities at the starter and finisher phases respectively and that at high dietary energy level broilers grew just as well when housed at high stocking densities as when housed at the low and middle densities at the starter and finisher phases respectively of the first study.

1. INTRODUCTION

Meat birds of the hybrid type or broilers raised intensively and kept under optimal conditions reach slaughter weight within the prescribed time of 8 to 10 weeks. Intensive management of broiler type birds begins with artificial brooding of the day old chicks through the starter phase up to 4 or 5 weeks of age. During the later finishing phase and under tropical conditions, broilers do not necessarily require supplemental heat because, physiological mechanisms are so fully developed such that the rate of heat loss to the surrounding is adequately compensated from the heat produced in the body.

There are a variety of factors that can influence the environment of a bird. These factors can be separated into; thermal factors, which include temperature, relative humidity, air movement and radiation; physical factors, such as floor area, light, sound and pressure and lastly social factors which include number of birds per pen or cage (Carter 1967). In view of this it is therefore important in broiler production that proper consideration be made to the control of these factors so that an optimal poultry environment be created at which broiler birds can benefit from better growth, increased feed efficiency and resistance to diseases, so that the ultimate product which is broiler meat can be efficiently produced.

Although floor area is considered a physical factor, it is very important as it influences many other factors.

Overcrowding which is due to limited floor area allowed per chick is a common problem in broiler production. Williamson and Payne (1965), reported that if the weather is hot and chicks are overcrowded the loss of heat by the chick is greatly reduced. This results in a heat load on chicks which they cannot tolerate and therefore they appear to lose appetite for food and lose vigour which in turn leads to reduced resistance to diseases.

Nutritional deficiencies due to a loss of appetite for food which affects feed intake and hence nutrient intake may also occur. The provision of optimal floor area per bird avoids crowded conditions and therefore reduces heat load and cannibalism in the broilers, thereby allowing the broilers to maximise feed intake and grow and develop optimally (Williamson et al., 1965, North, 1972 and Morley, 1977).

Most of the studies on floor space requirements have been done in the temperate regions, therefore there is justification for studies to be done in tropical regions to establish the optimal stocking rates at brooding and finishing phases under tropical conditions. In view of this lack of information, an examination has been made of the effects of different stocking densities during the brooding and finishing phases of broiler production in order to establish some guidelines for optimal floor space requirements for tropical conditions. In addition further studies were made based on the observations of Siegel and Cole (1958), Andrews and Goodwin (1969), who reported that if the production of broiler meat needs to be expanded quickly, it would be feasible in some instances to grow more birds per unit of space, despite the adverse effects from overcrowding. Tests were made with broilers at high stocking densities against two diets of low and high energy levels with a view to observe whether high energy diets can compensate growth depression under high density conditions.

2. REVIEW OF LITERATURE

2.1 Floor space recommendations

Earlier floor space recommendations were particularly meant for the layers. Literature cited shows that, Jull (1951), recommended 744 cm^2/bird as desirable minimum floor space for layers (probably even broilers too). When hovers or cannopies were used floor space had to be 64.6 cm^2/chick and 77.5 cm^2/chick if electric brooders were used. Rice and Botsford (1956), recommended 930 cm^2/bird for both light and heavy breeds from 3 to 8 weeks, 1 385 and 1 860 cm^2/bird from 8 to 12 weeks for light and heavy breeds respectively, 1 860 and 2 790 cm^2/bird from 12 to 16 weeks for light and heavy breeds respectively and 2 790 to 3 720 cm^2/bird for light and heavy breeds respectively from 16 weeks onwards.

Biddle (1963), Williamson *et al*., (1965) , and Ensminger (1971), recommended 744 cm^2/bird throughout the year and 930 cm^2/bird in the summer; Card and Nesheim (1966), suggested 272 and 465 cm^2/bird (probably the former at early brooding and the latter at late brooding). North (1972), recommended 930 cm^2/bird. Reece (1978), proposed the following brooding space requirements; 111 cm^2/chick for the first 2 weeks, 372 cm^2/chick for 2 to 4 weeks and 465 cm^2/chick up to 6 weeks.

2.2 Body weight and body weight gain as affected by floor space allowances

On the examination of the effects of floor space allowances of 930, 744 and 465 cm^2/bird, Heishman, Cunninghum and Clark (1952), observed a reduction in body weight as floor space per bird decreased from 930 to 465 cm^2/bird. Studies of the economics of floor space on broiler production were reported by Brooks, Judge, Thayer and Newell (1957). These studies showed a progressive increase in total body weight per unit floor area as floor space per bird decreased from 1 860 to 465 cm^2/bird. They reported relatively small differences in body weight up to 9 weeks of age. After this age the weight differences between broilers in pens at 930 and 465 cm^2/bird became progressively greater, and reported a trend of linear relationship between body weight gain and time.

In their studies on the effects of floor space allowances of 465, 744, 930 and 1162.5 cm^2/bird, Siegel et al., (1958) observed no floor space effects on body weight at 4, 6 and 9 weeks of age. However they reported inverse relationship between floor space allowance and return per unit of floor area. Moreng, Enos, Bruss and Harting (1961), in their studies on the relationship of floor space and broiler growth, they used floor spaces of 465, 744, 930 and 1 162.5 cm^2/bird up to 11 weeks of age in two trials. In the first trial results showed a progressive reduction in average 11-week body weight with a decrease in floor space when the average body weights for broilers in pens at 1 162.5, 930, 744 and 465 cm^2/bird were 2 460, 2 400, 2 370 and 2 270 grams respectively. In their second trial broilers reared at 465 cm^2/bird at 5 weeks of age were 3.8 and 9 percent heavier than those at 930 and 1 162.5 cm^2/bird respectively.

Average body weights of 511 and 500 grams for the starters reared at 744 and 1 162.5 cm^2/bird were significantly lower than 525 grams which was the average body weight for starters reared at 930 cm^2/bird. They reported an inconsistencey in the pattern of growth response to floor space up to 8 weeks and that the influence of floor space became increasingly apparent as body weight increased at 10 weeks of age.

James, Deaton, Floyd, Reece and Verdaman (1968), conducted their studies on the effects of temperature and density on broiler performance. The floor spaces of 650 and 929 cm^2/bird were both examined in the high and low temperature regimes (69.98^{0}F to 98.6^{0}F and below 69.98^{0}F respectively). At the end of week 8, birds at 650 cm^2/bird were not significantly heavier than birds at 929 cm^2/bird in the high temperature regime but were significantly lighter than birds at 929 cm^2/bird in the low temperature regime (1 477 grams as opposed to 1 520 grams). They also noted no significant effects due to density between corresponding treatments in the high and low temperature regimes, that is broilers reared at 650 cm^2/bird in the high temperature showed almost the same response as the broilers at the same stocking density in the low temperature and the same case applied to broilers reared at 929 cm^2/bird. They suggested that the density effects of broilers reared in the low temperature regime at 650 cm^2/bird were almost equal to the depressing effects of high temperature in the high temperature regime. Using the floor spaces of 465, 650 and 929 cm^2/bird they reported significantly heavier broilers reared at 929 cm^2/

bird than broilers reared at 650 cm^2/bird at 8 weeks of age, and a significantly lower 8-week body weight of 1 473 grams for broilers at 465 cm^2/bird.

On their studies on the effects of floor space and dietary energy levels on broiler growth, Andrews et al., (1969) used floor spaces of 372, 465, 558, 651 and 744 cm^2/bird against 2 149.4, 2 314.4 and 2 488.2 kilocalories of productive energy per kilogram of feed. The 8-week body weights were 1 384, 1 396 and 1 405 grams in the increasing order of the productive energy, thereby showing a general increase in average body weight with an increase in the productive energy of the ration. On floor space allowances, the results obtained were increasing body weights of 1 394, 1 404, 1 409 and 1 416 grams with the increasing order of floor space allowed per bird. They reported no significant differences in average body weights as a result of floor space allowances of broilers at 465 and 558 cm^2/bird, 650 and 744 cm^2/bird. The average body weight of 1 356 grams was lowest for broilers in pens with 373 cm^2/bird. They reported total weight of broilers per square centimetre as 1.79, 2.06, 2.46, 2.84 and 3.52 grams for 744, 651, 558, 465 and 372 cm^2/bird respectively, showing much more total weight of broilers per pen as the number of birds per pen was increased due to high stocking density.

Lei and Slinger (1970), reported the results of their studies on the energy utilisation in chicks in relation to floor space allowances and environmental temperatures in the two trials. When chicks were reared at 420, 210 and 105 cm^2/chick, during the 2-week experimental period, the results showed 49 and 18 percent higher body weight gains of chicks at 420 cm^2/chick than chicks at 105 and 210 cm^2/chick respectively at the end of 2 weeks. The low body weight gains as a result of overcrowding were attributed to a reduction in feed intake at high stocking densities which was a result of heat load and competition effects on chicks in high density pens.

Borton, Dewar, Morley and Thompson (1972), observed no systematic trend at 7, 8, and 9 weeks on average body weights of straight run flock (1 319, 1 294, 1 313 and 1 320 grams; 1 589, 1 570, 1 560 and 1 560; 1 855, 1 812, 1 824 and 1 812 grams on densities 930, 780, 640 and 470 cm^2/bird respectively for the 3-week period).

They reported a progressive reduction in body weight as the space per bird decreased at 10 weeks of age. These results are in agreement with those reported by Brooks _et al_., (1957) and Moreng _et al_., (1961), who suggested that density exerts its influence on growth rate of broilers in the 10th week probably due to increase in body weight and size and hence an apparent reduction in space per bird.

Deaton, Reece, Kubena and May (1974) compared the body weights of broilers at 8 weeks of age reared in cages at 558 cm^2/bird and on floor at 558 and 744 cm^2/bird in their first study. In their second study two trials were conducted under summer and winter conditions to separate seasonal effects on cage and floor rearing of broilers. They reported significantly heavier male caged broilers at 8 weeks of age at 558 cm^2/bird than those on the floor at the same stocking density

(1 754 grams versus 1 636 grams respectively), but were not significantly heavier than those reared on the floor at a density of 744 cm^2/bird, which had an average body weight of 1 708 grams. This was attributed to the fact that in caged broilers air circulates underneath while in the floor reared broilers because of more space allowed per bird, air circulates in the spaces between thereby cooling the conditions in the pens. On seasonal effects they observed significantly heavier caged male and female broilers at 8 weeks of age in summer than the floor reared broilers and suggested that this could be due to the fact that the caged reared broilers were removed from the heat producing litter and that the air circulating between them could prevent a stress condition. In winter the caged male broilers were significantly heavier than those on the floor at 558 cm^2/bird (1 806 grams versus 1 692 grams), but were not significantly heavier than floor reared broilers at 744 cm^2/bird, which weighed 1 790 grams on average. While the caged female broilers were significantly heavier than those at 558 and 744 cm^2/bird on the floor. The results also showed that broilers reared at 744 cm^2/bird were significantly heavier than those reared at 558 cm^2/bird (1 556.5 versus 1 505.5 grams), both on floor.

