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SOME ECONOMIC AND NUTRITIONAL ASPECTS OF DIFFERENT GROWER AND LAYER RATIONS IN EGG PRODUCTION

A Thesis presented in partial fulfilment
of the requirements for the degree
MASTER OF AGRICULTURAL SCIENCE
in Animal Science
at
Massey University

STEPHEN EDGAR JAMES SWAN

1970

A C K N O W L E D G E M E N T S

I am grateful for the supervision of both Mr. M. R. Patchell and Professor A. R. Frampton in this thesis.

I am also indebted to Professor R. J. Townsley for his advice and constructive comment.

Thanks are also due to the Poultry Research Centre Staff for help with data collection; Mrs. E. Self for the competent typing; and my wife for her encouragement.

PREFACE

Chapter One of this thesis presents background information on the rearing of laying pullets and describes an experiment evaluating a series of rearing rations (with continuous variation of the levels of three major ingredients) in terms of overall profitability.

Chapter Two looks particularly at the layer phase, and considers possibilities of reducing feed costs in this phase. An experiment evaluates a series of layer rations (with continuous variation of the levels of three major ingredients) in terms of overall profitability.

The final chapter presents an appraisal of the methods available for economic analysis of livestock rations, and discusses the problems associated with their application in layer nutrition. A profit function is suggested as a means of economic evaluation.

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INTRODUCTION.

In New Zealand, the modern commercial egg producer faces a cost structure in which feed costs are 50 to 65% of his variable costs. Therefore any economically oriented research in the field of poultry husbandry should be aimed at reducing this feed cost to the producer, while maintaining egg revenue.

There are three main approaches to the solution of this problem:

(1) Reduction of the cost of the ration by the inclusion of cheaper ingredients without significantly altering the total amount of feed consumed.

(2) Reduction of the feed cost by altering a parameter (such as time) which reduces the total amount of feed consumed.

(3) Reduction in feed cost by genetic selection for birds with a better feed conversion efficiency.

This thesis examines the first two of these proposals applied to feed cost reduction in the rearing and the laying phase of the egg-producing hen.

A detailed knowledge of poultry nutrition is required before the problem of feed cost reduction can be investigated. More is known about poultry nutrition than other livestock nutrition, and there are several reasons for this:

(1) The small unit cost per bird for experiments.

(2) The degree of technological control of the birds environment.

(3) Poultry are simple-stomached animals.

(4) The production period for poultry is relatively short.

(5) Poultry is important in the economy of Britain and the U.S.A.

It is important to know how much of each of the basic nutrients is required by the bird, and then at what levels and availabilities these nutrients are present in dietary feedstuffs. These nutrients have physiological effects on intake regulation, and there exist numerous interaction effects between different nutrients, and also between similar nutrients from different feed scurces. Thus there is the question of whether to consider the problem in terms of basic nutrients, or feedstuff ingredients.

Nutritionists generally aim to achieve a diet supporting optimal physiological growth and development, or even maximum growth rate. This aim is often not compatable with an economic or profit-oriented position. The confusion between economic and physiological optima is common in many fields of research.

In the search for a solution to the problem of feed cost reduction, one requires a method of production analysis within which the nutritional knowledge may be used to the best advantage, which also attaches importance to economic considerations. The economic analysis of livestock rations has received closer study in recent years.

Livestock products can be divided into two categories on the basis of the biological processes involved:

(1) Those products resulting from animal growth, e.g. meat.

(2) Those products which are manufactured or secreted by the animal, e.g. milk and eggs.

This thesis is concerned with the second category - egg production.

The response curve or production function is considered to be a useful method for economically oriented research as it is very suitable for marginal price analysis using calculus methods to find constrained optima. Response studies can be approached by considering the variable inputs as chemical nutrients, or actual raw ingredients. Both approaches have been used in the past to derive production functions.

A production function is an expression of a production situation as a mathematical model, and can represent the output or yield response to continuously changing levels of input(s). (Heady and Dillon 1961). It is purely a physical concept and can be considered completely separate from any economic or price analysis. However, the main use and development of the production function has been in the field of economics.

The continuous response curve, as the production function curve is often named, differs from the classical or discrete approach in the analysis of experimental results. The usual object of the discrete approach to experimentation is the establishment of statistical significance (or otherwise) between the yield or output level of several discrete treatments or input levels. Response, or production function analysis, often involves the use of a greater number of levels of inputs and outputs and thus may have a higher experimental cost. However, the cost per unit of useful management information obtained is generally much less for the response curve design.

The"ideal" nutritional production function relates chemicals available in rations to those required in the manufacture of the egg product. This involves a knowledge of cell mechanisms, digestive processes, nutrient absorption and transport, together with the various enzymes and hormones controlling these reactions. This detailed nutritional knowledge is not known and may not be required as long as an accurate and repeatable production function can be estimated using the more easily measured inputs of either nutrients or feedstuffs. With either approach to livestock ration analysis, there is equal difficulty in interpretation of results because of the large biological variation inherent in livestock and plant products.

This thesis is an example of the necessity for the combination of knowledge from two widely different disciplines : poultry nutrition and economics. Interdisciplinary cooperation in research is very important in such projects and this has become clear particularly in the analysis of the experiments dealt with in this thesis. Some appreciation of the economic problems involved must be gained by the nutritionist (and vice versa for the economist) for successful co-operation in this type of research.

CHAPTER ONE

GROWTH AND DEVELOPMENT OF LAYING PULLETS

1.1 The rearing of the chicken differs in many important aspects from the typical picture with larger domestic animals:

(1) They are incubated artifically and reared in large numbers in intensive conditions over the first four weeks after hatching. Subsequently they may be reared extensively on range, but the modern system is to continue the intensive system over the whole of the rearing period.

(2) During the initial 4 weeks brooding phase, the chick is partly poikelothermic and does not reach a fully homeothermic condition until 14 days after hatching. They therefore, must be provided with a source of heat, and this continued to 4 weeks or longer if external environmental temperatures are low. Research over the years (Barrott and Pringle 1945, Sainsbury and Osbaldiston 1963, Charles 1970) has defined the optimum conditions of temperature, light (Morris 1966, 1967a, Morris and Fox 1958, 1960) and ventilation, both over the brooding period and the subsequent growing phase. The trend towards intensive systems has resulted in a high degree of control of the general environment for optimum performance.

(3) The growing phase extends from 4 weeks to an arbitrary point varying from 20 to 25 weeks depending on breed and strain. Usually this point is 7 to 10 days before the first egg from the flock is expected to be laid, it being considered desirable to shift the growing birds to the laying quarters before the event of lay. Growth of the body size continues for a period after the onset of lay until mature body size is reached at 32 to 48 weeks of age depending on breed and strain.

(4) In normal commercial practice, the growing phase terminates with the shifting of the stock to laying quarters at 19 to 25 weeks of age. This is usually achieved by delaying sexual maturity until about this time by controlling the light pattern or photoperiod, which partly determines the rate of sexual maturity.

(5) Although a given strain may, with a particular light pattern, be induced to commence laying at 16 weeks of age, the long period between this time and attainment of mature body size, results in an extended period with egg size being depressed - a natural result of attempting to use the available nutrients for two purposes: growth to mature size, and egg production. Small sized eggs yield a low monetary return. Also, the pullet laying at 16 weeks of age is not in an optimum condition for laying and there is a high mortality from prolapse of the uterus and associated egg peritonitis infections.

(6) Delaying sexual maturity is also aided by nutritional means. Limited feeding time, and low nutrient concentrations reduce the cost of the rearing ration, and also delay the onset of lay until a more mature body size is reached. Both light and nutritional methods will be discussed in greater detail under sections 1.2 and 1.4 respectively.

(7) Being simple stomached animals, usually reared intensively, a completely formulated diet has to be provided, with the correct nutrient levels commensurate with economic development in relation to subsequent production.

(8) The housing and management systems used in the brooding and growing phases differ widely: free range on grass, deep litter wood shavings, and cages of various shapes and sizes.

(9) With high stock concentration, disease control is particularly important to maintain low levels of mortality.

(10) The numbers involved in any one batch or farm run into thousands at a time so that physical space and weight of feedstuffs consumed, manure to be removed and bird weight to be shifted at housing time, is considerable. There is no such thing as "driving mobs of poultry" - they must be handled singly at every stage.

(11) The aim in the rearing phase is to produce a bird capable of laying a large number of eggs of an economically large size. Income from egg production is determined mostly by egg number, but egg weight can also become important depending on the body size of the breed or strain concerned. (Nordskog 1959)

1.2 Delaying Sexual Maturity.

Of the many important management factors contributing to successful rearing, the aspect of most relevance to this thesis concerns the control of sexual maturity.

As has already been mentioned, the object in delaying sexual maturity is to allow body size (as indicated by skeletal frame and condition, rather than body weight alone) to reach a stage on the growth "curve" such that there is an optimum economic delay between the commencement of lay and the point where egg size attains a weight sufficient for an increasingly significant proportion of eggs laid to qualify for the higher priced grades.

The factors determining the economically optimum age at sexual maturity are:

(1) The strain or breed growth characteristics.

(2) The price differential of the different egg grades.

(3) The price of the rearing ration.

(4) The price of the layer ration.

(5) The labour, and building depreciation costs associated with the different objects of a layer versus a growing house. (A laying house involves the use of more expensive equipment.)

(6) The time factor associated with a yearly cycle of farm operations.

The Role of Light in Sexual Maturation.

The physiological mechanism which determines the rate of sexual maturity is activated by light of a certain wavelength, intensity, and photoperiod, falling on the eye of the bird. This stimulus works through the optic nerve, and if the nutritional status of the body is of a certain minimum standard, then the pituitary gland begins to secrete the sex hormones.

In conditions of complete darkness, pullets will still reach maturity and lay eggs (though usually at a reduced rate) so the photoperiod-light stimulus only modifies an already existing "physiological" clock.

Under natural jungle conditions the wild fowl from which the domestic fowl evolved, only lays one or two clutches of ten to twelve eggs each, per year. This occurs in spring or early September in the Southern Hemisphere. Thus the growing chickens which hatch from these eggs are exposed to an increasing daylength or photoperiod until mid-December. From this day onwards, the birds are exposed to a diminishing photoperiod and this has a delaying effect on their rate of sexual maturity which occurs between late summer and early winter. It is not until August that the mating urge comes upon the flock, and by this time the pullets are about 11 months old. For the purposes of commercial egg production, one cannot afford this delay before egg production commences. While genetic selection has increased the number of eggs that each hen can lay in a year, manipulation of the light pattern can hasten or delay the actual onset of lay.

Morris et al (1958, 1960) describe methods for delaying sexual maturity by exposing growing birds to a decreasing photoperiod. The same effect can be achieved by a constant but low level photoperiod such as 10 hours of light per day (Morris 1966, 1967a)(used at the Poultry Research Centre (P.R.C.)). If growing birds are exposed to an increasing photoperiod during the rearing phase then maturity will be hastened, and the bird will begin to lay before body size is sufficient to enable an economic-physiological balance between egg production rate and egg size. Egg size will remain uneconomically small for a long period.

Even this size produces such a strain on the bird, that prolapse of the uterus can occur.

It may be useful to further discuss the concept of body size. Body weight is a function of the skeletal framework and the amount of muscle and fat laid on this frame-work. Obviously then, body weight on its own is not a good indication of body size or body preparedness to commence lay. Some measure of the skeletal frame-work such as shank length (which is highly correlated to total skeletal size and thus body size) may be more useful. This concept is discussed in more detail in section 1.5.

Nordskog and Briggs (1967) found that on a genetic scale a lower body weight than the mean produced an early sexual maturity and increased egg numbers, e.g. the White Leghorn is inherently lighter than the New Hampshire breed.

On an environmental scale, a lower body weight than the mean was found to be associated with delayed sexual maturity and reduced egg production, e.g. a small, runty White Leghorn takes longer to mature and lays fewer eggs than its heavier, possibly more healthy, sibling.

Birds heavier than the mean on an environmental scale are also poor producers, probably because of excess fat deposition.

The optimum body size for egg production commencement is thus the result of a compromise between physiological and economic factors.

Though light is the easiest and cheapest method of delaying sexual maturity, there are other methods which act through the same hormone network, such as high iodine levels in the diet (Wilson, Arrington, Harms 1968), and restriction of essential dietary nutrients which affect the state of body preparedness for the gonadotrophic hormones to act upon. (See section 1.4)

Diets low in essential nutrients are generally cheaper. So the primary concern with such rations is not that they delay sexual maturity, but that they reduce the cost of rearing.

Another Approach:

Delaying sexual maturity may be attacking the problem of optimum body size from the wrong angle. Research in genetics and nutrition may eventually enable us to produce a mature bird of optimum body size at 16 weeks of age. This may require a good quality ration, but the extra expense of this would be offset by the shorter growing period.

The genetic change required is for a faster growing bird - like the broiler or meat chicken which already exists today. The problem to be overcome is a negative genetic correlation between rapid growth rate and egg production. Broiler stock has a rapid growth rate and an associated poor egg production.

To overcome this problem would require major changes in the genetic make-up of the bird. Until then, we continue to use light and nutritional means to delay sexual maturity. Before a discussion on the extent to which different nutrient restrictions will delay maturity, it is pertinent to look at the nutritive requirements of growing pullets.

1.3 The Nutritive Requirements of Growing Pullets.

As a result of the intensive technological advances in the knowledge of poultry nutrition, much is known about the nutrient requirements of poultry, and the nutrient contents of a large number of feedstuffs. This knowledge is in the form of protein levels (Kjeldhal nitrogen x 6.25); energy levels (measured in terms of Metabolisable Energy); amino acids (obtained by automated amino acid analyser machines); amino acid availability (obtained less accurately by a combination of chemical and biological assay techniques); mineral, and vitamin levels.

Hence the list of essential nutrients and/or desirable nutrients, and levels of nutrients is quite a large one in the field of modern poultry nutrition.

There are several sources of variability to be considered when formulating a diet to provide adequate growth and development.

(1) There is insufficient knowledge of nutrient levels required for various breeds, strains and ages of poultry, together with interactions between

these and factors such as housing and equipment type, temperature and other environmental factors.

(2) There is wide variability of nutrient levels in ingredients as determined by soil types, fertilizer applications and climatic factors.

(3) The processing of ingredients of plant or animal source varies widely, for example : the heat treatment effects on amino acid availability in meatmeals.

(4) Nutrients from different ingredient sources (e.g. protein from barley or meatmeal) will interact in different ways when mixed in a ration (e.g. high levels of iron in the diet will prevent utilization of phosphorus.)

Hence, there is insufficient knowledge to enable precise and accurate levels of nutrients to be stated. The combined information on requirements and ingredient contents should only be used as a guide in nutrition.

An example where such information is often used is in linear programming for least cost feed mixes. On testing these rations in practice, they are not always the most profitable - a situation caused by the inaccurate information used. Hence one must use the information only as a guide, and within this broad framework - by actual experimentation - narrow the limits within which economic growth and production can be achieved.

Requirements are most critical in the early growing stages. For the first four to eight weeks a "starter" ration is usually fed. This provides a high concentration of nutrients and is relatively expensive although with the small chickens, the volume consumed is not great (say 600 gms per bird over 4 weeks).

Nutrient requirements, especially protein, decrease with age. As a bird grows, a greater percentage of the diet consumed must be used for maintenance, and less for growth. Since the quantity of protein needed for maintenance is relatively low compared with that needed for growth, the protein requirement, expressed as a percentage of the diet, usually falls.

Table 9.13. EXAMPLES OF STARTER, GROWER AND DEVELOPER DIETS FOR REPLACEMENT PULLETS

Ingredients	*Starter (0–6 wks)*		*Pullet grower (6–12 wks)*		*Pullet developer (12–20 wks)*	
	a	*b*	*a*	*b*	*a*	*b*
			pounds per 1000 pounds			
Corn meal, No. 2, yellow, ground	560	470	630	662	677	675
Wheat middlings	–	–	–	100	–	100
Barley, pulverized	–	150	100	–	150	75
Oats, pulverized	100	–	–	–	–	–
Stabilized grease	–	10	–	–	–	–
Soybean meal, low fiber, 50% protein	240	225	190	125	100	60
Fish meal, 65% protein	50	–	25	10	20	–
Fish solubles, dried basis	–	5	–	–	–	–
Meat and bone scraps, 50% protein	–	60	–	55	–	50
Corn distillers dried solubles	–	25	–	10	–	–
Whey, dried product	–	15	–	–	–	–
Alfalfa meal, 17% protein	25	25	25	25	25	25
Dicalcium phosphate	10	–	15	–	15	–
Limestone	10	7.5	7.5	5	5	7.5
Salt, iodized	2.5	2.5	2.5	2.5	2.5	2.5
DL-Methionine	0.5	0.75	0.4	0.5	0.2	0.5
Vitamin premix	5	5	5	5	5	5
Calculated composition:						
Protein, %	21.7	21.8	18.2	17.8	14.4	14.3
Metabolizable energy, Kcal/lb	1350	1340	1370	1350	1390	1380
ME/P	62	61.5	75	76	96.5	96.5
Calcium, %	1.0	1.0	0.9	0.9	0.8	0.82
Phosphorus, total, %	0.69	0.7	0.67	0.7	0.64	0.62
available, %	0.48	0.48	0.45	0.45	0.42	0.40
Lysine, % of protein	5.6	5.4	5.2	4.9	4.5	4.2
Methionine, % of protein	1.97	1.97	2.0	1.95	2.0	2.0
Cystine, % of protein	1.6	1.6	1.6	1.6	1.7	1.7

Table 1.3.1.

From "Nutrition of the Chicken." M.L. Scott, M.C. Nesheim, R.J. Young (1969) M.L. Scott and Associates, Publishers, N.Y. p.455.

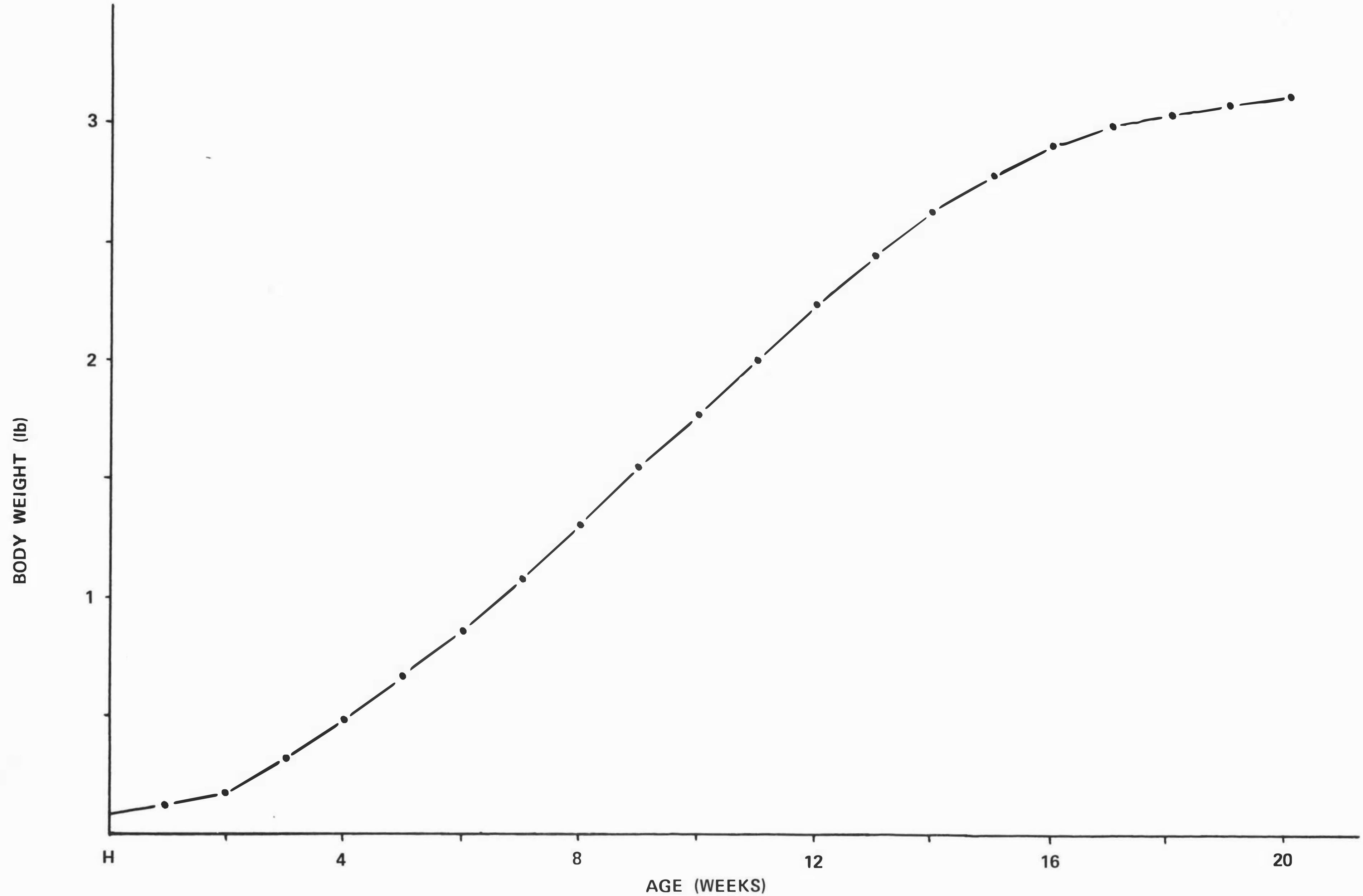


Fig. 1.3.2. – An idealised growth curve for a laying pullet: body weight change with age.

After 4 to 8 weeks, the starter ration is usually replaced with a grower ration, containing less concentrated nutrients. It is cheaper but more is eaten as the stock grow larger.

The grower ration may be fed until maturity though a "pullet developer" ration may be fed from 12 weeks of age. This is even lower in protein level.

Table 1.3.1 gives examples of the 3 types of rations mentioned - as formulated for conditions in the state of New York (U.S.A.)

Observation of this table in conjunction with figure 1.3.2 will illustrate how the ration composition alters with rate of growth (as represented by the slope of the graphed line.)

Within certain limits, birds will eat to satisfy their energy requirements. Accordingly, there is a need to adjust nutrient concentrations depending on the energy level of the ration. (Morris 1967, Dewan and Gleaves 1969)

Nutrients are provided by 3 major dietary fractions :

(1) Cereal portion : barley, wheat, maize and pollard are commonly used in N.Z.

(2) Protein Concentrate : meatmeals and fishmeals are used in N.Z. Soyabean is a vegetable protein more common in Britain and the United States.

(3) Vitamin - mineral supplement : a mixture of concentrated nutrients provided by some manufacturers. Starter, grower and layer supplements are common in N.Z.

1.4 The Effect of plane of Nutrition during rearing on production.

In section 1.2 it was noted that nutrient restriction had the effect of delaying sexual maturity. While manipulation of the photoperiod is the easiest and safest way to delay maturity, some assistance from nutrient restriction may be of value. However, as previously mentioned, the prime aim of the rearing diet is to produce an adequate laying bird at as low a cost as possible. Feed constitutes a major cost item in rearing, and lower planes of nutrition utilise cheaper ration ingredients. Thus the major aim in nutrient restriction in the growing period is to reduce costs. It is only incidental that these cheaper rations have effects such as delaying sexual maturity. It should be noted, however, that the delaying effects are usually additional to photoperiod effects, which may result in an excessive delay in maturity.

There are 4 main methods of restricting nutrient intake :

(1) Limited feeding time - where food is only available for certain periods during the day.

(2) Restricted quantity of a balanced food per unit of time (e.g. per day) on the basis of an ad lib. quantity.

(3) Nutrient dilution - by using ingredients with inherently low nutrient levels, or dilution with high fibre ingredients such as oat, rice or wheat brans.

(4) A diet containing imbalanced levels of nutrients such as amino acids.

Comparisons between results of different workers in this field are made difficult for several reasons :

(1) No evaluations are made on an economic basis. The best evaluation of any growing programme is to look at results in the laying period and compare profitability.

(2) A more difficult problem to solve is that of environmental variation due to the degree of management efficiency and housing type. Some restrictive nutrient levels might be stressful in some poorly managed environments - consequently that particular treatment would be penalised by a high mortality, or low performance.

(3) Most restriction programmes follow after a period varying from 4 to 12 weeks, during which time the chicken was fed on a highly nutritive starter ration. However, some recent work is being done looking at programmes which restrict the diet from day-old.

(4) Any physical evaluation that is carried out on the basis of laying results is faced with the problem of when to finish the comparisons.

Bullock, Morris and Fox (1963) put forward an interesting hypothesis to explain the later peak and more persistent egg production of restricted birds, which also shows that depending whether comparisons between restricted and full-fed birds are made : after the egg production curves have crossed, or to a fixed finishing age, or to equal periods after respective maturity - then it is possible to conclude respectively, that ; rate of lay is better, or worse, or no different - following restricted feeding.

The hypothetical model assumes that the only response to restricted feeding is a delay in maturity, so that the production curve is displaced to the right.

Attempts to restrict nutrient intake by limiting feeding time generally fail because the birds learn to eat more quickly in the time allowed. (Lepkovsky, Chari-Bitron, Lemmon, Ostwald and Dimick 1960.)

Food allowance is usually restricted by feeding a pre-determined fraction of the ad lib. intake of a control contemporary flock. A 70% level is common. (Gowe, Johnson, Crawford, Downs, Hill, Mountain, Pelletier, Strain 1960.) Confusion has arisen over this particular method because of significant interactions between restriction and photoperiod (Proudfoot and Gowe 1966.) This restriction technique is suitable for experimental purposes but not in practical situations, because of a high labour input.

Economic advantages of this type of restricted feeding are more obvious in the second and third years of lay. (Hollands and Gowe 1961.) Thus it would seem that the beneficial effects of restricted feeding on reproductive potential are not obvious or even economically utilizable unless pullets are taken beyond their first year of lay. As it is seldom economically feasible to do this, the advantage of such restricted quantity programmes is dubious.

The first two types of nutrient restriction as are discussed above, seem to have little practical application, though Lee(1969) would dispute this statement.

Qualitative Restriction.

Fibre dilution methods can result in substantial feed cost reduction in certain price situations, and also delays sexual maturity. In some situations high fibre diets may be uneconomic as they lead to increased food intake because of the low energy content. (Quisenberry 1959.)

Most experiments dealing with restricted feeding have been concerned with restriction of all components of the diet in equal proportions : energy, protein, minerals and vitamins. This is true of fibre dilution techniques as well as quantity and time restrictions.

It is difficult to distinguish between the effects of nutrient restriction achieved by dilution with high fibre brans, or the use of inherently low nutrient ingredients. Cost savings can be similar in either cases.

The distinction between inherently low protein ingredients, and amino acid imbalance effects on delaying sexual maturity is also difficult to evaluate.

However, the major difficulty in comparisons of published data is the variation in energy level, protein level, and the periods over which each is fed. Energy effects on consumption are probably also a confounding factor, as low protein and low energy are generally associated in a diet - and where the bird "overconsumes" to fulfil energy requirements, it also increases the protein intake.

Low-nutrient restrictive diets have an important feature which enables them to be classified into two groups (for review purposes).

