# THE EFFECT OF AD LIBITUM AND REGULATED FEEDING ON THE GROWTH, BODY COMPOSITION AND REPRODUCTIVE PERFORMANCE OF BROILER BREEDERS

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DEDICATED

TO

MY FAMILY

IN

BAGHDAD, IRAQ

I no longer need their consent,
but I will always need their love.

The results of an experiment are never wrong
only our interpretation

Leonardo da Vinci

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## ABBREVIATIONS

The standard abbreviations, as recommended by the British Standard Institution, B.S. 1991: Part 1 (1976) are used in this thesis, wherever found necessary, with the following additions:

A = Ad libitum

R = Regulated

L = Low feed energy level

M = Medium feed energy level

H = High feed energy level

P = Level of probability

SE = Standard Error = Residual of Mean of Sum Square

SED = Standard Error of Differences of Means

ME = Metabolisable Energy

MJ = Megajoule

kJ = Kilojoule

g = Gram

kg = Kilogram

b = bird

d = day

m = Meter

L = Litre

ml = millilitre

No. = Number

$^{o}C$ = Degree centigrade

et al. = And others

Fig. = Figure

Exp. = Experiment

% = Percentage

ANOVA = Analysis of variance

hr. = Hour

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Summary

Two experiments were conducted to investigate the effect of two feeding systems, ad libitum (A) and regulated (R) feeding on the growth and reproductive performance of broiler breeders in floor pens and in cages from day old to 55 weeks of age. The degree of restriction used was more severe than some years ago and regulation started at an earlier age.

The opening literature review deals with the management of broiler breeders, experiments to control breeding weight, the effect of nutrition on the growth, the control of feed intake in the fowl and energy requirements. In addition the factors affecting reproductive fitness of broiler breeders and responses to artificial insemination and natural mating are also reviewed.

In the first experiment the objective was to compare the growth, feed intake and body composition of females and males on A and R feeding. The starter and grower feeds contained 12.2 and 12.5 MJ ME/kg.

At 10 weeks the body weight of A birds was twice that of the R birds. This difference was maintained to about 20 weeks. Regulated females did not catch up the growth of ad libitum females while regulated males reached similar body weight to ad libitum males. At 55 weeks the body weight of the A males and females was 5.29 and 4.79 kg and for the R males and females was 4.84 and 3.51 kg. To achieve target weight with both sexes the highest level of feed restriction was 65 per cent during the growing period. The highest fat content of the carcass weight in A females was 9 times that of females on R feeding and twice more protein than thos on R, by 20 weeks of age. From 30 weeks the carcass protein of females was relatively constant, whereas in the males growth of protein continued until 40 weeks, after which it was relatively constant.

Ad libitum females began egg production 4 weeks earlier than the R females and by 55 weeks they had produced a total of 118 eggs compared with 139 eggs for the R females. Mean weight of hatching egg was 63.6g from the R females and 66.6g from the A females. Mean fertility and hatchability of egg set was 74.5 and 66.4 per cent respectively for the R group.

Regulated feeding increased the total number of chicks produced per hen (reproductive fitness) by about 60 per cent. The components of the improvement were: an increase in hen-day egg production and fertility (each accounted for 24 per cent of the improvement); an improvement in embryo viability which accounted for 9 per cent of the increase and the remaining 3 per cent was due to the increase in the proportion of settable eggs.

Second experiment was conducted to investigate the effects of dietary energy levels on feed intake, energy intake of females and to study the reproduction by artificial insemination of caged hens.

Three breeder feeds (L, M and H) containing 10.1, 12.2 and 13.3 MJ ME/kg respectively, were used. Experiment 2 was conducted in two phases which were 22 to 35 weeks (phase 1) and 36 to 54 weeks (phase 2). The feeds were offered to the ad libitum fed birds and only feed M was given to those hens fed regulated amounts of feed. At 36 weeks of age, the number of treatments was increased from 4 to 10. The 6 treatments comprised ad libitum hens changed from L to H, from M to R or from H to L (treatments LH, MR and HL) and hens on R changed from R to L, from R to M or from R to H (treatments RL, RM and RH). Daily feed intake values directly decreased as dietary energy level increased. The highest daily feed intakes were 194 and 184 g/b for hens on L and M respectively at 30-31 weeks of age while for those on H it was 165 g/b at 28-29 weeks, and, for those on R it was 181 g/b at 34-35 weeks of age. Ad libitum hens adjusted their feed intake to

dietary energy levels better than was expected on the basis of previous research by other workers. Throughout the first phase, the highest daily weight gain occurred with hens on R feeding while during the second phase it occurred with hens on RH. After 35 weeks of age hen-day production of hens on regulated feeding and those hens previously on R (RL, RM and RH) was about 19 per cent greater than ad libitum groups. The body fat content of hens previously on R did not affect their egg production. As with experiment 1, the egg weights of ad libitum fed birds was heavier than those produced from the regulated birds.

The fertility and hatchability for all hens mated with ad libitum males in cages were higher than those on the floor except those on feed H which was lower. For hens mated with regulated males the levels of fertility and hatchability were lower than those on the floor except hens on H which had a higher hatchability. The main effect of ad libitum feeding of males was to depress the reproductive performance of all females.

There was a higher mortality associated with ad libitum feeding and a high energy layers feed (H or LH groups).

## INTRODUCTION

The genetic improvement in broiler growth is still continuing and there is a close relationship between progeny size and their parents' size. The body weight of broiler breeder females under *ad libitum* feeding can reach more than 3kg at 20 weeks of age. To maintain a profitable level of reproductive performance breeders have developed breeding weights suitable for their strain in order to prevent excessive amounts of fat in the body.

Broilers are selected on early growth rate and it is evident that this genetic potential is present in the parent stock. This fast early growth rate is associated with precocity and both factors can affect adversely the performance of breeders. Research on qualitative feed restriction has been continued to develop self restricting unbalanced rations (low in energy, protein, minerals or amino acids) which when fed *ad libitum* will reduce body weight.

Most studies on quantitative feed restriction have investigated a system of daily or every other day (skip-a-day) feeding. Blair *et al* (1976) demonstrated that quantitative feed restriction during rearing resulted in a reduction in the uniformity of bird weights in the same flock.

Various nutritional methods have been employed with breeder pullets in an attempt to reduce the body weight at point of lay to improve performance during the laying period. Lee *et al* (1971a) concluded that quantitative restriction was to be preferred because of its advantageous effect of egg weight, rate of lay and fertility and it avoided the high mortality found with severe lysine restriction. Pym and Dillon (1974) provided evidence that feed restriction during the rearing period coupled with full feeding during the adult period gave superior performance.

Generally quantitative restriction of broiler breeders has been adopted in preference to qualitative restriction by breeding companies. One of the problems associated with feed restriction is that it can lead to undesirable variation in body weights.

For about 20 years broiler breeder companies have been concerned with controlling body weight during the rearing period. The representatives of the various breeding companies usually insist that their programme is the one to follow on the grounds that their birds are different from that of their competitors and therefore require a different programme. Average target body weight at the end of the laying period of the different broiler parent females from various companies' flock management literature are as follows:-

| | |
|---|---|
| Ross 1 | 3250g |
| Cobb 500 | 3320g |
| Shaver | 3280g |
| Marshall | 3395g |
| Hubbard | 3200g |
| Lohmann | 3300g |

Now the broiler breeder has become increasingly more difficult to manage during the rearing stages due to the genetic improvement in growth rate. As laying performance has gradually declined so the breeding companies have struggled with the problem and now there is a considerable variation in recommended rearing programmes.

The modern broiler is more than twice the weight at the same age as a broiler of the same strain 15 years ago (Chambers et al, 1978). The progress of the growth of the Cobb broiler is given in Table 1. As the early growth of the progeny of broiler strains

has been increased, body weight of the eight week old parent pullets has also increased. For instance over the 1954-1964 period, the eight week body weights increased by about 45 percent. During the same decade, the breeding body weight of hens has changed little, if at all (Tables 2, 3), thus indicating that a rapidly increasing percentage of total growth to breeding weight is capable of occurring during the early weeks of life. Genetically, rapid growth rate and early sexual maturity are very closely associated. This rapid early growth rate is highly desirable from the broiler growers' point of view but it is physiologically undesirable from the hatching egg producers' viewpoint because early sexual maturity results in lower hatchability.

In the last 10 years, the breeding weights have not changed, although the feed restriction programme has changed, probably with an increasing severity of restriction (J. Ewart, personal communication). Breeding weights have changed little from 1972-1980 for Ross 1. This is shown in Fig.1,2. While the breeding weight of the parents has remained relatively constant the growth potential of the broiler has been consistently increased. Therefore the level of feed restriction imposed on the growing replacement stock must have become progressively increased. The extent of restriction currently being imposed on replacement pullets has not recently been examined. The detrimental effect on reproductive fitness of parents allowed to grow to mature weight has also not been recently investigated. The main purpose of the experiments reported in this thesis was to compare the growth and reproductive performance of parents grown to mature weight and breeding weight.

Table 1

Body weight (g) progress for progeny* of broiler breeders during 1964-1981

| Weeks | 1964 | 1974 | 1981 |
|---|---|---|---|
| 5 | 727 | 1227 | 1207 |
| 7 | 1318 | 1682 | 1984 |
| 9 | 1909 | 2227 | 2676 |
| 10 | 2136 | 2455 | 2982 |

From Cobb Company

*Females and males as hatched

Table 2

The change in body weights for females and males during the decade 1955-1964 at eight weeks of age

| | Average body weight (kg) | |
|---|---|---|
| Year | Female | Male |
| 1955 | 1.16 | 1.51 |
| 1956 | 1.15 | 1.43 |
| 1957 | 1.25 | 1.55 |
| 1958 | 1.29 | 1.61 |
| 1959 | 1.42 | 1.78 |
| 1960 | 1.45 | 1.80 |
| 1961 | 1.51 | 1.88 |
| 1962 | 1.66 | 2.06 |
| 1963 | 1.63 | 2.03 |
| 1964 | 1.68 | 2.10 |
| Change in body weight | 0.52 | 0.59 |

## (1) General view of management of broiler breeders to attain breeding weights

Broiler breeder profitability is dependent upon their egg production, hatchability and feed consumption; these factors are affected by management of the bird before maturity.

The majority of workers who have reported experiments on restricted feeding have taken the food consumption of fully fed controls as a basis for allocating food to the restricted groups (see review by Lee et al, 1971a).

Research by other workers was initiated to study the energy requirements and methods of regulating the feed intake of broiler breeder strains. It is generally accepted that regulated feeding of broiler breeder stock has to be used to control body weight and obesity at point of lay. It is also important to regulate the feed intake of most broiler breeder stocks during the laying period to limit weight gain and to get high rates of egg production.

Target body weights for age of two stocks of broiler breeders are given in Table 1. Breeding companies believe that the given target weights at point of lay are the most suitable for high performance of their broiler breeder.

Table 1

The target body weights from two breeders for both sexes (g)

| | Ross 1 Parents* | | Marshall M Parents* | |
|---|---|---|---|---|
| weeks | female | male | female | male |
| 2 | 165 | 198 | - | - |
| 6 | 595 | 820 | 540 | 907 |
| 8 | 795 | 1127 | 726 | 1089 |
| 10 | 995 | 1402 | 907 | 1270 |
| 12 | 1175 | 1655 | 1089 | 1451 |
| 14 | 1335 | 1905 | 1270 | 1724 |
| 16 | 1475 | 2145 | 1451 | 1996 |
| 18 | 1620 | 2360 | 1633 | 2268 |
| 20 | 1790 | 2550 | 1814 | 2540 |

*Data obtained from the respective company stock management guides.

The basic information required for regulated feeding is given in Table 2. This consists of a statement of the amount of total protein and metabolisable energy (ME) required per bird per day. The males have the same feed allowance as a female after the mating age (Table 3).

Table 2

The feed intake (g) for two breeders for both sexes

| week | Ross 1 Parents | | Marshall M Parents | |
|---|---|---|---|---|
| | female | male | female | male |
| 0-2 | Ad lib. | | Ad lib. | |
| 3 and 4 | 26.5 | 27.5 | 36 | 41 |
| 5 and 6 | 42.5 | 44.5 | 41 | 45 |
| 7 and 8 | 56.5 | 60.0 | 45 | 50 |
| 9 and 10 | 67.5 | 73.0 | 50 | 54 |
| 11 and 12 | 74.0 | 81.5 | 54 | 59 |
| 13 and 14 | 75.0 | 84.5 | 59 | 63 |
| 15 and 16 | 75.0 | 87.0 | 63 | 68 |
| 17 and 18 | 76.0 | 92.0 | 68 | 73 |
| 19 | 81.0 | 101.0 | 73 | 77 |
| 20 | 85.0 | 109.0 | 77 | 77 |

Table 3

Feed intake (g) during the laying period

| week | Ross 1 Parents female and male | Marshall M Parents female and male |
|---|---|---|
| 21 | 93 | 86 |
| 22 | 101 | 95 |
| 23 | 115 | 108 |
| 24 | 127 | 122 |
| 25 | 137 | 136 |
| 26 | 148 | 150 |
| 27 | 160 | 159 |
| 28 | 167 | 163 |

Table 3 continued

The composition of the feeds

| | Protein g/kg | | ME MJ/kg | |
|---|---|---|---|---|
| Feeds | Ross 1 | Marshall | Ross 1 | Marshall |
| Starter | 190 | 180 | 11.5 | 11.8 |
| Grower | 150 | 150 | 11.5 | 11.4 |
| Breeder | 155 | 170 | 11.5 | 11.5 |

The feed restriction of poultry employed by various investigators has usually begun no earlier than six weeks, and more commonly after eight to twelve weeks of age. It is likely that restricted feeding of pullets was not done earlier than six weeks because of concern that restriction during the starting period would have negative consequences. It was recognized that nutrient requirements decline during the growing and development phases. In contrast, the restriction of broiler breeders could be applied earlier than six weeks of age. Three weeks(Isaacks et al., 1960) to seven weeks of age (Lee et al, 1971a) has been recognized as a safe point to start feed restriction when breeder pullets are fed ad libitum. Their feed consumption reaches about 75 g/b·d from three to four weeks of age and more than 100g after seven weeks of age. To achieve a relatively low body weight the degree of restriction, if started at seven weeks, should be very severe and if it started at two weeks, will be mild restriction.

The feeding plan for regulated birds was to provide feed weekly so that the birds followed the target weight guide for the stock. When the actual weight of birds is heavier than the target weight, they will be given the same amount of feed as the previous week. When the actual weight is lighter than the target weight, the amount of feed given is as for the following week to allow growth to catch up. The

purpose of increasing or decreasing feed intake is to achieve actual body weights similar to the target weights (see Table 1:6).

Satisfactory results are obtained with this system of controlling body weight in the rearing period by regulating feed intake of the birds. Few experiments have extended the study of regulated feeding into the laying phase. Sherwood et al (1964) reported that restricting feed intake during the rearing and the laying period resulted in a lowered production of about 3.7-13.7 per cent, depending on the degree of restriction, compared with ad libitum fed birds. There is little information available as to the effects on the breeders' performance of feed regulation during the rearing and the laying periods. Most of the research work on broiler breeders has been with restricted feeding either during the rearing period, or, during the laying period (see Table 4).

(2) Experiments to control breeding weight

Various systems of controlling food intake during the rearing period have been studied and reviewed by Aitken et al, (1963), Fuller et al (1970), Lee et al (1971a), Blair, (1972) and Van Wambeke, (1977).

(a) Body weight and sexual maturity

Systems controlling the food intake of birds have been developed to improve performance and food utilisation of laying hens, breeders and turkeys. Early studies involving feed restriction were done with the aim of reducing food cost. However in recent years, the studies investigated ways to control feed intake to improve performance, food utilisation and control body weight, particularly for meat-type birds. Various systems of controlling food intake during the rearing or laying period have been studied by many workers.

Table 4. A summary of research showing the effect of feeding system on the performance of broiler breeders.

| Bird type | Amount of Restriction of *ad libitum* | Effects during the rearing period | Effects during the laying period | Workers |
|---|---|---|---|---|
| Broiler hens | About 21% during 3-21 weeks | Body weight at 21 weeks reduced by 16-17%<br>Age at 50% production increased by 6-7 days.<br>Increased mortality of 0.8-10.5% | % mortality increased by 2-7%<br>Settable eggs increased by 3-10.5% | Isaacks *et al* 1960 |
| Broiler hens | 5.3% during 11-23 weeks | Body weight at 23 weeks reduced by 14.7% | % egg production increased by 3.3%<br>% mortality reduced by 3.3%<br>Final body weight reduced by 6% | Summers 1967 |
| Broiler hens | About 45% during growing period | Body weight at 24 weeks reduced by 51%<br>Age at 30% production increased by 24 days | 6.4% more settable eggs per hen | Harms *et al* 1968 |
| Broiler hens | a-23% during 8-23 weeks<br>b-21.9% during 24-55 weeks | a-body weight at 23 weeks reduced by 16%<br>b-none | a-none<br>b-body weight at 65 weeks reduced by 18%, decrease of 9% in egg production of hen previously fed *ad lib.*, egg size reduced by 2g. | Schumair & McGinnis, 1969 |
| Broiler hens | About 23% during growing period | Reduction in adiposity of 5% delay sexual maturity of about 6 weeks | Increase in number of eggs up to 23%, increase in egg weight up to 8.7% | Fuller *et al* 1970 |
| Broiler hens | a-10% during 6-22 weeks<br>b-30% during 6-22 weeks | a-body weight at 22 weeks reduced by 5.3% mortality decreased by 0.3%<br>b-body weight at 22 weeks reduced by 8.8% mortality decreased by 0.6% | a-% egg production increased by 3.1% settable eggs increased by 4% fertility increased 4.4% mortality decreased by 4.8% body weight at 60 weeks decreased by 5.2%<br>b-egg production increased by 2.4% settable eggs increased by 4% fertility increased by 4.2% mortality decreased by 2% body weight at 60 weeks decreased by 7.2% | Lee *et al* 1971 |

continued....

| Bird type | Amount of Restriction of *ad libitum* | Effects during the rearing period | Effects during the laying period | Workers |
|---|---|---|---|---|
| Broiler hens | 25% during 6-22 weeks | Body weight at 22 weeks reduced by 23%<br>Mortality increased by 7%<br>Delayed sexual maturity at 5% production by 22 days | Egg production increased by 3.3%<br>Settable eggs increased by 2.5%<br>Mortality increased by 4%<br>Hatchability increased by 6% | Watson and Pyne 1972 |
| Broiler hens | 20% during rearing<br>40% during rearing | a-mortality increased by 2.5% sexual maturity at 20% production delayed about 4 days<br>b-mortality increased by 1.8% delayed about 14 days | a-egg production increased by 4%<br>b-egg production increased by 5.8% | Pym and Dillon 1974 |
| Broiler hens | 20% during<br>30% rearing<br>40% period | a-body weight at 22 weeks decreased by 16%<br>b-body weight at 22 weeks decreased by 23%<br>c-body weight at 22 weeks decreased by 32% | a-% egg production increased by 8.6%<br>b-% egg production increased by 7.2%<br>c-% egg production increased by 8.4% | Watson 1975 |
| Heavy layer hens | 10.9% during the laying period | - | Mortality increased by 4.1%<br>Final body weight reduced by 3.2% | Aitken *et al* 1963 |
| Broiler hens | 15% during laying period | - | Egg production reduced by 7%<br>Mortality increased by 2.2%<br>Hatchability decreased by 2.5% | Standlee 1963 |
| Broiler hens | About 23% during 8-26 week period | Reduced growth<br>Delayed maturity | None | Howes & Cottier 1964 |
| Broiler hens | a-15% in laying period<br>b-27% in laying period | -<br>- | a-egg production reduced by 3.7% chicks/hen increased by 6%<br>b-egg production reduced by 13.7% chicks/hen reduced by 18% | Sherwood *et al* 1964 |

Quantitative regulation is the method most widely studied by researchers. Lee et al (1971b) established the relationships between the severity of restriction, body weight and age at sexual maturity. The earlier the food regulation is introduced the more the reduction in body weight and delay in sexual maturity. The more severe the food restriction the lower the body weight. Watson and Payne (1972) found that the body weight reduction was directly proportional to the degree of restriction during 6-22 weeks of age.

Voitle et al (1974) reviewed the literature concerning various methods of feed and nutrient restriction for delaying sexual maturity. It was found that the skip-a-day programme was the most effective in controlling body weight at 24 weeks of age and subsequent age of sexual maturity. Also Harms et al (1979) studied various methods of feeding growing breeders such as full fed, skip-a-day, continuous low protein and modified skip-a-day. They reported that birds grown on the skip-a-day program performed better than those grown on the other treatments.

Other methods of regulating nutrient intake have been investigated. Experimental and practical application of energy limitation to broiler breeders or heavier strains has been successful. Peters et al (1972), found that the body weight of restricted birds on low energy feed was 14 per cent less than that of ad libitum fed birds during the rearing period. Chaney et al (1975) reported that 20 per cent reduction in energy intake of broiler breeder hens caused a reduction in body weight of about 12 per cent of full fed birds.

Low energy diets have been used on the basis that their bulkiness may decrease feed intake. However, the effect of reductions in dietary energy content tend to be reduced by the compensatory increase in feed intake so that unless very low energy

contents are used, energy intake is not significantly reduced. Waldroup et al (1976) found that pullets fed a grower diet diluted with ground rise hulls compensated in feed intake to such an extent that even a 50:50 dilution was not sufficient to control body weight. Wilson et al (1971) found that diets containing 90g/kg protein or less resulted in a delay of sexual maturity. Also Harms et al (1968) found that broiler pullets fed ad libitum on a diet containing 100g/kg protein delayed sexual maturity of pullets by 12 days compared with others fed on a diet containing 160g/kg protein. Luther et al (1976) found that environmental temperature and photoperiod had an effect on the food intake of pullets fed low lysine diets.

Generally, growth rate is depressed when diets low in essential nutrients are fed. It is interesting to know which nutrients are being limited in the various controlled feeding systems. Most forms of dietary restriction involve a reduction in energy intake. A high correlation exists between energy intake, growth rate and age at sexual maturity, when quantitative food restriction is practised or low energy diets are fed. Pearson and Shannon (1979) listed some consequences of food restriction in the rearing period as follows:

Reduced body weight at the end of rearing.

Reduced fat deposition.

Delayed sexual maturity.

Increased mortality in rearing period.

Reduced food costs.

Increased rate of lay in first and subsequent years.

Increased average egg size in lay.

Increased number of chicks hatched in breeding birds.

Reduced mortality in laying period.

Generally feed restriction causes a depression in weight gain and changes body composition. The severity of restriction may be measured by the rate of gain or loss of body weight during that period. Retarded growth is influenced not only by severity but also by the duration and stage of development of the animal at the time when under-nutrition is applied.

(b) Mortality

Most workers have found a higher mortality during the rearing period with restricted feeding than with ad libitum feeding. Pym and Dillon (1974) found that the mortality was directly related to the current plane of nutrition and to the plane of nutrition during the rearing period, body weight and fat deposition as well as metabolic heat were thought to be involved. However, mortality during the laying period is generally lower in restricted birds than in those fed ad libitum during the rearing period (Sherwood et al 1964, Summer et al 1967, Lee et al 1971 and Watson and Payne 1972). Mortality during the laying period may be increased by feed restriction throughout this period (Isaacks et al 1960, Aitken et al 1963, Standlee 1963 and Peters, Davy and Griffin 1972).

(3) The effect of nutrition on the growth

(a) Growth

McCance (1977) reported there are two critical periods in the development of all animals, which can influence their future behaviour and growth. In the rat, one of these is the first week after birth, which corresponds to the fourth to seventh month of foetal life in man and half-way through gestation in the guinea pig. The second critical period is at sexual maturity. There are many factors which control growth, one of these is genotype which affects body size, another one is nutrition. When an under-nourished child is given

access to ample food, it usually begins to eat according to its size, not its age, and gains weight rapidly. Catch-up growth and compensatory growth in animals is under the control of the hypothalmus, the integrating centre in the brain which co-ordinates nervous messages to and from the body and which, among many other functions, regulates the food eaten in relation to size, rate of growth, age and activity.

The growth catch-up is not always complete however, it depends on the duration of the under nutrition and on the age and sex of the animals (McCance, 1977).

If some animals eat more than others, they could be up to three times heavier at weaning. If after weaning all the animals are allowed to eat ad libitum, the smaller ones do not always catch up with the larger ones (Widdowson and McCance, 1963).

Sexual maturity depends more upon the body attaining a certain mass and composition than upon chronological age (Widdowson and McCance, 1960).

McCance (1977) highlighted two facts regarding the central part played by age on the growth of animals. The first is that the rate of cell division declines steadily from conception and ceases at a certain chronological age which is peculiar to each species and perhaps each organ. The second is that it is always the later stages of growth which are the first to fail during any form of under-nutrition.

Auckland (1970) in his review, stated that if the restriction continued for a long time, it was impossible for the animal to catch up with control feed. Many chemicals, organic and inorganic, are involved in the complex anabolic and catabolic reactions which occur during the growth of animals. Any lack or deficiency of essential nutrients will affect the growth and performance of the chicken. If there is a severe deficiency of a single essential nutrient the animal

will lose weight and eventually die. Growth rate and efficiency of food utilisation depend upon the diet which provides the essential nutrient in appropriate forms and in the amounts needed for efficient functioning of all body cells, especially those involved in the growth process. The young chicken needs all nutrients such as metabolisable energy, amino acids, vitamins and minerals for growth and maintenance in a greater concentration than adult chickens. Scott (1977) found maximum growth and efficiency of utilization in chicken is achieved when diets of appropriate energy content are precisely balanced in essential amino acids, minerals and vitamins.

(i) Growth of the skeleton

Bone has intrinsic powers of self differentiation, with the proportion of the skeleton being determined mainly by hereditary, other factors such as nutrition, and hormones modify this by varying degrees (Wise, 1977).

As bone is rigid, linear growth in long bone depends upon the cartilageous growth plates at the end, between the epiphyses and diaphysis.

During embryonic and post-natal growth, bones grow at different rates so that conformation changes with age. The rate of skeletal growth is determined by plane of nutrition. Osbourn and Wilson (1960) suggested that mild feed restriction had little effect on the skeletal growth of cockerels. Auckland (1972) found that low protein diets caused reduced skeletal proportions in fast-growing turkeys but did not so affect a slow-growing strain. At equal body weights however the skeletal systems of broilers were both qualitatively and quantitatively less mature than those of layers (Wise, 1970).

(ii) Growth of protein

Muscle is a meat and is one of the main forms of protein. Goldspink (1977) reviewed growth of protein. During embryological development, muscle fibres are formed from precursor cells called myoblasts, which align in rows and fuse to form multinucleated myotubes. These myotubes synthesise the myofibrillar protein (myosin, actin, trypomyosin, troponin etc.) which are accumulated into myofibrils. In most muscles of mammals and birds the number of fibres does not increase after embryonic differentiation of the tissues are completed.

The number of myotubes and also the number of muscle fibres formed are under genetic control. Young muscles increase in the number and length of myofibrils during growth. Other cellular components such as the mitochondria and soluble enzymes increase, however, during postnatal growth muscle fibres also increase greatly in length. This increase is associated with an increase in the number of sarcomeres in series along the myofibrils and also along the length of fibres.

The muscle increasesin width and length during post-natal growth. The increase in fibre size during post-natal growth is due mainly to synthesis of contractile proteins.

(iii) Growth of fat

Pfaff and Austic (1974) concluded that the pattern of the growth of the fat pad in chicks is similar to that of other animals reported by Hirsch and Han (1969), Johnson and Hirsch, (1972). Pfaff and Austic found that the fat pad declines slightly between the second and seventh weeks of age and then increases several-fold until 16 weeks of age. Hyperplasia

occurs until a period in development after which fat pad mass increases mainly by cell hypertrophy. This occurs at approximately 12-16 weeks in white leghorn pullets. Fat pad cellularity begins to increase in the fourth week of life, but total lipid accumulation in fat pad lags behind body growth until after the sixth week of life. The most dynamic stage of fat pad growth occurs between the sixth and sixteenth week of age, when the rate of fat pad growth exceeds the rate of body growth by a factor of 10-12 fold.

The accumulation of fat within adipose tissue depends upon the uptake of circulating lipid synthesised in the liver or directly from the diet (Evans, 1977).

The amount of fat is varied, depending upon factors which affect the state of development of the tissue, such as the age of the animal, differences in the composition of diet and the amount of nutrients consumed.

Obesity is a problem where food supplies are more than adequate for normal growth and development. It occurs in domestic animals as well as man, and has stimulated much research into the regulatory mechanisms of food intake and lipogensis.

Early studies have shown that cellular development of adipose tissue may contribute to the onset of obesity. Proponents of this theory demonstrated that "juvenile onset" obesity in man is usually associated with excessive cellularity as well as hypertrophy of fat cells (Hirsch and Knittle, 1970).

Supporting evidence is provided by studies with rats (Hirsch and Han, 1969) and mice (Johnson and Hirsch, 1972) which demonstrated that adipose tissues of some genetically obese strains seem to contain excessive cell numbers. Nutritional restriction of developing rats, moreover, has produced leaner carcasses with apparently reduced adipose cell numbers (Knittle and Hirsch, 1968).

There have been no studies conducted on the growth of fat tissue in broiler breeders.

(b) The growth curve.

The growth curve of all animals is approximately S shaped. The curve starts from nearly zero and body weight then increased gradually to some mature body weight. During the accelerating phase of growth from hatching, the point of inflexion in the growth curve is the point at which growth is maximum (Wilson, 1977). In this stage of growth body weight is rate increasing progressively with age, but at the second stage (peak of the curve) growth begins decreasing and continues till body weight becomes approximately constant. In this stage absolute growth rate decreases while body weight continues to increase (Auckland, 1970).

The joining point between these two stages is called the point of inflection and absolute growth rate reaches a maximum. The shape of the curve appears in general terms to be the result of growth accelerating and deccelerating (Fig. 1).

Wilson (1977) indicated that the growth of males increased more rapidly than females and is related to the physiological and genetical ability of males to grow faster.

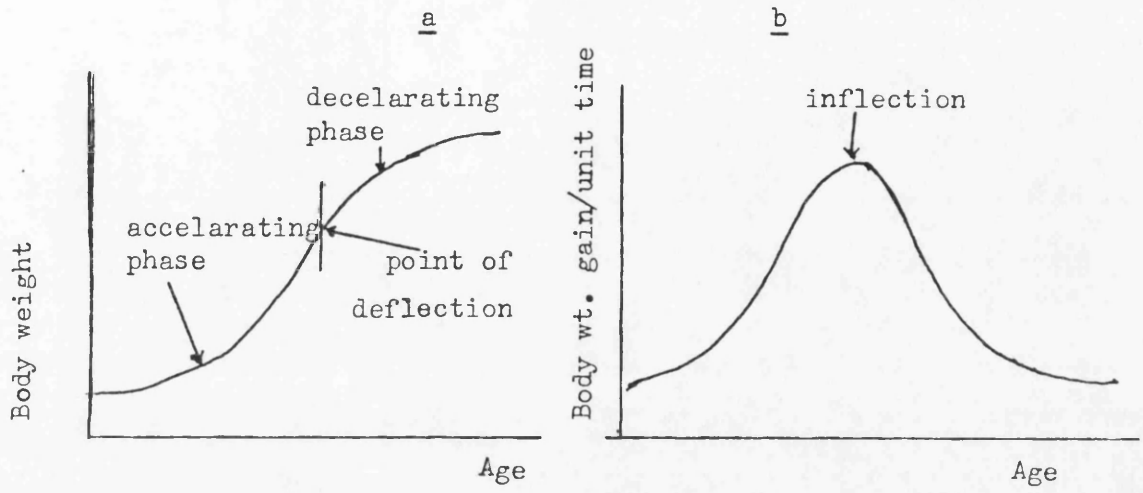



Fig. 1 The general curve of animals:

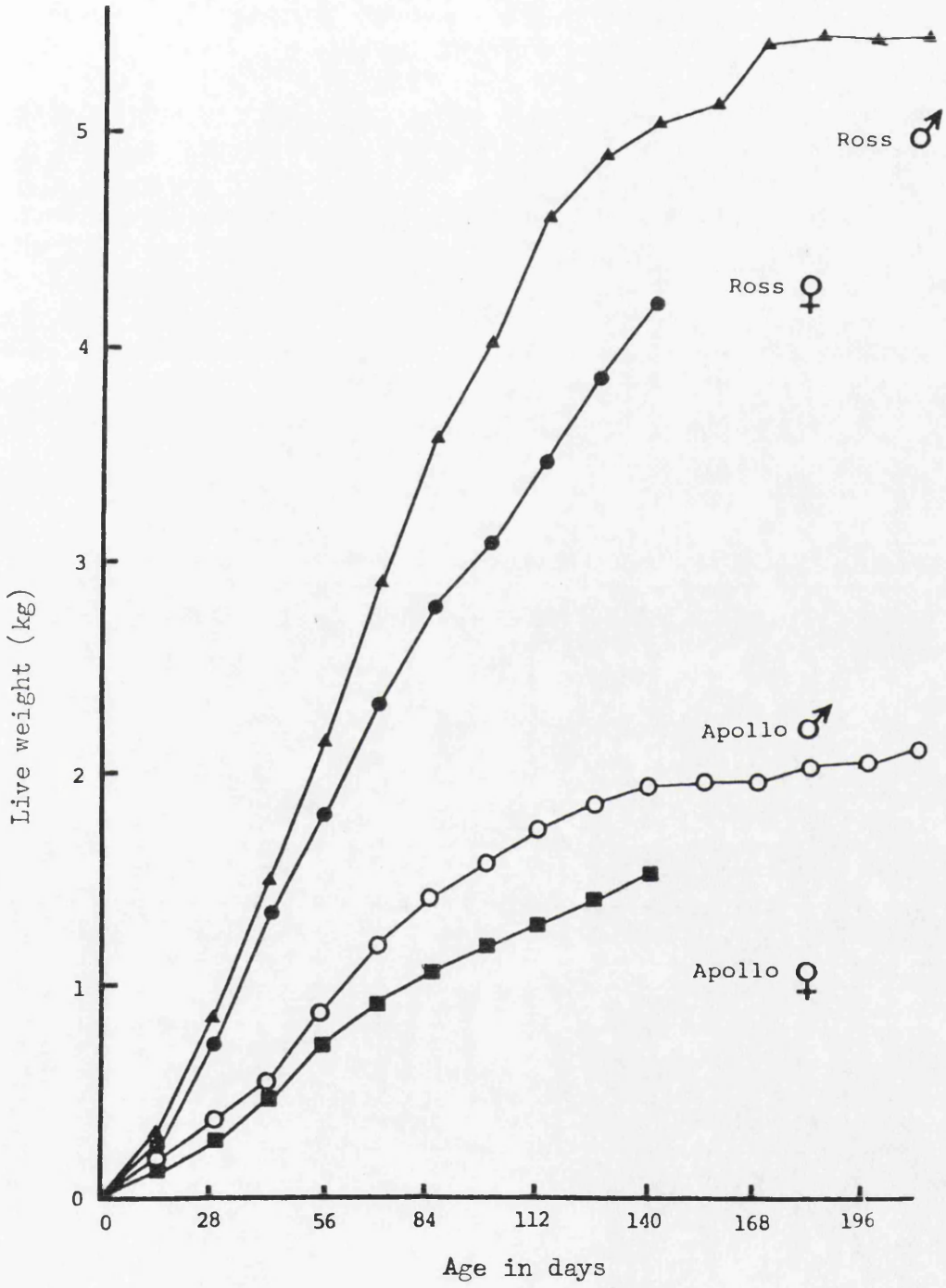
a) Body weight.

b) Body weight gain.

(c) Compensatory growth.

When the animal becomes small for its age due to some factors decreasing growth, that animal tries immediately to grow faster for a time, than normal larger animals at the same age; this is one definition of compensatory growth (Fig. 3).

Fig. 2 Growth of male and female Ross 1 and Apollo chicken when fed ad libitum ( Wilson, 1977 ) .



Figures-3a,b are theoretical growth curves. These growth curves are not special to chickens but are also exhibited by other species, other animals and by plants (Wilson, 1977). These figures illustrate the possible ways which growth might take when the restriction to growth is removed (Auckland, 1970). Normal growth rate increase with age (Fig.-3a), and any retardation which occurred may be regained by compensatory growth, when the restricting factor to growth is removed. The deficit in body weight may or may not be regained.

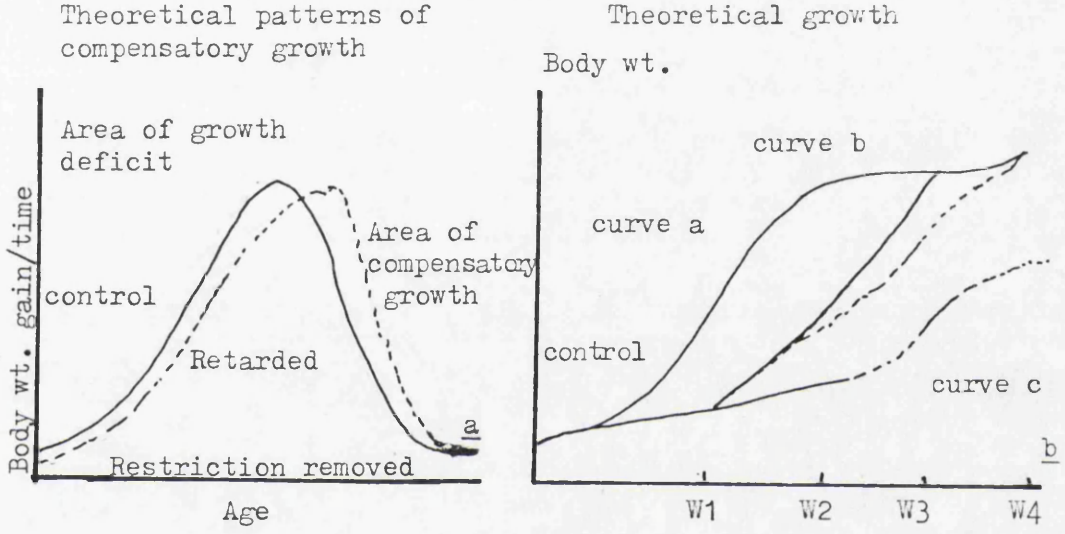



Fig.-3. Theoretical patterns of growth and compensatory growth.

During the period when the retarded animal begins to reduce the growth deficit and catch up with the growth rate of controls, the growth rate at any age is greater than the control. If the area of compensatory gain (Fig.-3a) were equal to the area of growth deficit, the retarded animal attains the same weight as the control. Fig. 3b indicates that retarded animals may subsequently reach their normal weight for age by growing faster than the controls (curve A) and reaching the weight of controls at or before the age when the controls cease growing (W3). But if growth (curve B) is not faster than the controls the retarded animals may catch up sometime after the controls have ceased growing (W4)

and if the growth was retarded by restricted feeding till W2 (curve C), it cannot have any chance to reach a normal mature body weight because the growth deficit becomes larger than compensatory growth.

McCance (1977) has reported that if growth is delayed, and if after a period of the time animals are subsequently fed to capacity, catch up or compensatory growth will occur, and they may or may not regain their predestined size.

The general concept is that growth rate is increased following a growth depression, at a rate more appropriate to the animal size, but when the restriction is in operation for a long time, the animals may never reach normal mature size.

(4) The control of feed intake in the fowl.

(a) Selection of diet

In nature animals are faced with many foodstuffs, most of which are nutritionally unbalanced. To ingest an adequate feed they require mechanisms allowing them to select a suitable amount of each feed. The kind of feed chosen by a bird will depend on the nature of the foods, on the experience of the bird in sampling them and on its physiological requirements at a particular time (Hughes, 1979). Temporary changes in external and internal conditions will modify the eating habits until such a time when equilibrium is restored.

The bird has to adjust feed intake to constraints controlled by many factors such as nature of feed, environmental condition, genetics and physical capacity. In the wild the supply of feeds are seasonal in quantity and quality. Requirements will change with the kind of demands for the amount of nutrients which enable them to become ready for migration or reproduction. The bird chooses a satisfactory diet from what is available in nature and to satisfy nutrient requirements without ever

experiencing a deficiency they must learn to respond to small internal signals (Hughes, 1979). Food selected by the bird will depend on the nature of the feeds. Harper (1964) found that pheasants leave an area poor in calcium and then fly to another area rich in calcium sources. This behaviour of animals can be observed only in the breeding season when egg formation increases the calcium requirement; ducks eat molluscs with a calcium-rich shell during the breeding season (Laughlin, 1975). It is interesting to know that even modern strains of fowls are able to select a uniform diet when given an appropriate choice of feedstuffs (Pitries, Dun and Emmans, 1980).

(b) Short term regulation of feed intake

Booth (1979) reported that short term feed intake control involves anticipatory and feedback mechanisms. Effects of experience on feeding may be due to habit, which is partly caused by repetition if given the same feed. Feed regulation is affected by the consequences of digestion and would be made more acceptable by regular "improvement" consequences and less acceptable by regular "worsening" consequences. If such mechanisms exist control by conditioning (Booth, 1979) can help to regulate the amount of intake according to need. Jacobs and Scott (1957, quoted by Booth, 1979) divided the factors affecting food intake in animals into nutrients need and habit from experience (learning), plus "tasting good" (palatability) which may interfere with good nutrition.

Booth (1979) stated that the absolute or relative deficiencies in amino acids such as methionine, isoleucine and histidine in the diet caused decreases in intake. Also a severe deficiency of protein quality resulted in a large decline in the intake of a single diet in all animals examined (Boorman, 1979). A quantitative or qualitative alteration in the dietary protein may cause a change in the overall

consumption of food, as the system for control of protein intake responds to the dietary change, so long as changes in other dietary characteristics do not confound the animal. Such compensation has been demonstrated with rats (Booth, 1974). The effects of imbalanced and deficient diets are therefore the same. Boorman (1979), reported that an imbalance of an amino acid in a diet produced a decrease in growth rate and food intake. However Morris and Wethli (1978) showed that with laying hens, diets in which a relatively small degree of amino acid imbalance was maintained in constant proportion to protein content, there was no effect of the imbalance on food intake or production.

The sensitivity of animals to control food intake depends on the variety of receptors. Chicks after hatching show an innate preference for both the colour and texture of food but it is improved by their experience (Gentle, 1979). Deleterious stimulation of the gut rapidly prevents the animal from pecking at or swallowing the food which initiated this noxious stimulation (Capretta, 1961 quoted by Gentle, 1979). In mammals receptors which monitor blood nutrients are present in the brain and liver and are important in the control of food intake (Gentle, 1979).

(c) Long term regulation of feed intake

Long term regulation of feed intake by animals has been investigated by many researchers. Investigations have examined the role of the nervous and gastro-intestinal systems, as well as the influence of circulating and body stores of energy providing compounds, such as carbohydrates and lipids on food intake. Body temperature has been involved in the control of feed intake. Three separate hypothesis have been proposed for the control of feed intake. Brobeck, (1960) postulated a thermostatic mechanism based on the close correlation between body temperature and food intake. Kennedy (1953)

formulated a hypothesis for a food intake control mechanism based upon depot fat. This hypothesis, called the lipostatic hypothesis, is based on the fact that animals adjust food intake in relation to energy contents of the diet and depot fat stores and energy expenditure. Mayer (1953) postulated a glucostatic hypothesis linking blood glucose levels and food intake. These three separate mechanisms were combined into a multifactors or control by Hamilton (1965) in which all of the factors are integrated within hypothalamus. Each of three above systems of control are directed towards some bodily goal other than feeding itself e.g. prevention of over distension of the gut, maintenance of suitable cell glucose concentration, and the regulation of body temperature. All the systems which influence feeding may be linked together to form an integrated control system which may be called the controller of energy balance of the body.

Although the relationship is not necessarily linear, laying hens tend to adjust food consumption to satisfy their energy requirements (Morris, 1968, Jensen, 1977). Ahmad (1973) and Jones et al (1976) indicated that changing the diet of hens from one of lower to one of higher energy content resulted in an inverse change in voluntary food intake within one day. Also Farjo (1981) found that Warren ISA laying hens adjusted food consumption after changes in dietary energy within two days.

Adipose tissue homeostasis is actively defended in chickens (Lepkovsky and Furuta, 1971) and appetite control mechanisms respond, either directly or indirectly, to energy intake and storage for long term preservation of a relatively constant body weight (Cherry, 1979). Cherry (1979) indicated that the failure of laying hens to adjust food consumption immediately in response to changes in dietary energy is because they become adapted to a given food volume or density.

Many factors have an effect on energy intake such as environ-

mental temperature which is rarely stable for a long time . Davis et al. (1972) studied the adaptation of laying hens to a change in temperture. At 35°C there was a prompt decrease in energy intake and at 7°C there was also an immediate decrease in energy intake and negative balance during the same week. Emmans (1974),Sykes (1977), studied the effect of environmental temperture on the regulation of feed and energy intake. Emmans (1974) found that intake declinedas environmental temperture increases and vice-versa.

Generally the hen is able to regulate its feed intake in response to a wide range of internal and external stimuli. In the long term intake is adapted to meet the changing demands of egg production,physical activity and climate.

(d) Responses to nutrients intake.

Adequate nutrition of any animal species requires a knowledge of the quantitative nutrient requirements at various stages of the life cycle and various physiological functions. Wilson (1977),reported that the requirement is changing in different strains of birds at different ages for different types of output. It is necessary to adjust the nutrient content of the diet as the quantity fed.

The quantitative needs for the essential nutrients may be expressed in terms of concentration per unit weight of diet. One of the primary factors influencing feed intake is the energy concentration of diet.
Seasonal fluctuations also occur and it can be expected that energy intake will be 5-7 per cent below the annual mean during the warm season, (Hill,1969). The largest nutrient requirement of poultry is for energy because this requirement is so dominant, the biological and economic efficiency of feeding programmes are largely determined by dietary energy and its relation to other essential nutrients. Hill (1969) examined the effects of different rates of feed intake with different levels of dietary protein, on growth or egg production, in deriving ME values for dietary materials. ME values so determined were influnced

very little by level of feed intake, age, sex, breed, rate of growth or egg production, dietary imbalance and administration of hormones.

Food intake will influence performance, with such large proportion of food intake going to body maintenance, it also follows that any factor that enhances food intake should improve feed utilization or decrease the amount of feed consumed per unit of the meat or eggs produced.

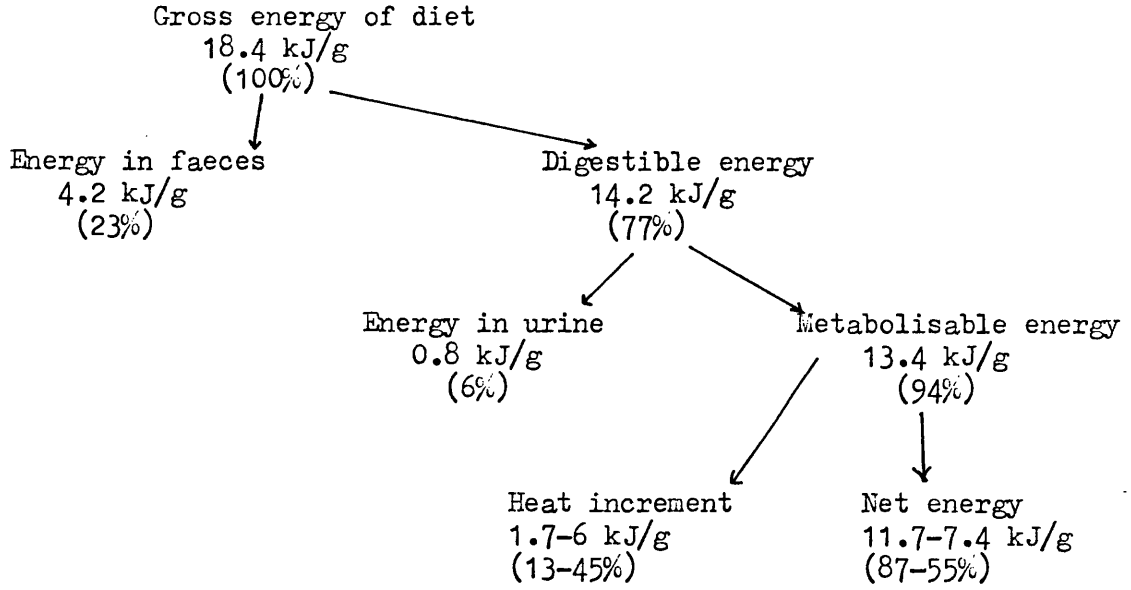
Lowering the energy level or nutrient density of diet will result in increased food consumption but not necessarily increased weight gain or an improvement in food utilisation. Wilson and Emmans (1979) reported that the form and density of the food will influence the time and activity required for eating and will thus affect the productive energy available. Donaldson et al. (1955) found that an increased energy level in isonitrogenous rations reduced feed consumption, but efficiency of energy utilization became progressively poorer. But Sherwood and Marion (1974) found that feed energy levels did not have a consistent effect on growth rate, though the lowest energy level resulted in slightly poor growth.

(5) Energy requirement for broiler breeders.

Metabolisable energy is the current means of assessing the energy content in the feed for poultry. Net energy is the remaining portion when the heat increment is subtracted from ME content.

Farrel (1974) determined the metabolizable energy of a food and corrected for heat increment, what remains is the net energy. This is available to the bird for maintenance and production, however the heat increment may be used to warm the bird if it is in a cold environment. Farrel (1974) partitioned the energy in a typical feed as follows:-

Fig.-4. The partition of dietary energy in poultry feeds.




Heat increment of

a - Maintenance 1.7 kJ/g

b - Protein synthesis 6.0 kJ/g

c - Fat synthesis 4.0 kJ/g

d - Egg production 4.7 kJ/g

From Farrel (1974).

Net energy.

Net energy is the metabolisable energy less the energy used in utilizing it. The net energy may be used for maintenance, for the production of fat, eggs or other animal products or body movements, or work. The proportion of metabolizable energy which can be used as net energy may depend upon the use made of it. This is shown in Figure-4. Also net energy may be different when for work (Fraps, 1946). The efficiency of energy utilisation is commonly measured by the energy in eggs or weight gain divided by ME intake with dietary energy. Many investigators measured the utilisation of metabolisable energy for growth and production and found the requirement of energy for maintenance 414-563 kJ/kg $^{0.75}$/day at 10-20 weeks of age (Table-5). It is obvious that the

Table-5. The utilisation of the ME of balanced diets by growing and mature chickens.

| Reference | Breed & Sex | Age week | Weight kg. | Temp. °C | Starving heat requirement kJ/kg$^{0.75}$d. | Maintenance requirement kJ/kg$^{0.75}$d. | Net availability of ME(%) Maintenance | Production | Diet | Production |
|---|---|---|---|---|---|---|---|---|---|---|
| DeGroote | Hubbard | 2-4 | 0.25-0.7 | 28 | 490 | 540 | 91.6 | 58.7 | cereal | growth |
| (1968)[a] | o | | | 28 | 255 | 344 | 73.6 | 73.6 | cereal | |
| Shannon & Brown (1970) | Broiler o | 10-18 | 1.9-2.8 | 22 | 474 | 563 | 85.1 | 85.1 | cereal | growth |
| Velu et al. (1971) | Broiler o | 1-3 | 0.8-0.3 | - | - | - | - | 57.8 | purified free amino acids | growth |
| Waring & Thornber Brown 1965 | 404 | 18 | 1.68-2.11 | 22-24 | 356 (301 non layer) | 444 | 83.7 | 83.7 | - | Egg production + body changes |
| Tasaki and Sasa (1970) | W1. | - | 1.3-2.1 | 21 | 318 | - | - | 72.9 | | Egg production + body changes |
| Hoffmann & Schiemann (1973) | W1. | 10-20 | 1.0-2.5 | 18 | - | 414 | - | 80 | | body storage + egg production |

From DeGroote (1974) (Energy requirement)

maintenance requirement increases with progressive age and body weight, and also depends on the temperature. The body composition of the hen depends on the precise balance between energy intake and output. Energy retention of a sufficient period of time is reflected in the deposition of lipid and protein. An abnormal weight and fat content must signify an abnormal balance at some time in the past. There are many factors which affect the energy requirement of broiler breeders, one of them related to the nature of feed or to the relationship between energy and protein, the second concerns the age and stage of stock. Wilson (1977) reported that the requirement depends on the strain of birds, their age and level of output. The third concerns the environmental condition or seasonal effect. Balnave (1974) has added to this list, feather cover, activity, laying activity and seasonal effect. Bornstein(1980) reported that the energy requirement of broiler breeders depends not only on productive performance, body weight and weight gain but also on ambient temperature. Many workers investigated the energy requirement of breeders under various environments, with various strains and different stages of production. Scott (1975) estimated the energy requirements for broiler breeders at 1758 kJ ME/day for moderate climates and 1590 kJ/day for hot climates. Blair (1976) stated that a very unsatisfactory level of settable eggs was obtained with 1548 kJ ME/day. Waldroup and Hazan (1976), and Van Wambeke (1977), concluded that the daily energy needs for peak production for broiler breeders lies in the range of 1779-1988 kJ ME per hen. These results were obtained under moderate temperatures (average 16°C). Van Wambeke (1981) used the following equation for daily energy needs:

$y(kJ/h/d) = 314 + 8.4\ (20-T)\ W + 11.19EM + 19.7\Delta W$

for a standard broiler hen W = 3.255kg

y = daily ME intake
W = body weight (kg)
EM = egg mass (g/day)
$\Delta W$ = gain of body weight (g/day)
T = temperature in $^{o}C$

Byerly et al. (1980) used the following equation for daily feed intake:

$$F = (0.275-0.00275T)W^{.75} + 2.9\Delta W + 0.85EM$$

where,

T = ambient temperature in $^{o}C$
F = feed intake g/hen/day
W = live weight g.
$\Delta W$ = change in live weight (g/hen/day)
EM = egg mass (g/hen/day)

This equation was derived from the results of hens fed a diet containing 12.1 MJME/kg. The energy requirements for the broiler breeder are affected less by environmental temperature than the laying hens. Sykes (1977) in his review found the effect of ambient temperature on energy requirement of egg strain layers, at $20^{o}C$ the average energy intake is 1298 kJ/d; with a change of 21 kJ/$^{o}C$; this corresponds to a change of 1.6 per cent/$^{o}C$. Using the above equation it may be calculated that the energy requirement for the broiler breeder changes by 0.5 per cent/$^{o}C$ according to Van Wambeke (1981) and 0.8 per cent/$^{o}C$ according to Byerly et al. (1980).

Chaney and Fuller (1975) reported that 20% reduction in energy intake of broiler breeder hens below voluntary consumption reduced production of a total and settable eggs significantly during the cold months but had no effect on performance during the summer months.

(6) The factors affecting reproductive fitness of the broiler breeder.

(a) Factors affecting fertility and hatchability.

The fertility of animals can be explained to mean its reproductiveness of off-spring and a distinction is made between;

1. failure to effect fertilisation of ova
2. mortality of embryos and foetuses at various stages after fertilisation, or even at birth. This is dependent upon the integrity of chains of events occurring in the reproductive physiology of the male and female (Table-6). Many factors affect on the fertility such as management, environment and physiology which influence the growth and development of the reproductive organs and maintenance of their ability to produce eggs and good quality of semen (Lake 1969).

Table-6

A schematic representation of the main events in the reproductive physiology of the bird leading to the production of offspring, and the factors influencing each process.

| Events | Factors influencing the events |
|---|---|
| Growth and development of male & female reproductive organs, and Maintenance of reproductive organs (endocrine milieu) in active state in the adult for:<br>(i) Egg laying in the female<br>(ii) Production of spermatozoa in the male. | Photoperiodism, nutrition, drugs, temperature, genetic factors, disease behaviour & management, altitude, irritation of the oviduct. |
| Mating and insemination | (a) Mating behaviour & ejaculation. Rearing experience, genetic factors, floor area and density of birds, peck order, mating frequency, libido of male & female, preferential mating, ratio of males to females, diurnal rhythm in semen production & mating.<br>(b) Artificial insemination. Several factors determining success of technique. |
| Survival & activity (transport) of spermatozoa in the oviduct | (a) Storage of spermatozoa in the oviduct. Species, breed & strain differences in the fertile period, sustenance in the oviduct. |

Continued...

| | |
|---|---|
| | (b) Possible immunisation against spermatozoa reducing fertility.<br>(c) Movement of spermatozoa in the oviduct, nature of mobilising agent. |
| Fertilisation | Polyspermy, ageing of spermatozoa in oviduct, number of spermatozoa per inseminate, egg laying capacity of hen, oviducal selection of spermatozoa for fertilisation, age of hen, seasonal effects, clutch effect, quality of spermatozoa, genetic factors. |
| Embryonic development | |

From Lake, 1969.

Several studies have been made on the lighting conditions required for the development and maintenance of reproductive performance in poultry. Morris (1967) reported that the age at sexual maturity in pullets and the subsequent patterns of egg production can be varied by using different light regimes. As well as management and environment, nutrition is important for achieving maximum reproductive performance of the adult. Starvation for 6 days reduced semen production in male fowl (Boone et al., 1967). Sherwood (1964) found that the mildest of restriction during rearing period resulted in an increased number of chicks hatched for each hen housed was due to an improvement in fertility. Ingram (1979) found fertility increased more slowly for the birds on restricted feeding and the hatchability of fertile eggs tended to be higher for eggs from restricted laying strain hens.

Some evidence has been produced that should prompt further investigations into the role of calcium in controlling normal reproductive activity. Mehring (1965) examined the effect of different levels of calcium in the diet on broiler hens and his data indicated that egg production began to decline once the calcium in the diet fell below 2 per cent. The essential fatty acids are necessary for good reproductive performance in poultry. Diets deficient in linoleic caused a reduction

in hatchability of fertile eggs (Calvert, 1967). Cockerels reared on diets deficient in the essential fatty acids had deficient testes (Edward, 1967). Environmental temperature influences the reproductive performance of birds directly or indirectly because of the effect on feed consumption.

Generally for the laying hens production will be decreased when average temperature exceeds 26-30°C (Smith, 1981). Smith (1981) in his review found that the male is less sensitive than the female to higher environmental temperature.

(b) Responses to insemination

(i) Artificial insemination

Artificial insemination in fowl breeding flocks has not been widely used in commercial practice in the UK. Primarily because of the necessity to cage hens and secondly because many factors affect the success of artificial insemination, one of which is the quantity of semen. Van Krey and Siegel (1976) found that increasing numbers of spermatozoa inseminated improved fertility, improved the percentage hatch of total eggs and decreased the number of abnormal embryos.

There is much individual variation in the number of times that males can be used without impairing their fertility because the sperm producing powers of healthy males are not quickly exhausted. Hughes (1978), indicated in his review that increasing the frequency of artificial insemination to one every six days did not produce or improve the fertility rates significantly higher than those obtained with artificial insemination once every seven days

Artificial insemination of poultry has become established as a valuable technique in both industry and research. It has been used to a much greater degree in the turkey than the broiler industry. McDaniel (1974), and Van Kery and Siegel, (1976), suggested that

artificial insemination of broiler breeders maintained in cages is feasible. Perry, (1960) reported that the factors influencing the quality and quantity of semen included nutrition, environmental temperature, quantity of semen, frequency of use of males, disease, age and inheritance. Hughes (1978) found a number of factors such as varying techniques, different strains of birds, age of birds and depth of insemination influenced fertility. Biellier et al (1961) inseminated turkey females to depths of 2, 5 and 8 cm and obtained fertility rates of 57, 68 and 80 per cent respectively. Cooper and Rowell (1959), obtained an improvement of 15.6 per cent in fertility by inseminating chickens to a depth of 4 cm. It is obvious that the depth of insemination has an effect on the fertility rate, therefore any faulty technique can affect fertility. Cooper (1969) reported that in many cases poor technique has been the cause of the low fertility syndrome.