Tarrago and Puchal, (1977) reported significantly heavier birds at 5 and 8 weeks of age at a density of 833 cm^2/bird (12 birds per square metre) than those at 556 cm^2/bird (18 birds per square metre) when broilers were reared in cages. At 5 weeks of age the broilers at 833 cm^2/bird weighed 1 103.75 grams as opposed to 827.5 grams for the broilers at 556 cm^2/bird. At 8 weeks of age the heavier broilers at low stocking density weighed 2 019.75 grams as opposed to 1 891 grams at high stocking density. This therefore means the higher body weight at both stages was the favoured response of the broilers at low stocking density.

2.3 Temperature and body weight gain

On the use of 3 environmental temperatures of 60.8^0F, 75.2^0F and 89.6^0F and two dietary energy levels of 3 000 and 3 500 kilocalories of metabolisable energy per kilogram of feed, Lei *et al*., (1970), reported 7.6 and 4 percent higher body weight gain of chicks in pens at the environmental temperatures of 75.2^0F than chicks in pens at the highest and lowest environmental temperatures respectively. They attributed this to low feed utilisation efficiency due to the slow growth and increased thermogenesis on the highest and lowest temperatures respectively.

2.4 Dietary energy and growth rate

Payne and Lewis (1966) using starter diets with energy levels between 2 750 and 3 390 kilocalories of metabolisable energy per kilogram of feed, observed an increase in growth rate as nutrient density level increased. On finisher diets with slightly higher energy levels, they observed more body weight with an increase in energy concentration.

Lei et al., (1970) observed 18 percent increase in body weight gain as energy level of the diet increased from 3 000 to 3 500 kilocalories of metabolisable energy per kilogram of feed. Gooch, Summers, and Moran (1972), reported no significant differences in body weight gain at 5 weeks and observed significantly lower body weight gain of broilers fed the diets with low energy in their studies to examine the effects of various energy levels on growth of broilers.

2.5 Floor space and feed intake

The studies by Lei et al., (1970) on the effects of floor space on feed intake, showed 25 and 9.9 percent higher feed intake by chicks in pens at 420 cm^2/chick than in pens at 105 and 210 cm^2/chick respectively. The results demonstrated a progressive decrease in feed intake as floor space per chick decreased. Borton et al., (1972), observed a decrease in the amount of feed consumed per bird as the space per bird decreased from 930 to 465 cm^2/bird at 10 weeks of age. They further suggested that the minimum linear feeder space of 1.27 cm is adequate so as not to affect feed intake. Savory (1975), reported that chicks in groups of 2 and 4 consumed significantly less feed and emphasised the fact that limited feeding space results into less feed consumed.

2.6 Theory on floor space and feeding space

Hansen and Becker (1959), in their studies to examine the effects of feeding space and population density obtained results which led them to postulate a theory which stated that as more birds, feeders and waterers are added to a given floor it becomes increasingly difficult for individual birds to move about to secure feed and water. Presumably this is due to the fact that space in pens becomes limited as a result there is no free movement by the chicks. The overall results of their studies showed a depressed growth as population density was increased from 1 162.5 to 465 cm^2/bird due to a decrease in feed consumed.

2.7 Temperature and feed intake

Card *et al.*, (1966) stated that at high temperatures chicks have the desire to dissipate heat to the surroundings to cool their bodies. In this case they require less feed for maintenance and therefore consumed less feed. This statement agrees with the report by Lei *et al.*, (1970) who showed that at lower temperatures there is increased thermogenesis which requires more feed as a result of increased metabolic rates. James *et al.*, (1968), Andreda, Rogler, Featherston and Alyston (1977), reported that at high temperatures feed intake decreases because of stress which results in a loss of appetite for feed plus the fact that at these high temperatures energy requirements for maintenance are less hence less feed is consumed.

2.8 Dietary energy and feed intake

Lei *et al.*, (1970) when they fed chicks on diets containing energy levels of 3 000 and 3 500 kilocalories of metabolisable energy per kilogram of feed, reported an increase in feed intake with an increase in the energy level of the diet. However Lei, Stefanovic and Slinger (1972), on the effects of dietary energy level on feed intake amongst other parameters, reported that on energy levels of 2 040 and 3 400 kilocalries per kilogram of feed, significantly lower feed intake was observed on the high energy diet. These contra-dictory results can be attributed to the facts that in the first study reported above temperature and density were considered and that the short experimental period of two weeks could probably not be adequate to show results from which definite conclusions could be made. Farrell, Cumming and Hardaker (1973) and Farrell (1974) reported an inverse relationship between feed intake and energy concentration of the diet.

2.9 Floor space and feed efficiency

The studies reported by Brooks et al., (1957) showed that feed was utilised more efficiently in the pens where broilers were provided 930 and 465 cm^2/bird than pens of broilers at 1 860 and 1 395 cm^2/bird. Siegel et al., (1958) observed no floor space effects on feed efficiency at 4, 6 and 9 weeks of age when broilers were housed at 465, 744, 930 and 1 162.5 cm^2/bird. James et al., (1968) observed no significant differences for feed efficiency when broilers were housed at 650 and 929 cm^2/bird in the high and low temperature regimes (69.98^{0}F to 98.6^{0}F and below 69.98^{0}F respectively). Andrews et al., (1969) when testing floor spaces against energy levels, noted that broilers in pens at 744, 651 and 558 cm^2/bird ate 2.26, 2.35, 2.34 kilograms of feed to gain a unit body weight respectively, impying that feed efficiency was higher at 744 cm^2/bird.

Lei et al., (1970) reported that chicks in pens at 420, 210 and 105 cm^2/chick consumed 1.98, 2.25 and 2.60 grams of feed to gain a unit of body weight. These results showed the highest feed efficiency at the lowest stocking density. Since the chicks at the high stocking density gained body weight at a much slower rate, it was stated that these slower growing chicks used a greater proportion of their total feed intake for maintenance rather than for growth which resulted into lower feed utilisation efficiency.

On floor spaces of 930, 780, 640 and 470 cm^2/bird, Borton et al., (1972) showed a significant decrease in the amount of feed consumed per unit of body weight gain at 10 weeks of age as space per bird decreased, but observed no significant differences between consecutive treatments. They attributed the high feed efficiency at high stocking densities to the fact that densly packed birds insulate each other from heat loss and together with any reduction in the movements of birds tend to reduce caloric demand. In their summary amongst other factors they attributed improved growth rate to feed efficiency.

Proudfoot (1973) reported significantly low feed conversion efficiency at 988 cm^2/bird. Deaton et al., (1974) reported significantly low feed efficiency in caged male and female broilers raised at 558 cm^2/bird than the floor reared male and female broilers at 558 and 744 cm^2/bird but reported no significant differences between the two. In caged reared broilers the higher feed requirement per unit of body weight was attributed to feed wastage which they related to the depth of the trough and the amount of feed consumed between the feedings and lack of recycling the feed as would be the case with broilers on the floor. Savory (1975), reported that chicks in groups of 2 and 4 converted their feed more efficiently than chicks in groups of 1 and 8 chicks per cage.

Tarrago et al., (1977), reported that at 5 weeks of age, at floor space allowances of 833 and 556 cm^2/bird broilers consumed 1.83 and 1.80 grams of feed respectively to gain a unit of body weight, while at 8 weeks of age broilers at low stocking density consumed 2.07 grams as opposed to 2.18 grams being feed consumed by broilers at high stocking density to gain a unit of body weight. Thus implying that feed efficiency at 5 weeks of age was higher while it was significantly lower at high stocking density at 8 weeks of age.

2.10 Dietary energy and feed efficiency

Payne *et al*., (1966), Lei *et al*., (1970 and Farrell (1974), reported higher feed efficiency with an increase in dietary energy level. Andrews *et al*., (1969), reported no significant differences in feed efficiency between the two rations of 2 314.4 and 2 488.4 kcal/kg, but reported significantly lower feed efficiency at the dietary energy level of 2 149.4 kcal/kg.

Savory (1975) noted that birds fed on pellets converted feed more efficiently. This he attributed to the little time birds spend feeding which results in less energy expenditure and that birds fed on pellets wasted less feed through spillage while there was greater spillage on mash feed, implying that the feed efficiency was affected by energy loss and feed wastage.

2.11 Temperature and feed efficiency

James *et al*., (1968) observed no significant differences in feed efficiency at temperature regimes of 69.98^{O}F to 98.6^{O}F and below 69.98^{O}F. However these results did not agree with the findings of Lei *et al*., (1970), who reported that chicks in pens at environmental temperatures of 60.8^{O}F at 4 weeks of age consumed 2.07 grams of feed to gain a unit of body weight which was 6 and 4 percent lower than the feed consumed by chicks in pens at 75.2^{O}F and 89.6^{O}F respectively.

This therefore meant that chicks in the environmental temperatures, of 75.2^{0}F utilised their feed most efficiently. At the lower environmental temperatures, the lowest feed efficiency was attributed to increased thermogenesis while at the higher temperatures the lower feed efficiency was due to the fact that as chicks were growing more slowly more feed was partitioned to maintenance.

Andreda et al., (1977), reported higher feed efficiency at temperatures above 69.98^{0}F. and attributed this to the fact that birds at these high temperatures become meal eaters and hence converted their feed more efficiently. In addition to this, as they become meal eaters they do not behave as nibblers thereby reducing movements to the feed with a resulting reduction of energy expenditure.

3. METHODS AND MATERIALS

3.1 Plan of experiment

An experimental house at the Poultry production unit at Kabete Campus of the University of Nairobi was used for the experiments. Two main experiments were conducted each in the starter and finisher phases.

3.1.1 Starter phases of experiments1 and 2

In the starter phase of experiment 1, the objective was to examine the influence of floor space allowances on growth rate of broiler chicks. In the starter phase of experiment 2 the influences of high stocking densities were examined against two diets of low and high energy levels.