The major group of workers employed a programme of feeding a good quality starter ration to 6 or 8 weeks of age, followed by restrictive diet until 20 to 22 weeks of age. Such a feeding programme places a "stress" of rapid growth on birds during the starting period, and a further stress of nutrient restriction in the growing period. A more logical approach would attempt to remove these stresses by allowing the pullets to grow at a slower, more uniform rate from day-old until point of lay. This desired type of programme, can be compared graphically with the one most farmers are now using. (Fig.1.4.1)

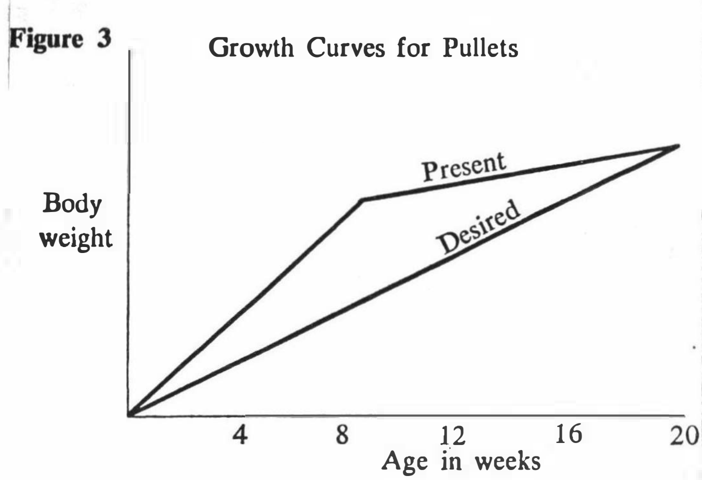


Fig. 1.4.1.

From "Poultry Feed Formulas" J.D. Summers, W.F. Pepper, E.T. Moran (1970) Ontario Dept. Agric. and Food. p.31.

There is a considerable volume of published material which describes the two-level system ("present"), but there are very few utilising the alternative "desired" hypothesis.

Most experiments used a single high level starter ration up to 6 weeks (Blair, Bolton, Morley Jones 1969), 8 weeks (Berg and Bearse 1958), 9 weeks (Bullock, Morris and Fox 1963),12 weeks (Smith 1966) or some intermediate age.

These groups of birds were then "split" over several restrictive "planes" of restriction in protein and energy; the protein levels ranging from 21% (the same as some starter levels) to 10.5% (Bullock <u>et al</u> 1963).

Energy levels usually varied at the same time, and in most cases, where corn starch was used as a diluent, (Bullock <u>et al</u> 1963; Smith 1966) the lower protein rations were higher in energy. This may have affected the consumption rate as appetite is supposed to be controlled mainly by energy requirements. However, in one case (Smith 1966) the lowest protein and highest energy ration (11% and 2850 kcs ME/kg or 1294 kcs ME/lb) also had the highest consumption rate. Bullock <u>et al</u> (1963) made a special effort to make the rations all isocaloric at 2590 kcs ME/kg (1175 kcs ME/lb) so as to separate energy and protein restrictive effects. Blair <u>et al</u> (1969) also came close to the isocaloric ideal with rations varying only between 2592 kcs ME/kg (1340 kcs ME/lb) and 3062 kcs ME/kg (1390 kcs ME/lb) for a protein range of 11.5 to 16.3% respectively.

All of these workers quoted above carried the restrictive regime on until point of lay, or housing in laying quarters, or 20 weeks of age - except for Blair <u>et al</u> (1969) who raised the protein levels at the end of the 16th. week.

Where energy levels were reasonably constant: as protein levels fell, so did rate of consumption (Bullock <u>et al</u> 1963, Blair <u>et al</u>1969). Sexual maturity was usually delayed (Bullock <u>et al</u> 1963, Smith 1966) but in less restrictive rations (11.5% protein to 16 weeks: Blair <u>et al</u> 1969; 15% protein to 20 weeks : Berg <u>et al</u> 1958) there were no significant delays. The same situation occurred with weight gains during the experimental period: protein levels below 12% depressed growth.

Subsequent food conversion efficiency (as measured by food consumption per dozen eggs) in the laying period, seemed not to be affected by the rearing treatment (Berg et al 1958, Blair et al 1969). However, where reported, egg weight was smaller at the beginning of the lay (Blair et al 1969, Bullock et al 1963, Berg et al 1963) but "soon" recovered. The critical factor economically is whether this initial depression was sufficient to affect profit comparisons between treatments. This comparison was never made.

The number of eggs laid in varying production periods was usually not significantly different from the high plane grower controls. The production periods varied up to the ages of 64 and 71 weeks. This makes comparisons between the results of different workers of doubtful value - especially so in the light of the hypothesis discussed above (Bullock et al 1963). Here again, the most interesting comparison would have been a profit index which could encompass the lower price for a greater number of smaller eggs - (but possibly an idential total mass) when compared with a fewer number of high price large eggs.

Mortality levels over the growing and laying periods were never significantly different between treatments, though Bullock et al (1963) did hypothesise that restricted birds might have a better survival value. Summers et al (1970) give a possible explanation of the mortality situation in their consideration of the stress placed on birds with these type of restrictive growing programme. Evidence is accumulating (Summers et al 1970) that where the restriction programme is a uniform one from day-old, the stress is considerably reduced. Summers et al (1970) report an experiment using 20% and 14% protein starter rations where the more restrictive ration "notably reduced" losses dues to Mareks Disease.

Proudfoot and Aitken (1969) looked at 5 White Leghorn strains fed 10% and 16% protein rearing diets from 8 weeks of age (previously on a high quality starter ration). Mortality due to Mareks Disease was significantly lower in some genotypes, and also lower in the low protein treatments. This result is contrary to those of Berg et al (1958), Bullock et al (1963), Blair et al (1969), in that mortality levels varied at all; and also contravenes the hypothesis expounded by Summers et al (1970) above.

Experiments with energy restriction (looked at independently of protein restriction) generally follow the pattern of a high starter ration level, then a constant lower energy level until maturity (Bullock et al 1963, Bolton, Blair and Knight 1969), though Wolf, Gleaves, Tonkinson, Thayer and Morrison (1968) allowed a gradual lowering of energy levels until 20 weeks. This latter experiment is interesting in that very low energy levels were used throughout. Until 8 weeks of age all birds were on a 2203 kcs ME/kg (1000 kcs ME/lb) ration which was lowered at varying rates to 1460, 1820 and 2190 kcs ME/kg (662, 827 and 993 kcs ME/lb) by 21 weeks of age. These variable levels were able to be considered independent from ration density and protein level consideration, by the use of polyethylene fluff, and sand diluents in the diets.

The low energy rations delayed sexual maturity and raised food consumption levels. The lowest energy level was the most depressive on subsequent egg production - though the comparison was only made until 64 weeks of age. Egg weight was not significantly affected.

These results follow those of Bullock et al (1963) and Bolton et al (1969) though the latter workers used relatively higher energy levels: Bullock et al (1963) comparing 2590 and 1940 kcs ME/kg (1175 and 822 kcs ME/lb); and Bolton et al (1969) comparing 2996 and 2290 kcs ME/kg (1360 and 1040 kcs ME/lb) which followed a 6 to 8 week starter period.

Bolton et al (1969) had a uniform calorie-protein ratio of 79 for the grower rations, so the high energy ration was also a high protein ration. Even though the stock used were light hybrids ("Thornber 606") the body weights were excessively high on the high energy ration, and egg production was lower in the following laying period. Like Blair et al (1969), Bolton et al (1969) only ran the experiment from 6 to 16 weeks.

Wolf et al (1968) changed the ration protein levels every 4 weeks from hatch to 20 weeks. Two planes of nutrition were used, and the two sequences were as follows: 21, 20, 15.2, 13.9, 13.3% proteins for the high plane; 17, 16, 11.8, 10.6, 9.9% for the low plane. Both levels were placed on a 14.7% protein and 2675 kcs ME/kg (1215 kcs ME/lb) layer ration at 20 weeks of age.

Bolton et al (1969) changed levels at 6, 16, and 49 weeks of age, again choosing a high and low plane which were both less restrictive than those of Wolf et al (1968). The two sequences were as follows: 21, 16.9, 18.1% protein for the high plane; and 18.5, 15.0, 16.2% protein for the low plane. These levels were not very restrictive and no effects on sexual maturity, body weight gain, eventual egg weight or food conversion efficiency were found. Even with the more restrictive regime of Wolf et al (1968), a delay in sexual maturity was the only difference between the planes of restriction.

The idea of a uniformly restrictive diet from day-old until point of lay was first explored by Lillie and Denton (1966). This exploratory step involved comparisons between 21, 16 and 12 % protein diets throughout the growing period, with combinations changing at 8 weeks in addition (for example one group changed from 16% to 12% after 8 weeks).

The associated energy levels were 2920, 2490 and 2510 kcs ME/kg (1326, 1130 and 1140 kcs ME/lb) respectively.

Peterson, Sauter and Lampman (1966) compared isocaloric diets with 20, 18, 16 and 14% protein levels from day-old, as did Santana and Quisenberry (1967); Summers Pepper and Moran (1969), over a similar range of proteins, and a slightly larger range of energy values. Diet ingredients used, play an important part in these comparisons, and in this way imbalances in amino acids can occur even though crude protein levels might be high.

Santana et al (1967) supplemented their 14 and 12% diets with lysine, methionine and tryptophan while still claiming a cost saving over the 18 and 16% protein diets; however egg production and egg weight on the subsequent layer diet were very reduced as a result of the 12% protein grower diet, so presumably other amino acids became limiting in the grower ration.

Weight gains during the growing period were significantly lower as reported by Lillie et al (1966) on a 12% protein diet, but compensatory growth occurred in early lay. Peterson et al (1966) found that a 14% protein diet depressed growth to a level twice as low as that expected on the basis of amino acid level considerations. A change to 12% protein after 7 weeks of age necessitated methionine and lysine supplementation whereupon cost savings became questionable.

Summers et al (1969) reduced protein levels from 14% to 13% at 8 weeks until 25 weeks of age (a corn-soyabean based diet) with no apparent ill effects, though in Australia, Payne (1969) found that when barley replaced a wheat-sorghum combination in the cereal fraction of the diet, egg production was depressed, and this was worse in some particular strains. This effect (Payne 1969) was partially alleviated by methionine supplementation and the provision of a good quality layer diet from point of lay.

Sexual maturity was significantly delayed (by an unstated amount) at protein levels below 14% (Peterson et al 1966, and Santana et al 1967), but neither Summers et al (1969) nor Lillie et al (1966) reported any significant delaying effect.

Food consumption was higher on the lower protein rations, but these were also the low energy diets (Lillie et al 1966). However, Summers et al (1969) reported no differences in consumption rates - however, these birds were all placed on a 13% protein ration from 8 weeks. (It will be recalled that where isocaloric diets were used (Blair et al (1969) and Bullock et al (1963)), the low protein diets were consumed at the lowest rates.)

Food conversion efficiency into weight gain was only recorded by Lillie et al (1966) who reported no significant differences up to 20 weeks of age.

Egg production was not depressed in the laying period at 14% or even 12% protein grower levels (Summers et al (1969) and Lillie et al (1966) respectively, in some experiments, but in others, these same levels (Peterson et al (1966) and

Santana et al (1967) respectively, caused a lowering in egg number and a reduced egg weight.

Egg weight however was not depressed at 12% protein levels with some workers (Lillie et al (1966)) though 14% protein in the first 8 weeks in others (Summers et al 1969) caused a 0.6% reduction in egg size (though only significant at the 5% level of probability.)

Most of the above workers recommend a programme for rearing using a slightly higher starter level (between 14 and 16% protein,) dropping about 2% at 7 to 8 weeks until point of lay is reached.

Nutrient imbalance effects on growth and development probably act indirectly in these low protein regimes, and some workers even advise amino acid supplementation to avoid imbalance depression additional to the already low protein regime (Peterson et al 1966, Santana et al 1967, and Payne 1969).

Some workers have deliberately included poorly balanced (amino acid-wise) ingredients to investigate imbalance effects independent of low protein levels.

Summers et al (1969) replaced soyabean meal with hydrolysed feather meal (fed from day-old), which is limiting in methionine and lysine, but making up a 20% crude protein ration. Egg production in the laying period was lower than the 14% corn-soyabean-protein starter ration. Feed conversion per dozen eggs and egg size were lower and food consumption also low on the feather meal diet. Compensatory growth in the laying period was twice as high as those birds grown on the 14% ration.

By feeding a diet deficient in lysine (59% of requirement) from 4 to 12 weeks of age, Singsen, Nagel, Patrick and Matterson (1964, 1965) managed to delay sexual maturity and reduce the bodyweight of meat type laying pullets without other ill effects becoming apparent.

An approach not commonly seen is the use of Calorie (per pound) - Protein ratios to compare profitability of various rearing programmes. Wegner (1962) reared pullets most successfully (a margin of 4% higher egg number) on a ration ratio of 70 (for example 1050 kcs ME/lb or 2313 kcs ME/kg and 15% protein) from 8 weeks to 20 weeks of age, when compared with ratios either side of this.

The calorie/protein ratio concept is assessed and found limiting by Creek (1969) who suggests that a protein/mega-calorie ratio (% protein per ten kcs or per mega-calorie) gives a linear, more easily interpreted, curve of ratio against % of the protein ingredient.

The most economically suitable type of nutrient restriction to aid lighting programmes in delaying sexual maturity and reduce growth rate appears to be a low protein-low energy ration fed from day-old.

Less feed is involved at this time but management at this stage is often superior than later on in the growing period when most nutrient restriction programmes seen to be applied.

More research is required to look particularly at the removal of stress by the uniformly restrictive type of diet.

1.5 Compensatory Growth during and after Undernutrition.

Previously reference was made to utilizing compensatory growth in relation to feed restriction for birds over the growing phase (Bullock *et al* 1963, Blair *et al* 1969).

The phenomenon of compensatory growth is not unknown with larger farm animals (Wilson and Osborn 1960), such as cattle (Winchester and Harvey 1966), sheep (Hammond 1932, Palsson 1955), and pigs (McMeekan 1940).

In general, the phenomenon may be described as a period of rapid and efficient growth following a period of food restriction. Obviously the nature of the diet, the severity and duration of the treatment, the age of the animal, and the level of nutrition after the restricted period are all variables which may influence the efficiency of the compensation.

The actual physiological mechanisms involved are poorly understood, Wilson *et al* (1960) merely describing the observed phenomena.

With poultry, a similar compensatory situation could occur as a result of food restriction over the growing period (20 weeks), followed by the normal high quality layer ration. On the other hand, provided the restriction is not too severe, there may be some compensatory growth occurring early in the growing period. For example: Nutrient requirements for growth over the first 4 to 5 weeks are of a high order with particular emphasis on amino acid levels. Following this there may be a period of adjustment and compensatory growth resulting from an age effect whereby nutrition levels and tolerances are less critical. Provided the restriction is not too severe over the first 4 weeks, with a further 16 weeks to point of lay, there is adequate time for compensatory effects to operate such that final body weights at 20 weeks, and particularly subsequent egg production is satisfactory.

As indicated previously (Summers et al 1970 and graph 1.4.1), the philosophy of a straight line growth curve versus the more usual diminishing returns curve to 20 weeks, is concerned in part with compensatory growth.

There are some reports in the literature dealing with the true compensatory phenomenon (Wilson et al 1960, Winchester et al 1966), but there are few concerned with the variations described above. Possibly workers have not considered this line of approach.

Auckland, Morris and Jennings (1968) looked specifically at the compensatory mechanism in turkeys after an initial 6 weeks of restriction. The compensating birds had a greater feed-to-body-weight conversion efficiency (FCE) but no tests were carried out to examine the nature of the body tissue increases - fat or muscle.

Because of the lower Basic Metabolic Rate (BMR) in the compensating turkeys, it is impossible to determine whether the apparent advantage in FCE was not due merely to lower maintenance requirements.

The aim in utilizing the compensatory growth mechanism is to reduce the total area under the growth curve. Too severe a restriction may increase the total area because of the longer time required to reach a given body weight.

Wilson *et al* (1960) observed that compensating animals tended to have the greater amount of carcass fat at the end of the compensatory period.

Compensating birds have lower BMR's perhaps because of lower energy intakes.

Priority of body demands for available nutrients are ranked as : nervous tissue, skeleton, muscles and fat. (Brody 1945)

If this is the case, then food restriction (unless severe) may not be expected to influence skeletal growth, but perhaps restrict some of the muscle and most of the body fat growth.

Nordskog *et al* (1967) conclude that because of this phenomenon, body weight alone may not be a good indication of body condition or maturity. (Lerner 1936, Jull and Glazener 1945.) The statistic "coefficient of variability" is greater for body weight.

1.6 Measurement of Body Development.

Though some workers (Seebeck 1968) feel that "skeletal" measurements on the live animal have dubious utility in body composition studies; for practical purposes of speed and expense the *in vivo* techniques will probably continue to be used. One such measure in poultry recommended by Lerner (1936), is the length of the shank.

The shank length of a bird represents the length of the tarsometatorsal bone and associated tissues (see figure 1.6.1). It is bounded at the proximal end by the angle of the "hock"; and at the distal end by the first bones of the phalanges or toes. Thus it is equivalent to the separate metatarsal bones of the human ankle which have elongated and fused. In the cock, the bony core for the spur arises about two-thirds down its length.

Lerner and Gunns (1938) derived the following relationship between the tarsometatarsus (TM) (the dissected bone) and the shank length (SL) (measured *in vivo*) from data collected throughout the growing period with White Leghorn birds.

$$TM = 0.7863 \times SL - 0.2481.$$

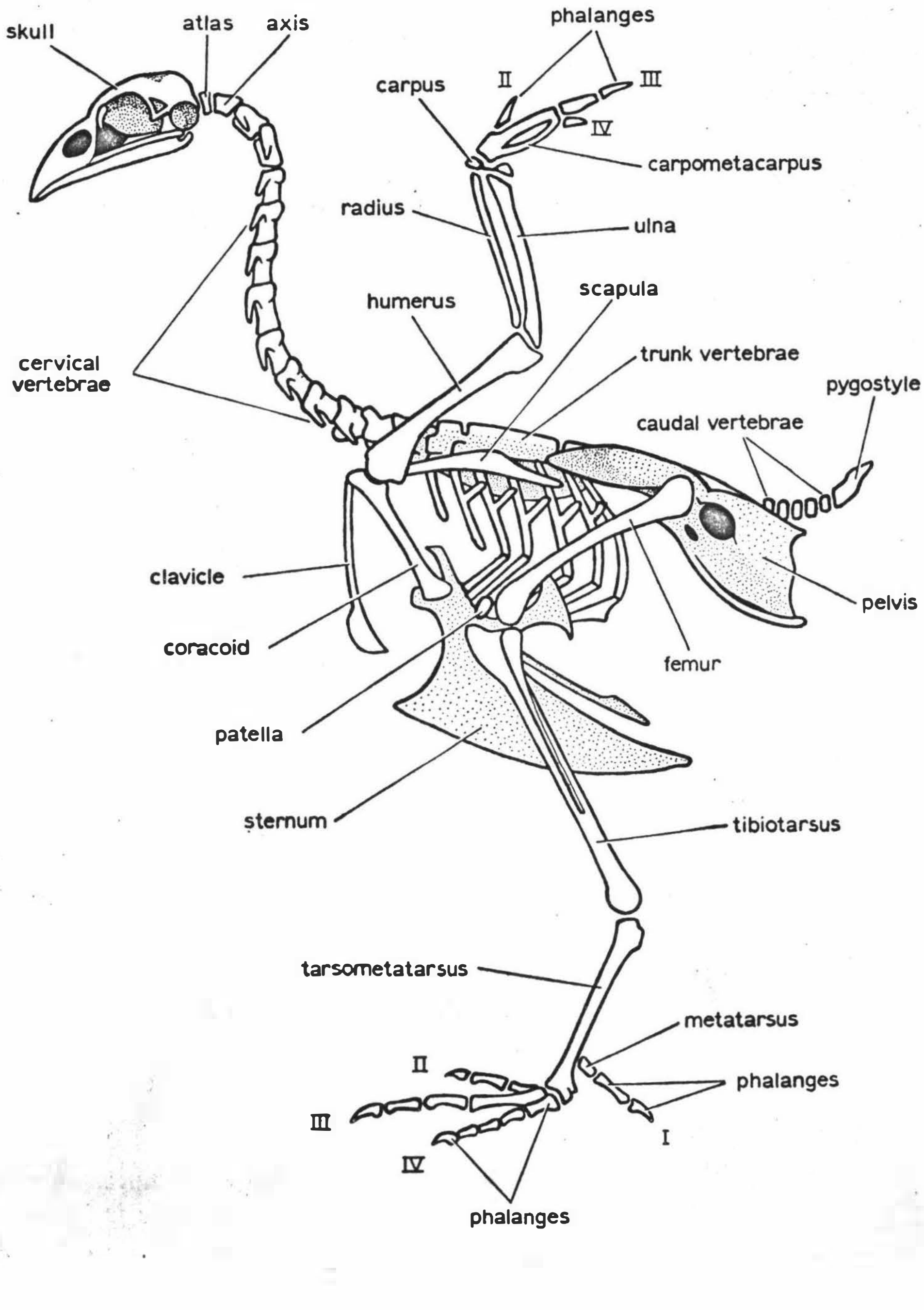


Fig. 1.6.1: Skeleton of the domestic fowl showing tarsometatarsus. From "Bird Structure," D.A. Ede (1964) Hutchinson Educational Publications, Edinburgh (1968). p.28.

The shank is conveniently available for measurement (Burmester and Lerner 1936) in the live bird, and this measurement also correlates highly with total skeletal weight (+0.703) (Morris, Taylor and Brookhouse 1965) and with body weight (+ 0.92 at 4 weeks, + 0.81 at 16 weeks of age) (Asmundson and Lerner 1942).

Thus while skeletal growth (as indicated by shank length) parallels that of body weight (Lerner 1939, 1940), this relationship only lasts through the first 16 weeks of the grower phase (Asmundson et al 1942, Lattimer 1924, Oshima and Fuse 1967).

When feeding poultry on low planes of nutrition, the skeleton (as represented by shank length) has a high priority demand on nutrients (Brody 1945, Wilson et al 1960). Thus shank length may be a valuable criterion to evaluate the lower limit of an economically optimum restriction programme. As long as there are sufficient nutrients to provide an adequate skeletal framework during the growing phase, then compensatory growth in muscle and fat, can be provided by the layer phase ration. The bird produced by such a programme may have lower maintenance requirements and have a better FCE as well as producing eggs of a desirable weight and number.

Wilson (1951, 1952, 1953) studied the effect of plane of nutrition on shank length, carcass composition and egg production. The high plane was represented by a 19.5% protein ration fed from day old to 10 weeks of age, and then changed to a 20.4% protein ration. The low plane levels were 13.9% and 11.6% protein correspondingly. A layer ration (unspecified) was fed after the 24th. week of age. The numbers of birds carried through to the laying phase on the low and high planes were very small (12 on each plane), and the treatment effects were confounded with natural photoperiod effects. Four months delay in age at first egg for the low plane birds appears incredible and is possibly due to the severity of the 11.6% protein ration which was probably imbalanced with respect to amino acids.

Wilson, however, did establish significant differences in shank length growth between the two planes up to 10 weeks of age, but not at subsequent ages. Indeed beyond 17 weeks of age, no significant increase in shank length of the high plane birds occurred, though the low plane birds continued to increase their shank lengths until 23 weeks of age - at which point they were longer than the shanks of the high plane birds. A similar phenomenon was observed by Outhouse and Mendel (1933) with rats, Hammond (1932) with sheep, and McMeekan (1940) with pigs.

The latter two workers attributed the effect to the longer growing period of the skeletal tissue of the low-plane animals.

Body weight effects showed that the high plane birds grew rapidly until 24 weeks of age, and gained a further 0.2 lb to reach 5 lb at 40 weeks of age, whereas the low plane birds gained a further 1 lb to reach 4 lb at 40 weeks, growth rate being very slow until the change to the laying ration at 24 weeks of age. The stock used were Light Sussex-Rhode Island Red progeny.

CHAPTER ONE B (EXPERIMENTS)

1.7 Aims and Objects.

The growing trial (code named CN/50) was designed to evaluate the effect of several planes of nutrition (as determined by protein levels) from day-old until 20 weeks of age on subsequent laying period performance when all birds were fed the same layer ration (20 to 64 weeks of age).

In designing the experiment, the arrangement of the feed ingredients making up the various rations, was organised with the aim of fitting a production function to the resulting data. It was hoped that it would be possible to determine the optimum ratio of ingredients in the grower ration using marginal price analysis.

In this respect the design was similar to that described in Chapter 10 of Heady and Dillon (1961). However, on further study, and particularly as elaborated by R. J. Townsley (personal communication 1970) it was found that the design as used by Heady et al (1961) was unsuitable for such an analysis, though they did attempt such analysis. Details of this anomaly, together with other economic aspects, will be discussed in Chapter 3.

1.8 Experimental Design.

Brooder Phase. The 9 treatments were replicated 3 times in a randomised block design within each of 3 tier-brooders (3 tiers labelled P, Q, R) with 14 pullets per replicate (one quadrant of a tier). (see plates one and two).

Grower Phase. At the end of the 4 week brooding phase the pullets were re-randomised within a treatment on transfer to the grower cages with 4 replicates of 8 birds in a randomised block design. The stock remained in the grower cages until 20 weeks of age. (see plates three, four and five).

Layer Phase. The pullets were again re-randomised within a treatment on transfer to the laying shed with 3 replications each of 10 birds in a completely randomised design over 2 tiers of a 3-tiered battery. (see plates six and seven).

1.9 Rations:

There were 9 treatment rations (labelled A to I) fed over the period hatch

PLATE ONE

Chickens of trial 3N/58 in battery brooders.

PLATE TWO

Detail of battery brooder.

to 20 weeks of age. There were 4 major feed fractions in the diet:

(1) A barleymeal fraction which made up 84% of ration A and was decreased in steps of 6% to reach 36% of the 9th ration I.

(2) A pollard fraction making up 11% of ration A and increasing in steps of 5% per ration to reach 51% of ration I.

(3) A meatmeal fraction ranging from zero in ration A to 8% in ration I in steps of 1%.

(4) A basal fraction which supplied some of the protein together with the birds' requirements (according to Bolton 1967) for vitamins and minerals. This fraction made up 5% of every ration.