McDaniel (1973) showed cage birds had fertility which was equal to that of birds on the floor, but hatchability was lower than birds on the floor because early embryonic mortality (4.9%) occurred. But Hughes (1978) found the fertility of birds reared on the floor was significantly higher than that obtained with artificial insemination.

(ii) Natural mating

The fertility of males in broiler breeders is economically more important than females because the male is responsible for the fertility of eggs from 10 to 15 females. The selection of such males may be facilitated to get best semen quality. Wilson et al (1969) showed that the selection of males for the breeder flock is usually based on such characteristics as body conformation, maturity, body size, condition of legs and feet and general health. Some researchers found that semen quality characteristics are generally believed to be inherited (Marini and Goodman, 1969) and also semen quality can be

affected by dietary deficiencies (Boone et al 1967). Lee et al (1971b) Watson and Payne (1972) and Blair et al (1976) reported that pullets reared on feed restriction showed better fertility than fully fed birds. Hanson (1960) quoted by Beer (1969) showed that nutrition was still at that time the most important single cause of poor hatchability and defined two types of deficiency - direct and indirect. A direct effect was defined as a deficiency of some essential nutrient factor, and, an indirect deficiency resulted from dilution of food, effects due to parasitism and lack of trough space.

Abnormally high levels of iodine affected the semen quality (Wilson et al 1971). Scott (1966) listed thirteen factors which could modify vitamin requirements in relation to hatchability. These were genetic, energy content of diet, environment, natural availability of the vitamins, destruction in the gastro-intestinal tract, interference with absorption, biosynthesis, microbial synthesis, antimetabolites, metabolic interrelationships, effects of hormones, disease and stress.

Van Wambeke (1977) found that average hatchability of eggs set was not affected by energy intake during the reproduction period but hatchability at 65 weeks was lower for treatment fed ad libitum. But Beer (1969) indicated that inadequate energy, like inadequate protein, may affect the egg size and rate of lay rather than hatchability per se.

In 1968 the Reading Laboratories investigated an analysis of hatchability problems which showed that just under 25 per cent involved nutrition, 25 per cent resulted with problems of egg storage, egg handling or hygiene, 5 per cent caused by genetic/nutrition interactions and 7.5 per cent due to the faulty incubation practices or techniques;

the remaining were either due to a mixture of the above or disease, or were unsolved (Beer, 1969). It is evident that faulty nutrition is one of the main causes of hatchability problems.

# CHAPTER ONE

## MATERIALS AND METHODS

### 1:1 Design of experiments

Two experiments were conducted, each with two phases.

The first phase took place in the rearing house from 0-15 weeks of age. The house was divided into six pens. There were two replicates of females and one replicate of males on each feeding system. Although it would have been desirable to have two replicates of the males it was not practical to subdivide male pens. The total number of birds used for the experiments was 720 and 480 females on A and R feeding respectively and 100 males for each feeding system (see diagram 1).

In the second phase of Experiment 1 some of the birds were placed in the two floor pens in the laying house with one replicate each for ad libitum and regulated birds. For the beginning of the second phase, Experiment 1, the females and males were together. The number of birds used on the floor was 21 and 31 per cent from total females on A and R feeding respectively and 25 per cent of males on each feeding system.

In experiment 2, the total number of females place in cages was 53 per cent of the ad libitum and regulated fed females from phase 1. Also, from each feeding system in phase 1, 28 per cent of males were placed in cages. All birds transferred to the laying house for phase 2 were chosen at random. The rest of the birds were discarded.

During 16 to 21 weeks, the only data collected for Experiment 2 was feed intake and body weight. At 22 weeks of age the experimental design was applied. Three ad libitum groups of females were each given a different feed (L, M or H). Those previously on

regulated feeding were given feed M in regulated amounts (see diagram 2).

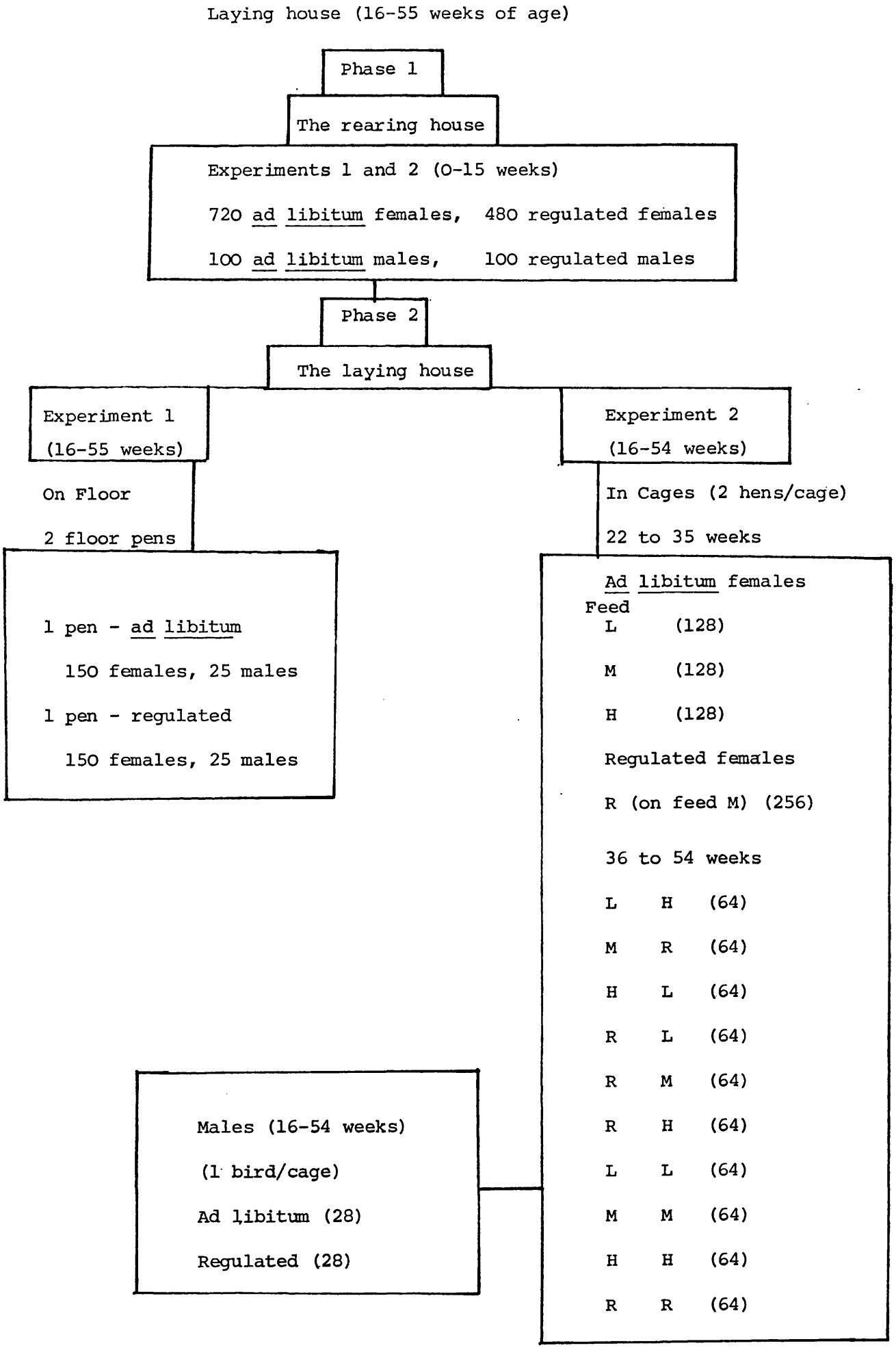
At 36 weeks of age, half of the ad libitum groups were changed to another feed and the other half continued on the same feed until the end of the experiment; while three-quarters of the females previously given regulated amounts of feed were changed to feeds L, M or H with ad libitum feeding. The remaining quarter of the females continued on regulated feeding to the end of the experiment.

Diagram I

Rearing house (0-15 weeks of age)

| | Ad libitum | | Regulated | |
|---|---|---|---|---|
| | Females | Males | Females | Males |
| Total birds | 720 | 100 | 480 | 100 |
| Total pens | 2 | 1 | 2 | 1 |
| Birds per pen | 360 | 100 | 240 | 100 |
| Duration in days | 105 | 105 | 105 | 105 |

Diagram 2


Laying house (16-55 weeks of age)
Phase 1
The rearing house
Experiments 1 and 2 (0-15 weeks)
720 ad libitum females, 480 regulated females
100 ad libitum males, 100 regulated males
Phase 2
The laying house
Experiment 1
(16-55 weeks)
On Floor
2 floor pens
1 pen - ad libitum
150 females, 25 males
1 pen - regulated
150 females, 25 males
Experiment 2
(16-54 weeks)
In Cages (2 hens/cage)
22 to 35 weeks
Ad libitum females
Feed
L (128)
M (128)
H (128)
Regulated females
R (on feed M) (256)
36 to 54 weeks
L H (64)
M R (64)
H L (64)
R L (64)
R M (64)
R H (64)
L L (64)
M M (64)
H H (64)
R R (64)
Males (16-54 weeks)
(1 bird/cage)
Ad libitum (28)
Regulated (28)

1:2 Birds and Management

A total of 1200 females and 200 males Ross 1 broiler breeders were housed on the 7th March, 1980. The day old chicks were randomly divided into two groups of each sex. Each of the female groups were further divided into two replicates. The male groups were unreplicated. The number of females in each replicate were 360 and 240 for the ad libitum and regulated groups respectively. There were 100 males on each feeding treatment.

During the brooding period, which was day old till 3 weeks of age, the chicks were placed randomly into tier brooders. Each brooder consisted of four tiers with each tier heated independently. Each tier was supplied with slide-out dropping trays, wire floors and inspection windows. There were 50 males and 60 females placed in each tier. They were reared on the different feeding systems except for the first two weeks when all groups were fed the started feed ad libitum. At 24 days of age, they were transferred to the floor pens in the same house. Litter was provided by 100mm of wood shavings. At 15 weeks of age, all the birds were moved to the laying house and kept either in floor pens or in cages. Two floor pens, one for each feeding system were used, because the design of the house did not allow replication. Each pen contained 150 females and 25 males. The remaining birds were placed in cages for Experiment 2. Birds in the floor pens were fed the grower feed to 21 weeks of age and then the layer feed to the end of the experiment. The caged birds were fed the grower diet till 21 weeks of age and then the females were given one of three laying feeds with ad libitum or regulated feeding.

## 1:3 Lighting

Pullets and cockerels received only artificial light in the rearing and laying houses. In the rearing house the lights were 25W and in the laying house were 40W. The light intensity was controlled by dimmers and recommended intensities for the stock were followed. The lighting programme was controlled by 24h time clocks.

A photo-period of 23h was given for the first two days of age and then it was reduced gradually to 8h at 10 days. From 11 days to 18 weeks, the photoperiod was constant 8h. From 18 to 30 weeks, the photoperiod was increased weekly to reach 17h at 30 weeks of age. Then it was kept constant until the end of the experiment. The females and males received similar lighting programmes. The programme is summarized in Table 1:1.

Table 1:1 Lighting programme recommended by Ross Company.

| Age | | Day length |
|---|---|---|
| weeks | days | hour |
| - | 1 | 23 |
| - | 3 | 19 |
| - | 4 | 16 |
| - | 5 | 14 |
| - | 6 | 12 |
| - | 7 | 11 |
| - | 8 | 10 |
| - | 9 | 9 |
| - | 10-125 | 8 |
| 18 | 126 | 8½ |
| 19 | 133 | 9 |
| 20 | 140 | 10 |
| 21 | 147 | 11 |
| 22 | 154 | 12 |
| 23 | 161 | 13 |
| 24 | 168 | 14 |
| 25 | 175 | 14½ |
| 26 | 182 | 15 |
| 27 | 189 | 15½ |
| 28 | 196 | 16 |
| 29 | 203 | 16½ |
| 30 onwards | 210 onwards | 17 |

1:4 Temperature and Ventilation Control

In the rearing and laying houses, the daily maximum and minimum temperatures are recorded each day. A summary of the temperatures are given in Table 1:2. In the rearing house the ventilation was by means of thermostatically controlled exhaust fans in the roof, with side wall air inlets. The fans were controlled by two Danfoss thermostats, one controlling a single fan for minimum ventilation rate and the other thermostat controlled the remaining four fans. In the laying house ventilation was controlled independently in the cage and floor section. In each section a single thermostat controlled all the fans. Temperatures were measured at the top and bottom tier levels in the cage section. In the floor section temperature was recorded at bird head height.

Table 1:2 The temperature during the whole experiment in both houses.

| | Rearing house | | | | | |
|---|---|---|---|---|---|---|
| | Top | | Middle | | Bottom | |
| | Max. | Min. | Max. | Min. | Max. | Min. |
| 7 March - 18 April | 22.8 | 20.7 | 21.7 | 19.7 | 20.0 | 18.1 |
| 19 Apr. - 30 May | 20.8 | 16.8 | 19.5 | 16.6 | 19.1 | 15.5 |
| 31 May - 20 June | 19.9 | 15.8 | 18.5 | 14.9 | 18.6 | 15.3 |
| 21 June - 13 July | 20.6 | 18.2 | 20.3 | 17.9 | 21.0 | 18.7 |
| | Laying house | | | | | |
| | Cage section | | | | Floor section | |
| 14 July - 7 Aug. | 20.2 | 17.6 | 19.9 | 17.6 | 21.0 | 17.2 |
| 8 Aug. - 28 Aug. | 21.8 | 17.5 | 20.7 | 17.5 | 23.3 | 15.4 |
| 29 Aug. - 23 Sep. | 21.1 | 18.2 | 20.5 | 17.4 | 21.5 | 17.3 |
| 24 Sep. - 22 Oct. | 20.0 | 17.0 | 19.0 | 15.6 | 19.0 | 14.0 |
| 23 Oct. - 10 Nov. | 20.0 | 17.7 | 19.4 | 16.0 | 19.8 | 17.2 |
| 11 Nov. - 3 Dec. | 20.7 | 17.7 | 19.1 | 15.3 | 20.2 | 16.8 |
| 4 Dec. - 12 Jan. | 18.6 | 14.7 | 17.1 | 14.0 | 19.2 | 14.4 |
| 13 Jan. - 21 Feb. | 17.1 | 14.3 | 16.5 | 13.9 | 17.5 | 14.3 |
| 22 Feb. - 25 Mar. | 18.3 | 14.5 | 17.0 | 14.0 | 19.3 | 15.4 |

1:5 Hygiene or disease prevention

From 1-15 weeks of age, the rearing ration contained a coccidiostat. All pullets and cockerels were debeaked at 5 days of age. Vaccination and disease control followed the Ross programme as shown in Table 1:3.

Table 1:3 Vaccination during the rearing period.

| Age/weeks | Vaccine | Method | Disease |
|---|---|---|---|
| 3 | Bronchimune H-120 | In drinking water | Bronchitis |
| 3 | Hitchner $B_1$ | A fine spray | Newcastle |
| 5 | Mareks | Injection | Mareks |
| 7 | Lasota | In drinking water | Newcastle |
| 9 | Bronchimune | In drinking water | Bronchitis |
| 11 | Lasota | In drinking water | Newcastle |
| 11 | Gumboro | Used by spray | Infection Bursal |
| 12 | Tremimune A.E | In drinking water | Infectious avian encephacomyelitis |
| 15 | Bronchitis | In drinking water | Bronchitis |
| 16 | Newcadin | Injection | Newcastle |
| 20 | Gumboro | In drinking water | Infections Bursal disease |

1:6 Houses

(a) The rearing house (1-15 weeks of age )

The house was windowless with a concrete floor which was covered with wood shavings. Lighting was provided by 30 lamps (25W) divided into three lines, with a distance of 2.5m between the lines. The trough space allowed for ad libitum and regulated females was 5.0 and 7.5 cm/b respectively. But for ad libitum and regulated males it was 18.0 cm/b. Water was provided from automatic drinkers, 7and 5 drinkers for each replicate of ad libitum and regulated females respectively, while for males 2 drinkers were allowed for each replicate. Water space was allowed at one drinker for approximately 50 birds.

The ad libitum females had two replicates and their floor area was 60 $m^2$ each, but for regulated females it was 35 $m^2$ each, and, finally it was 23 $m^2$ for each group of males. The stocking density was 6, 6.8 and 5 birds per 1 square metre for ad libitum females, regulated females and males respectively.

The layout of the pens and stocking density is shown in the diagram below.

| 5m. | 5m. | |
|---|---|---|
| Ad lib. Females S.D. = 6/$m^2$ | Ad lib. Females | 12m. |
| Reg. Females S.D. = 6.8/$m^2$ | Reg. females | 7m. |
| Ad lib. Males S.D. = 5/$m^2$ | Reg. males | 4.6m. |

(b) The laying house (from 16-55 weeks of age)

There is a description of this house in Chapter II.

(1) Floor pens

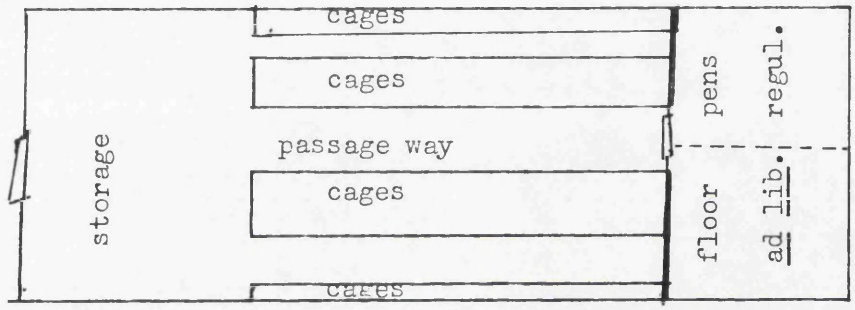
The layout of the house is shown in the diagram below. There were two floor pens with an equal area of 27 $m^2$. One of them held the ad libitum females and males and the other the regulated females and males, containing initially 175 birds each.

(2) Cages

The cages were wooden (designed for turkey hens) and held 2 female broiler breeders with no crowding. The cages divided into 8 blocks, each block had 10 plots and each plot had 4 cages, 2 females or 1 male were placed in each cage. Food was provided from a continuous

trough in front of the plot. Water was supplied from nipple dinkers at the front of the cage. The cages had plastic covered wire floors which did not collect droppings. The length of the house in cage section was 17 m and the width was 8.1 m . The droppings collected under the cages and were removed weekly.

The laying house




1:7 Feed formulation and composition of feeds

The following feeds were used for the experiments, a starter, a grower, and three layer feeds with low (L), medium (M) and high (H) ME contents (Table 1:4). The starter and grower feeds had similar ME contents and were formulated using the nutrient specifications given in the Ross management guide. The feeds were formulated on a computer using a least cost programme. Feed M was produced as 50:50 mixture of feed L and H. Nutrient contents were in fixed proportion to ME

content in each feed on a calculated basis. All the feeds were mixed at Seafield Mill, Midlothian. The amounts mixed were designed to last no longer than one month. The composition and the analysis of feeds used are shown in Table 1:5. The starter was used from 1 day to 6 weeks of age, the grower laying was used from 7-21 weeks of age, and layer feed L, M and H were used throughout the whole period (22 till 54 weeks of age).

Table-1:4. Composition of feeds (g/kg)

| | Rearing feeds | | Laying feeds * | |
|---|---|---|---|---|
| Ingredient | Starter | Grower | L | H |
| Barley | 200 | 300 | 200 | - |
| Wheat | 200 | 350 | 100 | - |
| Maize | 342.68 | 201.14 | 100 | 730 |
| Fish meal | 50 | 25 | 20 | 120 |
| Meat & bone meal | 25 | 25 | - | - |
| Soyabean meal | 160 | 75 | 65 | 45 |
| Oats | - | - | 320.25 | - |
| Fat premix | - | - | - | 40 |
| Wheat food | - | - | 95 | - |
| Grass meal | - | - | 25 | - |
| Limestone | 15 | 12.3 | 59 | 65 |
| Dicalcium phosphate | 6 | 9.5 | 15 | - |
| Methionine | 0.2 | 0.26 | 0.6 | - |
| Salt | 1.12 | 1.80 | 0.15 | - |
| Vitamins & minerals[1] | 12.5 | 12.5 | - | - |
| Coccidiostat | added | added to 15wks | - | - |

* Feed M = 50 % L + 50 % H

[1] The vitamins and minerals mixture contained the following quantities per kg. Vit. A 10 M1U, $D_3$ 3.0 M1U, E 12g., K 4g., $B_1$ 2g., $B_2$ 10g., $B_6$ 2g., $B_{12}$ 10mg. nicotinic acid 25g., pantothenic acid 10g., folic acid 1g., choline 100g., biotin 50mg., copper 10g., cobalt 2g., manganese 100g., zinc 80g., iron 20g., iodine 2g., selenium 0.1g., molybdenum 1g., antioxidant 100g.

Table 1:5. Analysis of Feeds.

| | Rearing | | Laying | | |
|---|---|---|---|---|---|
| Calculated | Starter | Grower | L | M | H |
| ME.k/kg. | 12.3 | 12.3 | 10.3 | 11.3 | 12.3 |
| Crude protein g/kg. | 196.8 | 151.1 | 134.0 | 147.0 | 160.0 |
| Phosphorus g/kg | 4.5 | 4.4 | 5.0 | 5.0 | 5.0 |
| Calcium g/kg | 13.4 | 11.6 | 25.0 | 27.5 | 30.0 |
| Lysine g/kg | 10.0 | 6.7 | 6.7 | 8.0 | 9.2 |
| Methionine g/kg | 3.9 | 3.1 | 3.0 | 3.5 | 3.9 |
| Chemical analysis of feed | | | | | |
| Dry matter g/kg | 874.0 | 863.0 | 866.0 | 871.0 | 878.0 |
| ME kJ/kg | 12.2 | 12.5 | 10.0 | 12.2 | 13.2 |
| Crude protein g/kg | 191.0 | 145.0 | 123.0 | 142.0 | 164.0 |
| Phosphorus g/kg | 7.9 | 7.6 | 7.8 | 7.3 | 7.8 |
| Calcium g/kg | 16.7 | 15.7 | 36.7 | 41.1 | 45.8 |

A coccidiostat was included in the feed from 1 day old to 16 weeks of age.

All feeds were in mash form. Samples of feeds were taken at all periods (starting, growing and laying period) to determine dry matter, protein, calcium and phosphorus by the Chemistry Dept.

1:8. Feeding scale.

The feeding plan for regulated birds was to follow the target weight guide for the stock. The suggested and actual amount of feed are given in Table 1:6. The amount of feed intake increased with advancing age. These feeding levels are normally adequate for the birds. However, for a variety of reasons benefits of increased production can be obtained particularly in the pre-peak period by feeding more than the recommended levels during the challenge feeding periods.

Table 1:5b

The chemical analysis of layer feeds at 30 and 45 weeks of age.

| | L | | M | | H | |
|---|---|---|---|---|---|---|
| Chemical analysis of feeds | 30w. | 45w. | 30w. | 45w. | 30w. | 45w. |
| Dry matter g/kg | 870.0 | 862.0 | 877.0 | 865.0 | 880.0 | 876.0 |
| ME kJ/kg | 10.4 | 9.7 | 12.1 | 12.3 | 13.4 | 13.2 |
| Crude protein g/kg | 124.0 | 122.0 | 142.0 | 142.0 | 163.0 | 164.0 |
| Phosphorus g/kg | 7.9 | 7.6 | 7.5 | 7.1 | 7.8 | 7.8 |
| Calcium g/kg | 36.8 | 36.5 | 42.0 | 40.2 | 46.0 | 45.6 |

Table 1:6. Feeding scale used in the rearing period and laying periods: ( daily feed intake allowance g/b ).

| | Female | | Males | |
|---|---|---|---|---|
| Age/weeks | Suggested intake | Actual intake | Suggested intake | Actual intake |
| First 2wks. | Ad lib. | Ad lib. | Ad lib. | Ad lib. |
| 3 | 23 | 23 | 24 | 24 |
| 4 | 30 | 30 | 31 | 41 |
| 5 | 39 | 39 | 41 | 48 |
| 6 | 46 | 42.5 | 48 | 63 |
| 7 | 54 | 46 | 57 | 63 |
| 8 | 59 | 54 | 63 | 76 |
| 9 | 65 | 59 | 70 | 80 |
| 10 | 70 | 59 | 76 | 80 |
| 11 | 73 | 59 | 80 | 83 |
| 12 | 75 | 59 | 83 | 83 |
| 13 | 75 | 70 | 84 | 85 |
| 14 | 75 | 70 | 85 | 85 |
| 15 | 75 | 75 | 86 | 86 |
| 16 | 75 | 75 | 88 | 88 |
| 17 | 75 | 75 | 90 | 88 |
| 18 | 77 | 75 | 94 | 88 |
| 19 | 81 | 77 | 101 | 94 |
| 20 | 85 | 77 | 109 | 94 |
| 21 | 93 | 77 | Same as female | 94 |
| 22 | 101 | Same as suggested intake | | Same as female |
| 23 | 115 | | | |
| 24 | 127 | | | |
| 25 | 137 | | | |
| 26 | 148 | | | |
| 27 | 160 | | | |
| 28 | 167 | | | |
| 29-39 | challenge feeding | | | |
| 40 | 165 | | | |
| 43 | 163 | | | |
| 46 | 161 | | | |
| 49 | 159 | | | |
| 52 | 156 | | | |
| 55 | 154 | | | |

1:9 Feeding.

The frequency of feeding was adjusted as needed during the experiment. During the first two weeks of age, the feed was weighed for two weeks and presented daily. Some feed was wasted because it was given in trays during the first week. At 3 weeks of age, the feed given to chicks was following the feeding scale as given in Table 1:6. The feed allocated depended on the target weight. If the body weight of chicks was lighter than target an increased amount of feed was given and if heavier, the feed amount was kept the same as the previous week. This was continued till 21 weeks for birds on the floor. The feed was provided daily for regulated birds in cages or on the floor, while the feed was provided every two days for ad libitum birds in cages and daily for those on the floor in order to prevent wastage of the feed.

1:10 Metabolisable energy (ME) determination

On four occasions during this study (at 6, 20, 32 and 49 weeks of age) ME evaluations were made for each feed used. The method used was total collection based on the description by Hopkins (1974). The ME determination of the starter was carried out in the brooder house where the birds were housed in heated cages. Females were removed from the large groups in the rearing house and taken to the brooder house for the duration of the determination. ME determination of the grower and layer feeds were carried out in situ. Each determination was based on the combined feed intake and dropping output of two plots, 6 birds each for the starter and 8 birds each plot for the grower and layer feeds. Alumunium trays, covered with aluminium foil, were fitted under the plots to facilitate the collection of the droppings and the same troughs in front of the plots were used for measuring food intake. The troughs were thoroughly emptied and the feed added at 9 a.m. for three

consecutive days, the actual collection period. An accurate record was kept of feed consumed and the droppings produced by all the birds under the test. Although feed was always available to the birds, to avoid spillage care was taken to ensure that the trough was never more than one third full. The fresh droppings were collected every day, at the same time. The droppings were identified by plot number and date of collection. After the droppings had been cleaned of foreign materials and they were covered with aluminium foil, which retained the moisture of the faeces, and then stored in the freezer. Sub samples of the feeds on offer were taken and bulked for subsequent chemical analysis. At the end of the three days collection period the feed troughs were emptied and the residual feed weighed and also a sub-sample was retained for chemical analysis.

At the end of the collection period the total fresh droppings for each plot which were bulked, in the spare trays in and weighed and then dried at 100°C for 48 hours in the oven. The dry material was ground in a mill with a 1mm screen before being sub-sampled for subsequent analysis.

Samples of feeds were dried at 100°C for 16-20 hours overnight. The nitrogen (N) contents of duplicate sub-samples of the fresh feed and dried droppings were measured by the macro-kjeldahl method (Mitchell, 1972). For gross energy contents an Adiabatic Bomb Calorimeter was used following the standard method. If any difference between the three replicates were more than 2 per cent a further sample was done. If the three replicates were closer than ±2 per cent of their mean the values were averaged. ME values then were calculated using:

$$\text{ME of feed (kJ/g)} = \frac{\text{Gross energy of feed eaten (kJ)} - \text{Gross energy in droppings (kJ)}}{\text{Weight of feed eaten (g.)}}$$

The determined ME values were corrected to N-equilibrium.

1:11 ME value

The details of the ME determinations for the two rearing feeds are given in Table 1:7. The ME results of the determination for the three layer feeds, average over the two determinations, are given in Table 1:8. The determined values for ME for the medium and high energy feeds were higher than the calculated values. The difference between the calculated and determined ME values of the M and H feeds could be due to a combination of errors. Of the possible sources of error the most probable ones are (1) errors in the technique such as: incomplete collection of excreta and food wastage, contamination of excreta with spilt food and feathers, loss of fat during pellet preparation; (2) a difference in the ME of ingredients to those used in formulation (3) interaction of feed nutrients in the birds to alter utilization of energy, because of the effect of some nutrients on the rate of food passage. Other sources of error which are important include age effects (Sibbald, 1978), and food intake (Sibbald, 1977). In relation to (3) above Sibbald, (1981) has described the difficulties in assigning a value to supplemental fats. The determined ME values were used in all the analyses of data.

1:12 Chemical analysis

(a) Feeds

Samples of feed were taken from bags to obtain a 1kg sample which was then divided into two replicates, one for chemical analysis and the other replicate preserved by deep freezing (-15°C). Dry matter and ash were determined conventionally (D.M. 3 x 100g at 100°C, ash 2 x 1.0 ± 1mg at 480°C) on a sub-sample of the milled materials. Crude protein, Ca and P were determined on the same digest from a 250mg sample, using a $H_2SO_4$ digest and selenium dioxide as a catalyst ( Spillane, 1973 ). The crude protein in the digest was determined spectrophotometrically using a technique based on that of Mitchell, (1972). Phosphorus and calcium were determined spectrophotometrically

Table 1:7

ME determination for the two feeds (starter at 6 weeks grower at 20 weeks of age)

| Feeds | Plot No. | Gross E. in Feed kJ/g. | Feed intake g | Gross E. intake kJ | Fresh weight of faeces g. | DM of the faeces g. | Gross E. in faeces DM(kJ/g.) | Gross E. in faeces kJ | ME eaten kJ | ME content kJ/g | Mean kJ/g |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Starter | 6[1] | 16.23 | 2073 | 33638.57 | 2352.90 | 547.1 | 15.09 | 8255.74 | 25382.83 | 12.24 | 12.23 |
| | | 16.30 | 2255 | 36751.99 | 2373.80 | 600.5 | 15.31 | 9193.66 | 27558.33 | 12.24 | |
| Grower | 20[2] | 15.55 | 4859 | 75557.45 | 4752.50 | 1072.4 | 13.83 | 14832.4 | 60725.05 | 12.50 | 12.44 |
| | | 15.55 | 4430 | 68886.50 | 4434.50 | 974.2 | 14.28 | 14102.5 | 54784.00 | 12.37 | |

[1] 6 birds per plot.

[2] 8 birds per plot.

Table 1:8

ME determination for the three feeds (low, medium and high) on ad libitum and regulated feeding.

| Feeds | Plot No. | Gross E. in feed kJ/g | Feed intake g | Gross E. intake kJ | Fresh weight of faeces g. | DM of the faeces g. | Gross E. in faeces DM(kJ/g.) | Gross E in faeces kJ | ME eaten kJ | ME content kJ/g feed | Mean kJ/g |
|---|---|---|---|---|---|---|---|---|---|---|---|
| L | 32[1] | 14.245 | 2325.50 | 33126.75 | 2649.50 | 639.90 | 13.84 | 8856.22 | 24270.53 | 10.44 | 10.06 |
| | 49 | 14.123 | 3703.00 | 52297.47 | 4132.00 | 1236.3 | 13.32 | 16465.04 | 35832.43 | 9.68 | |
| M | 32 | 15.467 | 2323.50 | 35937.57 | 2349.50 | 603.60 | 13.04 | 7872.44 | 28066.63 | 12.08 | 12.21 |
| | 49 | 15.617 | 3414.00 | 53316.44 | 3000.50 | 971.00 | 11.85 | 11503.19 | 41813.25 | 12.28 | |
| H | 32 | 16.200 | 2160.00 | 34992.0 | 2058.50 | 504.35 | 12.05 | 6074.90 | 28917.10 | 13.38 | 13.27 |
| | 49 | 16.012 | 3323.00 | 53207.88 | 2955.40 | 850.3 | 11.14 | 9470.91 | 43736.97 | 13.16 | |
| R[2] | 32 | 15.400 | 2052.00 | 31600.80 | 1854.50 | 517.7 | 12.82 | 6636.91 | 24963.89 | | 12.16 |
| | 49 | 15.600 | 3720.00 | 58032.00 | 3965.50 | 1020.50 | 12.54 | 12797.07 | 45234.93 | 12.16 | |

[1] 8 birds each plot, each value represents the mean of the two determinations.

[2] Feed M with regulated feeding.

using molybdovanadate (Kitson and Mellon 1944) and Glyoxyl B15-2-Hydroxanil (G.B.H.A.) respectively (Kuczerpa, 1967). Initially ether extract was determined by Soxhlet extraction for 5 hours with 40/60°C petroleum/ether. Later samples were analysed using Soxtec apparatus and the technique recommended by Tecator Ltd.

(b) Faeces

As described under ME determination

1:13 Technique of carcass analysis

(a) Preparation of the carcass for analysis

Birds (females and males) were selected at random for chemical analysis. Birds were killed by slaughter method at the end of each 5 weeks till 20 weeks of age and then at 25, 30, 41 and 55 weeks of age for females while for females at 41 and 55 weeks of age (see Table 1:9). Five birds of each sex at each age were chosen from ad libitum and regulated birds on the floor. Before killing, birds chosen for carcass analysis were starved for 24 hours. Their live empty body weights were recorded. After they had been killed they were completely plucked by a standard machine and weighed again. This weight was the whole carcass less blood and feathers. The carcasses were then opened and the weight of liver, heart, gizzard and intestine determined (cleaned from the surrounding fat and feed remains). After weighing these organs they were returned to the carcasses. The whole carcasses were kept in numbered plastic bags in a deep freezer until required for chemical analysis.

At 5 and 10 weeks of age for all groups and at 20 weeks of age for ad libitum females the 5 birds for each group were minced and thoroughly mixed together. At other ages analyses were completed on individual birds. Duplicated samples were taken from each mince for analysis. Higher values for all chemical analysis at 10 weeks of age

Table 1:9 Programme of killing the birds on ad libitum and regulated feeding systems

| | Females | | Males | |
|---|---|---|---|---|
| Age/week | Ad lib. | Reg. | Ad lib. | Reg. |
| 1 day old | 5 | | 5 | |
| 5 | 5 | 5 | 5 | 5 |
| 10 | 5 | 5 | 5 | 5 |
| 15 | 5 | 5 | 5 | 5 |
| 20 | 5 | 5 | 5 | 5 |
| 25 | 5 | 5 | - | - |
| 30 | 5 | 5 | - | - |
| 41 | 5 | 5 | 5 | 5 |
| 55 | 5 | 5 | 5 | 5 |
| Total | 40 | 40 | 30 | 30 |

may have been caused by water loss during the hanging overnight in the slaughter house before mincing. Also there were some unusual results obtained from the analysis of carcass ash content. Adjusted values were used in subsequent calculations (see Chapter II).

(b) Chemical analysis

Carcasses were frozen and cut into small pieces with a band saw and minced twice through a 9.5mm port and then twice through a 3.2mm port of a Crypto Ac 22 mincer. Approximately 20g duplicate sub-samples were taken from the homogenised minced material, freeze-dried and weighed out for fat, protein, and ash determinations. Residual moisture was determined by drying at 100°C for 24 hours. Ash was determined on this dry material by ignition overnight at 480°C. Ashing was continued until a constant weight was achieved. Ether extract was measured by Soxhlet extraction using petrol/ether (AOAC method of analysis, 1969). Later, a Soxtec extraction apparatus was used, using a version of the technique recommended by Tecator Ltd.

sample using the macro-kjeldahl and micro-kjeldahl methods, but EDTA was added to the standard and to the samples to suppress the influence of copper (Mitchell, 1972).

1:14 Artificial insemination

Insemination of hens in cages was completed without removing them from the cage by pulling the feet and shanks through the cage door and leaving the body of the bird resting on the floor of the cage. The legs were held firmly together so as to exert some pressure on the anterior abdomen. The left hand is then used in inverting the oviduct and then injecting the semen. The hens were inseminated weekly. Hens in top cages were inseminated by ad libitum males and hens in the bottom cages were inseminated by regulated males. This process was reversed in adjacent rows, (i.e. regulated males inseminated hens in the top cages and ad libitum males inseminated hens in the bottom cages).

All the eggs collected from the cages and floor of one week were categorised into hatching eggs and non hatching eggs. Hatching eggs were cleaned before sending to the hatchery.

At 13 days of incubation, all eggs candled to measure the percentage of apparent fertility. At 21 days after the chicks hatched they were then categorised into normal and cull chicks.

1:15 Equipment

Different types of balances were used for weighing birds, feed, eggs, carcass and body organs (see Table 1:10).

Table 1:10 The equipments used in the two experiments

| Make | Type | Capacity | Division | Use |
|---|---|---|---|---|
| Avery | 3303C0B | 30kg | 50g | Feeds + heavier males |
| Avery | 126522/77 | 6kg | 5g | Feeds + body weight |
| Oertling | CC121/100 | 1200-12000g | 1g | Body composition + eggs weight |

1:16 Recording procedure

(a) Body weights

The regulated birds were weighed weekly and the ad libitum birds fortnightly until 22 weeks and thereafter every five weeks as given below.

| Age/week | On Floor | | In Cages | |
|---|---|---|---|---|
| | Females | Males | Female | Males |
| 22 | 40-60 | Initial 20 | 160 | 56 |
| 25 | " | " | " | " |
| 30 | " | " | " | " |
| 35 | " | " | " | " |
| 38 | - | - | " | " |
| 40 | 40-60 | 15 minus deaths | - | - |
| 41 | - | - | 160 minus deaths | 56 minus deaths |
| 45 | 40-60 | 15 minus deaths | " | " |
| 50 | " | " | " | " |
| 54 | - | - | " | " |
| 55 | 40-60 | 15 minus deaths | - | - |

The females were weighed by taking a sample of about 40-60 hens for each group. The males were identified by spray painting blue on their back and the same males were weighed at each age. This is described in Chapter II. Two birds in cages were weighed individually from each plot and the same birds used for each weighing. All males in the cages on both feeding systems were weighed.

(b) Feed intake

Feed intakes were calculated weekly from 3 to 15 weeks of age, based on the number of birds alive at the end of the previous week.

After 15 weeks of age the feed intake was calculated every two weeks for both birds in cages and on floor for both feeding systems. This is also described in Chapters II and III.

(c) Egg production

Egg production was recorded daily. Egg production included hatching and non hatching eggs (double yolk, cracked eggs, soft shell and shell less). This recording procedure was followed for all hens. This is described in Chapter II and Chapter III.

(d) Egg weight

Eggs were weighed weekly from birds on the floor and every two weeks from birds in cages. Eggs were collected for weighing over two consecutive days, as described in Chapters II and III.

(e) Fertility and Hatchability:

See section 1:14.

1:17 Statistics

There were no ANOVA completed in Experiment 1. Means and standard error of body weight were done. While feed intake, egg production and egg weights were obtained from the data from each measure for both groups on floor. Regression analysis between egg weights and embryo weights were done for the experiment I.

While the experiment II, all the data for feed intake, body weights, egg weights, hen-day production, hen-housed production, non-hatching eggs and mortality were recorded every two weeks for each plot. Fertility and hatchability data were analysed for three hatches. The

analysis of variance was done for two phases. The first phase from 22 to 35 weeks and the second one from 36 to 54 weeks of age. Also phase 1 divided into two periods (22-29 and 30-35 weeks) and phase 2 into four periods (36-41, 42-45, 46-51 and 52-54 weeks) where analysis of variance was done for each.

CHAPTER TWO

# The Growth, Body Composition and Reproductive Performance of Broiler Breeder with Ad libitum and Regulated Feeding

## Introduction

The growth of broiler breeder stock is controlled carefully in order to obtain satisfactory reproductive performance. Over the last 15 years it has been necessary to maintain a controlled feeding programme for the growing stock to produce parent stock which, over that time, have changed very little in body weight. However, the body size of the progeny has increased steadily each year.

There is a lack of information about broiler breeders in two aspects. Firstly, there is no clear indication of the absolute benefits of a controlled feeding programme. Secondly, there has not been a comprehensive study of the growth and body composition of male and female broiler breeders. This experiment was designed to provide information about these aspects with ad libitum fed stock and those grown to conform during the rearing period, to the Company target body weights.

## Experimental Objectives

1. The first aim of the experiment was to compare the growth, feed intake and body composition of females and males on ad libitum and regulated feeding.
2. The second aim of the experiment was to compare the egg production of females and reproductive performance of birds on ad libitum and regulated feeding.

## Materials and Methods

### 1. General Design

As explained in Chapter I, the studies were carried out in two houses. Birds were maintained in the rearing house till 15 weeks of age and in the laying house to 55 weeks when the experiment was terminated. The results of this study have been obtained with birds on litter for all their life. Information was obtained from the entire population in the rearing house while in the laying house two small breeding groups were continued on litter. The size of breeding groups was such that the reproductive information must only be considered as estimates whereas more confidence may be placed on the growth and body composition data.

The birds were given two feeding systems, one feeding system allowed ad libitum feeding from day old (A), the second feeding system regulated daily allowance so that birds followed as closely as possible the target growth curve given by Ross Breeders, (R).

### 2. Feeds

The ingredient composition of the feeds used were described in Chapter I. The starter and grower feeds and the layer feed M were given to ad libitum and regulated fed groups.

### 3. Body composition

The sampling of the males to provide body composition data was restricted to two ages so that the male:female ratio was slightly lower than the necessary 1:7 initially but was about 1:12 at the end of the experiment.

### 4. Laying house

The laying house was a deep pit design, 24.4m long x 8.1m wide.

It was windowless and fitted with pressurized ventilation system. The house was divided into floor section and cages section within each section ventilation was independent. Lighting was provided by 40W lamps and was controlled separately in both section by time clock and dimmer. In the floor pens the litter was provided by wood shavings. The litter was kept as dry as possible at all time. This was not difficult in ad libitum pen but frequent turning and replacement of the litter was necessary in the regulated pen. Nests were provided at the rate of one nest for every four hens.

5. Recording

From 3 to 21 weeks of age the birds were weighed weekly and from 22 to the end of the experiment every five weeks. Birds were weighed individually on the 5kg scale. Forty to sixty birds were selected at random from each group. The cockerels for weighing were identified by spraying a blue maker on their backs. The birds were weighed at the same time on each Friday of weighing. Food intake was recorded every two weeks. The feed remaining in the trough was returned to the empty food bag and the total food intake was recorded. Food intake measurements were always started at the same time of day. All eggs produced were recorded twice per day from the floor and nests and egg weights collected during two consective days each week. The sample of eggs collected were very small, cracked and large eggs were counted as eggs and remove; then the remainder (hatching eggs) were weighed in egg trays.

6. Fertility and Hatchability

All eggs were collected for one week and then categorised into hatching eggs and non-hatching eggs. These eggs were sent to the Department Hatchery at 30, 35, 40 and 50 weeks of age and on 21 occasions to the Cample Hatchery, Ross Poultry Great Britain Ltd. Other procedure

were detailed in Chapter I.

7. Statistics

The data from body weight throughout this experiment was statistically analysed by using standard error for each group and by using the t test to compare two means. The t value was calculated as follows.

$$t = \frac{D}{\left(\frac{(n_1 - 1)(S.E)^2 + (n_2 - 1)(S.E)^2}{n_1 + n_2 - 2}\right)\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}$$

where D was the difference between the two means, $n_1$ and $n_2$ were numbers of observations for each group. $SE_1$ and $SE_2$ were standard error, each degree of freedom equal to the total number of observations for both groups minus 2. The data for food intake, egg weight and egg production for this experiment were not statistically analysed.

8. Embryo development

Forty eggs were selected at random from each group at 35 and 40 weeks of age. The eggs were weighed individually just prior to setting. During the incubation period, both samples of eggs were set in the same tray and set side by side. Both samples were used for embryo weights at 13 days of incubation, all eggs were candled and the embryo weighed immediately after the eggs were broken. The method was as follows - the shell was broken, all the shell membranes and all extra embryonic membranes were removed. The embryo was rolled on absorbent paper to remove excess moisture during 15-20 seconds and then weighed. The relationship between fresh egg weight and embryo weight, was evaluated by regression analysis during the hatches at 35 and 40 weeks. Twenty eggs were set from each group at 50 weeks of age. The embryos obtained

were used to determine dry matter from each group.

## RESULTS

### 1. Feed Intake

Results for feed intake are given in Tables 2:1, 2:4 for birds on A feeding and on R throughout the experiment. Feed consumption was higher on A than R throughout the rearing period. Initially the difference between them was small and then increased substantially till the females reached their peak of intake at 12 weeks of age. At this age the feed intake of females and males on R feeding was 33 and 36 per cent of those fed ad libitum. This is shown in Fig. 2:2.

In the first 21 weeks of the experiment the females and males on A consumed more feed than those on R by 54 and 51 per cent, respectively. The mean daily feed intake was 121 and 145 g/d for females and males on A, while for those on R it was 56 g/d and 71 g/d respectively up to 21 weeks of age. The intake of the A birds increased gradually with age but there were two fluctuations in feed intake during the period 16 to 21 weeks of age. The first one was at 16 weeks when the birds were transferred to the laying house and the second one was at 19-20 weeks during the onset of lay. Following these reductions in feed intake the hens consumed more feed to compensate their intake deficit for a short period (Fig. 2:1). The mean daily feed intake during this period was 158 g/d and 76 g/d for birds on A and R respectively. There was a big difference in the accumulative feed intake over the 21 weeks in which the females and males on ad libitum feeding consumed about 9.6 kg/b and 10.9 kg/b more, respectively, than those on R feeding (Table 2:2). Food consumption was higher on A than those on R throughout the laying period (22-25 weeks of age) except in the few weeks during the challenge feeding period at 28 to 39 weeks. Birds on

Table 2:1

Daily feed intake of ad libitum and regulated birds and the regulated intake as a percentage of ad libitum during the rearing period.

| Age Weeks | Females | | | Males | | |
|---|---|---|---|---|---|---|
| | Regulated (g) | Ad libitum (g) | Regulated % of ad libitum | Regulated (g) | Ad libitum (g) | Regulated % of ad libitum |
| 3 | 23 | 38 | 60 | 24 | 47 | 51 |
| 4 | 30 | 50 | 60 | 41 | 64 | 64 |
| 5 | 39 | 76 | 51 | 48 | 96 | 50 |
| 6 | 43 | 93 | 46 | 63 | 109 | 58 |
| 7 | 46 | 116 | 40 | 63 | 124 | 51 |
| 8 | 54 | 112 | 44 | 76 | 160 | 48 |
| 9 | 59 | 138 | 43 | 80 | 198 | 40 |
| 10 | 59 | 171 | 35 | 80 | 206 | 39 |
| 11 | 59 | 169 | 35 | 83 | 209 | 40 |
| 12 | 59 | 178 | 33 | 83 | 232 | 36 |
| 13 | 70 | 163 | 43 | 85 | 214 | 40 |
| 14 | 70 | 161 | 43 | 85 | 212 | 40 |
| 15 | 75 | 108 | 70 | 86 | 203 | 42 |
| 16 | 75 | 108 | 70 | 88 | 108 | 82 |
| 17 | 75 | 184 | 41 | 88 | 184 | 48 |
| 18 | 75 | 191 | 39 | 88 | 191 | 46 |
| 19 | 77 | 147 | 52 | 94 | 147 | 64 |
| 20 | 77 | 147 | 52 | 94 | 147 | 64 |
| 21 | 77 | 168 | 46 | 94 | 168 | 56 |

Table 2:2

Total feed consumption during the rearing period of four periods kg/b

| Age/weeks | Female | | Male | |
|---|---|---|---|---|
| | A | R | A | R |
| 0-5 | 1.421 | 0.917 | 1.719 | 1.061 |
| 6-11 | 5.667 | 2.237 | 7.042 | 3.115 |
| 12-15 | 4.267 | 1.918 | 6.025 | 2.373 |
| 16-21 | 6.469 | 3.192 | 6.469 | 3.822 |
| Total | 17.824 | 8.264 | 21.255 | 10.371 |

Table 2:3

Accumulative feed and daily feed intake during the laying period

(22 - 55 weeks)

| Treatment | Accumulative feed intake kg/b | Feed intake g/b/d |
|---|---|---|
| Ad libitum | 41.956 | 176 |
| Regulated | 38.862 | 163 |
| Difference | 3.094 | 13 |

Table 2:4

Daily feed intake of laying period of ad libitum and regulated groups.

| Age/weeks | A g/b | R g/b | |
|---|---|---|---|
| 22 + 23 | 177 | 89 | |
| 24 + 25 | 165 | 140 | |
| 26 + 27 | 179 | 160 | |
| 28 + 29 | 193 | 171 | |
| 30 + 31 | 197 | 174 | |
| 32 + 33 | 188 | 180 | |
| 34 + 35 | 181 | 192 | Challenge Feeding |
| 36 + 37 | 180 | 191 | |
| 38 + 39 | 180 | 181 | |
| 40 + 41 | 172 | 161 | |
| 42 + 43 | 168 | 164 | |
| 44 + 45 | 168 | 163 | |
| 46 + 47 | 168 | 161 | |
| 48 + 49 | 168 | 160 | |
| 50 + 51 | 168 | 159 | |
| 52 + 53 | 166 | 156 | |
| 54 + 55 | 165 | 155 | |

Fig. 2:1 Mean daily feed intake (g/b) for *ad libitum* and regulated birds during the whole experiment.

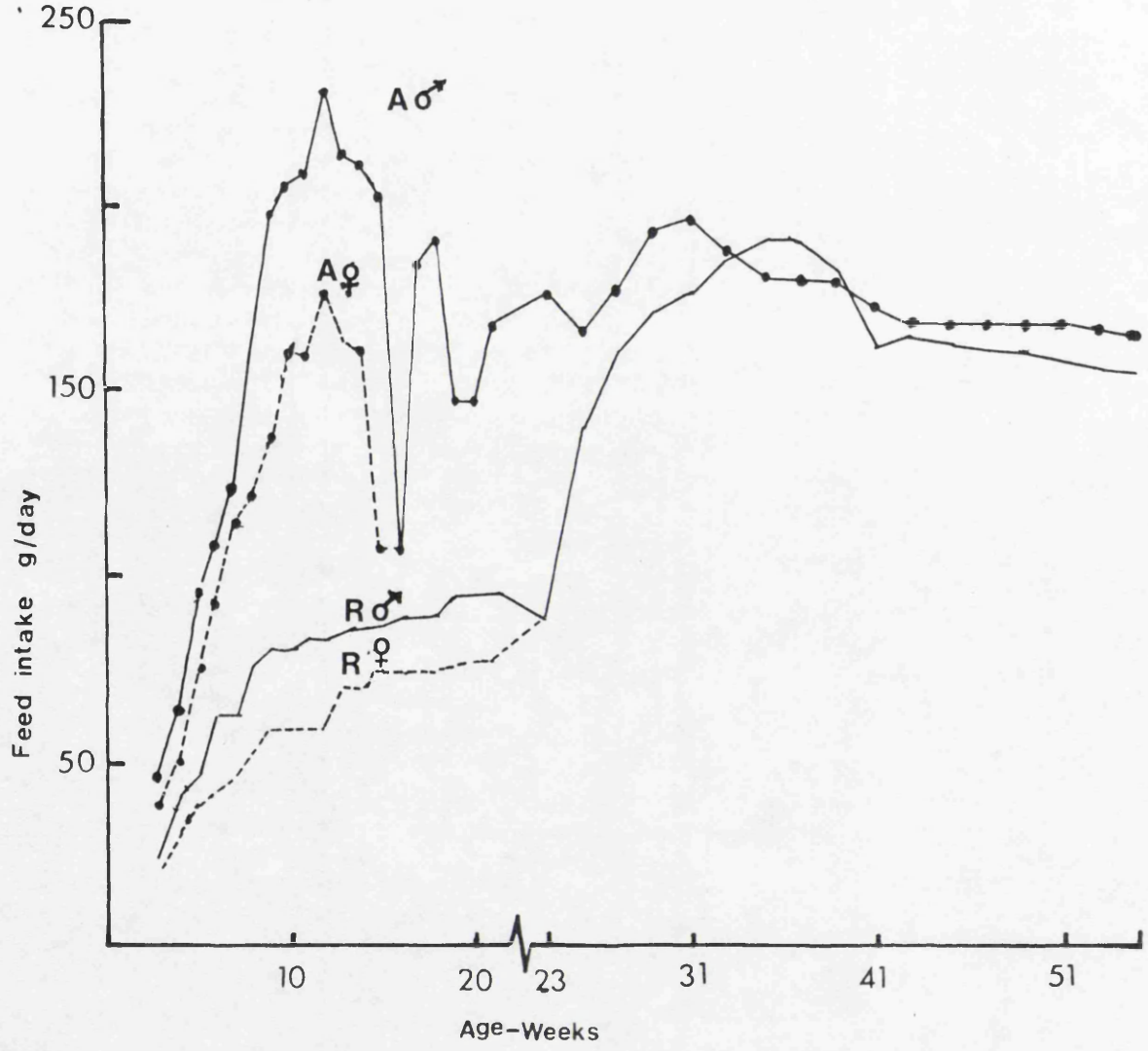
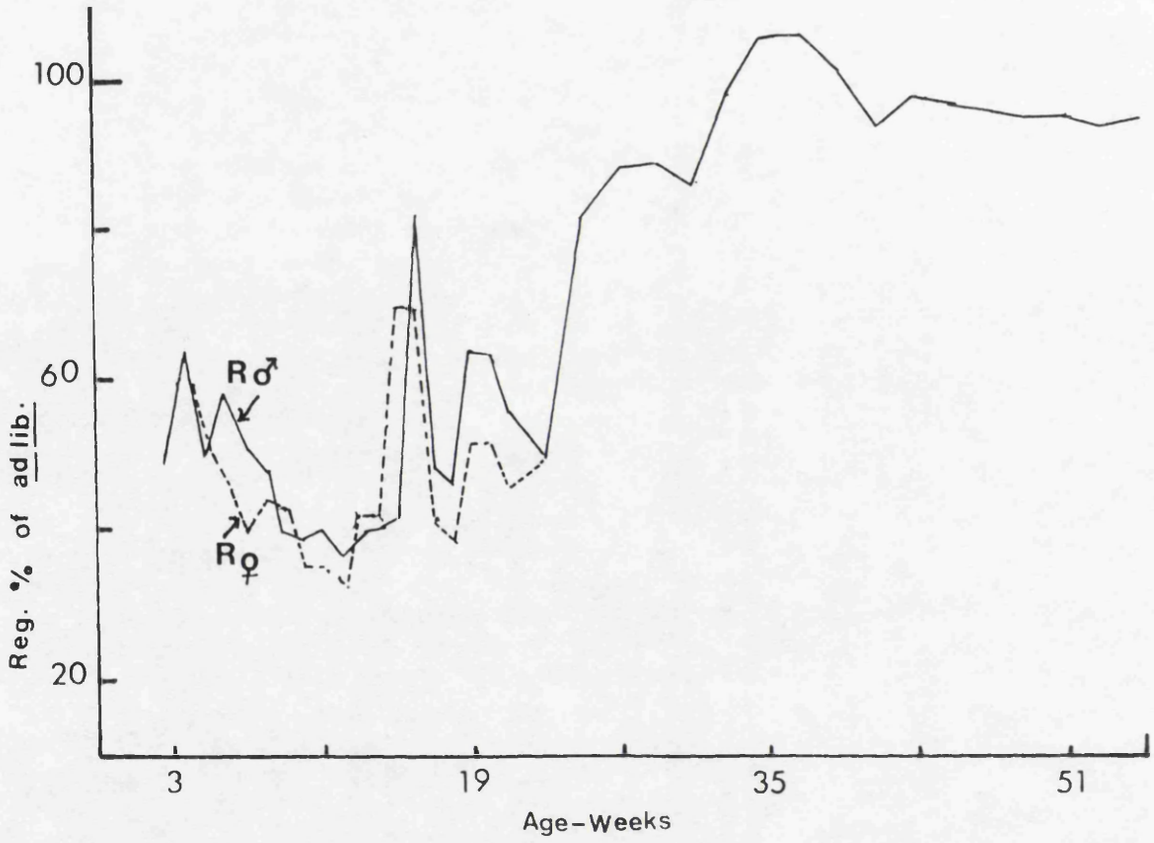


Fig. 2:2 The regulated feed percentage of *ad libitum* feeding for both sexes during the whole experiment.



R consumed more than those on A by 11 g/d during 34 to 37 weeks (Table 2:4). The mean daily feed intake during this period (challenge feeding period) was 186.5 and 181.5 $gd^{-1}$ for A and R birds respectively. The deterioration in feed intake and egg output at 39 and 40 weeks of age is accounted for by the accidental cut in water supply for about 10 hr. The highest daily feed intake was 197 g/d and 192 g/d for hens on A feeding (at 31 weeks) and those on R feeding (at 35 weeks) respectively. The mean daily feed intake during the laying period was 176 and 163 $gb^{-1}$ (Table 2:3) for ad libitum and regulated birds respectively. The accumulative feed intake over all the experiment for females and males on A was approximately 47 kg and 49 kg respectively. The birds on A feeding consumed more feed than those on R by about 22 per cent during the 55 weeks. The mean daily feed intake during the whole experiment was 156 and 164 g/b for females and males on A, while for those on R it was 122 and 127 g/b respectively.

2. ME Intake

ME intakes were obtained by multiplying the daily feed intake data by the determined ME values of the feed. The results for ME intake are given in Tables 2:5, 2:6.

During the rearing period (0-21 weeks of age) the females and the males on A feeding consumed more ME than those on R by 802 kJ/d and 914 kJ/d. This was 55 and 51 percent respectively, more than those on R. The highest daily ME intake was 1493 kJ/b and 1790 kJ/b for females and males on A, while for those on R it was 681 kJ/b and 876 kJ/b respectively.

The difference in ME intake became less gradually with advancing age during the laying period. The maximum daily ME intake was 2405 kJ/b at 31 weeks, for hens on A feeding, while for those on R it

was 2280 kJ/b at 35 weeks of age. Over the entire experimental period (55 weeks) females on A feeding consumed about 155 MJ/b more than those on R and the males on A feeding ate about 172 MJ/b more than those on R. Birds on A consumed approximately 22 per cent more energy than those on R.

Table 2:5

ME intake (MJ/b) during the rearing period

| Period/ Weeks | Female | | Male | |
|---|---|---|---|---|
| | A | R | A | R |
| 0-5 | 17.538 | 11.318 | 21.216 | 13.095 |
| 6-11 | 69.942 | 27.609 | 86.912 | 38.445 |
| 12-15 | 52.663 | 23.672 | 74.361 | 29.288 |
| 16-21 | 79.840 | 39.396[1] | 79.840 | 47.171[1] |
| Total | 219.983 | 101.995 | 262.329 | 127.999 |

[1]ME intake was taken from females and males in cages.