In the first study three floor spaces of 279, 372 and 465 cm^2/chick were examined up to 4 weeks of chick's age, while in the second study two floor spaces of 240 and 300 cm^2/chick were tested against 2 700 and 3 000 kilocalories of metabolisable energy per kilogram of feed up to 5 weeks of chick's age. In these studies 183 and 270 as hatched Shaver Hybrid Broiler - type chicks were used in the first and second studies respectively. In each case the day old chicks were first weighed singly and placed in two groups on a weight basis (30-34 grams and 35-40 grams). This was done to come up with an almost average group weight of chicks in each pen hence an equal average weight per chick. For the total number of chicks required in a pen, half the number was taken from each group to achieve the intended group average weight of chicks in each pen, that is; 16 chicks in pens at floor space of 465 cm^2/chick in the starter phase of experiment 1 were composed of 8 chicks from the group of chicks which weighed between 30-34 grams and the other 8 chicks from the group of chicks which weighed between 35-40 grams. The same procedure was followed in other pens at the respective stocking densities for both phases.

In the starter phase of experiment 1 the floor space allowances of 279, 372 and 465 cm^2/chick were replicated three times. While in the starter phase of experiment 2, as a result of a 2 x 2 factorial arrangement, the four treatments which resulted, were also replicated three times. In each case the treatments were assigned to the pens designed for each experiment at random using the random number tables of three digits in completely randomised designs.

As dietary energy levels formed part of the treatments in the starter phase of experiment 2, the starter diets were formulated. The low and high energy starter diets had 21 and 23 percent crude protein respectively and were formulated to have a constant calorie:protein ratio of approximately 130 kilocalories (metabolisable energy)/kilogram per percent of crude protein. The compositions of starter diets used are shown in Table 1.

3.1.2 Finisher phases of experiments 1 and 2

At finisher phases, the same number of treatments as at the starter phases were used in each case. In the finisher phase of experiment 1, the influences of floor spaces of 558, 744 and 930 cm^2/bird were examined. In the finisher phase of experiment 2, 2 floor spaces of 465 and 558 cm^2/bird were examined against the finisher diets of slightly higher energy levels of 2 930 and 3 200 kilocalories of metabolisable energy per kilogram of feed. A total of 219 and 288 Shaver Hybrid broiler finishers were used in the first and second finisher phases respectively.

In each case the broilers from one treatment at the starter phase were assigned to the corresponding treatment at the finisher phase i.e. broilers from the low, medium and high stocking densities at the starter phase of experiment 1 were assigned to the corresponding low, medium and high densities at the finisher phase of experiment 1 and the same procedure was followed in experiment 2.

As before the treatments were assigned to the pens at random in a completely randomised design. In pens where more birds were required than available, additional birds of the same age and average weight were included.

The low and high energy finisher diets used in the finisher phase of experiment 2 had 17.5 and 19 percent crude protein respectively and were formulated with calorie:protein ratios of 167.4 and 168.4 kilocalories (metabolisable energy)/kilogram per percent of crude protein respectively. The compositions of finisher diets used are shown in Table 2.

3.1.3 Data collection

In all experiments, original total group weight of birds were recorded. Body weight gain was calculated weekly as the difference between the previous and present recorded weekly group weights. Feed intake was calculated by the difference between the total feed given to the birds in each pen at the beginning of the week and the feed left over at the end of the week. Feed efficiency was calculated by dividing the total body weight gain in each pen by the total feed consumed by the broilers in each pen during the week.

This feed efficiency was calculated on the assumption that the birds consumed feed at the same rate throughout the days of the week and that all the feed not left was eaten by the birds. Mortality was recorded as it occurred.

At weeks 4 and 5 during the starter phases of experiments 1 and 2 respectively and at the end of 8 weeks in both experiments, the birds in each pen were weighed for the overall body weight. Total feed for the first and second phases in both experiments was recorded, while total feed intake for the 8-week period of experiment 2 was recorded.

3.1.4 Statistical analysis

Analysis of variance was carried out on weekly data collection between the 1st and 8th week and a separate analysis of variance was done on cummulative data at the end of the first phase and at the end of experiment 1. Duncan's Multiple Range test was used in each case to determine the treatments means which were significantly different at 0.05 probability level.

Table 1: Composition of the starter diets used in the starter phase of experiment 2

Ingredient	Low energy diet (%)	High energy diet (%)
Maize	54	50
Lard	-	5
Sunflower seed cake	12	15
Cotton seed cake	12	15
Meat and bone meal	6	6
Blood meal	-	4
Fish meal	5	3
Wheat bran	9	-
Limestone	1	1
Salt	0.5	0.5
Vit./Mineral premix[1]	0.5	0.5
	100	100

Calculated analysis

Crude protein percent	21	23
Energy (cal of M.E./kg)	2 700	3 000

[1]Premix supplied the following per kilogram feed:

Vitamin A 3600 iU, Vitamin D 900 IU; Vitamin E 2.25 IU; Vitamin K_3 0.9 mg; Vitamin B_1 0.45 mg; Vitamin B_6 0.75 mg; Vitamin B_2 5 mg; Choline chloride 135 mg; Niacin 6.75 mg; d-Ca pentothenate, 3.15 mg.

Folic acid 0.18 mg; Fe 20 mg; Mn 20 mg; Zn 175.5 mg; Cu 1.0 mg; Co 100 mg; I 500 mg and BHI 40 mg.

Table 2: Composition of the finisher diets used in the finisher phase of experiment 2

Ingredient	Low energy diet (%)	High energy diet (%)
Maize	68	60
Lard	-	6
Sunflower seed cake	12	11
Cotton seed cake	12	11
Meat and bone meal	6	6
Blood meal	-	4
Limestone	1	1
Salt	0.5	0.5
Vit./Mineral premix[2]	0.5	0.5
	100	100

Calculated analysis

Crude protein percent	17.5	19
Energy (kcal of M.E./kg)	2 930	3 200

[2]Premix composition as in Table 1.

In the second experiment, analysis of variance was conducted on the treatments. This was followed by a computation of sums of squares for main treatment effects and interactions for stocking density and dietary energy level. Duncan's Multiple Range test was used as before on the treatment means.

3.2 Management practices observed

In the trials, 9 pens each of sizes 56 x 128 cm (7 168 cm^2 each pen) and 12 pens each of sizes 59 x 102 cm (6 048 cm^2 each pen) were used in the first and second starter phases respectively. These pens were separated by partitions with a lower hardboard part up to 23 cm and an upper wire mesh part. Each pen was thoroughly cleaned and fumigated a few days before the start of the trials. The birds were kept on a litter of wood shavings which was renewed fortnightly.

The chicks were brooded under infrared lamps. Each pen was equiped with a 250 watt dull emitter infrared lamp suspended 73.5 and 75 cm above the floor in the first and second starter phases respectively. These heights gave initial brooding temperatures of $88^{0}F$ and $90^{0}F$ respectively. The lamps in each pen were raised 8.25 cm weekly in order to regulate pen temperature. In the third week each of the two adjacent pens shared one infrared lamp as an additional means of regulating pen temperature. At this time the bottom of the lamps were suspended 118.25 and 120.25 cm from the floor on the middle partitioning wire of every two adjacent pens during the first and second starter phases respectively. The infrared lamps were withdrawn 5 days before the end of the brooding or starter phase.

Commercial broiler starter feed and formulated diets of low and high metabolisable energy were supplied *ad libitum*. The feed troughs used at first were typical starter troughs with holed lids to reduce spillage and each trough was 59 cm long. Pens at low stocking density and pens at the middle and high stocking densities were each allocated one and two troughs respectively in the starter phase of the first trial and two troughs each pen in the starter phase of the second trial.

These feeders and waterers were raised from the floor in the second week to avoid further spillage and contamination with litter. In the third week the trough feeders were replaced by the tube feeders of curcumference 123 cm, one in each pen.

In the finisher phase of the first trial, 6 pens of sizes 128 x 112 cm (14 336 cm^2 each pen) each and 3 pens of sizes 186 x 122 cm (22 692 cm^2 each pen) each were used. In the finisher phase of the second trial, 12 pens of sizes 126 x 96 cm (12 096 cm^2 each pen) each were used. In both trials and in all pens new litter was replaced. At this stage linear water troughs were used to supply water to the chicks but each pen during the early stage was additionally supplied with a water fountain. The broilers in the finisher phase of the first trial continued to be fed on a commercial broiler finisher feed while the broilers in the finisher phase of the second trial were fed on the formulated finisher diets of low and high metabolisable energy levels. The birds continued to have feed from tube feeders.

4. RESULTS

4.1 Experiment 1 - Starter phase

The results of the starter phase of experiment 1 are shown in Tables 3,4 and Figure 1.

4.1.1 Average weekly body weight gain

In Table 3 are shown the average weekly body weight gains, average feed intake, feed conversion efficiency and mortality of broiler chicks from 1 to 4 weeks of age.

The results in Table 3 show consistently higher average body weight gains of 2 to 4 weeks old chicks housed at 465 cm^2/chick followed by chicks housed at 372 cm^2/chick. The 4 week old chicks in pens at 279 cm^2/chick showed a response equal to that of chicks in pens at 465 cm^2/chick. Fig. 1 illustrates the results in Table 3, showing a consistently higher body weight gain in weeks 2 to 4 by the steepness of the curve on 465 cm^2/chick, which was followed by the curve on 372 cm^2/chick and then that on 279 cm^2/chick coming last.

Table 3: Average weekly body weight gain, feed intake, feed conversion efficiency and mortality of broiler starter chicks from 1 to 4 weeks of age housed at three stocking densities of 465, 372 and 279 cm^2/chick

Parameter	Age in weeks	Stocking density (cm^2/chick)			
		465	372	279	*S.E.M.
Body weight gain (g/chick/week)	1	59.26^{a}	61.06^{b}	57.69^{c}	0.032
	2	127.08^{d}	118.94^{e}	117.95^{f}	0.04
	3	150.39^{g}	149.82^{g}	139.60^{h}	0.132
	4	208.98^{i}	193.51^{j}	198.18^{i}	0.196
Feed intake (g/chick/week)	1	94.79^{a}	106.14^{b}	101.27^{c}	0.037
	2	311.46^{d}	332.98^{e}	310.13^{d}	0.649
	3	424.38^{f}	402.10^{g}	358.08^{h}	0.13
	4	462.96^{i}	480.35^{i}	427.22^{j}	0.502
Feed efficiency	1	1.6^{a}	1.74^{ab}	1.76^{b}	0.044
	2	2.45^{c}	2.80^{d}	2.63^{cd}	0.067
	3	2.82^{e}	2.68^{e}	2.56^{e}	0.104
	4	2.23^{f}	2.48^{g}	2.16^{f}	0.05
Mortality (% and number)		2.08 (1/48)	0 (0/57)	3.85 (3/78)	

*S.E.M. - Standard error of the means.