All mashes fed were coarse ground. They were mixed by a local feed mill, with sufficient initially (720 lb. per ration) to last the complete 20 week period. Subsequently as rations G, H and I were consumed at a greater rate than anticipated, supplies of these 3 rations (125 lb. per ration) had to be obtained. The mashes were purchased in bags because of the small quantities involved. In practice, bulk buying would be used, and this reduces the cost per ton by \$3. (Table 1.9.1)

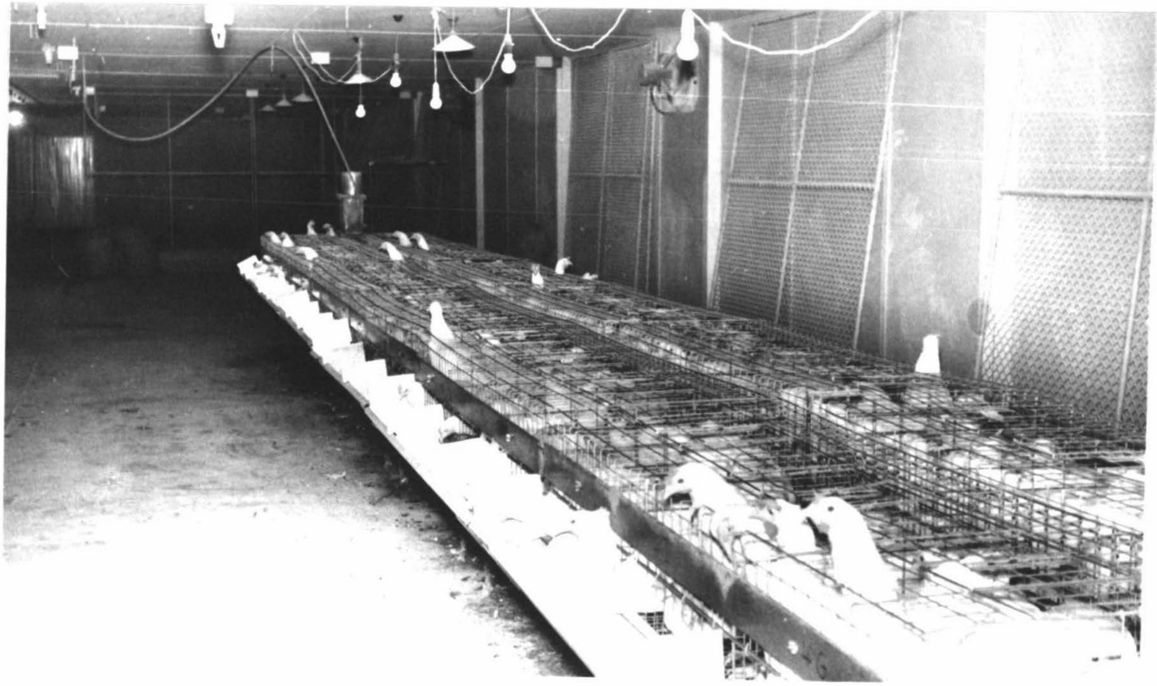


PLATE THREE

Chickens of trial CN/50 in rearing cages.

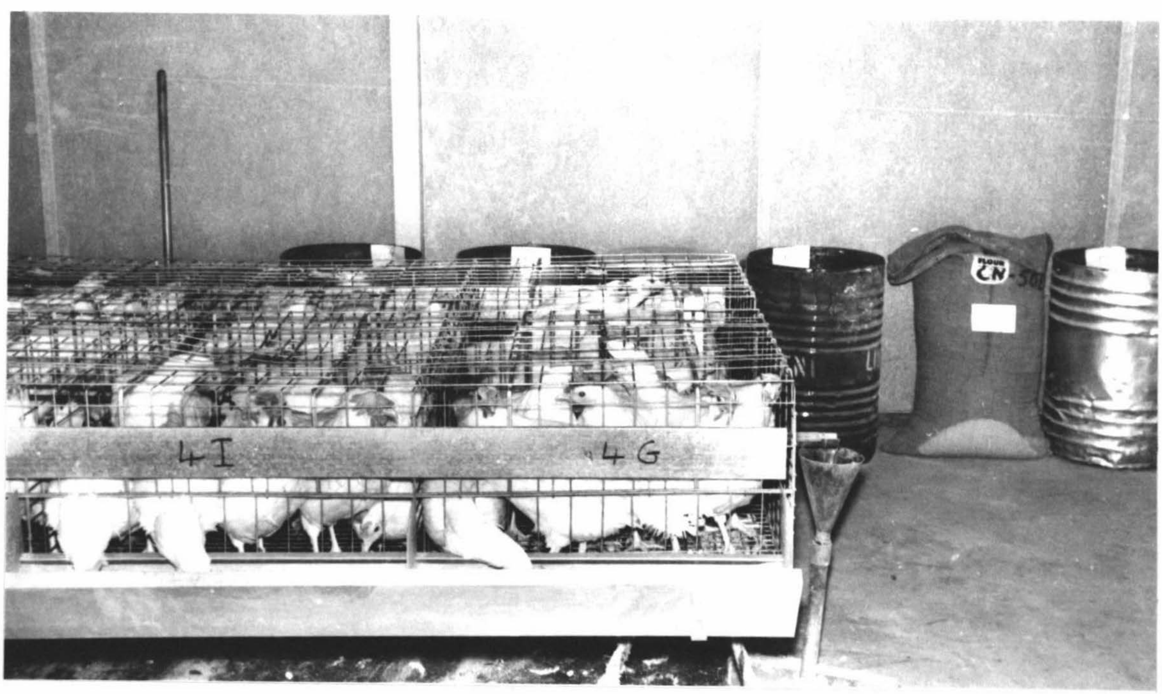


PLATE FOUR

Detail of rearing cage.

Percentage composition of the rations were as follows:

Table 1.9.1.

Percentage composition of rations; chemical and ingredients together with a calculated cost per 2,000 lb. ton if delivered in bulk.

RATION	A	B	C	D	E	F	G	H	I
Barleymeal	84	78	72	66	60	54	48	42	36
Pollard	11	16	21	26	31	36	41	46	51
Meatmeal	0	1	2	3	4	5	6	7	8
Lucurnemeal	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Buttermilk Powder	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Bonemeal	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Iodised Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin-Mineral Supplement*	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
TOTAL	100	100	100	100	100	100	100	100	100
$ per ton (bulk)	61.89	62.08	63.28	62.47	62.67	62.86	63.06	63.25	63.45
Kjeldhal ** Protein %	12.0	10.2	12.8	12.9	13.7	15.3	14.7	15.6	15.6
Calculated Protein %	11.9	12.5	13.1	13.8	14.3	15.0	15.6	16.2	16.8
Energy (kcs ME/lb.)	1183	1184	1184	1185	1185	1186	1186	1187	1187
Energy (kcs ME/kg	2606	2607	2608	2609	2610	2611	2612	2613	2614
Cal/pr.Ratio	99	95	90	86	83	79	76	73	71
Pr/Mcal Ratio	10.1	10.6	11.1	11.6	12.1	12.6	13.2	13.7	14.2
Calcium %	0.42	0.51	0.60	0.69	0.78	0.87	0.96	1.05	1.14
Phosphorus	0.58	0.64	0.70	0.76	0.82	0.88	0.94	1.00	1.07
Ash%	3.8	3.5	4.9	3.1	4.0	4.4	5.0	5.1	5.1
Moisture %	10.8	11.6	10.6	11.2	10.5	11.5	11.7	10.8	11.0

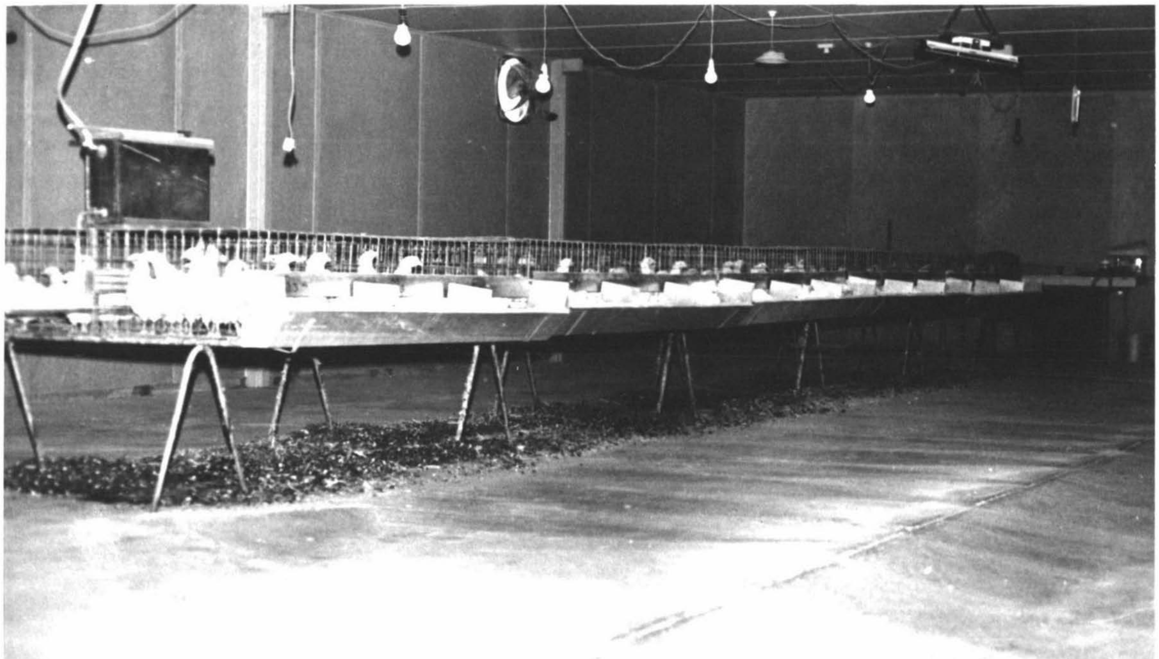


PLATE FIVE

Rearing cages from North end of Brooder-Rearer shed.

* Composition of the vitamin-mineral supplement is shown in Appendix I table 1.

** After arrival, samples of each ration were taken and analysed for Kjeldhal nitrogen, ash, and moisture content. All figures are given on an air dry basis.

Calculated analyses for protein, metabolisable energy, calcium and phosphorus are also given in table 1.9.1. These are based on figures given in Appendix I table 2. The Calorie (per lb.)/ Protein ratio is given; with Creek's (1969) - Protein/Megacalorie ratio for comparison purposes.

From the 20th week of age, all birds were fed on an identical ration which is the normal one fed to layers at the P R C and to entrants in the N.Z. Poultry Board's most recent Random Sample Test. Details of ingredient composition, chemical and amino acid analysis, can be seen in Appendix I table 3.

1.10 Materials and Methods.

General. The stock used were strain cross White Leghorn pullets from the P R C White Leghorn Control strain. Details of the artificial insemination, egg collection and storage, and incubation of eggs from this stock can be found in Appendix I (a).

The chickens were sexed, and one wing band placed on the left wing. After initial measurements (see section 1.11) the birds were housed in a semi-controlled environment brooder-rearer shed in 3 electrically heated battery brooders ("Multiplo") with 14 chickens per cage. 378 pullets were housed for the 9 treatments (3 replicates per treatment).

Any birds dying within 3 days of housing were replaced as mortality was probably not due to treatment effects.

In the flat deck ("Multiplo") growing cages there were 4 replications per treatment each of 8 birds. Any spare birds remaining were sold as there was room for housing only288 pullets.

In the semi-controlled environment laying shed, pullets were housed 2 per 11 inch cage with 3 replications per treatment,each of a 5-cage block (for convenience

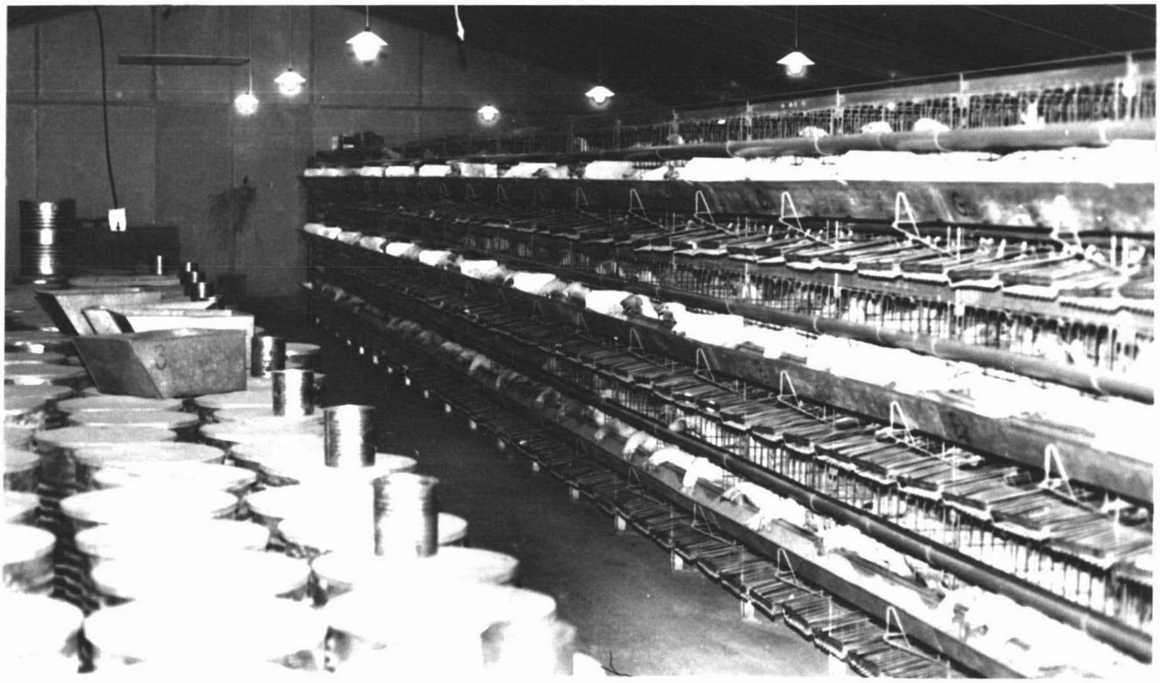


PLATE SIX

Pullets of trial CU/58 in laying battery.

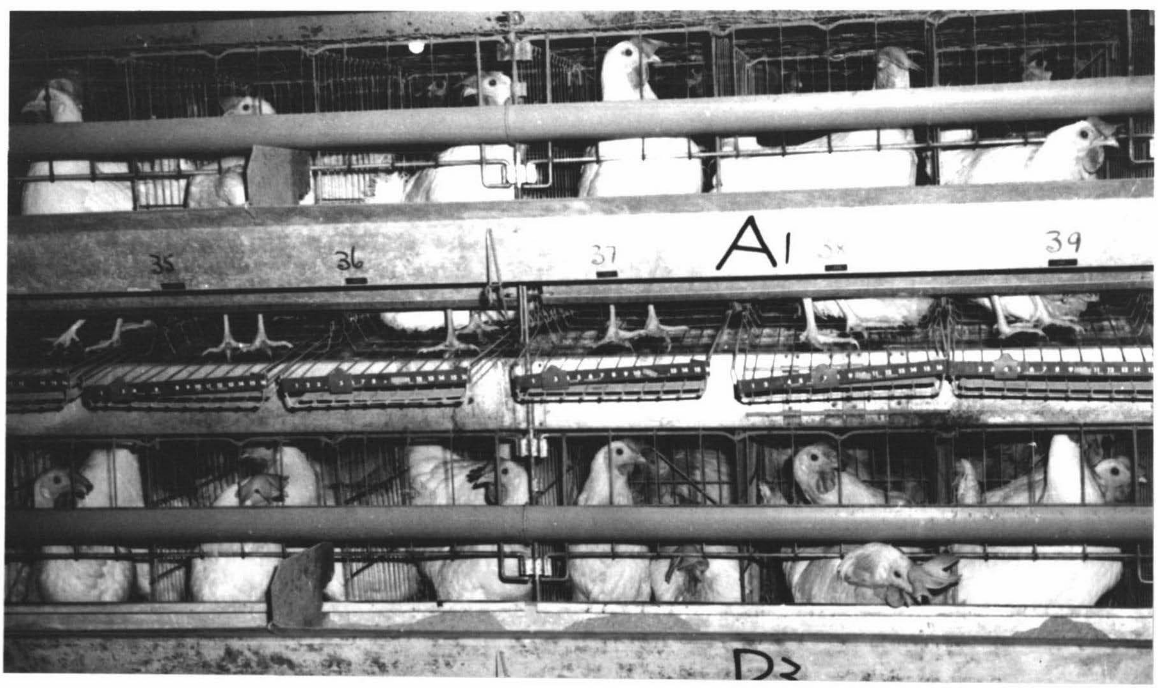


PLATE SEVEN

Detail of laying battery. Note egg counters.

in feeding). The cages occupied the top 2 rows of a 3 tiered double-sided laying battery (manufactured in the U.K. by Cope and Cope Ltd.)

A daily diary in triplicate was kept in which was recorded temperature maxima and minima for the shed, weights of food fed, details of birds sent for post mortem and any event which could conceivably affect the results of any trial.

A coded sheet accompanied all birds sent for post mortem examination which described the clinical symptoms of the bird together with a complete identification to wingbard, ration, replication and cage placement.

Heating. The brooder temperature, starting at approximately $95^{\circ}F$ ($35^{\circ}C$) was lowered gradually to achieve a uniform house temperature of $71^{\circ}F$ ($22^{\circ}C$) by the 4th week. Some fan control was necessary at times as mid-summer conditions prevailed outside. The heat was provided by an electric resistance coil inside a metal tube and was thermostatically controlled. The grower cages were unheated.

Lighting. The lighting system was a 14 hours constant light for the first 4 weeks, followed by 12 hours till 20 weeks. At housing in the laying shed, a constant 14 hours of light prevailed.

Intensity was controlled at all stages by dimmer devices (using an electronic "choke" principle). An intensity of 3 lux (see Appendix I (b)) was used after the first 14 days of bright light (.25.lux) for the starting chickens. White light was used at this stage, but red bulbs at 3 lux were used in the growing phase. White light at 5 lux was used in the laying shed. All intensities were measured using a G.E.C. Minilux illumination meter.

1.11 Measurements.

Body Weight. The pullets were weighed individually at day-old and subsequently at 14 day intervals to 20 weeks, and in the laying shed at weekly intervals to 28 weeks, and 28 day intervals to the 47th week. Weights were taken weekly in the early laying period as a check on possible compensatory growth with the layer ration being fed, and to provide some indication of weight changes associated with attainment of sexual maturity. Measurements to 20 weeks were made on a "Mettler" balance (type P3; 3,000 gm. in 1 gm. units). After 20 weeks, a "Salter" spring balance was used (No.60M Mark II; 60 lb. in 0.1 lb. units).

Food Consumption. The stock were fed ad lib at all times. Additions of mash to the food troughs were weighed, with refusals weighed back weekly for the first 4 weeks, then at 2 week intervals to 20 weeks. Food was weighed into the brooder food troughs using a "Salter" scale (No.159; 2,000 gm. in 20 gm. units).

In the laying shed, sufficient mash to last each replicate group of 10 birds (5 cages) 4 weeks, was weighed into a drum and the stock were then fed ad lib from the drum with refusals returned to the drum at the end of the 4 week period to calculate consumption by difference.

Food consumption was measured (using an "Avery" scale (Type 4; 500 lb. in 4 oz. units) in the laying period for 12 weeks after housing to record possible compensatory consumption effects.

Shank Length. Measurements were taken from an 8-bird sample chosen randomly from within each treatment using a pair of "Goodline" (German) 16 cm (6 inch) slide calipers. Measurements were taken at day-old and then at 4 week intervals until the 24th week of age. The author and Miss P. Hopkirk (P.R.C. Technician) made all the measurements, thus reducing possible errors between different observers.

Mortality. All deaths or obviously sick birds were sent to the Veterinary Poultry Pathologist, Dr. R. Pohl, for diagnosis. An information sheet accompanied these birds, and this was returned with a diagnosis attached.

Age at First Egg and Egg Number. Bullock and Jennings (1963) have shown that the best estiaate of differences in average age at first egg between treatments where birds are housing in pairs in cages, is obtained by calculating the mean of the ages represented by the dates of the first egg from each cage (the average age of first birds in pairs.)

An indication of the age when the second bird began to lay was gained by recording the first day on which 2 eggs per cage were observed.

Each cage was fitted with a metal strip along the edge of the rollaway egg tray, on which numbers were painted from zero to fourteen. A movable indicator enabled one week's egg production to be recorded per cage. At the end of each 7-day period, information was transferred to a card, and the indicator returned to zero.

The metal strip was also used to mark the date of the first egg - using coloured tape placed over the appropriate day number.

Egg Grading. A sample of one days production was collected every 2 weeks. Each egg was weighed individually as well as each treatment's eggs being graded as a whole on a "Cope and Cope" egg grading machine. The grading scheme used in N.Z. can be seen in Appendix I (c).

Egg Quality. A 3 day collection of eggs at 41 weeks of age were broken out to enable measurement of yolk colour (using the New "Roche" Colour fan), meat and blood spot incidence and size, and albumin height (in millimetres using a tripod dial micrometer).

Haugh unit values (a conventional measure used in egg quality investigations) were subsequently derived using the individual egg weights and albumin heights with a circular normograph. Haugh units are albumin heights of eggs, standardised to a 56 gm. egg weight, and converted to a log scale.

Amino Acid Analysis. Rations A, B, C, G, H and I were acid hydrolysed and analysed on a "Beckman" 120C Automatic amino acid analyser.

1.12 RESULTS.

Body Weight. Analysis of variance and subsequent comparison of treatment means for weight gains (using Tukey's method (Snedecor and Cochran 1967) are shown in Appendix I, tables 4 and 5 respectively.

These results show that gains made by birds on rations A and B were significantly lower than most other rations in the first 12 weeks. Those birds on rations C and D also gained less than the remainder over the latter part of this period.

At some point around the 12th week of age, the weight gain per 4 week period began to fall for those birds on the higher protein rations - especially rations H and I. Gains made while on these rations were significantly less than those made on rations A, B, C, and D over the period 12 to 16 weeks. After this time weight gains on all rations except ration A were markedly reduced, and not significantly different from each other.

At 20 weeks of age the body weights of birds on rations A and B were significantly lower than those on other rations.

Graphs of body weight and body weight gain for birds fed ration A and I can be seen in Figures 1.12.1 and 1.12.2. Some selected points over the experimental period show body weight distributions as seen in table 1.12.1.

Table 1.12.1

Treatment Mean Body Weights from Hatch to 47 weeks.(lb)

	Age (weeks)								
	Hatch	4	8	12	16	20	24	28	47
Treatment									
A	0.09	0.29	0.76	1.49	2.21	2.67	3.18	3.56	4.31
B	0.08	0.33	0.95	1.80	2.47	2.93	3.53	4.11	4.50
C	0.08	0.41	1.10	2.00	2.67	3.12	3.95	4.20	4.92
D	0.09	0.40	1.15	2.04	2.66	3.07	3.66	3.86	4.36
E	0.08	0.46	1.25	2.16	2.79	3.26	4.07	4.23	5.39
F	0.08	0.49	1.31	2.21	2.83	3.31	4.09	4.22	4.69
G	0.09	0.52	1.33	2.18	2.76	3.25	3.99	4.37	4.96
H	0.06	0.56	1.41	2.33	2.84	3.28	3.84	3.98	5.25
I	0.08	0.55	1.38	2.26	2.80	3.23	3.86	4.03	5.24

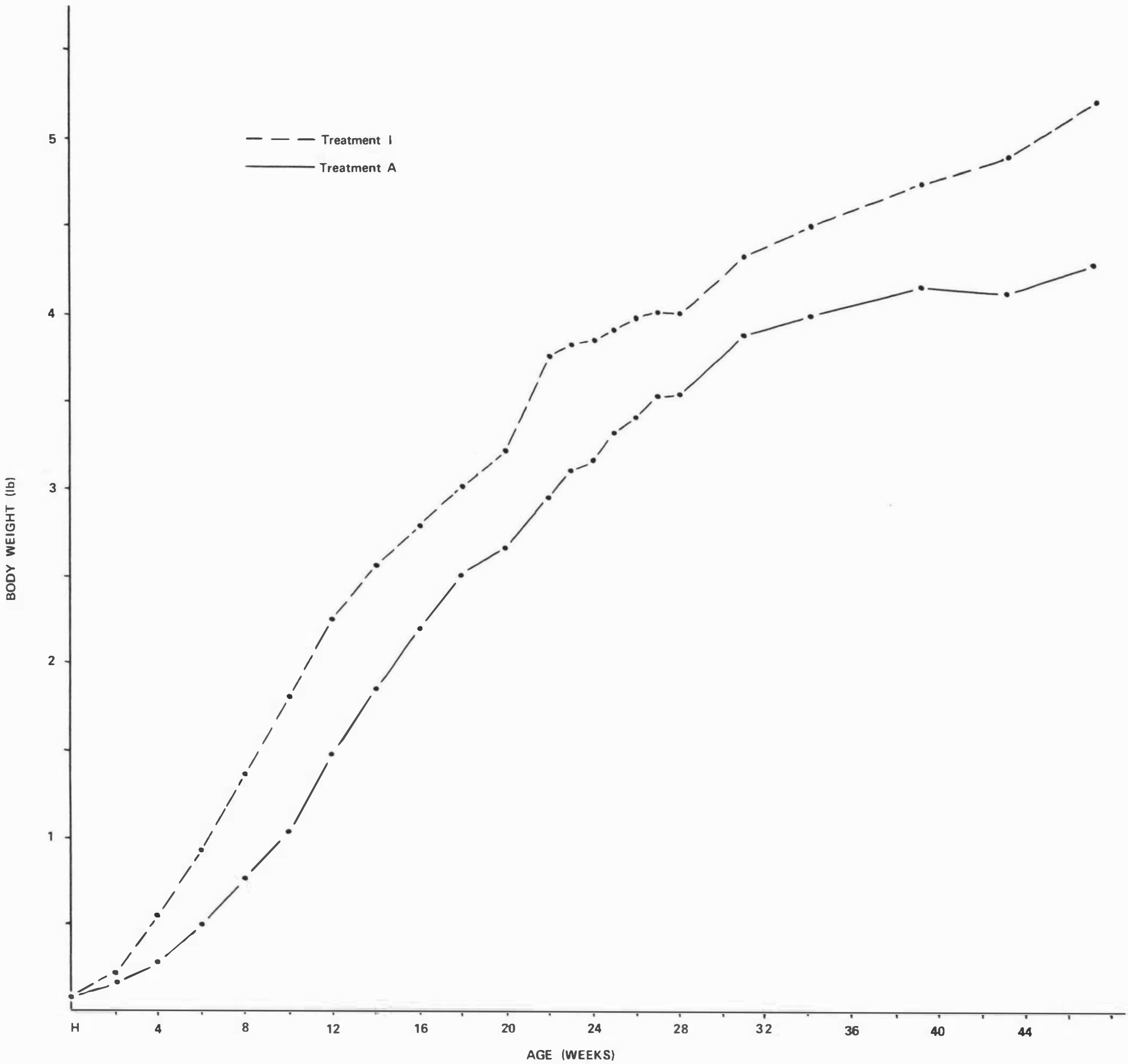


Fig. 1.12.1 – Change in body weight with age for treatments A and I in trial CN/50.