Table 2:6

Daily energy intake (kJ/b) at different ages for birds on feed A and on R

| Age(week) | Feeding Systems | | |
|---|---|---|---|
| | A | R | Difference |
| 22-30 | 2197 | 1753 | 444 |
| 31-35 | 2306 | 2220 | 86 |
| 36-40 | 2159 | 2172 | -13 |
| 41-45 | 2062 | 1989 | 73 |
| 46-50 | 2050 | 1952 | 98 |
| 51-55 | 2025 | 1915 | 110 |

3. Body Weight

The body weight data on A and R feeding for the rearing period are given in Table-2:7, 2:8 and for the laying period, they are given in Table-2:9. The average body weight of birds on A were significantly ($p<0.05$) greater than those on R from 5 weeks of age. Birds on A feeding had body weight gains of about 27 g/d and 32 g/d for females

and males,while those given regulated amounts of feed gains were about 12 g/d and 18 g/d for females and males respectively (Fig. 2:5). During 6 to 11 weeks of age, the weight gains of females and males on A were 53 and 44 per cent greater than those on R respectively (Table 2:10). Following housing at 16 weeks of age, it was noticed that caging affected body weights. At 21 weeks of age the females on A and those on R in cages were heavier by 98 and 99 g than those on floor respectively. The males on A in cages were heavier by 464g than those on the floor. But conversely males on R in cages were 30 g lighter than those on the floor (Table 2:8b, c,d ). Before the birds started laying, body weight increased sharply particularly for hens on A. But the cockerels which were gaining weight rapidly up to 15 weeks of age had a slower weight gain subsequently (Fig. 2:4 ). Regulated feeding resulted in a higher variation in body weight (Table 2:8). During the time from onset of lay until peak egg production at 32 and 35 weeks of age for hens on R feeding and those on A respectively, hens on A showed a greater increase in their body weight compared with those on R (Fig. 2:3). The difference in body weights between females on A and those on R feeding at 35 weeks of age was about 29 per cent. For males the difference was about 11 per cent. Females on A were never less than 1 kg heavier than females throughout the whole laying period. From 25 to 55 weeks of age, the differences in body weight between A and R males gradually become narrower. The difference was 452g at the end of the experiment. There was a significant ($P<0.05$) differene in body weight between females on A and those on R, and, between males on A and those on R from 25 till 55 weeks of age except for males at 50 weeks of age.

4. Egg production

Age at first egg

Hens on A feeding reached sexual maturity at 136 days but those on R laid their first egg at 169 days of age. This was 33 days later

Table 2:7

The mean body weights on different feeding systems for both sexes compared with target body weight during the rearing period (g)

| | Females | | | Males | | |
|---|---|---|---|---|---|---|
| Age | Regulated | | Ad libitum | Regulated | | Ad libitum |
| weeks | Target | Actual | | Target | Actual | |
| 1 day | | | 35 | | | 35 |
| 1 | | | 91 | | | 85 |
| 2 | | | 166 | | | 161 |
| 3 | 265 | 267 | 340 | 346 | 258 | 403 |
| 4 | 365 | 400 | | 500 | 462 | |
| 5 | 485 | 520 | 778 | 660 | 617 | 938 |
| 6 | 595 | 635 | | 820 | 817 | |
| 7 | 695 | 707 | 1216 | 977 | 901 | 1500 |
| 8 | 795 | 800 | | 1127 | 1100 | |
| 9 | 895 | 901 | 1838 | 1267 | 1319 | 2268 |
| 10 | 995 | 1058 | | 1402 | 1407 | |
| 11 | 1085 | 1112 | 2333 | 1530 | 1582 | 3072 |
| 12 | 1175 | 1162 | | 1655 | 1637 | |
| 13 | 1255 | 1391 | 2856 | 1780 | 1895 | 3725 |
| 14 | 1335 | 1394 | | 1905 | 1890 | |
| 15 | 1405 | 1517 | 3170 | 2025 | 2258 | 4487 |
| 16 | 1475 | 1691 | 3297 | 2145 | 2304 | 4521 |
| 17 | 1545 | 1690 | 3370 | 2255 | 2434 | 4795 |
| 18 | 1620 | 1570 | 3600 | 2360 | 2300 | 4960 |
| 19 | 1700 | 1899 | 3796 | 2460 | 2521 | 4793 |
| 20 | 1790 | 1860 | | 2550 | 2806 | |
| 21 | 1890 | 1844 | 3950 | 2640 | 2639 | 4711 |

Table 2:8

Live weight ± Standard error and Coefficient of variation during the period (1 - 21 weeks) of females and males on different feeding systems.

| Age/weeks | Feeding systems | Sex | Body weight ± SE g/b | CV[1] |
|---|---|---|---|---|
| 1 | A | F | 91 ± 2 | 22.0 |
| | " | M | 85 ± 2 | 16.6 |
| 5 | A | F | 778 ± 8 | 10.3 |
| | " | M | 938 ± 15 | 11.3 |
| | R | F | 519 ± 8 | 15.4 |
| | " | M | 617 ± 10 | 11.5 |
| 9 | A | F | 1838 ± 19 | 10.3 |
| | " | M | 2268 ± 37 | 11.5 |
| | R | F | 902 ± 12 | 13.3 |
| | " | M | 1319 ± 22 | 11.8 |
| 15 | A | F | 3170 ± 41 | 12.9 |
| | " | M | 4487 ± 85 | 13.4 |
| | R | F | 1517 ± 28 | 18.5 |
| | " | M | 2258 ± 69 | 21.6 |
| 21 | A | F | 3950 ± 53 | 13.4 |
| | " | M | 4711 ± 106 | 15.9 |
| | R | F | 1844 ± 29 | 15.7 |
| | " | M | 2639 ± 76 | 20.4 |

1 Coefficient of variation.

Table 2:8b

The body weight (kg) of ad libitum females and males in cages during 16 to 21 weeks of age.

| Age/ weeks | Ad libitum | |
|---|---|---|
| | Female | Male |
| 16 | 3.300 ± 0.025[1] | 4.521 ± 0.011 |
| 18 | 3.592 ± 0.029 | 4.950 ± 0.103 |
| 21 | 4.048 ± 0.037 | 5.175 ± 0.105 |

Table 2:8c

The body weight (kg) of regulated females and males in cages during 16 to 21 weeks of age.

| Age/ weeks | Regulated | |
|---|---|---|
| | Female | Male |
| 16 | 1.689 ± 0.027[1] | 2.304 ± 0.049 |
| 19 | 1.899 ± 0.029 | 2.521 ± 0.056 |
| 21 | 1.943 ± 0.028 | 2.609 ± 0.070 |

[1] Standard error

Table 2:8d

Daily feed intake (g) of ad libitum and regulated birds in cages from 16 to 21 weeks of age.

| Age/ weeks | Ad libitum | | Regulated | |
|---|---|---|---|---|
| | Female | Male | Female | Male |
| 16 | 135 | 189 | 75 | 83 |
| 17 | 160 | 182 | 75 | 83 |
| 18 | 170 | 146 | 75 | 86 |
| 19 | 181 | 185 | 77 | 88 |
| 20 | 158[1] | 187[1] | 77 | 88 |
| 21 | | | 77 | 88 |

[1] average feed intake for two weeks

Table 2:9

Average body weight (kg/b) of birds on different feeding systems during the laying periods.

| | Age/weeks | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 22 | 25 | 30 | 35 | 40 | 45 | 50 | 55 |
| A female | 4.152 | 4.252 | 4.316 | 4.493 | 4.541 | 4.683 | 4.629 | 4.792 |
| R female | 2.004 | 2.524 | 2.924 | 3.193 | 3.333 | 3.375 | 3.511 | 3.507 |
| Difference | 2.148 | 1.728 | 1.392 | 1.300 | 1.208 | 1.308 | 1.118 | 1.285 |
| A male | 4.790 | 4.715 | 4.820 | 4.978 | 5.029 | 5.187 | 5.389 | 5.290 |
| R male | 2.977 | 3.527 | 4.229 | 4.411 | 4.641 | 4.875 | 5.122 | 4.838 |
| Difference | 1.813 | 1.188 | 0.591 | 0.567 | 0.388 | 0.312 | 0.267 | 0.452 |

Table 2:10

Effect of different feeding systems on body weight gain (g/b).

| Age weeks | Female | | Male | |
|---|---|---|---|---|
| | A | R | A | R |
| 0-5 | 743 | 485 | 903 | 582 |
| 6-11 | 1555 | 592 | 2134 | 965 |
| 12-15 | 837 | 465 | 1449 | 722 |
| 16-21 | 780 | 327 | 190 | 335 |

Fig. 2:3 The live body weight for *ad libitum* and regulated females during the whole experiment.

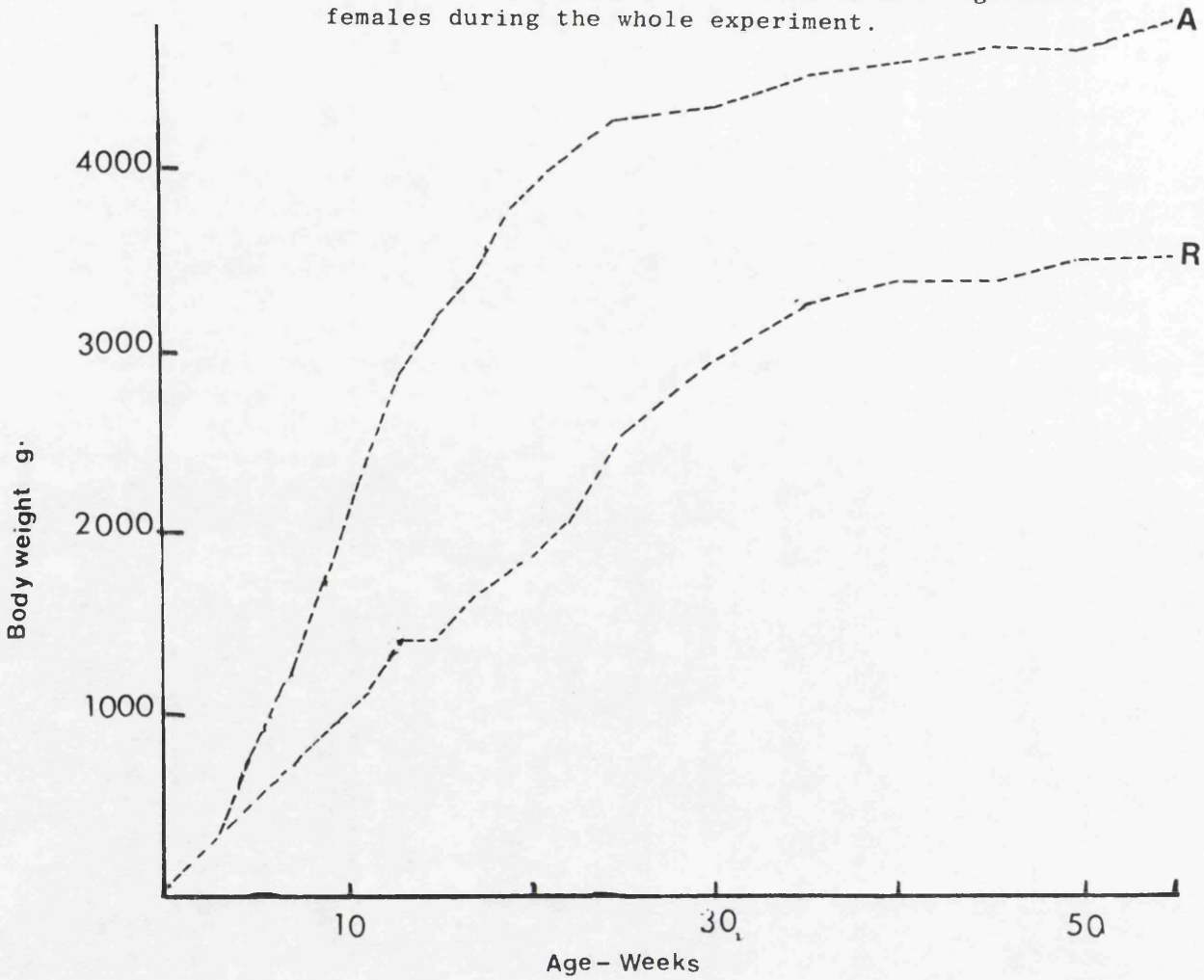


Fig. 2:4 The live body weight for *ad libitum* and regulated males during the whole experiment.

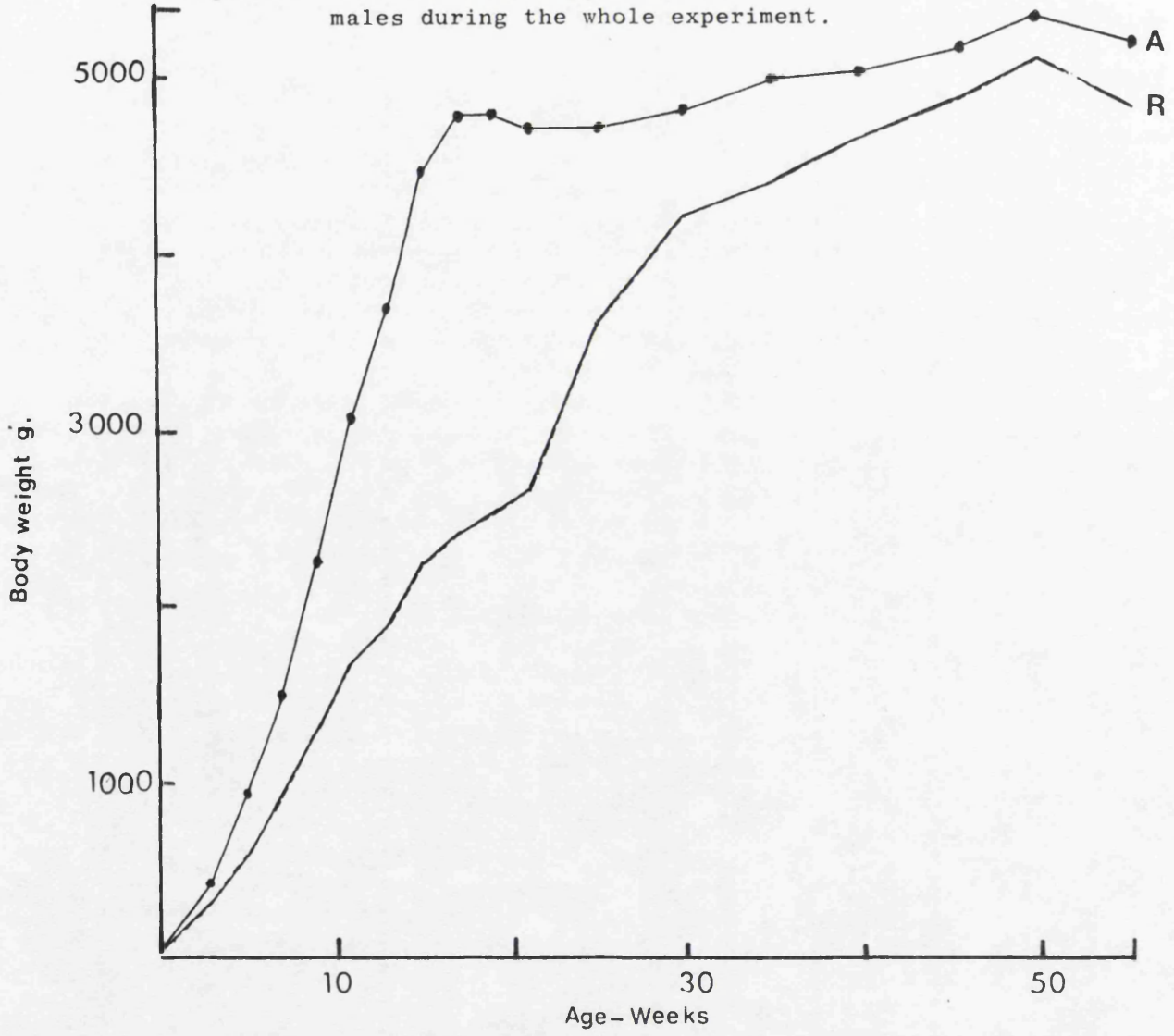
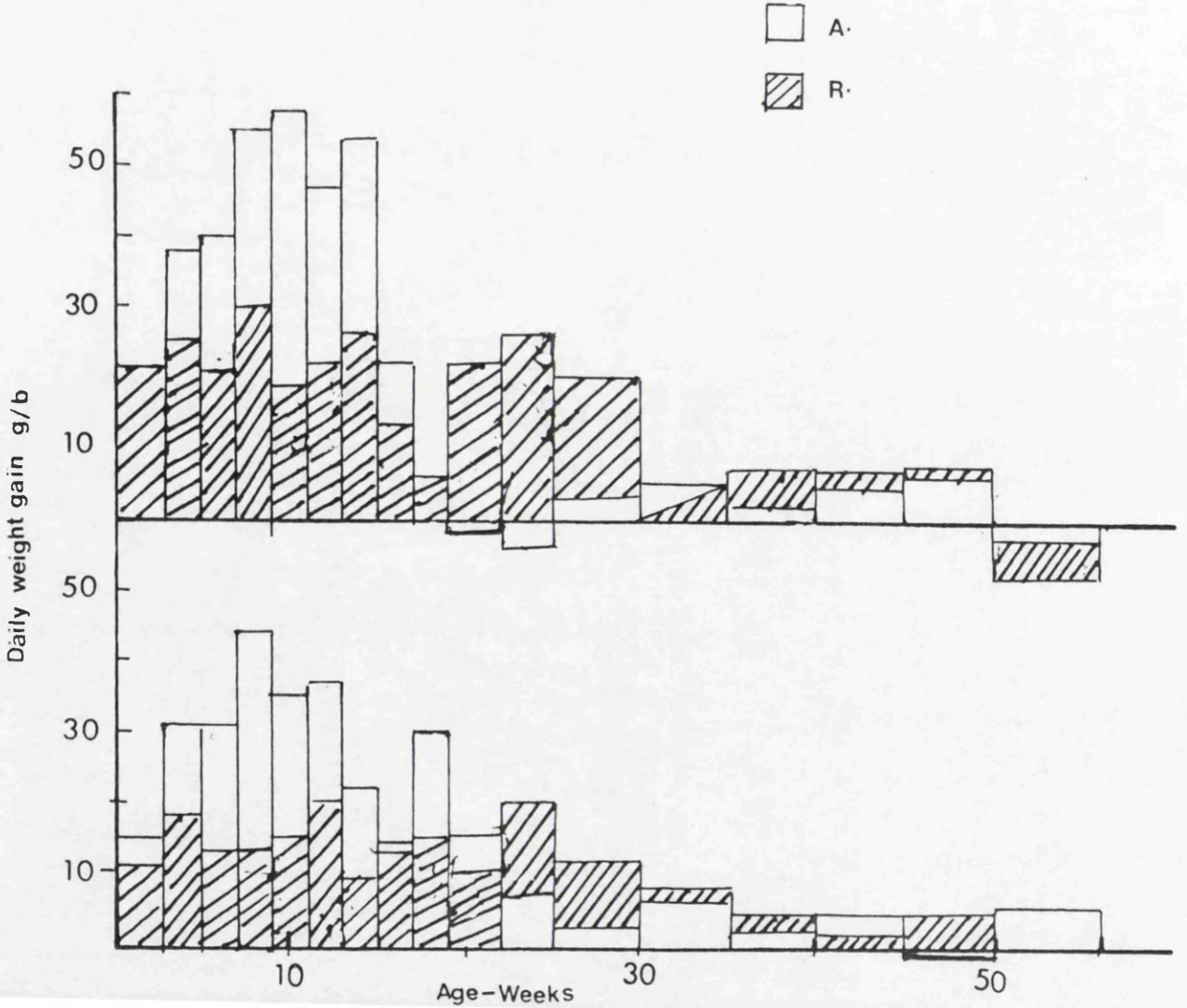


Fig. 2:5 Mean body weight gain for *ad libitum* and regulated females and males during the whole experiment.



than those on A feeding. The hens on A reached 50 per cent egg production at 175 days of age while those on R achieved it at 193 days of age. These data indicate that hens allowed ad libitum feeding matured faster than those on regulated feeding. The weekly hen-day production for the whole experiment for the birds on A and R are plotted against age in Fig. 2:6, and the bi-weekly results are given in Appendix 2:1 and 2:2. These results have been summarized and are given in Table 2:11

Table 2:11

Effect of different feeding systems on % hen-day production at different periods throughout the experiment.

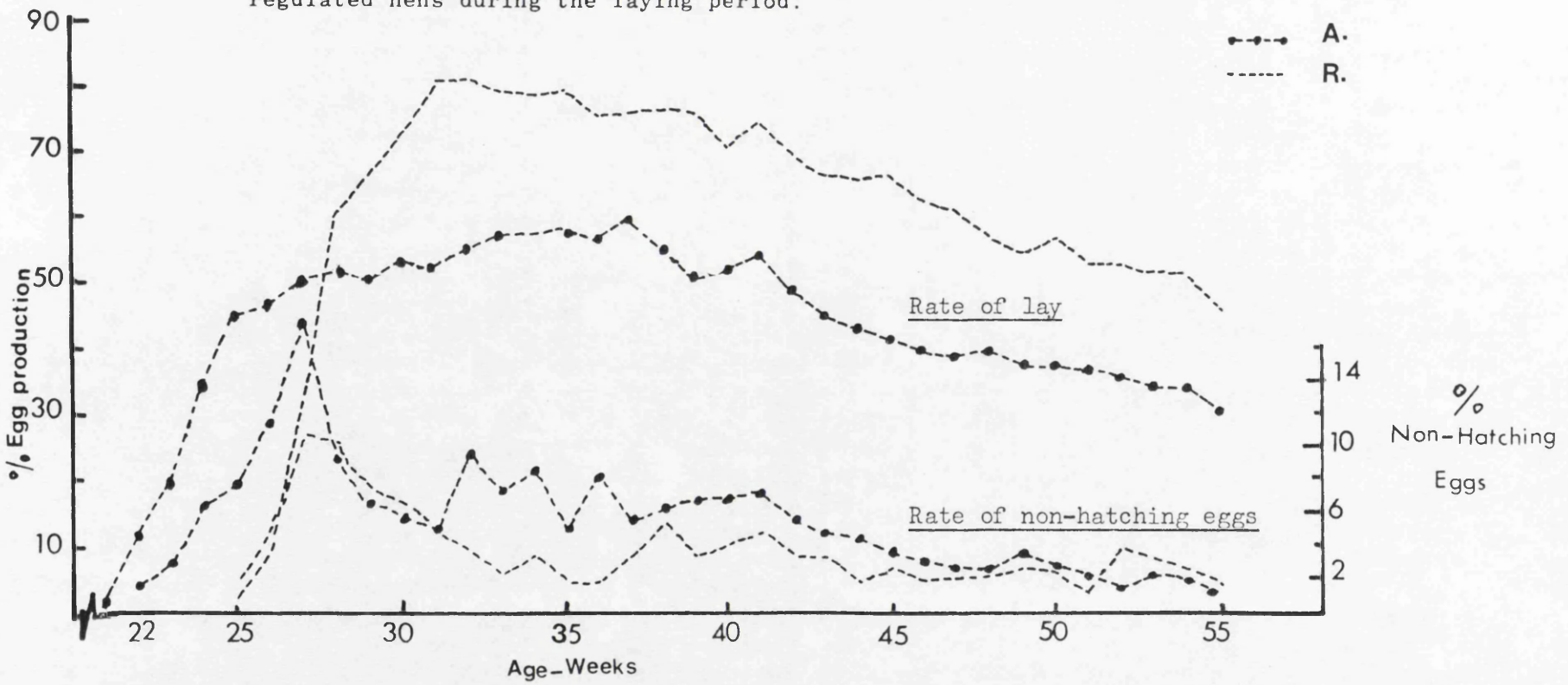
| Age/weeks | % A | % R |
|---|---|---|
| 20-30 | 33.0 | 39.7[1] |
| 31-35 | 55.5 | 77.5 |
| 36-40 | 53.5 | 75.5 |
| 41-45 | 47.0 | 68.7 |
| 46-50 | 38.0 | 57.5 |
| 51-55 | 34.5 | 51.8 |
| Mean | 44.0 | 62.0 |

[1]recorded from 24 weeks of age.

Over the whole experiment the rate of lay was reduced in the A females. The difference in egg production between hens on A and R during 20-30 weeks of age was approximately 7 per cent. The highest rate of lay for both feeding systems was during 30 to 35 weeks of age (Table 2:11). The peak production of hens on A feeding was 58 per cent while for those on R it was 81 per cent (Fig. 2:6). Rate of lay for both groups gradually declined after peak production.

It is apparent that hens on R reached a peak production faster than those on A. During 36-40 weeks of age, the difference was 22 per cent between hens on A and those on R feeding. Following

Fig. 2:6 Mean hen-day production and non hatching eggs for *ad libitum* and regulated hens during the laying period.



this period, there was similar difference between them. Hens on ad libitum feeding had declined to 30 percent while those on regulated feeding had only declined to 45 percent production at the end of the experiment. The differences between both groups in hen-day production was approximately 15 percent. The hen-housed production was 3.0 per cent less than hen-day production for hens on ad libitum, but by contrast it was 4 percent for hens on regulated feed. This was due to the difference in their mortality. The difference in hen-housed production between hens on A and those on R feeding during the whole period was 17 percent less for hens on A. Hens on A produced more non-hatching eggs than those on R (Table 2:12). Most of the non-hatching eggs were produced during the first 5 to 7 weeks of laying (Fig. 2:6). The difference in non-hatching eggs between both groups was 1.6 eggs.

Table 2:12

Effect of different feeding systems on hen-day, hen-housed and non-hatching eggs during 22 to 55 weeks of age.

| | A | R |
|---|---|---|
| % Hen-day production | 44.0 | 62.0 |
| Cumulative hen-day | 118.4 | 139.0 |
| % Hen-housed production | 41.3 | 58.0 |
| Cumulative hen-housed | 114.8 | 130.0 |
| % Non hatching eggs | 5.6 | 3.6 |
| Cumulative non-hatching eggs | 6.6 | 5.0 |
| No. of settable eggs | 111.8 | 134.0 |

5. Egg weight

Egg weight (g/egg) recorded weekly during the laying period are shown in Fig. 2:7. Egg weights as bi-weekly means are given in Appendix-2:1 & 2:2. In the first four weeks of the laying period, there were not enough eggs for weighing particularly for hens on A

while those on R were still not laying. The first egg weight comparison was possible at 25 weeks when hens on ad libitum produced heavier eggs by an average of 6.6g than those on R. During 31-35 weeks of age, all the hens reached their peak production, and at this stage, hens on A were producing eggs 2.6g heavier than those on R (Table-2:13). In the following periods, hens on A still laid heavier eggs than those on R with a difference of about 3.6g at 55 weeks of age. The average egg weight during the laying period was 66.6g for hens on A feeding while those on R feeding was 63.6g.

Table 2:13

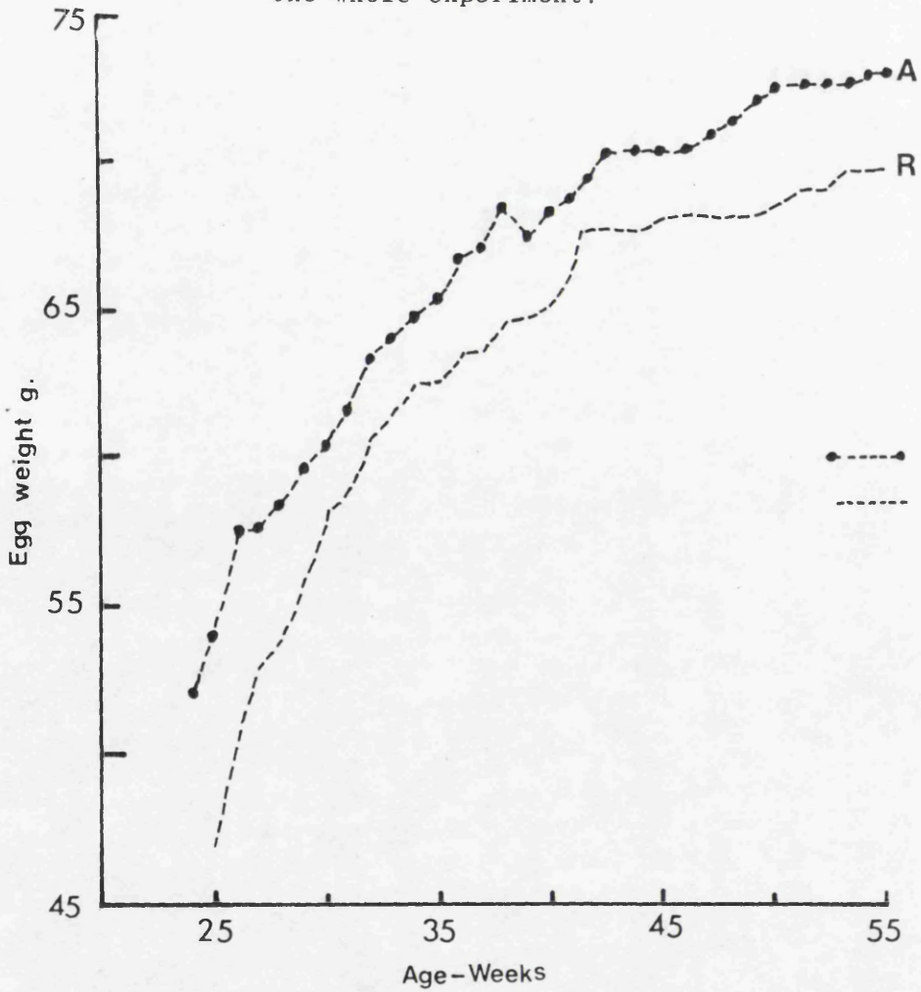
Effect of different feeding systems on egg weight.

| Age/weeks | A g/egg | R g/egg |
|---|---|---|
| 24-30 | 57.8 | 53.0 |
| 31-35 | 63.3 | 60.7 |
| 36-40 | 67.9 | 64.6 |
| 41-45 | 69.8 | 67.0 |
| 46-50 | 71.7 | 68.4 |
| 51-55 | 72.5 | 69.5 |

6. Egg mass

The average egg mass output produced (g/b day) every two weeks for the whole laying period is given in Appendix-2:3. When the birds reached their peak in egg production, the daily egg mass output increased substantially from 30 to 35 weeks of age for both groups (Table 2:14). At this age birds showed their peak in egg mass production on both feeds. Thereafter, the egg mass output declined was associated with age on both feeds. The egg mass produced by hens on A feeding was lower than that on R feeding; this was mainly because of their lower egg production. The mean daily egg mass output during the whole period was 31.2g/b for hens on A feeding while for those on

Fig. 2:7 Mean egg weight for both groups during the whole experiment.



R feeding it was about 41.3g/b.

Table 2:14

Effect of different feeding systems on daily egg mass output during the laying period

| Age/weeks | A g/b | R g/b |
|---|---|---|
| 20-30 | 19.9 | 22.6 |
| 31-35 | 35.1 | 47.1 |
| 36-40 | 36.3 | 48.8 |
| 41-45 | 32.7 | 45.8 |
| 46-50 | 27.3 | 39.3 |
| 51-55 | 24.9 | 36.0 |

7. Feeding Efficiency

Over the period 24 to 35 weeks of age, hens on A feeding consumed 1.2kg feed more than those on R to produce one dozen eggs. Also hens on R consumed less feed to produce one kg egg than those on A feeding (Table 2:15). Hens on A consumed 27 percent more feed or energy to produce one dozen eggs, and ate 23 percent more feed to yield 1kg eggs.

Table 2:15

Effect of different feeding systems on daily egg mass output, feed conversion, and energy conversion during the laying period

| Treatment | Egg mass g/d | Feed conversion kg feed/doz.eggs | Feed conversion kg feed/kg eggs | Energy conversion MJ ME/doz.eggs |
|---|---|---|---|---|
| A | 27.4 | 4.52 | 5.69 | 55.05 |
| R | 38.2 | 3.31 | 4.37 | 40.3 |
| Differences | 10.8 | 1.21 | 1.32 | 14.75 |

8. Fertility and Hatchability

The results of the four hatches that were carried out in the Department hatchery are given in Table 2:16 and those of the 21 hatches which were completed by a Ross poultry hatchery are given in Appendix-2:6. Fertility and hatchability from these hatcheries are also plotted against age for both treatments and are shown in Fig. 2:8. Results from all hatches during this experiment shows that the fertility and hatchability was different between the groups. The differences existed for all hatches. Fertility was maintained at a nearly constant level up to 48 weeks of age and then declined rapidly for both treatments. A lower level of fertility was obtained with birds on A feeding. Peak fertility levels were 87 and 96 per cent for birds on A and those on R, respectively. At the end of the laying cycle fertility of hens on A feeding had declined to 46.0 per cent while those on R had only declined to 73.5 percent at 50 weeks of age. The percentage of fertility was associated with egg production, in that the peaks were attained at about the same age and declined subsequently. To compare the fertility and hatchability from both hatcheries the results are summarized in Table 2:17. The fertility of eggs incubated in the Department hatchery were higher than those incubated at the Ross hatchery by about 4 and 3 percent for hens on A and those on R respectively. Disturbance in water availability at 39 weeks of age affected the fertility of birds on both feeding systems. It is unlikely that decrease in the house temperature at 42 weeks of age should have any effect on their fertility.

9. Weight loss during incubation and embryo weights

Results for two hatches of eggs from hens on A and those on R are given in Table 2:18. The data for both hatches of the fresh egg weight and embryo weight are shown in Figures 2:9 and 2:10.

Table 2:16

Effect of different feeding systems on the fertility and hatchability in Department hatchery.

| | Feeding System | | | |
|---|---|---|---|---|
| | A | | R | |
| Hatch no. | % Fertility | % Hatchability | % Fertility | % Hatchability |
| 1 | 87 | 80 | 93 | 89 |
| 2 | 88 | 76 | 97 | 92 |
| 3 | 77 | 72 | 93 | 88 |
| 4 | 46 | 37 | 80 | 73 |
| Mean | 74 | 66 | 91 | 85 |

Table 2:17

Effect of feeding systems on average fertility and hatchability from the Ross hatchery and the Department hatchery.

| | Department | | Ross | |
|---|---|---|---|---|
| | A | R | A | R |
| Total egg set | 1552.0 | 2136.0 | 3624.0 | 4500.0 |
| Infertile eggs | 407.0 | 201.0 | 872.0 | 403.0 |
| % fertile eggs | 74.0 | 91.0 | 70.0 | 88.5 |
| % cull chicks | - | - | 1.8 | 1.5 |
| % hatch of total eggs | 66.0 | 85.0 | 63.2 | 81.2 |
| % hatch fertile eggs | 89.2 | 94.0 | 89.6 | 92.0 |

Table 2:18

Effect of different feeding systems on embryo weight and chicks weight produced by ad libitum and regulated parents for two hatches.

| | Hatch 1 at 35 weeks | | Hatch 2 at 40 weeks | |
|---|---|---|---|---|
| | Ad lib. | Reg. | Ad lib. | Reg. |
| No. of eggs set | 40.0 | 40.0 | 40.0 | 40.0 |
| Egg weight at setting g/egg | 64.9 | 63.1 | 67.8 | 65.9 |
| Egg weight at 12 days incubation g/egg | 61.9 | 59.0 | 64.0 | 61.6 |
| Water loss mg/day | 253.0 | 336.0 | 316.0 | 357.0 |
| Embryo weight g. | 6.4 | 5.8 | 5.9 | 5.4 |
| Chick weight g. | 44.0 | 41.7 | 47.1 | 44.0 |

Table 2:19

Effect of different feeding systems on the composition of embryo at 50 weeks of age.

| Treatment | No. of embryos | Total weight of embryos | Fresh embryo weight g. | Dry matter g/embryo | % of water |
|---|---|---|---|---|---|
| A | 4 | 32.6 | 8.2 | 0.7 | 92.0 |
| R | 16 | 122.5 | 7.7 | 0.8 | 90.0 |

Fig. 2:8 Mean fertility and hatchability for *ad libitum* and regulated hens during the whole laying period.

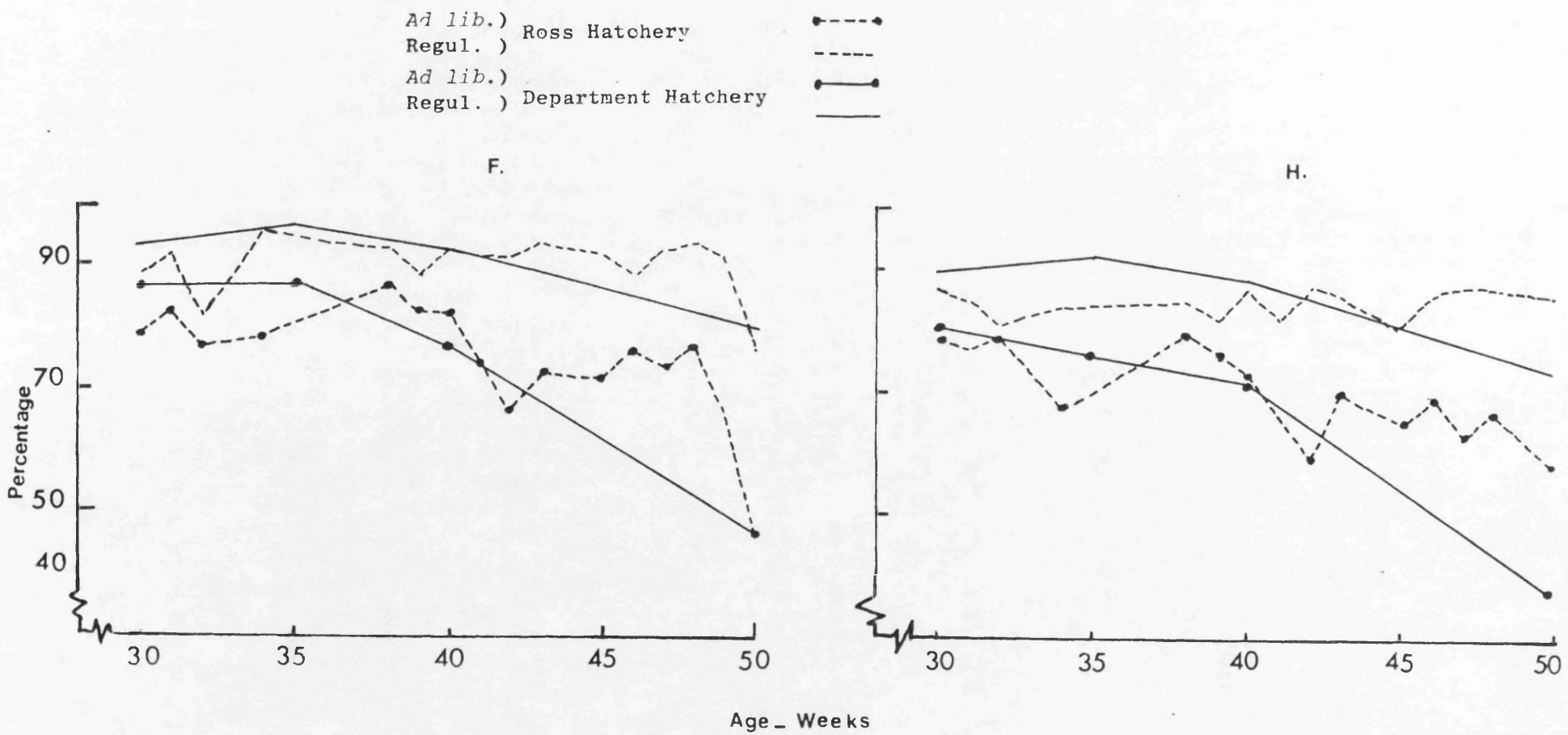


Fig. 2:9 The relationship between embryo weight and egg weight from parents on different feeding systems at 35 weeks of age.

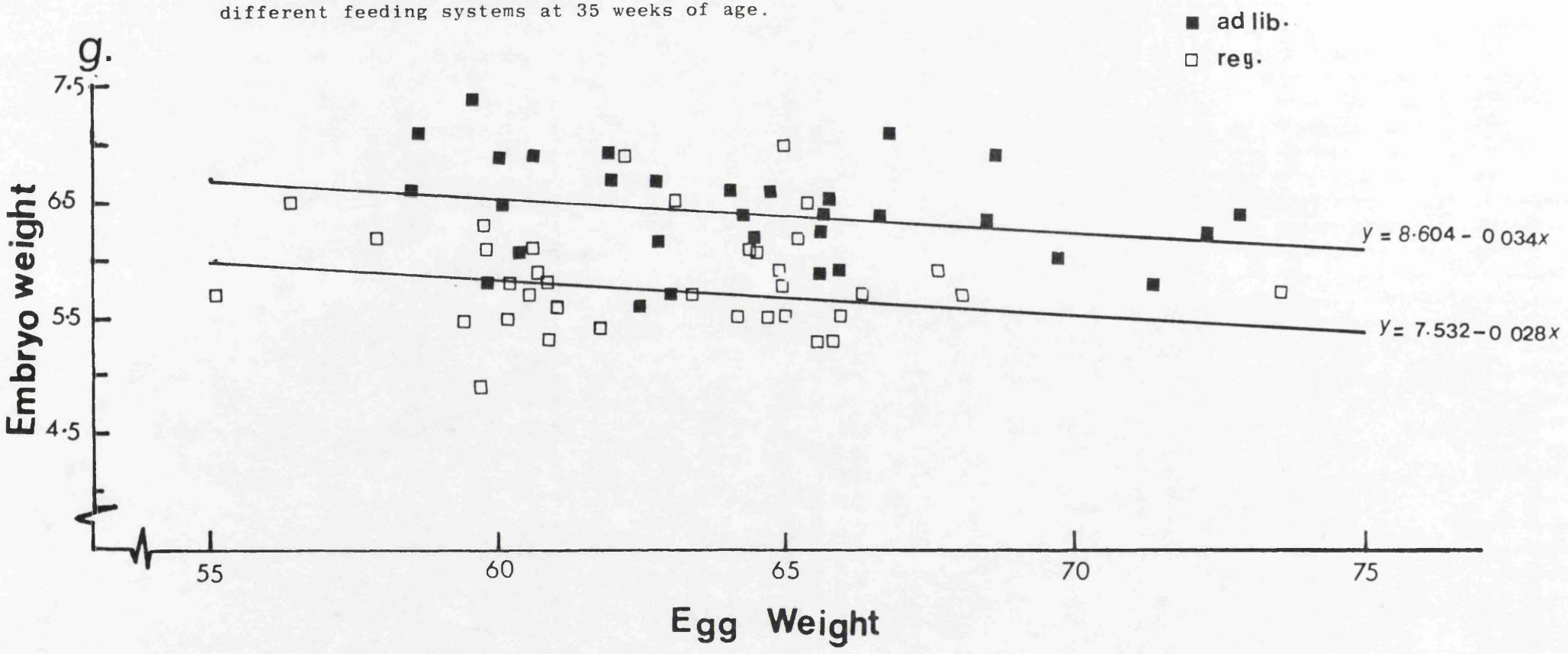
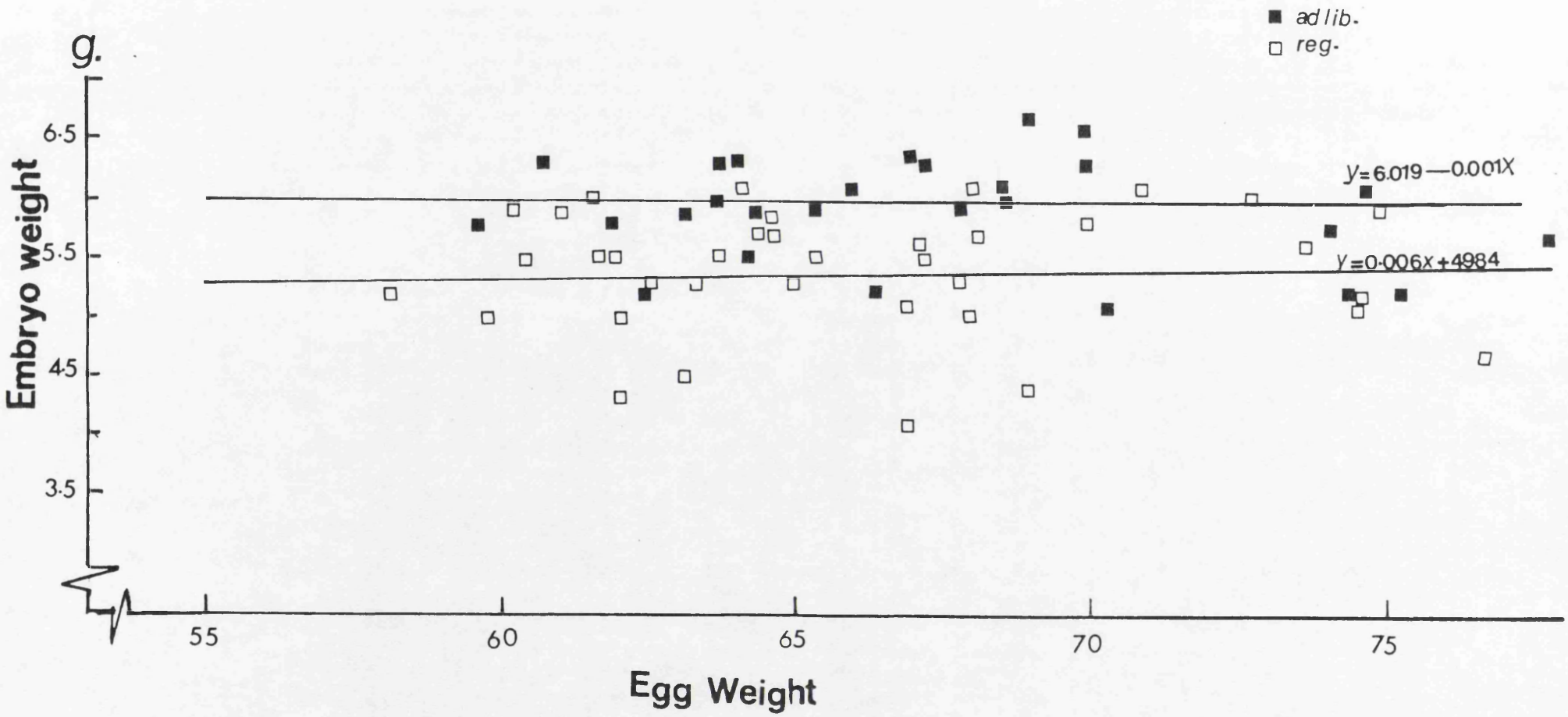


Fig. 2:10 The relationship between embryo weight and egg weight from parents on different feeding systems at 40 weeks of age.



The average egg weight at setting from hens on A were substantially heavier than those on R by about 2g/egg. The weight loss from eggs produced by A hens at 13 days of incubation was less than that from eggs produced by R hens. The difference in embryo weights between parents on A and those on R feeding at first hatch was about 0.63g/embryo and at the second hatch it was about 0.56 g/embryo. There was a significant difference ($p < 0.05$) in embryo weights between the two feeding systems for both hatches. There was no relationship between embryo weight and egg weight. The correlation coefficients between egg weight at setting and embryo weights were not significant. The embryo weights at 13 days of incubation were 9.4 and 8.7 percent of un-incubated egg weight while those of hatched chick weights were about 68.7 and 66.6 percent of the un-incubated egg weights for those from ad libitum and regulated parents. The third hatch was done to determine the composition of the embryo. The results from both groups are given in Table 2:19. Chemical analyses were planned although not completed because the sample of embryos from ad libitum parents was small. From 20 eggs were found 4 fertile eggs. The water content of embryos from A parents was slightly greater than that of embryos from R parents.

10. Mortality

The mortality data on A and R feeding during the rearing and laying periods for both sexes are given in Table 2:20. Generally during the first two weeks mortality rates for females and males were high. According to Veterinary Laboratory diagnoses, most of these deaths were caused by yolk sac infection and omphalits. The birds on R had a lower mortality than those on A. During the growing period, the results show that males on A feeding had a higher mortality than

the A females. The converse was true for those on R feeding. The difference between both sexes on A was 6.5 per cent compared with 1.6 per cent for those on R. During the laying period, the mortality rate of females and males fed ad libitum were higher than that on R feeding. The difference being 1.7 and 5.3 per cent for females and males on R, respectively. The overall mortality in the experiment was low. The types of diseases which affected the stock are presented in Table 2:22. Deaths during the laying period were mainly due to oviduct prolapse and egg peritonitis.

Foot examination was carried out twice in this experiment. Male toes and feet were main problem which occurred with those reared on floor due to damp litter, their toes became partially clenched, cracked, swollen and other litter lesions. At 38 and 55 weeks of age a sample of A and R males were examined for feet problems and the results are given in Table 2:21. From these results, it is clear that toes and feet of regulated males were more often affected than those on ad libitum. This is partly due to a failure to keep dry litter in the pen. This is partly due to the fact that the regulated birds consume more water than ad libitum birds.

## 11. Body composition

Results of body composition for all group are presented in Tables 2:25, 2:26 and 2:27. The amounts of protein, fat and ash in the carcasses are shown in Figures 2:11, 2:12 and 2:13. The weight of defeathered carcasses relative to the starved weight were slightly higher for birds on regulated feeding than those on ad libitum feeding for both sexes, except at 55 weeks of age when the situation was reversed (Table 2:23). It is clear that the ad libitum birds had more feathers ( and blood) except at the end of the experiment. The live weight of the flock,starved and plucked body weight of slaughtered birds are given in Appendix 2:4b.

Table-2:20

The effect of different feeding system on the percentage of mortality throughout the experiment

| Treat. | Sex | Rearing period | | | Laying period | |
|---|---|---|---|---|---|---|
| | | No. of birds | Age/week 1-6 | 7-21 | No. of birds | Age/week 22-55 |
| A | F | 720 | 2.10 | 0.57 | 144 | 6.25 |
| " | M | 100 | 2.00 | 7.10 | 19 | 10.53 |
| R | F | 480 | 0.83 | 3.60 | 130 | 4.60 |
| " | M | 100 | 0.00 | 2.00 | 19 | 5.26 |

Table-2:21

Foot survey of males in floor pens at 36 and 55 weeks of age: numbers of birds affected with the various foot problems.

| Age/ week | Treatment | Birds examined | Toes | | Pad | | Normal feet |
|---|---|---|---|---|---|---|---|
| | | | Crooked | Swollen | Lesions | Lesions | |
| 38 | A | 12 | 1 | - | 2 | 1 | 8 |
| | R | 16 | 1 | - | 7 | 7 | 1 |
| 55 | A | 11 | 2 | 2 | 2 | - | 5 |
| | R | 13 | 1 | - | 7 | 4 | 1 |

Table-2:22

Summary of diseases diagnosed during the rearing and laying periods.

| Periods | Disease |
|---|---|
| First 6 weeks | yolk sac infection, omphalitis |
| 7-21 weeks | staphylococcal arthritis in hock and knee joints<br>swollen hock joints<br>rupture of heart and haemmorrhage into pericardial sac |
| 22-55 weeks | tumor in liver<br>grossly over fat and severe fatty infiltration of the myocardium and liver<br>friable liver and ruptured liver<br>tumor of ovary<br>lesions due to egg peritonitis<br>pale hearts caused by the deposition of abnormal amount of fat<br>chronic peritonitis<br>Mareks disease<br>a liver haemmorrhage<br>partially eviscerated through the cloaca<br>foot pad problems<br>heart haemmorrhage |

The relative weight of the dry matter in the carcass was dependent on sex, the feeding system and age (Table-2:24). The dry matter percentage increased with age, and was higher with ad libitum feeding and was greater with females. The higher values at 10 weeks may have been caused by water loss overnight when carcasses were hanging on the slaughter line without a plastic bag cover (see materials and methods in Chapter II).

There were some unusual results obtained from the analysis of carcass ash content. Adjusted values were used in sunsequent calculations. (The justification of the adjustments are given in Appendix 2:4). There may have been some differences due to feeding system during the first 20 weeks but the unusual results make interpretation difficult. From 25 weeks of age onwards, there were no significant differences in percentage of carcass ash in both sexes. There were two phases in the growth of ash content, the first phase up to 20 weeks and the second phase after 20 weeks (Fig. 2:11).

There was a rapid growth of ash in ad libitum birds in the first phase but in the second phase it was greatly reduced but nevertheless accumulation continued slowly to the end of the phase. Regulated feeding drastically reduced ash accumulation between 10 and 20 weeks of age. In phase 2, the increase in feeding levels allowed ash accumulation of males to increase evenly to 55 weeks of age, whereas that of the females had an initial increase and then gradually slowed down during the phase.

Ad libitum females and males had a higher percentage of fat content than those on R feeding (Table-2:26). However there was a sex difference in fat content, the females had a higher relative weight of fat than males on both feeding systems. The sex differences in fat content were 19 and 10 percent at 15 weeks of age for birds on A

and those on R, respectively. Where it was possible to use the t test, the results showed that ad libitum fed birds had a significantly ($p < 0.05$) higher fat content than regulated birds except for males at 41 weeks of age.

The fat deposition increased rapidly up to 20 weeks of age for ad libitum birds. In the first part of the laying period, fat accumulation was drastically reduced, the males actually lost approximately 20 percent of their carcass fat between 20 and 41 weeks of age. In the later part of the laying period, the carcass fat content was constant. The consequences of regulated feeding was to gradually reduce the accumulation of fat to zero between 10 and 15 weeks of age and cause a loss of fat from 15 to 20 weeks. After 20 weeks, the increased feeding levels allowed the fat content of females to increase gradually until the end of the experiment. In the female, fat accumulation averaged 4g/day during 20-30 weeks. After 30 weeks of age, it was gradually reduced and over the last 14 weeks of the experiment, the fat content was essentially constant. At the end of the experiment the coefficient of variation was greater for all groups, except regulated males.

Females given regulated feeding had slightly higher relative weight of the protein than those fed A. Where a t test was possible to be completed the differences were found to be significant ($p < 0.05$).

The regulated males had a higher protein content ($p < 0.05$) at 15 weeks of age, but subsequently the differences between ad libitum and regulated males were not significant. At 20 weeks of age, ad libitum fed birds had 2 times more actual amount of protein than those on regulated feeding. From 30 weeks the carcass protein of females was relatively constant, whereas in the males growth of protein continued until 40 weeks, after which age, it was relatively constant.

Although there was a clear difference in the carcass protein content the two female groups in the period of relative stability (30 to 55 weeks of age), the males on R feeding caught up to those on A feeding and the carcass protein content was not significantly different during the period relative stability ($p < 0.05$). The percentage of carcass weight gains are given in Table-2:28. To obtain these data, the amounts of carcass dry matter, protein fat and ash were plotted against carcass weight.

The amounts in the carcass at selected weights were read off the graphs and the gains of protein, fat, ash and dry matter were calculated for selected weight gains.

Generally the second 500g gain of carcass weight had the higher proportion of protein for both sexes. The last kilogram gain of ad libitum males had a similar protein content as the second 500g of gain. In females the fat content of gains increased with carcass weight. In ad libitum females fat comprised about half of the gain between 3 and 5kg carcass weight.

In males fat gain was very low especially in the regulated birds and comprised only 2.5 percent in the second kilogram. Regression analyses were used to determine the relationships between lean carcass weight and protein content (Fig.-2:14 and 2:15). From the regression analyses it was found that the simple regression of lean carcass on protein accounted for 97.5 to 97.8 percent of observed variation. The common slope for females on A and R was 0.2261 (SE 0.005, t = 44.85) while for males was 6.2368 (SE = 0.006, t = 37.63). The regression equations for protein and lean carcass weight for birds of all ages were

(1) protein = -22.74904 + 0.22605 x lean..... females

(2) protein = -55.03546 + 0.23677 x lean..... males

Table 2:23

Defeathered weight as percentage of starved live weight at different ages for different feeding systems for both sexes.

| | Live-weight basis | | | |
|---|---|---|---|---|
| | Females | | Males | |
| Age/ weeks | Ad libitum | Regulated | Ad libitum | Regulated |
| 5 | 91.6 | 92.9 | 91.5 | 92.8 |
| 10 | 88.3 | 89.3 | 89.9 | 92.3 |
| 15 | 91.6 | 93.6 | 87.6 | 91.0 |
| 20 | 91.9 | 91.2 | 92.9 | 92.6 |
| 25 | 94.9 | 96.2 | - | - |
| 30 | 94.4 | 95.8 | - | - |
| 41 | 95.7 | 97.0 | 92.9 | 92.9 |
| 55 | 94.9 | 91.8 | 91.9 | 90.8 |

Table 2:24

Dry matter percentage of carcass weight at different ages for different feeding systems for both sexes.

| Age/ weeks | Females | | Males | |
|---|---|---|---|---|
| | Ad libitum | Regulated | Ad libitum | Regulated |
| 5[1] | 30.7 | 28.7 | 31.1 | 29.2 |
| 10[1] | 41.3 | 37.7 | 42.5 | 35.8 |
| 15 | 40.1 ± 1.6[2] | 34.3 ± 4.1 | 36.3 ± 0.1 | 29.3 ± 0.7 |
| 20 | 49.3[1] | 31.0 ± 1.7 | 37.4 ± 2.0 | 27.6 ± 0.6 |
| 25 | 48.2 ± 0.9 | 34.3 ± 2.8 | - | - |
| 30 | 45.2 ± 2.0 | 36.6 ± 0.7 | - | - |
| 41 | 47.8 ± 1.1 | 39.1 ± 0.8 | 33.5 ± 0.9 | 29.8 ± 1.3 |
| 55 | 51.8 ± 1.9 | 40.2 ± 2.2 | 38.3 ± 2.2 | 31.2 ± 0.2 |

[1]Five birds were minced together and it was analysed.

[2]These values express the mean and standard errors.

Table 2:25

Ash percentage of carcass weight at different ages for different feeding systems for both sexes.

| Age/ week | Females | | Males | |
|---|---|---|---|---|
| | Ad libitum | Regulated | Ad libitum | Regulated |
| 5[1] | 2.9 | 3.2 | 2.7 | 3.2 |
| 10[1] | 3.7 | (4.6)[3]5.5 | 4.0 | 4.8 |
| 15 | (3.8[3])2.8±0.1 | 4.0±0.5[2] | (4.0)[3] 3.5±0.1 | 4.4±1.9 |
| 20 | 3.9 | 4.0±0.4 | 4.6±0.4 | 4.6±0.2 |
| 25 | 3.4±0.1[a] | 3.8±0.5[a] | - | - |
| 30 | 3.2±0.2[a] | 3.7±0.1[a] | - | - |
| 41 | 3.5±0.3[a] | 4.0±0.1[a] | 4.5±0.4[a] | 3.7±0.3[a] |
| 55 | 3.7±0.5[a] | 4.1±0.2[a] | 4.9±0.6[a] | 4.4±0.4[a] |

[1]Five birds were minced together and it was analysed.

[2]These values express the mean and standard errors.

[3]These values were adjusted.

a,b - Means within sexes with different syperscripts are significantly different ($p < 0.05$).

Table 2:26

Fat percentage of carcass weight at different ages for different feeding systems for both sexes.

| Age/ weeks | Females | | Males | |
|---|---|---|---|---|
| | Ad libitum | Regulated | Ad libitum | Regulated |
| 5[1] | 10.6 | 7.4 | 9.9 | 8.0 |
| 10[1] | 18.5 | 8.9 | 18.0 | 8.7 |
| 15 | 21.0±1.6[2a] | 8.9±4.4[b] | 14.4±0.3[a] | 5.9±0.7[b] |
| 20 | 27.4[1] | 7.1±1.5 | 17.2±1.6[a] | 2.7±0.3[b] |
| 25 | 29.3±0.9[a] | 10.1±1.8[b] | - | - |
| 30 | 26.4±1.4[a] | 13.2±0.5[b] | - | - |
| 41 | 29.5±1.2[a] | 17.7±0.7[b] | 8.2±1.8[a] | 5.4±1.1[a] |
| 55 | 33.4±2.2[a] | 17.1±3.3[b] | 14.3±3.0[a] | 6.2±0.5[b] |

[1]Five birds were minced together and it was analysed.

[2]These values express the mean and standard errors.

a - Means within sexes with the same superscripts are not significantly different ($p < 0.05$).