Note: Weekly treatment means in each row with different superscripts are significantly different (P <.05).

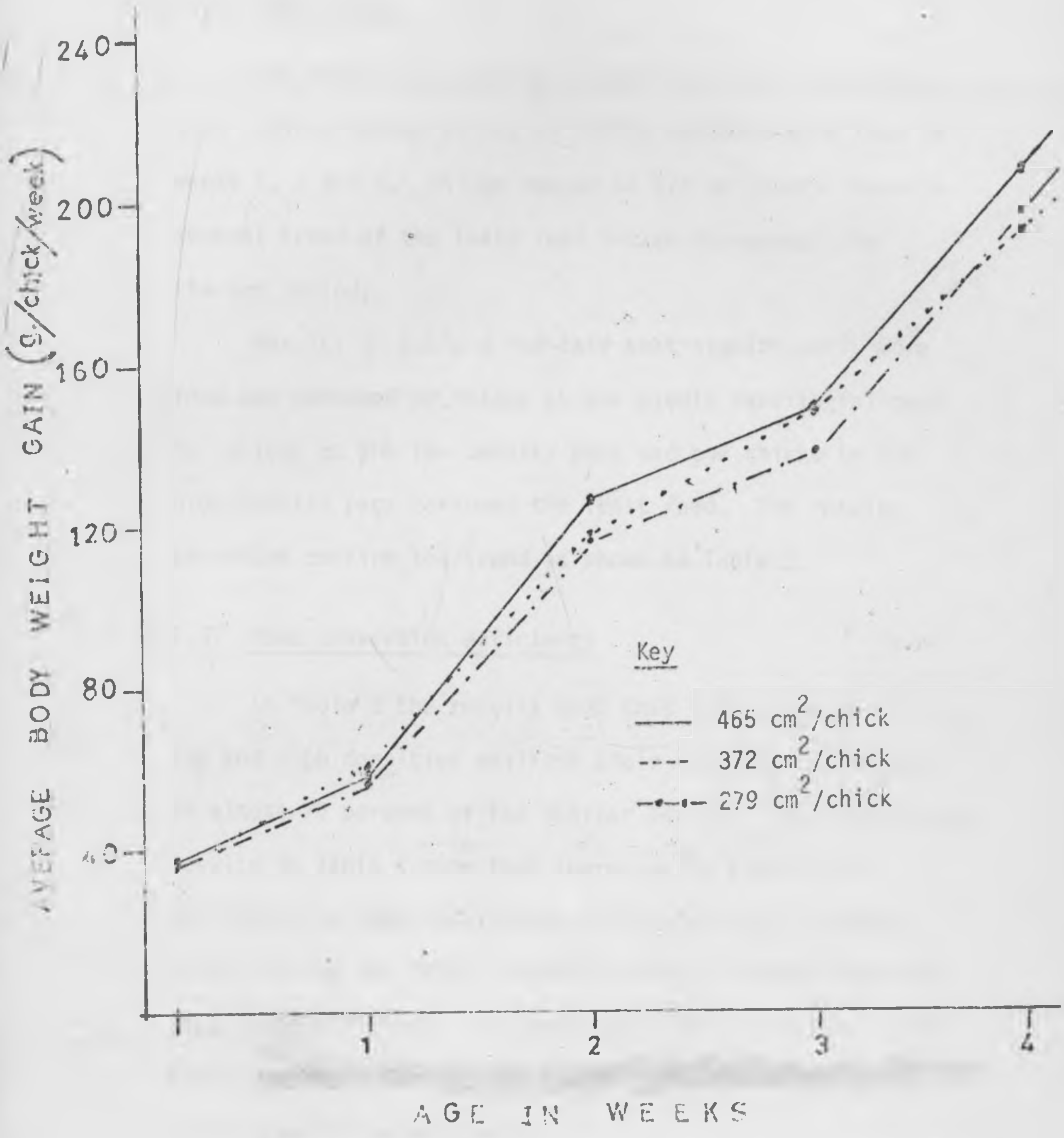

Fig. 1. Average body weight gain at the starter phase of experiment 1.

4.1.2 Feed intake

The results in Table 3 on average feed intake, show that chicks housed at 372 cm^2/chick consumed more feed in weeks 1, 2 and 4. Chicks housed at 279 cm^2/chick showed a general trend of the least feed intake throughout the starter period.

Results in Table 4 indicate that significantly more feed was consumed by chicks at the middle density followed by chicks at the low density pens and the chicks in the high density pens consumed the least feed. The results therefore confirm the trend as shown in Table 3.

4.1.3 Feed conversion efficiency

In Table 3 the results show that chicks housed at the low and high densities utilised their feed more efficiently in almost 75 percent of the starter period. The cummulative results in Table 4 show that there was no significant difference in feed utilisation efficiency at all density levels during the total brooding period. However the feed conversion efficiency was much lower for the chicks at the middle density than at the low and high densities by 15 and 20 percent respectively.

4.1.4 Mortality

Mortality occurred only in the first few days of the first brooding week and only in 2 treatments, as a result no analysis was done on the data as it was assumed that these chicks died from hatching and natural causes that were considered independent of the stocking densities.

4.1.5 Summary of results at the starter phase of experiment 1

Table 4 shows the summary of results for the total 4-week brooding period on total average body weight gain, rate of body weight gain percent which is defined as the percentage 4-week body weight gain of the body weight at the beginning of the starter phase, average feed intake, feed conversion efficiency and mortality.

The results in Table 4 show that chicks housed at 465 cm^2/chick, gained significantly more body weight ($P < .05$) than chicks housed at 372 and 279 cm^2/chick. Chicks at the latter stocking density gained the least body weight of 513 grams.

These results show a progressive decrease in body weight gain as floor space per bird decreased from 465 to 279 cm^2/chick at 4 weeks of age. The linear and quadratic components were both significant at 5 percent probability level. Similarly chicks at the low density showed the highest rate of gain percent, followed by chicks at 372 cm^2/chick and the least rate of gain percent was shown by chicks at the high stocking density.

Table 4: Average body weight gain, rate of gain percent, feed intake feed efficiency and mortality of broiler chicks for the 4 week starter period.

	Stocking density (cm^2/chick)			
Parameter	465	372	279	S.E.M.
Average body weight gain (g)	545.73^a	523.33^b	513.00^c	.169
Rate of gain percent	1451	1407	1381.8	-
Feed intake (g/chick)	1294.58^a	1321.58^b	1196.7^c	.437
Feed efficiency (g feed/g body weight)	2.37^a	2.52^a	2.09^a	.17
Mortality (% and number)	2.08 (1/48)	0 (0/57)	3.85 (3/78)	

Note: Treatment means in each row with different superscripts are significantly different ($P < .05$).

4.2 Experiment 1: Finisher phase

The results of the finisher phase of experiment 1 are shown in Tables 5, 6, 7 and Fig. 2, while Figs. 3 and 4 illustrate the results of experiment 1.

4.2.1 Average weekly body weight gain

Table 5, shows average weekly body weight gains, feed intake feed conversion efficiency and mortality of broilers from weeks 5 to 8.

The results in Table 5 show no significant difference in average body weight gains in weeks 5 and 7 for broilers in all pens. In week 6 pens of broilers at 558 cm^2/bird showed significantly higher body weight gain. However in week 7 besides the results showing no significant difference in body weight gain, there was a tendency for broilers housed at 744 cm^2/bird to show higher average body weight gain and this persisted in week 8 when the broilers showed significantly higher body weight gain ($P < .05$).

Fig. 2 illustrates that broilers in pens at 744 cm^2/bird showed a higher rate of body weight gain from week 7 and showing a small decline in week 8 but still showing best growth rate.

Table 5: Average weekly body weight gain, feed intake, feed conversion efficiency and mortality of broilers at finisher phase (5 to 8 weeks) at three stocking densities of 930, 744 and 558 cm^2/bird

Parameter	Age in weeks	Stocking density (cm^2/bird) 930	744	558	S.E.M.
Body weight gain (g/chick/ week)	5	247.3^a	234.7^a	243.3^a	1.01
	6	255.5^b	222.0^b	283.8^c	1.05
	7	279.8^d	281.03^d	194.6^d	1.47
	8	138.18^e	236.38^f	142.7^e	.52
Feed intake (g feed/chick/ week)	5	650.9^a	533.04^a	552.8^a	2.83
	6	736.9^b	699.1^b	708.4^b	3.1
	7	796.0^c	752.35^c	708.4^c	3.13
	8	891.3^d	849.12^d	839.03^d	3.87
Feed efficiency (g feed/g body weight)	5	2.59^a	2.36^a	2.24^a	.16
	6	2.87^{bc}	3.15^b	2.5^c	.16
	7	2.91^d	2.89^d	3.66^d	.43
	8	6.41^e	3.59^f	5.89^e	.47
Mortality (% and number)		1.8 (1/56)	1.45 (1/69)	0 (0/93)	

Note: Weekly treatment means with different superscrips are significantly different ($P < .05$)