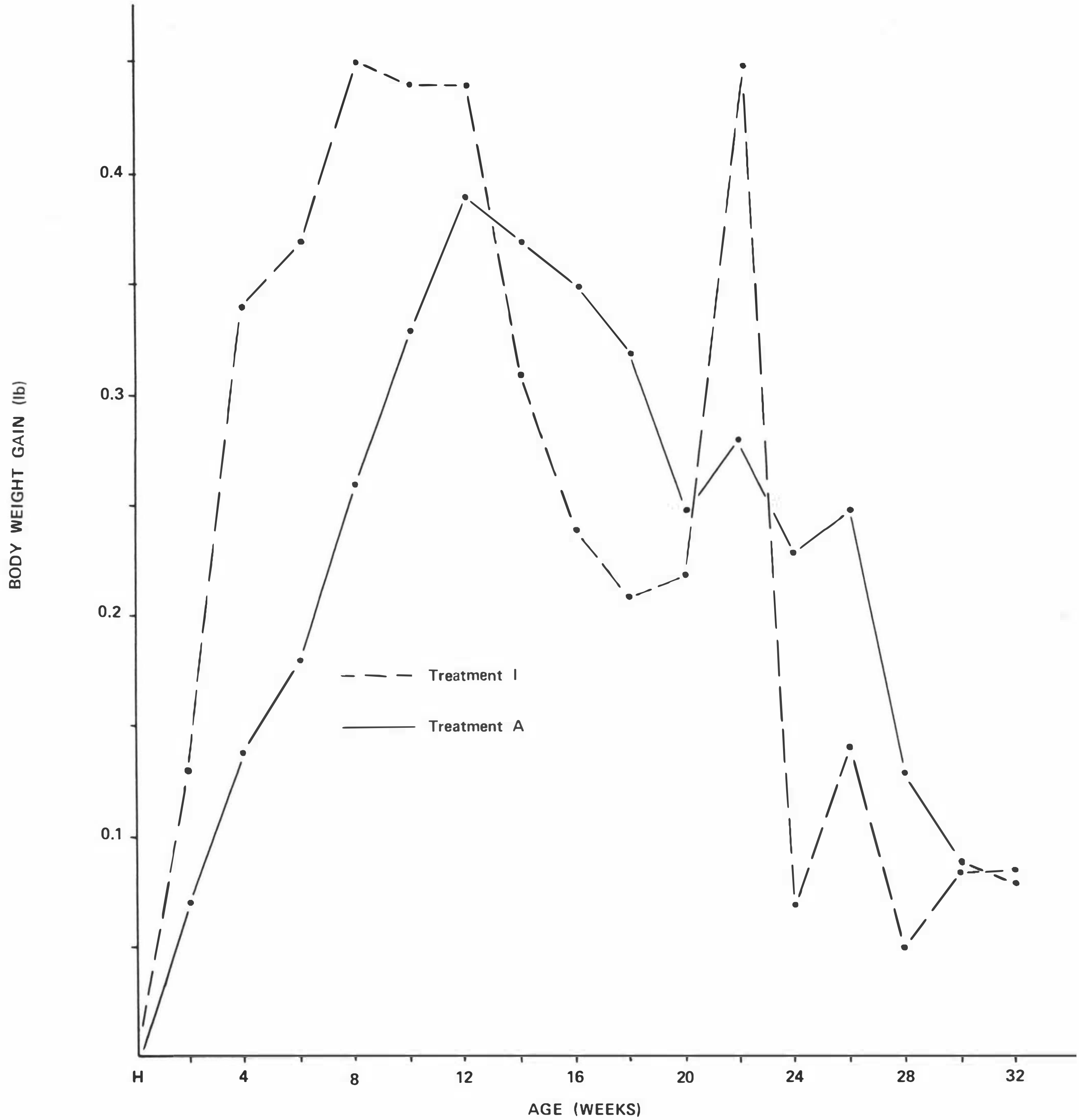


Fig. 1.12.2 – Rate of change of body weight ("marginal productivity") with age for the extreme treatments of trial CN/50.

<u>Shank Length</u>. Growth of the shank followed a similar pattern to that of body weight. (Table 1.12.2)

At the end of the 4th week, the birds on rations A and B had significantly lower gains in shank length than those birds on rations F and H. Over the next 4 weeks, gains were similar on all rations except that the birds on ration A were gaining significantly less than all others. Soon after the 8th week, rate of gain in shank length began to decrease for birds on the higher protein rations. Over the period 8 to 12 weeks, gains by birds on rations B, C, and D were significantly greater than those on ration H. By the 16th week shank length gains on all rations except ration A, had dropped to a similarly low level. After this time gains were of the order of 1 millimetre per 4 week period. Experimental measuring error probably contributed largely to any variation between treatments beyond the 16th week.

A graph of shank length and shank length gains for birds on rations A and I can be seen in Figures 1.12.3 and 1.12.4.

Analysis of variance of shank length gains and a comparison of treatment means can be found in Appendix I, tables 6 and 7.

Table 1.12.2

Treatment mean shank lengths (cm) from hatch to 24 weeks age.

	Age (weeks)						
	Hatch	4	8	12	16	20	24
Treatment							
A	2.51	4.07	5.44	7.07	8.38	8.57	8.50
B	2.48	4.03	6.48	8.14	8.89	9.14	9.23
C	2.49	4.26	6.21	8.07	8.66	8.63	8.62
D	2.51	4.31	6.22	8.07	8.58	8.61	8.54
E	2.49	4.35	6.45	8.11	8.45	8.61	8.52
F	2.46	4.73	6.69	8.38	8.96	8.88	8.78
G	2.50	4.57	6.61	8.12	8.60	8.66	8.61
H	2.49	4.85	6.96	9.03	9.34	9.43	9.39
I	2.51	4.67	6.72	8.30	8.67	8.62	8.56

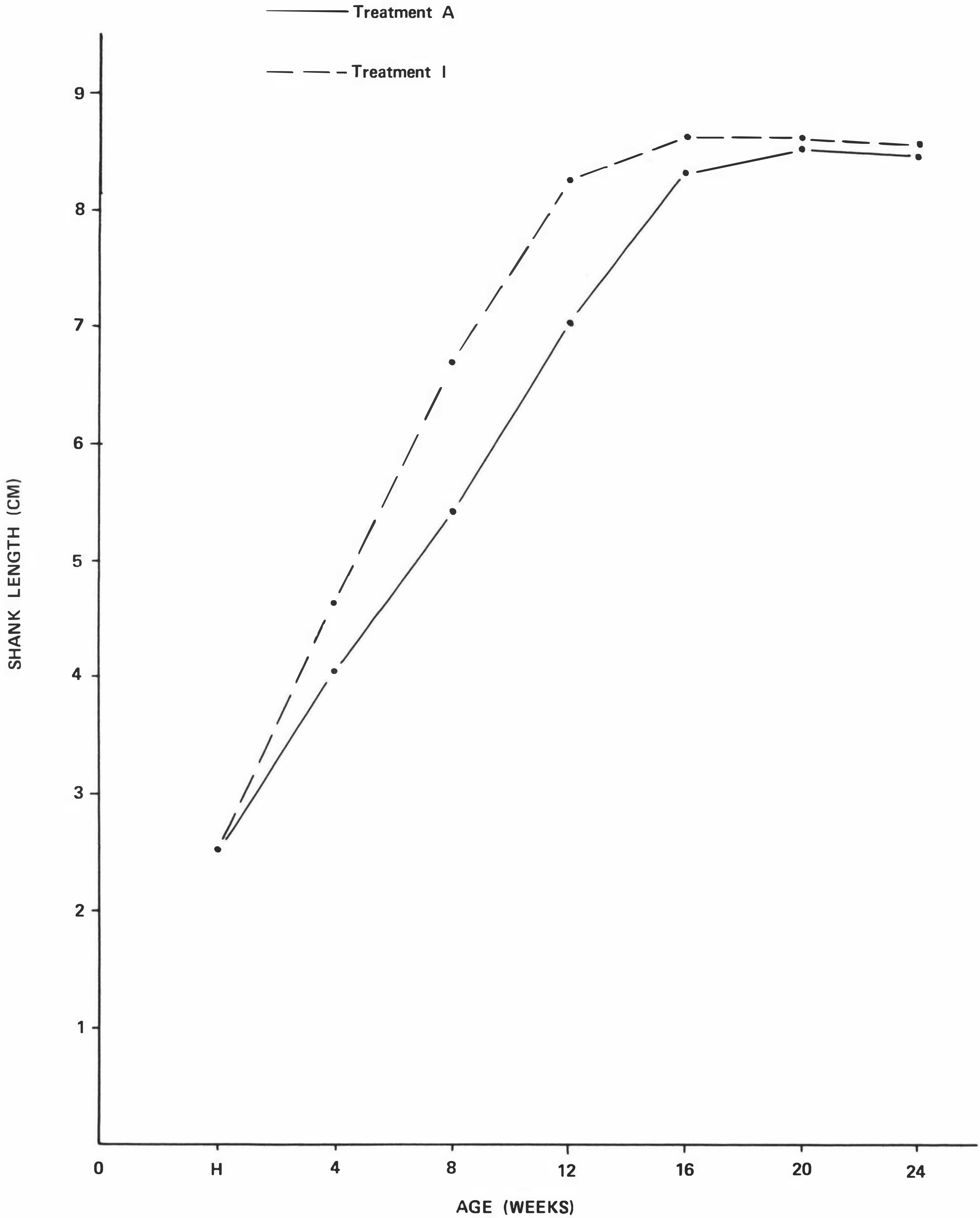


Fig. 1.12.3 – Changes in shank length with age for birds on the extreme treatments of trial CN/50.

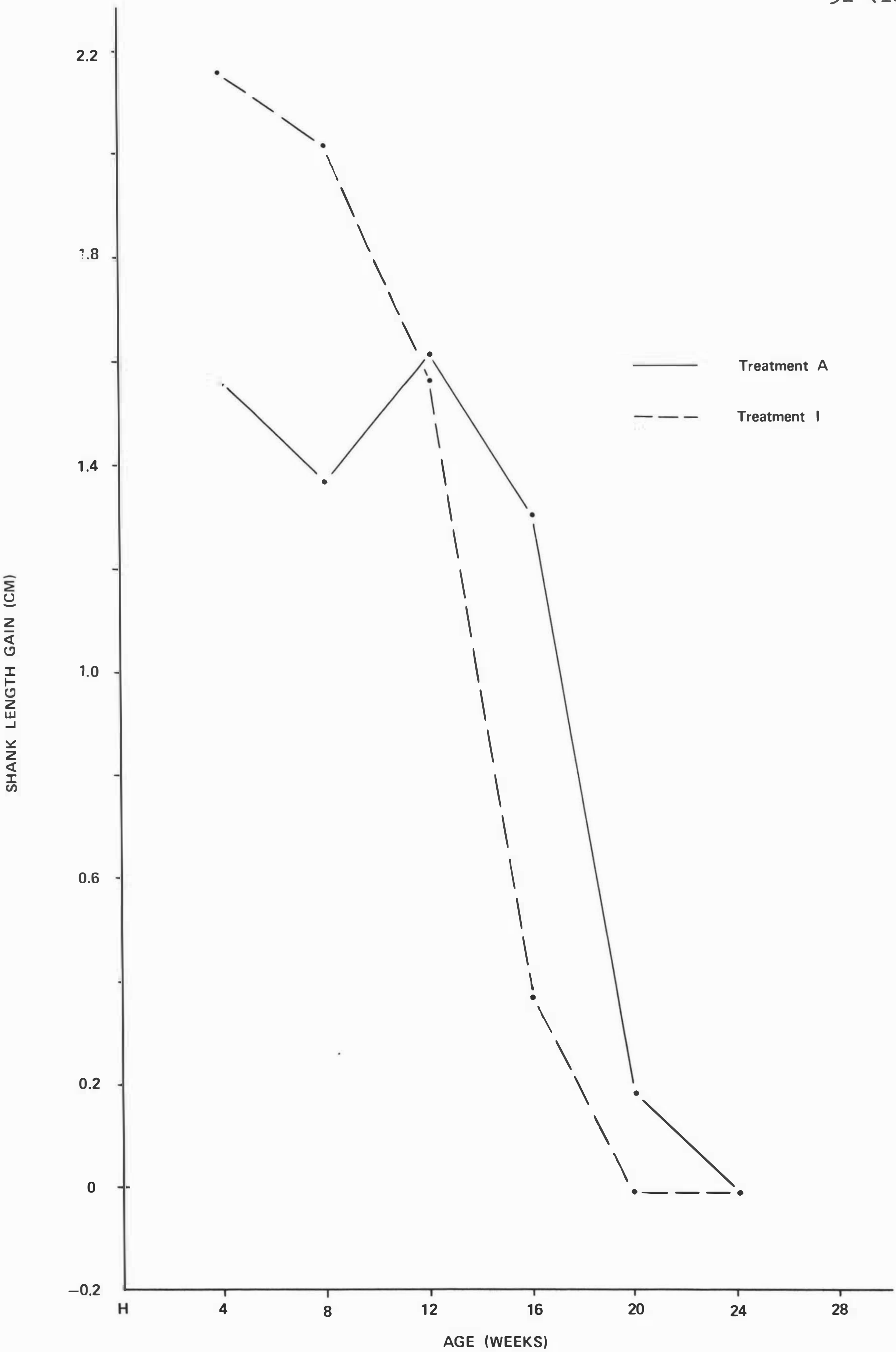


Fig. 1.12.4 – Rate of change of shank length with age for the extreme treatments of trial CN/50.

Food Consumption. Results were considered in the form of hen-day food consumption which allowed provision for birds dying during the period over which food consumption was measured. The figure for the total amount of feed consumed in a period was divided by the number of hen-days. The hen-day index was derived by a summation of the number of days each hen was alive during the period being considered. Thus the period hen-day food consumption was the hen-day food consumption multiplied by the number of days in the period. Each unit cell in table 1.12.3 below describes the hen-day period food consumption in pounds, on a per bird basis.

Analysis of variance between treatments over the periods shown, and a comparison of treatment means, can be seen in Appendix I, tables 8 and 9.

In the first 4 weeks, birds on rations A, B, C, and D ate significantly less than the remainder, and less than those birds on rations G, H, and I over the following 4 weeks. Rations A and B were consumed less than others from 8 to 16 weeks, and in the period 16 to 20 weeks rations A and I were consumed in amounts significantly lower, and higher, respectively, than all other treatments.

After the 20th week there were no significant differences in food consumption.

The total consumption during the rearing period (hatch to 20 weeks) differed significantly between almost every treatment; birds on ration A only consuming 75% of the quantity consumed by those on ration I. A graph showing cummulative food consumption for birds on rations A and I is shown in Figure 1.12.5.

Mortality. A distribution table of mortality for causes and treatments can be seen in Appendix I, table 10 with an analysis of variance for mortality in different periods in table 11. (Summary in table 1.12.4)

Overall there was an 8.0% mortality to 20 weeks of age, and a further 8.9% mortality in the laying period until 52 weeks of age. There was no significant treatment effect on mortality.

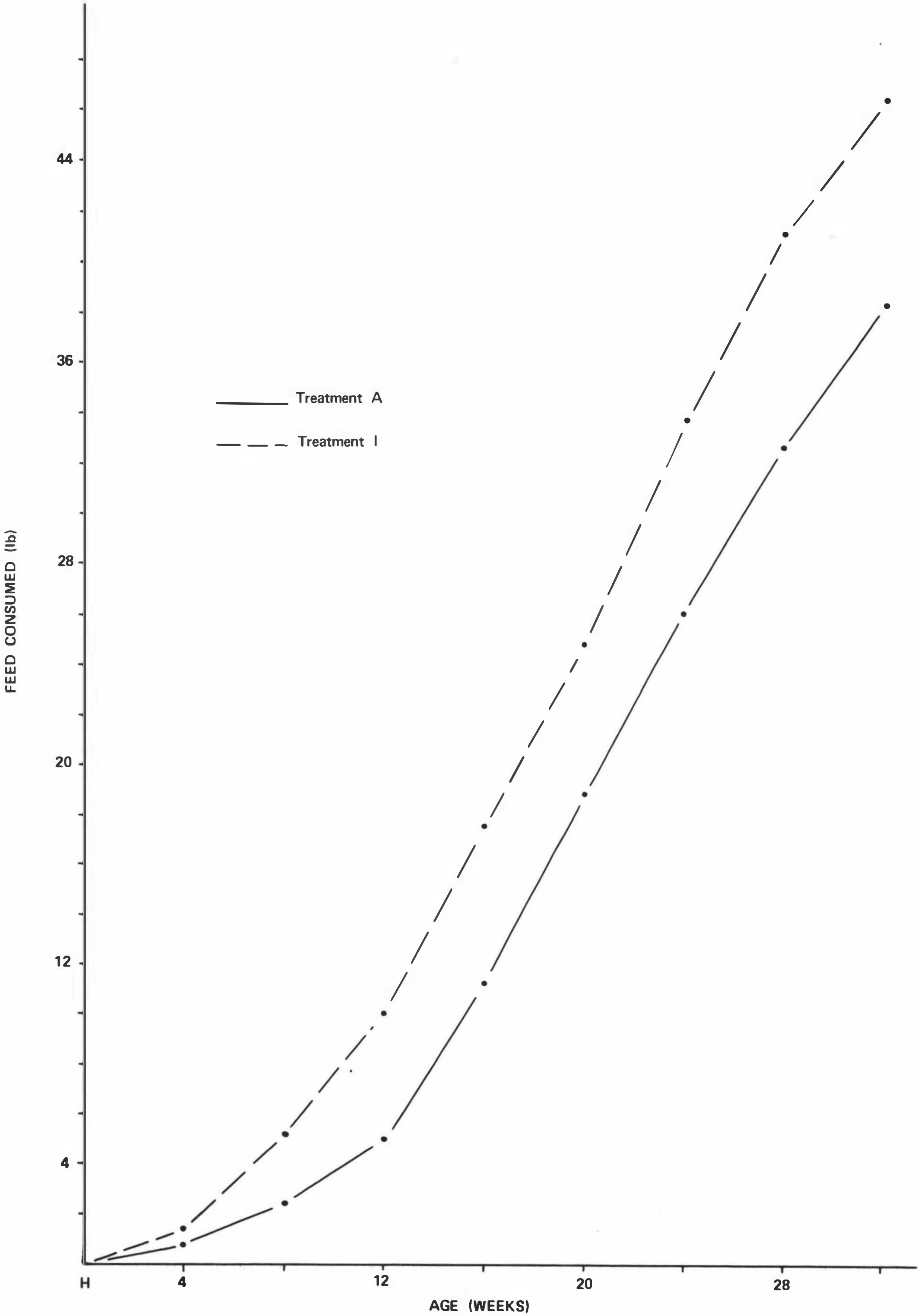


Fig. 1.12.5 – Commulative food consumption from hatch (H) to 32 weeks of age for the two extreme treatments of trial CN/50.

Table 1.12.3

Treatment means for Hen-day Food Consumption periods from hatch (H) to 32 weeks of age (lb/bird).

Treatment	H - 4	4 - 8	8 - 16	16 - 20	H - 20	20 - 32
A	0.84	1.67	8.84	6.15	17.50	20.96
B	0.90	2.49	9.48	6.15	19.02	21.74
C	1.01	2.67	10.08	5.85	19.61	20.75
D	1.02	2.92	10.62	6.26	20.81	20.90
E	1.18	3.15	10.93	6.56	21.82	21.89
F	1.30	3.33	11.18	6.51	22.32	21.38
G	1.32	3.51	11.09	6.72	22.63	21.85
H	1.41	3.66	11.87	6.61	23.56	21.52
I	1.48	3.83	12.36	7.30	24.97	21.75
M S D (1%) *	0.19	0.58	1.35	0.82	2.13	3.29
M S D (5%)	0.16	0.48	1.12	0.68	1.76	2.66

* M S D = Minimum Significant Difference (Snedecor et al 1967)

Age at First Egg. An analysis of variance and subsequent comparison of treatment means (Appendix I tables 12 and 13) showed that birds on ration A matured significantly slower than those on rations G, H or I. (Summary in table 1.12.4) All other differences were not significant. A difference of 11 days was required for a 5% level of significance, illustrating the considerable variation with this measure.

Body Weight at Age at first egg. Analysis of variance and comparison of means (Appendix I tables 14 and 15) of body weight at sexual maturity (as represented by age at first egg) showed that birds on ration A were significantly lighter (0.5 lb) than those on all other rations.

Egg Number. These results (summarised in table 1.12.4) were computed in 3 forms: Hen-day (HD) egg number, HD% egg number, and hen-housed (HH) egg number, this last form used the number of hens alive at the time of housing in the laying shed, as its divisor. HH production thus took account of viability or livability of the birds on that particular ration. The laying period was 222 days from 20 weeks of age.

For a detailed explanation of the above terms, see Appendix I (d).

Analysis of variance of treatment differences over each 4 week period from 20 weeks of age, can be seen in Appendix I table 16. A comparison of treatment means for the 2 periods in which significant differences appeared can be seen in Appendix I table 17. These results showed that over the period 20 to 24 weeks, those birds fed rations A and B in the grower phase, laid significantly fewer eggs on a HD basis, than most other treatments. In the following 4 weeks only those birds reared on ration A were still significantly lower in HD egg production.

In all other periods, there were no significant differences between HH egg numbers laid.

An analysis of variance of total HD egg numbers (Appendix I table 16) showed no significant differences between treatments, but when the results were uncorrected for mortality effects as in HH egg production (Appendix I tables 18 and 19) then birds on ration F showed a significant 18 egg advantage over those birds on rations C, G and H.

Appendix I table 16a shows the period HD% production for 14-day periods from 20 to 52 weeks of age. These results for rations A and I are graphed in Figure 1.12.6.

Amino Acid Analysis. The results of the analysis are shown in Appendix I, table 23, with an indication of the degree of inadequacy of each amino acid when compared with theoretical requirements.

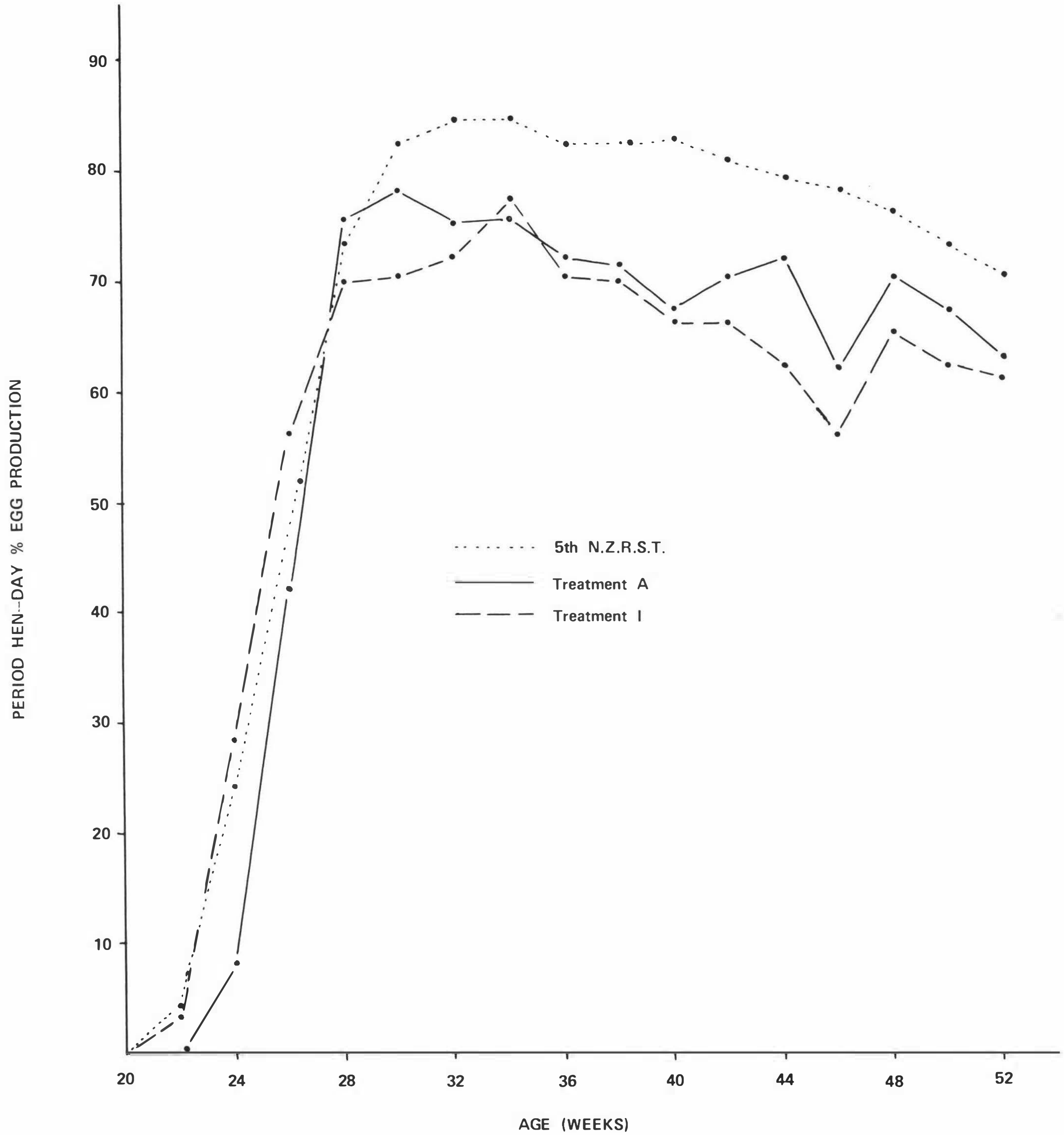


Fig. 1.12.6 -- Period Hen-day percent egg production for the extreme treatments of trial CN/50 compared with that of the 5th N.Z.R.S.T.

Table 1.12.4

Summary of treatment means for Age at First Egg (days); Body Weight (lbs) at first egg, HH and HD egg number; and mortality(%).

	A	B	C	D	E	F	G	H	I	MSD (5%)
Age at first egg	175	171	170	165	165	165	164	163	160	11
Weight at first egg	3.33	3.58	3.73	3.75	3.82	3.82	3.72	3.83	3.69	0.33
HH egg number	129.7	127.0	119.1	127.1	130.1	137.7	119.6	119.2	125.7	14.4
HD egg number	137.5	137.5	134.1	136.2	138.3	137.7	130.7	133.7	134.5	9.1
Rearing Mortality	12	21	8	12	0	2	0	6	6	-
Laying Mortality	7	7	10	0	17	0	7	13	20	-
Total Mortality	19	28	18	12	17	2	7	19	26	-

Egg Grading. Analysis of variance was used to detect significant individual egg weight differences at various points during the laying period. (Appendix I table 20). No significant differences were found.

A "weighted" egg weight was calculated for each treatment using individual egg weights for each period and "weighted" according to period egg number (Table 1.12.5). Analysis showed no significant treatment effects. (Appendix I table 21).

A summation percentage of all eggs within the various grades (see Appendix I (b)) together with the total mass of eggs laid per hen from each treatment, can be seen in table 1.12.5 below.

Grading information is of significance in economic evaluation and is therefore mentioned in more detail in Chapter 3.

Table 1.12.5

% of eggs laid in various grades for the 9 treatment, over the laying period; total mass of egg weight produced; and "weighted" egg weight (gm).

Rations.	% Grades.						
	Large	Standard	Medium	Pullet	Undergrade	Weighted Egg Weight	Total (kg) Mass per hen
A	3.4	65.6	22.6	4.6	3.8	52.6	7.31
B	3.3	60.1	29.4	5.2	1.8	51.4	7.25
C	9.1	48.0	35.8	4.9	2.2	51.8	8.03
D	11.8	58.6	25.8	2.8	1.1	53.3	7.33
E	11.0	62.9	21.7	3.0	1.4	53.2	7.46
F	7.0	59.7	25.5	5.9	1.8	52.4	7.35
G	8.6	64.6	20.4	4.9	1.5	52.8	6.78
H	18.5	50.1	23.4	4.9	3.0	54.0	7.34
I	10.4	57.3	23.3	6.4	2.7	53.5	7.32

Egg Quality. Analysis of variance for treatment effects on Haugh Units, yolk colour, and size of meat and blood spots (Appendix I table 22) indicated that there were no significant differences between treatments. A table of mean values for Haugh Units and "Roche" yolk colour measures is seen in table 1.12.6. If yolk colour falls below 7.0, this is classified "unacceptably pale". Haugh Unit values must fall below an average of 66 before quality becomes unacceptably low.

Distribution of blood and meat spots is also shown in table 1.12.6. These figures were arcsin.root percentage transformed before analysis.