Table 2:27

Protein percentage of carcass weight at different ages for different feeding systems for both sexes.

| Age/ weeks | Females | | Males | |
|---|---|---|---|---|
| | Ad libitum | Regulated | Ad libitum | Regulated |
| 5[1] | 15.7 | 16.7 | 16.2 | 16.1 |
| 10[1] | 20.2 | 23.2 | 20.9 | 22.0 |
| 15 | 17.6±0.3[2b] | 19.2±0.6[a] | 18.7±0.3[b] | 20.6±0.3[a] |
| 20 | 17.2[1] | 21.7±0.7 | 20.2±0.7[a] | 22.2±0.6[a] |
| 25 | 16.8±0.3[b] | 21.7±1.1[a] | - | - |
| 30 | 16.9±0.4[b] | 20.0±0.2[a] | - | - |
| 41 | 16.1±0.2[b] | 18.4±0.2[a] | 22.9±0.8[a] | 22.3±0.5[a] |
| 55 | 15.5±0.8[b] | 19.4±1.3[a] | 22.0±1.2[a] | 22.3±0.6[a] |

[1]Five birds were minced together and it was analysed.

[2]These values express the mean and standard errors.

a,b - means within sexes with different superscripts are significantly different ($p < 0.05$).

Table 2:28

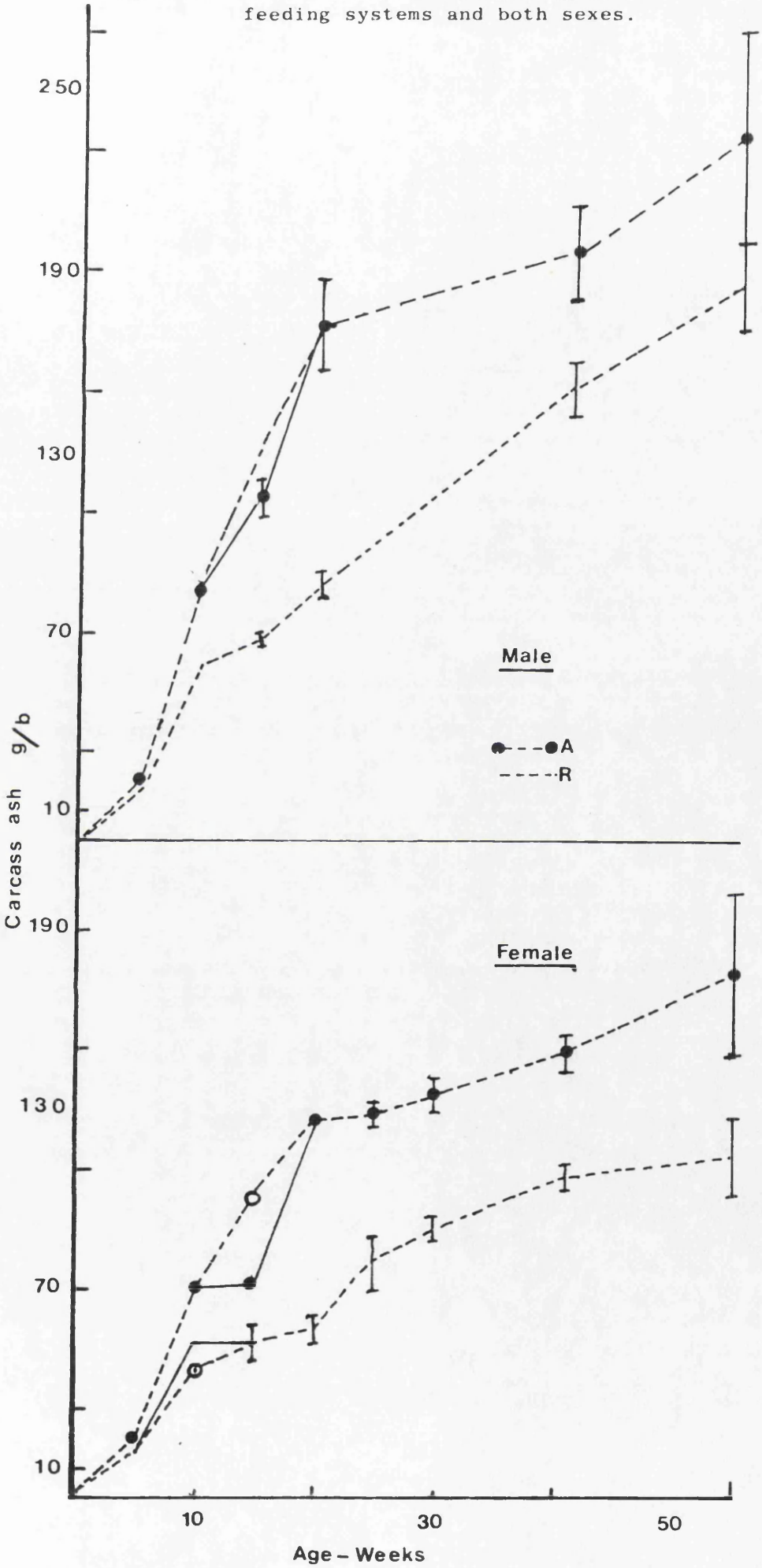
Percentage composition of carcass weight gains of broiler breeders under *ad libitum* and regulated feeding.

| Carcass wt. gain kg. | percentage composition of carcass weight gains | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Dry matter | | protein | | fat | | ash | |
| | A[1] | R[2] | A | R | A | R | A | R |
| | Females | | | | | | | |
| 0–0.5 | 28.2 | 32.2 | 13.8 | 19.2 | 9.7 | 7.7 | 2.4 | 4.1 |
| 0.5–1.0 | 50.0 | 36.0 | 27.0 | 24.0 | 20.0 | 8.0 | 4.2 | 4.4 |
| 1.0–2.0 | 45.0 | 25.5 | 19.0 | 16.5 | 23.0 | 12.0 | 4.2 | 2.8 |
| 2.0–3.0 | 39.0 | 57.5 | 10.0 | 15.0 | 28.0 | 31.5 | 3.4 | 4.4 |
| 3.0–4.0 | 63.5 | | 15.5 | | 46.0 | | 2.5 | |
| 4.0–5.0 | 67.5 | | 10.0 | | 51.5 | | 2.7 | |
| | Males | | | | | | | |
| 0–0.5 | 28.0 | 28.3 | 14.9 | 15.9 | 8.6 | 8.6 | 2.4 | 3.2 |
| 0.5–1.0 | 41.0 | 38.0 | 27.0 | 25.0 | 23.0 | 8.0 | 3.4 | 5.8 |
| 1.0–2.0 | 48.0 | 26.0 | 20.5 | 20.0 | 19.5 | 2.5 | 4.6 | 3.8 |
| 2.0–3.0 | 24.5 | 30.5 | 12.5 | 21.5 | 7.5 | 5.0 | 3.6 | 3.5 |
| 3.0–4.0 | 32.0 | 30.5 | 19.5 | 21.5 | 7.5 | 5.0 | 5.3 | 3.5 |
| 4.0–5.0 | 46.0 | 36.5 | 28.0 | 20.5 | 16.5 | 11.0 | 3.7 | 3.4 |

1 – Birds fed *ad libitum*

2 – Birds fed regulated.

Fig. 2:11 Carcass body ash weight (g/b) for both feeding systems and both sexes.



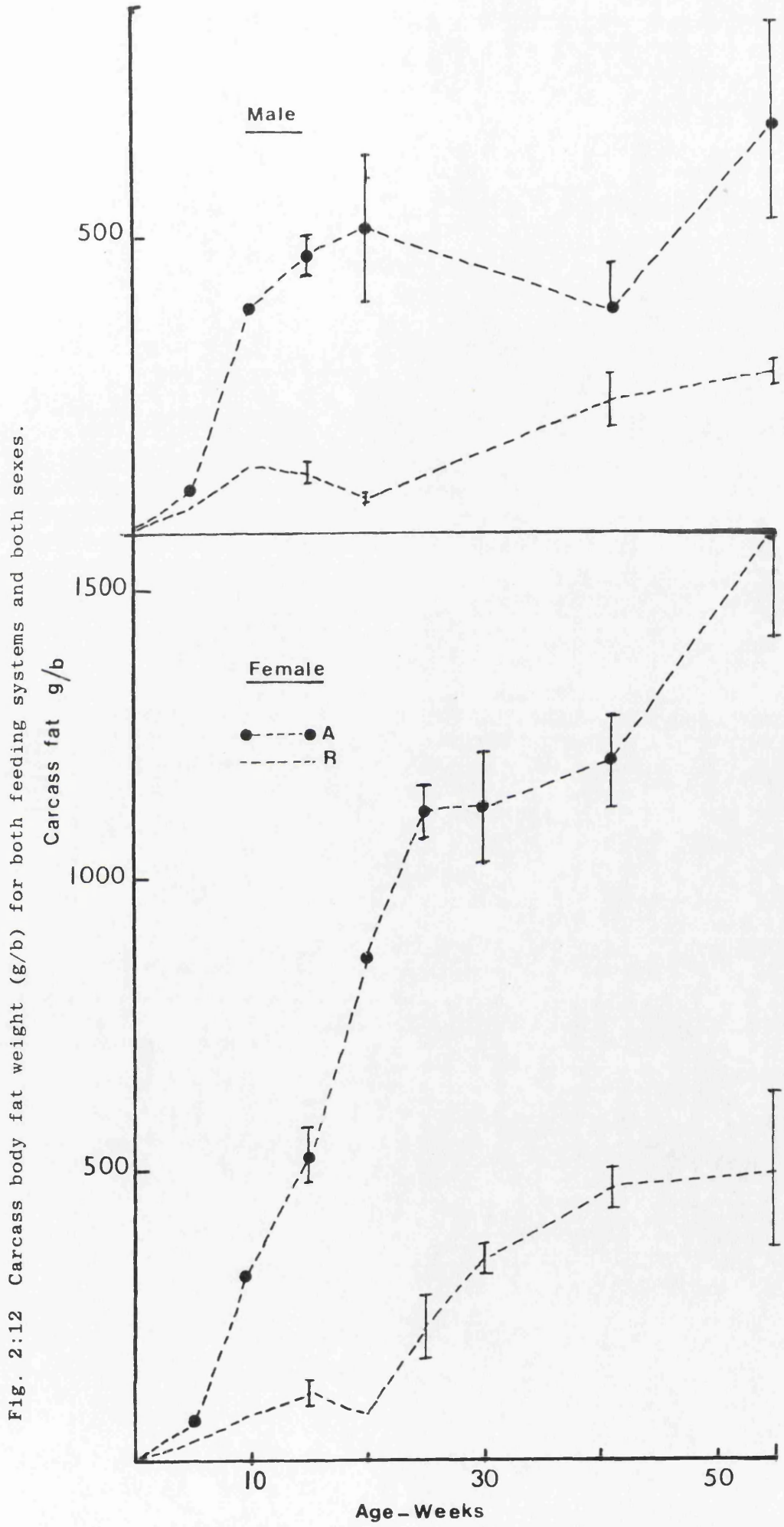



Fig. 2:12 Carcass body fat weight (g/b) for both feeding systems and both sexes.

Fig. 2:13 Carcass body protein weight (g/b) for both feeding systems and both sexes.

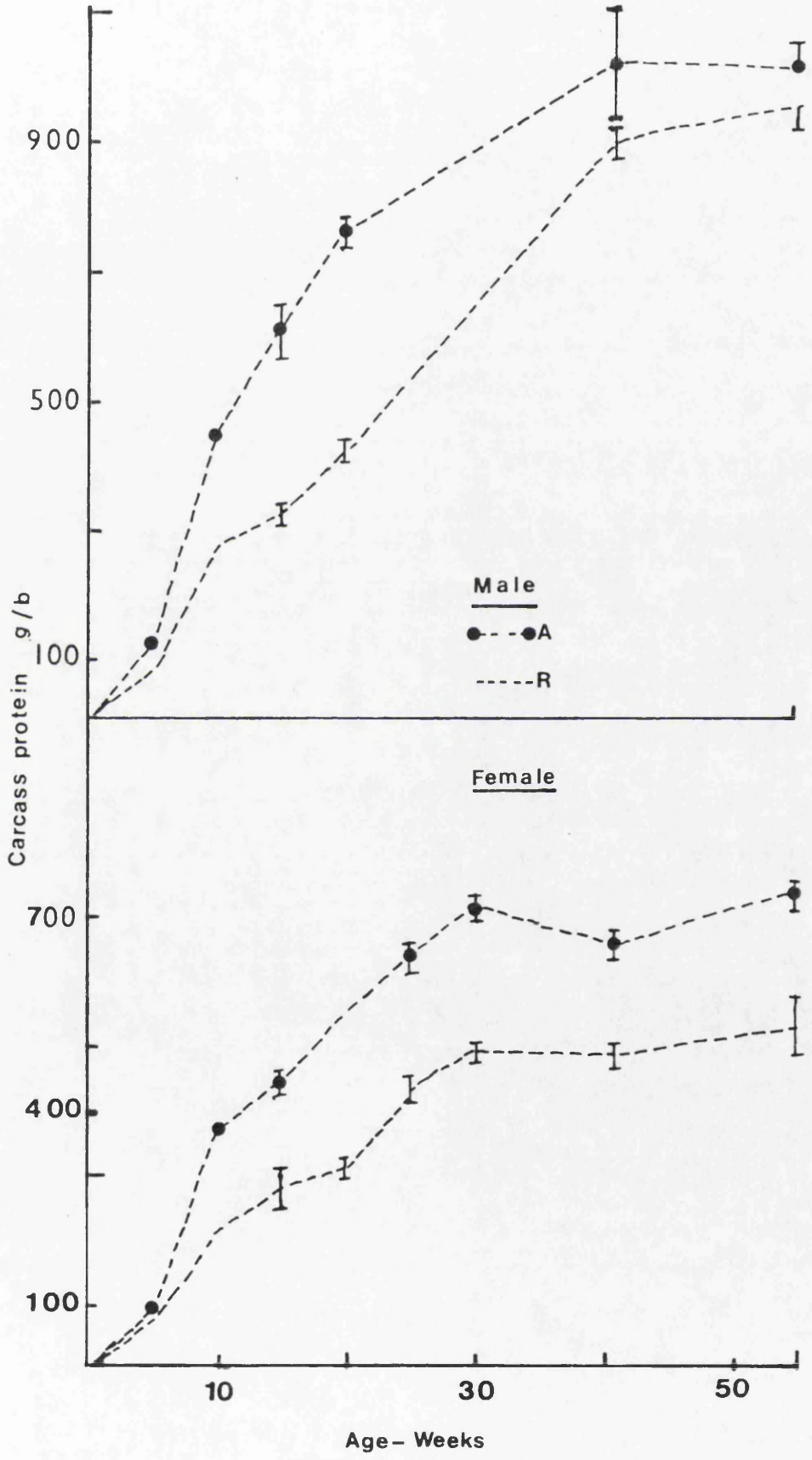


Fig. 2:14 The relationship between lean carcass weight and protein carcass weight of *ad libitum* and regulated females.

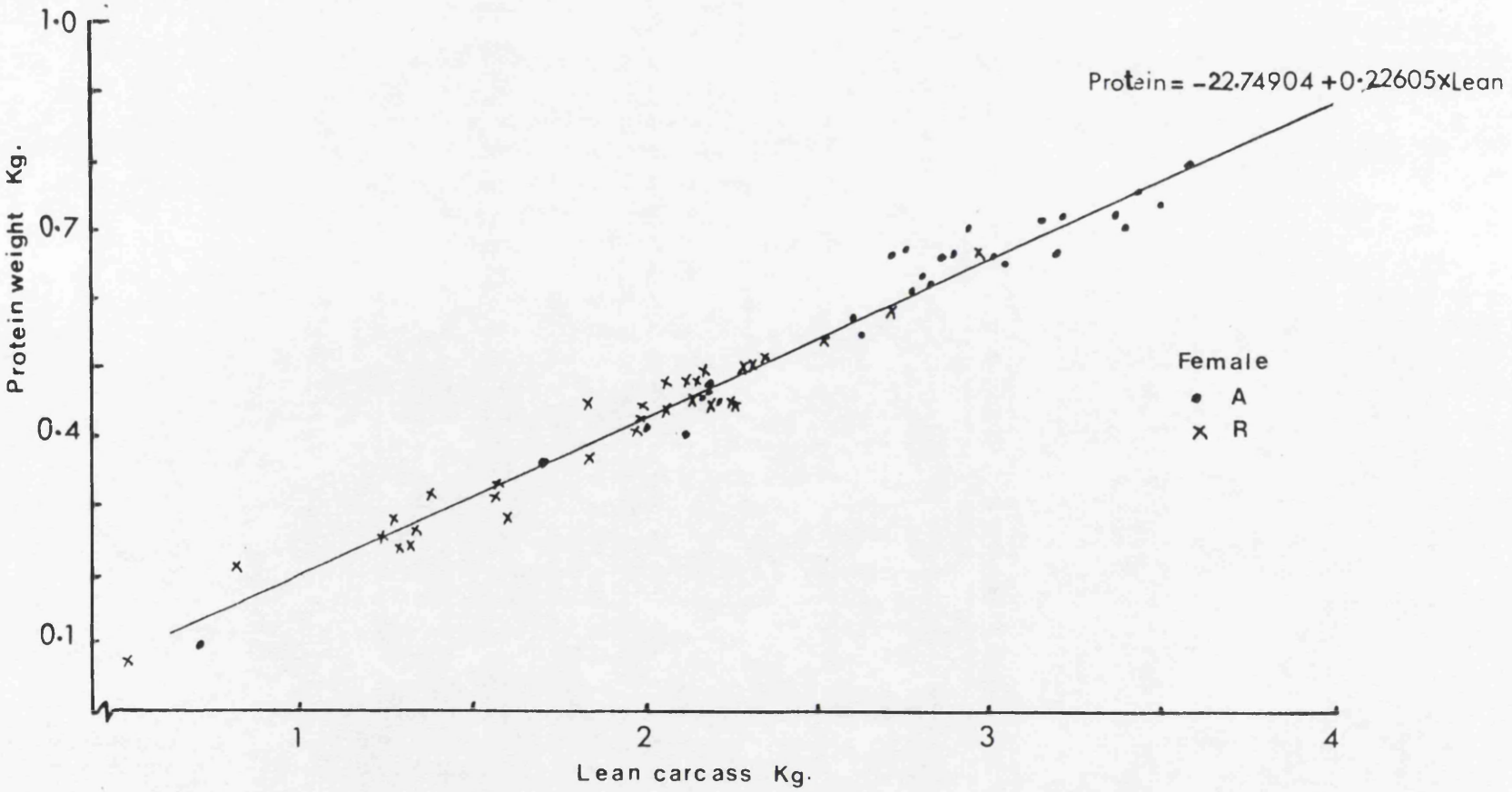
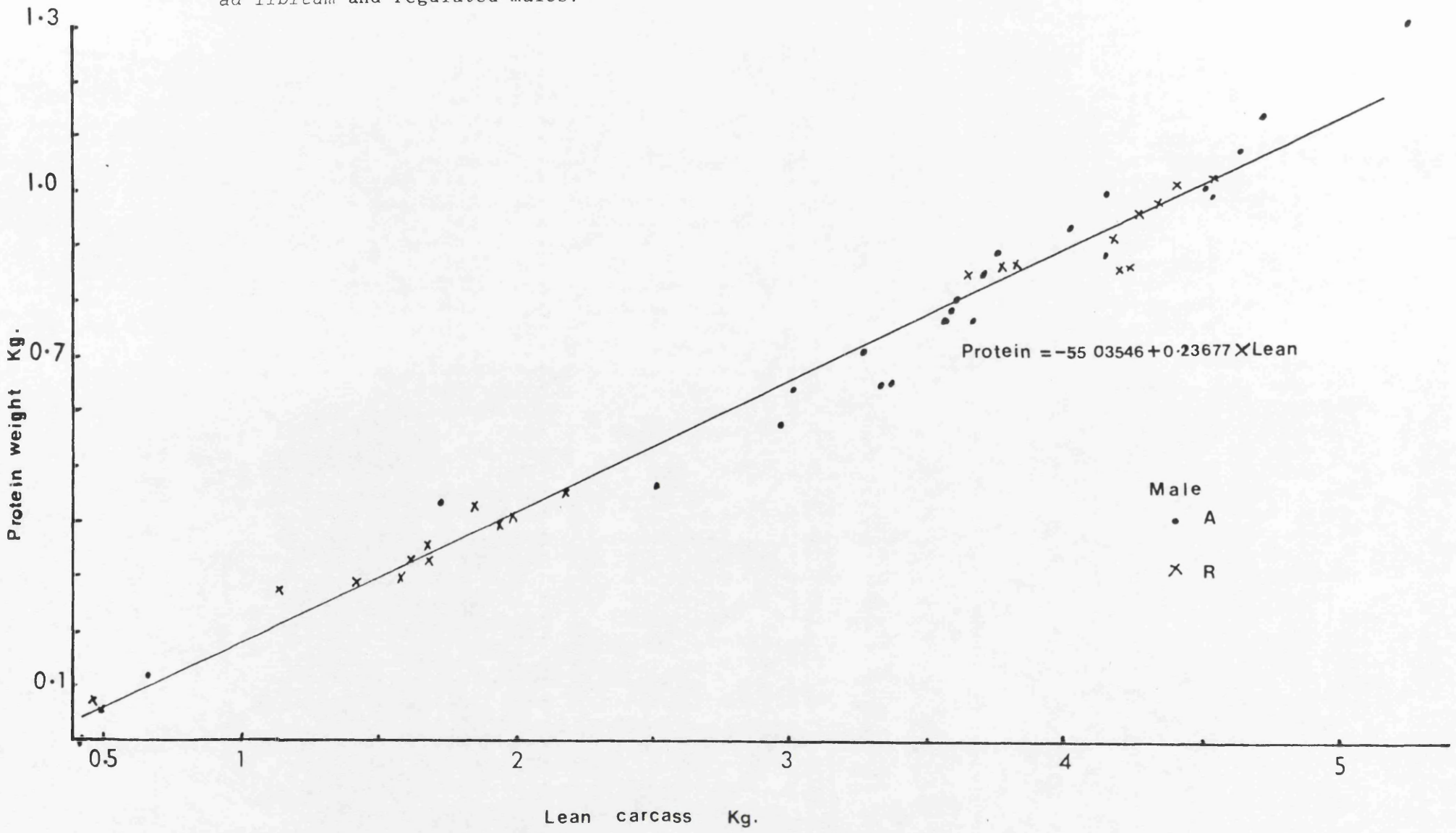


Fig. 2:15 The relationship between lean carcass weight and protein carcass weight of *ad libitum* and regulated males.



The 95% confidence limits for the regression coefficient were:

0.216 to 0.236 for females

and, 0.224 to 0.249 for males.

12. Organ weights

The organ weight data are given in Appendix 2:5. Also these results are summarized and given in Table 2:29. These results showed that the ad libitum females and males had a higher organ weight than those on regulated feeding.

The relative weight of the liver was approximately constant for all groups after 15 weeks of age (Appendix 2:5). The absolute weight of the liver was greater in birds fed ad libitum than in birds given regulated feeding. While the relative weight of the heart was almost constant for all groups. The growth of absolute weight of the heart from 5 weeks to the end of the experiment (55 weeks) were 16.4 and 10.4g. for ad libitum and regulated females, respectively; while for the males it was 28 and 22.4g of ad libitum and regulated feeding respectively. The absolute weight of the heart was smaller in birds on regulated feeding than in birds fed ad libitum. The absolute weight of the gizzard tended to increase with age for all groups. At the end of the experiment, hens on ad libitum had a higher gizzard weight than males on the same feeding, but conversely for those on regulated. The males had a higher intestinal weight than females, except ad libitum males at 55 weeks had a lighter intestine than ad libitum females. The difference in intestinal weight between hens and males on ad libitum and regulated feeding was 4.8 and 4.6g respectively. The relative weights of the organs were almost nearly constant after the 15 weeks of age.

Table 2:29

The selected organ weights and organ weights as percentage of live weight at different ages for different feeding systems for both sexes.

| Age/ week | Organs wt. | Ad lib.F | Reg.F | Ad.lib.M | Reg.M |
|---|---|---|---|---|---|
| 5W | Liver | 21.4(3.4)[1] | 12.4(2.6) | 21.2(2.6) | 13.4(2.5) |
| | Heart | 4.0(0.6) | 2.4(0.5) | 4.8(0.6 | 3.o(0.6) |
| | Gizzard | 21.7(3.2) | 16.9(3.5) | 23.2(2.9) | 15.8(3.0) |
| | Intestine | 30.7(4.5) | 17.9(3.7) | 31.2(3.9) | 18.7(3.5) |
| 20W | Liver | 49.6(1.3) | 30.4(1.8) | 51.0(1.2) | 34.0(1.5) |
| | Heart | 16.4(0.4) | 8.4(0.5) | 25.6(0.6) | 8.3(0.4) |
| | Gizzard | 45.8(1.2) | 41.4(2.4) | 50.4(1.1) | 46.8(2.1) |
| | Intestine | 54.2(1.4) | 41.8(2.5) | 66.4(1.5) | 46.0(2.1) |
| 41W | Liver | 46.0(1.1) | 34.8(1.3) | 56.4(1.1) | 50.0(1.1) |
| | Heart | 16.2(0.4) | 11.8(0.4) | 30.4(0.6) | 26.0(0.6) |
| | Gizzard | 41.8(1.0) | 37.6(1.4) | 48.2(1.0) | 44.8(1.1) |
| | Intestine | 54.6(1.3) | 52.0(1.9) | 68.8(1.3) | 57.4(1.3) |
| 55W | Liver | 70.0(1.3) | 46.6(1.5) | 66.0(1.2) | 53.4(1.1) |
| | Heart | 20.4(0.4) | 12.8(0.8) | 32.8(0.6) | 25.4(0.5) |
| | Gizzard | 55.6(1.1) | 46.6(1.5) | 49.0(0.9) | 52.2(1.0) |
| | Intestine | 76.2(1.5) | 55.2(1.7) | 71.4(1.3) | 59.8(1.2) |

[1]Numbers in parentheses are values expressed as percentage of live body weight.

## Discussion

### Body Weight

As shown in the results, the largest differences during the rearing period between females on A and those on R and between males on A and those given regulated feeding were 2030 and 2660g which occurred at 18 weeks of age respectively. But the final differences at 55 weeks of age to decreased 1285 and 452g for females and males, respectively. As shown in these results, female on regulated feeding were significantly lighter than the *ad libitum* female.

Table 2:30

Body weight of *ad libitum* females in this experiment compared with those obtained by other workers.

| Author | Strain | Age wks. | Body weight other experiment | Body weight this experiment |
|---|---|---|---|---|
| Lee *et al.* 1971 | Broiler breeder pullets | 20 | 3.01 | 3.87 |
| Voitle *et al.*1974 | Peterson broiler breeder females | 15 | 2.16 | 3.17 |
| Chaney *et al.* 1975 | Broiler breeder | 22 | 3.17 | 4.15 |
| | females | 25 | 3.64 | 4.52 |
| Powell *et al.*1977 | Broiler | 22 | 3.09 | 4.15 |
| Harms *et al.* 1979 | Cobb pullets | 20 | 2.85 | 3.87 |
| | | 25 | 3.22 | 4.52 |
| Proudfoot 1979 | Broiler | 20 | 3.16 | 3.87 |

The body weight of females on A in this experiment are heavier than those obtained in other experiments (Table 2:30). These differences give an indication of the changes in growth potential over a 10 year period, over which time breeding weights have remained unchanged. During the rearing period (1 to 21 weeks), that the growth of *ad libitum* females appeared to follow a typical growth curve (Wilson, 1977).

But ad libitum males which were growing normally until 15 weeks of age actually stopped growing for about five weeks. This may have been partly due to the transfer to the laying house, and partly due to mixing with females; the males placed in cages also had a reduction in growth but not to the same extent. However the body composition data indicated that the growth of lean continued but fat growth slowed and decreased. The deficit in body weight of males which was a maximum at 15 weeks of age, was diminished steadily with advancing age. However for females the deficit was reduced gradually until at a point between 30 and 35 weeks, the catch-up growth stopped. The body weight deficit at 35 weeks remained throughout. The difference between females and males in respect of catch-up growth, could be related to the competition for nutrients between egg production and growth in female, and the stimulation of protein growth by males sex hormones.

The depression in performance of ad libitum stocks could be due to body size differences per se or due to differences in body composition. The carcass of the ad libitum females contained 9 times more fat but twice as much protein as the carcasses of regulated females therefore the difference in the carcass fat could be implicated as the cause of the depression of performance. The maximum degree of feed restriction of ad libitum fed birds was 65 per cent at 12 weeks for both sexes. There were two fluctuations in feed intake at 15 and 19 weeks of age (Fig. 2:1) which reflected the reajustment of the birds after removal to the new house. The first fluctuation occurred when the birds were transferred to the laying house which reflected an adjustment of the birds or an adjustment of the management practice. The second one occurred just before the hens started laying. It is known that the first oviposition was preceded by a reduction in feed intake (Foster, 1968). The birds in cages were disturbed to a lesser extent and their feed intake would reflect more closely that expected of birds on floor.

Energy requirement

The energy requirements at two ages were estimated using equations of Byerly et al. (1980) and Van Wambeke (1981).

The Byerly et al. (1980) equation is:

$$F = (0.259-0.00259T)W^{.75} + 2.76\,\Delta W + 0.80\,EM$$

Where F = feed per hen per day in grams

T = ambient temperature in °C

W = live body weight in grams

ΔW = weight gain (g/b d)

EM = egg mass per hen-day

The Van Wambeke (1981) equation is:

$$Y(ME,kJ/hen/day) = \left(314 + 8.4(20-T)\right) W + 11.19EM + 19.7\,W$$

Where

W = body weight in kg

ΔW = weight gain (g/h/d)

EM = egg mass (g/h/d)

T = house temperature °C

The difference between estimated ME requirement, and the energy consumption was large (Table 2:31). On this occasion, it could be explained that was due in part to feed wastage by the birds. If the feed wasted was 5 percent, it means that the actual daily energy consumption was about 2285 and 1948 for A, and, 1964 and 1794 kJ/b for R at 30 and 50 weeks of age, respectively. The levels are still higher than the estimated ME requirement. It could be also partly explained if one assumed the males consumed larger quantity of feed than females, if the males consumption exceeded that of the females by 10 percent, the ME intake of females was calculated to be 1927 kJ/b for the R females at 30 weeks. Finally it could be explained by a greater maintenance requirement due to a lower effective temperatures experienced by the birds than the recorded dry bulb temperatures. At 1°C

difference would alter the maintenance requirement by about 16 kJ (using Byerly's equation).

Table 2:31

A comparison of estimated daily energy requirement and actual energy cosumption. The equation of Byerly et al. 1980 and Van Wambeke 1981 were used to estimate energy requirement.

| | | Esimated ME requirement kJ/b | | Actual ME |
|---|---|---|---|---|
| Treat. | Age | Byerly | Van Wambeke | consumption kJ/b |
| A | 30 | 1833 | 1908 | 2405 |
| | 50 | 1779 | 1883 | 2051 |
| R | 30 | 1807 | 1691 | 2088 |
| | 50 | 1628 | 1643 | 1941 |

Reproductive Fitness

The actual difference in reproductive fitness between hens on A and those on R was 57.9 %(Table 2:32). It is clear that the 57.9 % improvement in reproductive fitness was due to regulated feeding. It is common knowledge that heavier hens have a lower reproductive fitness. Most research workers in this area of work have reported it, but have not investigated the factors influencing the lower fitness. Singsen et al. (1959) reported that problems of obesity caused a lower egg production and poorer utilization of feed for egg production in broiler breeder hens. Although Chaney et al. (1975) found that the carcass fat had no effect on egg production.

Certainly, more work needs to be done in this area to fully understand the implications of lowered fertility with breeders that became too heavy. Generally, when fertility and hatchability start to decline as flocks get older, the blame is placed on the male which may be incorrect. However Bushong (1980) reported that when females are too heavy, the males likewise will be heavy, which further compounds

Table-2:32

Actual and estimated results assuming that individual components of reproduction of ad libitum hens were the same as R.

| | A | R | Percentage difference |
|---|---|---|---|
| Total eggs | 118.4 | 139.0 | |
| Total hatching eggs | 111.8 | 134.0 | |
| Total fertile eggs | 82.5 | 120.6 | |
| Total chicks | 73.6 | 116.2 | 57.9 |
| | 5.9 | | |
| Total chicks with same hatch of fertiles as R | 79.5 | 116.2 | 50.0 |
| | 17.4 | | |
| Total chicks with same hatchability of settable eggs | 96.9 | 116.2 | 19.9 |
| | 2.1 | | |
| Total chickens with same hatching egg yields. | 99.0 | 116.2 | 17.4 |

the problem. If the ad libitum birds had the same hatchability of fertile eggs as R, they would produce about 79.5 chicks (Table 2:32). This would reduce the difference in fitness by 8 per cent to 50 per cent. If ad libitum hens had the same hatchability of settable eggs as R, hens on A would produce 96.9 chicks. This number of chicks would reduce the difference between both feeding systems to 19.9 per cent. If the ad libitum hens had the same hatching egg yield the difference between the systems would be 17.4 per cent. The remaining component is egg number which account for the remainder of the difference in reproduction fitness. The relative importance of these 4 components was estimated, and are shown in Table 2:33.

Table 2:33

Components of the reduction in reproductive fitness.

| Component | Relative Importance % |
|---|---|
| 1. Lower proportion of settable eggs | 5 |
| 2. Lower embryo viability | 15 |
| 3. Lower hen-day production | 40 |
| 4. Lower fertility | 40 |

1 - Lower proportion of settable eggs.

The lower proportion of settable eggs could have been due to:-

a. A greater proportion of cracked eggs.

b. Misshapen eggs.

c. Shell-less eggs.

d. Double yolk and yolk-less eggs.

It is known that (Jaap, 1970 and Smith, 1981) the broiler breeders produces greater numbers of defective eggs than laying hens, the number of defective eggs also increased with ad libitum feeding,as these results show. However this is smallest components of reproductive fitness.

2. Lower embryo viability.

The lower embryo viability could have been due to:-

a. ad libitum females laid a greater proportion of eggs on the floor and consequently these eggs were more contaminated with bacteria and other micro-organisms. However it was necessary to clean more eggs produced by regulated fed hens than from ad libitum fed hens because the litter was wetter. Yet on balance, the contamination of eggs from ad libitum fed hens would have been greater. This contamination could have resulted in higher deaths of embryos.

b. The disturbance of eggs on the litter could have lead to yolk displacement from the normal position, subsequently during incubation the displaced yolk may have moved too close to the shell which lead to the death of embryo.

c. Total nutrients available in the egg for embryo developement could have been different in A fed and R fed birds.

3. Lower hen-day production.

Ovulation rate determines egg production rate and therefore it is important to examine factors affecting ovulation rate, yolk developement and yolk capture by the oviduct. Ovulation is controlled by lutenizing hormone (LH) and if the release of LH from anterior pituitary gland was diminished below a threshold level ovulation would not take place. But Jaap (1970), estimated that 25 per cent of yolks produced in ovary are lost between ovulation and oviposition for ad libitum fed pullets. The large amount of abdominal fat could restrict movement of the infundibulum and occasionally prevent the capture of released yolks. Fat deposits around the ovary might affect normal developement heavy hens, it is known that the number of developing follicles in broiler breeders is less than the number in smaller hens, (Watson, 1975). These factors would combine to reduce the rate of ovulation.

4. Lower fertility.

There are three areas which may be involved in poorer fertility:-

a. Male

b. Female

c. Mating.

The relative importance of these three were investigated and are dicussed in Chapter 3.

The greater relative weight of organs in regulated birds is in agreement with Watson (1975), especially in relation to the digestive tract. Watson (1975), suggested that the intestine is large as a consequence of regulated feeding which improves efficiency of utilization of nutrients.

Embryo development

Embryonic respiratory exchange involves an equal mass of oxygen entering and carbon dioxide leaving the egg. Therefore weight loss of eggs is entirely due to loss of water. Variation in chick weight at hatch can be explained mainly by fresh egg weight loss during the incubation.

The water loss from an egg is proportional to the water vapour conductance of the egg shell and the difference in water vapour pressure across the egg shell. For eggs incubated together, the latter component of water loss would be the same. Therefore all differences in egg weight loss would be due to variations in the water vapour conductance of the eggs. Water vapour conductance a mathematical depression of shell porosity. Shell porosity depends on shell thickness, the number of pores and the area of the pores (Tullet, 1981). The differences in water loss of eggs from ad libitum and regulated hens is therefore due to the differences in egg shell porosity. The chickens from regulated hens were 66.6 and 67.1 percent of setting egg weight from hatch 1 and 2 respectively. The expected chick weights from ad libitum hens were 42.9 and 45.5g from hatch 1 and 2 respectively. The actual weight of ad libitum chicks were 1.16 and 1.64g heavier than expected for hatch 1 and 2 respectively. Thus ad libitum chickens may contain a greater amount of water. Unfortunately the hatch at 50 weeks which was to test this

point failed to yield sufficient ad libitum embryos to give a definite answer.

## Conclusions

1. Ad libitum females and males consumed 22 percent more feed than those on regulated feeding.
2. To achieve target weights with Ross 1 parents the highest level of feed restriction was 60-65 percent at 12 weeks, when daily feed intake was greatest.
3. The mature weight of ad libitum female was 1.285kg greater than regulated females but in contrast that of the ad libitum male was 0.452kg greater than regulated male.
4. The ad libitum feeding reduced egg numbers to 55 weeks by 17 percent.
5. The ad libitum feeding increased egg weight at 55 weeks by 3.6g.
6. Regulated feeding improves reproductive fitness by about 60%, the main components of which are fertility and egg numbers.

CHAPTER THREE

# The effect of ad libitum and regulated feeding on reproductive performance of broiler breeders in cages

## Introduction

Broiler breeders differ in many aspects from the light and medium weight laying hens. Some of the most important differences are:

a) the body weight and growth rate;

b) modern broiler breeder strains reach a lower peak production than laying strains and decline more rapidly;

c) the use of dietary protein for tissue growth may receive a higher priority in the broiler hens than in the laying type hens.

It follows therefore that the nutrition requirements for breeder hens are different and more critical than thoseof laying hens because health and fast growing chicks are expected. Over the last 15 years or so, a reduction in the overall reproductive performance of broiler breeders has occurred. This has come about by a decline in fertility and egg production. Over this period of time the art and science of feed regulation of broiler breeders has been developed to maintain acceptable levels of performance. Most research workers found that the physical restriction of feed intake, without creating nutritional deficiencies, improved feed conversion, reduced obesity and mortality and did not affect egg production of broiler breeders. Early attempts to limit feed intake of the laying hens resulted in significantly poorer egg production rate. Limitation of the total ration reduces the intake of all nutrients and unless compensatory modification of the amino-acid vitamin and mineral concentration is made, satisfactory production rates and egg size cannot be achieved. When rations are limited,

dietary increases in the essential amino-acids, vitamins and minerals must be made proportional to anticipated decreases in intake. Thus the intake of energy should be the only factor limited in a feed restriction programme. Applications of limited feeding programme in which energy intake has been reduced by 5 to 10 percent and in which appropriate ration adjustments have been made, have indicated that limit fed hens have a higher viability per laying cycle with no loss with hen-day production (Snetsinger and Zimmerman, 1974).

The problem may be entirely different, however with broiler breeders which have been selected for large size, rapid growth and high feed efficiency. The increased capacity to eat, together with relatively lower egg production, encourages obesity. The feeds offered to broiler breeders allowed daily intakes of amino-acids, vitamins and minerals to be in excess of daily requirement by a fair margin, and it is daily energy supplies which control performance. Thus regulating feed intake of the broiler breeder controls primarily energy intake as Snetsinger and Zimmerman (1974) have managed for laying hens. If broiler breeders reach mature body weight the rate of production is reduced and the aim of feed restriction is to limit body size. Singsen et al. (1958) indicated that energy need does not adequately regulate energy intake of meat type hens when they are full fed a high energy ration. Under these conditions White Plymouth Rock hens became obese and suffered excessive mortality which appeared to be directly related to excessive energy intake, whereas controlled feeding of the high energy ration eliminated the excessive body weight gain and reduced mortality to the same low level obtained with the lower energy diet. The necessity to restrict heavy broiler breeders during the rearing and during the laying periods is well recognised. Nutrition of broiler breeder strains has been reviewed

by Pearson and Shannon (1979). Most researchers have reported that the effect of ad libitum feeding during the rearing period is to reduce reproductive performance (see for example Sherwood et al., (1964) and Proudfoot et al. (1978)). The plan of this experiment was to investigate the effect of manipulation of energy intake on the reproductive performance of hens brought to mature body weight and to target breeding weight mated to males brought to target breeding weight or mature body weight.

Experimental Objectives

The objectives of this experiment were to investigate the responses of ad libitum and regulated fed pullets to

a) feed energy levels

b) changes in feed energy levels

c) changes in feeding system

d) mating with ad libitum or regulated fed males

## MATERIALS AND METHODS

### 1. Design of Experiments

Birds for this experiment were chosen from the total in the rearing house. At 16 weeks of age, they were transferred to the laying house at the same time as those used in Experiment 1. Males and females were chosen at random, and placed in cages. At 22 weeks of age the experimental design was applied as shown in Table 3:1, which cover the two phases (22-35 and 36-54 weeks) using the three feeds on L, M and H (Table 3:2). The three feeds were offered to the ad libitum fed birds and only feed M was used for those hens given regulated feeding (R). A total of 320 cages (2 females per cage) divided into 80 plots (4 cages per plot) were used in this experiment. For treatments L, M and H, 16 plots were allocated at random to each treatment. The remaining 32 plots were used for regulated feeding. From 36 weeks of age the number of treatments was increased from 4 to 10 treatments. The new 6 treatments included hens changed from L to H, from M to R or from H to L, (treatments LH, MR, and HL) and hens which were changed from regulated feeding to ad libitum feeding, either R to L, R to M or R to H (treatments RL, RM and RH). During the second phase there were 8 plots per treatment.

### 2. Houses, Cages and environment

This study was carried out in the laying house. The house contained six banks of two-tier wooden cages originally built to house

Table 3:1

Simplified scheme shows the general design with actual number of birds in each case.

| Females | Phase 1 | | | Phase 2 | | |
|---|---|---|---|---|---|---|
| Plot no. | Bird no. | on feed | | Plot no. | Bird no. | on feed and feeding system |
| 16 | 128 | L | | 8 | 64 | L |
| 16 | 128 | M | ad libitum | 8 | 64 | M |
| 16 | 128 | H | | 8 | 64 | H |
| 32 | 256 | M | Regulated | 8 | 64 | R |
| | | | | 8 | 64 | LH |
| | | | | 8 | 64 | HL |
| | | | | 8 | 64 | MR |
| | | | | 8 | 64 | RL |
| | | | | 8 | 64 | RM |
| | | | | 8 | 64 | RH |
| Total 80 | 640 | | | 80 | 640 | |
| Males | | | | | | |
| 7 | 28 | A | | 7 | 28 | A |
| 7 | 28 | R | | 7 | 28 | R |
| Total 14 | 56 | | | 14 | 56 | |

Table 3:2

Design of feeding plan for caged female

| Treatment | Feeding to 35 weeks | | Feeding after 35 weeks | | |
|---|---|---|---|---|---|
| | Level | M.E. content | Level | M.E. content | Treatment code |
| 1 | Ad lib. | low | Ad lib. | low | L |
| 2 | Ad lib. | medium | Ad lib. | medium | M |
| 3 | Ad lib. | high | Ad lib. | high | H |
| 4 | Ad lib. | low | Ad lib. | high | LH |
| 5 | Ad lib. | high | Ad lib. | low | HL |
| 6 | Ad lib. | medium | Reg. | medium | MR |
| 7 | Reg. | medium | Reg. | medium | R |
| 8 | Reg. | medium | Ad lib. | low | RL |
| 9 | Reg. | medium | Ad lib. | medium | RM |
| 10 | Reg. | medium | Ad lib. | high | RH |

turkey females. Two banks were on the house side walls and the remaining four banks were in two rows back-to-back. The females were housed in each cage and four cages made up a plot. Eighty such plots housed the 640 females. Each single cage measured 230mm wide x 690mm high x 610mm deep. Males were housed one per cage using fourteen plots of 4 cages each. Each plot had one feed trough in front of it. Each feed trough measured 140mm wide x 920mm long x 120mm deep. The feed trough was continuous along the front of cages and was divided at the plot divisions to allow feed intake to be measured on a plot basis. The birds were not able to eat from the feed trough of birds in neighbouring plots. Water was provided from a nipple drinker situated in the side of the front of each cage.

3. Feeding and feed preparation

Each plot had a numbered feed bag which contained a weighed quantity of feed. The feed was transferred to the trough which had the same number as the bag. Feeds were always available ad libitum but not for regulated birds. The feeds were stored for no more than one month in a store area within the house. There was no visual evidence of deterioration.

4. Birds

As described in Chapter I.

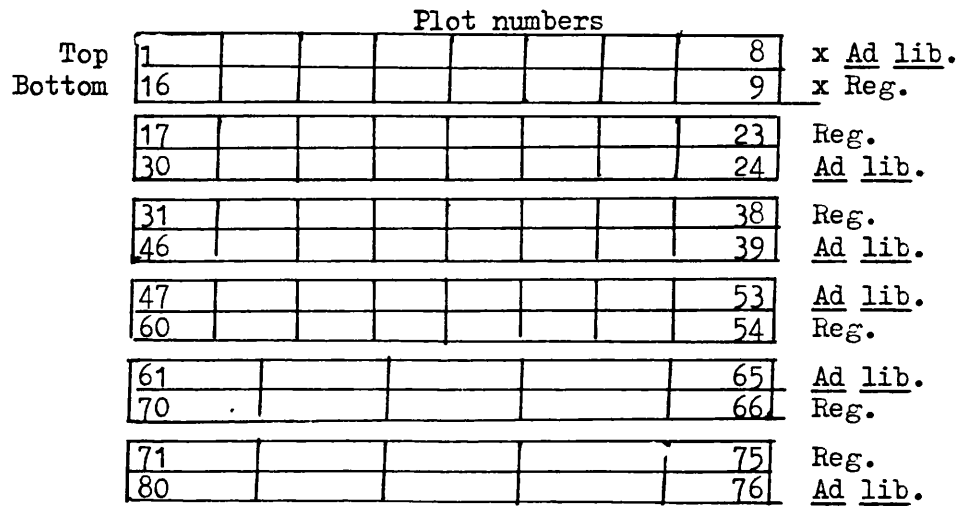
5. Recording procedures

Records were kept for each plot of eggs produced, egg weight, feed intake and body weight. Feed intake and egg weight were recorded every two weeks and daily for eggs produced. Body weights were recorded at 22, 25, 30, 35, 38, 41, 45, 50, 54 weeks of age for all females and males.

Each day eggs were collected for each plot and counted. On two consecutive days every two weeks, eggs were left at the front of the plot and then counted and weighed in bulk. Very small and extra large (double yolked) eggs were counted as eggs but not included in the weighing. All abnormal eggs, i.e. very small, large or soft shell, were sent for marketing. Normal eggs were sent to a commercial hatchery weekly. These eggs were not identified by treatment number, and no results were obtained from them. Eggs incubated in the Department hatchery were identified by the treatment plot number. Feed intake was recorded by putting a weighed quantity of feed into a tared bag for each plot and then at the end of the two weeks, the feed remaining in trough was returned to the bag and the total weight of the feed remaining was recorded. Food intake recording or changing of feeds always started at the same time each morning.

6. Artificial insemination.

The hens were inseminated on one day weekly with pooled semen from ad libitum males or from the males on regulated feeding. Equal bird numbers of hens on ad libitum or regulated feeding were inseminated by either ad libitum or regulated pooled semen (see diagram below). The results of fertility were obtained for each plot on each treatment.



7. Statistics

For statistical analysis the two phases which were of 14 (22 to 35 weeks) and 19 weeks (36 to 54 weeks) duration were considered as 6 periods. The first period was 22 to 29 weeks, periods 2, 3 and 5 each consisted of 6 weeks, while the periods 4 and 6 consisted of 4 and 3 weeks respectively. Where mortalities occurred data was estimated using a missing values procedure. The analysis were done through the ICL computer in Edinburgh using the link up facilities available at the College. In the first phase the data were analysed as four treatments and the second phase the data were analysed as 10 treatments.

Results

1. Feed Intake

Results for feed intake are given in Appendix-3:1, 3:2,3:3 and 3:4 for birds on L, M, H and R feeding throughout the experiment. The groups of birds used for this study were continued on L, M, H and R feeding till 35 weeks and then part of those birds which continued on L, M, H and R as treatments L (low), M (medium), H (high energy) and R (regulated feeding). During the 22 to 35 weeks (Table 3:3) feed intake was not significantly different ($P<0.05$) between all treatment groups but was in the following order $L<M<H<R$. The differences between M, H and R were evident during the first period (22 to 29 weeks of age) (Table 3:3) but it was not until the second period that intakes on L and M were significantly different. Daily feed intake values directly decrease as dietary energy levels increased. Feed intake increased substantially till the hens reached their peak egg production at 30 to 35 weeks of age (Fig. 3:1), and then decreased gradually with advancing

age. During 22 to 35 weeks the accumulative feed intake was 17.8, 16.8, 15.8 and 14.4kg/b for those on L, M, H and R feeding respectively. In the second and third periods there were significant differences ($p < 0.05$) in feed intake between ad libitum fed hens but there were no significant differences between hens on feed M and R feeding.

During the challenge feeding period (28-39 weeks), which covers the last part of the first phase and the first part of the second phase, the mean daily feed intakes were 184, 170, 159 and 172g/b for hens on L, M, H and R feeding respectively. The highest daily feed intake was 194g/b and 184g/b for hens on L and M respectively at 30-31 weeks of age while for those on H it was 165g/b at 28-29 weeks of age, and, for those on R it was 181g/b at 34-35 weeks of age. The position of cages did not effect feed intake during this phase (22 to 35 weeks).

During the periods from 42 to 54 weeks of age, the differences in feed consumption between birds on L, M and H gradually decreased. Also the feed intake declined with advancing age.

Throughout the last period, hens on M consumed approximately the same amount of feed as those on H while for those on L consumed at least 11-16 per cent more. Hens on R ate 7 to 12 per cent more than those on M and H respectively.

There was one fluctuation in feed intake at 39 weeks due to the disturbance in water availability. In the following week the feed intake recovered. This is shown in Fig. 3:1.

There was a difference in the accumulative feed intake throughout this phase (36-54 weeks) in which hens on L feeding consumed about 1.8kg/b more than those on M while those on M consumed 2.1kg/b more than those on H feeding. The mean daily feed intake was 169g/b

Table 3:3

Effect of feeding treatments on daily feed intake (g/b) throughout the two phases.

| Phase | Period | Weeks | Treatments L | M | H | R | SED |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 22-29 | $176^{a}$ | $170^{a}$ | $159^{b}$ | $129^{c}$ | 3.1 |
| 1 | 2 | 30-35 | $189^{a}$ | $174^{b}$ | $163^{c}$ | $170^{b}$ | 2.5 |
| 2 | 3 | 36-41 | $181^{a}$ | $162^{b}$ | $150^{c}$ | $170^{b}$ | 4.6 |
| 2 | 4 | 42-45 | $164^{a}$ | $157^{ab}$ | $136^{c}$ | $151^{b}$ | 5.3 |
| 2 | 5 | 46-51 | $166^{a}$ | $162^{ab}$ | $140^{c}$ | $154^{b}$ | 5.4 |
| 2 | 6 | 52-54 | $156^{a}$ | $140^{bc}$ | $134^{c}$ | $150^{ab}$ | 5.9 |
| | Mean | | 172 | 161 | 147 | 154 | |

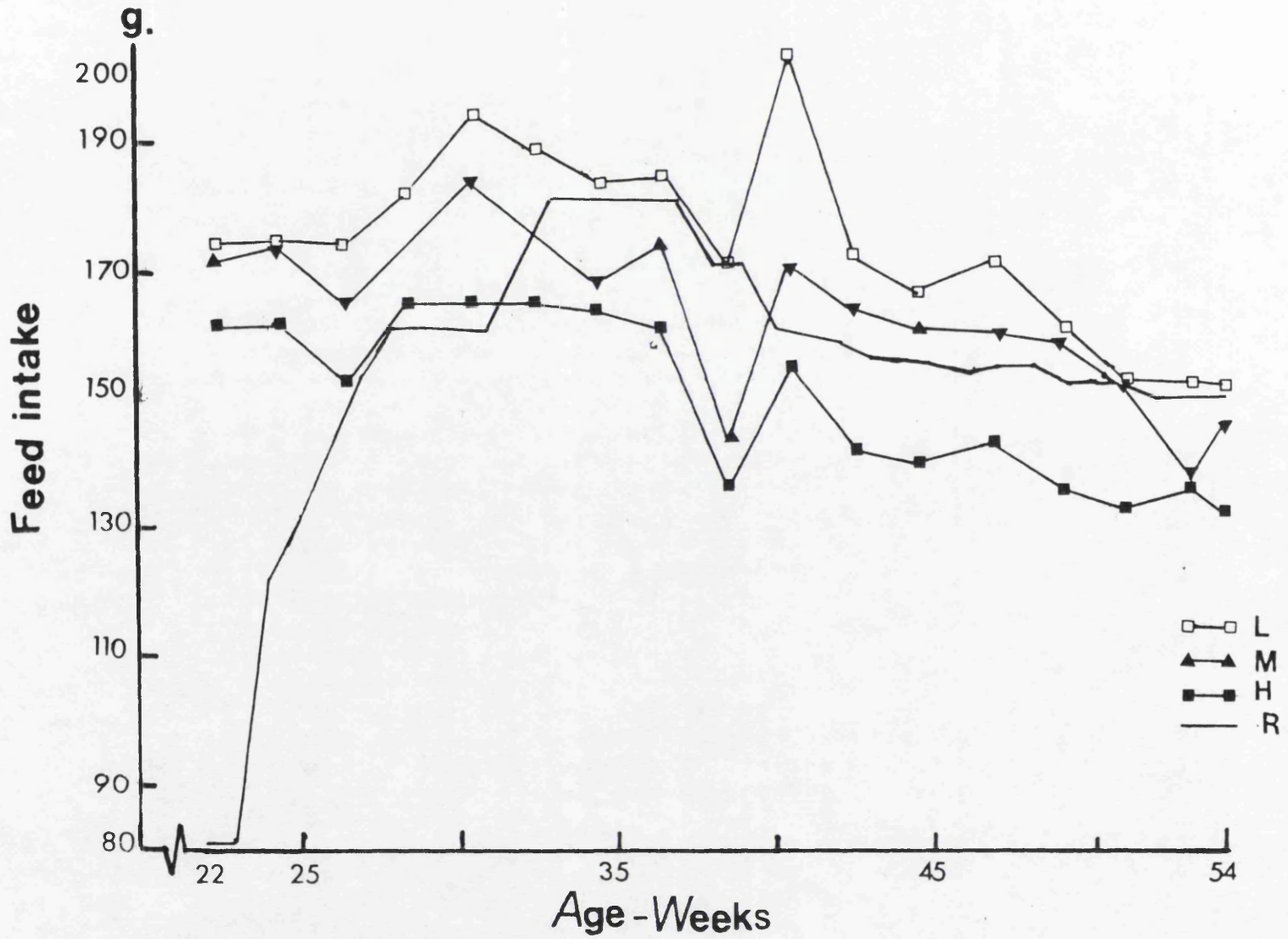
Table 3:4

Effect of feeding treatments on daily feed intake (g/b) throughout the second phase.

| Phase | Period | Weeks | Treatments LH | HL | MR | RL | RM | RH | SED |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 3 | 36-41 | $163^{c}$ | $167^{bc}$ | $168^{abc}$ | $177^{a}$ | $176^{ab}$ | $167^{bc}$ | 4.6 |
| 2 | 4 | 42-45 | $136^{c}$ | $163^{ab}$ | $158^{b}$ | $169^{a}$ | $159^{ab}$ | $156^{b}$ | 5.3 |
| 2 | 5 | 46-51 | $147^{c}$ | $172^{ab}$ | $148^{c}$ | $177^{a}$ | $163^{b}$ | $152^{c}$ | 5.4 |
| 2 | 6 | 52-54 | $138^{b}$ | $162^{a}$ | $145^{b}$ | $162^{a}$ | $158^{a}$ | $145^{b}$ | 5.9 |
| | Mean | | 146 | 166 | 155 | 171 | 164 | 155 | |

$^{a,b,c}$Means within period with different superscripts are significantly different ($p < 0.05$).

Fig. 3:1 Mean daily feed intake (g/b) for *ad libitum* groups and regulated group during the two phases



and 140g/b for those on L and those on H, while for those on M and R it was 155 and 156g/b during the second phase respectively. The total feed consumption during this phase was approximately 22.5kg/b and 18.6kg/b for hens on L and H respectively, and for hens on M and R it was about 20.7kg/b.

Table 3:5

Total feed intake during the laying period for treatments L,M,H and R which remained on the same feed allowance.

| Treatment | Accumulative feed intake (kg/b) |
|---|---|
| L | 39.7 |
| M | 37.2 |
| H | 34.0 |
| R | 35.6 |

Total feed intake during the laying period for all treatments is given in Table 3:5.

a) Responses to change in feeding system and feed ME content

At 36 weeks, the hens used for this study were from ad libitum hens which initially were on feeds L, M and H. These hens had changed from L to H, from M to R or from H to L, called treatments LH, MR and HL respectively. Also part of hens on regulated feeding in phase 1 were used for study in this second phase. Those hens which initially were fed regulated feeding changed to ad libitum feeding, either R to L, R to M or R to H and were called treatments RL, RM and RH respectively. The data of feed intake throughout the second phase are presented in Appendix 3: 5, 3: 6, 3: 7, 3:8 , 3: 9 and 3:10. These results are summarized and given in Table 3:4, and also plotted against age in Fig. 3:2, 3:3, 3:4 and 3:5. The analysis of variance was done for all periods.

b) Feed intake of ad libitum and regulated hens: response to changes.

The change to feeds and feeding systems caused a decrease in feed intake with hens on LH, HL, RL and RH but not for hens on MR feeding (which remained on the same feed and given regulated amounts). The following comparisons are made:-

1. LH v RH
2. HL v RL
3. MR v RM
4. LH v H
5. HL v L
6. RL v L
7. RM v M
8. RH v H

During the third period (the first period after the change), there were no significant differences between LH and RH, and MR and RM, but there was a significant difference ($p < 0.05$) for hens on HL and RL. During the fourth period, the deterioration in feed intake is accounted for by the disturbance in the water availability; this was mentioned in Chapter 2.

In the following periods, there were no significant differences in feed intake between hens on LH and RH or between HL and RL (Table 3:4). Throughout all periods in phase 2 hens on RH and RL consumed slightly more than those on LH and HL respectively. The accumulative feed intake was 19.4, 20.6, 22.1 and 22.7kg/b for hens on feed LH, RH, HL and RL, while for hens fed MR and RM it was 20.6 and 21.8kg/b respectively.

Throughout this phase, the accumulative feed intake for hens on LH was 0.8kg/b more than those on H, and for hens on HL, it was 0.4kg/b less than those on L. Hens on RL, RM and RH consumed more

feed than those on L, M and H by 0.2, 1.1 and 2.0kg/b respectively.

b) Feed density

The density (mL/g) of each feed was measured four times during the experiment. The means of these measurements are presented in Table-3:6. Throughout the laying period, the mean daily feed intake was 172, 161, and 154g/b for hens on L,M and H respectively. The volume of feed consumed deduced from measurement of each feed. The daily volume consumption of feeds L, M and H were 307, 264 and 227 mL/g, respectively. There was a clear reduction in the volume of feed consumed as energy content increased.

Table 3:6

Feed density (mL/g) of feeds on different energy levels.

| Feeds | ME kJ/g | Volume ml. | Weight g. | Density ml/g |
|---|---|---|---|---|
| L | 10.1 | 1000 | 560 | 1.8 |
| M | 12.2 | 1000 | 611 | 1.6 |
| H | 13.3 | 1000 | 649 | 1.5 |

2. ME intake

ME intake was obtained by multiplying the feed intake data by the determined ME values of the feeds. All the data are presented in Table 3:7. The analysis of variance was done among all treatments. ME intake increased with advancing age up to peak of production and then decreased throughout the rest of the laying period.