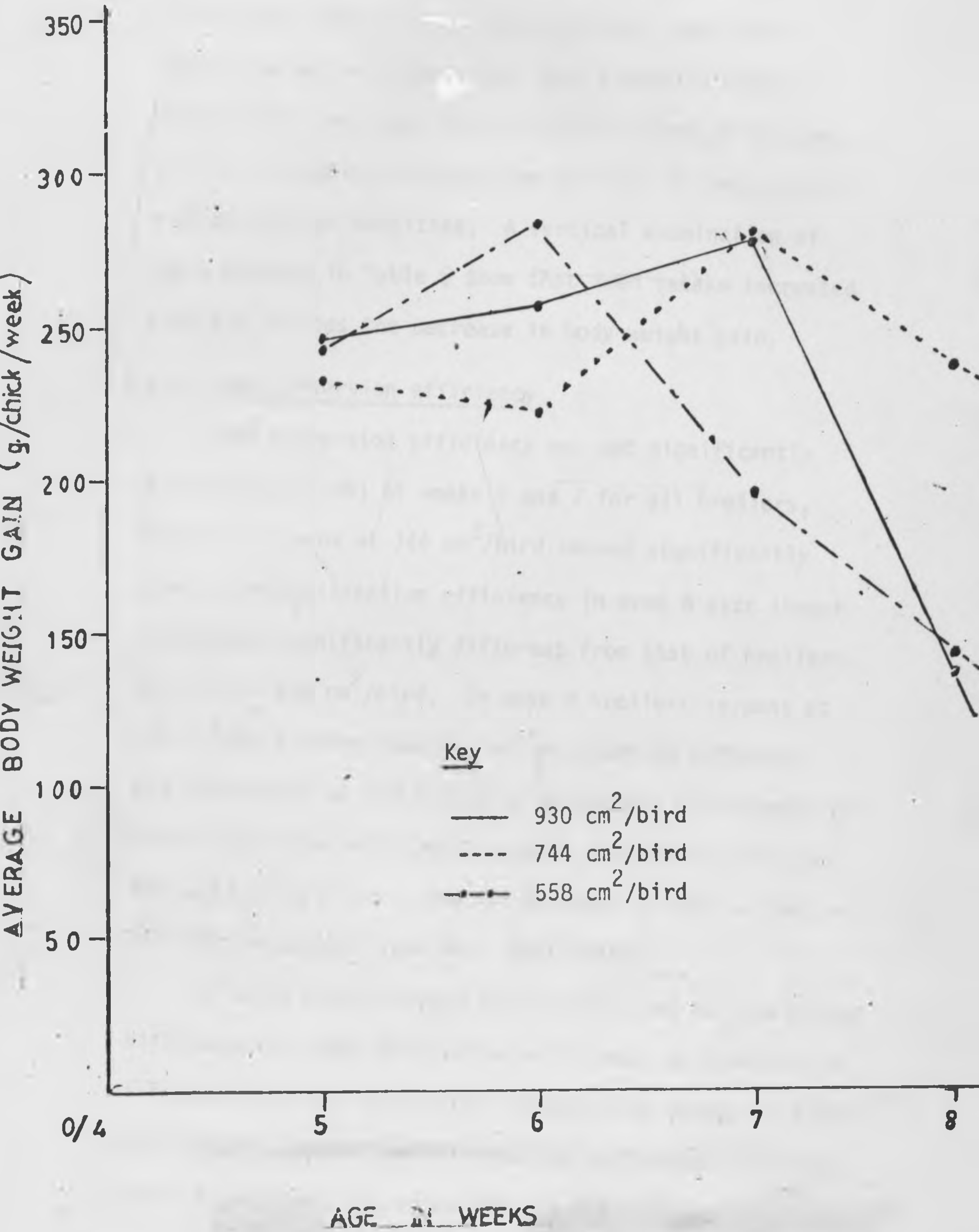

Fig. 2. Average body weight gain for the finisher broilers.

4.2.2 Feed intake

The results in Table 5 show that there was no significant difference in total average feed intake during the period under study on all density levels. However the trend was that broilers in pens at the low density consumed more feed than broilers in pens at the middle and high densities. A vertical examination of these results in Table 5 show that feed intake increased with age besides the decrease in body weight gain.

4.2.3 Feed conversion efficiency

Feed conversion efficiency was not significantly different ($P < .05$) at weeks 5 and 7 for all broilers. Broilers in pens at 744 cm^2/bird showed significantly poorer feed utilisation efficiency in week 6 even though it was not significantly different from that of broilers in pens at 930 cm^2/bird. In week 8 broilers in pens at 558 cm^2/bird showed poorer feed utilisation efficiency and there were no statistically detectable differences in feed utilisation efficiency between pens of broilers at 930 and 558 cm^2/bird. However broilers in pens at 744 cm^2/bird utilised their feed most efficiently.

In Table 6 even though the results show no significant differences in feed utilisation efficiency by broilers in all pens, broilers in pens at 744 cm^2/bird showed 14.4 and 11.6 percent higher feed utilisation efficiency than that shown by broilers housed at 930 and 558 cm^2/bird.

4.2.4 Summary of results at the finisher phase of experiment 1

Table 6 shows the average body weight gain, feed intake, feed conversion efficiency and mortality of broilers for the 4-week finishing period and the average body weight at the end of the experiment.

These results in Table 6 show that average body weight at the end of week 8 did not differ significantly. The results also show no significant differences on all parameters for the overall period of 5 to 8 weeks. However broilers in pens at 744 cm^2/bird showed 44.11 and 109.55 grams of body weight gain more than that shown by broilers in pens at 930 and 558 cm^2/bird respectively, thereby showing that the response of broilers at the middle density was higher followed by that of broilers at 930 cm^2/bird.

4.2.5 Total weight of broilers per unit of floor space (gram of broilers/cm^2)

Production weight of broilers per unit of floor space as shown in Table 7 was calculated by dividing the total body weight by the total floor area per treatment. The total production weight of broilers per square centimetre of floor space was, 1.64, 2.07 and 2.61 for 930, 744 and 558 cm^2/bird respectively, showing an increase in production weight as space per bird decrease.

Table 6: Average body weight gain, average body weight, feed intake, feed conversion efficiency and mortality of broilers for the 4-week finishing period

Parameter	Stocking density (cm^2/bird) 930	744	558	S.E.M.
Average body weight gain (g/bird)	930.00[a]	974.11[a]	864.569[a]	3.46
Average body weight (g/bird)	1529[a]	1558[a]	1437[a]	10.36
Average total feed intake (g/bird)	3100.36[a]	2858.05[a]	2808.6[a]	12.70
Feed conversion efficiency	3.33[a]	2.91[a]	3.25[a]	0.156
Mortality (% and number)	1.81 (1/56)	1.45 (1/69)	0 (0/93)	

The 4-week cummulative treatment means with different superscripts are significantly different ·t (P< .05)

Table 7: Total production weight of broilers per square centimetre of floor space (grams of broiler/cm^2) at the end of experiment 1.

Treatment (cm^2/bird)	Total liveweight (g/cm^2)
465/930	1.64
372/744	2.07
279/558	2.61

Note: Treatments are a combination of the stocking densities at starter and finisher phases.

4.2.6 Correlation and Linear regressions of body weight gain on age and feed intake

Results from the calculated correlation coefficients and linear regressions of body weight gain on time and feed intake for the three pairs of stocking densities, (from starter phase to finisher phase) of 279/558, 372/744 and 465/930 cm^2/bird in experiment 1 are shown in Figs. 3 and 4.

The calculated correlation coefficients show that there was no close relationship between body weight gain and age in weeks, body weight gain and feed intake for broilers housed at the low and high densities. On the middle stocking density, results show that variations in time and feed intake significantly contributed to variations in body weight gain and that there was linear relationship between body weight gain and time and feed intake (r = .924 and .922 respectively).

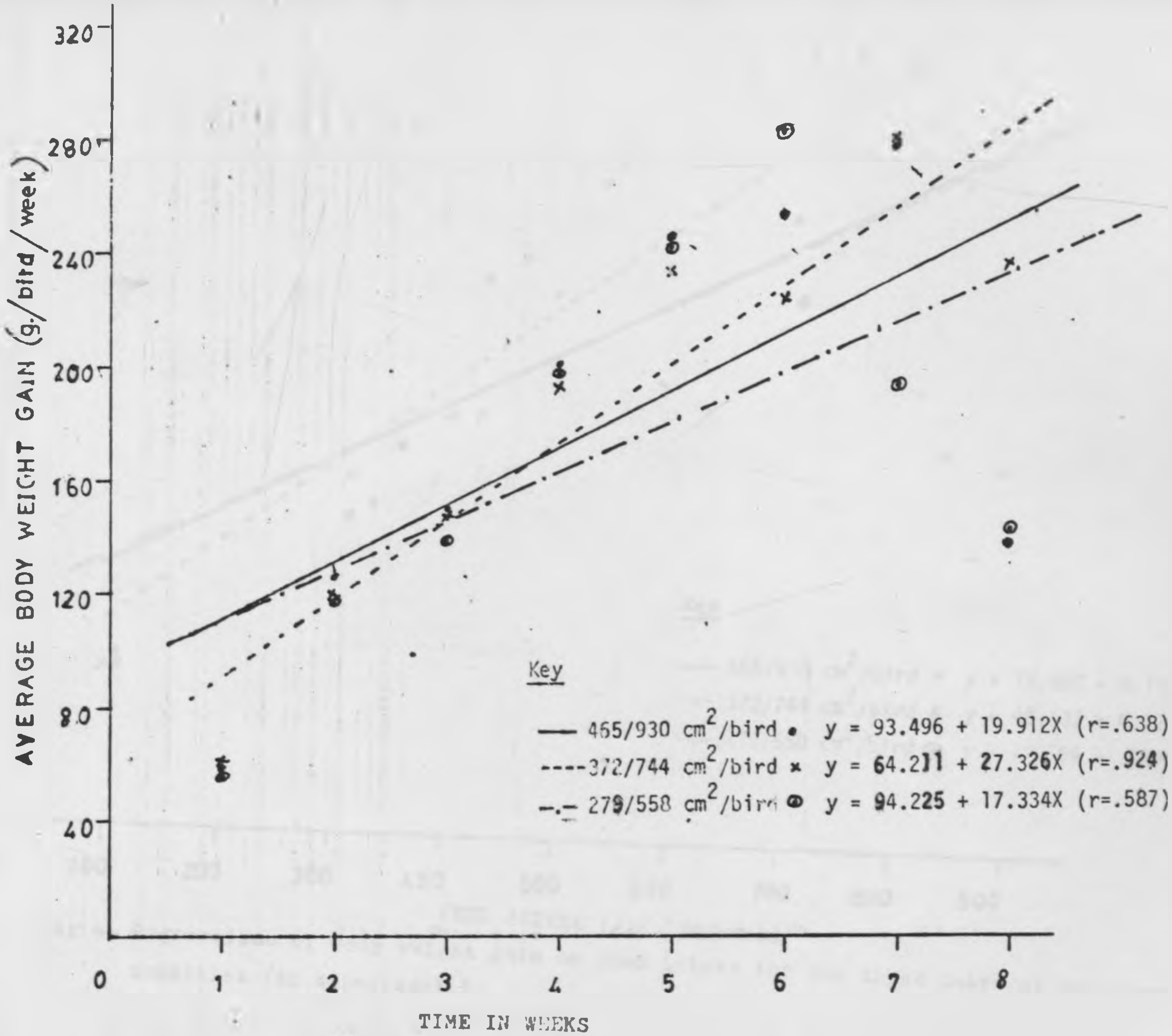

Fig 3. Regressions of body weight gain on time for the three pairs of stocking densities for experiment 1.