Table 1.12.6

Treatment mean values for Haugh Unit, yolk colour, meat and blood spots (untransformed) of eggs broken out at 41 weeks of age.

Treatment	Haugh Unit	Yolk Colour	% Large * Blood Spots	% Large Meat Spots	% Small** Blood Spots	% Small Meat Spots
A	81.4	8.2	11	0	11	0
B	83.1	7.9	4	0	8	0
C	82.3	8.3	0	0	11	4
D	81.3	8.2	7	0	4	7
E	82.0	8.2	3	0	7	0
F	79.6	8.4	7	0	3	0
G	81.7	8.2	0	0	19	0
H	79.5	8.6	0	0	0	0
I	80.9	8.2	3	0	10	0

* Greater than 1/8 inch in diameter.

** Less " 1/8 inch " "

1.13 DISCUSSION

Analysis. The different measurements taken varied as to the efficiency of estimation. Body weight was measured for individual birds whereas food consumption was measured on a group basis - the size of which varied between 8 to 14 birds.

From a statistical point of view, food consumption means squares are therefore derived using fewer degrees of freedom - which reduces the chance of establishing significant differences between treatment food consumption unless these are quite large.

Growth and Development. Birds fed the lower protein grower rations (A, B, C and D) showed evidence of a reduced body weight gain and reduced skeletal growth rate (as represented by shank length) in the growing period. The period of most rapid body weight gain appeared to be over the period 7 to 13 weeks for birds on the high protein rations. Those birds on ration I gained 1.2 lb. over these 6 weeks (see Figure 1.12.2). The period of most rapid growth in the more restricted birds was delayed. This delay was 3 weeks with birds on ration A, but during the period 10 to 16 weeks, these birds also gained 1.2 lb. After the peak growth rate periods, weight gains were markedly reduced. After the 14th week the restricted birds were still gaining weight faster than the unrestricted birds. This marked an obvious compensatory growth while birds were still on the restrictive rations.

Presumably some adjustment to the diet had begun much earlier - probably from the 4th week of age. This period of compensatory weight gain may account for the fact that there was only a 2 week delay in sexual maturity between birds fed Rations I and A (compared with the 3 week delay in peak growing periods.)

Skeletal growth closely parelleled that of body weight gain though the maximum rate of shank elongation in birds fed the restricted ration A was 6 weeks behind that of birds on ration I. (see Figure 1.12.4)

Weight increase with time had the standard sigmoid flexure curve relationship. (Figure 1.12.1) Birds on Ration I showed an increasing rate of growth over the first 8 weeks; followed by a period of uniformly high growth rate until 12 weeks. Diminishing returns began after the 12 week and a slow decline in growth rate was observed up until the 20th week when a 2 week period of rapid growth rate began - probably reflecting the sexual development of the ovary and oviduct.

Sexual maturity (as measured by the age at first egg) occurred at the end of this short period of rapid growth; at the 23rd week. Then followed a period of gradually diminishing growth rate until measurements were terminated after the 47th week of age.

The average 19 week body weight of White Control stock (R.S.T.W.C.) in the 5th N.Z.R.S.T. was 2.9 lb., or approximately the weight achieved in 20 weeks by birds fed the low protein rations A and B in this trial. These birds were significantly lower in body weight than those on rations E, F, G, H and I at 20 weeks. This probably reflects the generally reduced growth rate of these restricted birds.

The final body weight of the R.S.T.W.C. birds at 70 weeks of age, was 4.4 lb. Even at 47 weeks of age, all CN/50 birds except those reared on rations A and D had exceeded 4.4 lbs.

The lower body weight of the R.S.T.W.C. birds may reflect the deep litter floor conditions where birds are much more active and perhaps exposed to greater "stress" levels of disease.

The growth data for this trial indicated that the restrictive rations fed during the growing period did reduce body weights throughout the experimental period, compensatory body weight gain becoming obvious after the 14th week of age. The skeletal frame growth reflects the reduced body weight growth in the first 12 to 14 weeks, but after that period only birds fed the most restrictive grower ration had a significantly smaller skeleton.

A delay in sexual maturity was observed as a result of feeding the more restrictive growing rations, those birds fed grower ration A not commencing lay until 25 weeks of age - which could be regarded as an unacceptably long (economic) delay. However, ultimate assessment made in relation to profit per bird indicated that this was not so.

Table 1.13.1 indicated the changes in weight which occurred between sexual maturity and the end of the experiment (at 47 weeks), and the measured gain in weight over the period in which the layer ration was fed (20 to 47 weeks).

Table 1.13.1

Body Weight (B.W.) Changes during the Experiment.

	A	B	C	D	E	F	G	H	I
B.W. at 20 weeks	2.67	2.93	3.12	3.07	3.26	3.31	3.25	3.28	3.23
B.W. at Point of Lay	3.33	3.58	3.73	3.75	3.82	3.82	3.72	3.83	3.69
B.W. at 47 weeks	4.31	4.50	4.92	4.36	5.39	4.69	4.96	5.25	5.24
B.W.Gain after maturity	0.98	0.92	1.19	0.61	1.57	0.87	1.24	1.42	1.55
B.W. Gain 20 to 47 wks.	1.64	1.57	1.80	1.29	2.13	1.38	1.71	1.97	2.01

These results indicate that even though the skeletal frame of most birds was uniform, the weight gain after sexual maturity depended largely on the rate of gain before maturity.

A possible explanation is that the gut capacity had become higher for the birds fed Rations F, G, H, I and the birds may have continued to eat a similar amount in the laying period due to the inelasticity of adaption to a different energy-content diet. This extra energy would be likely to be laid down in the bird as fatty tissue, thus giving rise to a greater weight gain during the laying period.

The information provided by body weight measurements is adequate, and the extra expense involved in measurement of shank length for the information provided was possibly not justified.

Food Consumption. After only 2 weeks from commencing the trial, it was apparent that birds fed the higher protein (and therefore higher pollard) diets, consumed more feed.

The assumed metabolisable energy (M.E.) values for the ration ingredients may have been incorrect - in which case the higher protein rations may have been lower in energy.

A lower M.E. value for pollard would help to explain the increased rate of consumption on the higher pollard rations as it is known (Hill 1962) that birds consume to satisfy their energy requirements (within certain limits as discussed by Morris (1967)).

The source of pollard for this experiment included wheatgerm and variable amounts of fine bran in the product. Bran is higher in fibre and has only 65% of the M.E. value of pollard.

There may have been other factors affecting consumption such as flavour, and toxins of various types. The ratio of barley to pollard may be important if there is an interaction between the two. Feeding trials at the P.R.C. have indicated that a 1:1 ratio between these ingredients in a ration is optimal with respect to growth rate and food conversion efficiency (F.C.E.)

An amino acid analysis carried out on rations A, B, C, G, H and I (Appendix I table 23) indicated some deficiencies on a %-of-ration basis. However the theoretical requirements were based on higher energy and higher protein rations than those used in the CN/50 rations. There is very little information in the literature on daily intake requirements for amino acids, Scott et al (1969) indicating that about 0.35 gm Lysine per day is required for growing chickens. Due to the high consumption rates of the high pollard rations, levels of lysine were apparently adequate in rations G, H and I; but grossly inadequate for rations A, B and C, where consumption rates were low. Only about one half of the required daily intake of lysine was obtained on the latter rations. Thus it seems likely that one of the principle reasons for a reduced body weight gain in the growing period was an inadequate amino acid intake.

The imbalanced calcium-phosphorus ratio may have affected consumption in some way, the lower protein rations being more imbalanced, but other trials at the P.R.C. taken up to the 4 week stage indicated no significant effect.

Consumption to 19 weeks averaged 17.4 lb. for the R.S.T.W.C. birds which is approximately equivalent to amounts consumed by the experimental birds fed ration A, though comparison with birds reared in cages may not be very meaningful. The level of consumption on the experimental rations containing a high protein-high pollard level could be regarded as greater than normal. Apart from the reasons above discussing this, the bulk density of the ration is reduced by the presence of high pollard levels. The wastage of mash by flicking would thus have been increased by this factor. The average density of rations A, B and C was 0.516 gm/cc.; 18.7 lb. of these being consumed per bird in rearing which amounts to 16.5 litres of mash-volume consumed. The average density of rations G, H and I was 0.433 gm/cc.; 23.7 lb. or 25 litres of these were consumed per bird.

Thus the birds on the high pollard rations (GHI) consumed over 50% more mash on a volume basis. Apart from wastage considerations, it may be that the birds overestimated the extra amount they would need to consume, of these "light" rations, to get the same weight eaten.

Recent experiments at the P.R.C. to determine M.E. values have shown that pollard is only 80 Kcs M.E./lb. lower than barley, which is evidence to support the assumption of the high energy value used in calculations of ration energy levels. However, the experimental method of M.E. determination is susceptible to numerous sources of error in determination.

There are difficulties in using M.E. figures because of interaction between diet energy ingredients. These, and other limitations are discussed by Sibbald, Summers and Slinger (1959), and Vohra (1966).

Crude fibre estimations for barley and pollard at the P.R.C. were 2.8% and 5.8% respectively, and high fibre is usually associated with low energy values.

The FCE to body weight up to 20 weeks of age was better for birds on the lower protein diets (6.55 lb. food/lb. gain for those birds on ration A; 7.70 lb. food/lb. gain for those on ration I). By 20 weeks of age, the unrestricted birds had consumed 7.5 lb. more food per bird for a mean weight advantage of 0.6 lb.

As the grower ration composition changed from that of treatment A through to I, there were steady increases in the amount of each that was consumed in each of the time periods measured. Because the changes in ingredients between each ration were not large, statistical significance was only established between consumption of extremes. However, the steady increase in consumption can be seen in Table 1.12.3 over the range of rations.

Further support to the conclusion that with this experiment, all the compensatory growth occurred while birds were still being fed the grower rations, comes from results of consumption of the layer ration from 20 to 32 weeks of age. There were no significant differences between the treatments; though there may have been indication of a trend to slightly lower consumption in the laying period, where birds were reared on more restrictive diets.

Mortality. Mortality levels were lower in the rearing period and higher in the laying period for birds on the less restrictive rations. The situation was reversed for birds reared on the restricted rations. These results are in accord with published data but the causes of such a distribution are not indicated. An hypothesis that a restrictive growing rations eliminates those birds susceptible to stress in later life is often advanced by workers. Overall mortality during the rearing phase was higher than generally achieved at the P.R.C. with larger populations reared on litter. Cage rearing appears to be more "stressful" than floor rearing.

The lowest total mortalities were observed for birds fed rations of intermediate protein levels. A comparison of overall mortality levels with the White Control birds of the 5th. R.S.T. shows a 2% mortality in rearing (c.f. 8% in CN/50) and a further 8% till the 70th week of age (c.f. 8.9% up to the 52 week in CN/50).

Egg Production. The H D period data showed that the delayed sexual maturity of birds on the more restrictive growing diets affected their production until the 28th week of age. After this time there were no significant differences in period production.

Production for the whole period to 52 weeks showed no significant differences between treatments, indicating that the delayed birds had made up their disadvantage by laying at an increased rate. This result also indicates that production comparisons made on a production-after-sexual-maturity basis would show a definite advantage to those birds reared on restricted regimes.

When H H production was used to assess treatment effects, birds reared on ration F (total mortality 2.4%) had a significant advantage over those birds reared on rations C, G and H (mortalities of 17.9%, 6.7% and 19.6% respectively). It was apparent that high mortality was important in rating production on a H H basis, although the treatment showing highest (28%) total mortality (ration B) still rated 6th highest in H H egg number.

Period H D% production for each 14-day period throughout the layer phase is shown in Appendix I, table 16a. Comparisons between the 1967-68 R.S.T. results and CN/50 results are made to provide some perspective, but the systems of management and housing were considerably different. A graph comparing H D% period egg production is seen in Figure 1.12.6 for birds from treatments A and I compared with the 5th R.S.T. as a whole. A study of this graph will reveal a depression in egg production between the 46th and 48th week over all treatments. This was caused by the stress placed on the birds when they were shifted (for operational reasons) from one battery to another.

The restricted birds, though attaining sexual maturity at a later age, generally attained an earlier and higher peak of production, which was maintained for a longer period. The exception to this was treatment F which reached a production peak before all other treatments, and also laid at a high rate throughout (second only to those birds on treatment E).

Egg Weight and Quality. Though the number of eggs has the most significant effect on income from eggs, size considerations become more important as the price differential between grades increases.

Table 1.12.5 shows the average egg weights for the different treatments, which were not significantly different.

The restricted birds laid fewer eggs in the Large grade, and the price differential between this grade and Standard grade was 4 cents per dozen throughout the laying period.

The price difference in the drop to Medium grading varied between 3 and 8 cents per dozen, becoming smaller as the October, Spring seasonal oversupply began to reach the market.

Haugh Unit values and yolk colour measurements indicated that there were no adverse treatment effects on egg quality.

A discussion of the production function and economic aspects of CN/50 will be found in Chapter 3.

CHAPTER TWO.

MANAGEMENT OF LAYING STOCK.

2.1 Factors Affecting Egg Production.

(a) Housing Methods. In normal commercial practice, the pullet is transferred to laying quarters before the commencement of lay.

The laying shed is designed to provide an environment that will allow an optimum level of egg production and a means of collecting the eggs. The industry cost structure determines economic levels of investment in buildings and equipment for different climatic conditions.

The housing and management systems used in the laying phase differ widely: deep litter wood shavings, wire floor pens, colony cages, and single bird cages. There is a considerable volume of literature comparing various systems, comparisons being difficult because of the numerous interactions between housing systems, rearing methods, feed and water space, diet, light treatment, disease resistence, breed and strain of bird (Jennings, Fox, Marsden and Morris 1959; Singsen 1962; Proudfoot 1967; Balloun and Speers 1968; Balloun 1969; Cardin, Zimmerman, Snetsinger and Greene 1969; Wildey, Flegal and Coleman 1969).

Though performance in the laying phase is determined to some extent by the treatment received in the growing phase, there is a more direct temporal relationship between treatment and output in the laying stage.

(b) Light. The photoperiod affects rate of egg production, without having the power to stop or start the actual process. Poultry are more affected by changes in photoperiod than by the actual level of photoperiod at any one time.

Maximum rates of lay can be achieved with 9 to 10 hours of constant photoperiod (where this is maintained from day-old.) (Morris 1966).

Egg production is stimulated by an increase in photoperiod, and is depressed by a decrease in photoperiod, changes within the range from 8 to 16 hours being more potent than changes at other levels.

There are interaction effects between rearing and laying light patterns for optimum egg production. The system used depends whether daylight is being supplemented, or a light-proof shed is being used (Morris 1967a). The literature on light requirements is reviewed by Morris (1966).

Light intensities of 5 lux (see Appendix I (b)) as measured at the food trough, are the minimum practical levels for maximum egg production (Morris and Owen 1966, Morris 1967b).

There is no satisfactory direct evidence about the effect of different light colours on the rate of lay, though data from McGinnis, Ramirez, Boyd and Lauber (1966) implies that photoperiodic response is maximal with light in the orange-to-red band of the spectrum. Red glass or paint does not increase the output of these wavelengths from a bulb, but only filters out the green-blue part with a consequent reduction in light intensity.

(c) Temperature. There is an interaction between environmental temperature and food consumption. Metabolisable energy (M.E.) requirements, and hence food consumption, being lowered by 1.6% per Centigrade degree rise in temperature (Payne 1966). This effect operates only over a limited temperature range. At 86° F (30° C) there is an improvement in food conversion efficiency because less food is eaten for an identical egg mass output compared with a 64–68° F (18 to 20° C) environment. The nutrient concentration in the ration needs to be higher with the high temperature diet to maintain absolute nutrient intake requirements. Even so, egg size is reduced because of an inadequate M.E. intake. The reason for this is an over-estimation, by the hen, of the reduction in energy output of the body. Strain effects, acclimatization effects and heating verus food costs are all important factors to consider in relation to optimum environmental temperature in the laying shed.

There are other factors affecting egg production such as ventilation, humidity, and disease; but of major concern in this thesis are the nutritional factors.

2.2 The Nutrition of Laying Pullets.

As with growing birds, the major cost item with laying birds is feed. Any means of reducing feed costs while maintaining high egg revenue returns will increase profit. There are many methods of restrictive feeding which claim to increase profit, but before considering these, it is useful to consider the theoretical nutrient requirements of laying pullets.

During the early laying phase, requirements for tissue growth and feathers are most important. As the pullet approaches point of lay, there is a rapid increase in growth and development of the reproductive organs which places a priority demand on nutrient intake. During the 8 to 10 weeks following onset of lay, the pullet must consume sufficient nutrients to allow for egg production at rates approaching 80 to 90%; to increase her body weight; to maintain bone and muscle tissue; to fight disease and "stress"; and to do this with maximum feed conversion economy.

An example of ingredients and nutrient contents for a good laying ration can be seen in Appendix I, table 3 - the N.Z.R.S.T. Layer Ration in current use.

Requirements for nutrients should ultimately be considered on the basis of absolute requirements per hen per day. Requirements will vary tremendously depending on body weight, level of egg production, breed and strain and all the environmental factors mention in 2.1. Because of this inherent source of variation in requirements there is probably not much added inconsistency in considering requirements on the basis of concentration per weight of ration. The use of this inexact requirement form is sometimes seen in the literature (Ohori, Makada and Kinbara (1968)).

Some interesting work on the influence of physiological factors on the intake regulation in the laying hen was carried out at Oklahoma State University by Gleaves, Tonkinson, Dunkelgod, Thayer, Sirny and Morrison (1962); Tonkinson, Gleaves, Thayer, Folks and Morrison (1965); Gleaves, Tonkinson, Wolf, Harman, Thayer and Morrison (1965); Dewan and Gleaves (1969).

They found that layer ration protein levels varying (independent of energy and density) from 10.6% to 17% of the ration did not affect the level of food consumption, but the higher protein rations produced larger hens which laid at a higher rate of egg production and also had a higher mortality rate.

Diet levels of energy varying between 1020 kcs ME/lb (2247 kcs ME/kg) and 1230 kcs ME/lb (2710 kcs ME/kg) caused a decrease in food consumption as energy levels rose. This indicated an energy-sensitive intake regulation.

Density of the ration was varied independently using graded levels of cellulose and sand. The lighter rations depressed the weight of food consumption with an associated highly significant depression of egg production and body weight gain. Density varied between 0.735 gm/cc. and 0.444 gm/cc. (a normal ration density being about 0.58 gm/cc. (Scott <u>et al</u> (1969)). There were no density effects on mortality.

Tonkinson <u>et al</u> (1965) constructed production response curves between the 2 input factors: energy and protein intake: and egg number output. These curves will be discussed in Chapter 3. Hill (1962) had already established the relationship between dietary energy level and voluntary calorie intake of laying birds, Morris (1967) finding that the adjustment of the hen to maintain the same calorie intake is imperfect - such that on high energy diets, hens overconsume, and on low energy diets they underconsume. The range of dietary energy levels over which birds eat to equate energy intake varies with breed and strain, body size and environmental temperature. For a "moderate" temperature and a "high producing" White Leghorn strain, an intake of 300 to 320 kcs M.E. per hen per day is required. Within the range 1180 kcs ME/lb (2600 kcs ME/kg) to 1521 kcs ME/lb (3350 kcs ME/kg) a decrease in M.E. of 50 kcs/lb of diet will increase food consumption per hen by about 3.5 to 4% (Scott <u>et al</u> 1969). Thus if the high energy diets are not more than 4% more expensive than a diet 50 kcs/lb lower in energy, than the high energy diet is more economical on a feed-cost per dozen eggs basis.

High energy laying diets (Brown 1964) used to be popular commercially, but have lost popularity because of several factors, among which is the increase in vices due to greater time being available to the bird apart from that spent eating.

Protein intake is the most important single nutrient affecting egg production. The level of intake being determined mainly by the energy level in the ration.

Protein requirement in terms of egg output usually has a curvilinear relationship. The maximum egg output point is difficult to determine, and varies with breed and strain for each environment.

Harms, Damron and Waldroup (1966) found that high producing commercial laying strains required higher levels of protein intake and were more sensitive to reduction in diet protein levels than were New Hampshire hens. There was also much variation within the high producing strains.

Hutt (1961) found that some genotypes are able to withstand certain dietary deficiencies in amino acids, and vitamins D, E, Riboflavin and Thiamine - probably correlating with levels of production and growth rates.

For a constant egg output, Sharpe and Morris (1964) found a correlation between body weight and protein requirement for White Leghorns and Rhode Island Reds. The heavier bird required 4 to 5 gm extra protein per day for a daily output per hen of 35 gm egg mass. Part of this extra protein is doubtless required for maintenance of the (average) extra 1.1 kg Body Weight and also the faster body growth. Guillaume (1966) suggested a method to determine the amount of protein used for growth knowing body weight, live weight gain and protein % of the diet, which is claimed satisfactory for predictions with up to 21% protein in the diet.

There will exist for every set of conditions, a point where maximum egg output is achieved with a certain protein intake. However this maximum may not be an economic optimum. <u>This</u> point is discovered where the marginal cost of protein equals the marginal revenue of egg output.

Most factors which affect the response to protein intake will also have a direct effect on egg production itself. Output on a protein basis can be considered a function of egg number plus growth and maintenance requirements. It may also be a function of the rate of attainment of sexual maturity (Fisher (1965) re-interpretting Bray, Jennings and Morris (1965)); where results showed that the later maturing birds (5 weeks delay) required 2 gm protein hen-day more than the early maturing birds for maximum egg production. However the early maturing birds' intake of 16 gm protein per hen day produced only 45 gm egg mass, whereas the delayed birds produced 52 gm egg mass per hen day. The price differential between the different egg grades, as well as the price of a unit intake of protein, must be used to determine the economic optima in such a situation.

A simplification for comparative purposes used by Fisher (1965) considered output only on the basis of egg material - but some account must be made for body weight and growth differences.

Estimated protein intake requirements vary throughout the literature, as do the conditions under which they are measured. Squance and Brown (1964) estimate a requirement of 13.3 gm protein per hen-day for hybrid layers with diet energy levels of 1350 kcs ME/lb (2974 kcs ME/kg). Ration protein levels in that experiment (using colostomised hens) varied between 13 and 17%.

Novacek and Carlson(1969), experimenting with a 9.4% protein corn-soya ration supplemented with lysine and methionine, found a requirement of 11.3 gm protein per hen day for a 2 kg hen at 60% level of egg production.

Bray and Gesell (1961) found that a 60% egg production level was supported for 12 weeks from 31 weeks of age by a protein intake of only 7.5 gm per hen per day on an 8% protein diet. This intake produced an output of only 32.7 gm egg per hen day and the maximum egg output of 50.6 gm per day per hen was reached on a 14% protein ration; consuming 16.7 gm protein per hen-day under a temperature regime of 76° F (24.4° C). These results shown graphed in Figure 3.3.3.

Under more normal temperature conditions, but as measured over only a 4 week assay period, Thornton, Blaylock and Moreng (1957) found that on a 15% protein diet, birds required 14.2 gm of protein per hen-day to reach an output of only 36.3 gm of egg per hen day, on a 61% egg production level. (See figure 3.3.3.)

From the variety of experimental conditions, the variation in estimates is not unexpected. An increase in protein level of the diet from 12% to 18% was found to produce an increase in protein content of the egg of only 0.5% or less than 1 gm (Gardner (1970)). This fact justifies the use of egg mass as an output rather than egg protein.

As the laying phase progresses, pullets become less efficient at converting food material into egg material - specifically, the utilization of ingested protein is less efficient. It is for this reason that reduction in diet protein levels - called Phase Feeding, will often result in a lower egg production unless more than sufficient levels were fed initially. This condition of initial over-supply of protein is a common occurrence and is the reason for the published successes of phase feeding experiments. (Fisher 1965)

Restricted feeding methods as used in the laying phase are discussed in the following section.

2.3 Restricted Feeding of Laying Stock.

As early as 1939 the effects of a restricted feed intake on egg production and egg weight were being studied. Quantitative restrictions, as discussed in section 1.4 of this thesis (for grower rations), is more demanding from a labour point of view (Hollands et al 1961), though Heywang (1939) experimented with this method to try and establish input-output relationships between food intake and egg production. He used 75% and 87.5% of ad lib feeding amounts and found that a 1% reduction in input quantity resulted in a 2 to 2.5% reduction in output (egg number per hen). His data implied an unbounded linear relationship between feed input and egg output, but it appears likely that there is an increased rate of production at low feed levels and a diminishing marginal product at feed levels defining maximum egg number per hen.

Restricted feeding by letting the birds run out of feed occassionally, say for several hours per day, (Summers et al (1970)) has had some success in improving F C E and egg production. "Skip-a-day" restriction, where 24 to 39 consecutive hours per week were allowed with no feed, depressed egg production with broiler-type laying birds (Pepper, Slinger, Summers and McConachie (1966)), even though the scheme was commenced 2 weeks after the peak of egg production.

Phase Feeding. This method of restricted feeding of layers has achieved some popularity in the United States. Phase feeding is an attempt to reduce protein intake during the later stages of egg production.

Scott et al (1969) divided the laying season into 3 phases: from 22 to 42 weeks; from 42 weeks to 65% egg production (about 62 weeks); and thereafter. They recommend (using isocaloric rations containing 1300 kcs ME/lb. (2863 kcs ME/kg)) protein levels of 17.5%, 15.0% and 14.5% for the 3 phases.

Blount (1968), working in Britain, was unable to agree with these recommendations, which, under British conditions, introduced a risk of depressing egg production and egg weight. Thus even though the feed costs were reduced, overall egg revenue was reduced more.

Summers et al (1970) recommend a similar programme, but placed emphasis on the fact that the information should be used only as a guide. Not all layers have the same requirements for protein, energy, and other nutrients - thus it is not possible to suggest a programme to meet all situations. Other factors of importance are : the season of the year, strain of bird, and level of egg production.

The main reasons for reducing the protein intake are to reduce feed costs and to reduce egg size. The advantages of the first point are obvious, but the advantages of egg size reduction depends on the price received for different egg grades. Extra large eggs in the latter stages of production are uneconomical since no extra return is received for eggs larger than the minimum specification for the large egg grade. Extra large eggs are also more prone to cracking.

While realising that it is necessary to consider a phase reduction programme on an individual flock basis, Summers et al (1970) provide the following phase feeding guide: 17 gm protein intake per hen-day until 75 to 80% egg production is reached; then a reduction to 15 gm per day until 65-70% production; then 13 gm per day. For an average feed intake of 100 gm per day, this is equivalent to 17%, 15% and 13% diet protein levels.

Owings (1963) working with deep litter birds, lowered diet protein levels from 17.5% to 15.3% and 13.3% six weeks after the peak of egg production and found no effect on egg number, egg weight, hen body weight or egg quality. The F C E appeared to be improved as well.

Peak egg production does not necessarily place maximum demand on the reproductive system. Egg mass as used by Blount (1968) and Fisher (1965) may be a more accurate biological criterion. For example, egg mass is less at 80% egg production x $1\frac{3}{4}$ oz., than 70% egg production x $2\frac{1}{8}$ oz.

Physical maturity of body size is also not reached until after the peak of egg production. If egg mass production stays relatively constant until the end of the laying period, the bird may adjust its own appetite and consume less feed once body development has ceased. Thus it may phase its own feeding programme. (Blount 1968).

Fisher (1965), as mentioned at the end of section 2.2, is in agreement with the use of mass of egg product as a production criterion, and adds that the bird uses diet protein less efficiently as the laying phase progresses.