During the first period (22-29 weeks of age), hens on H ate more than those on L by 20 per cent and by about 2 per cent than those on M, while those on regulated feeding received less than those on feed H by about 38 per cent. ME intake was significantly different ($p < 0.05$) between L, M, H and R.

The maximum daily ME intake of ad libitum fed hens occurred during the second period (Table 3:7). Hens on H consumed significantly ($p < 0.05$) more energy than those on L, and R feeding throughout phase 1, the overall differences were 312 and 399 kJ/d for H v L and H v R respectively. When the hens passed their peak production throughout the third period compared to the second period, ME intake decreased for those on H by 177 kJ/d and by 139 kJ/d for those on M and for hens on L it decreased by 84 kJ/d, while for those on R feeding it increased by 7 kJ/d (Fig. 3:6).

During the challenge feeding period (28-39 weeks), hens on R consumed more ME than those on L by 10 per cent and by 1.6 and 4 per cent less than those on M and H respectively. In the last period the hens on feed H consumed more than those on L by 14 per cent and 4.6 per cent more than those on M while those on R consumed the same amount of ME as treatment H. During Phase 2, daily ME consumption was 1675, 1895, 1861 and 1858 kJ/b for hens on L, M, H and R feeding respectively. Throughout the laying period (22-54 weeks of age) the accumulative ME intakes of the hens were 399.4 MJ/b, 453.5 MJ/b, 451.6 MJ/b and 423.0 MJ/b for those on L, M, H and R feeding respectively.

Responses to change in feeding system and feed ME content.

The data of ME intake throughout the second phase for all treatments after the changes of feeding system and feeds are recorded in Appendix 3: 5, 3: 6, 3: 7, 3: 8, 3: 9 and 3:10. These results are summarized and given in Table 3:8. The analysis of variance was carried out for all periods.

Fig. 3:3 Mean daily feed intake of hens on low energy feed during the two phases and their response to high energy level after 35 weeks

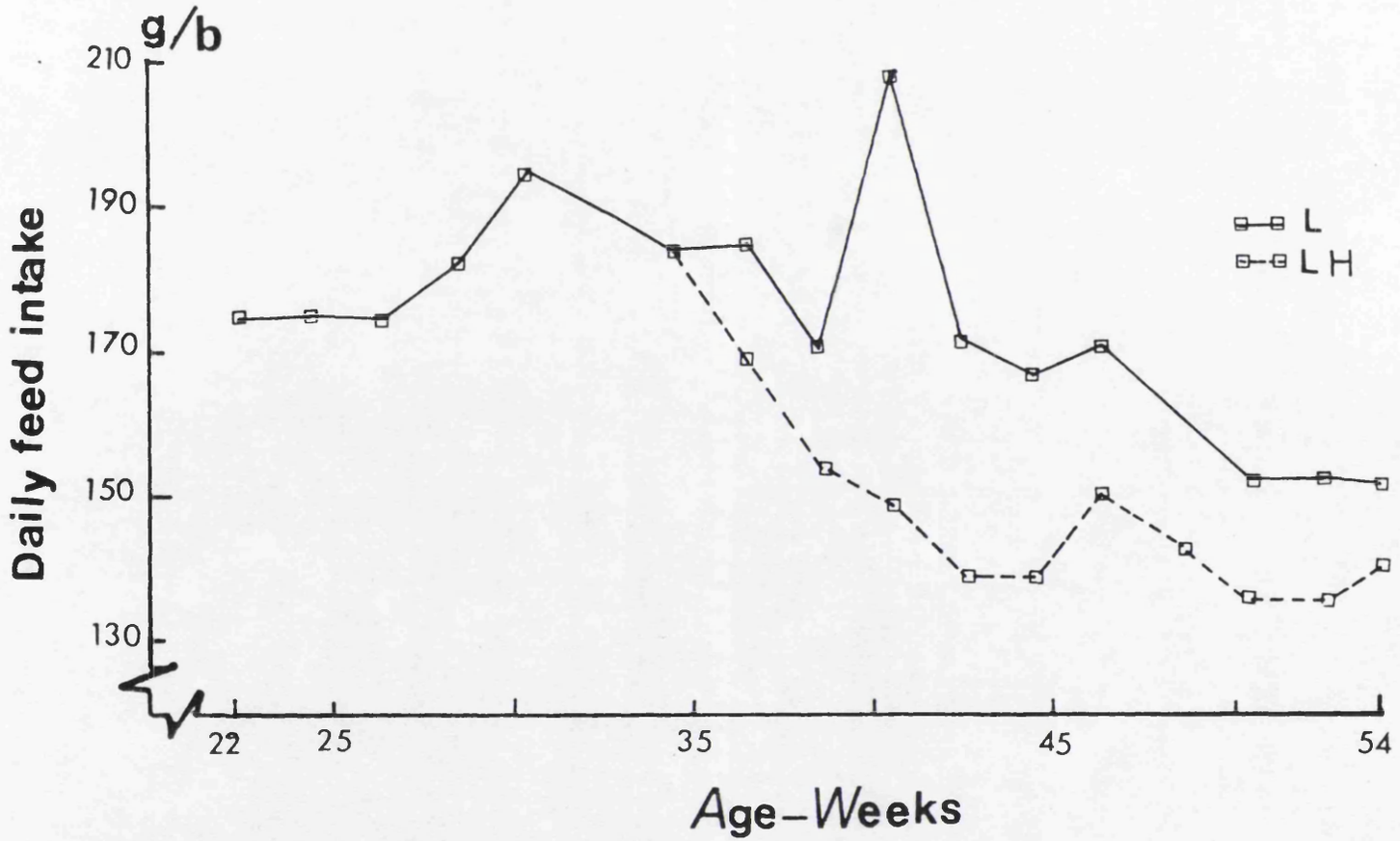


Fig. 3:4 Mean daily feed intake of hens on the *ad libitum* medium energy feed during the two phases and their response to regulated feeding after 35 weeks of age

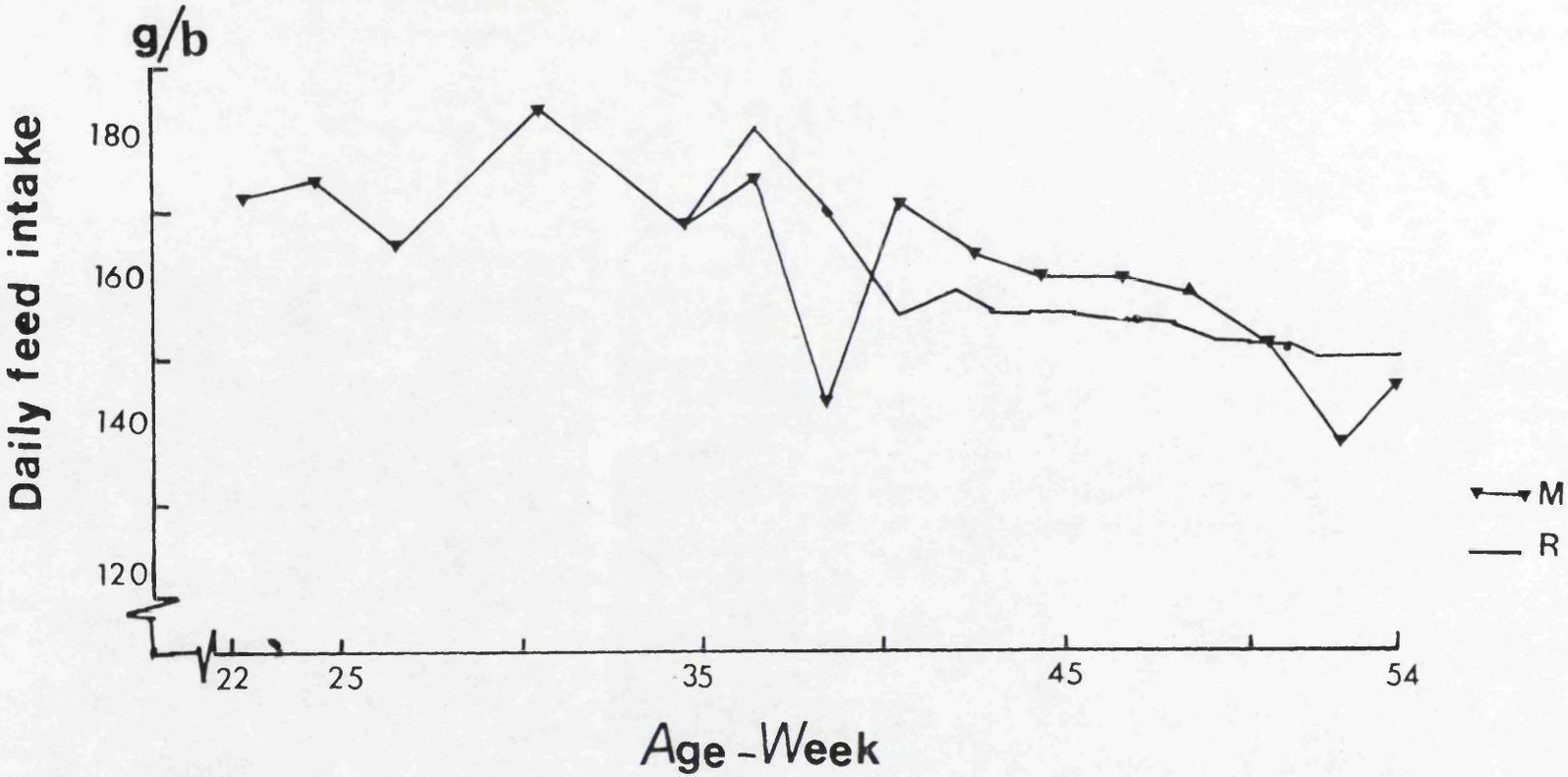
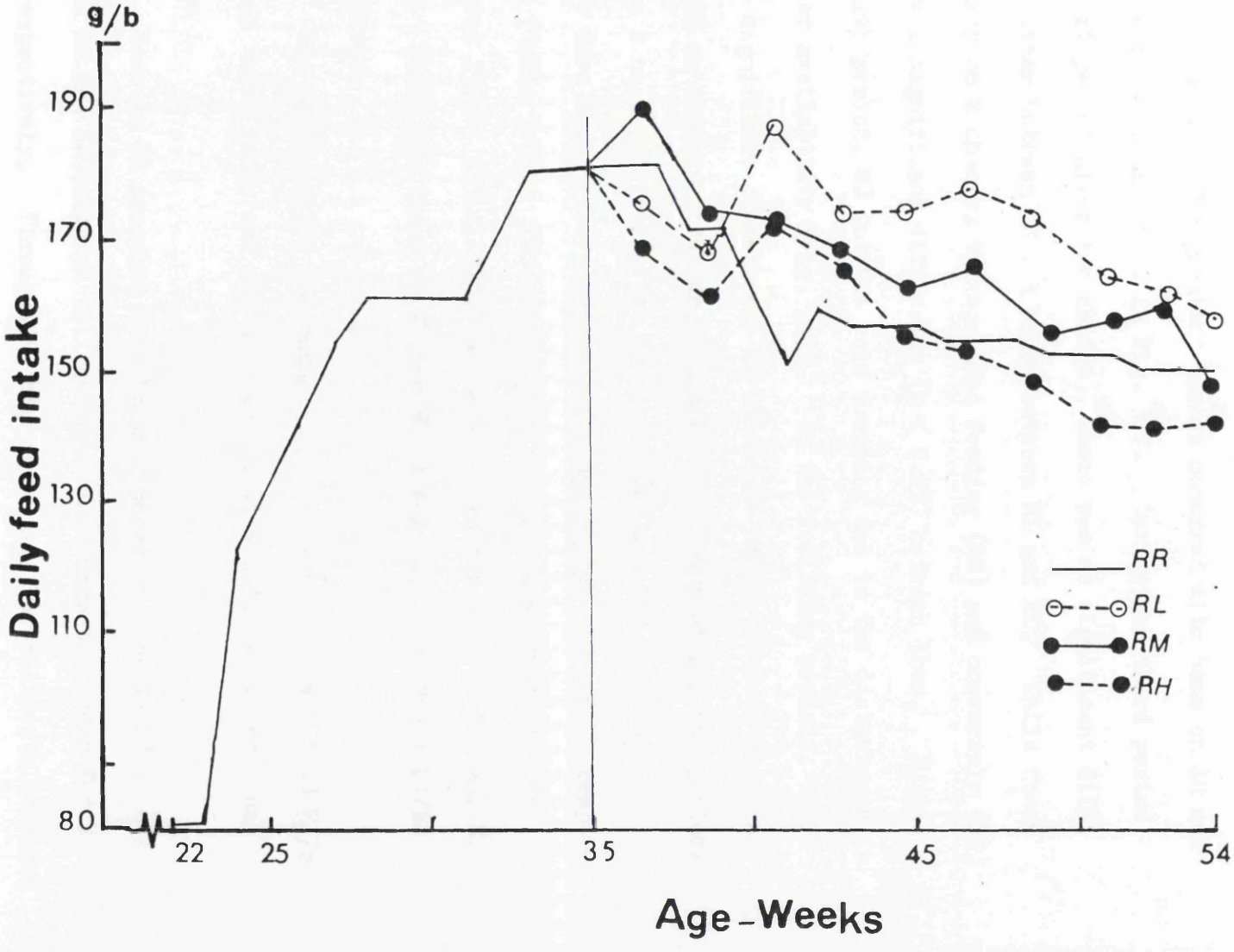


Fig. 3:5 Mean daily feed intake of regulated hens during the two phases and their response to *ad libitum* feeding after 35 weeks of age



ME intake of ad libitum and regulated hens: response to changes.

At 36 weeks of age, when the feeds changed from one to another of different energy content or from one feeding system to another, it caused a decrease in ME intake during the first four weeks after the change. The greatest change occurred with hens on LH and MR. The changes are shown in Fig. 3:7. During the third period (the first period after the change), there was no significant difference either between LH and RH or between HL and RL. While those previously on M changed to regulated feeding (MR) and conversely (RM) did show a significant difference ($p < 0.05$) between them. During the fourth period, ME intakes were dropping due to the disturbance in the water availability (Fig. 3:7). In the following periods, there were no significant differences in ME intake either between hens on LH and RH or between those on HL and RL. Throughout all the periods in phase 2 hens previously fed regulated (RH and RL) consumed slightly more than those previously fed ad libitum (LH and HL respectively) (Table 3:8). Throughout this phase, the accumulative ME intake was 257.8, 273.4, 221.7 and 299.2 MJ/b for hens on LH, RH, HL and RL. While for those on MR and RM it was 244.6 and 265.1 MJ/b respectively.

The accumulative ME consumption for hens on LH was 10.3 MJ/b more than those on H, and for hens on HL, it was 1.1 MJ/b less than those on L.

Hens on RL consumed more ME than those on L by 72 MJ/b, also those on RM and RH consumed 13.1 and 25.9 MJ/b more than hens fed M and H respectively. Throughout this phase all the treatments consumed more ME after the change than those continued on the same feed except HL.

Table 3:7

Effect of feeding treatments on daily energy intake (kJ/b) throughout the two phases.

| | | | Treatments | | | | |
|---|---|---|---|---|---|---|---|
| Phase | Period | Weeks | L | M | H | R | SED |
| 1 | 1 | 22-29 | $1768^{c}$ | $2076^{b}$ | $2116^{a}$ | $1533^{d}$ | 24 |
| 1 | 2 | 30-35 | $1905^{c}$ | $2120^{a}$ | $2170^{a}$ | $2017^{b}$ | 30 |
| 2 | 3 | 36-41 | $1821^{b}$ | $1981^{a}$ | $1993^{a}$ | $2024^{a}$ | 56 |
| 2 | 4 | 42-45 | $1645^{b}$ | $1916^{a}$ | $1804^{a}$ | $1799^{a}$ | 64 |
| 2 | 5 | 46-51 | $1671^{c}$ | $1979^{a}$ | $1864^{ab}$ | $1829^{b}$ | 62 |
| 2 | 6 | 52-54 | $1563^{b}$ | $1704^{ab}$ | $1783^{a}$ | $1781^{a}$ | 72 |
| | Mean | | 1729 | 1963 | 1955 | 1831 | 41 |

Table 3:8

Effect of feeding treatments on daily ME intake (kJ/b) throughout the second phase.

| | | | Treatments | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Phase | Period | Weeks | LH | HL | MR | RL | RM | RH | SED |
| 2 | 3 | 36-41 | $2169^{a}$ | $1677^{c}$ | $1999^{b}$ | $1782^{c}$ | $2143^{a}$ | $2216^{a}$ | 56 |
| 2 | 4 | 42-45 | $1798^{b}$ | $1637^{c}$ | $1871^{b}$ | $1700^{c}$ | $1941^{a}$ | $2067^{a}$ | 64 |
| 2 | 5 | 46-51 | $1951^{a}$ | $1730^{b}$ | $1759^{b}$ | $1780^{b}$ | $1988^{a}$ | $2012^{a}$ | 62 |
| 2 | 6 | 52-54 | $1833^{ab}$ | $1624^{c}$ | $1725^{bc}$ | $1629^{c}$ | $1901^{a}$ | $1929^{a}$ | 72 |
| | Mean | | 1938 | 1667 | 1839 | 1723 | 1993 | 2056 | 41 |

$^{a,b,c}$Means within period with different superscripts are significantly different ($p < 0.05$).

Fig. 3:6 Mean daily energy intake for all groups during the laying period which remained on the same diet

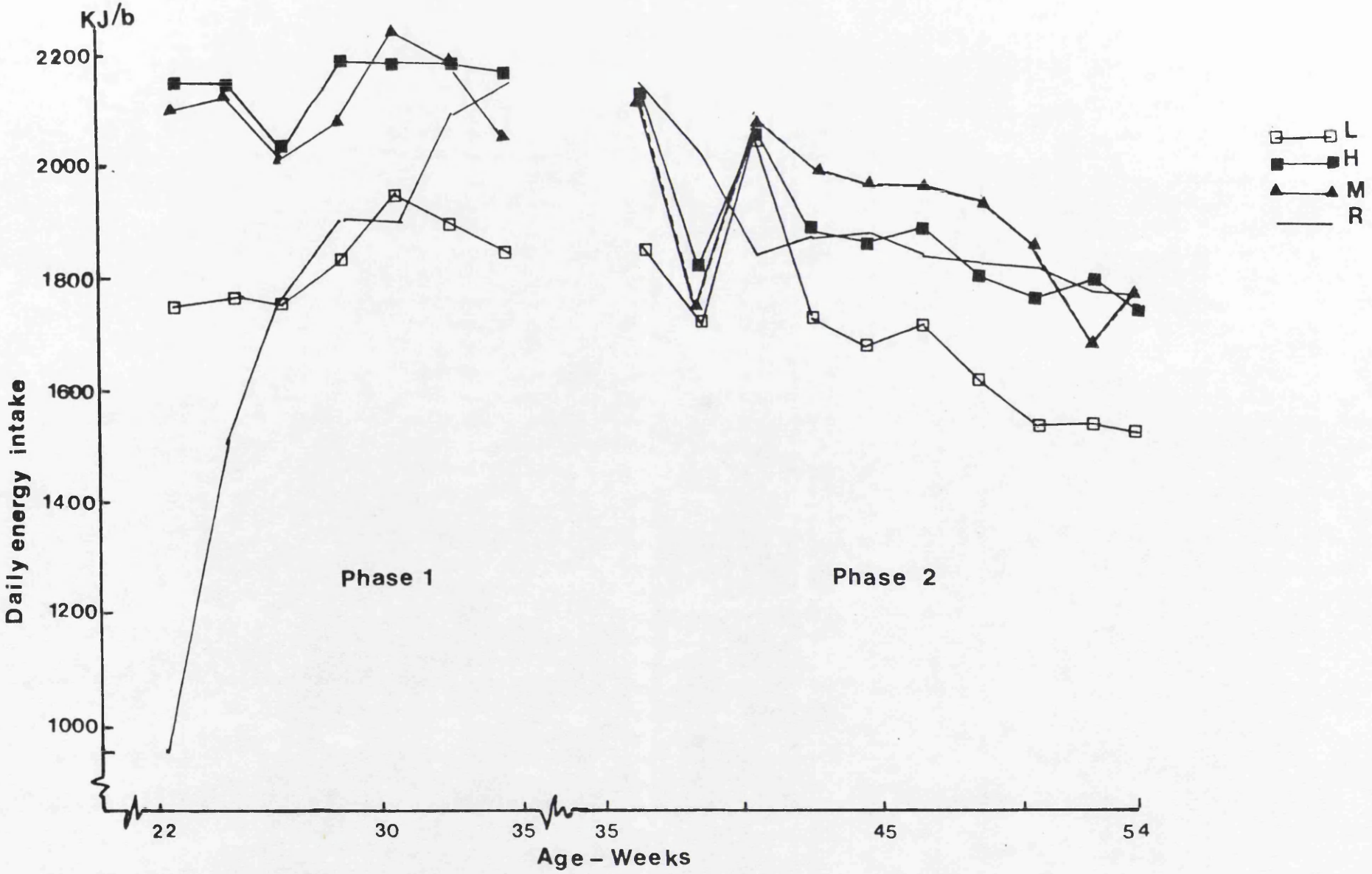
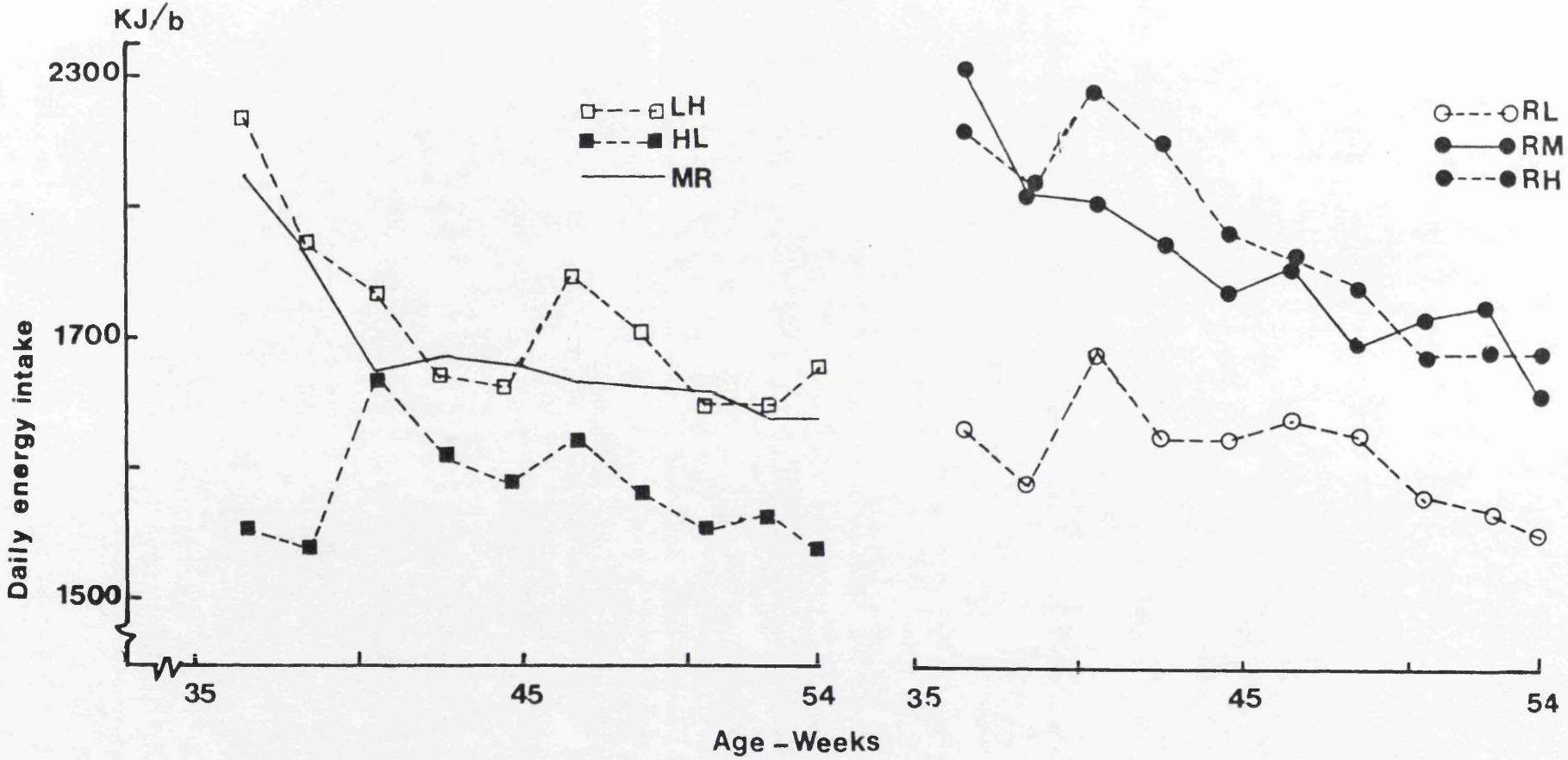


Fig. 3:7 Mean daily energy intake for all treatments after the change in feeds at 35 weeks



3. Body weight

The analysis of variance for body weight data for hens fed continuously feeds L, M, H and R feeding throughout the two phases were done and the results are given in Tables 3:9, 3:10 and 3:11. Also these data are shown in Fig. 3:8, 3:9, 3:10 and 3:11 when plotted against age.

a) Phase 1 (22-35)weeks.

These results showed that the hens on feed H were gaining more than those on L and M (Table 3:12), while hens given regulated amount of feed were gaining 12.8g/d (about 9g/d more than hens on M). The body weight gains of hens on ad libitum feeding were not significantly different but a significant difference ($p < 0.05$) existed in body weight gains between hens on ad libitum and regulated feeding (Table 3:9) after the second period. The differences in body weight among hens at the beginning of this phase (22 weeks) and at the end of this phase (35 weeks) were 3.4, 7.1, 8.5 and 59.7 per cent for hens on L, M, H and R respectively. The position of cages, top or bottom, had no effect on the body weight. In the first four weeks (22-25 weeks), body weight increased gradually for all ad libitum treatments and then became almost stable, although the body weight of those on R continued to increase throughout this phase (Fig. 3:8).

b) Phase 2 (36-54 weeks)

In this phase, half of ad libitum hens (L, M, H) and a quarter of regulated hens (R) were continued on the same feeds until the end of the experiment and the remaining birds were assigned to the other treatments. During the challenge feeding period (28-39 weeks), which covered the last part of the first phase and the early part of the second phase, hens on R feeding had a greater increase in body weight.

The increase was 23 per cent for those on R while those on L, M and H had increases of 4.5, 4.7 and 9.0 per cent respectively.

During the second phase, the body weights of ad libitum hens were essentially stable (Fig. 3:8). There were no significant differences in body weight gains between all treatments (L, M, H and R) at this phase (Table 3:12). Throughout the laying period (Phases 1 and 2) the mean daily weight gain was 1.2, 1.8, 3.6 and 7.3g/b for hens on L, M, H and R respectively.

c) Body weight of ad libitum and regulated hens: response to changes.

The body weight data throughout the second phase (36-54 weeks) for all treatments after the changes of feeding system and feeds are presented in Table 3:12. Also these data are shown in Fig. 3:9 and 3:10 plotted against age. The analysis of variance was done for all treatments. The hens were weighed at 38 and 41 weeks of age after the change of feeds, and then weighed at 45, 50 and 54 weeks of age. During the third period (the first weighing after the change), there were significant differences in body weight between hens on LH and HL and between HL and RL, as well as MR and RM.

Throughout this phase the mean daily weight gain was 3.4, 7.4, 0.0, 3.3, 2.1 and 5.0g/b for hens on LH, RH, HL, RL, MR and RM respectively. This is given in Table 3:12. The differences in body weights for hens on LH, RH, HL, RL, MR and RM between the beginning and at the end of this phase were 10, 29, 0, 14, 2 and 20 per cent respectively.

At the end of the experiment, the difference in body weight for hens on LH was 2 per cent lighter than hens continued on H and also for hens on HL was 5 per cent lighter than those on L, while those on MR were 2.5 per cent heavier than those on M. The difference in body

Table 3:9

Effect of feeding treatments on the body weight (kg/b) at different ages of broiler breeder in cages throughout the first phase.

| | Treatments | | | | |
|---|---|---|---|---|---|
| Age/weeks | L | M | H | R | SED |
| 22 | $4.30^{a}$ | $4.11^{b}$ | $4.19^{ab}$ | $2.10^{c}$ | 0.06 |
| 25 | $4.37^{a}$ | $4.20^{b}$ | $4.40^{a}$ | $2.61^{c}$ | 0.06 |
| 30 | $4.39^{a}$ | $4.34^{a}$ | $4.50^{a}$ | $3.03^{b}$ | 0.07 |
| 35 | $4.44^{a}$ | $4.40^{a}$ | $4.54^{a}$ | $3.35^{b}$ | 0.08 |

$^{a,b,c}$Mean within period with different superscripts are significantly different ($p < 0.05$).

Table 3:10

Effect of feeding treatments on the body weight (kg/b) of females throughout the second phase.

| | Treatments | | | | |
|---|---|---|---|---|---|
| Age/weeks | L | M | H | R | SED |
| 35 | $4.42^{b}$ | $4.34^{b}$ | $4.71^{a}$ | $3.41^{c}$ | 0.11 |
| 38 | $4.59^{b}$ | $4.54^{b}$ | $4.89^{a}$ | $3.50^{c}$ | 0.13 |
| 41 | $4.64^{a}$ | $4.47^{b}$ | $4.92^{a}$ | $3.59^{c}$ | 0.15 |
| 45 | $4.61^{b}$ | $4.49^{b}$ | $4.90^{a}$ | $3.70^{c}$ | 0.15 |
| 50 | $4.60^{b}$ | $4.57^{b}$ | $4.90^{a}$ | $3.71^{c}$ | 0.16 |
| 54 | $4.58^{b}$ | $4.54^{b}$ | $5.03^{a}$ | $3.79^{c}$ | 0.17 |

$^{a,b,c}$Means within period with different superscripts are significantly different ($p < 0.05$).

Table 3:11

Effect of feeding treatments on body weight (kg/b) of females after change of the feeds at 35 weeks of age.

| Age/ week | Treatments | | | | | | |
|---|---|---|---|---|---|---|---|
| | LH | HL | MR | RL | RM | RH | SED |
| 35 | $4.46^{a}$ | $4.35^{a}$ | $4.38^{a}$ | $3.14^{c}$ | $3.32^{bc}$ | $3.36^{b}$ | 0.11 |
| 38 | $4.75^{a}$ | $4.37^{b}$ | $4.57^{ab}$ | $3.35^{d}$ | $3.51^{cd}$ | $3.75^{c}$ | 0.13 |
| 41 | $4.75^{a}$ | $4.39^{b}$ | $4.62^{ab}$ | $3.53^{d}$ | $3.72^{cd}$ | $3.85^{c}$ | 0.15 |
| 45 | $4.88^{a}$ | $4.38^{bc}$ | $4.59^{ab}$ | $3.48^{e}$ | $3.80^{d}$ | $4.09^{cd}$ | 0.15 |
| 50 | $5.04^{a}$ | $4.37^{b}$ | $4.58^{b}$ | $3.54^{d}$ | $4.05^{c}$ | $4.32^{bc}$ | 0.16 |
| 54 | $4.92^{a}$ | $4.35^{b}$ | $4.66^{ab}$ | $3.58^{d}$ | $3.99^{c}$ | $4.34^{b}$ | 0.17 |

$^{a,b,c,d,e}$Means within period with different superscripts are significantly different ($p < 0.05$)

Table 3:12

Effect of feeding systems on the weight gain of females (g/b) throughout the two phases.

| Treatment | Phase 1 | Phase 2 |
|---|---|---|
| L | $1.5^{b}$ | $1.2^{d}$ |
| M | $3.0^{b}$ | $1.5^{d}$ |
| H | $3.6^{b}$ | $2.4^{d}$ |
| R | $12.8^{a}$ | $2.9^{d}$ |
| LH | | $3.5^{c}$ |
| HL | | 0.0 |
| MR | | $2.1^{d}$ |
| RL | | $3.3^{c}$ |
| RM | | $5.0^{b}$ |
| RH | | $7.4^{a}$ |

$^{a,b,c,d}$Means for each a column within each treatment that possess different superscripts differ significantly ($p < 0.05$).

Fig. 3:8 Body weight curve for all treatments which remained on the same diet during the laying period

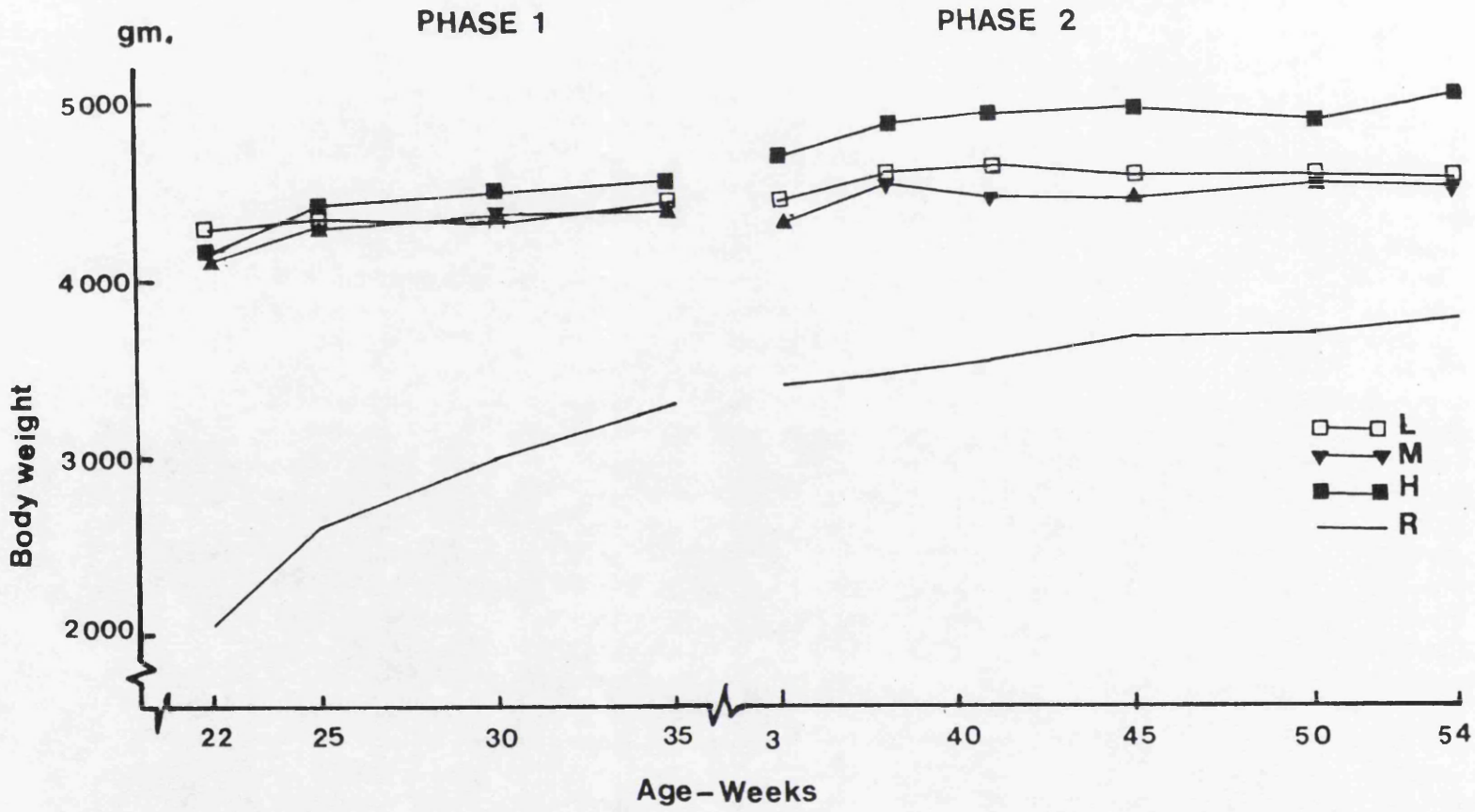


Fig. 3:9 Body weight of hens previously on *ad libitum* changed after 35 weeks of age on low and high energy feed and to regulated feeding

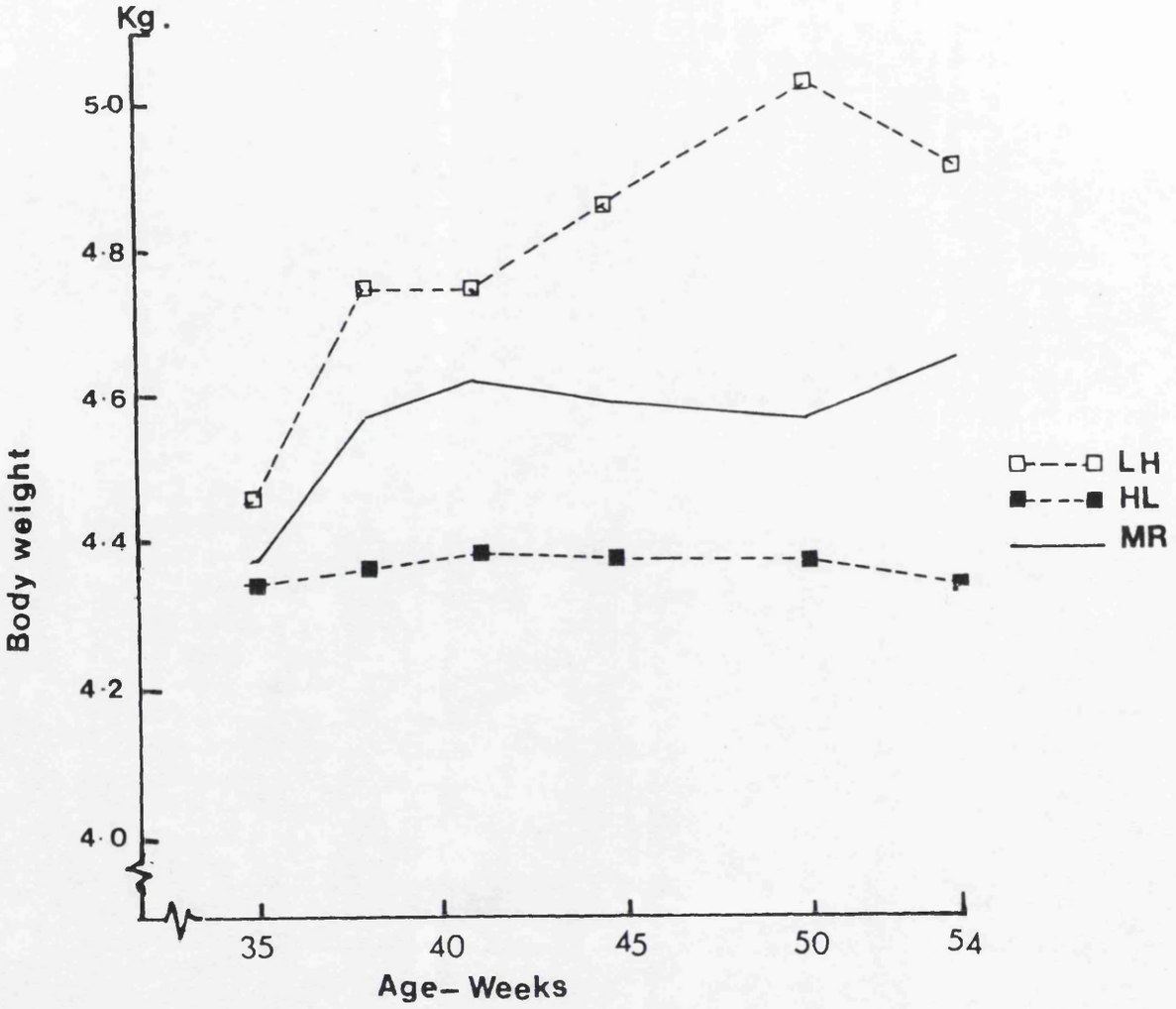


Fig. 3:10 Body weight changes in the second phase of hens previously regulated feeding

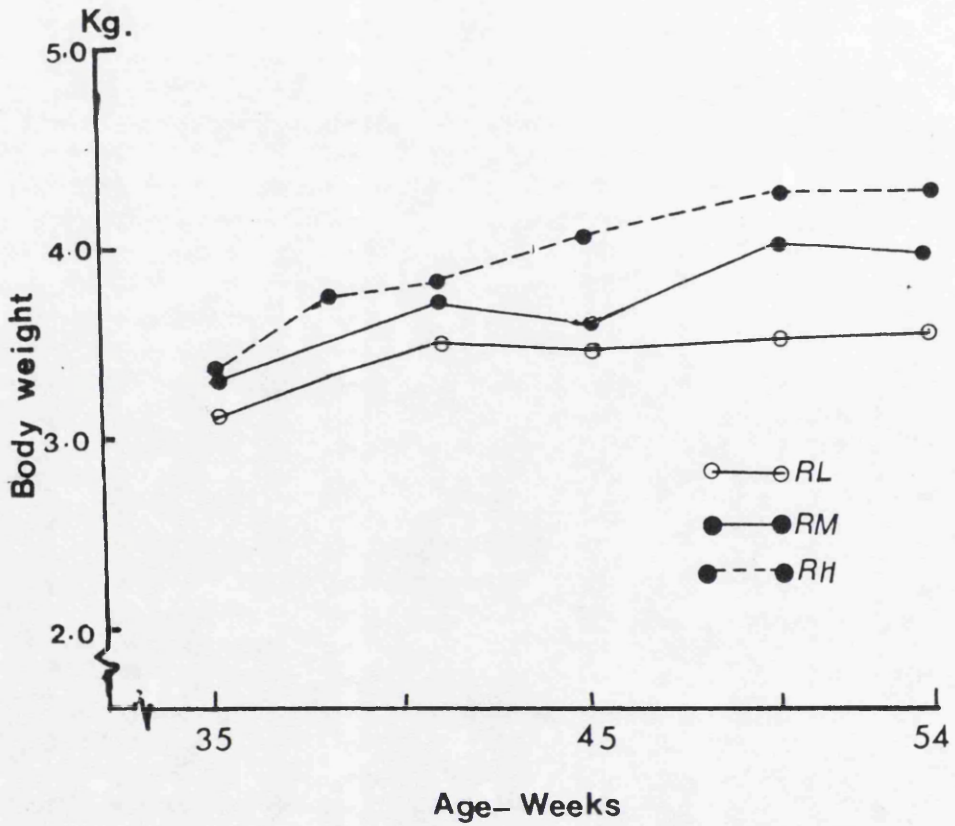


Fig. 3:11 Daily feed intake and body weight after changing for 4 and 6 weeks respectively

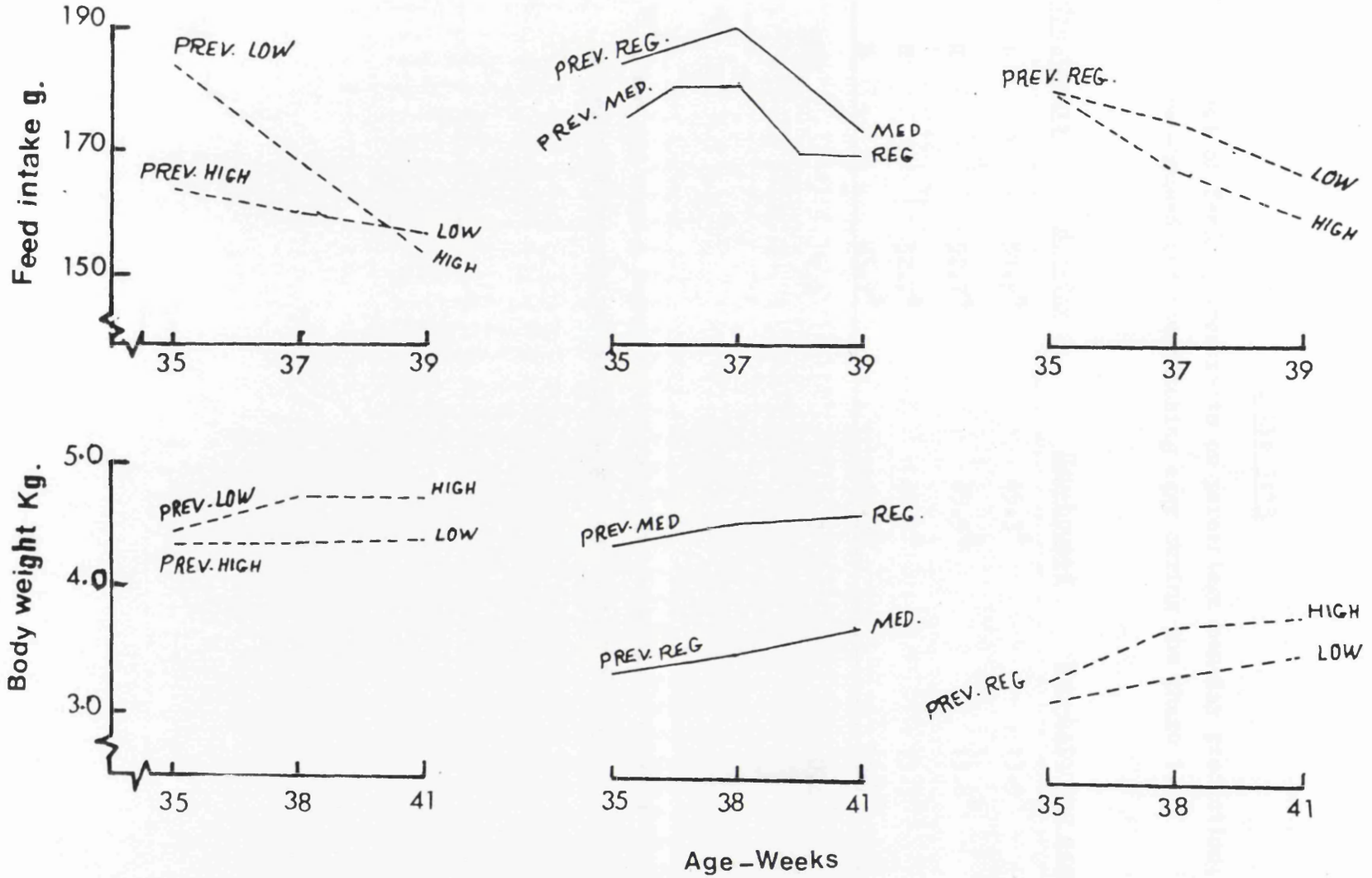


Table 3:14

Effect of feeding treatments on percentage hen-day production throughout the two phases.

| Phase | Period | Weeks | Treatment L | M | H | R | SED |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 22-29 | $46.5^{a}$ | $48.1^{a}$ | $48.8^{a}$ | $25.5^{b}$ | 1.4 |
| 1 | 2 | 30-35 | $59.4^{b}$ | $59.3^{b}$ | $58.1^{b}$ | $73.8^{a}$ | 1.6 |
| 2 | 3 | 36-41 | $49.6^{b}$ | $53.1^{b}$ | $47.9^{b}$ | $68.7^{a}$ | 3.2 |
| 2 | 4 | 42-45 | $45.7^{b}$ | $46.6^{b}$ | $40.8^{b}$ | $59.5^{a}$ | 4.0 |
| 2 | 5 | 46-51 | $42.6^{b}$ | $41.9^{b}$ | $40.2^{b}$ | $56.6^{a}$ | 4.0 |
| 2 | 6 | 52-54 | $33.1^{b}$ | $35.0^{b}$ | $30.3^{b}$ | $53.1^{a}$ | 3.3 |
| Mean during the whole period | | | 46.2 | 47.3 | 44.2 | 56.3 | |
| During the second phase | | | 44.0 | 45.3 | 41.2 | 60.4 | |

Table 3:15

Effect of feeding treatments on percentage hen-housed production throughout the two phases.

| Phase | Period | Weeks | Treatment L | M | H | R | SED |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 22-29 | $46.3^{a}$ | $47.5^{a}$ | $47.7^{a}$ | $25.3^{b}$ | 1.5 |
| 1 | 2 | 30-35 | $57.7^{b}$ | $56.2^{b}$ | $54.7^{b}$ | $71.7^{a}$ | 2.0 |
| 2 | 3 | 36-41 | $48.7^{b}$ | $48.4^{b}$ | $44.2^{b}$ | $65.1^{a}$ | 3.4 |
| 2 | 4 | 42-45 | $44.3^{b}$ | $41.9^{b}$ | $36.3^{b}$ | $55.5^{a}$ | 4.3 |
| 2 | 5 | 46-51 | $41.1^{b}$ | $36.6^{b}$ | $35.6^{b}$ | $52.1^{a}$ | 4.2 |
| 2 | 6 | 52-54 | $32.0^{b}$ | $30.0^{b}$ | $25.0^{b}$ | $48.0^{a}$ | 4.2 |
| Mean | | | 45.0 | 43.5 | 40.6 | 53.0 | |

$^{a,b}$Means within period with different superscripts are significantly different ($p < 0.05$).

Table 3:16

Effect of feeding treatments on percentage non-hatching eggs throughout the two phases.

| | | | Treatments | | | | |
|---|---|---|---|---|---|---|---|
| Phase | Period | Weeks | L | M | H | R | SED |
| 1 | 1 | 22-29 | 25.0[a] | 24.4[a] | 24.9[a] | 26.0[a] | 1.9 |
| 1 | 2 | 30-35 | 9.0[b] | 11.1[a] | 11.6[a] | 7.2[c] | 0.9 |
| 2 | 3 | 36-41 | 5.3[a] | 6.2[a] | 6.8[a] | 2.5[b] | 1.2 |
| 2 | 4 | 42-45 | 3.8[a] | 2.4[a] | 3.5[a] | 1.6[a] | 1.4 |
| 2 | 5 | 46-51 | 3.7[a] | 4.6[a] | 4.6[a] | 2.1[a] | 1.2 |
| 2 | 6 | 52-54 | 3.3[a] | 3.4[a] | 5.0[a] | 3.3[a] | 2.0 |
| | | Mean | 10.1 | 10.5 | 11.1 | 8.9 | |

[a,b]Means within period with different superscripts are significantly different ($p < 0.05$).

weight between hens on RL and those on R was 6 per cent lighter than R while those on RM and RH was 5 and 14 per cent heavier than hens continued fed on regulated feeding (R) respectively.

4. Egg production

Weekly hen-day egg production over the whole laying period for hens in groups L, M and H and R feeding are shown in Fig. 3:12. Every two weeks, results are given in Appendix 3:1, 3:2, 3: 3 and 3: 4. A summary of results are presented in Table 3:14.

The analysis of variance was done between all treatments. During the first period (22-29 weeks of age), there was no significant difference between groups fed ad libitum. However ad libitum groups had significantly greater rate of lay ($p < 0.05$) than those on regulated feeding. The difference in egg production during this period was approximately 23 per cent between both feeding systems. The highest rate of lay was during the second period (30-35 weeks) for all treatments. Hens on feed L reached a peak of 65 per cent at 27 weeks whereas those on feed H reached a peak of 63 per cent at 29 weeks. Peak production of hens on R feeding was 78 per cent achieved at 33 weeks of age.

During the first phase there were no significant differences in egg production between hens on L, M and H but a significant difference ($p < 0.05$) existed between hens on regulated and those on ad libitum feeding. Rate of lay of all groups gradually declined after their peak production. During this phase (22-35 weeks of age), hen-day production was significantly greater for hens on ad libitum than those on regulated feeding, Table 3:13. There was however no significant difference in hen-housed production between both feeding systems due to the high mortality of ad libitum fed hens, Table 3:13.

Egg numbers (hen-day) produced by hens on L, M and H to 35

weeks were 58, 59 and 59 eggs while those on R feeding produced 51 eggs. This is due to the fact that the regulated hens started laying 4 weeks later than those on ad libitum.

During the second phase, there were no significant differences between ad libitum fed hens but regulated produced at a significantly ($p < 0.05$) higher rate than those hens on H, M or L.

Egg numbers produced by hens on L, M, H and R feeding was 110, 114, 107 and 126 eggs respectively throughout the laying period. The difference in hen-housed production between hens on regulated feeding and those on L, M and H during the whole period (22 to 54 weeks) was 8.0, 9.5 and 12.0 per cent less than those on R respectively. Hens given ad libitum feeding produced more non-hatching eggs than those on R feeding. Most of the non-hatching eggs were produced during the first few weeks of laying (Fig. 3:13, 3:14, 3:15 and 3:16). Throughout the laying period the difference in non-hatching eggs between hens on feed L, M, H and those on R was 1.2, 1.6 and 2.2 per cent respectively. It is obvious that the rate of non-hatching eggs decreased gradually with advancing age (Table 3:16).

Significant differences in non-hatching eggs between hens on ad libitum and hens on regulated feeding existed only during the second and third period. During the fourth period, there was not a significant difference in the rate of non-hatching eggs between hens on ad libitum and those on R feeding.

a) Egg production of ad libitum hens: response to changes.

Rate of lay (hen-day and hen-housed) and non-hatching eggs results for all treatment during the second phase are given in Appendix 3:5, 3:6 and 3:7 and also shown in Fig. 3:13, 3:14 and 3:15. Summary of results are given in Tables 3:17, 3:18 and 3:19.

1. Hen-day production

Over the third period, there was no significant difference between hens on LH, HL and MR. But in the following period, hen-day production of birds in groups LH and HL were significantly different.

Over the whole phase, rate of egg production of treatments LH, HL and MR were not significantly different. Egg numbers produced by hens on LH and HL were 55 and 59 eggs while those on MR produced 53 eggs during the same phase (36-54 weeks). The control groups (L, H and M) produced 56, 52 and 57 eggs respectively.

2. Hen-housed production

The results indicate that there was no significant difference between LH, HL and MR feeding during the second phase. During this phase, the hen-housed production was 7.7 and 5 per cent less than hen-day production on LH, HL and MR feeding respectively. This was due to their higher mortality rate. These results also indicate that hen-housed production for hens on MR was less than others. Also their mortality was less during this phase (Table 3:31).

3. Non-hatching eggs

The results of non-hatching eggs are summarized and given in Table 3:19. During the third and fourth periods there were no significant differences between LH, HL and MR. But during the fifth period, hens on MR produced more non-hatching eggs than those on LH or HL. This pattern did not continue into the last period. During the whole phase, hens on MR produced (but not significantly) more non-hatching eggs than those on HL and LH (Table 3:19).

b) Egg production of regulated hens: response to changes.

Rate of lay and non-hatching eggs results for RL, RM and RH groups, after the change are given in Appendix 3: 8, 3: 9 and 3:10 as

well as shown in Fig. 3:17. These results are summarized and given in Tables 3:17, 3:18 and 3:19.

1. Hen-day production

During the first period after the change, from R feeding to feeds L, M and H, hens showed no change in their rate of lay when compared with the control birds (R) (Fig. 3:17). Rate of lay of hens on RL, RM and RH declined at a rate of 1.0, 1.3 and 1.1 per cent weekly, respectively after the feed was changed. Rate of lay of hens on R declined by 0.8 per cent during this phase. Egg numbers produced by hens on RL, RM and RH was 76.0, 80.5 and 76.0 eggs respectively. While the control group (R) produced 76.5 eggs.

2. Hen-housed production

During the second phase, there was no significant difference between RL, RM and RH groups after period 3. Hen-housed production was about 4.7 per cent less than hen-day production of hens on RL, 2.5 per cent less for hens on RM and 4.1 per cent less for those on RH.

3. Non-hatching eggs

During the first period (36-41 weeks) the RL hens produced significantly more non-hatching eggs than the RH hens (3 per cent) as shown in Table 3:19.

In the following periods there were no significant differences in non-hatching eggs between all groups.

c) Feed Conversion

The results of feed or energy conversion for each dozen or kilogram of eggs are summarized and given in Table 3:20.