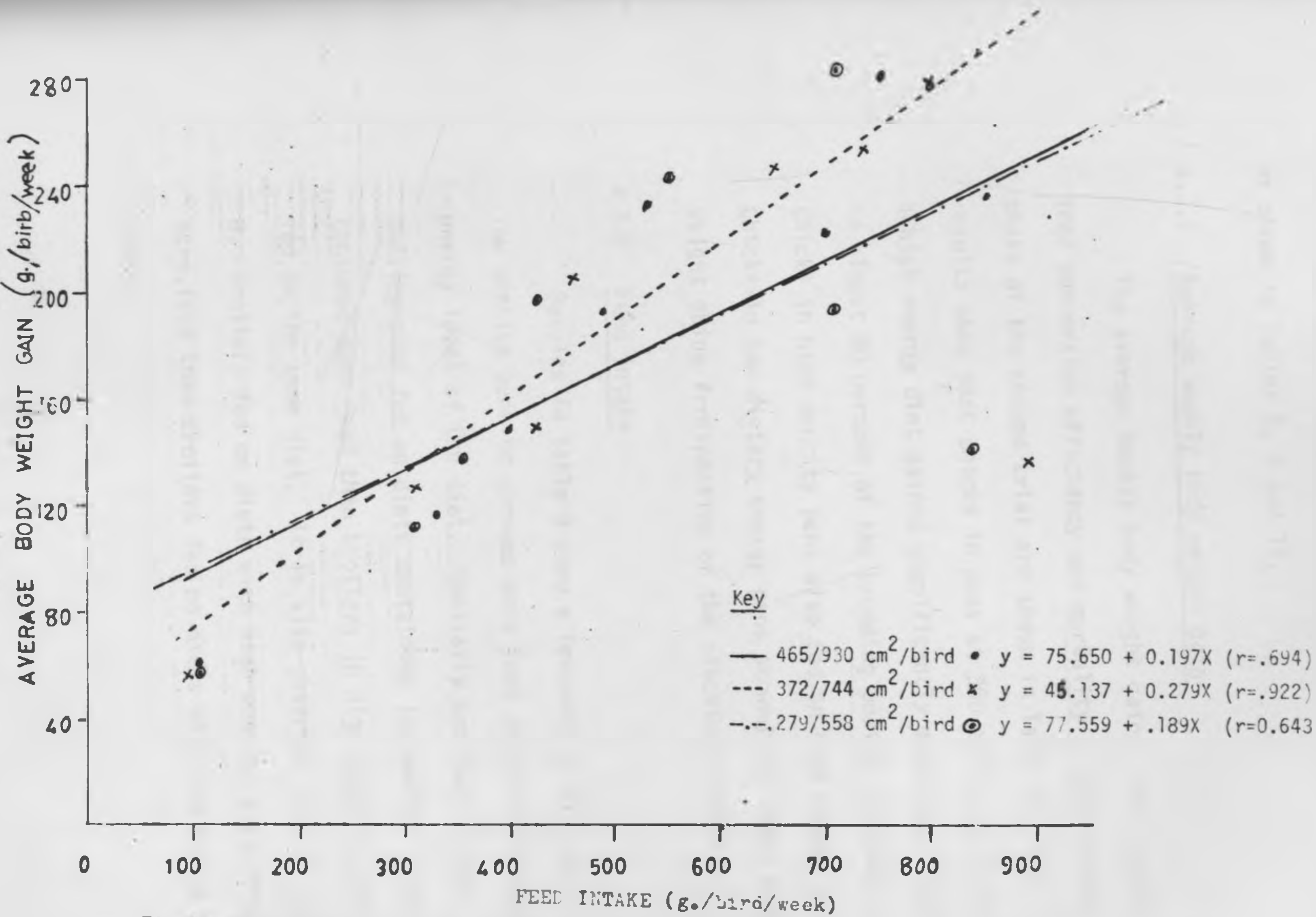

Fig 4. Regressions of body weight gain on feed intake for the three pairs of stocking densities for experiment 1.

4.3 Experiment 2: Starter phase

The results of the starter phase of experiment 2 are as shown in Tables 8, 9 and 10.

4.3.1 Average weekly body weight gain

The average weekly body weight gains, feed intake, feed conversion efficiency and mortality at the starter phase of the second trial are shown in Table 8. The results show that chicks in pens at 300 cm^2/chick fed on a high energy diet gained significantly more body weight in almost 80 percent of the brooding period followed by chicks in high density pens also fed on high energy diet. Chicks in low dietary energy pens showed the least body weight gains irrespective of the stocking densities.

4.3.2 Feed intake

Results in Table 8 show a tendency of broilers in low density pens to consume more feed despite the high energy level of the diet. Similarly broilers in low density pens fed on diets containing low energy level consumed more feed than broilers in high density pens fed on the same diet. It is also observed that in Table 8, broilers fed on diets with high energy level consumed more feed than broilers fed on diets with low energy level.

Table 8: Average body weight gain, feed intake, feed conversion efficiency and mortality of broiler chicks at the starter phase from 1 to 5 weeks for the two stocking densities of 240 and 300 cm^2/chick and two dietary energy levels of 2700 and 3000 kilocalories metabolisable energy per kilogram of feed.

Table

Parameter	Age in weeks	*TREATMENTS L.D./L.E.	H.D./L.E.	L.D./H.E.	H.D./H.E.	S.E.M.
Body weight gain (g/chick/week)	1	36.12^{a}	36.14^{a}	40.9^{a}	50.3^{b}	.058
	3	142.0^{a}	139.68^{a}	184.3^{b}	162.48^{b}	.124
	5	285.33^{a}	256.24^{a}	345.33^{b}	334.0^{c}	.256
Feed intake (g/chick/week)	1	83.6^{a}	78.83^{c}	85.52^{b}	86.55^{b}	.085
	3	357.96^{a}	336.88^{a}	419.9^{b}	355.38^{a}	.339
	5	806.0^{a}	714.66^{b}	837.5^{a}	700.00^{b}	.384
Feed efficiency (g feed eaten/g weight gain)	1	2.32^{a}	2.18^{a}	1.79^{b}	1.73^{b}	.105
	3	2.52^{a}	2.46^{a}	2.29^{a}	2.33^{a}	.204
	5	2.85^{a}	2.85^{a}	2.48^{b}	2.12^{c}	.076
Mortality (% and number)		8.3 (5/60)	2.7 (2/75)	8.3 (5/60)	9.3 (7/75)	

*L.D./L.E. - Low density : Low energy (300 cm^2/2700 kcal (M.E.)/kg). H.D./L.E. - High density : Low energy (240 cm^2/2700 kcal (M.E.)/kg). L.D./H.E. - Low density : High energy (300 cm^2/3000 kcal (M.E.)/kg). H.D./H.E. - High density : High energy (240 cm^2/3000 kcal (M.E.)/kg).

Note: Weekly and fortnightly treatment means with different superscripts are significantly different at ($P < .05$)

4.3.3 Feed conversion efficiency

In Table 8 chicks fed on high dietary energy level showed consistently higher feed efficiency throughout the brooding period than that showed by chicks fed on diets with low energy levels.

4.3.4 Rate of body weight gain percentage for the 5-week starter period

Table 9 was drawn to show the 5-week rate of body weight gain percentage as a measure of the overall gain in body weight. The rate of gain percent is defined as the percentage 5-week gain of the weight at the beginning of the starter phase. Results in Table 9 confirm the results shown in Table 8. Chicks housed at the low stocking density fed on a diet with high energy level showed a higher rate of body weight gain percentage. The chicks fed on a diet with low energy level showed the least rate of body weight gain percentage.

Table 9: The 5-week rate of body weight gain percentage for the two stocking densities of 240 and 300 cm^2/chick and two dietary energy levels of 2 700 and 3 000 kcal (M.E.)/ kg of feed.

Treatment	Total weight gain	Rate of body weight gain %
300 cm^2/2700 kcal/kg.	463.45	1 226
240 cm^2/2700 kcal/kg	432.06	1 152
300 cm^2/3000 kcal/kg	570.53	1 525
240 cm^2/3000 kcal/kg	546.78	1 458

4.3.5 Main treatments effects

The average 5-week body weight gain, feed intake, feed efficiency and mortality of broiler chicks as affected by floor space allowances of 240 and 300 cm^2/chick and energy levels of the diets of 2 700 and 3 000 kcal (M.E.)/kg are shown in Table 10.

Significantly higher body weight gain was observed with an increase in the metabolisable energy of the diet. Pens of chicks with 300 cm^2 of floor space per chick gained significantly more body weight than chicks raised in pens with floor space of 240 cm^2 per chick. Feed intake was not affected by the energy levels of the starter diets even though there was a tendency for higher feed intake with an increase in energy level of the diets. But as shown in Table 10, feed intake was significantly affected by floor space allowances. The diets with high energy level resulted into significantly higher feed utilisation efficiency and chicks in pens allowed 240 cm^2/chick utilised their feed more efficiently than chicks in pens allowed 300 cm^2/chick.

Both dietary energy levels and floor space allowance did not affect mortality. The results also show that interactions had no significant effects on all parameters, but each treatment had its effects independent of the other.

Table 10: Average 5-week body weight gain, feed intake, feed conversion efficiency and mortality of broiler chicks as affected by energy levels of the diets and floor space allowances

	Average body weight gain (g)	Feed intake (g)	Feed efficiency (g feed/g weight)	Mortality (% and number)
Energy level				
M.E./kg				
2700	453.21^{a}	1186.17^{a}	2.63^{a}	5.2^{a}(7/135)
3000	560.45^{b}	1231.25^{a}	2.21^{b}	8.8^{a}(12/135)
Floor space				
240	495.46^{a}	1139.49^{a}	2.33^{a}	8.3^{a}(10/150)
300	521.05^{b}	1295.25^{b}	2.51^{b}	6.0^{a}(9/120)

Note: Treatment means with the same superscripts on the same parameter are not significantly different (P <.05)

4.4 Experiment 2 - Finisher phase

Tables 11, 12, 13 and 14 show the results of the finisher phase of experiment 2.