Fisher and Morris (1966) studied this loss of efficiency in terms of gram-protein intake per H D, and gram-egg weight output per H D. The 3 phases studied were: 23 to 33 weeks; 33 to 48 weeks, and 48 to 63 weeks. Diet levels of 12%, 14% and 16% protein were fed in all possible combinations over the 3 phases. The range of protein intake was 13 to 19 grams per H D, and the average efficiency ratings for the 3 phases were: 2.2, 2.7, 2.3 gm egg produced per gm protein intake per H D.

The early laying phase is also characterised by a higher requirement of protein for growth of body tissues and growth and maintenance of feathers. This amounts to a requirement of about 3 gm of protein per day more than that required after growth ceases. (Scott _et al_ 1969)

Buist (1969) reviewed the phase feeding situation up to that period, but drew no conclusions as to whether or not phase feeding was profitable. There seemed, to him, to be more reports in favour of the method than against. More systematic profit comparisons need to be made before the advantages and disadvantages become obvious.

Qualitative Restriction. There has been very little work done looking at the profitability of low protein laying diets fed throughout the laying period.

It is well known that with some nutrients, notably calcium, low levels of diet inclusion encourage a greater efficiency of utilization of those particular nutrients.

Gardner (1970) reported that a reduction in diet protein levels from 18% to 12% only reduced the protein content of the egg from 11.5% to 11.0%.

This shows that for a constant body protein maintenance, lower protein intake levels are more efficiently utilized.

The efficiency of protein or amino acid utilization depends too, on the quality of the protein, and interaction with other dietary factors.

Lillie and Denton (1967) found that where the cereals: barley, oats, wheat and corn each provided 10%, 12.5% and 15% of the diet protein; where each was the major cereal ingredient (all diets isocaloric); then there were significant cereal, as well as protein, and cereal-by-protein interactions, effects on egg number and body weight gain.

As the diets were isocaloric, the different protein levels affected the daily protein intake per H D (which varied significantly between 11 and 16 gm for the barley diets.)

These rations were fed to caged laying birds throughout the laying phase, thus there were no phase feeding effects, and birds did have time to adjust their body utilization mechanisms to a more efficient level. It is suspected that there may be a hormone-enzyme mechanism involved in this efficiency adjustment.

Increasing protein intake increased egg production, body weight gain, food consumption and gave a better F C E per dozen eggs produced.

Ranked cereal effects on egg production (Lillie et al (1967)) regardless of protein level were: oats, corn, wheat and barley worst. The utilization and digestion of the amino acids in the low protein diets may have been affected by imbalance effects.

McGinnis (1965) found that amino acid utilization was also affected by the type of diet-carbohydrate and non-protein nitrogen present. Work done by McNab and Shannon (1970) supported this finding and also found that individual amino acids varied as to the efficiency of their digestion and absorption.

The above literature does suggest that in some circumstances, laying birds can adapt to lower protein intakes which are partly caused by the lower diet levels of protein. The reduction in cost of the ration, as well as the reduced food consumption, while depressing egg production slightly, may cause an increase in efficiency of utilisation such that overall profitability is increased.

CHAPTER TWO B (EXPERIMENTS)

2.4 Aims and Objects.

The laying trial (code named LT/19) was designed to evaluate the effect of several planes of nutrition (as determined by protein levels) over the laying period from 21 to 58 weeks of age.

All birds were fed the same rations up to 21 weeks of age. In designing the experiments, the arrangement of the feed ingredients making up the various rations was organised with the aim of fitting a production function to the resulting data. It was then hoped that it would be possible to determine the optimum ratio of ingredients in the layer ration using marginal price analysis.

In this respect the design was similar to that described by Heady and Dillon (1961), which was also used in the design of the grower trial CN/50.

For similar reasons (see section 1.7) it was found that this design was unsuitable for such an analysis. A modified production analysis was therefore made on the results.

2.5 Experimental Design.

Brooder-Rearer Phase: The stock were not selected for LT/19 until they were housed in the laying batteries. They were reared on deep litter as part of the Poultry Research Centre's 1969 major replacement population of 3,800 pullets.

Layer Phase: Both sides of one 3-tier battery unit were used. Food troughs were subdivided into sections of 3 single bird cages for group feeding. All nine birds (3 from each tier) received the same ration. This unit was called a "tier group". Each tier group was replicated at random within each of the 4 blocks of the battery. One block occupied half the length of one side of a battery. For statistical analysis, treatments and tiers were considered fixed, and blocks random.

2.6 Rations.

All birds were fed the P.R.C. Starter-A and then Grower-A rations until 19 weeks of age when they were transferred to the layer shed.

Appendix II, Table 1 shows the ingredient composition of the grower ration. Using ingredient costs as at February, 1969, this ration cost $76.20 per ton (delivered in bulk).

Birds were fed the normal P.R.C. layer ration (see Appendix I, table 3) for the first 2 weeks after transfer to the laying shed (19 to 21 weeks of age) to allow a settling period on a good quality ration.

There were 14 treatment rations (labelled 19/1 to 19/14) fed over the period 21 to 58 weeks of age. The diets were made up of 4 main fractions:

(1) A barleymeal fraction which made up 79% of ration 19/1 and was decreased in steps of 3% to reach 40% of the 14th ration (19/14).

(2) A pollard fraction ranging from 5% in ration 19/1 to 34.9% in ration 19/14 in steps of 2.3%.

(3) A meatmeal fraction ranging from 2% in ration 19/1 to 11.1% in ration 19/14 in steps of 0.7%.

(4) A basal fraction which supplied some of the protein together with the bird's requirements for vitamins and minerals. This fraction made up 14% of every ration.

All mashes fed were coarse ground. They were mixed by a local feed mill and ordered in batches with sufficient quantities to last about 4 weeks. (400 lb. per ration). Rations were stored in labelled 100 lb.-bins in the cage shed. The rations were purchased in sacks (which increased the cost by $3 per ton) because of the small quantities involved.

After arrival, samples of each ration were taken and analysed for Kjeldhal nitrogen %, ash %, moisture % and some for crude fat % (by ether extraction). These figures (all on an air-dry basis) are given in Table 2.6.1 on page 59, together with the % ingredient composition of each ration.

Table 2.6.1 % Composition of the 14 Layer Rations.

	19/1	19/2	19/3	19/4	19/5	19/6	19/7	19/8	19/9	19/10	19/11	19/12	19/13	19/14
Barleymeal	79.0	76.0	73.0	70.0	67.0	64.0	61.0	58.0	55.0	52.0	49.0	46.0	43.0	40.0
Pollard	5.0	7.3	9.6	11.9	14.2	16.5	18.8	21.1	23.4	25.7	28.0	30.3	32.6	34.9
Meatmeal	2.0	2.7	3.4	4.1	4.8	5.5	6.2	6.9	7.6	8.3	9.0	9.7	10.4	11.1
Lucernemeal	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Buttermilk Powder	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Limestone	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Bonemeal	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Iodised Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vit. Min. Suppl. *	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Cost per ton (Bulk)($)	59.50	59.65	59.81	59.96	60.12	60.27	60.42	60.58	60.73	60.88	61.04	61.19	61.35	61.50
Kjeldhal protein	11.6	11.8	12.1	12.4	12.8	13.1	14.0	14.2	14.1	14.6	15.6	15.6	15.8	16.3
Calculated protein **	11.8	12.2	12.6	13.0	13.3	13.7	14.1	14.4	14.8	15.2	15.6	15.9	16.3	16.7
Energy (Kcs M E/lb)	1098	1098	1099	1099	1099	1100	1100	1100	1101	1101	1102	1102	1102	1103
Energy (Kcs M E/kg)	2417	2418	2419	2420	2421	2422	2423	2424	2425	2426	2427	2428	2429	2430
Cal/Protein ratio	93	90	87	85	83	80	78	76	74	72	71	69	68	66
Protein/Megacal.ratio	10.8	11.1	11.5	11.8	12.1	12.5	12.8	13.2	13.5	13.9	14.1	14.5	14.7	15.2
Calcium	3.16	3.22	3.29	3.35	3.41	3.47	3.53	3.59	3.65	3.72	3.78	3.84	3.91	3.95
Phosphorus	0.93	0.96	1.00	1.05	1.08	1.12	1.15	1.19	1.23	1.27	1.30	1.34	1.38	1.42
Ash	9.4	8.5	6.7	11.1	9.8	6.2	8.6	8.8	9.9	12.4	12.1	11.7	11.4	12.9
Moisture	11.0	11.8	11.9	11.2	11.0	11.4	11.1	10.3	10.5	11.3	10.4	10.2	10.2	9.5
Ether extract	-	2.5	-	2.8	-	-	2.9	2.5	-	-	-	-	-	-

* Composition of the vitamin - mineral supplement is shown in Appendix I, table 1.

** Values used in computation of calculated protein are shown in Appendix I, table 2.

Calculated analyses for protein, metabolisable energy, calcium, phosphorus, Calorie/Protein ratio and Protein/Megacalorie ratio are also given in Table 2.6.1. These calculated figures are based on information from published tables except for protein values which were estimated from previous analyses of similar ingredients analysed in the laboratory.

Price per ton delivered in bulk (also given in Table 2.6.1) is based on ingredient costs at the time of formulation (February, 1969).

2.7 Material and Methods.

General. The stock used were strain cross White Leghorn pullets from the P.R.C. White Base A strain. The birds were identified by wingbands attached after sexing, and housed in pens of about 400 birds each on deep litter in a semi-controlled environment brooder-rearer shed.

In the laying shed, pullets were housed at 19 weeks of age, one per 11 inch cage, in a 3-tiered, 504-cage battery (Cope and Cope Ltd., England). There were 9 birds per replicate tier-group, and 4 replicates per treatment. (504 birds in all). The test period in the laying shed was for 9, 28 day periods.

Heating. Brooder heating to 4 weeks of age was provided by infra-red strip heaters. The initial brooding temperature (95° F) was lowered gradually to achieve a 70° F house temperature by 4 weeks of age. A diesel heater (output rated at 250,000 B.T.U. per hour) in the layer shed, was thermostatically triggered at temperatures below 55° F.

Lighting. The lighting system was a 10 hours constant light for the first 19 weeks. Fourteen hours constant light prevailed in the laying shed.

Intensity was controlled by a dimmer device to about 0.3 lux at floor level in the growing phase and a minimum of 5 lux, measured at the food trough level of the middle tier at a point midway between two lights, in the laying shed.

2.8 Measurements.

Body Weight. The pullets were weighed individually at 22 weeks and 58 weeks to provide information on gain during the laying period. A "Salter" spring balance was used (No.60 M Mark II; 60 lb. in 0.1 lb. units).

Food Consumption. Food was weighed into each 3-cage compartment at least twice a week throughout the experimental period. Some of the more bulky rations (high pollard) needed more frequent filling. Once every 4 weeks, refusals were weighed back and 4-weekly food consumption calculated. A "Salter" ("Dust" model) scale was used (weighing up to 10 lb. in 1 oz. units).

Mortality. All deaths or obviously sick birds were sent to Dr. Pohl for diagnosis. A coded information sheet accompanied all birds sent for diagnosis. Initial clinical symptoms were entered on this sheet by the shed technicians. The sheet was later returned by Dr. Pohl with a diagnosis attached.

Egg Number. A movable indicator attached to each cage enabled individual egg records to be cummulated for a 14 day period. This record was then transferred to a card and the indicator zeroed.

Egg Quality and Weight. A single 3-day collection of eggs was made after the 34th week of lay (56 weeks of age). A breakout was carried out to determine yolk colour, meat and bloodspot incidence and size, and albumin height.

Haugh unit values were subsequently derived using individual egg weights and albumin heights with a circular normograph.

2.9 Results.

Body Weight. Treatment means for body weights at the beginning and end of the trial (22 and 58 weeks age) are given in Table 2.9.1 with weight gains. Analysis of variance was carried out to detect differences in body weight gain between treatments, tiers and tier by treatment interactions, see Appendix II, table 2. There were no significant differences or interactions.

Table 2.9.1.

Initial (22 wks.) and final (58 wks.) body weights (B.W.) and weight gains.

Ration	Initial B.W.(lb.)	Final B.W.(lb.)	Gain (lb.)
1	3.39	4.27	0.88
2	3.40	4.15	0.75
3	3.29	4.10	0.81
4	3.53	4.31	0.78
5	3.34	4.07	0.73
6	3.28	4.11	0.83
7	3.28	4.18	0.90
8	3.31	4.11	0.80
9	3.14	4.04	0.90
10	3.19	3.91	0.72
11	3.33	4.16	0.83
12	3.30	4.22	0.92
13	3.25	4.07	0.82
14	3.28	4.06	0.78

The 5% M S D level for weight gain was 0.23 lb. There were no visible trends towards a greater weight gain over the laying period for birds on the high protein rations.

Food Consumption. Results were considered in the form of hen-day (H D) food consumption, which allowed provision for birds dying during the period over which food consumption was measured.

Data was analysed on the basis of H D food consumption per bird per day for the whole of the laying period. (See Appendix II, table 3). The mean food consumption per bird for the period of the trial for each ration is shown in Table 2.9.2.

Table 2.9.2.

H D Food Consumption per bird per treatment for the 36 week laying period.

Ration	Consumption (lb.)	Ration	Consumption (lb.)
1	70.22	8	68.02
2	68.99	9	69.91
3	67.83	10	67.66
4	68.02	11	69.66
5	66.63	12	72.07
6	68.82	13	71.61
7	70.33	14	69.93

There were N S differences in H D food consumption, thus the birds consumed similar amounts of their different rations, and gained a similar amount in body weight over the experimental period.

Mortality. At 30 weeks of age, after 9 weeks of lay, 17 non-layers were culled. Apart from this, some 14 birds (2.8%) died over the period of the trial. Details of the mortality are shown in Appendix II, table 4.

There were no significant differences in mortality and non-layer incidence as between rations. (Table 5, Appendix II)

Egg Number. Results were analysed on a Hen-housed (H.H.) basis (number of pullets present at 22 weeks of age) and a H D basis (see Appendix II, table 6 and 7).

Analysis of variance for H H and H D egg number gave non significant treatment, or tier, or tier-by-treatment effects.

The 5% M.S.D. level for H H egg number was 57 eggs, which is a reflection of the large variation in mortalities between treatments. On a H D basis, 17 eggs was the M S D between treatments (5% level). This is a good example of the reason why egg production is usually quoted on a hen-day basis for experimental purposes where numbers of birds per treatment may not be high.

Results are presented below in the form : H H, H D and H D% egg production for the different treatments (in Table 2.9.3.).

Thus despite the 5% range in protein levels between the rations (making a $2 per ton difference in mash price per ton, birds consumed similar amounts, gained a similar amount in body weight, and laid a similar number of eggs.

Table 2.9.3.

Egg Production/bird from 22-58 weeks of Age.

Ration	H H Egg Number	H D Egg Number	H D% Egg Number
1	155.2	158.5	62.9
2	154.5	154.5	61.3
3	155.1	156.2	62.0
4	159.3	163.0	64.7
5	146.0	159.6	63.4
6	148.0	155.0	61.9
7	156.7	162.7	64.6
8	149.3	155.8	61.8
9	154.3	159.6	63.4
10	155.5	162.7	64.6
11	154.7	160.6	63.7
12	144.6	154.1	61.2
13	162.8	162.8	64.6
14	155.4	160.9	63.8

Egg Quality and Weight. Yolk colour, Haugh Unit Values and Meat and Blood spot incidence were all satisfactory from an egg quality point of view. The egg weight averages for this sample all fell within the range of Standard grade eggs (55 to 57.5 gm.). These results are presented in Table 2.9.4 on page 65.

Table 2.9.4.

Egg Weight and Egg Quality measurements per treatment made on samples taken for breakout at 56 weeks of age.

Ration	Egg Weight. (gm.)	Yolk Colour ("Roche" Colour fan)	Haugh Units	Meat and Blood Spots (%)
1	56.38	7.2	77.8	2
2	55.45	7.5	78.6	2
3	56.91	7.2	78.5	4
4	56.48	7.2	78.8	2
5	56.37	7.3	78.1	0
6	56.88	7.5	77.9	4
7	56.56	7.2	79.4	0
8	56.94	7.6	78.5	4
9	57.41	7.3	79.4	2
10	55.57	7.0	78.0	0
11	54.96	7.0	77.2	2
12	56.84	7.0	79.3	2
13	56.59	7.1	80.2	2
14	57.26	7.2	80.4	4

2.10 Discussion.

There are several possible explanations for the lack of variation in response to the varying planes of nutrition used in this experiment.

There is the possibility that the lowest plane (11.8% protein) was providing sufficient for a protein intake optimal for egg production, and that all higher protein levels were surplus to the requirements of the hen.

The possibility that an increased efficiency of utilization occurred on the lower protein intakes is another explanation.

It may be that a similar experiment carried out on birds which had had less than an optimum rearing management and indeed laying management, would have showed a production depression at the lower protein levels.

When dealing with living biological entities such as poultry, the inherent flexibility of the bird to carry out its potential productive functions under a variety of nutritional and environmental situations, should not be surprising. An increased sensitivity of response could be expected for younger birds, as was seen in CN/50 for a similar range of protein levels.

This serves to introduce the most likely reason for lack of response in this trial; that the protein levels were not low enough to cause a depression in production.

This is illustrated more graphically in Chapter 3 where production response curves are dealt with in more detail.

CHAPTER THREE

ECONOMIC ANALYSIS OF RATIONS FOR LAYER POPULATIONS.

3.1 Outline of the economic model and the role of the production function.

3.1.1 Introduction.

It is of benefit to outline a generalised approach to the economic analysis of animal production problems. Initially there must be a description of the production situation of interest; this involves detail of the framework of production and the variables under operational control. A statement of the economic problem associated with the production set-up leads to the specification of the economic model to be used. This will show the scope encompassed by the model - whether it is, for example, to be a batch or whole farm model. Once this is established, the objective function most appropriate to the situation is chosen. The role of production functions in the model for economic analysis is simply that they provide a mathematical description of the physical production processes involved. The aim then is to manipulate the control variables in the economic model so as to optimise the appropriate objective function.

3.1.2 Review of some economic models in animal production.

Heady and Dillon (1961) presented a number of simple economic models of animal production. These models emphasised feed input/animal output relationships and gave only limited consideration to the question of the appropriate economic objective function. Least-time feed inputs or maximum profit per animal were the criteria most commonly considered. For example, Chapter Ten of their text concerns broiler production. Broiler liveweight gain is expressed as a function of cornmeal and soyabean meal intake. Least-cost rations for different cornmeal and soyabean meal price ratios are presented, though Townsley (1969) has criticised the requirement that least-cost rations must necessarily follow the expansion path. Broiler weights that maximised profit per bird for different product and feed prices were presented. The question of the optimum batch number was briefly considered for broiler production.

Brown and Arscott (1960) also considered the production framework of broiler meat production and recognised that broiler chickens are grown in batches either to a certain average live-weight, or for a certain time period. This concept led Brown and Arscott to form an objective function for maximum profit per unit time.

A second major achievement of these workers was the inclusion, in a least-cost ration linear programming model, of animal response information derived from a production function. They realised that the least-cost ration did not allow for the biological response of the animal to different levels of inputs. Animal response for any least-cost ration formulation was predicted by reference to a production function with nutrient (protein and energy) intakes as the independent variables. The common form of least-cost linear programming minimises the cost of satisfying stated nutrient requirements for some given bulk (weight) of feed. However, ration consumption may be an important component of profit in animal production situations, and under ad libitum feeding this level is uncontrollable for any given ration. Brown and Arscott therefore replaced the common bulk constraint in the least-cost linear programme with a consumption function that predicted animal intake, over some specified time period, as a function of protein and energy levels in the ration. The economic model was then manipulated to derive rations that maximised profit per unit time for different production periods.

A consumption function predicting ad libitum feed intake is an important part of animal production models. The amount of feed consumed contributes to feed costs as well as the cost per lb. of a ration. Also, predicted feed intake must be restricted to being less than or equal to the ad libitum rate in any model of animal production.

Dent (1964) apparently failed to recognise the need to include such a consumption function in the analysis of his experiments on pig meat production. Dent deliberately limited his objective function by selecting a specific level of performance (in terms of average pig weight gain per day and total weight gain) and minimised feed cost for this level of performance. Thus his objective function was to maximise profit per animal for a fixed level of performance. This implies a fixed production period and does not consider the time concepts raised by Brown and Arscott (1960).

Townsley (1968, 1969) formulated a quadratic programming model designed to identify a range of economically efficient rations for pig production. The model relates to a specified overall weight gain for pigs fed ad lib. but selects the least-cost ration for any number of feasible average daily rates of live-weight gain. In this way least-cost, least-time or maximum profit per unit time rations can be identified. This model requires that average daily live-weight gain be a quadratic function of nutrient intakes and that ad lib. feed consumption be a linear function of nutrient intakes. Where these two conditions are not met, generalised non-linear programming methods or the method described by Dent (1964), using linear programming, could be used (with the proviso that an intake function be included in the production model).

Dent and Casey (1967) and Powell and Dent (1969) discuss some other modifications of the least-cost linear programming models such as relaxation of the common bulk constraint. Such modifications are limited by their failure to recognise the importance of an intake or consumption function.

3.1.3 Production functions in animal production.

Production functions have been mentioned in the previous two sections - presenting them as a tool for use within a model for economic analysis of live-stock rations. Henderson and Quandt (1958)* give the following definition of a production function :-

* Henderson J.M., R.E.Quandt. "Microeconomic Theory." p.42. McGraw-Hill Book Co., N.Y. 1958.

> "a production function is a mathematical expression for the relationship between quantities of inputs used, and quantity of output produced."

A production function summarises information on the technical process of production, enabling an output level to be predicted, given the number and level of inputs on which the output is dependent. A production function can most generally be written :

$$Y = f \ (X_1, \ldots\ldots, X_n)$$

where output (Y) is a mathematical function (f) of various inputs (X_1 to X_n).

The method of regression analysis is suited to the estimation of production function coefficients. Predictions can then be made from the estimated function. There are three factors to consider when carrying out such a regression analysis: the choice of variables among which the relationship is supposed to exist; the mathematical form of the model; and the type of estimating procedure to use. The aim being to obtain as accurate a description of the actual production process as is possible. The method of Least Squares Regression (L S R)(Snedecor and Cochran 1967) is usually chosen as the procedure providing the most accurate estimation of output ($\hat{Y}$) with the least variance and bias. Cochran and Cox (1957) discuss the suitability of the L S R method of production function estimation for response research.

Production function estimation requires a particular type of experimental design where it is important to provide a sufficient number and spread of treatments so as to enable the continuous nature of the animal response to be measured, (Heady and Dillon (1961) page 147). This means that where funds for research are limited, there could be some sacrifice in statistical requirements for replication. A balance between number of treatments and number of replications per treatment must be reached. Williams and Baker (1968) compare the production function approach with factorial designs, while Anderson and Dillon (1968) illustrate an argument for response research on the basis of economic considerations.

The control variables decided upon for the production function inputs, (X_1 to X_n) are assumed to be alterable in a continuous fashion over some range of levels for each control variable. This continuity assumption is necessary if calculus methods are to be used in the analysis of an economic model based on technical production functions.

Problems in the methods of estimation of production functions in livestock feeding involve those of autocorrelation in successive observations on the same animal (Anderson 1952); biological variation in the experimental animals and in the ingredients used for the ration formulation, and interactions between these two latter factors causing unpredictable changes in intake with different foods and animals. The methods of estimation of production functions in the presence of these difficulties is described by Cochran and Cox (1957), Heady et al (1961), Duloy and Battese (1967), Dillon (1968), and Fuller (1968).

Early work with production functions (estimated by least squares regression (L S R) analysis) dealt with varying elemental levels in fertilizers, and measured the response of plant growth. McCarthy (1959) used increasing fertilizer levels with measured barley response, a similar example being chosen by Throsby (1961) in a clear illustration of the method used for fitting a production function to experimental data.

Most of the recent work in the field of animal production functions has been carried out with pig live weight gain. Townsley (1963) derived a whey:meal function for pigs; Dent (1964) and Dent et al (1966) using the nutrient approach with protein and energy intakes of bacon pigs; the latter incorporating a least cost programme.

Townsley (1969) looked critically at all the previous methods, and advanced a quadratic programming model for pig rations in an attempt to allow for the situations unaccounted for by many of the previous workers. Statistical estimating procedures advanced by Fuller (1968) were also illustrated in this study.

Choice of the control variables must be carefully made from the range of animal genotypes and environments available. In practical research situations, the choice of variables is usually limited by the expense of different types of equipment and the labour involved in measurements. With most nutrition studies, the control variables are the feedstuff ingredients of the ration. However where the choice of feedstuffs is large, estimation of a production in terms of the intake of individual feedstuffs is impractical and another approach is used. Each feedstuff is made up of certain nutrients which are the chemicals used by the animals in the synthesis of the output product being measured. The two nutrients usually considered as functional inputs are protein and energy - these nutrients being provided by each individual feedstuff in the ration. The nutrient approach places reliance upon the chemical analysis of ingredients for these nutrients. It is generally recognised that there are many problems involved with this approach concerned with how the chemical analyses reflect the biological value of the relevant nutrients. It should be realised that most of these problems also arise with the use of ingredients as inputs (where these are few) because of the variation present in the nutrient content of different samples of a given feedstuff. For example, analyses carried at the Poultry Research Centre (1968) on crude protein levels of barley in the Manawatu, showed a range of 8.5% to 12% for five samples.

The feedstuff approach does avoid problems such as variation in amino acid patterns which exist within any crude protein determination. For example, the amino acid pattern is different for protein from the sources barley and meatmeal. Anwar's (1970) suggestion for the use of Gross Protein Value Units may lead to a solution of this problem. An index made up of amino acid levels weighted for usefulness may be an alternative. Brown and Arscott (1960), Dent (1964) and Townsley (1969) all made some attempt to solve this problem by placing constraints on the amino acid composition of the ration as a whole. The use of Metabolisable Energy (M E) as an energy unit has many advantages over Gross Energy or Productive

Energy, but there are still problems associated with its method of determination. At the Poultry Research Centre, experiments have shown that feedstuff M E values serve only as a guide to overall ration energy values.

A solution to the problem of inaccuracy of estimation of the production function caused by nutrient variation awaits the testing of models which have been estimated by both approaches. For the economic models so far described to have any practical relevance, it is necessary to be sure that the feed mixes designed to meet the optimum nutrient specifications, will match the level of performance predicted by the production function. An introductory study to test a pig meat model was carried out by Dent and English (1966) and more recently by Dent, English and Raeburn (1969) who tested a regression model previously estimated by Dent, Blair, English and Raeburn (1970). These experiments introduced the concept of response to a graded intake of an amino acid (lysine) as shown by live weight gain and lean meat production of pigs. Protein and Total Digestible Nutrients (T D N) were also considered as input variables in regression equations, but the work still lacked the inclusion of an intake or consumption function which left open the question of which method of feeding was used: ad lib., or controlled.

No definite conclusions were drawn from the experiments of Dent et al (1969) which looked at the feasibility of basing pig feeding systems on nutrient ratios without reference to ingredient composition as part of the testing of the regression model set up by Dent et al (1970). There were no significant differences between ingredients for equivalent nutrients were lysine and energy substituted for three different rates of live weight gains over three growth stages. However the results did show that any change in diet during any of the growth stages, reduced the rate of live weight gain.