Table 3:17

Effect of feeding treatments on percentage hen-day production throughout the second phase.

| Phase | Period | Weeks | Treatments LH | HL | MR | RL | RM | RH | SED |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 3 | 36-41 | $52.1^{b}$ | $51.0^{b}$ | $48.7^{b}$ | $65.7^{a}$ | $70.8^{a}$ | $67.7^{a}$ | 3.2 |
| 2 | 4 | 42-45 | $42.1^{c}$ | $52.0^{b}$ | $46.0^{bc}$ | $64.5^{a}$ | $64.0^{a}$ | $64.7^{a}$ | 4.0 |
| 2 | 5 | 46-51 | $41.8^{b}$ | $44.8^{b}$ | $37.1^{b}$ | $57.7^{a}$ | $59.8^{a}$ | $55.5^{a}$ | 4.0 |
| 2 | 6 | 52-54 | $29.1^{d}$ | $36.5^{c}$ | $31.9^{cd}$ | $47.3^{b}$ | $55.6^{a}$ | $48.4^{b}$ | 3.3 |
| | | Mean | 43.1 | 47.0 | 41.8 | 60.0 | 63.5 | 60.2 | |

Table 3:18

Effect of feeding treatments on percentage hen-housed production throughout the second phase.

| Phase | Period | Weeks | Treatments LH | HL | MR | RL | RM | RH | SED |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 3 | 36-41 | $48.3^{c}$ | $45.1^{c}$ | $43.9^{c}$ | $62.3^{b}$ | $69.8^{a}$ | $65.1^{ab}$ | 3.4 |
| 2 | 4 | 42-45 | $37.8^{b}$ | $45.4^{b}$ | $41.3^{b}$ | $61.1^{a}$ | $63.0^{a}$ | $61.7^{a}$ | 4.3 |
| 2 | 5 | 46-51 | $34.6^{b}$ | $38.9^{b}$ | $33.7^{b}$ | $53.8^{a}$ | $58.2^{a}$ | $52.4^{a}$ | 4.2 |
| 2 | 6 | 52-54 | $24.1^{b}$ | $32.2^{b}$ | $28.1^{b}$ | $44.0^{a}$ | $53.1^{a}$ | $45.0^{a}$ | 4.2 |
| | | Mean | 36.2 | 40.4 | 36.8 | 55.3 | 61.0 | 56.1 | |

Table 3:19

Effect of feeding treatments on percentage non-hatching eggs throughout the second phase.

| Phase | Period | Weeks | Treatments LH | HL | MR | RL | RM | RH | SED |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 3 | 36-41 | $7.8^{a}$ | $5.9^{a}$ | $6.2^{a}$ | $5.5^{ab}$ | $3.9^{bc}$ | $2.7^{c}$ | 1.2 |
| 2 | 4 | 42-45 | $3.2^{ab}$ | $5.1^{a}$ | $4.2^{ab}$ | $2.3^{bc}$ | $1.9^{c}$ | $1.9^{c}$ | 1.4 |
| 2 | 5 | 46-51 | $3.3^{b}$ | $2.1^{b}$ | $7.9^{a}$ | $2.8^{b}$ | $1.2^{b}$ | $2.1^{b}$ | 1.2 |
| 2 | 6 | 52-54 | $4.0^{a}$ | $3.0^{a}$ | $5.0^{a}$ | $6.2^{a}$ | $3.0^{a}$ | $3.2^{a}$ | 2.0 |
| | | Mean | 4.6 | 4.0 | 5.8 | 4.2 | 2.5 | 2.5 | |

Table 3:20

Effect of different treatments on egg mass, feed conversion per dozen and per kilogram eggs and energy conversion from 22.54 weeks of age.

| Treatment | Egg mass g/d | Feed conversion kg feed 1 doz. eggs | Feed conversion kg feed/kg eggs | Energy conversion MJ ME/kg eggs |
|---|---|---|---|---|
| L | 30.17 | 4.40 | 5.60 | 56.31 |
| M | 31.14 | 4.01 | 5.16 | 63.00 |
| H | 28.81 | 3.92 | 5.10 | 67.66 |
| R | 34.03 | 3.40 | 4.38 | 52.06 |
| LH | 29.72 | 4.17 | 5.37 | 71.25 |
| HL | 30.90 | 3.96 | 5.14 | 51.70 |
| MR | 28.39 | 4.24 | 5.53 | 65.70 |
| RL | 34.45 | 3.58 | 4.54 | 45.65 |
| RM | 35.46 | 3.35 | 4.30 | 52.47 |
| RH | 34.24 | 3.40 | 4.31 | 57.21 |

Fig. 3:12 Hen-day egg production for *ad libitum* and regulated treatments during the laying period

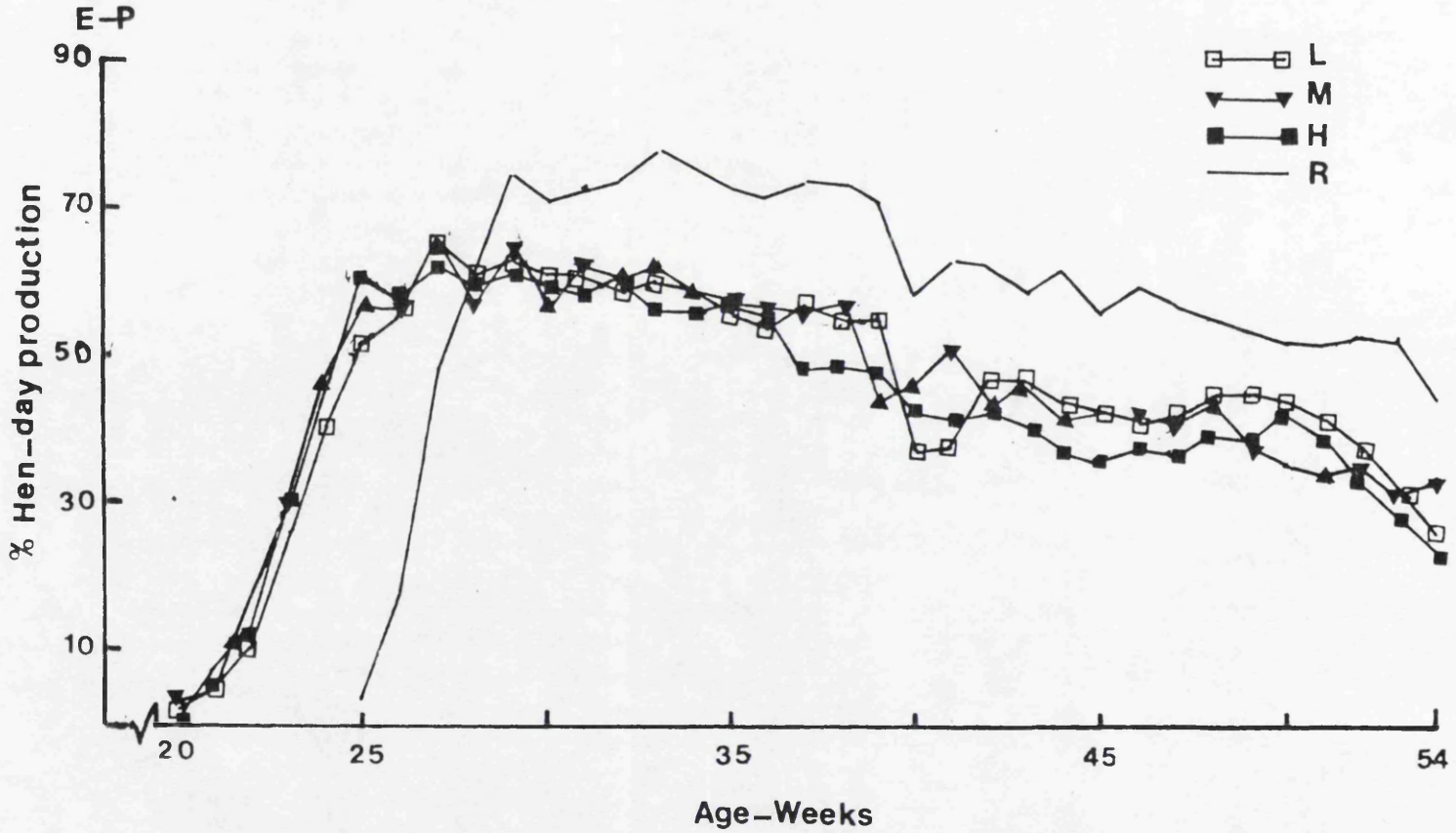


Fig. 3:13 Hen-day production and non-hatching eggs for hens on low energy feed and hens changed to high energy feed at 35 weeks of age

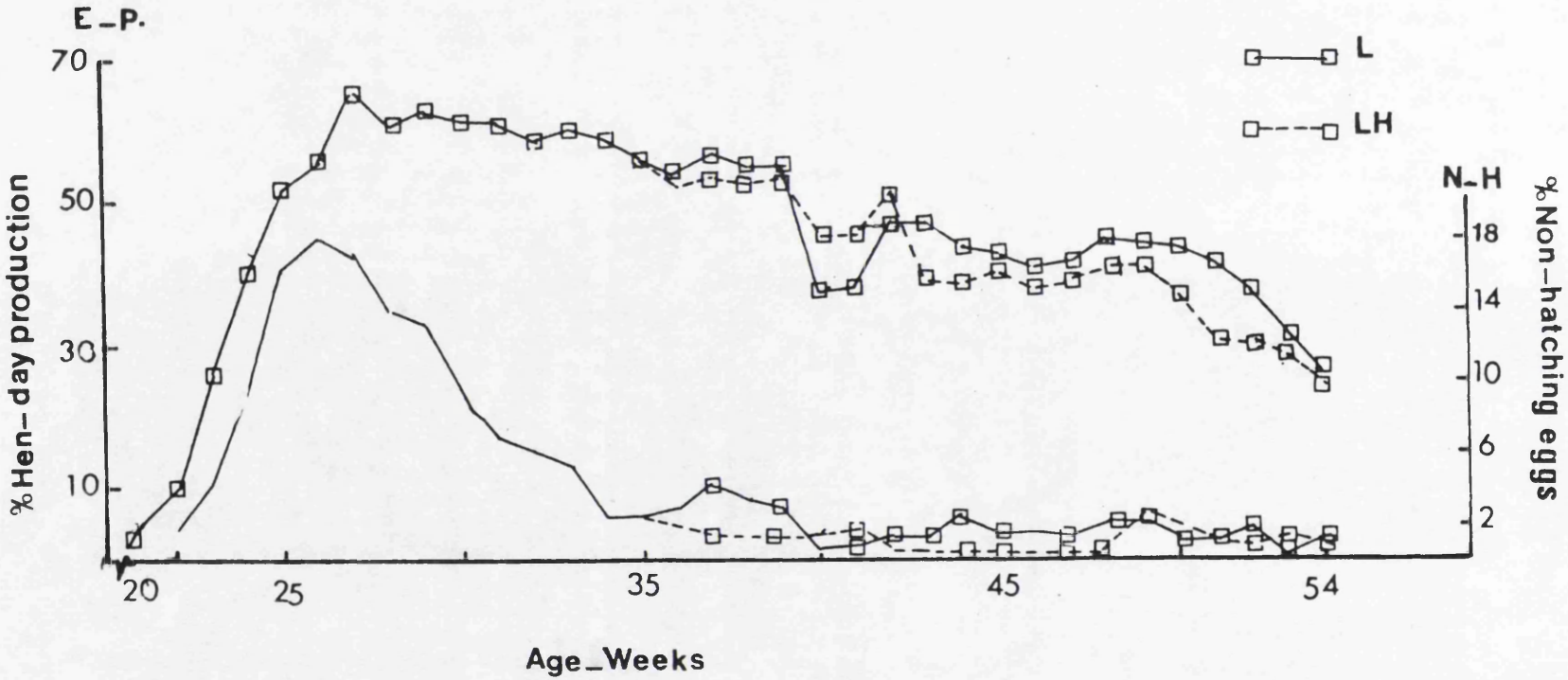


Fig. 3:14 Hen-day production and non-hatching eggs for hens on medium energy feed and hens changed to regulated feeding at 35 weeks of age

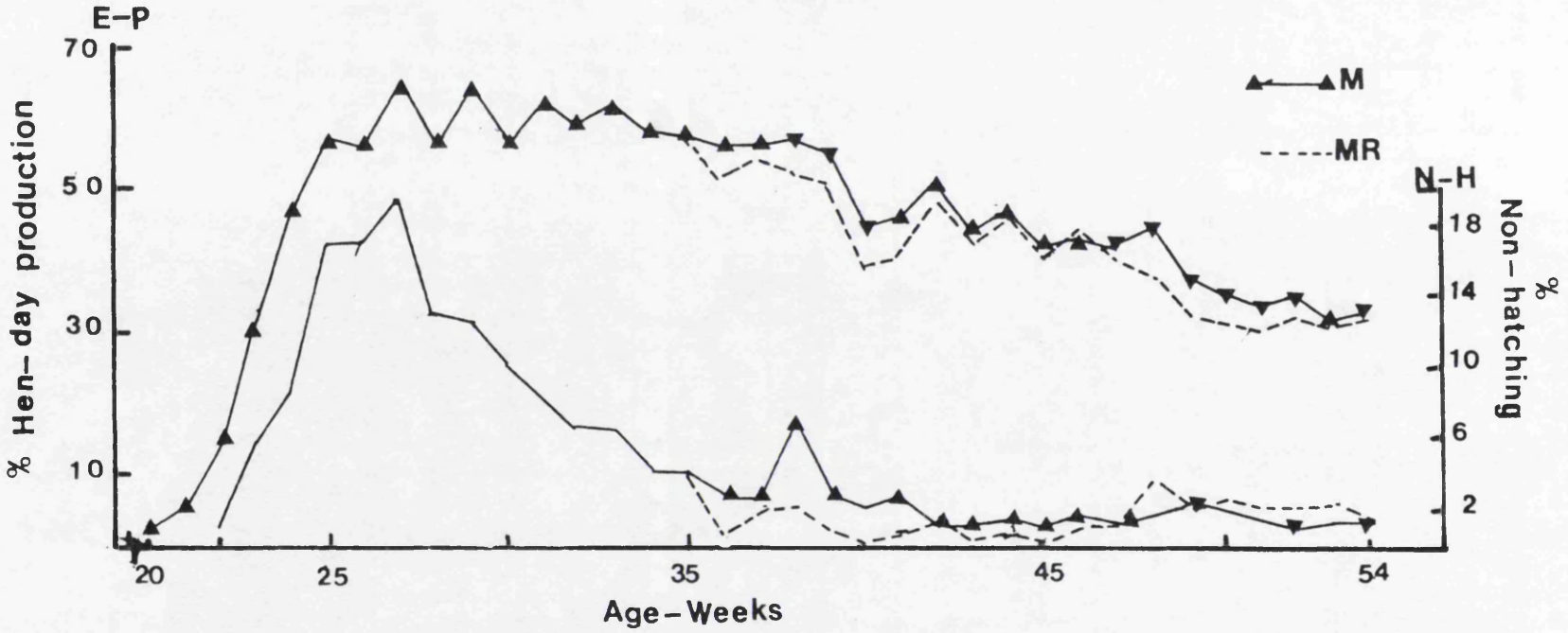


Fig. 3:15 Hen-day production and non hatching eggs for hens on high energy feed and hens changed to low energy feed at 35 weeks of age

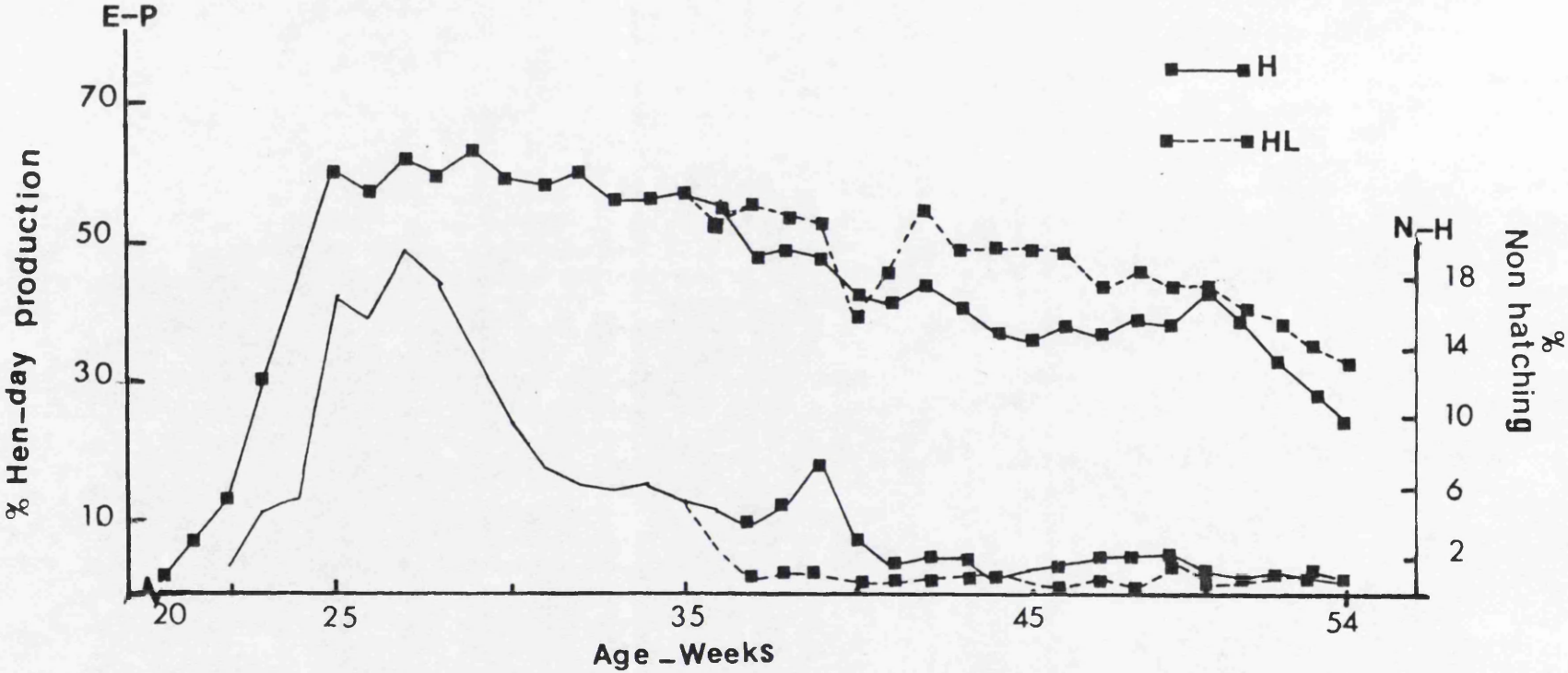
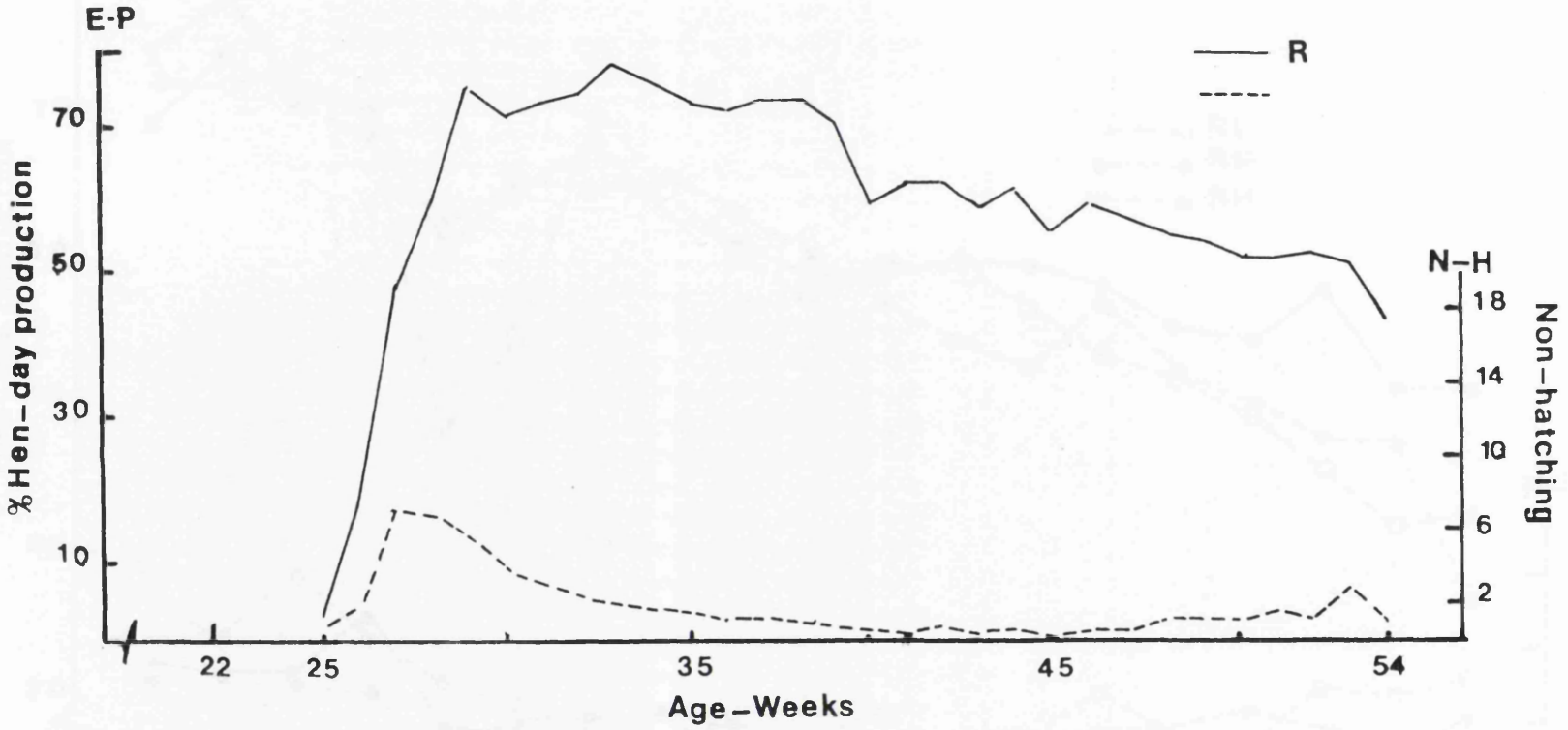


Fig. 3:16 Hen-day production and non hatching eggs for regulated hens during the laying period



over the whole laying period, hens on R feeding and those previously on R ( and changed to ad libitum feeding) consumed less feed per dozen eggs. Also hens on feed H consumed less feed than those on L and M per dozen eggs. Hens on ad libitum feeding for all treatments consumed more feed to produce one kilogram eggs. This was nearly one kilogram more than those on R or those previously fed R.

5. Egg Weight

Every two weeks, egg weight for the whole experiment for hens on feeds L, M, H and R feeding are plotted against age in Fig. 3:18. Bi-weekly results are presented in Appendix 3:1, 3:2, 3:3 and 3:4. These results are summarized and given in Table 3:23.
The analysis of variance was done for all periods. At the beginning of lay, there was not enough eggs for weighing and not enough for statistical analysis. These data were first recorded at 22 and 25 weeks for hens on ad libitum and regulated feeding, respectively.
In the first period (22-29 weeks), there was a significant difference ($P<0.05$) in egg weight between hens on ad libitum and those on R feeding but there was no significant difference between hens on ad libitum feeding. In the second period, there was no significant difference between all treatments. It is apparent that eggs laid by hens on R reached a similar size to those on ad libitum within a short time. The mean egg weight was approximately 62 g/egg for all groups.

During the first phase (22-35 weeks of age) the mean egg weight was about 59.5 g/egg for hens on L, M, H and R feeding. This is given in Table 3:21. In the third period, there was a significant difference in egg weight between hens on M and regulated fed hens. It was not until the fifth period that egg weight from hens on ad libitum feeding were heavier than those on regulated feeding. In the

Table 3:21

Effect of feeding treatments on the egg weight (g/egg) and daily egg mass (g/b) during phase 1.

| Treatment | Egg wt. | Egg mass |
|---|---|---|
| L | $59.8^{a}$ | $31.8^{a}$ |
| M | $59.6^{a}$ | $32.2^{a}$ |
| H | $59.6^{a}$ | $32.0^{a}$ |
| R | $59.6^{a}$ | $29.8^{b}$ |
| SED | 0.55 | 0.74 |

Table 3:22

Effect of feeding treatments on egg weight (g/egg) and daily egg mass (g/b) during phase 2.

| Treatment | Egg wt. | Egg mass |
|---|---|---|
| L | $70.6^{a}$ | $30.9^{b}$ |
| M | $70.0^{ab}$ | $31.7^{b}$ |
| H | $68.9^{bc}$ | $28.1^{b}$ |
| R | $67.8^{c}$ | $40.9^{a}$ |
| LH | $70.2^{ab}$ | $29.0^{b}$ |
| HL | $69.2^{abc}$ | $31.7^{b}$ |
| MR | $68.4^{bc}$ | $28.0^{b}$ |
| RL | $68.5^{bc}$ | $40.9^{a}$ |
| RM | $69.0^{ab}$ | $42.9^{a}$ |
| RH | $69.4^{bc}$ | $39.8^{a}$ |
| SED | 0.8 | 2.0 |

$^{a,b,c}$Means for each a column within each treatment that possess different superscripts differ significantly ($p < 0.05$).

Table 3:23

Effect of feeding treatments on egg weight (g/egg) throughout the two phases.

| Phase | Period | Weeks | Treatments L | M | H | R | SED |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 22-29 | $57.2^{a}$ | $56.9^{a}$ | $57.6^{a}$ | $55.2^{b}$ | 0.6 |
| 1 | 2 | 30-35 | $62.3^{a}$ | $62.3^{a}$ | $61.6^{a}$ | $61.5^{a}$ | 1.2 |
| 2 | 3 | 36-41 | $68.0^{ab}$ | $68.3^{a}$ | $66.1^{b}$ | $66.1^{b}$ | 1.1 |
| 2 | 4 | 42-45 | $72.4^{a}$ | $70.2^{ab}$ | $68.7^{b}$ | $67.5^{b}$ | 1.5 |
| 2 | 5 | 46-51 | $71.2^{a}$ | $70.6^{a}$ | $70.6^{a}$ | $68.5^{b}$ | 1.0 |
| 2 | 6 | 52-54 | $72.1^{a}$ | $72.2^{a}$ | $71.6^{a}$ | $70.4^{a}$ | 1.2 |
| Mean during the whole period | | | 66.4 | 66.0 | 65.3 | 64.2 | |
| During the second phase | | | 70.6 | 70.0 | 68.9 | 67.8 | |

Table 3:24

Effect of feeding treatments on egg weight (g/egg) throughout the second period.

| Phase | Period | Weeks | Treatments LH | HL | MR | RL | RM | RH | SED |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 3 | 36-41 | $67.4^{a}$ | $66.0^{a}$ | $66.5^{a}$ | $66.0^{a}$ | $65.8^{a}$ | $66.6^{a}$ | 1.1 |
| 2 | 4 | 42-45 | $70.7^{a}$ | $69.0^{a}$ | $68.8^{a}$ | $68.5^{a}$ | $68.0^{a}$ | $68.9^{a}$ | 1.5 |
| 2 | 5 | 46-51 | $72.2^{a}$ | $71.1^{ab}$ | $69.3^{b}$ | $70.0^{b}$ | $70.6^{ab}$ | $71.1^{ab}$ | 1.0 |
| 2 | 6 | 52-54 | $71.2^{ab}$ | $70.9^{ab}$ | $69.9^{b}$ | $70.3^{ab}$ | $71.6^{ab}$ | $72.3^{a}$ | 1.2 |
| | | Mean | 70.2 | 69.2 | 68.4 | 68.5 | 69.0 | 69.4 | |

$^{a,b}$Means within period with different superscripts are significantly different ($p < 0.05$).

Fig. 3:18 Mean egg weight for all *ad libitum* groups and regulated group during the laying period

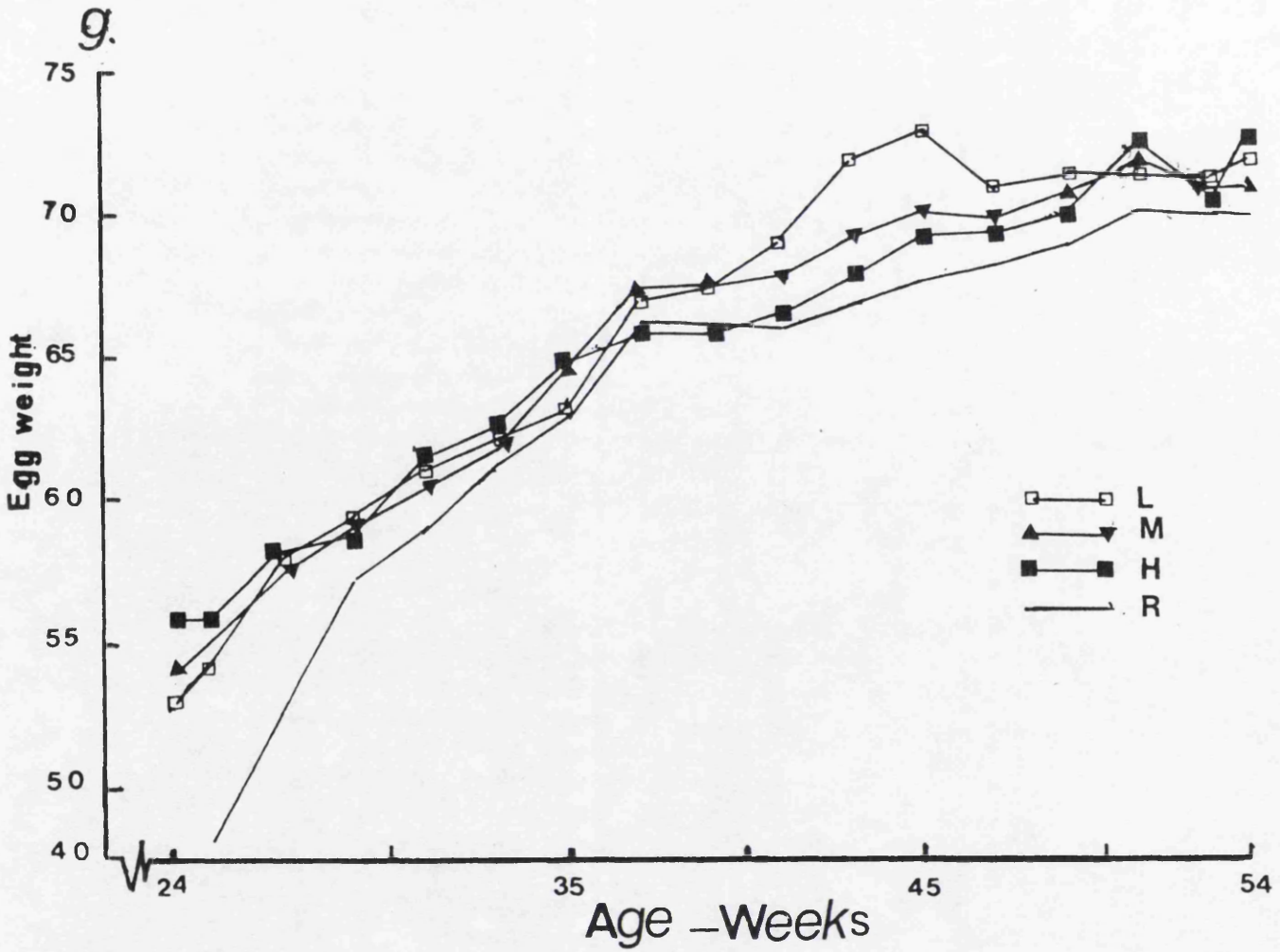


Fig.3:19 Effect of changing the diets on egg weight of hens previously fed *ad libitum*

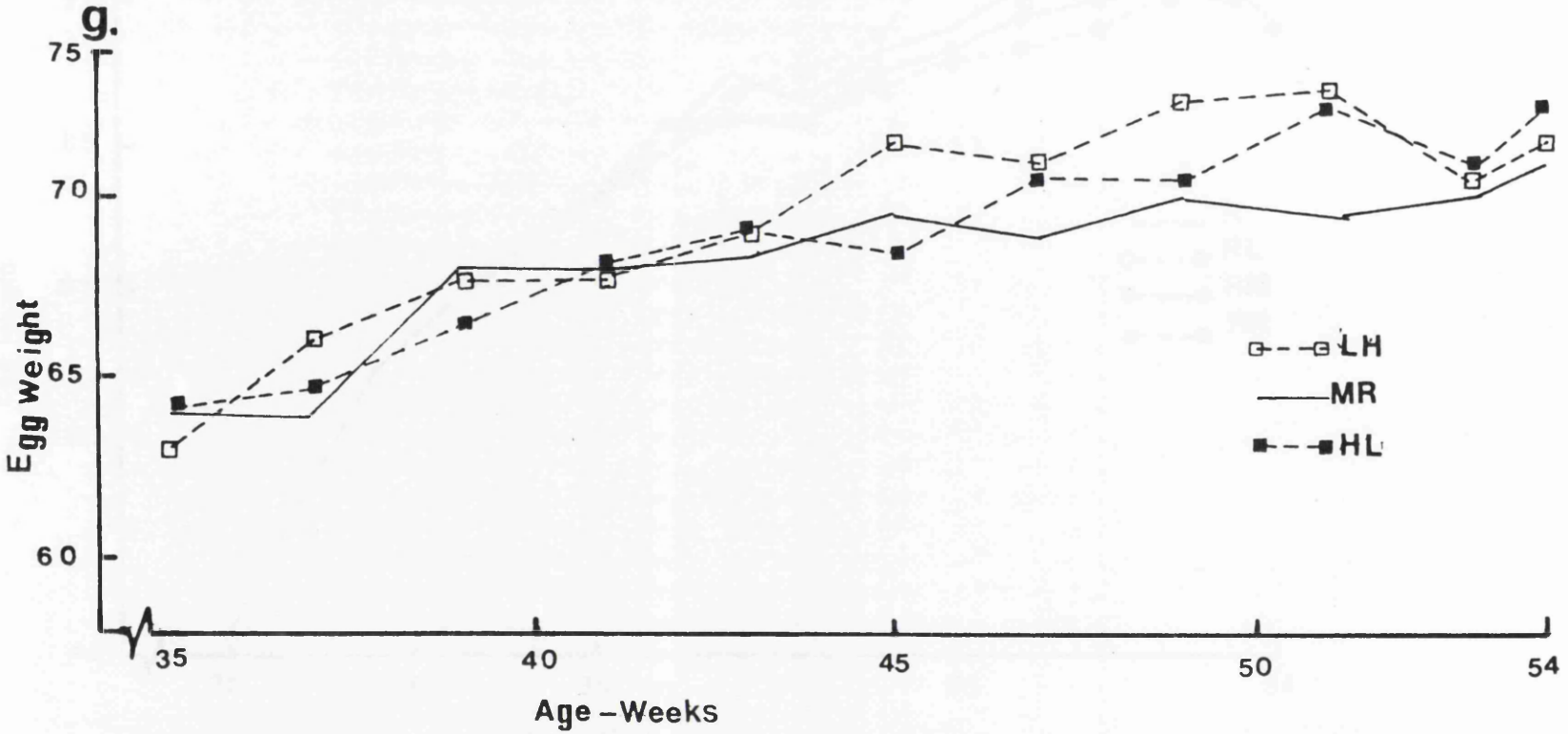
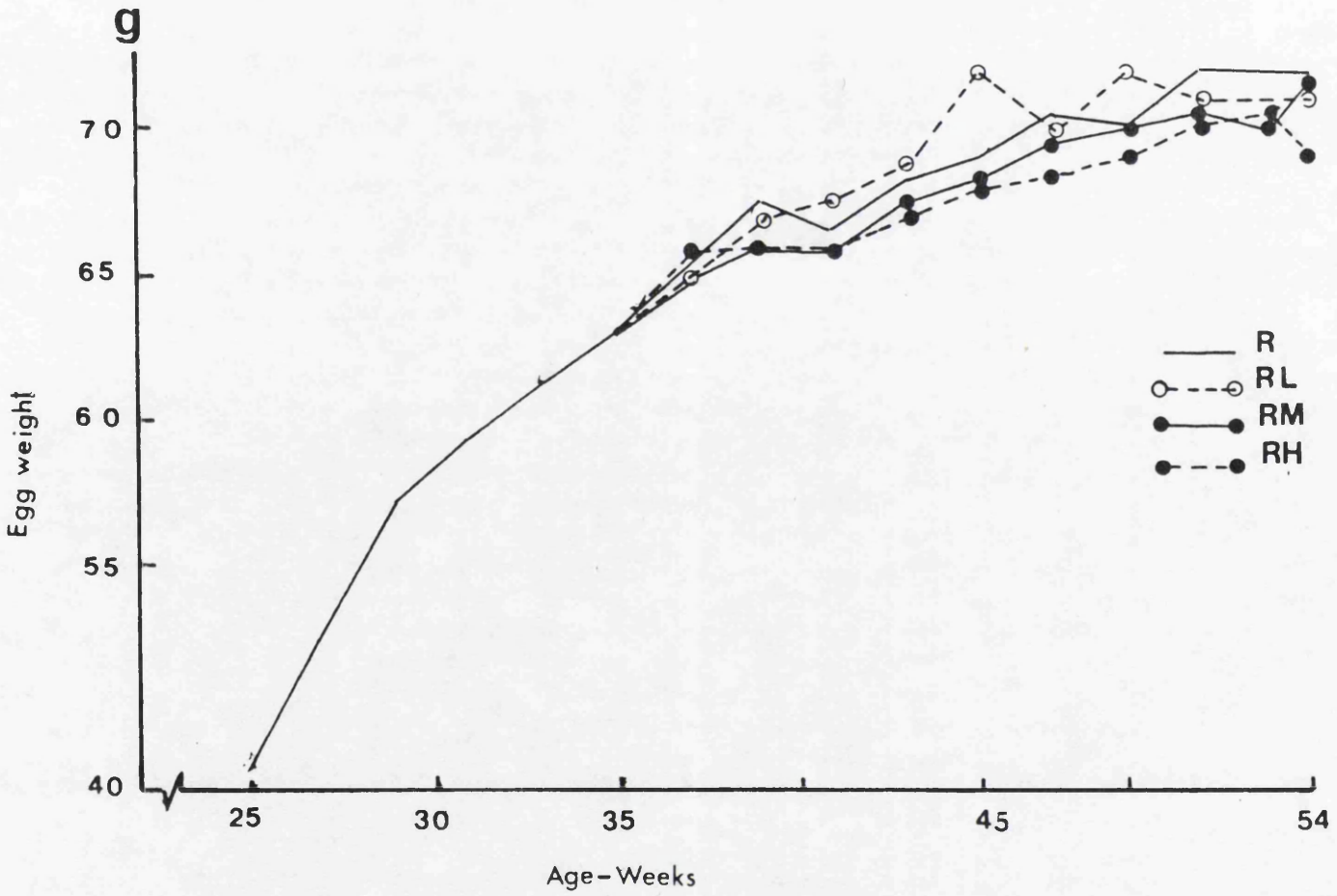


Fig. 3:20 Effect of regulated feeding on egg weight during the two phases and their response to *ad libitum* feeding after 35 weeks of age



last period, there was no significant difference in egg weight between hens on ad libitum and those on R feeding. During the 36 to 54 weeks, the difference between ad libitum treatments were small, however the differences between ad libitum and regulated treatments still existed (Table 3:22).

a) Egg weight of ad libitum and regulated hens: response to changes.

The egg weight data throughout the second phase for all treatments after the changes of feeding systems and feeds are given in Table 3:24. Also these data are shown in Fig. 3:19 and 3:20. The analysis of variance was carried out for all periods. During phase 2 there were no significant differences in egg weight between hens on LH and RH, HL and RL, and, MR and RM. The difference in egg weight for hens on LH, RH, HL, RL, MR and RM between the beginning and at the end of this phase was 3.8, 5.7, 4.9, 5.2, 3.4 and 4.8 g/egg respectively. Hens previously on R feeding showed a greater increase in egg weight (Table 3:24).

6. Egg mass

The analysis of variance for egg mass data for hens fed continuously feeds L, M, H and R feeding throughout the two phases were done and given in Table 3:25.

These results show that the hens on ad libitum feeding produced significantly more egg mass ($p < 0.05$) than those given regulated feeding during phase 1. Egg mass increased substantially until the hens reached their peak egg production at 30 to 35 weeks of age and then decreased gradually as egg production decreased. The highest egg mass was produced in the second period; it was 37, 37, 36 and 45g/d for hens on L, M, H and R feeding, respectively. During phase 1

Table 3:25

Effect of feeding treatments on daily egg mass (g/b) throughout the two phases.

| Phase | Period | Weeks | Treatments L | M | H | R | SED |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 22-29 | $26.6^{a}$ | $27.4^{a}$ | $28.1^{a}$ | $14.1^{b}$ | 0.8 |
| 1 | 2 | 30-35 | $37.0^{b}$ | $36.9^{b}$ | $35.8^{b}$ | $45.4^{a}$ | 0.9 |
| 2 | 3 | 36-41 | $33.8^{bc}$ | $36.2^{b}$ | $31.6^{c}$ | $45.4^{a}$ | 2.2 |
| 2 | 4 | 42-45 | $32.9^{b}$ | $32.7^{b}$ | $28.0^{b}$ | $40.2^{a}$ | 2.8 |
| 2 | 5 | 46-51 | $30.3^{b}$ | $29.7^{b}$ | $28.3^{b}$ | $38.8^{a}$ | 2.9 |
| 2 | 6 | 52-54 | $23.8^{b}$ | $25.3^{b}$ | $21.1^{b}$ | $36.9^{a}$ | 3.0 |
| During the second phase | | | 30.9 | 31.7 | 28.1 | 40.9 | |
| Mean during the whole laying period | | | 31.0 | 31.6 | 29.5 | 35.2 | |

Table 3:26

Effect of feeding treatments on daily egg mass (g/b) throughout the second phase.

| Phase | Period | Weeks | Treatments LH | HL | MR | RL | RM | RH | SED |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 3 | 36-41 | $35.1^{b}$ | $33.5^{b}$ | $32.4^{b}$ | $43.6^{a}$ | $46.6^{a}$ | $45.0^{a}$ | 2.2 |
| 2 | 4 | 42-45 | $29.8^{c}$ | $35.7^{b}$ | $31.7^{bc}$ | $45.2^{a}$ | $43.5^{a}$ | $44.6^{a}$ | 2.8 |
| 2 | 5 | 46-51 | $30.2^{bc}$ | $31.8^{b}$ | $25.8^{c}$ | $41.0^{a}$ | $42.0^{a}$ | $34.5^{b}$ | 2.9 |
| 2 | 6 | 52-54 | $20.7^{c}$ | $25.9^{c}$ | $22.3^{c}$ | $33.3^{b}$ | $39.8^{a}$ | $35.0^{ab}$ | 3.0 |
| | | Mean | 29.0 | 31.7 | 28.0 | 40.9 | 42.9 | 39.8 | |

$a,b_{M}$

$^{a,b}$Means within period with different superscripts are significantly different ($p < 0.05$).

the daily egg mass for all treatments are given in Table 3:25. These results indicate that hens on ad libitum feeding produced more egg mass than those on R feeding because these hens started laying four weeks later than those on ad libitum feeding. But the egg mass production by ad libitum hens was lower than those on R during the whole laying period (Table 3:25).

Egg mass of ad libitum and regulated hens: response to changes.

The egg mass data throughout the second phase for all treatments after the changes of feeding system and feeds are presented in Appendix 3:5, 3:6, 3:7, 3:8 3:9 and 3:10. Also these data are summarized and given in Table 3:26. The analysis of variance was done for all the periods.

Following the change, there were no significant differences between hens previously fed ad libitum (LH, HL and MR) and also between hens previously fed regulated and then changed to ad libitum in this phase (RL, RM and RH). But there were a significant differences ($p < 0.05$) between hens on LH and RH and between HL and RL, as well as MR and RM for all the periods except at fifth period between hens on LH and RH. During this phase, the differences in the daily egg mass for hens on LH was 10.8 g/d less than those on RH and also for hens on HL was 9.2 g/d less than those on RL and for hens on MR was 14.9 g/d less than those on RM.

7. Fertility and hatchability all eggs.

Fertility and hatchability all eggs were estimated by hatching a minimum of 25 eggs per plot at 4 different ages (30, 34, 40 and 50 weeks of age). The fertility and hatchability data for both groups of males (ad libitum and regulated) mated with hens on L, M, H and R and also for

those on floor on the same feeding system are given in Tables 3:27, 3:28, 3:29 and 3:30.

The analysis of variance was done for three hatches but it was not done for the fourth hatch because the number of eggs used was not large enough for statistical analysis.

Although differences existed between ad libitum and regulated hens (Table 3:27), the results show that feeding treatments had no significant effect on the fertility at any age.

Fertility results achieved from mating ad libitum males with hens on L, M, H and R, and also from mating regulated males with hens on the same feeds, showed that there was a significant difference in fertility between the hens on the same feed due to the male feeding treatment. The differences due to the male effect ranged 10 to 15 per cent. The fertility of birds on floor was higher than those on feed M in cages for the first two hatches (at 30 and 34 weeks) but not for the third hatch.

These results indicate that the A.I. technique was less successful than was hoped could be achieved. The insemination technique was reviewed and modified (O. Ravie, personal communication). The results of the third hatch indicated that fertility using A.I. was at a level similar to that achieved by natural mating. Consequently the results of first and second hatches can not be regarded with confidence. But the results of third hatch can be examined with confidence for the effect of male feeding, female feeding and mating.

There was a significant difference in fertility and hatchability for all eggs in the third hatch due to the effects of male feeding (Table 3:29 & 3:30). Generally the fertility and hatchability for all hens mated with ad libitum males in cages were higher than those on floor except those on feed H which was lower. While for hens mated with regulated males the levels of fertility and hatchability were lower than those on the floor

Table 3:27

Effect of feeding treatments on percentage fertility for all eggs at different ages.

| Age | Hatch no. | Treatments L | M | H | R |
|---|---|---|---|---|---|
| 30 | 1 | 73.5[a] | 72.8[a] | 70.7[a] | 80.0[a] |
| 34 | 2 | 76.2[a] | 76.2[a] | 77.5[a] | 81.8[a] |
| 40 | 3 | 85.6[a] | 86.7[a] | 81.6[a] | 84.7[a] |
| 50 | 4[1] | 78.0 | 79.9 | 77.2 | 82.4 |
| | Mean | 78.3 | 78.9 | 76.8 | 82.2 |

Table 3:28

Effect of feeding treatments on percentage hatchability for all eggs at different ages.

| Hatch no. | Treatments L | M | H | R |
|---|---|---|---|---|
| 1 | 68.0[ab] | 65.2[ab] | 63.0[b] | 74.9[a] |
| 2 | 70.5[a] | 71.3[a] | 67.4[a] | 76.3[a] |
| 3 | 79.0[a] | 78.3[a] | 77.7[a] | 78.5[a] |
| 4[1] | 57.7 | 65.3 | 55.9 | 62.2 |
| | 68.8 | 70.0 | 66 | 73.0 |

1 = ANOVA was not performed.

[a,b]Means within period with different superscripts are significantly different ($p < 0.05$).

Table 3:29

The effect of males feeding systems on percentage fertility of all eggs for both feeding systems on floor and in cages.

| Mated | Age/ weeks | Females L | M | H | R | on floor ad lib. hens |
|---|---|---|---|---|---|---|
| | 30 | $67.3^{b}$ | $64.1^{b}$ | $62.4^{b}$ | $77.9^{a}$ | 87.0 |
| Ad lib.male | 34 | $81.0^{a}$ | $83.5^{a}$ | $81.9^{a}$ | $84.8^{a}$ | 88.0 |
| | 40 | $82.7^{b}$ | $83.3^{b}$ | $73.0^{c}$ | $83.0^{b}$ | 77.0 |
| | | | | | | Regulated hens |
| | 30 | $79.2^{a}$ | $81.5^{a}$ | $79.0^{a}$ | $82.0^{a}$ | 93.0 |
| Reg. male | 34 | $70.3^{c}$ | $68.8^{c}$ | $73.1^{bc}$ | $78.7^{b}$ | 97.0 |
| | 40 | $88.5^{a}$ | $90.1^{a}$ | $90.2^{a}$ | $86.4^{ab}$ | 93.0 |

Table 3:30

The effect of males feeding systems on percentage hatchability of all eggs for both feeding systems on floor and in cages.

| Mated | Age/ weeks | Females L | M | H | R | on floor ad lib. hens |
|---|---|---|---|---|---|---|
| | 30 | $63.1^{c}$ | $59.0^{cd}$ | $56.1^{d}$ | $73.3^{ab}$ | 80.0 |
| Ad lib.male | 34 | $75.9^{ab}$ | $80.1^{a}$ | $68.7^{c}$ | $79.5^{a}$ | 76.0 |
| | 40 | $80.5^{b}$ | $76.6^{b}$ | $66.5^{c}$ | $76.4^{b}$ | 72.0 |
| | | | | | | Regulated hens |
| | 30 | $72.2^{ab}$ | $71.4^{ab}$ | $69.9^{b}$ | $76.5^{ab}$ | 89.0 |
| Reg. male | 34 | $64.1^{cd}$ | $62.4^{d}$ | $66.1^{cd}$ | $73.0^{bc}$ | 92.0 |
| | 40 | $77.6^{b}$ | $80.0^{b}$ | $88.9^{a}$ | $80.6^{b}$ | 88.0 |

$^{a,b,c,d}$Mean within period of mating with ad libitum and regulated males at the same age with different superscripts are significantly different ($p < 0.05$).

Table 3:30b

Effect of male feeding systems on percentage hatchability of fertile eggs for both feeding systems on floor and in cages.

| Mated | Age/ weeks | Females/Cages L | M | H | R | On floor ad libitum |
|---|---|---|---|---|---|---|
| Ad lib. Male | 30 | 93.7 | 92.0 | 89.9 | 94.1 | 92.0 |
| | 34 | 93.7 | 95.9 | 83.9 | 93.8 | 86.4 |
| | 40 | 97.3 | 92.0 | 91.1 | 92.0 | 93.5 |
| | | | | | | Regulated hens |
| Reg. Male | 30 | 91.2 | 87.6 | 88.5 | 93.3 | 95.7 |
| | 34 | 91.2 | 90.7 | 90.4 | 92.8 | 94.8 |
| | 40 | 87.7 | 88.8 | 98.6 | 93.3 | 94.6 |

except hens on H which had a higher hatchability.

The main effect of ad libitum feeding of males was to depress ($p < 0.05$) the reproductive performance of all females. However examination of male feeding x female feeding interaction indicated that the effect was confined to ad libitum females and regulated females were unaffected by the males feeding system. Within the ad libitum females, the interaction results of a lower fertility in ad libitum females and higher hatchability of fertile eggs depressed with the combination of ad libitum males and females on H (Table 3:30b).

8. Mortality

Mortality results are presented in Table 3:31 and 3:32 for birds on L, M, H and R feeding throughout the first and second phase and also during the six periods of the experiment. Two analyses of variance was completed. These results showed there was no significant difference in percentage of mortality between all hens on L, M, H or R feeding during the first phase. It is apparent that the mortality was not influenced by either the feeding of different energy levels or feeding system. During the second phase, there was a significant difference in mortality between hens on H and those on L, M and R. The difference being 13.4, 8.3 and 11.6 per cent more than those on L, M and R respectively. Most of deaths on treatment H were during the third and sixth periods (Table 3:32).

Results for hens which had a change of feed or feed system showed there were no significant differences in mortality between all treatments during all periods except in the fourth period where mortality on LH was higher than others (Table 3:33). It seems reasonable therefore to suggest that dietary energy content had no real effect on the percentage of mortality, especially as most of the deaths from treatment LH occurred during 36 to 45 weeks of age. However these results show that the mortality of ad libitum fed hens changed to ad libitum or to regulated

Table 3:31

Effect of different treatments on the mortality of females during two phases.

| Treatment | Phase 1 22-35 % | Phase 2 36-54 % |
|---|---|---|
| L | 3.1[a] | 1.56[a] |
| M | 7.8[a] | 6.70[a] |
| H | 7.8[a] | 14.96[b] |
| R | 3.5[a] | 3.35[a] |
| LH | | 15.10[b] |
| HL | | 1.79[a] |
| MR | | 3.12[a] |
| RL | | 1.79[a] |
| RM | | 3.35[a] |
| RH | | 4.69[a] |
| SED | 2.7 | 4.1 |

[a,b]Means for each a column within each treatment that possess different superscripts differ significantly ($p < 0.05$).

Table 3:32

Effect of different treatments on percentage mortality of hens throughout different periods.

| Phase | Period | Weeks | Treatments L | M | H | R | SED |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 22-29 | 2.34[a] | 4.69[a] | 3.91[a] | 1.95[a] | 2.9[1]-2.5[2] |
| 1 | 2 | 30-35 | 0.78[a] | 3.24[a] | 3.91[a] | 1.56[a] | 1.8-1.5 |
| 2 | 3 | 36-41 | 1.56[a] | 3.35[a] | 4.69[a] | 1.56[a] | 2.4 |
| 2 | 4 | 42-45 | 0.00 | 2.08[a] | 1.79[a] | 0.00 | 2.2 |
| 2 | 5 | 46-51 | 0.00 | 1.56[a] | 1.79[a] | 1.79[a] | 1.9 |
| 2 | 6 | 52-54 | 0.00 | 0.00 | 7.44 | 0.00 | 1.9 |

1 - Standard error difference for minimum replicates (L, M, H)

2 - Standard error difference for maximum and minimum replicates (R and other groups.

Table 3:33

Effect of different treatments on percentage mortality of hens at different periods.

| Phase | Period | Weeks | Treatments LH | HL | MR | RL | RM | RH | SED |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 3 | 36-41 | 5.21[a] | 0.00 | 1.56[a] | 0.00 | 0.00 | 1.56[a] | 2.4 |
| 2 | 4 | 42-45 | 7.19[a] | 1.79[b] | 0.00 | 1.79[b] | 0.00 | 1.56[b] | 2.2 |
| 2 | 5 | 46-51 | 1.79[a] | 0.00 | 0.00 | 0.00 | 3.35[a] | 0.00 | 1.9 |
| 2 | 6 | 52-54 | 1.79[a] | 0.00 | 1.79[a] | 0.00 | 0.00 | 1.56[a] | 1.9 |

[a,b]Means within period with different superscripts are significantly different ($p < 0.05$).

feeding was higher than those on regulated feeding changed to ad libitum.

9. Males in Cages

a. Feed Intake

Results for feed intake are given in Appendix 3:11 for males on A feeding and on R throughout the period 22 to 54 weeks of age. Also the feed intakes for both groups are plotted in Fig. 3:21. Feed intake of the R males followed that of the R females in terms of the daily allowance. The mean daily feed intake was 168 g/b and 151 g/b for males on A and R feeding respectively during 22 to 35 weeks while throughout 35 to 54 weeks it was 166 g/b and 159 g/b respectively. Thus in Phase 2 the feed intake of ad libitum males was similar to the allowance given to the R males. There was no significant difference in mean daily feed intake for this period. The average nutrient intakes during Phase 1 and Phase 2 are given in Table 3:34.

b. Body Weight of Males

The body weight data on ad libitum and regulated feeding for phases 1 and 2 are given in Table 3:35. Also the body weights for both groups are plotted in Fig. 3:22. The average body weight of ad libitum males was about double that of those on regulated feeding at 22 weeks of age. Throughout this period the body weight on R feeding was increased gradually and the difference between both groups was gradually reduced. At 35 weeks the difference was 1.638kg, and at 54 weeks of age it was just over 800g.

Males on A feeding had body weight gains of about 4 g/d while those given regulated amounts of feed had gains of 13.5 g/d during 22 to 35 weeks of age.

Body weights for both groups were significantly different until

45 weeks, thereafter they were not significantly different. Ad libitum males had weight gains of 3.6 g/d, while those on regulated feeding was 5.1 g/d during the whole period (22 to 54 weeks) (Table 3:36).

c. Mortality

During the whole period mortalities for ad libitum males were higher than those on R. It was 35.7 and 7.1 per cent (or 9 and 2 males) on A and R feeding respectively. Deaths during 33 to 35 weeks were higher for ad libitum males, they were mainly due to fatty liver or tunours in the liver.

Table 3:34

Daily feed, ME, protein, calcium and phosphorus intakes for males in cages at 22 to 54 weeks of age.

| Feeding system | Feed intake g/b | ME kJ/b | Protein g/b | Ca g/b | p g/b |
|---|---|---|---|---|---|
| Ad lib. | 171.2[a] | 2090[a] | 24.3[a] | 7.03[a] | 1.249[a] |
| Reg. | 151.4[a] | 1848[a] | 21.5[a] | 6.22[a] | 1.105[a] |
| Difference | 19.8 | 242 | 2.8 | 0.81 | 0.144 |

Table 3:35

Body weight (kg.) of males on different feeding systems in cages at 22 to 54 weeks of age.

| Feeding system | Age/weeks 22 | 25 | 30 | 35 | 38 | 41 | 45 | 50 | 54 |
|---|---|---|---|---|---|---|---|---|---|
| Ad lib. | 5.175[a] | 5.182[a] | 5.160[a] | 5.573[a] | 5.190[a] | 5.570[a] | 5.460[a] | 5.520[a] | 5.620[a] |
| Reg. | 2.609[b] | 2.850[b] | 3.387[b] | 3.935[b] | 4.330[b] | 4.480[b] | 4.490[a] | 4.650[a] | 4.790[a] |
| Difference | 2.566 | 2.332 | 1.773 | 1.638 | 0.860 | 1.090 | 0.970 | 0.870 | 0.830 |

[a,b]Means within a column with different superscripts are significantly different ($p < 0.05$)

Table 3:36

Body weight gain and mortality of ad libitum and regulated males throughout the laying period.

| Feeding system | Weight gain g/b | Mortality % |
|---|---|---|
| Ad lib. | 3.6 | 35.7 |
| Reg. | 5.1 | 7.1 |
| Difference | 1.5 | 28.6 |

Fig. 3:21 Mean daily feed intake (g/b) of *ad libitum* and regulated males from 22 to 54 weeks of age

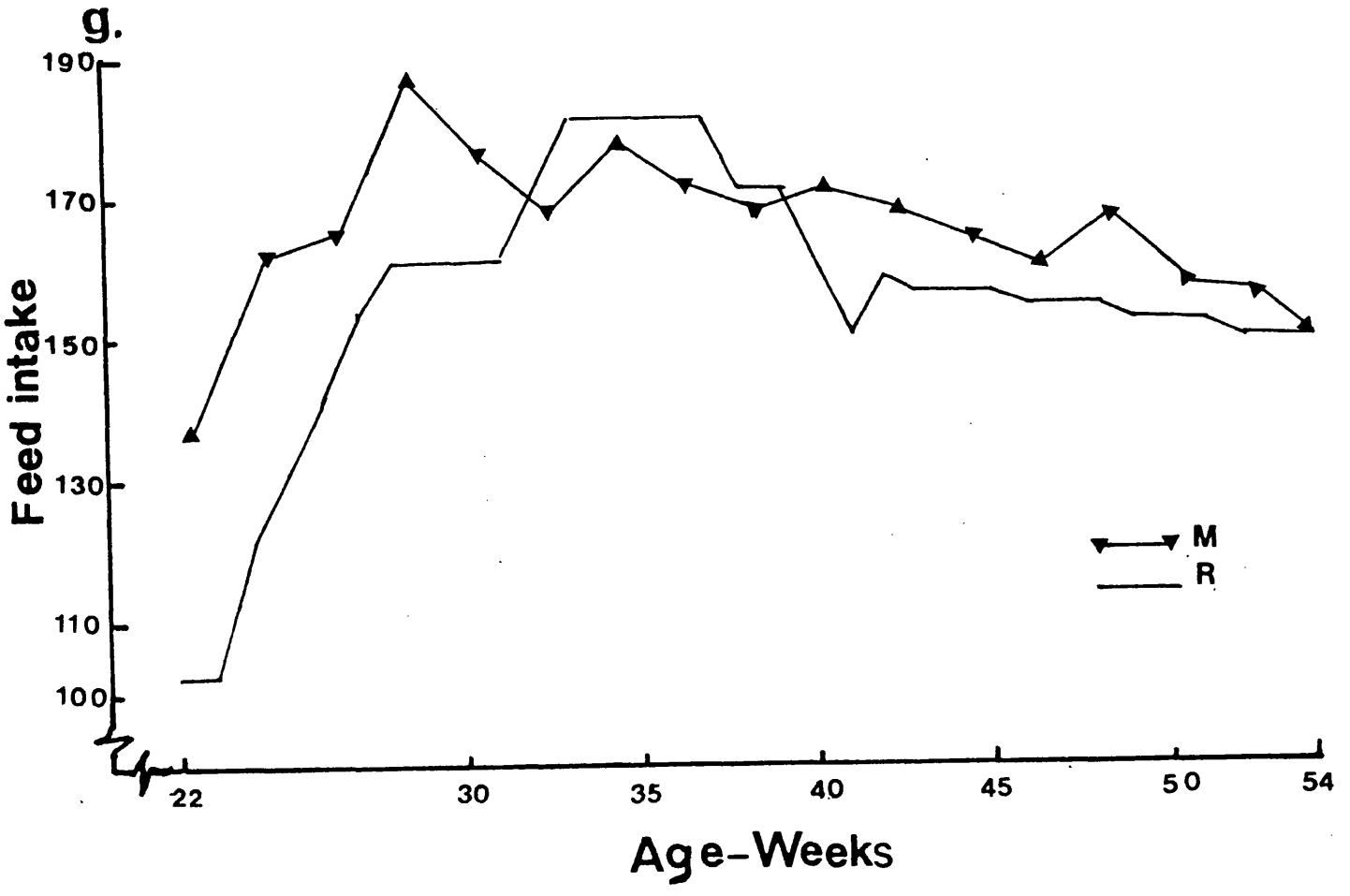
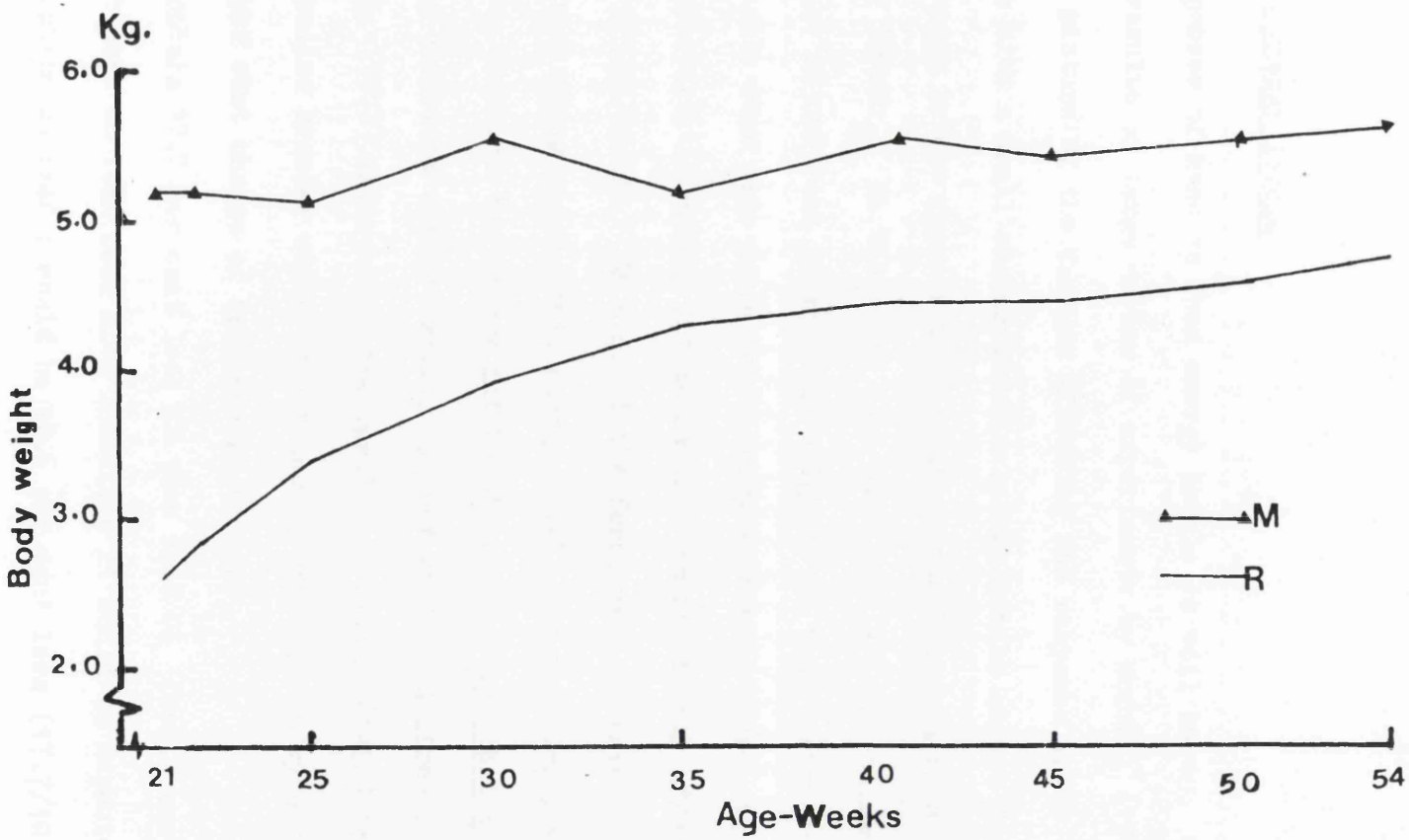


Fig. 3:22 Body weight of *ad libitum* and regulated males kept in cages from 21 to 54 weeks of age



## Discussion

There were two aims for this experiment. Firstly, to examine the responses of broiler breeders to different feed energy levels and to changes in feed energy levels during the laying period. Secondly, to examine the causes of the decline in reproductive fitness that were expected to be observed with natural mating and which have been described in Experiment 1.