4.4.1 Average weekly and 3-week body weight gain

Table 11, shows the weekly average body weight gains, the average cummulative body weight gains for the 3-week finishing period, feed intake, feed conversion efficiency and mortality of finishing broilers as affected by dietary energy levels of 2 930 and 3 200 kcal(M.E.)/kg and floor space allowances of 465 and 558 cm^2/bird. It is shown in Table 11 that body weight gains did not differ significantly throughout the weeks in the finishing period in all pens on the same dietary energy level in week 6. But with varying dietary energy levels, broilers showed a trend of more body weight gains in pens at high dietary energy levels in the later weeks. The same trend is shown on the cummulative body weight gain.

4.4.2 Feed intake

Feed intake was significantly different in week 6, with broilers in low density pens showing significantly more feed intake. In the later weeks there was no significant difference in feed intake in all pens. However the results in Table 11 show a trend of more feed consumed in pens of broilers with more space allowed per bird than broilers allowed less space per bird. The cummulative results on total feed consumed show that broilers in low density pens fed on diets with high energy consumed significantly more feed than

Table 11: Average body weight gain, feed intake, feed conversion efficiency and mortality of broilers at finishing phase from 6 to 8 weeks for the two stocking densities of 465 and 558 cm^2/bird and two dietary energy levels of 2930 and 3200 kcal (M.E.)/kg of finisher feed.

Parameter	Age in weeks	* T R E A T M E N T S				
		L.D./L.E.	H.D./L.E.	L.D./H.E.	H.D./H.E.	S.E.M.
Body weight gain (g/bird/week)	6	187.42^{a}	169.2^{a}	237.27^{b}	251.3^{b}	.44
	7	175.0^{a}	180.0^{a}	266.0^{a}	211.54^{a}	.61
	8	189.0^{a}	174.35^{a}	184.6^{a}	187.07^{a}	.44
	(6-8)	551.8^{a}	523.7^{a}	639.5^{a}	667.9^{a}	2.03
Feed intake (g/bird/week)	6	574.24^{a}	560.89^{c}	609.09^{b}	572.4^{c}	.69
	7	621.21^{a}	576.92^{a}	609.09^{a}	612.8^{a}	.61
	8	665.5^{a}	594.87^{a}	823.72^{a}	599.35^{a}	1.06
	(6-8)	1980.5^{a}	1732.69^{c}	2186.44^{b}	1800.0^{c}	.91
Feed efficiency (g feed/g weight)	6	3.06^{a}	3.39^{a}	2.62^{a}	2.41^{a}	.44
	7	3.72^{a}	2.75^{a}	2.29^{a}	3.10^{a}	.45
	8	3.21^{ab}	3.44^{ab}	4.15^{b}	2.68^{a}	.34
	(6-8)	3.26^{a}	3.24^{a}	2.86^{ab}	2.63^{b}	.17
Mortality (% and number)		1.6 (1/60)	0 (0/78)	0 (0/60)	1.3 (1/78)	

*L.D./L.E. - Low density/Low energy (558 cm^2/2930 kcal (M.E.)/kg). H.D./L.E. - High density/Low energy (465 cm^2/2930 kcal/M.E.)/kg). L.D./H.E. - Low density/High energy (558 cm^2/3200 kcal (M.E.)/kg).

H.E./H.E. - High density/High energy (465 cm^2/3200 kcal (M.E.)/kg).

Note: Weekly and cummulative treatment means with different superscripts are significantly different ($P < .05$)

broilers housed at the same stocking density but fed on diets with low energy level. No significant differences were noted in high density pens on varying dietary energy levels.

4.4.3 Feed conversion efficiency

Feed utilisation efficiency did not differ significantly in all pens in weeks 6 and 7. In week 8, broilers in high density pens fed on diets with high energy level utilised their feed more efficiently but did not differ significantly from the feed efficiency shown by broilers in pens at low and high density all fed on diet with low energy level. The cummulative 3-week results show significantly higher feed efficiency in pens at high density and on high dietary energy level.

4.4.4 Main treatment effects

The main effects of dietary energy and floor space allowances on average body weight gain, feed intake and feed conversion efficiency at the end of the 3-week finishing period of experiment 2 are shown in Table 12.

Results in Table 12 show that feed intake increased with an increase in metabolisable energy in the diet. It is also shown in Table 12 that feed intake decreased with a decrease in floor space allowed per bird. The diet with high energy was significantly more efficient ($P < .05$) than the diet with low energy level. At the end of 8 weeks, (Table 13) broilers fed on a diet with high energy level were significantly heavier than broilers fed on a diet with

Table 12: Average 5-week body weight gain, feed intake and feed conversion efficiency as affected by energy levels of the diets and floor space allowances

	Average body weight gain (g)	Feed intake (g)	Feed efficiency (g feed/g wt.)
Energy level			
M.E./kg			
2930	536.59^{a}	1840^{a}	2.30^{a}
3200	654.9 ^{a}	1970^{b}	2.75^{b}
Floor space (cm^2/bird)			
465	595.8^{a}	1766^{a}	3.06^{a}
558	596.68^{a}	1920^{b}	2.99^{a}

Note: Treatment means with the same superscripts on the same parameter are not significantly different ($P < .05$).

Table 13: Average 8-week body weight, feed intake and feed efficiency as affected by energy levels of the diets and floor space allowances throughout experiment 2.

	Average body weight ~~gain~~ (g)	Feed intake (g)	Feed efficiency (g feed/g weight)
Energy level			
*** M.E./kg			
2700/2930	1039^{a}	2992.38^{a}	2.87^{a}
3000/3200	1268^{b}	3143.62^{a}	2.46^{b}
Floor space (cm^2/bird)			
240/465	1132^{a}	2847.6^{a}	2.69^{a}
300/558	1180^{b}	3354.0^{b}	2.62^{a}

*** Energy levels and stocking densities are for the whole of experiment 2.

Note: Treatment means with the same superscripts on the same parameter are not significantly different ($P < .05$)

low energy level. Pens of broilers with more space allowed per bird showed significantly higher average body weights and more feed intake than the broilers raised in pens with less space allowed per bird. The diet with high energy level still resulted in higher feed efficiency.

4.4. 5 Total weight of broilers per unit of floor space at the end of experiment 2

In Table 14 it is shown that the total weight of broilers per square centimetre of floor space was 2.67, 2.36, 2.20, and 1.92 grams for pens of broilers at high stocking density and high dietary energy level, low stocking density and high dietary energy level, high stocking density and low dietary energy level and low stocking density and low dietary energy level respectively.

Table 14: Total production weight of broilers per square centimetre of floor space (grams of broiler liveweight/cm^2) at the end of experiment 2.

**** Treatment	Total liveweight (g/cm^2)
558 cm^2/2930 kcal/kg	1.92
465 cm^2/2930 "	2.20
558 cm^2/3200 "	2.36
465 cm^2/3200 "	2.67

****From brooding to finishing phase.

5. DISCUSSIONS AND CONCLUSIONS

5.1 Stocking density and dietary energy levels at the starter phases of broiler growth

The higher body weight gains of chicks housed at 465 cm^2/chick can possibly be attributed to the higher feed utilisation efficiency. The chicks in pens at 372 cm^2/chick showed lower body weight gains because of poorer feed utilisation efficiency. The lower body weight gains of chicks at high stocking density can probably be due to less feed intake. These results agree with the report by Lei et al., (1970), who reported higher body weight gain of chicks housed at 420 cm^2/chick, due to high feed utilisation efficiency. In the starter phase of experiment 2, chicks housed in low density pens and fed on diets with high energy level, showed higher body weight gain because of the high energy level of the diets which resulted into higher feed efficiency.

At high stocking densities in both phases, significantly less feed was consumed. Moreng et al., (1961), reported no feeder space effects on feed intake when chicks were allowed 2.54, 5.08 and 7.62 cm of linear feeder space per bird. Borton et al., (1972), reported minimum feeder space of 1.27 cm to be adequate to allow maximum feed intake. In the experiments the feeder space allowed per bird varied from 3 to 7.6 cm. It is therefore considered very unlikely that feeder space affected feed intake. However in linear feeders, 1.27 cm per chick would probably be quite adequate for they do not occupy a larger space in pens. In addition these linear feeders allow for all the feeder space to be readily seen by the chicks. Circular feeders do not allow for maximum access to the feed. Depending upon the size of the circular feeder and the size of the pen, some parts of the feeder are not readily seen by the chicks. The condition is made worse by the fact that young chicks tend to follow where other chicks are gathered together for feed, thereby not noticing the feeder space behind the feeder. According to the theory postulated by Hansen et al., (1960), with the bigger size of the circular feeders and the small sizes of the pens, it is considered most likely that chicks found it difficult to move about freely to procure feed. This possibly had an adverse effect on feed intake in the experiments with pen areas of 7 168 and 6 048 cm^2 each pen for the first and second starter phases respectively and with circular feeders with an area of 1 203.7 cm^2 each. This meant a reduction in total floor area as well as a reduction in space allowed per chick. This therefore resulted into less feeding space with an overall result of reduction in feed intake.

It could also be considered very likely that at high stocking densities the low feed intake resulted from competition effects which resulted into stronger chicks securing maximum access to the feeder space (Lei et al., 1970). These results confirm the reports by Borton et al., (1972) and Morley (1977), who stated that the amount of feed consumed to a large extent determines the rate of growth.

Energy levels of the diets did not significantly affect feed intake. The results disagree with the generally accepted principle of less feed intake at high dietary energy levels (Card et al., 1966, Lei et al., 1972, Farrell et al., 1973 and Farrell 1974). However the energy intake per unit of body weight gain irrespective of stocking density for the pens at low density and low dietary energy level, low density and high dietary energy level, high density and low dietary energy level and high density and high dietary energy level were 7.26, 7.06, 7.05 and 6.27 kilocalories per gram weight gain, showing almost constant energy intake per gram weight gain. The absence of significant differences in feed intake on the low and high dietary energy levels may mean that the 10 percent difference in energy content of the diets was probably not significant to affect feed intake but it was adequate to show significant effects on body weight gain.

Chicks at the low and high densities, utilised their feed more efficiently. The higher feed efficiency at low stocking density during the brooding period was probably due to the fact that as chicks grew faster, they required less energy for maintenance (Lei et al., 1970). It is therefore most likely that most of the energy was used for growth. At low stocking density chicks are allowed more space per bird. Considering the fact that at more space per bird, there is more movement (Hughes et al., 1975), which results in heat energy loss, it appears justifiable that this was still within the optimal range at which the chicks' movements could not result in energy loss and hence reduced body weight gain.