The initial requirement for a nutrient approach was necessary because of the large number of alternative feedstuffs usually included in any least-cost feed mix programme. It is suggested that if a least cost ration is derived, then it might be useful to then consider the main ingredients of the solution as inputs in a production function-type experiment. This idea was used in the design of rations for trials CN/50 and LT/19 and is discussed in section 3.2.2.

3.2 Economic models for analysis of rations for layer populations.

3.2.1 Review of economic analysis of layer rations.

Production functions in the field of poultry science have been mainly confined to the broiler field (Brown and Arscott 1960, Heady et al 1961, Heady, Balloun and Townsley 1966), but there is some earlier work published on the layer situation.

Heywang (1939) derived a linear function for food intake and egg number output based on experiments with quantitative food restriction. This experiment has been discussed previously (Page 53).

Hanson (1949) used laying trial results to derive a linear function which he suspected may indicate diminishing returns of egg number output to feed intake at higher, and then undetermined, food intake levels. He drew attention to the problems associated with the difference between live weight gain functions and continuously-produced-product functions such as milk or eggs. He noted that :

> "diminishing returns for continuous flow outputs are not clearly visible because of the flexible nature of biological (processing) machines. Eggs and milk are both secretory products of the reproductive system."
> (Hanson & Mighell (1952)).

The parallel between eggs and milk production output was taken from Brody (1945) who stated that the :

> "energetic efficiency is the same for milk and egg production. The maintenance fraction of the diet is higher for hens than for cows, thus any restriction of feed should have a more significant effect with hens, than with cows".

Heady (1966) and Heady and Brown (1961) also discuss and derive production functions using an output measure in terms of egg number. Heady and Brown (1961) fitted a power-form function for White Leghorn and "hybrids".

Heady (1966) introduced production functions and other econometric techniques to the modern poultry industry at a British Egg Marketing Symposium.

He presented the framework of a production function :

$$y = f(x_1, \ldots, x_z)$$

or $y = f(x_i);\ i = 1, \ldots, z$

where y = egg production

i = 1 to e : ration constituents

i = (e + 1) to n : variable costs e.g. labour.

i = (n + 1) to r : strains of hen used.

i = (r + 1) to z : fixed costs of different building types.

Emphasis was placed on the need for more research into the use of econometric techniques with poultry.

Tonkinson <u>et al</u> (1965) (at Oklahoma State University), while realising the interpretation problems associated with the nutrient input approach, estimated three quadratic functions in terms of input levels of protein (gram-intake per hen-day (H D)) and energy (M E intake per H D) :

$$Y_i = f(x_1, x_2)$$

where Y_i = production response, where $i = 1, 2, 3$.

Y_1 = body weight gain in the laying period (gm).

Y_2 = egg number (H D).

Y_3 = average egg weight (gm).

x_1 = protein intake.

x_2 = energy intake.

The L S R method produced the following functions :

$$\hat{Y}_1 = -1134.91 + \overset{*}{22.89}x_1 + \overset{*}{41.47}x_2 - 0.197x_1 x_2 + 0.235x_1^2 - 0.203x_2^2 \text{ (gm).}$$

$$\hat{Y}_2 = -205.67 + \overset{**}{22.49}x_1 + \overset{**}{10.15}x_2 + 0.033x_1 x_2 - \overset{**}{0.673}x_1^2 - 0.156x_2^2 \text{ (eggs).}$$

$$\hat{Y}_3 = 49.42 + \overset{**}{1.079}x_1 - 0.47x_2 + 0.0009x_1 x_2 - 0.029x_1^2 + 0.011x_2^2 \text{ (gm).}$$

* indicates that the estimated coefficient is significantly different from zero at the 5% level - the level of significance of the parameter sum of squares as they affect the respective production responses.

** 1% level of significance.

Levels of daily protein and energy intake for maximum egg production and egg weight (160 eggs at 55 gm. each for a 196 day period (82% H D egg production)) were found by derivation to be 16.6 gm. protein and 341 kcs per H D. These levels corresponded closely to nutrient standard levels set up by the Oklahoma University.

The isoquants for egg number, and the isoquant for zero body weight gain as derived by Tonkinson et al (1965) are seen in Figure 3.2.1.

The range of protein intake necessary for 76% production (150 eggs on Figure 3.2.1) is 13 to 22 gm per H D, which would be easily within the possibilities of most practical layer rations. This would represent a minimum level of 13% protein in a ration for a 100 gm per H D intake of food.

The data used in this analysis came from an experiment investigating the effects of protein, energy, and bulk density factors on physiological intake factors in the hen (Gleaves et al 1965). The experiment was a 3 x 3 x 3 factorial design with three levels each of protein, energy and bulk density (these latter changes being effected by additions of polyethylene fluff and sand). It was not clear whether the unusual experimental nature of these rations (caused by the inclusion of the inert substances) affected the intake of the factors being considered by Tonkinson et al (1965).

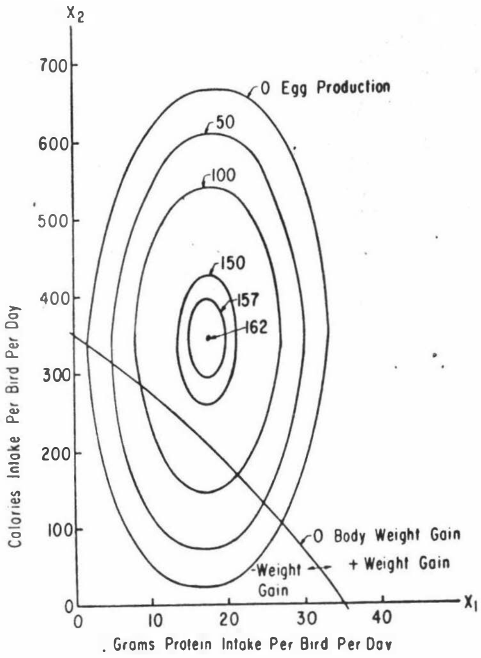


FIG. 2.—The response surface of egg production in relation to the line of zero body weight gain.

Fig. 3.2.1: Body weight and egg production isoquants for the factors energy intake, and protein intake.

From "Production responses as affected by nutrient intake of laying hens." Tonkinson L.V., E.W. Gleaves, R.H. Thayer, J.L. Folks, (1965). Poult. Sci. 47 (1), 32-38 (1968).

Fisher (1965) examined already existing data from many different sources in an attempt to find the optimum level of daily protein intake per hen, for an optimum output of egg mass per day. He found many sources of variation between breed and strain, housing type, temperature, environment and disease level, and interactions between these. Realising the importance of economic considerations, he attempted a marginal price analysis equating the marginal cost of the protein with the marginal cost of egg output. There were no definite conclusions drawn because of the lack of sufficient data from any consistent source. The effect of age on response was considered important. Thus for any set of environmental conditions and any one strain of bird, the optimum level of protein intake changed with age. This is related to the efficiency of protein utilization, and is discussed in Chapter 2, page 55.

Fisher and Morris (1969) and Fisher, Morris and Jennings (1970) looked at response curves for methionine intake in terms of egg mass output per day as part of a study on amino acid requirements. The model :

$$E = (1/a)\,(M\,E\,T - b\,W)$$

where E = egg output per day per hen (gms).

M E T = methionine intake per H D (mg).

W = body weight (gm).

b W = Maintenance requirement of methionine.

a = methionine requirement per gram of egg.

This model was directly related "to a simple biological concept" (unstated) and "produces simulated observations which are remarkably like those obtained in real experiments". Values of 4 mg. for "a" and 0.025 mg. per gm of body weight for "b", gave "E" values comparing well with the experimental data. (Fisher 1970 Personal Communication). For each bird, E increased as a linear function of M E T until a value E_{max} was reached, representing the maximum potential of that hen. Further increases in methionine input were assumed neither to increase or decrease the yield. (Fisher 1970).

Difficulties were experienced with determination of levels of methionine, a *Streptococcus zymogenes* bioassay being used. The function relies on a normally distributed egg output which is only strictly true for flocks of young pullets laying at a high rate.

No economic analysis was attempted on this function, insufficient continuous data being available for use of calculus methods.

3.2.2 A model for the economic analysis of layer rations.

The production process involved in egg production is a continuous output situation similar to milk production. It involves the intake of nutrients by the hen in the form of a mixture of feedstuffs, and the output of material in the form of eggs of various weights, quality and number - depending on the adequacy of nutrient supply from the ration, other environmental physiological and management factors, as well as the genetic potential of the hen for egg production.

The laying bird is non-productive for the first 18 to 24 weeks of age, and then it commences to lay : firstly the eggs are poor in quality, small in size and few in number, but there is a rapid improvement in all these factors under good management conditions.

Because the poultry farmer must decide at least 20 weeks in advance when he will replace a laying population, and also because the level of egg production usually falls more rapidly after 12 months of lay, the time period for egg production can be considered to be relatively inflexible at 12 months.

This means that the batch length of the model can be considered fixed, and the object is thus to maximise profit per hen per year.

The controllable variables in egg production include : age at sexual maturity; strain of hen used; type of building used; type of housing system within the building; number of birds per shed, and per cage, or per pen, or per unit floor area; temperature of the shed; relative humidity and other environmental variables, and feed factors. Feed factors could include nutrient composition of the ration; the ingredients and their levels used to achieve any given nutrient composition; the level of feed intake and variation in the nutrient and/or ingredient composition of the ration offered during the production period.

Because feed costs represent such a high proportion of the total costs on a poultry farm, it was decided to consider feed factors as control variables.

The next step was the formation of the economic model. Income is derived from the sale of eggs and the cull hen at the end of the laying season. There is a steady output of eggs over a certain time period, and the size of these eggs gradually increases with time. The rate of increase and the eventual size being determined by factors discussed in Chapters One and Two.

The physical product which determines egg revenue is a combination of weight of output within certain egg grades, and numbers of eggs. Neither one of these factors can be considered alone because the present price structure for eggs is determined through numbers within each grade, or numbers of eggs making one dozen eggs of a certain weight. Grade itself is a function of egg quality as well as egg weight, and the price within each grade changes throughout the calendar year in response to the supply from the national flock. However, fluctuations in egg prices can be considered exogenous (uncontrollable) from the individual producer's viewpoint.

Egg revenue per hen for the t-th price period, (i.e. some period of time over which egg prices paid to producers' remain stable), for a hen on the j-th ration treatment, is given by :

$$R_{jt} = \left(\left(\sum_{i=1}^{5} P_i \; G_{ij}\right) N_j\right)_t \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where P_i = The price received per egg for eggs in the t-th period. (i = 1 to 5, see Appendix I (c)).

G_{ij} = the proportion of eggs laid during the t-th period that are in the i-th grade.

N_j = the total number of eggs laid during the t-th period, measured on a hen-day basis.

N_j is based on a hen-day figure so that mortality differences between treatments, hypothesised not to be treatment effects, will not bias the revenue function. Depending on the statistical significance of the growth depressing and "stress" effect of a ration, level of mortality may or may not need to be considered as part of the revenue function. In the case where treatment significantly affects mortality, the N_j may be considered on a hen-housed basis. (Appendix I (d) explains the derivation of hen-day and hen-housed egg production).

Total egg revenue per hen from the j-th ration treatment is given by :

$$R_j = \sum_t R_{jt} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where R_{jt} is summed over the number of "price periods" that occur during a production run.

Income from cull hens at the end of the productive period is a function of their final live weight, and the price per lb. With the advent of broiler production in New Zealand, this price has dropped considerably, and only 15 cents per lb. was received for hens in the experiments reported in this thesis.

$$\text{Cull Hen Revenue} = P_b \; W_{bj}$$

where P_b = price per lb. live weight (15c.)

W_{bj} = live weight per hen at end of lay for the j-th treatment.

There is an increasing trend in poultry breeding to select for a high producing layer with a small body weight. These birds have a reduced food requirement for body growth and maintenance, but produce a lighter weight hen at the end of the laying period, thus reducing revenue from this source.

A simplification of the variable costs incurred during the life of the laying hen can consider feed cost alone, as this is the major variable cost to the farmer. The food cost is given by :

$$P_j \; Y_j = P_g \; Y_g + P_l \; Y_l \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where $P_j \; Y_j$ = The total cost of food consumed in the growing and laying period for the j-th treatment. (period hen-day basis).

P_g = price per lb. of the grower ration.

P_l = " " " " " layer "

Y_g = total consumption (lb.) of the grower ration.

Y_l = " " " " " layer "

Thus profit per hen per year for the j-th treatment can be stated :

$$Z_j = R_j + P_b \; W_{bj} - P_j \; Y_j \quad . \; . \; . \; . \; . \; . \; . \; (4)$$

Now that the profit function is established, it requires study to see where production function analysis can assist in the economic evaluation of rations associated with the function. It is emphasised that the production function approach is from the physical aspect only, the advantage being that physical responses need only be established once, to fit in with any set of factor-product prices.

The physical outputs that contribute to the profit function, and may thus have production functions usefully estimated for them are : G_i, N, W_b, Y_g, Y_l. The measurable quantities represented by these symbols can each be regarded as a function of the variable inputs considered. Attention must then be paid to several factors : firstly whether the range of input values chosen affects the output factor significantly (test by analysis of variance), and secondly, whether it is possible to attempt the fit of a production function.

The egg revenue function, equation (1), must be separated into its component parts before an attempt to fit production functions can be made.

The physiological causes behind the variation in grade and number of eggs laid have been mentioned earlier in this section. To simplify the following discussion, time concepts have not been considered. That is, the economic model is simplified by the assumption that egg prices do not vary during the production period. Relaxation of this assumption would imply a need to estimate production functions for the different price periods.

The feed input variable has some functional effect on each of the five grades, and this can be set up as :

$$G_1 = f_1 (X)$$
$$G_2 = f_2 (X)$$
$$\vdots$$
$$G_5 = f_5 (X)$$

where $\sum_{i=1}^{5} G_i = 1.0$ and where X refers to the feed control variables.

To include time concepts for each grade we could write :

$$G_{it} = f_t (X)$$

or $G_{it} = f (X, t)$

and also for egg number distribution over time :

$$N_{jt} = f_t (X)$$

or $N_{jt} = f (X, t)$

Regression equations for the five grades might have the form :

$$G_1 = a_1 + b_1 X$$
$$G_2 = a_2 + b_2 X$$
$$G_3 = a_3 + b_3 X$$
$$G_4 = a_4 + b_4 X$$

Then, as $G_5 = 1 - G_1 - G_2 - G_3 - G_4$

only the regression coefficients a_1 to a_4, and b_1 to b_4 would need be estimated because from the above :

$$1 - G_5 = a_1 + a_2 + a_3 + a_4 + b_1 X + b_2 X + b_3 X + b_4 X$$
$$= (a_1 + a_2 + a_3 + a_4) + (b_1 + b_2 + b_3 + b_4) X$$

To use this model requires periodic grade and number distribution for the different treatments. Replicate information separate within treatments would enable statistical analysis for significant differences.

This then completes the presentation of an economic model for the analysis of rations for egg production.

Before application of the model outlined above to the data presented in Chapters One and Two for the two trials, it is of benefit to digress for a section and outline the determination of input and output prices in the New Zealand marketing system for egg production.

3.2.3 The New Zealand economic environment for egg production.

Egg prices are set by the Price Tribunal. The price is based on current cost of production figures computed by a Committee of Public Accountants for the Egg Marketing Authority (E.M.A.) The E.M.A. can present a case at any time for a change in egg prices to the Price Tribunal. Cost of production is reviewed every six months and now includes an indication of the movement of egg production per bird.

The weighted cost figures approved by the Price Tribunal do not establish these as a guaranteed price for the poultry farmer. This amount is the maximum payout realisation if market returns make this possible. In fact, payout realisations have never reached the approved cost of production figure.

Cost of production per dozen eggs as at March 1970 was 48 cents in the North Island, and 44.8 cents in the South Island. These costs were carefully examined by the Trade Practices and Prices Division of the Ministry of Industries and Commerce, and were accepted as a fair indication of average costs by the Price Tribunal. Payout realizations for that season were 46.46 cents per dozen in the North Island, and 43.12 cents per dozen in the South Island.

The price for cull layers is not under Government control, nor are the ration ingredient inputs except for wheat products which are under the control of the Wheat Board.

3.2.4 Economic analysis of trials CN/50 and LT/19.

These two trials have been presented in the first two chapters of this thesis, and the reader will be referred to relevant tables and text where these are important for economic analysis.

Following the model described in section 3.2.2, it was hoped to consider the levels of consumption of the three major ration ingredients of barley (B), pollard (P) and meatmeal (M) as the independently variable inputs in a situation where egg production was the eventual measured output.

While realising the possible problems associated with a continuously produced output of eggs (compared with the broiler situation where live weight is the final product), the method described in Chapter 10 of Heady and Dillon (1961) with broilers, was used as a basis for the experimental design. In this experiment, Heady used graded levels of corn and soyabean product together with a constant basal level of essential vitamins and minerals. The principle difference between Heady's approach and that used in this thesis, is the concern with the time factor. Heady is dealing with live-weight gain of pigs, and there is interest either in attaining a certain live weight as quickly as is possible, or the maximum body weight within a certain time period. These situations differ in that they are concerned with iso-weight and iso-time curves respectively. Pig-meat production is focussed mainly on iso-weight curves to pork or bacon weight. Thus cumulative consumption and cumulative weight gain are useful parameters to work with. Cummulative body weight gain and cummulative corn and soyabean consumption were used as the dependent and independent variables respectively with Heady's work, observations being made on these variables at weekly intervals.

Their model could be considered as :

$$Y_t = f\ (C_t, S_t)$$

where weight gain after t weeks (Y_t) is a function of the amount of corn (C_t) and soyabean product (S_t) consumed in t weeks. There are statistical problems associated with Heady's use of data in the cummulated form for the estimation of production functions. This has to do with the fact that with any two sets of cummulated numbers the expected correlation between these is not zero. The curve showing the expected distribution is not in fact normally distributed about a zero value, but has the shape of an inverted normal curve with a high expectation of values close to + 1 or – 1. (Yule 1926).

This problem of irrelevant correlation values can be overcome by considering several separate time periods of cummulated food consumption over the production period. Alternatively a more simple model could be considered using total gain and total food consumption.

$$Y_t = f(\%C, \%S)$$

and

$$W_t = f(\%C, \%S)$$

where Y_t and W_t are the total weight gain and feed consumption over the whole experimental period of time t, with corn and soyabean considered as % of the ration. (Townsley 1970 Personal Communication).

With Heady's model, there are also statistical problems associated with the fact that all the variables are endogenuous – giving rise to "errors in variables" problems. The author refers to Townsley (1969) and Fuller (1968) for a discussion of these problems.

An egg production model is concerned with yields at particular times over the experimental period, but these can be considered as a total egg production for the whole experimental period. Thus the production function model can be stated :

$$Y_t = f(B, P, M)$$

where: Y_t = the total egg production for the period.

B = % barley in the ration.

P = % pollard " "

M = % meatmeal " "

There are a potentially large number of rations that can be made up from percentage levels of barley (B), pollard (P) and meatmeal (M), even when a constant basal level restraint is imposed. The only condition to be satisfied is :

$$M + B + P = 95 \quad \ldots\ldots\ldots \quad (A)$$
for trial CN/50

$$\text{and} \quad M + B + P = 86 \quad \ldots\ldots\ldots \quad (B)$$
for trial LT/19

$$\text{for } M, B, P \geq 0$$

However though the theoretical possibilities of ration combinations are large, there is only a limited range of practicable possibilities determined by a knowledge of poultry physiology and nutrition. In trials CN/50 and LT/19, ration formulations were based on such a knowledge - which included consideration of factors such as : palatability, wastage, bulkiness of the ration, frequency of feeding and manure disposal problems.

Though it was initially hoped to use B, P and M as independently variable inputs, later, more detailed consultation with the economists, revealed that there were fixed linear relationships between the levels of ingredients in the different treatments of trials CN/50 and LT/19. This was also true of Heady and Dillon's (1961 Chapter 10) rations. Because of this fact, there was only need to refer to the level of any one ingredient to be able to calculate the levels of the other ingredients associated with this reference level. Thus while :

$$Y = f\ (B, P, M)$$

there is only need to refer to either :

$$Y = f\ (B)$$

$$\text{or} \quad Y = f\ (P)$$

$$\text{or} \quad Y = f\ (M).$$

Thus, from hindsight, it was realised that in trial CN/50 linear constraints were applied to equation (A) such that :

$$B = a + b\,P$$

$$M = c + d\,P$$

Values for a, b, c and d being chosen (see Table 1.9.1 page 25) such that :

$$B = 97\frac{1}{5} - \frac{6}{5}\,P$$

$$M = -2\frac{1}{5} + \frac{1}{5}\,P$$

$$\text{for} \quad 11\% \leqslant P \leqslant 51\%$$

Note that while P was chosen as the reference independent variable, B or M could equally well have been used.

For trial LT/19, linear constraints were applied to equation (B) with M as the reference variable, such that :

$$B = e + f\,M$$

$$P = g + h\,M$$

Values for e, f, g and h being chosen (see Table 2.6.1 page 59) such that :

$$B = 87\frac{4}{7} - 4\frac{2}{7}\,M$$

$$P = -1\frac{4}{7} + 3\frac{2}{7}\,M$$

$$\text{for} \quad 2\% \leqslant M \leqslant 11.1\%$$

Thus when the economically optimum level of M is determined for data in trial LT/19, the levels of B and P can easily be calculated.

As there are also linear changes in price per unit weight, protein, energy, calcium and phosphorus (calculated) levels as ingredient levels change, these factors can also be related to levels of P by simple linear equations.

For trial CN/50 the equations were derived using P as the variable, and using data from Table 1.9.1 page 25 :

Protein %	:	Pr.	=	10.4	+ 0.1 P
Energy (kcs ME/lb)	:	En.	=	1181.9	+ 0.1 P
Calcium %	:	Ca.	=	0.222	+ 0.019 P
Phosphorus %	:	Ph.	=	0.448	+ 0.012 P
($) Bulk price/ton	:	$	=	64.80	+ 0.04 P

As an example, the equation relating price per (2000 lb.) ton to P, is derived in Appendix III (a).

These relationships hold for values of P between 11% and 51%: and where the basal mix is a constant 5% of the ration.

A similar set of equations for trial LT/19 using M for the independent variable and using data from Table 2.6.1 page 59 :

Protein %	:	Pr.	=	10.8	+	0.6	M
Energy (E)	:	En.	=	1097	+	0.5	M
Calcium	:	Ca.	=	3.00	+	0.09	M
Phosphorus	:	Ph.	=	0.82	+	0.05	M
Bulk price/ton	:	$	=	59.20	+	0.20	M

These relationships hold for values of M between 2% and 11.1%; and where the basal mix is a constant 14% of the ration.

3.3 Results and discussion for the grower trial CN/50.

The possible dependent variables from the Profit Function that could be related to levels of pollard % (P) in the ration were considered.

For example, the consumption function relating P to the amount of consumption of each ration (Y_g) was estimated for the growing phase :

$$Y_g = f (P)$$

Graphical representation of the data (Appendix III table 1) can be seen on Figure 3.3.1, the form of which suggested that it would be most appropriate to attempt the fit of a linear regression function. The method of Least Squares Regression was used to calculate regression coefficients.

The grower consumption function is represented by Y_1 below. Y_l, the consumption in the laying period was found to be not significantly different between treatments (Appendix I, table 8); similarly W_b, (Table 1.12.1) was not significantly different between treatments. For this reason, regression equations were not estimated for these factors. The variability of the grade distribution, G_i, with treatment, could not be statistically evaluated because of the lack of replicate information. However, available evidence from this experiment indicated that grade was not a functional variable of feed input.

Statistical analysis of hen-day egg production, N, for the total period (Appendix I, table 16) showed that there were no significant treatment effects. If time were being considered, then the fact that treatment [illegible] (the lowest plane of nutrition in the growing phase) was significantly lower in hen-day egg number before the 28th week of age, might be important. Regression equations for hen-housed and hen-day egg production (Y_6 and Y_7 respectively) were estimated but did not produce significant coefficients.

Regression equations were estimated for several factors of interest though these factors were not part of the profit function. Ration effects on body weight just before, at, and after the period of sexual maturity (Y_2, Y_3 and Y_4 respectively) are of interest because body weight indicates the maintenance requirements for nutrients, and also partly determines the grade distribution of eggs laid by a hen. Body weight gain during the laying period (Y_5) is also important for similar reasons.

Thus the dependent variables for which linear regression production functions were estimated were :

Y_1 = rearing period H D food consumption(lbs.) hatch to 20 wks.(Y_g).

Y_2 = body weight at 18 weeks of age (lbs.)

Y_3 = " " " 20 " " " "

Y_4 = " " " 31 " " " "

Y_5 = body weight gain during the laying period from 20 to 47 weeks of age (lbs.)

Y_6 = Hen-housed egg production.

Y_7 = Hen-day " " (N).

Y_8 = % mortality in the laying period (not graphed).

Y_9 = weighted egg weight for the laying period (gms).

The concepts of hen-housed and hen-day egg production are described in Appendix I (d); weighted egg weight is described on page 35.

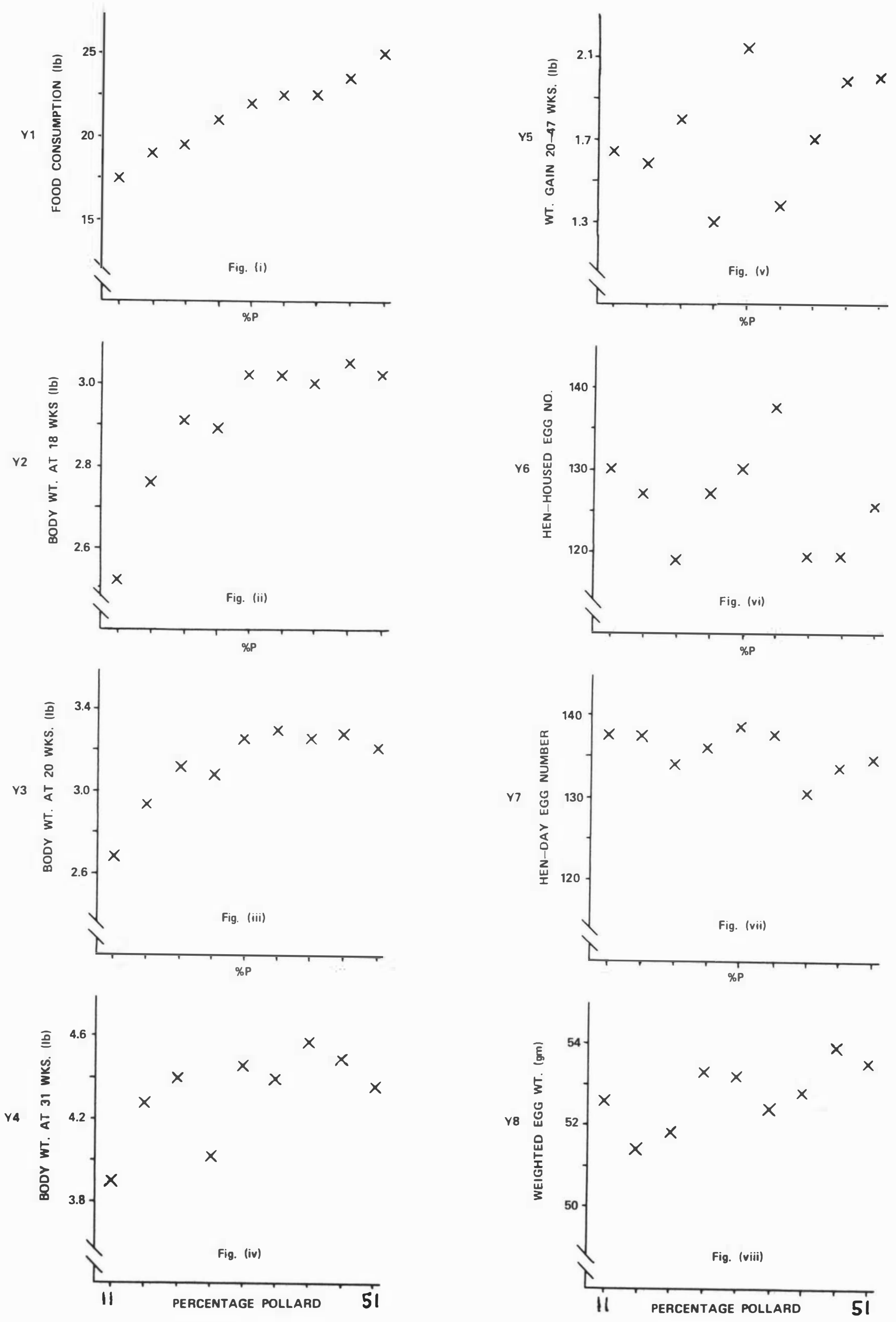
The regression coefficients were regarded as significant if the t-test fell at or below the 5% level. "Goodness" of fit is indicated by the value of r^2. These and other statistical terminology are explained in the footnote to Table 1, Appendix III.