### Responses to feed energy levels

The responses of hens to feed energy levels is well known. The analysis of the results of large number of experiments by Morris, (1968) enable a general picture of the factors affecting the response to be described. Hens with a small characteristic energy intake adjust feed intake so that energy intake remains relatively constant over a wide range feed energy levels. On the other hand hens with a large characteristic energy intake adjust feed intake only slightly so that energy intake changes substantially over wide range feed energy levels. Morris (1968), described the characteristic energy intake as that consumed when offered feed containing 11.3 MJ/kg ME. As none of the feeds used in this experiment contained approximately this energy level, the equation given by Morris (1968) to estimate the energy intake of hens fed ad libitum rations containing different energy levels, has not been used directly. However Gous et al. (1978) interpreted the results of Morris (1968) to indicate that a broiler breeder would adjust energy consumption by 6 per cent for each 10 per cent change of feed energy content.

Feed L contain 17.7 per cent less ME than feed M; feed H contains 8.7 per cent more ME than feed M. Therefore it would be expected that energy consumption on feed L would be 10.6 per cent less (17.7/10 x 6) than that on feed M, and, that energy consumption on feed H would be

5.2 per cent more ($8.6/10 \times 6$) than that on feed M.

The average daily ME intake during the laying period was 1960 kJ/b for hens offered feed M. The expected ME intake for hens offered feed L would therefore be 1752 kJ/b and for hens offered feed H would therefore be 2062 kJ/b. The actual ME consumption on feed L was 20 kJ/b less than expected and on feed H was 110 kJ/b less than expected (Fig. 3:24). Thus over the whole laying period the energy intake of hens on feed L was less than expected. It is possible that the volume of feed consumed was at the upper limit of hens digestive capacity.

Daily ME consumption for hens on H was 50 and 25 kJ/b higher than those on M for the first and second fortnights of the laying period respectively. In the third fortnight ME consumption on H and M was similar. Throughout the whole of phase 1, hens on H consumed 30 kJ/b more than those on M.

During the second phase hens on H consumed an average of 3.9 kJ/b less than those on M. It is possible that the higher mortality of hens on H may have contributed indirectly to the lower energy consumption for two reasons. Firstly, just prior to death the hens may have had a subdued appetite. Other hens may have been suffering from the diseases which caused the fatalities on H and these birds could be reasonably expected to also have had a subdued appetite. Secondly, those birds which died during phase 2 may have been among those which had a higher than average energy intake, and, as the post mortem results have shown the majority of causes of mortality were related to the consequences of obesity, therefore when the birds were removed from the groups the average ME consumption could be expected to decrease. A third reason for the differences may be due to experiment design whereby half of the hens on M and H became treatment MR and HL respectively.

It may be concluded from the evidence above that these hens

adjusted their feed intake better than was expected for birds of this type. Although Gous et al. (1978) assumed that broiler breeder hens increased energy intake by 6 per cent for each 10 per cent increase in energy content, the evidence obtained in this experiment does not support this assumption.

The mechanisms operating to control the feed intake may be related to the dietary energy content Smith and Baranowski-Kish (1979) have presented arguments supporting the hypothesis of Kennedy (1953) that animals adjust food intake in relation to the energy content of the diet, depot fat stores and energy expenditure. As the results of the body composition analysis in Experiment I have shown approximately ⅓ of the carcass weight of ad libitum females on M was fat.

A similar argument is adopted for birds transferred from regulated to ad libitum feeding. The average daily consumption in phase 2 for hens fed RM was 1990 kJ/b. The expected daily ME consumption for hens offered RL would be 1781 kJ/b; the actual consumption on RL was 61 kJ/b less than expected. The expected daily ME consumption for hens on RH would be 2094 kJ/b; the actual ME intake 44 kJ/b less than expected (Fig. 3:24).

The regulation of feed intake of these birds is consistent with the argument outlined above in that their adjustment was better than expected on feed H. In this respect during the six weeks of phase 2 the RH hens consumed less energy than those on RM. The energy intake of hens on L and RL was less than expected but the reason for this may be due to another factor controlling feed intake of these hens. The daily energy intake of hens on RL was 48 kJ/b greater than those on L in phase 2. The wide difference in energy intake between RL on one hand and RM and RH on the other hand (Fig. 3:24), suggests that the energy intake of RL hens was restricted by dietary volume. The same argument can be

applied to hens on L. The maximum daily volume consumption of hens on L was 340 ml while for RL hens it was 319 ml for periods 2 and 3 respectively. The birds on L could be expected to have a greater capacity to consume a greater volume of feed than those hens on RL, bearing in mind their feeding system during the rearing period. Hens transferred to LH from L consumed the highest amount of energy recorded during two weeks within laying period. Over the following 6 weeks consumption was reduced to a level similar to hens on H. This response supports the above argument that this strain of hens adjusts feed intake quite readily in response to changes in feed energy levels. The hens on H transferred to HL experienced a reduction in ME intake of about 30 per cent in the first four weeks and substantially recovered over the following weeks where consumption reached a level similar to hens on L. The average feed consumed by hens on L was slightly less than those on RL.

The results show that on the feeds used the volume capacity of broiler breeder hens is about 300 ml/day. Farjo (1981) demonstrated that the voluntary consumption of a feed similar to feed L by brown egg layers was between 250 and 270 ml/day during the later part of laying period, however when these birds were offered a feed of the same energy content as L, composed of a high energy feed and sawdust, the consumption rose to about 350 ml/day. From this observation it could be expected that broiler breeder hens could consume more than 300 ml/day.

Estimation of energy requirement

The energy requirements of ad libitum and regulated females were estimated using equations of Van Wambeke (1981) and Byerly et al. (1980) and which have been given in Chapter 2. The ME requirements were based on the data obtained during periods 2 and 5. The estimated requirements are compared with actual ME consumption in Table 3:37.

The difference between the estimated requirement and actual consumption expressed as percentage of actual consumption are shown in Fig. 3:23. As feed energy content increases the difference between actual consumption and the estimated requirement increased for ad libitum hens in period 2. The estimated requirement of hens on L was closer to the actual consumption (Table 3:37), indicating that the hens may have been limited by feed volume. If a small amount of wastage is accepted the 'True' energy consumption, as distinct from the 'Apparent' energy consumption, would have been closer to the requirement of hens on M and H and less than requirement for hens on L. This is still consistent with the hypothesis that feed volume had limited consumption on L.

In period 5 the same argument may be put forward for the data concerning feeds L, M and H. For feed H the change in position between period 2 and 5, relative to the other two feeds, is difficult to account for. But one reason might be related to the apparent depression of feed intake of hens on H during the latter part of phase 2 (period 4, 5 and 6). The possible causes of this depression have been discussed.

The two equations provided estimates which were in closer agreement for hens previously regulated (especially taking into account a small amount of wastage). This could be explained by an improvement in the utilization of ME by regulated birds. Standlee et al (1963) demonstrated that the efficiency of energy utilization was higher for birds on restricted feeding than those on ad libitum feeding on the same dietary energy content. Macleod and Shannon (1978) demonstrated that regulated birds had a higher gross utilization of ME. This was due to lower metabolic rate in regulated birds resulting in a lower maintenance requirement. Wenk and Van Es (1976) have indicated that animals on restricted feeding use a greater proportion of their maintenance requirements for activity.

Table 3:37

A comparison of estimated daily energy requirement and actual energy consumption. The equation of Byerly *et al.* 1980 and Van Wambeke (1981) were used to estimate the energy requirement.

| Treatment | Period | Byerly 1980 kJ/b | Van Wambeke 1981 kJ/b | Actual ME consumption kJ/b |
|---|---|---|---|---|
| L | 2 | 1808 | 1930 | 1905 |
| M | 2 | 1889 | 1954 | 2120 |
| H | 2 | 1884 | 1980 | 2170 |
| RL | 5 | 1650 | 1674 | 1780 |
| RM | 5 | 1945 | 1930 | 1988 |
| RH | 5 | 1924 | 1933 | 2012 |
| L | 5 | 1747 | 1884 | 1671 |
| M | 5 | 1810 | 1903 | 1979 |
| H | 5 | 1807 | 1966 | 1864 |

Fig.3 : 23 A comparison between actual ME consumption and estimated ME requirement for *ad libitum* (L, M and H) and regulated (RL, RM and RH) hens during the second and fifth period by using Byerly *et al* 1980(B) and Van Wambeke 1981(V) equations. The difference between the two values is expressed as a percentage + or - of the actual ME consumption.

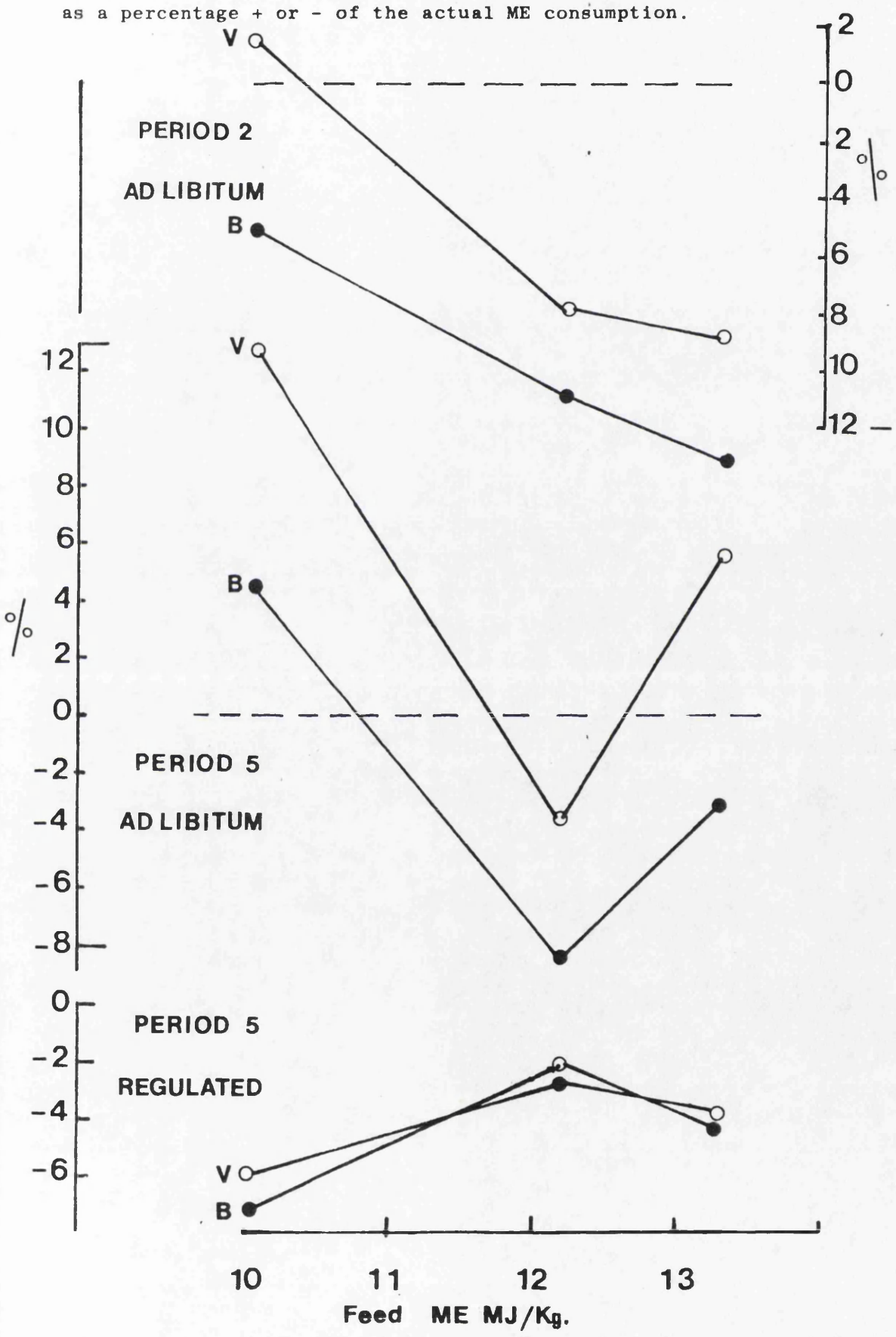
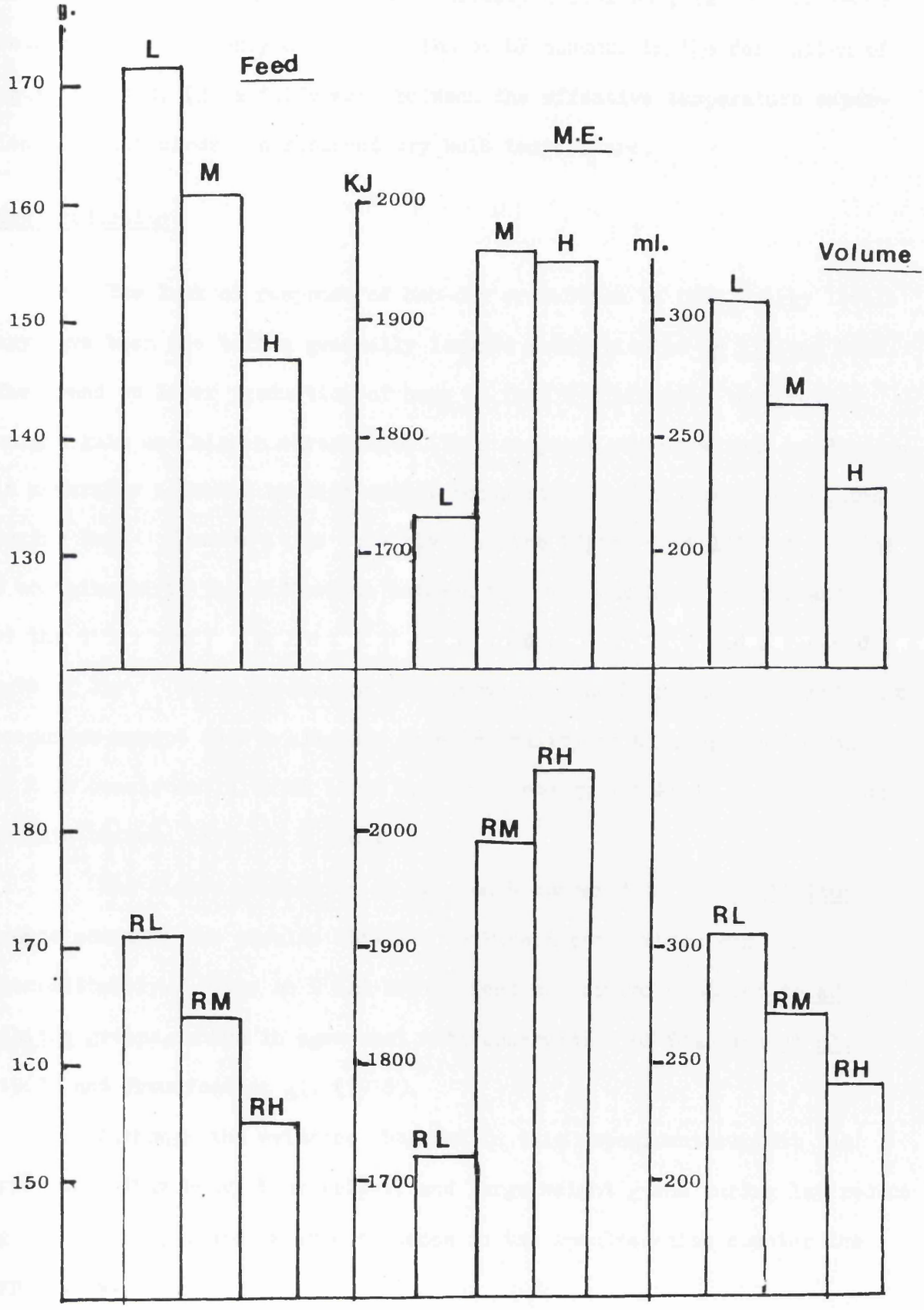


Fig. 3:24 Daily feed, energy and volume intake of treatments L, M and H from 22 to 54 weeks and for treatments RL, RM and RH from 35 to 54 weeks of age.



The difference between the relative value of L and RL is difficult to explain. Generally the comparison of estimated requirement and the actual consumption, and, the conclusion drawn, could be effected by three factors, (1) wastage of feed (already discussed), (2) a difference between the efficiency of utilization of ME assumed in the derivation of equation, and, (3) a difference between the effective temperature experience by the birds and recorded dry bulb temperature.

Egg production

The lack of response of hen-day production to feed energy levels may have been due to the generally lowered production of ad libitum hens. The trend to lower production of hens on feed H links with the greater weight gain and higher mortality. This supports the view that production is adversely affected by high energy consumption and higher weight gains during lay. However it is possible that the higher mortality of hens on H contributed to the difference between H on the one hand, and, L and M on the other hand; the hens just prior to death may have had a reduced rate of lay. The R feeding of hens previously on M produced inconsistent responses except that a slightly lower mortality on MR compared to that on M is consistent with MR birds having an energy intake in phase 2 intermediate between birds on M and L.

The higher production of hens on R compared to the ad libitum groups confirms the results obtained in Experiment I which was running concomittantly. Hens on R had better feed conversion compared to ad libitum groups, which in agreement with observation of Standlee et al. (1963) and Proudfoot et al. (1978).

Although the evidence obtained in this experiment support the hypothesis that heavy body weight, and large weight gains during lay reduce egg production, there is some evidence in the results which counter the hypothesis.

The performance of hens on HL in phase 2 was highest of the ad libitum group. Weight gains were lowest of all birds in phase 2 and mortality was similar to that of other hens on L. Thus the hens on HL were not predisposed to obesity related fatal diseases.

Hens on LH had the highest weight gain and also the highest mortality. Yet their production was not much less than those hens on L which had the lowest mortality in phase 2. The increased ME intake of hens transferred from R to RM and RH had little effect on mortality or hen-day egg production. However these hens had the highest weight gain but they were lighter at the end of phase 2 than ad libitum birds (Table 3:9). These observations are partly in agreement with the aforementioned hypothesis. Thus it seems that ad libitum fed birds are predisposed to fatal obesity related diseases, since mortality was increased on LH but not on RH. Although Pearson and Herron (1981) suggest that the optimum level of ME intake for maximum production is 1.7 MJ/b day, these results show that the higher levels of ME intake after 35 weeks of age are not detrimental to performance.

Egg Weight

The egg weights of ad libitum fed birds in phase 2 were heavier than those produced by R. This was not due to differences in energy or protein intake; hens on L consumed less energy and protein than those on R. Therefore the differences in egg weight could be attributed to differences in rate of production. There was some evidence of a response to nutrient intake by hens transferred to different feeds or feeding system in phase 2. This is in general agreement with Farjo (1981) and Pearson and Herron (1981).

Fertility and Hatchability

Generally fertility and hatchability for hens on the same feed with different feeding systems (M and R) was similar but within feeding systems performance was depressed by ad libitum fed males. Within ad libitum fed females the effect of the ad libitum fed male was most pronounced for hens on H. The above evidence indicates that the feeding systems of males was the main factor influencing fertility and hatchability in this experiment. But McDaniel et al (1979) have stated that the feeding system affected female performance.

Conclusion

1. Broiler breeder hens adjusted their energy intake in response to changes in feed energy levels much better than had been expected.
2. Hens on regulated feeding improved egg production to 54 weeks by about 19 per cent.
3. When hens on regulated feeding were changed to ad libitum feeding energy consumption increased on feeds M and H but rate of lay was not adversely affected.
4. Egg weights from regulated hens were approximately 2g less than those on ad libitum feeding.
5. The main effect of ad libitum feeding of males was to depress the reproductive performance of females on all treatments.
6. The mortality rate was not influenced by either the feeding system or feed energy levels or after the change of feeding at 35 weeks except those on H and LH which had a higher mortality.

General Discussion

1. Comparison of the performance of breeders on litter and in cages.

a) Growth Curve

The females and males differed in two respects in their growth characteristics. The females reached a breeding weight that was clearly different to mature body weight. Regulated females did not show any tendency to eventually catch-up to the ad libitum fed female. While the females exhibited a characteristic sigmoid growth curve, that of the males exhibited an unexpected truncation. The males in cages showed a similar growth pattern but the truncation was not so dramatic. The males in cages were 300 to 400g heavier than those on the floor at the end of the experiments. Although the body weight of males in cages was essentially stable after 35 weeks, it is difficult to conclude that this weight was the mature body weight in view of the sharp inflexion at 15 and 16 weeks.

Regulated males exhibited an ability to catch-up the growth deficit in direct contrast to the females. However this conclusion could be in error. The apparent ability of the males to catch-up could have been due to the ad libitum males being prevented in some way from reaching their true mature size. It could also have been due to the stimulation of protein growth by the males sex hormones; whereas continued growth of regulated females may have been hindered by competition of nutrients between egg production and growth.

b) Fertility

A comparison of fertility of birds in cages and on the floor is given in Table 1. Differences in fertility could be due to the following components:

Table 1

Representation of the main mating in the reproductive fitness of the broiler breeder and the factors influencing each mating at the third hatch.

| The mating Female x Male | Comparison No. | Rearing | % Fertility | Factors influencing the fertility |
|---|---|---|---|---|
| $A^1$ x $A^2$ | 1 | Floor | 77.0 | 16% depression |
| R x R | | Floor | 93.0 | mating + male + female |
| A x A | 2 | Cages | 83.3 | 3% depression due to |
| R x R | | Cages | 86.4 | male + female effect |
| A x A | 3 | Floor | 77.0 | 6% depression due to |
| A x A | | Cages | 83.3 | mating effect |
| A x R | 4 | Cages | 83.0 | 3% depression |
| R x R | | Cages | 86.4 | due to female |
| R x A | 5 | Cages | 90.1 | No depression due to |
| R x R | | Cages | 86.4 | male |
| A x A | 6 | Cages | 83.3 | No effect due to male |
| A x R | | Cages | 83.0 | |
| R x A | 7 | Cages | 90.1 | 7% depression due to |
| A x A | | Cages | 93.3 | females |

1 - female

2 - male

a. Female

1 - Storage and release of sperm

2 - Libido

b. Males

1 - Quality and quantity of sperm

2 - Libido

c. Females and males libido interaction.

The combination of these components produced a 16 per cent depression in fertility for birds on the floor.

The same mating in cages as on the floor produced a much smaller depression in fertility, indicating that the libido effect may be most important factor of those listed above. The reduction in fertility observed in the comparison 2 would be due to the effects of sperm production in the male and release in the females. However in comparison 4 the males sperm production effect is removed and yet a similar difference was observed as in comparison 2. This effect would indicate that there are differences between ad libitum and regulated females in their ability to store and release semen. The possibility of this effect has been suggested by Van Wambeke, (1981). Comparison 5, indicated that sperm from ad libitum males did not depress fertility of regulated females. This evidence is consistent with the effects shown in comparisons 2 and 4. Comparison 6 supports the evidence above that both types of males produced sperm of similar quality. Comparisons 5 and 7 show that the female semen effect produces a depression of about 3 to 7 per cent.

From these comparisons it may be concluded that the main factor affecting fertility are the libido and female semen effects. The conclusion in Chapter 3 was that the ad libitum males were responsible for the greater part of the depression of hatchability. But the above argument indicates that the sperm were very capable of fertilizing the ova. So this suggests that the embryos produced from ad libitum sperm were less viable than those from regulated sperm. If this suggestion was true then

the sperm from ad libitum fed males have abnormalities which effect embryo development yet the same abnormalities do not impair the fertilizing ability. Lamming (1969) noted in his review that obesity increased embryonic mortalities in pigs.

c) Egg production

Residence in cages did not impair the already depressed production of ad libitum fed females, yet for some unknown reason the performance of regulated females was depressed by residence in cages. Without access to litter the requirement for some vitamins and/or minerals may have higher and production in cages was less as result. The greater number of non-hatching eggs recorded in cages was probably due to a greater number of cracked eggs. This was observed but not recorded.

In phase 2 when hens were transferred to feed H (LH and RH) it is assumed that the extra energy intake was converted to fat. The gain in body fat in phase 2 of hens on LH and RH was about 0.5 and 1.0 kg respectively. The accumulation of fat did not effect the egg production of either LH or RH hens. The estimated amount of fat in hens on H was about 40 per cent off carcass weight. The large deposits of fat did not have a negative feedback on reproductive system to reduce rate of ovulation and hence egg production. This conclusion was in agreement with results of many workers studying over-consumption of energy by laying hens (e.g. DeGroote, 1972 ).

2. The growth and reproductive fitness

a) Growth

The current genetic gain in weight-for-age of the broiler has been predicted to continue for 10 to 20 years (Van den Eynden 1978,and

Ewart, 1981). Therefore the growth potential of parents will continue to increase and the difference between breeding weights and mature weights may be expected to continue to diverge. Provided the breeding weight of the birds does not change, the absolute amount of food required to reach breeding weight, assuming similar feeds are given, will not change. But because the mature body weight will be greater in future the amount of feed required to reach mature body weight will also be greater than the present. This means that we will observe that the amount of feed needed to reach breeding weight will become an increasingly smaller fraction of the amount consumed to obtain mature weight.

The problem associated with feed regulation of broiler breeders may be expected to continue for the foreseeable future. The stock may be expected to have a greater appetite and if this is correlated with aggression it may be more difficult to manage uniform body weights. Such birds may consume more water than at present and the problem of wet litter will continue and perhaps get worse.

b) Wet litter and feet problems

In a recent survey of feet problems in broiler breeder males (D. Wright, personal communication) one of the factors associated with an increase in the incidence and severity of feet problems was wet litter. The size of males is also considered to have an effect on the incidence of some foot problems.

In Experiment 1 the evidence supports the view that the condition of the litter has a greater effect on feet condition that does body size.

c) Regulation of energy intake

Interpretation of the results of energy intake of three feeds is difficult because ME content was not the sole variable; feed density and

ME density were also different in three feeds. In the previous discussion (Chapter 3), it was assumed that the density of L was such that the hens reached a maximum daily volume intake and the ME intake was less than expected. If this assumption is true then the regulation of energy intake of broiler breeders in this experiment must be assessed from the results obtained on feeds M and H. The hens showed an unexpected good ability to reduce feed intake in an inverse proportion to energy content. It was unexpected in view of the general relationship derived by Morris (1968), which means that it is possible to estimate the ability of a strain of hen to adjust energy intake as feed energy content is changed from the characteristic energy intake on a feed containing 11.3kJ/g. Hens with high characteristic intake increase their energy intake as feed energy content increases. Gous et al. (1978) interpreted the characteristic intake of the broiler breeder hen to mean that they would increase energy intake by 6 per cent for each 10 per cent change in feed energy content. The fact that hens on M and H consumed similar amounts of energy may be interpreted in two ways, 1) the broiler breeder hen should not be thought of as a large laying strain hen which obeys similar rules to other laying strain hens, 2) the sole use of feed energy content to interpret the results is an adequate one when so many other characteristics of the feed affect daily intake.

d) Body Composition

A comparison of composition between broiler breeders and laying hens are presented in Table 2. The body composition of regulated fed broiler breeder is similar to that of ad libitum fed laying hens. In respect of fat content it is of interest to note that the small Babcock B300 contained more carcass fat at similar age than the regulated fed Ross broiler breeder (if feathers had been included in the carcass mince the

Table 2

Chemical composition of hens: A comparison of the results of this experiment with other results, Lee et al. 1971, Blair et al. 1976, and Pearson et al. 1980.

| | Age/ weeks | Feeding system | Live weight | Carcass weight | Percentage | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Moisture | Fat | Protein | Ash |
| This experiment | 20 | ad lib.[1] | 3809.0 | 3500.0[4] | 50.7 | 27.4 | 17.2 | 3.9 |
| Lee et al. 1971 | 20 | ad lib.[1] | 3013.0 | 2868.0[4] | 54.5 | 25.0 | 17.3 | 3.3 |
| Farjo 1981 | 17 | ad lib.[2] | 1448.0 | 1314.0[4] | 66.2 | 10.2 | 18.7 | 3.7 |
| This experiment | 20 | Reg.[1] | 1702 | 1553[4] | 69.0 | 7.1 | 21.7 | 4.0 |
| Blair et al. 1976 | 22 | Reg.[1] | 2400.0 | 2221.0[4] | 64.7 | 11.1 | 20.5 | 3.8 |
| Pearson et al. 1980 | 22 | Reg.[1] | 2026.0 | 1445.0[4] | 65.7 | 10.8 | 19.4 | 3.6 |
| Pearson et al. 1981 | 21 | Reg.[1] | 1884.0 | 1755.0[4] | 67.2 | 7.9 | 20.6 | 4.5 |
| This experiment | 55 | ad lib.[1] | | 4708.0[4] | 48.2 | 33.4 | 15.5 | 3.7 |
| This experiment | 55 | Reg.[1] | 3200.0 | 2937.0[4] | 59.8 | 17.1 | 19.4 | 4.1 |
| Pearson et al. 1980 | 51 | Reg.[1] | 2808.0 | 1944.0[4] | 59.6 | 16.7 | 18.5 | 4.5 |
| McLeod and | 59 | ad lib.[2] | 2280.0 | - | 51.0 | 26.1 | 18.9 | 3.4 |
| Shannon, 1978 | 59 | ad lib.[3] | 1485 | - | 59.0 | 16.2 | 20.6 | 3.4 |
| Farjo, 1981 | 73 | ad lib.[2] | 2932 | 2732 | 48.5 | 34.3 | 14.2 | 3.0 |
| | 73 | ad lib.[2] | 2460 | 2301 | 55.0 | 24.9 | 15.9 | 3.8 |

1 - Broiler breeder hens

2 - Warren SSL laying hens

3 - Babcock B300

4 - Percentage composition is expressed on carcass weight.

fat content of the broiler breeder would have been lower than that of the Babcock B300). The accumulation of fat by broiler breeder hens is not greater than that of brown feathered laying hens at mature body weight. But it is possible that with ad libitum feeding broiler breeder hens deposit fat at a greater rate prior to sexual maturity than laying hens. The body composition data showed that at 20 weeks the ad libitum fed broiler breeder hens deposited 9 times more fat than their regulated fed counterparts. The conclusion may be drawn that the depression in egg production is connected with greater fat content prior to sexual maturity. This conclusion is in contradiction to the conclusion of Fuller (1977) that the beneficial effects of restricted feeding derived from increased age at sexual maturity rather than from the reduction of obesity. However because the effects of age at sexual maturity and obesity were not observed independently in the present experiment. Thus the effect of early sexual maturity of the ad libitum fed hens may have played some part in the depression of egg production. Finally it is concluded that the productivity of broiler breeder is primarily influenced by the body composition prior to sexual maturity and age at sexual maturity and changes in carcass fat content following sexual maturity have a very small effect on egg production of survivors, although fat accumulation increases mortality due to obesity related diseases. Therefore the adverse effect of over-consumption of energy is to reduce productivity through an increase in mortality and not through decreased egg production.

d) Breeding weight and reproductive fitness

The concept of breeding weight is generally applied to most types of farm livestock but the interpretation of breeding weight is different with each type. Of the farm animals the dairy heifer seems to

show a similar response to overfeeding as the broiler breeder hen. The overweight dairy heifer has a lower conception rate which may be related to steroid hormone balances. A young heifer has difficulty in calving especially if it is fat. Overfeeding produces an apparent deficiency in mammary gland development so that such heifers fail to lactate up to potential (Swanson, 1977). The broiler breeder is similar to the heifer in that overfeeding reduces reproductive fitness mainly through lower fertility (conception) and lower egg production (milk production).

As the broiler breeder's growth potential has increased with time the target body weights have remained relatively constant. For the Ross strain pullets hatched in 1980 the target body weight at 21 weeks recommended by the Company leads to a body weight at 35 weeks which is 25 per cent lighter than the body weights of pullets fed ad libitum from day old. The mature body weight of the broiler breeder may be defined as the weight achieved by the ad libitum fed pullet. Whereas the breeding weight may be defined as that weight reached at 35 weeks of age providing pullets achieved the target body weights at 21 weeks of age. The age of 35 weeks has been suggested because at that age carcass protein content is essentially stable. By keeping to the breeding weight the reproductive fitness of the broiler breeder is increased by about 60 per cent, with a saving in feed consumption of about 20 per cent.

It was suggested above that the main factor influencing reproductive fitness was the carcass fat content. If it was possible to grow a broiler breeder pullet to a higher target weight without an increase in carcass fat it may be possible to avoid the depression of reproductive fitness. This would mean feeding rations of a different nutrient content to those currently used, but it could also mean that larger daily feed allowances would be possible. Consequently the level of feed restriction

could be reduced and some of the problems associated with evenness of body weights and excess water consumption may be diminished.

# Appendix

## Appendix 2:1

The ME intake, food intake, egg weight, hen-day production, hen-housed production and non-hatching eggs, from 22 to 55 weeks with ad libitum feeding.

number of birds (144 females + 20 males) = 164

| Age weeks | Daily ME intake kJ/b | Daily food intake g/b | Egg weight g. | Hen day production % | Hen-housed production % | Non-hatching eggs % |
|---|---|---|---|---|---|---|
| 20-21 | 2113 | 169 | 48.0 | 2.1 | 2.1 | |
| 22-23 | 2161 | 177 | 51.0 | 15.0 | 15.0 | 2.3 |
| 24-25 | 2015 | 165 | 53.2 | 39.7 | 39.7 | 7.1 |
| 26-27 | 2185 | 179 | 57.8 | 48.0 | 46.7 | 14.5 |
| 28-29 | 2356 | 193 | 59.1 | 50.5 | 49.1 | 7.9 |
| 30-31 | 2405 | 197 | 61.0 | 52.7 | 50.0 | 5.0 |
| 32-33 | 2295 | 188 | 63.8 | 56.0 | 54.0 | 8.4 |
| 34-35 | 2210 | 181 | 65.3 | 57.6 | 55.2 | 6.7 |
| 36-37 | 2198 | 180 | 67.0 | 56.4 | 55.2 | 6.8 |
| 38-39 | 2198 | 180 | 68.4 | 51.8 | 49.1 | 6.4 |
| 40-41 | 2100 | 172 | 68.8 | 52.0 | 49.2 | 6.9 |
| 42-43 | 2051 | 168 | 70.0 | 46.5 | 44.0 | 5.1 |
| 44-45 | 2051 | 168 | 70.7 | 42.0 | 39.7 | 4.0 |
| 46-47 | 2051 | 168 | 70.9 | 39.3 | 36.8 | 2.8 |
| 48-49 | 2051 | 168 | 71.8 | 38.5 | 36.1 | 3.0 |
| 50-51 | 2051 | 168 | 72.5 | 36.6 | 34.0 | 2.2 |
| 52-53 | 2027 | 166 | 72.7 | 34.3 | 31.9 | 3.7 |
| 54-55 | 2014 | 165 | 72.4 | 32.1 | 29.8 | 2.2 |

## Appendix 2:2

The ME intake, food intake, egg weight, hen-day production, hen-housed production and non-hatching eggs from 22 to 55 weeks with regulated feeding.

number of birds (130 females + 19 males) = 149

| Age weeks | Daily ME intake kJ/b | Daily food intake g/b | Egg weight g. | Hen day production % | Hen-housed production % | Non-hatching eggs % |
|---|---|---|---|---|---|---|
| 22-23 | 1087 | 89 | - | - | - | - |
| 24-25 | 1648 | 135 | 46.6 | 2 | 2 | 2.0 |
| 26-27 | 1923 | 157 | 51.9 | 20.0 | 19.9 | 7.9 |
| 28-29 | 2088 | 171 | 54.9 | 62.8 | 62.0 | 8.7 |
| 30-31 | 2088 | 171 | 58.5 | 76.1 | 74.7 | 5.7 |
| 32-33 | 2271 | 186 | 61.1 | 79.7 | 78.3 | 3.0 |
| 34-35 | 2332 | 191 | 62.5 | 76.8 | 75.6 | 2.6 |
| 36-37 | 2332 | 191 | 63.5 | 79.0 | 75.8 | 2.7 |
| 38-39 | 2210 | 181 | 64.7 | 75.4 | 71.0 | 4.3 |
| 40-41 | 1966 | 161 | 65.6 | 72.1 | 67.4 | 4.4 |
| 42-43 | 2002 | 164 | 67.6 | 67.6 | 63.1 | 3.6 |
| 44-45 | 1990 | 163 | 67.7 | 66.3 | 61.9 | 2.4 |
| 46-47 | 1966 | 161 | 67.8 | 61.7 | 57.6 | 2.0 |
| 48-49 | 1953 | 160 | 68.3 | 55.8 | 52.1 | 2.6 |
| 50-51 | 1941 | 159 | 69.1 | 55.1 | 50.9 | 1.8 |
| 52-53 | 1904 | 156 | 69.5 | 52.0 | 48.1 | 1.9 |
| 54-55 | 1892 | 155 | 69.8 | 48.3 | 44.7 | 1.6 |

Appendix 2:3

Daily egg mass produced from regulated and ad libitum hens during the experiment in the floor pens.

| Age weeks | Regulated g/b | Ad libitum g/b |
|---|---|---|
| 20-21 | - | 1.0 |
| 22-23 | - | 7.7 |
| 24-25 | 0.9 | 21.1 |
| 26-27 | 10.4 | 27.7 |
| 28-29 | 34.5 | 29.8 |
| 30-31 | 44.5 | 32.1 |
| 32-33 | 48.7 | 35.7 |
| 34-35 | 48.0 | 37.5 |
| 36-37 | 50.2 | 37.8 |
| 38-39 | 48.8 | 45.3 |
| 40-41 | 47.3 | 35.7 |
| 42-43 | 45.3 | 32.6 |
| 44-45 | 44.9 | 29.7 |
| 46-47 | 41.8 | 27.9 |
| 48-49 | 38.1 | 27.6 |
| 50-51 | 38.1 | 26.5 |
| 52-53 | 36.1 | 24.9 |
| 54-55 | 33.7 | 23.2 |
| Mean | 38.2 | 27.4 |

## Appendix 2:4

Adjusted values of ash.

The possible reason for low ash gain (0.4 g/b week) from 10-15 weeks of ad libitum females.

1 - Wide difference between live weight of slaughter group and flock weight.

Weight loss due to 24 hour starvation = 50g.

Live weight loss = 50g.

Actual difference at 15 weeks between slaughtered and flock weight = 263g. See Appendix 2:4b.

∴ Starved weight difference is approximately = + 200g.

Adjusted weight of slaughter group at 15 weeks

= 2.907 + 0.200

= 3.107kg.

Freezer weight was approximately 85.3 per cent of slaughter weight

| | |
|---|---|
| Therefore freezer weight | = 3.107 x 0.853 = 2.650 |
| Therefore revised ash content | = 2.650 x 0.028 |
| | = 74.2 |
| Actual 10 week ash content | = 67.5 |
| Adjusted 10-15 week gain | = 6.7 |
| Therefore ash gain | = 1.34 g/week |

This analysis of difference produces only 1g/week more ash gain

2 - Low ash content (2.8 per cent) at 15 weeks in relation to value obtained at 10 and 20 weeks. Use of mean ash content of 10 and 20 weeks.

| | |
|---|---|
| Ash content at 10 weeks | = 3.7 per cent |
| Ash content at 20 weeks | = 3.9 per cent |
| Mean | = 3.8 per cent |
| Adjusted freezer weight | = 2.650 |
| Therefore adjusted ash content at 15 weeks | = 2650 x 0.038 = 100.7g. |
| 10 weeks ash | = 67.5 |
| 10-15 weeks gain | = 33.2g. (100.7-67.5) |
| Ash gain per week | = 6.6 g/week. |

This adjustment is more realistic than adjustment (1) and was used to adjust the following values

Ash at 20 weeks = 124.7g.

Ash gain 15-20 weeks *ad libitum* females

Ash at 15 weeks = 100.7g.

Gain from 15-20 weeks = 24.0g.

Gain per week = 4.8g/week

---

Regulated females low ash gain 10-15 weeks

Ash content, take 4.6 per cent at 10 weeks

Freezer weight = 906g.

Adjusted ash content at 10 weeks = 906 x 0.046 = 41.7g.

Actual 10 weeks ash = 50.1g.

5 weeks ash = 14.4g.

Therefore 5-10 weeks gain = 27.3g. (41.7-27.3)

Gain/week = 5.5g.

15 week ash = 51.1g.

Therefore 10-15 week gain = 9.4g. (51.1-41.7)

Gain/week = 1.9g.

---

*Ad libitum* males low ash gain at 10-15 weeks

Ash content, take 4.0 per cent at 15 weeks

Freezer *ad libitum* males at 15 weeks = 3269g.

Adjusted ash content = 3269 x 0.04

= 130.8g.

10 week ash = 83.8g.

20 week ash = 170.6g.

Therefore 10-15 week gain = 47.0g. (130.8-83.8)

Gain/week = 9.4 g/week

Therefore 15-20 weeks gain = 39.8g. (170.6-130.8)

Gain/week = 8.0g/week.

Appendix 2:4b

Average live weight of the flock (L), starved body weight (S) and plucked body weight (P) of slaughtered (kg/b) on different feeding systems during the whole experiment.

| Age/ weeks | Weight | Female | | Male | |
|---|---|---|---|---|---|
| | | A | R | A | R |
| 5 | L | 0.778 | 0.519 | 0.938 | 0.617 |
| | S | 0.681 | 0.478 | 0.798 | 0.530 |
| | P | 0.625 | 0.444 | 0.731 | 0.492 |
| 10 | L | 2.086 | 1.058 | 2.670 | 1.407 |
| | S | 2.048 | 1.015 | 2.358 | 1.348 |
| | P | 1.809 | 0.907 | 2.119 | 1.244 |
| 15 | L | 3.170 | 1.517 | 4.487 | 2.258 |
| | S | 2.907 | 1.494 | 4.004 | 1.854 |
| | P | 2.662 | 1.399 | 3.507 | 1.687 |
| 20 | L | 3.950 | 1.860 | 4.711 | 2.806 |
| | S | 3.809 | 1.702 | 4.393 | 2.216 |
| | P | 3.500 | 1.553 | 4.081 | 2.051 |
| 25 | L | 4.252 | 2.524 | ——— | ——— |
| | S | 4.252 | 2.524 | ——— | ——— |
| | P | 3.987 | 2.246 | ——— | ——— |
| 30 | L | 4.316 | 2.924 | ——— | ——— |
| | S | 4.536 | 2.641 | ——— | ——— |
| | P | 4.283 | 2.531 | ——— | ——— |
| 40 | L | 4.568[1] | 3.362[1] | 5.057[1] | 4.496[1] |
| | S | 4.347 | 2.722 | 5.007 | 4.588 |
| | P | 4.161 | 2.640 | 4.652 | 4.261 |
| 54 | L | 4.819[2] | 3.536[2] | 5.536[2] | 5.156[2] |
| | S | 5.200 | 3.200 | 5.570 | 4.980 |
| | P | 4.933 | 2.937 | 5.118 | 4.521 |

1 These values were estimated from 41 week body weights.

2 " " " " " 55 " " "

## Appendix 2:5

Organ weights and selected organ weights as percentage of live weight at different ages for different feeding systems for both sexes.

| Treatment | Organs | Age-Weeks | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 5 | 10 | 15 | 20 | 25 | 30 | 41 | 55 |
| Ad libitum female | | | | | | | | | |
| | Liver | 21.4(3.1)[1] | 45.1(2.2) | 37.0(1.4) | 49.6(1.3) | 52.4(1.2) | 56.8(1.3) | 46.0(1.1) | 70.0(1.3) |
| | Heart | 4.0(0.6) | 9.4(0.5) | 12.4(0.5) | 16.4(0.4) | 17.2(0.4) | 16.4(0.4) | 16.2(0.4) | 20.4(0.4) |
| | Gizzard | 21.7(3.2) | 37.6(1.8) | 42.2(1.6) | 45.8(1.2) | 40.4(1.0) | 46.8(1.0) | 41.8(1.0) | 55.6(1.1) |
| | Intestine | 30.7(4.5) | 66.9(3.3) | 62.8(2.3) | 54.2(1.4) | 57.0(1.4) | 75.8(1.7) | 54.6(1.3) | 76.2(1.5) |
| Ad libitum male | | | | | | | | | |
| | Liver | 21.2(2.6) | 43.2(1.8) | 55.0(1.4) | 51.0(1.2) | - | - | 56.4(1.1) | 66.0(1.2) |
| | Heart | 4.8(0.6) | 11.3(0.5) | 21.4(0.5) | 25.6(0.6) | - | - | 30.4(0.6) | 32.8(0.6) |
| | Gizzard | 23.2(2.9) | 36.7(1.6) | 48.0(1.8) | 50.4(1.1) | - | - | 48.2(1.0) | 49.0(0.9) |
| | Intestine | 31.2(3.9) | 71.3(3.0) | 78.8(2.9) | 66.4(1.5) | - | - | 65.8(1.3) | 71.4(1.3) |
| Regulated female | | | | | | | | | |
| | Liver | 12.4(2.6) | 22.0(2.2) | 23.2(1.6) | 30.4(1.8) | 30.0(1.6) | 42.0(1.6) | 34.8(1.3) | 46.6(1.5) |
| | Heart | 2.4(0.5) | 5.1(0.5) | 6.6(0.4) | 8.4(0.5) | 10.2(0.4) | 12.4(0.5) | 11.8(0.4) | 12.8(0.4) |
| | Gizzard | 16.9(3.5) | 29.6(2.9) | 44.0(2.9) | 41.4(2.4) | 43.2(1.9) | 42.6(1.6) | 37.6(1.4) | 46.6(1.5) |
| | Intestine | 17.9(3.7) | 34.0(3.3) | 38.4(2.6) | 41.8(2.5) | 46.4(2.0) | 63.2(2.4) | 52.0(1.9) | 55.2(1.7) |
| Regulated male | | | | | | | | | |
| | Liver | 13.4(2.5) | 28.0(2.1) | 29.2(1.6) | 34.0(1.5) | - | - | 50.0(1.1) | 53.4(1.1) |
| | Heart | 3.0(0.6) | 6.9(0.5) | 8.2(0.4) | 8.3(0.4) | - | - | 26.0(0.6) | 25.4(0.5) |
| | Gizzard | 15.8(3.0) | 34.5(2.6) | 49.6(2.7) | 46.8(2.1) | - | - | 44.8(1.1) | 52.2(1.0) |
| | Intestine | 18.7(3.0) | 41.5(3.1) | 42.4(2.3) | 46.0(2.1) | - | - | 57.4(1.3) | 59.8(1.2) |

[1]Numbers between brackets are values expressed as percentage of live body weight.

## Appendix 2:6

Effect of different feeding systems on the fertility and hatchability results from Ross Poultry Great Britain Ltd. Cample Hatchery.

| Age weeks | Feeding system | Egg set | Clears infertile | % Fertility | Culls (chicken) | Saleable chicks | % Hatchability |
|---|---|---|---|---|---|---|---|
| 26 | A | 90 | 19 | 78.9 | 4 | 67 | 74.4 |
| | R | 132 | 14 | 89.4 | - | 115 | 84.1 |
| 27 | A | 132 | 23 | 82.6 | - | 102 | 77.3 |
| | R | 396 | 30 | 92.4 | 2 | 333 | 84.6 |
| 28 | A | 240 | 56 | 76.7 | 10 | 180 | 75.0 |
| | R | 264 | 47 | 82.2 | 9 | 205 | 81.1 |
| 34 | A | 264 | 54 | 79.5 | 2 | 175 | 67.1 |
| | R | 528 | 25 | 95.7 | 6 | 446 | 85.7 |
| 37 | A | 456 | 60 | 87.2 | 4 | 358 | 79.7 |
| | R | 660 | 48 | 92.8 | 8 | 560 | 85.3 |
| 38 | A | 264 | 45 | 83.0 | 5 | 195 | 75.8 |
| | R | 264 | 29 | 89.0 | 2 | 214 | 81.8 |
| 39 | A | 132 | 22 | 83.3 | 2 | 96 | 72.7 |
| | R | 264 | 18 | 93.2 | 3 | 229 | 86.7 |
| 40 | A | 132 | 34 | 74.2 | 1 | 87 | 65.9 |
| | R | 132 | 11 | 91.7 | 4 | 108 | 81.8 |
| 41 | A | 252 | 83 | 67.1 | 5 | 149 | 59.1 |
| | R | 264 | 22 | 91.7 | 4 | 231 | 87.5 |
| 42 | A | 156 | 42 | 73.1 | 3 | 109 | 69.9 |
| | R | 264 | 16 | 93.9 | 3 | 226 | 85.6 |
| 44 | A | 264 | 74 | 72.0 | - | 171 | 64.8 |
| | R | 264 | 21 | 92.0 | 3 | 211 | 79.9 |
| 45 | A | 324 | 78 | 76.0 | 5 | 222 | 68.5 |
| | R | 264 | 28 | 89.4 | 4 | 226 | 85.6 |
| 46 | A | 162 | 42 | 74.0 | 1 | 102 | 63.0 |
| | R | 132 | 9 | 93.0 | 2 | 114 | 86.4 |
| 47 | A | 456 | 105 | 77.0 | 2 | 287 | 66.8 |
| | R | 264 | 16 | 93.9 | 2 | 231 | 87.5 |
| 50 | A | 132 | 73 | 44.7 | 4 | 46 | 34.8 |
| | R | 132 | 37 | 72.0 | 6 | 69 | 52.3 |
| 51 | A | 168 | 90 | 46.0 | 1 | 68 | 40.5 |
| | R | 132 | 30 | 77.0 | 1 | 90 | 68.2 |
| 54 | A | 132 | 71 | 46.0 | 2 | 50 | 37.9 |
| | R | 132 | 35 | 73.5 | - | 90 | 68.2 |

## Appendix 2:7

Actual and relative amounts of carcass components at different ages for different feeding systems for both sexes.

| Age weeks | Sex | % D.M.in carcass | Ash % | Fat % | Protein % | Actual amount Water g. | D.M. g. | Ash g. | Fat g. | Protein g. |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | Female | 24.4 | 2.1 | 3.9 | 16.7 | 27.4 | 8.9 | 0.7 | 1.4 | 6.1 |
| | Male | 23.2 | 1.8 | 4.8 | 15.5 | 28.1 | 8.5 | 0.7 | 1.76 | 5.7 |
| 5 | Ad lib. Female | 30.7 | 2.9 | 10.6 | 15.7 | 432.3 | 191.7 | 18.0 | 66.0 | 98.0 |
| | Reg. " | 28.7 | 3.2 | 7.4 | 16.7 | 316.5 | 127.5 | 14.4 | 33.0 | 74.1 |
| | Ad lib. Male | 31.1 | 2.7 | 9.9 | 16.2 | 503.2 | 226.8 | 19.5 | 72.3 | 118.1 |
| | Reg. Male | 29.2 | 3.2 | 8.0 | 16.1 | 348.4 | 143.6 | 15.7 | 39.5 | 79.1 |
| 10 | Ad lib. Female | 41.3 | 3.7 | 18.5 | 20.2 | 1062.0 | 747.2 | 67.5 | 333.9 | 365.5 |
| | Reg. " | 37.7 | 5.5 | 8.9 | 23.2 | 564.6 | 341.4 | 41.7 | 80.3 | 210.2 |
| | Ad lib. Male | 42.5 | 4.0 | 18.0 | 20.9 | 1219.4 | 899.6 | 83.8 | 381.4 | 444.0 |
| | Reg. Male | 35.8 | 4.8 | 8.7 | 22.0 | 798.7 | 445.3 | 59.3 | 107.6 | 274.0 |

Ad libitum Females at 15 weeks of age.

| Bird Number | %D.M.in carcass | Ash % | Fat % | Protein % | Water g. | D.M. g. | Ash g. | Fat g. | Protein g. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 34.1 | 2.8 | 16.2 | 17.2 | 1439.9 | 835.1 | 63.5 | 373.9 | 397.7 |
| 2 | 43.8 | 2.6 | 26.3 | 16.8 | 1345.1 | 1123.9 | 64.5 | 646.3 | 413.1 |
| 3 | 40.8 | 2.8 | 21.9 | 17.9 | 1527.2 | 1132.8 | 75.2 | 582.4 | 475.4 |
| 4 | 40.4 | 2.6 | 20.4 | 17.5 | 1481.0 | 1040.0 | 66.4 | 523.3 | 450.3 |
| 5 | 41.4 | 3.2 | 20.1 | 18.7 | 1387.9 | 1002.1 | 78.0 | 489.8 | 455.7 |
| Mean | 40.1 | 2.8 | 21.0 | 17.6 | 1436.2 | 1026.8 | 69.5 | 523.1 | 438.4 |
| S.E. | 1.6 | 0.1 | 1.6 | 0.3 | 32.4 | 53.9 | 3.3 | 45.8 | 14.3 |
| Regulated females at 15 weeks of age. | | | | | | | | | |
| 6 | 31.4 | 2.9 | 8.7 | 18.5 | 896.1 | 409.9 | 37.2 | 114.6 | 241.7 |
| 7 | 37.5 | 4.8 | 12.2 | 20.5 | 716.3 | 468.8 | 60.0 | 152.5 | 256.3 |
| 8 | 28.0 | 5.1 | 4.4 | 26.4 | 832.6 | 354.9 | 60.8 | 51.9 | 242.3 |
| 9 | 31.2 | 3.3 | 10.1 | 18.7 | 939.3 | 453.7 | 46.9 | 142.6 | 264.3 |
| Mean | 34.3 | 4.0 | 8.9 | 19.2 | 696.6 | 442.0 | 51.1 | 115.4 | 251.2 |
| S.E. | 4.1 | 0.5 | 4.4 | 0.6 | 118.3 | 22.9 | 5.6 | 22.6 | 4.9 |
| Ad libitum males at 15 weeks of age. | | | | | | | | | |
| 10 | 36.3 | 3.7 | 14.6 | 18.2 | 1524.8 | 931.2 | 93.8 | 373.0 | 464.4 |
| 11 | 36.5 | 3.1 | 15.5 | 19.0 | 2255.1 | 1409.9 | 116.7 | 581.2 | 712.1 |
| 12 | 36.5 | 3.9 | 14.3 | 19.6 | 1812.7 | 1117.3 | 115.5 | 423.7 | 586.7 |
| 13 | 36.2 | 3.4 | 14.1 | 18.8 | 2093.8 | 1234.2 | 114.6 | 479.6 | 640.1 |
| 14 | 36.0 | 3.5 | 13.5 | 17.9 | 2319.0 | 1306.1 | 128.4 | 490.7 | 648.5 |
| Mean | 36.3 | 3.5 | 14.4 | 18.7 | 2001.1 | 1199.7 | 130.8 | 469.6 | 609.2 |
| S.E. | 0.1 | 0.1 | 0.3 | 0.3 | 147.7 | 82.3 | 5.6 | 35.0 | 41.8 |
| Regulated males at 15 weeks of age. | | | | | | | | | |
| 15 | 29.6 | 4.3 | 5.5 | 21.1 | 927.4 | 422.6 | 58.8 | 75.2 | 288.6 |
| 16 | 30.2 | 4.2 | 6.4 | 20.7 | 1172.0 | 540.2 | 71.9 | 110.9 | 357.5 |
| 17 | 28.1 | 4.5 | 5.0 | 21.3 | 1089.0 | 474.9 | 69.1 | 77.7 | 328.0 |
| 18 | 31.1 | 4.0 | 8.2 | 20.1 | 1122.2 | 533.8 | 65.8 | 135.5 | 332.5 |
| 19 | 27.5 | 4.8 | 4.3 | 19.9 | 1647.7 | 432.3 | 71.5 | 64.0 | 296.8 |
| Mean | 29.3 | 4.4 | 5.9 | 20.6 | 1071.7 | 480.7 | 67.4 | 92.7 | 320.7 |
| S.E. | 0.7 | 0.1 | 0.7 | 0.3 | 41.4 | 24.6 | 2.4 | 13.3 | 12.5 |

Ad libitum Males at 20 weeks.

| | %D.M.in carcass | Ash % | Fat % | Protein % | Water g. | D.M. g. | Ash g. | Fat g. | Protein g. |
|---|---|---|---|---|---|---|---|---|---|
| 20 | 41.4 | 3.7 | 19.4 | 18.0 | 2497.7 | 1763.3 | 158.1 | 826.1 | 765.1 |
| 21 | 33.5 | 5.3 | 7.0 | 21.3 | 2327.5 | 1238.5 | 196.9 | 252.0 | 789.7 |
| 22 | 32.5 | 4.5 | 8.9 | 21.5 | 2069.2 | 1060.8 | 136.9 | 270.7 | 654 |
| 23 | 42.2 | 3.7 | 19.8 | 19.3 | 2323.7 | 1774.3 | 155.2 | 820.6 | 798.5 |
| 24 | 37.2 | 5.6 | 10.9 | 21.0 | 2213.8 | 1376.2 | 206.0 | 399.6 | 770.0 |
| Mean | 37.4 | 4.6 | 17.2 | 20.2 | 2286.4 | 1442.0 | 170.6 | 513.3 | 755.5 |
| S.E. | 2.0 | 0.4 | 1.6 | 0.7 | 70.8 | 141.9 | 14.5 | 129.2 | 25.6 |
| At 41 weeks | | | | | | | | | |
| 25 | 32.5 | 4.3 | 7.9 | 22.2 | 2768.4 | 1461.6 | 183.8 | 336.0 | 942.7 |
| 26 | 31.9 | 5.9 | 3.2 | 24.2 | 2343.5 | 1171.5 | 207.8 | 111.5 | 852.2 |
| 27 | 34.3 | 4.9 | 6.7 | 25.3 | 3347.6 | 1912.4 | 254.4 | 347.9 | 1313.7 |
| 28 | 32.4 | 3.6 | 8.7 | 22.1 | 3185.3 | 1680.0 | 174.3 | 427.5 | 1077.9 |
| 29 | 36.5 | 3.6 | 14.5 | 20.6 | 2719.1 | 1684.9 | 155.9 | 632.9 | 895.3 |
| Mean | 33.5 | 4.5 | 8.2 | 22.9 | 2872.8 | 1582.1 | 195.2 | 371.2 | 1016.2 |
| S.E. | 0.9 | 0.4 | 1.8 | 0.8 | 178.6 | 125.0 | 17.2 | 83.9 | 83.5 |
| At 55 weeks | | | | | | | | | |
| 30 | 33.4 | 4.4 | 10.7 | 21.1 | 2885.3 | 1521.7 | 184.2 | 451.4 | 886.1 |
| 31 | 46.3 | 6.9 | 24.8 | 19.0 | 2760.3 | 2477.7 | 365.2 | 1303.0 | 1002.0 |
| 32 | 36.8 | 3.4 | 17.6 | 20.5 | 3202.7 | 2015.3 | 167.1 | 853.9 | 994.2 |
| 33 | 38.7 | 4.8 | 8.6 | 26.3 | 3105.5 | 2049.5 | 247.9 | 441.2 | 1141.5 |
| 34 | 36.1 | 4.8 | 9.9 | 23.1 | 2771.3 | 1648.7 | 209.5 | 432.0 | 1007.2 |
| Mean | 38.3 | 4.9 | 14.3 | 22.0 | 2945.1 | 1942.6 | 234.8 | 696.3 | 1006.2 |
| S.E. | 2.2 | 0.6 | 3.0 | 1.2 | 89.5 | 168.3 | 35.3 | 171.4 | 40.6 |