Chicks at the high stocking density besides consuming less feed converted their feed into body weight gain more efficiently. The lower feed requirement per unit of body weight gain can possibly be attributed to the fact that birds at high stocking density insulate each other from heat energy loss. Also at high stocking densities there is a reduction in the movements of chicks. Consequently the energy that could be lost was used for growth. These results agree with the work of Andrews et al., (1969), Borton et al., (1972) and Tarrago et al., (1977), who reported higher feed conversion efficiency at high stocking densities.

Card et al., (1966), Payne et al., (1966), Andrews et al., (1969), Lei et al., (1970) and Farrell (1974), reported higher feed efficiency at high dietary energy concentration. The results confirm the report as they show higher feed efficiency at the high dietary energy level.

The results of this study disagree with the work of Reece (1978), who proposed minimum floor space at brooding of 111 cm^2/chick for the first 2 weeks and 372 cm^2/chick from 2 to 4 weeks. If brooding is to be done in 4 weeks which is the generally recommended period, and considering the fact that floor space is not changed as chicks grow, 372 cm^2 would be considered the minimum floor space as suggested by the results.

At brooding, particularly in the early part, space allocations are not very important. During this time chicks require external sources of heat to regulate body temperatures.

This is because their thermoregulatory mechanisms are not fully developed. As the chicks grow, they need less supplementary heat following the increase in the rate of heat production. It is at this time that floor space becomes more important (Card et al., 1966). However the results of the two studies, show that chicks attained higher body weight gain at 465 cm^2/chick and that at the end of brooding, chicks housed at 300 cm^2/chick and fed on a diet containing high energy showed a 4 percent higher body weight gain than chicks at the former floor space. To meet the requirements for space allocations at the latter part of brooding, it is important that space recommendations be available which suit both early and later parts of brooding.

5.2 Stocking density and energy levels in the diet at finisher phases and at the end of the two trials

At the end of week 8, there were no significant density effects on the average total body weight of broilers in the first study. The results in the second study show significantly heavier broilers at week 8 due to floor space effects and high dietary energy level which resulted in high feed efficiency. In the first study the results agree with the reports by Siegel et al., (1958), who reported no floor space effects on 4, 6 and 9 week body weights on floor spaces of 1 162.5, 930, 744 and 465 cm^2/bird, Moreng et al., (1961), who reported inconsistency in the pattern of growth rate up to 8 weeks on the above floor spaces, James et al., (1968), who reported no significant density effects on body weight at week 8 on floor spaces of 650 and 929 cm^2/bird. Borton et al., (1972), reported that floor space allowances of 930, 780, 690 and 470 cm^2/bird exert their influence on growth in later weeks but not earlier than 8 weeks. However the results in the first study disagree with the reports by Deaton et al., (1974) and Tarrago et al., (1977). The former reported 3 percent heavier broilers reared on the floor at 744 cm^2/bird than broilers reared at 558 cm^2/bird. The latter also reported 3 percent heavier broilers reared at 833 cm^2/bird than broilers reared at 556 cm^2/bird at the end of week 8. In the second study the results disagree with the reports by the above workers, and the report by Andrews et al., (1969), who reported no significant difference in body weights of broilers in pens at 465 and 558 cm^2/bird.

On weekly basis, the broilers housed at 744 cm^2/bird showed higher body weight gain in week 8 due to high feed utilisation efficiency. Similarly the lower body weight gains of broilers in pens at 558 and 930 can possibly be attributed to lower feed utilisation efficiency. The feed efficiency in the low and high density pens was affected presumably by, activity which possibly resulted from stress and space allowance. Broilers in the high density pens developed a habit of feather pecking and appeared to be active all the time especially in weeks 7 and 8. This disturbance was possibly due to stress which most likely resulted from overcrowding (Morley 1977 and Jean et al., 1975). This finding agrees with the principle stated by Hughes et al., (1974), which was supported by Jean et al., (1974) and which states that there is some positive relationship between activity and feather pecking arising from environmental factors. Since stocking density has an influence on some environmental factors, overcrowding which is as a result of less space allowed per bird can be considered as one of these factors. According to Lei et al., (1970), the slow growth rate of chicks at 558 cm^2/bird could also probably have contributed to the low feed utilisation efficiency.

At space allowances of 930 cm^2/bird, broilers had more room to allow maximum movement as exemplified by pacing and therefore a general increase in general activity. This agrees with the findings of Hughes et al., (1974), who reported that birds spend more time pacing when the stocking rate is lower. It is therefore obvious that birds in this way spent more energy.

In the second study broilers consumed significantly more feed of high energy level. These results disagree with the reports by many workers as reported earlier who reported less feed intake at high energy concentration of the diets. Presumably the high feed intake at the high dietary energy level was due to the calorie:protein ratio. Bartov et al., (1974), reported a compensatory increase in feed intake following diets of excessively high calorie:protein ratio. This consumption is an attempt to satisfy protein needs when diets of suboptimal protein content are fed resulting in an increase in fat deposition. Payne et al., (1966) reported calorie:protein ratios of 130 on the starter diets and 165 on the finisher diets to be more than adequate. In the second study the finisher diets had calorie:protein ratios of 167.4 and 168.4 on the low and high energy diets respectively. It is therefore suggested that the high feed intake on the high dietary energy level could be due to the demand to meet protein requirements at finishing. However from the results of the 8 week experimental period less feed was consumed at high stocking density and this could have been due to the big sizes and type of feeders and small pen sizes as well as competition for feed by the broilers at high stocking density.

If the production of broiler meat has to be intensified, it would be desirable to grow more birds per unit of floor space. The results in the first study show that broilers housed at 558 cm^2/bird produced more total weight per square centimetre. Similarly, broilers housed at 465 cm^2/bird and fed on a diet with high level of energy in the second study produced 2.3 percent more total weight per square centimetre than broilers housed at 558 cm^2/bird fed on a commercial feed. Besides the adverse effects of the high stocking density on feed intake as shown in the results and as reported by many workers, the results suggest that more total weight of broilers is produced at high stocking density as long as broilers are fed on diets with high energy level. It is also suggested that broilers at high stocking density and high and low energy levels of the diets, gained from the heat energy insulation effects and high level of energy in the diets. Therefore if it can be demonstrated that the growing bird is accumulating protein satisfactorily, in other words that the weight gain [illegible] opposed [illegible] gai[illegible] in fat [illegible] is predominantly protein gain as opposed to a gain in fat then this weight of broilers per unit of floor space will prove to be a satisfactory criteria for high broiler production. This therefore emphasizes the need to determine the right stocking density with optimum dietary energy level for minimum fat deposition.

On stocking density the results seem to agree with the recommendations of Biddle (1963), Williamson et al., (1965) and Ensminger (1971) who recommended 744 cm^2/bird throughout the year and 930 cm^2/bird in the summer. The results also suggest that birds housed at 558 cm^2 or 465 cm^2/bird can perform much better along with diets of high energy levels. It is also seen from the results that density started to show its influence in week 8. According to reports by workers above, it could be suggested that these effects could continue up to later weeks and hence show pronounced effects on the body weight.

5.3 A summary of consequences of reducing floor space per bird

North (1972), reported a number of consequencies of reducing floor space per bird. The results of this study confirm his observations.

(i) At very high stocking densities, the results show that feed intake decrease.

(ii) Accordingly the results show a decrease in body weight gain as a result of decreased feed intake.

(iii) The results also show that the view of higher feed efficiency due to a reduction in floor space per bird can only be accepted when considering higher stocking densities than 558 cm^2/bird.

(iv) Feather pecking results when birds are allowed less space per bird especially in the finishing phase.

(v) There is more total weight of broilers per unit of floor space at high stocking densities.

6. SCOPE FOR FUTURE STUDIES

The climate at Kabete, due to the high altitude does not typify the tropical climate. Because of this it is considered that the results obtained might not be representative of the results that could be obtained in a true tropical environment. It is therefore suggested that the studies should be repeated in the sites which have the tropical environment clearly defined. In planning these further studies four points must be considered; the first one is to separate seasonal effects to meet the requirements of the subtropical regions which have distinct hot and cold seasons, the second point is to increase the number of treatments or replicates inorder to get a wide range of data from which to make conclusions, thirdly, pens of bigger sizes should be used and lastly the later studies must be planned to end at 10 weeks as the results of this study have shown that floor space allowance started to influence broilers' growth in week 8.

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APPENDIX

Table I: Analysis of Variance for the 4-week average body weight gain, feed intake and feed conversion efficiency.

		MEAN SQUARES		
Source	df	Average body weight gain	Average feed intake	Feed conversion efficiency
Treatment	2	17.158**	81.782**	0.0895 ns
Error	6	0.0852	0.572	0.0879

Table II Analysis of Variance for the 8th week average body weight gain feed intake and feed conversion efficiency

		MEAN SQUARES		
Source	df	Average body weight gain	Average feed intake	Feed conversion efficiency
Treatment	2	6.214**	73.85 ns	6.727*
Error	6	0.823	45.064	0.783

*Significant (P < .05)

** " (P < .01)

ns - not significant

Table III: Analysis of Variance for the 8-week average body weight.

Source	df	MEAN SQUARES Average total body weight
Treatment	2	205.75 ns
Error	6	107.277

Table IV: Analysis of Variance for the 5-week body weight gain, feed intake and feed conversion efficiency for the starter chicks.

Source	df	MEAN SQUARES Average body weight gain	Average feed intake	Feed conversion efficiency
Treatment	3	9.708**	8.493*	0.209**
Energy	1	17.465**	3.088 ns	0.519**
Density	1	11.59**	20.003**	0.0868**
En x Den	1	0.07 ns	2.388 ns	0.0086 ns
Error	8	0.392	0.864	0.0083

* Significant (P <.05).

** " (P <.01).

ns - not significant.

Table V: Analysis of Variance for the 3-week average feed intake for the finishing broilers.

Source	df	MEAN SQUARES Average total feed intake
Treatment	3	25.069*
Energy	1	15.459*
Density	1	55.987**
Energy x Density	1	3.763 ns
Error	8	2.509

Table VI Analysis of Variance for the 8-week average body weight feed intake and feed conversion efficiency for broilers in experiment 2.

		MEAN SQUARES		
Source	df	Average body weight gain	Average feed intake	Feed conversion efficiency
Treatment	3	42.5036**	64.611*	0.179*
Energy	1	90.475**	36.303 ns	0.514**
Density	1	36.925**	144.824**	0.013 ns
En x Den	1	0.1102 ns	12.706 ns	0.011 ns
Error	8	3.6875	10.3276	0.0295

*Significant (P <.05)

** " (P <.01)

ns - not significant