Ad libitum females at 20 weeks

| | % D.M.in carcass | Ash % | Fat % | Protein % | Water g. | D.M. g. | Ash g. | Fat g. | Protein g. |
|---|---|---|---|---|---|---|---|---|---|
| 20 | 49.3 | 3.9 | 27.4 | 17.2 | 1606.4 | 1564.0 | 124.7 | 867.3 | 545.2 |
| At 25 weeks | | | | | | | | | |
| 21 | 50.1 | 3.7 | 29.4 | 18.1 | 1797.8 | 1862.2 | 135.0 | 1068.2 | 658.9 |
| 22 | 47.2 | 3.4 | 27.9 | 16.3 | 1794.6 | 1660.4 | 118.7 | 973.7 | 568.9 |
| 23 | 50.4 | 3.4 | 32.2 | 16.2 | 1805.4 | 2014.6 | 131.4 | 1258.3 | 631.1 |
| 24 | 47.7 | 2.9 | 29.9 | 16.6 | 2026.4 | 1950.6 | 113.6 | 1180.6 | 656.4 |
| 25 | 46.0 | 3.4 | 27.3 | 16.6 | 2168.2 | 1850.0 | 137.5 | 1097.9 | 667.1 |
| Mean | 48.2 | 3.4 | 29.3 | 16.8 | 1918.5 | 1867.6 | 127.2 | 1115.7 | 636.5 |
| S.E. | 0.9 | 0.1 | 0.9 | 0.3 | 76.4 | 59.9 | 4.7 | 48.6 | 17.9 |
| At 30 weeks | | | | | | | | | |
| 26 | 46.5 | 2.9 | 27.7 | 17.3 | 2127.2 | 1960.8 | 117.6 | 1135.4 | 707.6 |
| 27 | 41.6 | 3.3 | 22.2 | 16.1 | 2560.5 | 1816.5 | 147.7 | 993.6 | 720.5 |
| 28 | 46.3 | 3.8 | 25.6 | 17.6 | 2097.3 | 1874.7 | 151.5 | 1020.9 | 701.9 |
| 29 | 46.5 | 3.8 | 25.8 | 17.7 | 1960.6 | 1769.4 | 143.8 | 964.7 | 661.0 |
| 30 | 49.0 | 2.6 | 30.9 | 15.7 | 2389.1 | 2364.9 | 127.0 | 1485.1 | 752.8 |
| Mean | 45.2 | 3.2 | 26.4 | 16.9 | 2226.9 | 1957.3 | 137.5 | 1119.9 | 709.0 |
| S.E. | 2.0 | 0.2 | 1.4 | 0.4 | 108.5 | 106.8 | 6.5 | 95.8 | 14.9 |
| At 41 weeks | | | | | | | | | |
| 31 | 47.6 | 4.4 | 28.3 | 16.9 | 1883.3 | 1786.7 | 158.6 | 1020.2 | 609.3 |
| 32 | 50.2 | 3.1 | 30.9 | 15.7 | 2224.4 | 2275.6 | 140.6 | 1416.4 | 718.6 |
| 33 | 49.8 | 3.1 | 31.2 | 16.0 | 1952.6 | 2082.4 | 128.3 | 1292.0 | 662.2 |
| 34 | 44.4 | 3.7 | 25.3 | 16.2 | 2137.8 | 1803.3 | 146.0 | 1012.3 | 646.7 |
| 35 | 46.9 | 3.1 | 31.9 | 15.7 | 2017.0 | 1861.0 | 123.5 | 1266.2 | 622.9 |
| Mean | 47.8 | 3.5 | 29.5 | 16.1 | 2043 | 1961.8 | 139.4 | 1201.4 | 651.9 |
| S.E. | 1.1 | 0.3 | 1.2 | 0.2 | 61.8 | 94.6 | 6.3 | 79.8 | 19.0 |
| At 55 weeks | | | | | | | | | |
| 36 | 49.0 | 3.0 | 32.9 | 15.3 | 2350.4 | 2419.6 | 143.6 | 1553.6 | 722.5 |
| 37 | 55.8 | 5.1 | 33.9 | 14.7 | 2299.6 | 2909.4 | 277.9 | 1836.4 | 795.0 |
| 38 | 47.5 | 4.3 | 27.3 | 17.9 | 2141.9 | 2038.1 | 176.9 | 1123.2 | 736.4 |
| 39 | 49.7 | 3.5 | 32.1 | 16.4 | 1998.2 | 2131.8 | 144.0 | 1316.9 | 671.0 |
| 40 | 56.9 | 2.4 | 41.0 | 13.2 | 2246.8 | 3010.2 | 127.5 | 2180.4 | 702.4 |
| Mean | 51.8 | 3.7 | 33.4 | 15.5 | 2207.4 | 2501.8 | 174.0 | 1602.1 | 725.5 |
| S.E. | 1.9 | 0.5 | 2.2 | 0.8 | 62.7 | 197.9 | 27.2 | 187.4 | 20.6 |

Regulated Males at 20 weeks

| | %D.M.in carcass | Ash % | Fat % | Protein % | Water g. | D.M. g. | Ash g. | Fat g. | Protein g. |
|---|---|---|---|---|---|---|---|---|---|
| 41 | 28.4 | 5.1 | 2.8 | 23.4 | 1278.4 | 576.6 | 94.0 | 51.0 | 431.8 |
| 42 | 26.4 | 4.2 | 2.7 | 20.9 | 1335.9 | 519.1 | 78.7 | 50.8 | 389.6 |
| 43 | 26.6 | 4.7 | 1.8 | 21.6 | 1348.4 | 533.6 | 89.4 | 34.9 | 409.3 |
| 44 | 28.9 | 4.2 | 3.5 | 22.8 | 1354.0 | 601.1 | 82.1 | 69.1 | 450.8 |
| Mean | 27.6 | 4.6 | 2.7 | 22.2 | 1329.2 | 557.6 | 86.1 | 51.5 | 420.4 |
| S.E. | 0.6 | 0.2 | 0.3 | 0.6 | 17.3 | 19.0 | 3.5 | 7.0 | 13.3 |
| 41 weeks | | | | | | | | | |
| 45 | 30.6 | 3.4 | 4.4 | 22.8 | 2516.6 | 1113.8 | 129.2 | 167.4 | 866.6 |
| 46 | 28.1 | 4.4 | 3.3 | 23.2 | 2748.9 | 1221.1 | 172.8 | 131.3 | 917.0 |
| 47 | 32.6 | 4.3 | 8.2 | 23.2 | 2429.0 | 1307.0 | 158.1 | 299.3 | 849.6 |
| 48 | 32.3 | 3.6 | 7.7 | 21.6 | 3058.7 | 1468.0 | 165.0 | 348.5 | 983.6 |
| 49 | 25.6 | 3.0 | 3.4 | 20.5 | 3145.4 | 1079.6 | 128.0 | 143.4 | 864.5 |
| Mean | 29.8 | 3.7 | 5.4 | 22.3 | 2779.6 | 1237.9 | 150.8 | 218.0 | 896.3 |
| S.E. | 1.3 | 0.3 | 1.1 | 0.5 | 142.2 | 70.2 | 9.4 | 44.3 | 24.6 |
| 55 weeks | | | | | | | | | |
| 50 | 31.1 | 5.3 | 4.2 | 24.2 | 2865.6 | 1424.4 | 224.5 | 177.9 | 1024.9 |
| 51 | 31.5 | 4.5 | 6.2 | 23.3 | 2901.2 | 1468.8 | 193.4 | 267.4 | 1007.7 |
| 52 | 31.8 | 5.0 | 7.2 | 22.1 | 2914.4 | 1493.6 | 216.2 | 313.1 | 963.8 |
| 53 | 30.4 | 3.6 | 7.1 | 20.6 | 2958.8 | 1386.2 | 151.4 | 297.2 | 864.0 |
| 54 | 31.1 | 3.6 | 6.3 | 21.4 | 2615.7 | 1276.3 | 146.6 | 258.6 | 871.8 |
| Mean | 31.2 | 4.4 | 6.2 | 22.3 | 2851.1 | 1409.9 | 186.4 | 262.8 | 946.4 |
| S.E. | 0.2 | 0.4 | 0.5 | 0.6 | 60.7 | 38.1 | 16.1 | 23.4 | 33.6 |

Regulated Females at 20 weeks

| | % D.M.in carcass | Ash % | Fat % | Protein % | Water g. | D.M. g. | Ash g. | Fat g. | Protein g. |
|---|---|---|---|---|---|---|---|---|---|
| 55 | 36.0 | 3.3 | 12.5 | 20.8 | 928.7 | 533.3 | 50.0 | 89.3 | 314.1 |
| 56 | 28.8 | 4.6 | 7.6 | 22.6 | 847.8 | 392.2 | 57.6 | 94.1 | 280.0 |
| 57 | 31.8 | 4.4 | 6.4 | 22.8 | 981.8 | 493.2 | 64.5 | 93.8 | 334.3 |
| 58 | 26.2 | 2.8 | 3.3 | 19.5 | 1077.0 | 382.0 | 41.3 | 47.6 | 284.5 |
| 59 | 32.4 | 4.8 | 5.6 | 22.6 | 892.5 | 463.5 | 67.0 | 79.0 | 317.5 |
| Mean | 31.0 | 4.0 | 7.1 | 21.7 | 945.6 | 452.9 | 56.0 | 80.8 | 306.1 |
| S.E. | 1.7 | 0.4 | 1.5 | 0.7 | 39.5 | 29.1 | 4.7 | 8.7 | 10.3 |
| at 25 weeks | | | | | | | | | |
| 60 | 32.5 | 3.1 | 10.2 | 20.1 | 1491.4 | 765.6 | 71.2 | 230.2 | 456.6 |
| 61 | 31.7 | 4.5 | 7.3 | 20.4 | 1478.9 | 726.1 | 100.0 | 165.0 | 456.3 |
| 62 | 32.3 | 2.4 | 11.1 | 20.4 | 1369.7 | 697.3 | 48.3 | 228.9 | 419.9 |
| 63 | 40.1 | 4.1 | 16.2 | 19.8 | 1287.0 | 923.0 | 94.4 | 372.9 | 445.8 |
| 64 | 29.8 | 4.9 | 5.9 | 21.6 | 1223.1 | 561.9 | 85.0 | 102.3 | 374.7 |
| Mean | 33.3 | 3.8 | 10.1 | 20.5 | 1331.6 | 734.7 | 79.8 | 231.9 | 430.7 |
| S.E. | 1.8 | 0.5 | 1.8 | 0.3 | 76.3 | 58.2 | 9.25 | 47.1 | 15.5 |
| at 30 weeks | | | | | | | | | |
| 65 | 36.3 | 3.6 | 14.4 | 20.2 | 1390.0 | 860.1 | 80.9 | 324.6 | 454.5 |
| 66 | 36.4 | 3.9 | 14.3 | 19.4 | 1619.1 | 976.9 | 102.0 | 371.8 | 502.3 |
| 67 | 36.0 | 3.5 | 13.2 | 20.3 | 1483.3 | 881.7 | 82.3 | 314.8 | 484.6 |
| 68 | 35.1 | 3.7 | 12.1 | 20.4 | 1492.5 | 852.5 | 87.4 | 285.7 | 481.8 |
| 69 | 39.2 | 3.8 | 11.8 | 19.7 | 1498.9 | 1025.1 | 94.9 | 433.3 | 496.9 |
| Mean | 36.6 | 3.7 | 13.2 | 20.0 | 1496.7 | 919.3 | 89.5 | 346 | 484.0 |
| S.E. | 0.7 | 0.1 | 0.5 | 0.2 | 36.4 | 34.6 | 4.0 | 25.8 | 8.3 |
| at 41 weeks | | | | | | | | | |
| 70 | 40.0 | 3.6 | 19.8 | 17.7 | 1582.0 | 1007.8 | 97.3 | 535.0 | 478.2 |
| 71 | 38.5 | 4.1 | 16.7 | 18.6 | 1421.1 | 937.9 | 97.6 | 397.5 | 442.8 |
| 72 | 41.3 | 4.2 | 18.8 | 18.1 | 1603.6 | 1181.4 | 119.8 | 540.0 | 521.6 |
| 73 | 36.6 | 4.1 | 16.2 | 18.5 | 1508.9 | 956.1 | 101.9 | 399.6 | 454.8 |
| 74 | 39.3 | 4.2 | 17.0 | 18.9 | 1545.9 | 1054.1 | 110.2 | 446.0 | 495.9 |
| Mean | 39.1 | 4.0 | 17.7 | 18.4 | 1519.9 | 1032.4 | 105.4 | 463.6 | 478.8 |
| S.E. | 0.8 | 0.1 | 0.7 | 0.2 | 34.2 | 49.9 | 4.3 | 31.4 | 14.2 |
| at 55 weeks | | | | | | | | | |
| 75 | 48.1 | 3.8 | 27.8 | 15.5 | 1787.4 | 1662.6 | 134.7 | 980.3 | 547.6 |
| 76 | 41.0 | 4.4 | 17.6 | 19.0 | 1591 | 1109.0 | 125.1 | 500.2 | 540.0 |
| 77 | 39.6 | 4.7 | 13.8 | 21.7 | 1789.2 | 1240.8 | 145.5 | 426.2 | 669.0 |
| 78 | 37.8 | 3.9 | 16.5 | 18.3 | 1397.8 | 896.2 | 91.1 | 382.4 | 422.6 |
| 79 | 34.6 | 3.9 | 9.7 | 22.7 | 1263.2 | 716.8 | 75.9 | 189.8 | 444.1 |
| Mean | 40.1 | 4.1 | 17.1 | 19.4 | 1565.7 | 1125.1 | 114.5 | 495.8 | 524.7 |
| S.E. | 2.2 | 0.2 | 3.3 | 1.3 | 104.7 | 161.5 | 13.3 | 131.5 | 43.9 |

## Appendix 3:1

The ME intake, food intake, egg weight, hen-day, hen-housed and non-hatching eggs from 20-54 weeks on the low energy feed (L).

number of hens till 35 week = 128

number of hens from 36-54 week = 63

| Age weeks | Daily ME intake kJ/b | Daily food intake g/b | Egg weight g. | Hen day production % | Hen-housed production % | Non-hatching eggs % |
|---|---|---|---|---|---|---|
| 20-21 | - | - | - | 3.5 | 3.5 | - |
| 22-23 | 1749.9 | 174 | - | 18.0 | 18.0 | 3.5 |
| 24-25 | 1760.0 | 174 | 54.3 | 46.0 | 46.0 | 13.1 |
| 26-27 | 1749.9 | 174 | 58.0 | 60.5 | 60.0 | 17.7 |
| 28-29 | 1830.4 | 182 | 59.4 | 61.7 | 60.9 | 13.7 |
| 30-31 | 1951.1 | 194 | 61.1 | 60.8 | 59.4 | 7.8 |
| 32-33 | 1900.8 | 189 | 62.2 | 59.5 | 58.1 | 5.7 |
| 34-35 | 1850.5 | 184 | 63.7 | 57.6 | 56.3 | 2.4 |
| 36-37 | 1860.5 | 185 | 67.3 | 55.7 | 54.8 | 3.5 |
| 38-39 | 1719.7 | 171 | 67.5 | 55.1 | 54.2 | 3.4 |
| 40-41 | 2051.6 | 204 | 69.3 | 37.5 | 36.3 | 0.7 |
| 42-43 | 1729.8 | 172 | 72.3 | 46.8 | 45.6 | 1.2 |
| 44-45 | 1679.5 | 167 | 72.8 | 43.6 | 42.2 | 2.0 |
| 46-47 | 1719.7 | 171 | 71.0 | 41.4 | 40.1 | 1.4 |
| 48-49 | 1619.2 | 161 | 71.4 | 45.1 | 43.7 | 2.1 |
| 50-51 | 1538.7 | 153 | 71.4 | 43.2 | 41.7 | 0.9 |
| 52-53 | 1538.7 | 153 | 71.7 | 34.8 | 33.7 | 1.0 |
| 54 | 1528.7 | 152 | 72.4 | 27.2 | 26.3 | 1.4 |

## Appendix 3:2

The ME intake, food intake, egg weight, hen-day, hen-housed and non-hatching eggs from 20 to 54 weeks on the medium energy feed (M)

number of birds till 35 weeks = 128

number of birds from 36-54 weeks = 60

| Age weeks | Daily ME intake kJ/b | Daily food intake g/b | Egg weight g. | Hen day production % | Hon-housed production % | Non-hatching eggs % |
|---|---|---|---|---|---|---|
| 20-21 | | | | 3.8 | 3.8 | |
| 22-23 | 2099.9 | 172 | 54.0 | 22.0 | 22.0 | 13.4 |
| 24-25 | 2112.4 | 173 | 55.2 | 51.9 | 51.9 | 13.1 |
| 26-27 | 2014.5 | 165 | 57.8 | 59.5 | 59.5 | 18.4 |
| 28-29 | 2112.4 | 173 | 59.3 | 58.2 | 58.4 | 12.9 |
| 30-31 | 2246.5 | 184 | 60.6 | 56.8 | 56.8 | 9.1 |
| 32-33 | 2136.6 | 175 | 61.9 | 58.0 | 58.3 | 6.6 |
| 34-35 | 2051.1 | 168 | 64.7 | 54.3 | 54.3 | 4.1 |
| 36-37 | 2124.4 | 174 | 67.4 | 52.2 | 52.2 | 2.5 |
| 38-39 | 1758.1 | 144 | 67.5 | 50.8 | 50.8 | 5.0 |
| 40-41 | 2087.7 | 171 | 68.0 | 41.1 | 41.1 | 2.4 |
| 42-43 | 2002.3 | 164 | 69.5 | 42.8 | 42.8 | 1.0 |
| 44-45 | 1965.6 | 161 | 70.3 | 37.9 | 40.1 | 1.3 |
| 46-47 | 1965.6 | 161 | 70.0 | 38.4 | 38.0 | 1.5 |
| 48-49 | 1941.2 | 159 | 70.8 | 36.5 | 36.5 | 2.1 |
| 50-51 | 1855.8 | 152 | 71.8 | 34.3 | 30.0 | 1.9 |
| 52-53 | 1684.8 | 138 | 71.1 | 33.3 | 29.2 | 1.1 |
| 54 | 1782.5 | 146 | 70.9 | 33.2 | 29.0 | 1.3 |

## Appendix 3:3

The ME intake, food intake, egg weight, hen-day, hen-housed and non-hatching eggs from 20 to 54 weeks on the high energy diet (H).

number of birds from 22 to 35 weeks = 128
number of birds from 36 to 54 weeks = 63

| Age weeks | Daily ME intake kJ/b | Daily food intake g/b | Egg weight g. | Hen-day production % | Hen-housed production % | Non-hatching eggs % |
|---|---|---|---|---|---|---|
| 20-21 | | | | 3.9 | 3.9 | - |
| 22-23 | 2150.2 | 162 | 56.1 | 21.5 | 21.5 | 3.1 |
| 24-25 | 2150.2 | 162 | 56.2 | 53.0 | 53.0 | 12.0 |
| 26-27 | 2030.0 | 153 | 57.8 | 59.8 | 59.3 | 17.9 |
| 28-29 | 2190.0 | 165 | 59.2 | 61.6 | 60.8 | 15.9 |
| 30-31 | 2190.0 | 165 | 61.5 | 59.0 | 57.8 | 8.6 |
| 32-33 | 2190.0 | 165 | 62.3 | 58.2 | 56.4 | 6.1 |
| 34-35 | 2176.8 | 164 | 64.7 | 56.7 | 54.0 | 5.5 |
| 36-37 | 2137.0 | 161 | 65.8 | 51.9 | 48.7 | 4.2 |
| 38-39 | 1818.4 | 137 | 65.6 | 48.7 | 45.6 | 6.1 |
| 40-41 | 2057.3 | 155 | 66.8 | 42.9 | 39.5 | 2.5 |
| 42-43 | 1884.8 | 142 | 68.3 | 42.9 | 38.8 | 2.0 |
| 44-45 | 1858.2 | 140 | 69.4 | 36.6 | 33.1 | 0.9 |
| 46-47 | 1898.0 | 143 | 69.0 | 37.6 | 34.0 | 1.9 |
| 48-49 | 1805.1 | 136 | 70.3 | 38.8 | 34.5 | 2.1 |
| 50-51 | 1765.3 | 133 | 72.5 | 41.5 | 36.9 | 1.4 |
| 52-53 | 1805.1 | 136 | 70.8 | 31.4 | 27.7 | 1.4 |
| 54 | 1752.0 | 132 | 72.5 | 23.6 | 19.5 | 0.5 |

## Appendix 3:4

The ME intake, food intake, egg weight, hen-day, hen-housed and non-hatching eggs from 22-54 weeks on the regulated feed (R)

number of birds from 22 to 35 weeks = 256
number of birds from 36 to 54 weeks = 61

| Age weeks | Daily ME intake kJ/b | Daily food intake g/b | Egg weight g. | Hen-day production % | Hen-housed production % | Non-hatching eggs % |
|---|---|---|---|---|---|---|
| 22-23 | 950.2 | 80 | | | | |
| 24-25 | 1508.4 | 127 | 48.3 | 2.4 | 2.4 | 1.7 |
| 26-27 | 1757.8 | 148 | 52.7 | 33.2 | 32.8 | 10.3 |
| 28-29 | 1912.2 | 161 | 57.3 | 67.3 | 66.2 | 14.6 |
| 30-31 | 1912.2 | 161 | 59.2 | 72.1 | 70.4 | 8.2 |
| 32-33 | 2090.4 | 176 | 61.8 | 76.0 | 73.6 | 4.7 |
| 34-35 | 2149.7 | 181 | 63.3 | 73.9 | 71.2 | 3.3 |
| 36-37 | 2149.7 | 181 | 65.9 | 72.4 | 69.0 | 2.5 |
| 38-39 | 2031.0 | 171 | 66.1 | 71.9 | 68.6 | 1.9 |
| 40-41 | 1852.8 | 156 | 66.1 | 61.0 | 57.2 | 0.6 |
| 42-43 | 1876.6 | 158 | 67.1 | 60.7 | 57.0 | 1.0 |
| 44-45 | 1864.7 | 157 | 67.9 | 58.5 | 54.8 | 0.8 |
| 46-47 | 1840.9 | 155 | 68.4 | 58.0 | 54.8 | 0.8 |
| 48-49 | 1829.1 | 154 | 69.1 | 54.7 | 51.3 | 1.2 |
| 50-51 | 1817.2 | 153 | 70.3 | 51.7 | 48.4 | 1.3 |
| 52-53 | 1781.6 | 150 | 70.6 | 52.6 | 49.4 | 1.9 |
| 54 | 1781.6 | 150 | 69.3 | 44.3 | 41.5 | 1.2 |

## Appendix 3:5

The ME intake, food intake, egg weight, hen-day, hen-housed and non-hatching eggs from 35 to 54 weeks on feed LH.

number of birds = 61

| Age weeks | Daily ME intake kJ/b | Daily food intake g/b | Egg weight g. | Hen-day production % | Hen-housed production % | Non-hatching eggs % |
|---|---|---|---|---|---|---|
| 36-37 | 2243.1 | 169 | 66.0 | 53.7 | 52.8 | 4.4 |
| 38-39 | 2044.0 | 154 | 67.8 | 53.7 | 51.9 | 3.6 |
| 40-41 | 1977.7 | 149 | 67.4 | 45.6 | 43.7 | 3.9 |
| 42-43 | 1844.9 | 139 | 69.6 | 45.7 | 43.5 | 1.4 |
| 44-45 | 1831.7 | 138 | 71.7 | 40.0 | 35.8 | 1.5 |
| 46-47 | 2004.2 | 151 | 71.2 | 39.0 | 34.6 | 1.3 |
| 48-49 | 1911.3 | 144 | 72.5 | 40.6 | 35.6 | 1.5 |
| 50-51 | 1805.1 | 136 | 73.4 | 39.8 | 34.6 | 1.5 |
| 52-53 | 1805.1 | 136 | 70.5 | 30.1 | 25.9 | 1.2 |
| 54 | 1858.2 | 140 | 71.7 | 25.3 | 21.5 | 1.4 |

## Appendix 3:6

The ME intake, food intake, egg weight, hen-day, hen-housed and non-hatching eggs from 35 to 54 weeks on feed HL

number of birds = 57

| Age weeks | Daily ME intake kJ/b | Daily food intake g/b | Egg weight g. | Hen-day production % | Hen-housed production % | Non-hatching eggs % |
|---|---|---|---|---|---|---|
| 36-37 | 1609.1 | 160 | 64.9 | 54.3 | 54.3 | 4.0 |
| 38-39 | 1578.9 | 157 | 66.5 | 53.9 | 53.9 | 3.1 |
| 40-41 | 1840.4 | 183 | 68.3 | 42.4 | 42.4 | 1.5 |
| 42-43 | 1719.7 | 171 | 69.1 | 52.2 | 51.8 | 2.3 |
| 44-45 | 1679.5 | 167 | 68.7 | 48.9 | 48.0 | 2.5 |
| 46-47 | 1749.9 | 174 | 70.5 | 45.8 | 45.0 | 1.4 |
| 48-49 | 1669.5 | 166 | 70.5 | 89.6 | 44.0 | 1.1 |
| 50-51 | 1609.1 | 160 | 72.7 | 41.8 | 41.8 | 0.6 |
| 52-53 | 1629.2 | 162 | 71.0 | 37.0 | 36.4 | 1.2 |
| 54 | 1578.9 | 157 | 72.7 | 33.2 | 32.6 | 0.8 |

## Appendix 3:7

The ME intake, feed intake, egg weight, hen-day, hen-housed and non-hatching eggs from 35 to 54 weeks on feed MR.

number of birds = 58

| Age weeks | Daily ME intake kJ/b | Daily feed intake g/b | Egg weight g. | Hen-day production % | Hen-housed production % | Non-hatching eggs % |
|---|---|---|---|---|---|---|
| 36-37 | 2149.7 | 181 | 64.1 | 52.6 | 52.6 | 3.6 |
| 38-39 | 2031.0 | 171 | 67.9 | 52.1 | 51.6 | 4.2 |
| 40-41 | 1852.8 | 156 | 68.1 | 40.5 | 39.8 | 1.2 |
| 42-43 | 1876.6 | 158 | 68.6 | 46.0 | 45.2 | 2.2 |
| 44-45 | 1864.7 | 157 | 69.7 | 44.6 | 43.9 | 1.6 |
| 46-47 | 1840.9 | 155 | 69.4 | 42.5 | 41.7 | 3.3 |
| 48-49 | 1829.1 | 154 | 70.3 | 35.5 | 34.6 | 2.9 |
| 50-51 | 1817.2 | 153 | 69.5 | 31.5 | 30.4 | 2.2 |
| 52-53 | 1781.6 | 150 | 70.3 | 31.5 | 30.4 | 2.2 |
| 54 | 1781.6 | 150 | 71.2 | 32.7 | 31.0 | 1.0 |

## Appendix 3:8

The ME intake, feed intake, egg weight, hen-day, hen-housed and non-hatching eggs from 35 to 54 weeks on feed RL.

number of birds = 61

| Age weeks | Daily ME intake kJ/b | Daily feed intake g/b | Egg weight g. | Hen-day production % | Hen-housed production % | Non-hatching eggs % |
|---|---|---|---|---|---|---|
| 36-37 | 1770.0 | 176 | 65.2 | 72.1 | 72.1 | 4.2 |
| 38-39 | 1689.6 | 168 | 66.9 | 71.1 | 71.1 | 4.6 |
| 40-41 | 1880.7 | 187 | 67.5 | 51.8 | 51.8 | 2.3 |
| 42-43 | 1749.9 | 174 | 68.8 | 67.8 | 67.8 | 1.7 |
| 44-45 | 1749.9 | 174 | 71.7 | 59.8 | 58.8 | 1.3 |
| 46-47 | 1780.1 | 177 | 70.4 | 60.4 | 59.4 | 1.6 |
| 48-49 | 1749.9 | 174 | 71.8 | 56.0 | 55.1 | 1.9 |
| 50-51 | 1659.4 | 165 | 71.0 | 51.8 | 51.8 | 1.4 |
| 52-53 | 1639.3 | 163 | 71.4 | 45.0 | 44.3 | 2.8 |
| 54 | 1599.1 | 159 | 71.0 | 44.3 | 43.6 | 3.1 |

## Appendix 3:9

The ME intake, food intake, egg weight, hen-day, hen-housed and non-hatching eggs from 35 to 54 weeks on RM.

number of birds = 63

| Age weeks | Daily ME intake kJ/b | Daily food intake g/b | Egg weight g. | Hen-day production % | Hen-housed production % | Non-hatching eggs % |
|---|---|---|---|---|---|---|
| 36-37 | 2319.7 | 190 | 65.1 | 76.4 | 76.4 | 2.9 |
| 38-39 | 2124.4 | 174 | 66.3 | 70.9 | 70.9 | 3.6 |
| 40-41 | 2112.2 | 173 | 66.3 | 63.4 | 63.4 | 1.4 |
| 42-43 | 2051.1 | 168 | 67.4 | 65.8 | 65.8 | 2.3 |
| 44-45 | 1977.9 | 162 | 68.4 | 60.5 | 60.5 | 1.3 |
| 46-47 | 2014.5 | 165 | 69.7 | 59.8 | 59.8 | 0.9 |
| 48-49 | 1892.4 | 155 | 70.1 | 60.1 | 60.1 | 0.7 |
| 50-51 | 1929.0 | 158 | 70.7 | 56.6 | 56.2 | 0.6 |
| 52-53 | 1953.4 | 160 | 70.2 | 56.1 | 56.1 | 1.0 |
| 54 | 1819.1 | 149 | 71.7 | 49.5 | 52.5 | 2.0 |

## Appendix 3:10

The ME intake, food intake, egg weight, hen-day, hen-housed and non-hatching eggs from 36 to 54 weeks on feed RH.

number of birds = 62

| Age weeks | Daily ME intake kJ/b | Daily food intake g/b | Egg weight g. | Hen-day production % | Hen-housed production % | Non-hatching eggs % |
|---|---|---|---|---|---|---|
| 36-37 | 2243.1 | 169 | 65.5 | 71.6 | 71.6 | 1.9 |
| 38-39 | 2137.0 | 161 | 67.4 | 70.1 | 68.9 | 2.5 |
| 40-41 | 2283.0 | 172 | 66.7 | 64.2 | 63.2 | 1.2 |
| 42-43 | 2203.3 | 166 | 68.4 | 65.6 | 64.6 | 1.7 |
| 44-45 | 2070.6 | 156 | 69.3 | 62.8 | 61.3 | 0.9 |
| 46-47 | 2030.8 | 153 | 70.6 | 56.8 | 55.0 | 0.6 |
| 48-49 | 1977.7 | 149 | 70.0 | 55.9 | 54.1 | 1.3 |
| 50-51 | 1884.8 | 142 | 72.0 | 52.1 | 50.4 | 2.0 |
| 52-53 | 1884.8 | 142 | 71.9 | 49.4 | 47.4 | 1.2 |
| 54 | 1884.8 | 142 | 71.9 | 38.0 | 36.2 | 1.7 |

## Appendix 3:11

The daily ME intake and feed intake from 22 to 54 weeks of age for *ad libitum* and regulated males.

| Age weeks | Ad libitum | | Regulated | |
|---|---|---|---|---|
| | Feed intake g/b | ME intake kJ/b | Feed intake g/b | ME intake kJ/b |
| 22-23 | 138 | 1684 | 103 | 1257 |
| 24-25 | 162 | 1976 | 127 | 1549 |
| 26-27 | 165 | 2013 | 148 | 1806 |
| 28-29 | 187 | 2281 | 161 | 1964 |
| 30-31 | 176 | 2147 | 161 | 1964 |
| 32-33 | 168 | 2050 | 176 | 2147 |
| 34-35 | 178 | 2172 | 181 | 2208 |
| 36-37 | 172 | 2098 | 181 | 2208 |
| 38-39 | 169 | 2062 | 171 | 2086 |
| 40-41 | 171 | 2086 | 156 | 1903 |
| 42-43 | 168 | 2053 | 158 | 1928 |
| 44-45 | 164 | 2001 | 157 | 1915 |
| 46-47 | 160 | 1952 | 155 | 1891 |
| 48-49 | 168 | 2050 | 154 | 1878 |
| 50-51 | 158 | 1928 | 153 | 1867 |
| 52-53 | 157 | 1915 | 150 | 1830 |
| 54 | 150 | 1830 | 150 | 1830 |

References Too Late To Be Included In Text

Byerly, T.C., Kessler, J.W., Gous, R.M. and Thomas, O.P. (1980).Feed requirements for egg production. Poult. Sci., 59: 2500-2507.

Foster, W.H. (1968). A fall in food consumption immediately prior to first egg. Brit.Poult.Sci., 9: 367-369.

Hanson, B.S. (1960). Common causes of poor hatchability. Agriculture, London 67: 308-314.

Hirsch, J. and Han, P.W. (1969). J. Lipid Res. 10: 77.

Hirsch, J. and Knittle, J.L. (1970). Federation Proc. 29: 1516.

Jhonson, P.R. and Hirsch, J. (1972). J.Lipid Res. 13: 2.

Jones, J.E., Hughes, B.L. and Barnett, B.D. (1976). Effect of feed regimes on body weight of turkey hens at 32 weeks of age and subsequent reproductive performance. Poult. Sci., 55: 1356-1360.

Knittle, J.L. and Hirsch, J. (1968). J. Clin. Invest. 47: 2091.

Lee, P.J.W., Gulliver, A.L. and Morris, T.R. (1971a). Aquantative analysis of the literature concerning the restricted feeding of growing pullets. Brit. Poult. Sci., 12: 413-437.

Macleod, M.G. and Shannon, D.W.F. (1978). Effect of feed intake regulation on the energy metabolism of laying hens. Brit. Poult. Sci., 19: 349-363.

Perry, E.J. (1960). The artificial insemination of farm animals, PP. 95-112.

Pfaff, F.E. and Austic, R.E. (1974). Influence of diet on adipose tissue accumulation in the pullet. Proc. Cornell Nutrition Confernce for Feed Manufacturers.

Scott, M.L. (1966). Factors modifying the practical vitamin requirements of poultry. Paper presented a Conference Organised by Research and Advisory Service (Agric.) Ltd, Reading, England.

Wilson, B.J. and Emmans, G.C. (1979). The animals relationship to its food.

In: Food intake regulation in poultry, Edit. Boorman, K.N. and Freeman, B.M., British Poultry Science Ltd. Edinburgh, Symposium, No., 14.

## REFERENCES


Ahmed, M.S. (1973). Effect of environmental temperature and dietary energy of feed intake in chickens. Ph.D. Thesis, University of Nebraska. Cited by Sykes (1979).

Aitken, J.R., Meyer, H.E.W., Griesbach and Merritt, E.S. (1963). Performance of heavy-type layers on a low energy ration, Can. J. Anim. Sci. 43: 290-293.

Auckland, J.N. (1970). Compensatory growth after under nutrition in market turkeys. Ph.D. Thesis, University of Reading.

Auckland, J.N. (1972). The effect of low protein feeding and realimentation on skeletal growth and proportions in two strains of male turkey. Brit. Poult. Sci., 13: 251-266.

Balnave, D. (1974). Biological factors affecting energy expenditure. In: Energy Requirements of Poultry. pp. 25-46. Edited by Morris, T.R. and Freeman, B.M. British Poultry Science Ltd., Edinburgh.

Beer, A.E. (1969). A review of the effects of nutritional deficiencies on hatchability. In: The Fertility and Hatchability of the Hens Egg, pp. 93-108. Edited by Carter T.C. and Freeman, B.M. Edinburgh, Oliver and Boyd.

Biellier, H.V., Paschang, R. and Funk, E.M. (1961). Effect of depth of artificial insemination on fertility of broad breasted bronze turkey hens. Poult. Sci., 40: 1379.

Blair, R. (1972). Feed restriction in breeding birds. Feedstuffs, Minneap., 44 (10): 36-38.

Blair, R., MacCowan, M.M. and Bolton, W. (1976). Effects of food regulation during the growing and laying stages on the productivity of broiler breeders, Brit. Poult. Sci., 17: 215-223.

Blaxter, K. (1979). Discussion paper. Use of Energy For Maintenance and Growth. The Rowett Research Institute, Bucksburn, Aberdeen, Scotland.

Boone, M.A., Hughes, B.L. and Barnett, B.D. (1967). Starvation and its effect on semen quality. Poult. Sci., 46: 1235.

Boorman, K.N. Regulation of protein and amino acid intake. In: Food Intake Regulation in Poultry, pp. 87-126, Edited by Boor, K.N. and Freeman, B.M. British Poultry Science Ltd., Edinburgh, 1979.

Booth, D.A. (1979). Feeding control systems within animals. In: Food Intake Regulation in Poultry, pp. 13-62, Edit. Boorman, K.N. and Freeman, B.M., British Poultry Science Ltd., Edinburgh, 1979.

Brobeck, J.R. (1960). Food and temperature. Recent prog. Horm. Res. 16: 439-466.

Burmester, B.R. and Card, L.E. (1939). The effect of restricted feeding time on food intake, body weight and body production. Poult. Sci. 18: 402.

Bushong, R.D. (1980). Feeding broiler breeders. Poult. Digest. pp.116-117.

Calvert, G.G. (1967). Studies on hatchability of fertile eggs from hens receiving a linoleic acid deficient diet. Poult. Sci., 17: 224-226.

Capretta, P.J. (1961). An experimental modification of food preference in chickens. J. Comp. Physiol. Psychol., 54: 238-242.

Chambers, J.R., Gavora, J.S. and Fortin, A. (1978). Genetic changes in meat-type chickens in the last twenty years. Animal Research Institute, Ottawa, Ontario, Canada.

Chaney, L.W. and Fuller, H.L. (1975). The relation of obesity to egg production in broiler breeders. Poult. Sci. 54: 200-208.

Cherry, J.A. (1979). Adaptation in food intake after changes in dietary energy. In: Food Intake Regulation In Poultry, Edited by Boorman, K.N. and Freeman, B.N. British Poultry Science Ltd., Edinburgh, pp. 77086.

Combs, G.F. (1968). Amino acid requirements of broiler and laying hens. pp. 86-96 in proc. Maryland Nutr. Conf.

Cooper, D.M. and Rowell, J.G. (1957). Laboratory prediction of fertilising capacity of cock semen. Poult. Sci., 36: 284-285.

Cooper, D.M. and Rowell, J.G. (1958). Relations between fertility, embryonic survival and some semen characteristics in the chicken. Poult. Sci. 37: 699-707.

Cooper, D.M. (1969). The use of artificial insemination in poultry breeding, the evaluation of semen and semen dilution and storage. In: The Fertility and Hatchability of the Hens Egg. pp. 31-44. Edit. Carter, T.C. and Freeman, B.M. Oliver and Boyd, Edinburgh.

Couch, J.R. and Trammell, J.H. (1970). Effect of feeding low lysine starters and developers on growth, sexual maturity and subsequent performance of broiler breeder pullets. Brit. Poult. Sci. 11:489-499.

Costa, M.S. (1981). Broiler growth rate control is management tool, feed stuffs.

Cunningham, D.C. and Morrison, N.D. (1977). Dietary energy and fat content as factors in the nutrition of developing egg strain pullets and young hens. Poult. Sci., 56: 1405-1416.

Cuthbertson, D. (1969). Requirements for energy. In: Nutrition of Animals of Agricultural Importance. Part 2. Edit. by Cuthbertson, D. pages 1096-1135.

Davis, R.H., Hassan, O.E.M. and Sykes, A.H. (1972). The adaptation of energy utilization in the laying hen to warm and cool ambient temperatures. J. Agric. Sci., Camb., 79: 363-369.

Deaton, J.W., Kubena, L.F., Chen, T.C. and Reece, F.N. (1974). Factors influencing the quantity of abdominal fat in broilers. 2 - Cage Versus Floor Rearing. Poult. Sci. 53: 574-576.

Decroote, G. (1974). Utilisation of metabolisable energy. In: Energy requirements of poultry. Edit. Morris, T.R. and Freeman, B.H. pp. 113-133. Brit. Poult. Sci. Ltd. Edinburgh.

Donaldson, W.E., Combs, G.F., Romeser and Supplee, (1955). Body composition, energy intake, feed efficiency growth rate and feather condition of growing chicks as influenced by the calorie/ protein ratio of the ration. Poult. Sci. 34: 1190.

Edwards, H.M. (1967). Studies of essential fatty acid deficiency of the growing domestic cock. Poult. Sci. 46: 1128-1133.

Emmans, G.C. (1974). The effects of temperature on the performance of laying hens. In: Energy Requirements of Poultry, pp.79-90. Edit. Morris, T.R. and Freeman, B.M. Edinburgh, British Poultry Science Ltd.

Evans, A.J. (1977). The growth of fat. In: Growth and Poultry Meat Production, pp. 26-64. Edited by Boorman K.N. and Wilson, B.J. British Poultry Science Ltd., Edinburgh, 1977.

Ewart, J. (1981). Breeding better poultry. In: Scottish Agricultural Colleges Poultry Conference, Edinburgh.

Farjo, G.Y. (1981). Studies on the factors affecting food and energy intake of brown egg layers. Thesis M.Sc. pp: 73-94.

Fraps, G.S. (1946). Composition and productive energy of poultry feeds and rations. Bulletin 678: 5-37.

Farrel, D.J. (1974). General principles and assumptions of calorimetry. In: Energy Requirements of Poultry, pp. 1-24. Edit. Morris, T.R. and Freeman, B.M. Edinburgh, British Poultry Science Ltd.

Fuller, H. (1977). Feeding the growing pullets for subsequent production pp. 102-110. In: Proceedings Georgia Nutrition Conference for the Feed Industry. University of Georgia.

Fuller, H.L., Potter, D.K. and Kirkland, W.M. (1970). Effects of age at maturity and obesity on reproductive performance of broiler breeder pullets. Feedstuffs, Minneap., 42 (5), 28-29, 34-35.

Gentle, M.J. (1979). Sensory control of food intake. In: Food Intake Regulation in Poultry, pp. 259-273. Edited by Boorman, K.N. and Freeman, B.M. British Poultry Science Ltd., Edinburgh, 1979.

Goldspink, G. (1977). The growth of muscles. In: Growth and Poultry Meat Production, pp. 13-28. Edited by Boorman, K.N. and Wilson, B.J. British Poultry Science Ltd., Edinburgh, 1977.

Gous, R.M., Byerly, T.C., Thomas, O.P. and Kessler, J.W. (1978). A partition equation to predict food and energy intake by laying hens. Worlds poultry Congross Brasil. Vol. II-AB, pp: 1-8.

Greenwood, M.R.C. and Hirsch, J. (1974). Postnatal development of a dipocyte cellularity in the normal rat. J. Lipid Res., 15: 474-483.

Hamilton, C.L. (1965). Control of food intake. In: "Physiological controls and regulations". Eds. Yamamoto and Brobeck. Saunders, London.

Harms, R.H., Damron, B.L. and Wilson, H.R. (1968). Performance of broiler breeder pullets as influenced by composition of grower and layer diets. Brit. Poult. Sci., 9: 359-366.

Harms, R.H., Voitle, R.A. and Wilson, H.R.O. (1979). Performance of broiler breeder pullets in various grower programs, Nutrition Reports Internation 20(4) 561-566 Dept. Poultry Science, Florida. Agriculture Experiment Station, Gainesville, Fla. 32611, U.S.A.

Harper, J.A. (1964). Calcium in grit consumed by hen pheasants in East Central Illinois. J. Wildlife Management, 28: 264-270.

Harvey, G.R. (1971). Physiological mechanisms for the regulation of energy balance, Proc. Nut. Soc. 30, 109.

Heywang, B.T. (1940). The effect of restricted feed intake on egg weight egg production and body weight. Poult. Sci. 19: 29-34.

Hill, F.W. (1969). Poultry nutrition and nutrient requirements. In: Nutrition of Animals of Agricultural Importance. Part 2. Edit. by Cuthbertson, D. pages 1137-1206.

Hopkins, J.R. (1974). The evaluation of metabolisable energy values of poultry diets for experimental purposes. ADAS Science Arm. Report. 1974, pp. 124-128, HMSO, London.

Howes, J.R. and Cottier, G.J. (1964). A comparison of various methods of delaying maturity in heavy-type breeders. Poult. Sci. 43: 1330.

Hughes, B.L. (1978). Efficiency of producing hatching eggs via artificial insemination and natural mating of broiler breeder pullets. Poult. Sci. 57: 534-537.

Hughes, B.D. (1979). Appetites for specific nutrients In: Food Intake Regulation in Poultry pp. 141-169 Edit. Boorman K.N. and Freeman, B.M. British Poultry Science Ltd., Edinburgh, 1979.

Ingram, D.R., Wilson, H.R. and Harms, R.H. (1979). Restricted feeding of broiler breeders. Poult. Sci. 58: 1016.

Isaacks, R.E., Reid, B.L., Davies, R.E., Quisenberry, J.H. and Couch, J.R. (1960). Restricted feeding of broiler breeder type replacement stock. Poult. Sci., 39: 339-346.

Jaap, R.G. (1970). Selection for body size and reproductive fitness chicken. British Poultry Breeders Roundtable Conference, 17th-19th November, 1970.

Jacobs, J.L. and Scott, M.L. (1957). Factors mediating food and liquid intake in chickens. I. Studies on preference for sucrose or saccharine solution. Poult. Sci. 36: 8-15.

Jensen, L.S. (1977). Dietary energy studies with laying hens. Proc. Md. Nutr. Conf., 40-46.

Kennedy, G.C. (1953). The role of depot fat in the hypothalamtic control of food intake in the rat. proc. R. Soc. (London), B140: 578-592.

Kubena, L.F., Deaton, J.W., Chen, T.C. and Reece, F.N. (1974). Factors influencing the quantity of abdominal fat in broilers-1-Rearing temperature, sex, age or weight, and dietary choline chloride and inositol supplementation. Poult. Sci. 53: 211-214.

Kuczerpa, A.V. (1967). Analytical chemistry, 39: 11-97.

Lake, D.E. (1969). Factors affecting fertility. In: The Fertility and Hatchability of the Hen's Egg. edited by Carter, T.C. and Freeman, B.M. Oliver and Boyd, Edinburgh.

Lamming, G.E. (1969). Nutrition and reproduction. In: Nutrition of Animals of Agricultural Importance, part 1. Edited by Cuthbertson, S.D. pp. 411-455.

Laughlin, K.F. (1975). The bioenergetics of the tufted duck (Aythya Fuligula) Ph.D. Thesis, University of Stirling.

Lee, P.J.W., Gulliver, A.L. and Morris, T.R. (1971). Restricted feeding of broiler breeder pullets during rearing period and its effect on productivity and breeding. Brit. Poult. Sci. 12: 499-510.

Lepkovsky, S. and Furuta, F. (1971). The role of homeostasis in adipose tissues upon the regulation of food intake of White Leghorn cockerels. Poult. Sci., 50: 573-577.

Luther, L.W., Abbot, W.W. and Couch, J.R. (1976). Low lysine, low protein and skip-a-day restriction of summer and winter reared broiler breeder pullets. Poult. Sci. 55: 2240-2247.

Macleod, M.G. and Shannon, D.W.F. (1978). Effects of food intake regulation on the energy metabolism of laying hens. Brit. Poult. Sci. 19: 349-363.

Marini, P.J. and Goodman (1969). Semen characteristics as influenced by selection for divergent growth rate in chickens. Poult. Sci. 48: 859-865.

Mayer, J. (1953). Genetic, tramatic and environmental factors in the etiology of obesity. Physiol. Rev. 33: 472-508.

McCance, R.A. (1977). Thoughts on the physiology of growth. In: Growth and Poultry Meat Production, pp. 3-11. Edited by Boorman, K.N. and Wilson, B.J. British Poultry Science Ltd., Edinburgh, 1977.

McDaniel, G.R. (1973). The production of broiler breeder hatching eggs in cages. Poult. Sci. 53: 1954.

McDaniel, G.R. (1974). The production of broiler hatching eggs in cages. Poult. Sci. 53: 1954.

McDaniel, G.R. (1981). Overweight breeders: Still Learner diet? Broiler Industry 44: 70-74.

McDaniel, G.R., Roland, D.A. and Coleman, M.A. (1979). The effect of egg shell quality on hatchability and embryonic mortality. Poult. Sci. 58: 10-13.

McGinnis, J. and Dronawat, N. (1967). Do laying hens need all of the feed they consume? Feedstuffs, 39 (24): 18.

Mehring, A.L. (1965). Effect of level of dietary calcium on broiler type laying chickens. Poult. Sci. 44: 240-248.

Miller, W.S. (1974). The determination of metabolisable energy. In: Energy Requirement of Poultry, Pages 91-112. Edit. Morris, T.R. and Freeman, B.M., Edinburgh, Brit. Poult. Sci. Ltd.

Mitchell, (1972). Micro determination of nitrogen in plant tissues. Journal A.O.A.C., Vol: 55, No. 1, pages 1-3.

Morris, T.R. (1968). The effect of dietary energy on voluntary calorie intake of laying birds. Brit. Poult. Sci., 9: 285-295.

Morris, B.A. and Taylor, T.G. (1967). The daily food consumption of laying hens in relation to egg formation. Brit. Poult. Sci. 8: 251-257.

Morris, T.R. and Wethli, E. (1978). The tryptophan requirements of young laying pullets. Brit. Poult. Sci., 19: 455-466.

Osbourn, D.F. and Wilson, P.N. (1960). Effects of different patterns of allocation of a restricted quantity of food upon the growth and development of cockerels. J. Agric. Sci. Camb., 54: 276-289.

Pearson, R.A. and Herron, K.M. (1980). Feeding standards during lay and reproductive performance of broiler breeders. Brit. Poult. Sci., 21: 171-181.

Pearson, R.A. and Herron, K.M. (1981). Effects of energy and protein allowances during lay on the reproductive performance of broiler breeder hens. Brit. Poult. Sci. 22: 227-239.

Pearson, R.A. and Shannon, D.W.F. (1979). Controlled feeding systems In: Food Intake Regulation in Poultry. Edit. by Boorman, K.N. and Freeman, B.M. Brit. Poult. Sci. Ltd., Edinburgh, pp. 365-390.

Perry E.J.(1960) The artificial insemination of farm animals,PP.95-112 .

Peters, Davy and Griffin, (1972). The effect of rearing regime on broiler breeder productivity. World Poultry Science Association. 1972, pp. 219-228, Sydney Univ., Australia.

Polin, D. and Wolford, J.H. (1972). The effect of meal eating on egg production and body weight of White Leghorn chickens. Poult. Sci. 51: 1109-1118.

Powell, T.S., Douglas, C.R., Stonerock, R.H. and Harms, R.H. (1972). Feed intake of hens fed various levels of energy from feed and/or sucrose-water. Poult. Sci., 51: 1851.

Powell, T.S. and Gehle, K.H. (1977). Evaluation of dietary tryptophane levels as a restriction method for broiler breeder pullets. Poult. Sci. 56: 407-414.

Proudfoot, F.G. (1979). Effect of rearing and adult feed restriction and photoperiod regimes on the performance of four meat parent chicken genotypes. Can. J. Anim. Sci. 59: 749-759.

Pym, R.A.E. and Dillon, J.F. (1974). Restricted food intake and reproductive performance of broiler breeder pullets. British Poult. Sci., 15: 245-259.

Quaade, F. (1962). On the "glucostatic" theory of appetite regulation I: Capillovenous glucose differences in normal, obese and diabetic persons during hunger and satiety. Am. J. Med. Sci., 61: 427-436.

Scharrer, E. and Geary, N. (1979). Regulation of food intake with special reference to monogastric animals, pp. 1-8 - 30th Annual Meeting British Society of Animal Production.

Schumaier, G. and Mcginnis, J. (1969). Effect of a limited time feeding system on reproductive performance of heavy breed pullets. Poult. Sci. 48: 949-953.

Scott, M.I. (1975). Nutrient requirement of chickens and turkeys. Feedstuffs, Minneapolis, 47 (38): 58-60.

Sherwood, D.H., Caskey, C.D., Krautmann, B.A., Van Warner, M.C., Smith, S.B. and Ward, R.E. (1964). Management and feeding of meat-type breeder chickens, Poult. Sci. 43: 1272-1278.

Sibbald, I.R. (1981). Energy values of feeding fats for poultry. Feedstuffs, 53: No. 23, pp. 19-20.

Singsen, E.P., Matterson, L.D., Tiustohowitz, J. and Potter, L.M. (1958). The effect of energy intake and controlled feeding on the performance of broiler type breeder hens. Proc. A.F.M.A. Nutrition Coun.

Singsen, E.P., Matterson, L.D., Tinstohowitz, J. and Potter, L.M. (1959). The effect of controlled feeding, energy intake, and type of diet on the performance of heavy-type laying hens. Storrs Agric. Exp. Sta. Bull. 346: 1-14.

Smith, W.K. (1981). The efficiency of the ovary and oviduct in laying and broiler breeder hens. WPSA U.K. Branch Spring Seminar, London, April 10.

Smith, W.K. (1981). Poultry housing problems in the tropics and sub-tropics. In: Environmental Aspects of Housing For Animal Production. Edit. by Clark, J.A. University of Nottingham.

Smith, C.J.V. and Baranowski-Kish (1979). Mechanisms of regulation of energy intake poultry. In: Food Intake Regulation in Poultry. Edited by Boorman, K.N. and Freeman, B.M. British Poultry Science Ltd., Edinburgh, pp. 63-76.

Snetsinger, D.C. and Zimmermann, R.A. (1974). Limiting the energy intake of laying hens. In: Energy Requirements of Poultry, pp. 185-199. Edit. Morris, T.R. and Freeman, B.M. Edinburgh, British Poultry Science Ltd.

Spillane, R.A. (1973). An forces Taluntais-Research report. Analytical Advisory Services, pages 114-115.

Standlee, W.J., Strother, A.S., Creger, C.R. and Couch, J.R., (1963). Feeding and management of broiler strain breeder hens. Poult. Sci. 42: 452-457.

Summers, J.D., Pepper, W.F., Slinger, S.J. and McConachie, J.D. (1967). Feeding meat type poultry and breeders, Poult. Sci. 46: 1158-1164.

Swanson, E.W. (1977). Effects of level of nutrition on growth, reproduction and lactation of dairy heifers. In: Proceeding Georgia Nutrition Conference For the Feed Industry, pp. 125-137.

Sykes, A.H. (1977). Nutrition-environment interaction in poultry. In: Nutrition and the Climatic Environment, pp. 17-29. Edited by Haresign, W., Swan, H. and Lewis, D. London, Butterworths.

Sykes, A.H. (1979). Environment temperature and energy balance in the laying hen. In: Food Intake Regulation In Poultry, pp. 207-229. Edited by Boorman, K.N. and Freeman, B.M. British Poultry Science Ltd., Edinburgh, 1979.

Tullet, S.G., (1981). Theoretical and practical aspects of egg shell porosity, Presented at the 4th Technical Turkey Conference, Lincolnshire College of Agriculture, April 23rd and 24th, 1981 pp: 24-29.

Van den Eynden, G. (1978). Genetica E Produca o DE Frangos, no ano 2000 pp: 64 In: XVI Worlds Poultry Congress, Rio de Janeiro, Brasil, 1978.

Vankrey, H.P. and Siegel, P.B. (1976). A revised artificial insemination schedule for broiler breeder hens. Poult. Sci. 55: 725-728.

Van Wambeke, F. (1977). Food regulation of broiler breeder stock. In: 1st European Symposium on Poultry Nutrition, pp. 53-64. Edit. Sørensen, L.D. Denmark, working group No. 2, European Federation of W.P.S.A. and Danish branch of W.P.S.A.

Van Wambeke, F. (1981). Nutritional regimes for heavy broiler breeders. Presented at 3rd European Poultry Nutrition Symposium, Edinburgh, October, 1981.

Voitle, R.A., Wilson, H.R. and Harms, R.H. (1974). Comparison of various methods of nutrient restriction for delaying sexual maturity in broiler breeder hens. Nutr. Rept. Int. 9: 149-157 (1974).

Waldroup, P.W., Bussell, W.D. and Jhosnson, Z.B. (1976). Attempts to control body weight gains of growing broiler breeder females with high fibre diets. Poult. Sci. 55: 1118-1120.

Waldroup, P.W. and Hazan, K.R. (1976). A comparison of the daily energy needs of the normal and dwarf broiler breeder hens. Poult. Sci. 55: 1383-1393.

Waldroup, P.W., William, O., Bussell, W.D. and Zelpha, B, Jhonson, (1976). Attempts to control body weight gains of growing broiler breeder females with high fiber diets, Poult. Sci. 55: 1118-1120.

Watson, N.A. (1975). Reproductive activity of broiler breeder hens subjected to restricted feeding during rearing. Brit. Poult. Sci. 16: 259-262.

Watson, N. and Payne, C.G. (1972). Nutrient allowances for broiler breeding stock, in proceedings 1972, Australasiam poultry science convention, Auckland, New Zealand, World poultry science association, Sydney, In: Nutrition Abstract 43: 611, 1973.

Wenk, C. and Van Es, A.J.H. (1976). Energy metabolism of growing chickens as related to their physical activity. 7th Symp. Energy metabolism of farm animals. pp. 189-192.

Widdowson, E.M. and McCance, R.A. (1960). Some effects of accelerating growth. 1. General somatic development. Proc. R. Soc., B. 152: 188-206.

Widdowson, E.M. and McCance, R.A. (1963). The effect of finite periods of undernutrition at different ages on the composition and subsequent development of the rat. Proc. R. Soc. B. 158: 329-342.

Wilson, B.J. (1977). Growth Curves: Their analysis and use. In: Growth and Poultry Meat Production, pp. 89-115. Edited by Boorman, K.N. and Wilson, B.J. British Poultry Science Ltd., Edinburgh, 1977.

Wilson, H.R. and Harms, R.H. (1971). Male to female ratios for broiler type and egg production-type breeders. Brit. Poult. Sci. 12: 327-331.

Wilson, H.R. and Persons, J.N., Rowland, L.O. and Harms, R.H. (1969). Reproduction in White Leghorn males fed various levels of dietary calcium. Poult. Sci. 48: 789.

Wise, D.R. (1970). Comparison of the skeletal systems of growing broiler and laying strain chickens. Brit. Poult. Sci., 11: 333-339.

Wise, D.R. (1977). The growth of the skeleton. In: Growth and Poultry Meat Production, pp. 65-78. Edited by Boorman, K.N. and Wilson, B.J. British Poultry Science Ltd., Edinburgh, 1977.

Yule, W.J. and Fuelling, D.E. (1979). Effect of different patterns of food restriction from different ages on growth and efficiency of broilers. Brit. Poult. Sci. (1979) 20(3) 273-279.