Equations for regressions Y_1, Y_2, Y_4 and Y_9 were formed, as only these reached significance. Data is presented in the form used for calculation in table 1 of Appendix III, and is shown graphically in Figures 3.3.1 (i) to 3.3.1 (viii). An explanation of the statistical parameters calculated for the regression relationships are presented in more detail in Appendix III, table 2. Table 3.3.1 below summarises this data with equations where appropriate.

Table 3.3.1.

Equation	b	S_b	t	Prob.	r^2
$Y_1 = 16.09 + 0.17X$	0.170	0.009	18.889	0.001	0.98
$Y_2 = 2.58 + 0.01X$	0.011	0.003	3.667	0.01	0.71
$Y_3 =$ –	0.130	0.017	0.759	N S	0.08
$Y_4 = 3.99 + 0.01X$	0.011	0.005	2.330	0.05	0.43
$Y_5 =$ –	0.009	0.007	1.250	N S	0.17
$Y_6 =$ –	0.093	0.166	0.559	N S	0.05
$Y_7 =$ –	0.095	0.059	1.607	N S	0.27
$Y_8 =$ –	0.200	0.170	1.060	N S	0.18
$Y_9 = 51.51 + 0.04X$	0.040	0.017	2.434	0.05	0.46

From the table it can be seen that the level of pollard in the ration (ingredient variable X) had a significant effect on the amount of food consumed; the weight of the birds at a period just before sexual maturity (18 weeks) and just after sexual maturity (31 weeks). The variation in age at sexual maturity with associated changes in body weight probably accounted for the "non significant" relationship between ingredient make-up of the ration and body weight at



Figures 3.3.1 (i) to 3.3.1 (viii) — Regression data from trial CN/50

twenty weeks. The apparent curvilinear response at this age is also a function of the difference in rate of sexual maturity.

It is interesting to note that the amount of pollard in the rearing ration had no effect on the weight gain during the laying period. It will be recalled (from Appendix I, table 8) that there were no significant consumption differences found between treatments in the laying phase. This is further evidence for a conclusion that no compensatory growth occurred while birds were fed the layer ration.

The effect of rearing ration formulation on subsequent egg size in the laying period (equation 9, table 3.3.1) indicates a very small but significant increase with increasing P in the rearing ration. This is probably a function of the effect of the ration on body size: the larger birds laying slightly larger eggs.

As G_i, N, W_b and Y_l appeared to have no significant contribution to the profit function when considered separately, it appears that profit relies only on feed cost in the rearing phase - which is a function of the consumption level and the cost per unit weight of feed.

There are statistical problems concerned with the fact that while the components of the profit function may not have significant differences between treatments, they may have significant effects on profit when considered together.

This thesis also considered a simple analysis of variance test between treatments to assess the likelihood of a significant functional relationship arising between the variables considered. This is probably sufficient in most cases, but to be strictly correct one should follow the regression analysis of variance as set out by Heady and Dillon (1961) page 157, before rejecting a regression as not significant.

Manipulation of the Economic Model.

The implications of the above are to maximise profit per hen per year by minimising the cost of the ration consumed per bird in the growing phase :

$$\text{Minimise } P_g \; Y_g$$

Price per lb. of grower ration (see Appendix III (a) for derivation) is given by :

$$P_g = 3.241 + 0.00195 \, P \text{ (cents)}$$

The rearing consumption function is equation one of table 3.3.1 :

$$Y_g = 16.09 + 0.17 \, P$$

$$\text{Thus } P_g \; Y_g = (0.00195 \, P + 3.241)(16.09 + 0.17 \, P)$$

$$= 52.148 + 0.582 \, P + 0.0003 \, P^2 \text{ cents feed cost.}$$

for $11\% \leqslant P \leqslant 51\%$ (corresponding to the range for trial CN/50).

This equation has the general form :

$$P_g \; Y_g = a + bP + cP^2$$

where $b, \; c > 0$.

Thus the minimum feasible value of P minimises feed cost and maximises profit. However the coefficients of the quadratic function while both positive for this price situation, could well be negative or have different signs in some other price situation. If this were the case the profit maximising level of P may be at some other value within the experimental range.

3.4 Results and discussion for layer trial LT/19.

With the more direct temporal relationship between food intake and productive characteristics in the layer trial, it was hoped that more significant relationships would emerge. However analysis of variance indicated that there were no treatment differences in the components of the profit function. Even so, estimates of the linear regression of N and Y_1 on M (the % meatmeal in the ration) were made, together with other factors of interest which are listed below. No significant relationships were discovered by linear regression calculations.

Y_1 = Hen-day egg production. (N)

Y_2 = Hen-housed egg production.

Y_3 = Mortality in the laying period.

Y_4 = Food consumption per hen-day. (Y_1)

Y_5 = Average egg weight at 56 weeks age.

Y_6 = Body weight gain in the laying period.

The data used to calculate the regression coefficients (Appendix III, table 3) is graphically displayed in Figures 3.3.2 (i) to 3.3.2 (vi).

The graphs illustrate the difficulty in the establishment of any significant treatment effects. It was not felt justifiable to attempt to fit any other than linear functions to the data. A summary of regression information is presented in table. 3.4.1 below :

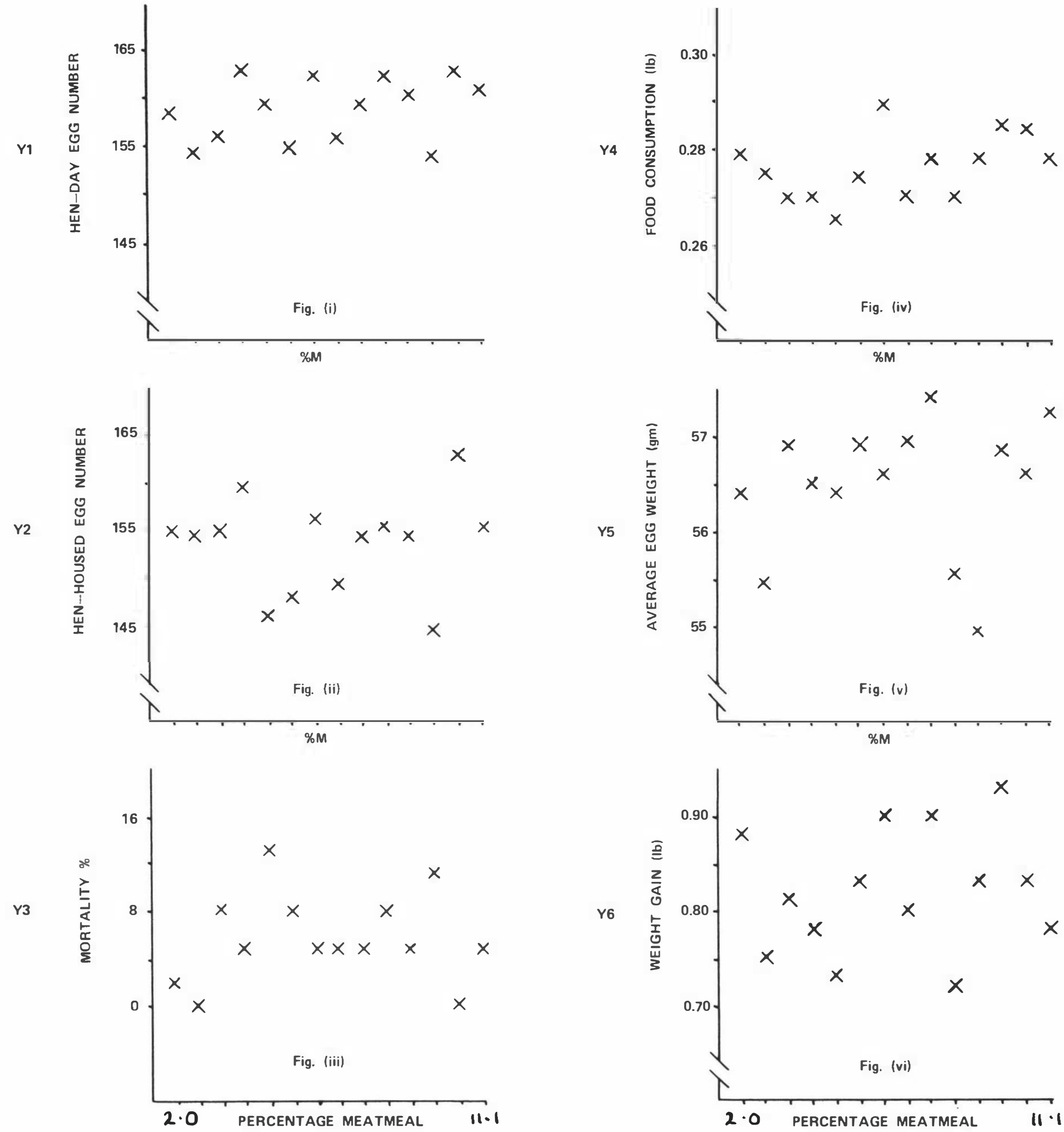
Table 3.4.1.

Summary of Regression Information (LT/19).

Dependent Variable	b	S_b	t	Prob.	r^2
Y_1	0.334	0.31	1.10	N S	.02
Y_2	0.08	0.50	0.116	N S	.02
Y_3	0.079	0.374	0.211	N S	.04
Y_4	0.001	0.0005	1.996	N S	.24
Y_5	0.034	0.052	0.644	N S	.02
Y_6	0.003	0.006	0.45	N S	.02

A more detailed presentation of regression data is seen in Appendix III, table 4.

It was disappointing to note the lack of relationship between ration ingredient levels and the productive characteristics measured. An investigation into possible reasons for the apparent lack of response was initiated by re-presenting the data in the "nutrient" form used by Fisher (1965). Table 3.4.2 below shows the intake per hen-day of protein and energy, and the output of egg mass per hen-day; for each of the 14 different rations. While energy intake



Figs. 3.3.2 (i) to 3.3.2 (vi) – Regression data from trial LT/19

and egg output were remarkably constant over the range covered by the rations, the protein intake increased with the diets higher in protein %.

Table 3.4.2.

Productivity (egg mass per day) related to nutrient intake (protein and energy per day) for LT/19.

Ration	Egg output (gm) per H D	Energy intake (kcs) per H D	Protein intake (gm) per H D
1	35.5	306	15.1
2	34.0	302	15.8
3	35.3	296	15.6
4	36.6	296	16.1
5	35.7	291	16.2
6	35.2	301	17.2
7	36.6	306	18.1
8	35.1	296	18.0
9	36.3	306	19.0
10	35.9	297	19.0
11	35.0	306	20.1
12	34.8	315	21.1
13	36.6	314	21.5
14	36.6	307	21.6

This effect is consistent with the theory that birds eat to equate energy intake irrespective of protein level in the ration.

Fisher (1965) collected response data from workers whose aim was to determine the physiological optimum protein intake per day. This data has already been discussed in section 2.2. Any comparisons of data must be made with the realisation that experiment aims and environmental conditions were very different in each case.

For example the data graphed for LT/19 in Figure 3.3.3 is from the short 37 week test period used in this trial. Thus the proportion of the early growing period of the laying phase is larger; and protein requirement for growth

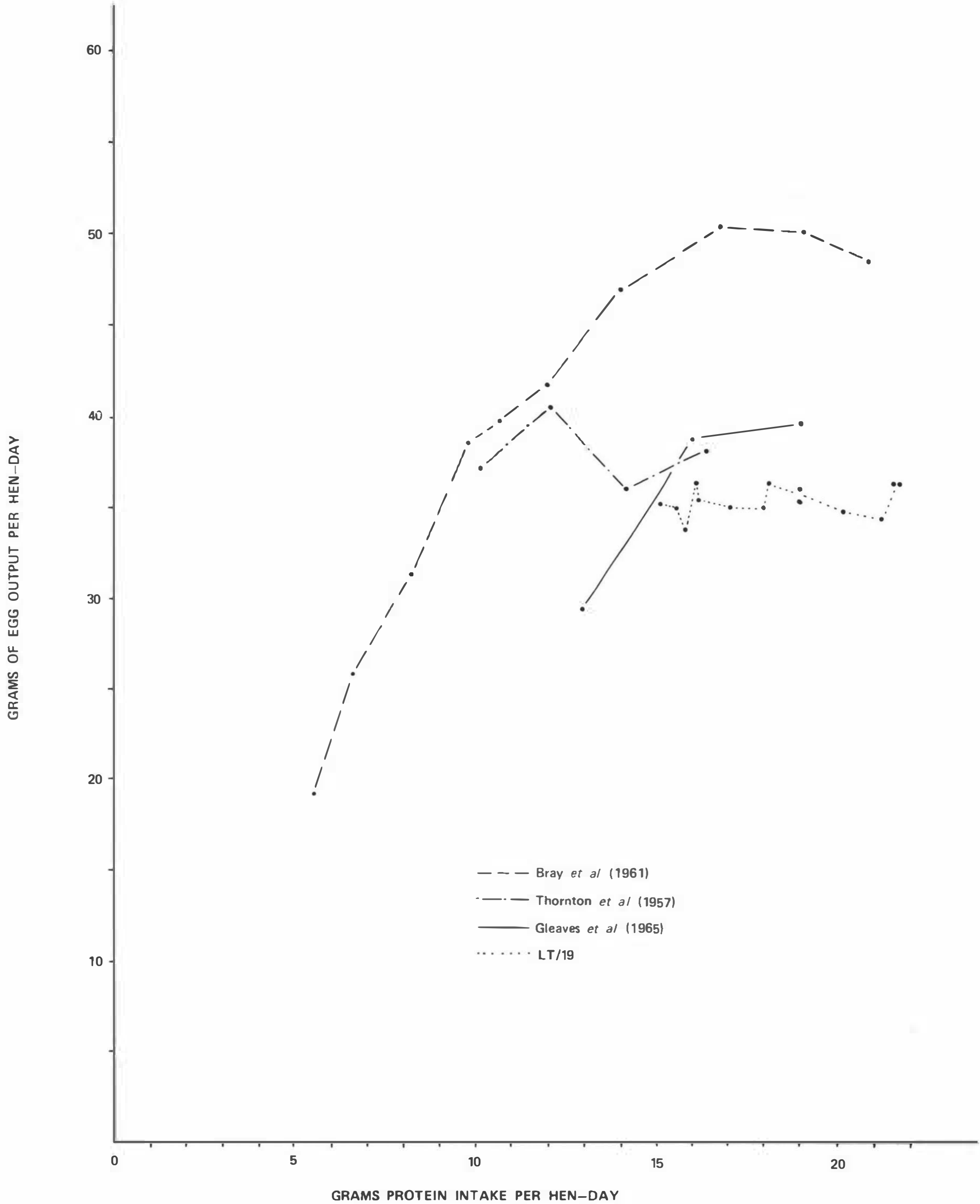


Fig. 3.3.3 – Response of egg output (gm) to protein intake (gm). Published data compared with that from trial LT/19.

is higher in this period. However it is obvious from the graph that the lower levels of intake in layer trial LT/19 were not low enough to depress output. Data from the other workers were collected for varying time periods during the laying phase. Bray and Gesell's (1961) data was collected from an experiment with high temperature (76°F (24.4°C)) nutrition. Data extracted from Gleaves et al (1965) was graphed and daily calorie intake was found to be similar to that of the hens in LT/19 (see table 3.4.2), at 300 kcs per H D. Protein level in the rations varied between 13% and 19%.

3.5 A simple profit function for economic analysis of layer and grower rations in egg production.

Though the functional aspect of the profit equation is evident from discussion in previous sections, it was thought that within a given price environment, the profit equation might be a useful tool to evaluate relative profitability between different rations. In this form, all production function aspects are ignored and values for the functional components of the profit equations are simply substituted within each ration treatment. Table 3.5.1 below presents the component information for trial CN/50. Income-less-food-cost is included because this parameter is commonly given in Random Sample Tests. Egg prices for the different grades and time periods are used from Appendix III, table 5. Cull hen income (P_b W_b) was based on a price received in this experiment of 15 c per lb. live weight.

Comparison of the nine rations used in trial CN/50 used body weight data from table 1.12.1 (page 30); rearing ration cost (P_g) from table 1.9.1 (page 25); grower phase food consumption (Y_g) from table 1.12.3 (page 33); and layer phase food consumption (Y_l) from table 1.12.3 (page 33). Cost of the layer rations was $67 per ton.

Table 3.5.1

Profit Function Calculations ($ per hen) for CN/50.

	Ration Treatments.								
	A	B	C	D	E	F	G	H	I
Income from eggs	4.49	3.26	3.94	4.51	4.49	4.66	4.09	4.13	4.27
Food cost 20-32 wks.	0.70	0.73	0.70	0.70	0.73	0.72	0.73	0.72	0.73
Food cost H-20 wks.	0.54	0.59	0.61	0.65	0.68	0.70	0.71	0.75	0.79
(Income less food cost)	3.25	1.94	2.63	3.16	3.08	3.24	2.65	2.66	2.75
Cull hen income	0.65	0.68	0.74	0.65	0.81	0.70	0.74	0.79	0.79
Relative profit index	3.90	2.62	3.37	3.81	3.89	3.94	3.39	3.45	3.54

For trial CN/50, information on layer phase food consumption was only available for 12 of the 32 week test period. However as consumption levels between treatments were not significant, the use of the existing information in the calculation of a Relative Profit Index was thought justifiable.

Treatment differences have two aspects which contribute to their relative economic importance. Firstly there are "real" differences which are statistically detectable. Secondly there is the magnitude of the differences. For example in the egg income row of table 3.5.1 it will be seen that the magnitude of the difference in money terms is very large, however the numerical differences in egg number and weighted egg weight which contributed to this income figure were not statistically detectable. For food cost in the growing period (table 3.5.1), the treatment differences were statistically significant, but in money terms the magnitude of the differences is not so economically significant. Hence there is danger in placing too much faith in the relative profit figures of tables 3.5.1 and 3.5.2.

Those birds reared on rations A, E, D and F were the most profitable, and these birds also had the highest egg revenue returns. Little can be concluded about this data without tests for statistical significance, but it does appear that a low plane of nutrition in the rearing phase (as provided by ration A) is not detrimental when all aspects of profitability are considered.

A profit function for layer trial LT/19 was calculated on the basis of incomplete information on the distributions of eggs laid in different grades. Only a single sample was graded after 34 weeks of lay, and on this basis, all of the 14 ration treatments were placed within the Standard grade for eggs. The assumption was made that the change of egg size with age was the same for all treatments. This assumption seems reasonable because all measured aspects of egg production were not significantly different between treatments. Thus an indication of relative egg revenue was gained using the price for Standard eggs (P_1 = 42 cents/dozen) and the period H D egg number (N). Revenue from cull hens was calculated using 15 cents/lb. live weight (P_b) and weight data (W_b) from table 2.9.1, page 62.

Food cost in the rearing stage was assumed to be the same for all treatments and thus could not affect a relative profitability index. Food consumption data was available for the duration of the laying period and information was taken from Table 2.6.1, page 59 (P_1); and table 2.9.2, page 63 (Y_1). The data used to form the profit index is presented in table 3.5.2 below.

The Profit Index is computed on a per hen basis in this situation where all birds are of the same genetic strain, and are housed in the same environment.

Table 3.5.2

Profit Function Calculations ($ per hen), for LT/19.

Ration	Egg Income	Food Cost	Egg Income less food cost	Cull Hen Income	Relative Profit Index
1	5.55	2.09	3.46	0.64	4.10
2	5.41	2.06	3.35	0.62	3.97
3	5.47	2.03	3.44	0.62	4.06
4	5.71	2.04	3.67	0.65	4.32
5	5.59	2.00	3.59	0.61	4.20
6	5.46	2.07	3.39	0.62	4.01
7	5.69	2.12	3.57	0.63	4.20
8	5.45	2.06	3.39	0.62	4.01
9	5.59	2.12	3.47	0.61	4.08
10	5.69	2.06	3.63	0.59	4.22
11	5.62	2.14	3.48	0.62	4.10
12	5.39	2.21	3.18	0.63	3.81
13	5.70	2.12	3.58	0.61	4.19
14	5.63	2.15	3.48	0.61	4.09

3.6 Improved feed conversion efficiency as an aid to feed cost reduction.

A different approach to feed cost reduction with poultry, has been achieving some attention recently. If food conversion efficiency could be improved by genetic means, this would also reduce feed costs.

The sex-linked dwarfing gene received attention from broiler breeders (Jaap 1969, 1969a) because the smaller hen was still able to produce commercially "large" offspring and yet have an improved food conversion efficiency mainly because of the almost 50% reduction in adult body weight.

There may be a possibility of applying selection pressure to existing stock without the use of the dwarfing gene. Nordskog, French and Balloun (1969) suggest an indirect method of measuring food conversion efficiency through body weight and egg weight measurements. Wallace (1970) forsees the use of "midget" layers with an improved food conversion efficiency as measured per pound of eggs produced. This hen would have a final body weight of only 3 lb. compared with the present 4.5 lb. average. Smaller birds have lower maintenance food requirements, but are more susceptable to cold stress (and less affected by heat stress) than today's hen.

Conclusions and possibilities for further research.

The economic model outlined for analysis of rations for laying stock appears to be satisfactory. The lack of response of egg output to the input factors used, may be a function of the type of output product that eggs constitute. A greater range of nutrient levels may have given a more variable output.

Separate analysis of the physical components of the profit function may have given rise to some problems. Lack of significant differences between treatments for each component may not necessarily imply lack of significant differences in profit between treatments. However the desire to treat prices (for eggs, cull hens, and feed) as exogenous variables forces a component approach to the profit function.

The egg revenue function is complex, and reflects the system of egg marketing in New Zealand at the present time. Future problems with egg marketing in the food industry may force the adoption of the sale of eggs on a "per unit weight" basis, as this makes eggs more competitive with other protein foods, but has associated packaging problems. If this system is adopted, then the egg revenue function will be simpler, and the production function approach will be enhanced.

The concept of a profit function for a given price situation as used in section 3.5, appears to be useful in the comparison of profitability between

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different rations.

This thesis has emphasised the need to carefully consider nutrient and feed ingredient aspects in the planning of experiments designed to investigate profitable layer and grower rations.

The use of least cost programming in conjunction with production functions should assist in economic ration analysis, but there are several well recognised improvements desired in the use of this economic tool :

(1) The incorporation of better nutrient information on feedstuff composition - particularly with amino acid availabilities and interactions.

(2) The incorporation of some measure of palatability or appetite in the matrix.

The output variable measured, bears closer examination because of price imputation problems. This applies to pig live weight gain outputs where lean meat may be a more useful measure; or perhaps "lean meat production per unit of housing space per year".

From a poultry husbandry and nutritional point of view, it was clear that food cost reduction could be achieved by the use of a lower plane of nutrition at both the grower and layer phases. The achievement of this saving with the use of restrictive rations in the rearing phase had additional benefits of a slightly delayed peak of egg production and a more persistent level of production. The permanent reduction in mature body weight meant that maintenance food requirements in the layer phase were reduced and there was less need for a high protein (expensive) layer ration.

This means that cheaper ingredients can be used in both layer and grower rations, which reduces the overall cost of these rations, and has the additional benefit of a better food conversion efficiency.

Some uncertainty exists as to the level of hygiene and general management necessary for profitable operation of a restrictive feeding plan. There are claims that a low plane of nutrition will be beneficial for disease resistance, and reduce mortality in the laying phase.

There is also conflicting evidence as to <u>when</u> the restrictive regime should be applied to the growing birds: some workers claiming that an initial adjustment period for the first few weeks of life on a high plane of nutrition is beneficial; while others claim that this entails a stress-laden switch to a low protein ration at a crucial growing stage, and thus recommend a uniform low plane diet fed from day-old.

It seems illogical to suggest that a low protein diet is less stressful than a high protein diet for all management circumstances. Thus in evaluation of the alternatives for a restricted feeding programme, the standard of management and farm hygiene should be carefully assessed in relation to the particular programme that is to be used.

Appendix I.

(a) Mating and Incubation Details.

The parent stock were mated by artificial insemination. Semen from 31 males was pooled and diluted 1:1 with a diluent (2% sodium phosphate buffer solution containing a 4:1 mixture of anhydrous disodium hydrogen phosphate and sodium dihydrogen phosphate (Lake, Schindler and Wilcox 1959)), and used to inseminate 252 dams at a dose rate of 0.5 ml/hen. Inseminations were repeated 3 times at 3-day intervals, eggs being collected over a 7 day period and stored in "Cryovac" plastic bags in racks (turned 3 times daily), in a coolroom (55°F or 13°C). 1250 eggs were set, 12 days after the first insemination, in a "Multiplo Chick-master" setter-hatcher (10,200 egg capacity).

A fertility test conducted after 14 days reduced egg numbers to 80.3% fertile, and final hatchability was 68.5% of eggs set or 85.2% of fertile eggs.

(b) Illumination intensity units.

1 lux = 1 lumen/ square metre

= 0.1 lumens/square foot

= 0.1 foot.candle.

(c) Commercial Egg Grades.

Undergrade : less than 36 gm (1¼ ozs.)

Pullet : between 36 and 44 gm (1¼ to 1 9/16 ozs.)

Medium : between 44 and 53 gm (1 9/16 to 1 7/8 ozs.)

Standard : between 53 and 62 gm (1 7/8 to 2 3/16 ozs.)

Large : more than 62 gm (2 3/16 ozs.)

The grades correspond to the weight-per-dozen classification in current use, of : 15's, 18's, 22's, 24's and 26's respectively.

(d) Methods of presentation of egg production data.

$$\text{H D egg production} = \text{Total Egg Number} \times \frac{\text{Total Days in Period}}{\text{Total Days Alive}}$$

$$\text{\% H D egg production} = \frac{\text{Total Egg Number}}{\text{Total Days Alive}} \times \frac{100}{1}$$

$$\text{H H egg production} = \frac{\text{Total Egg Number}}{\text{Total number of hens housed.}}$$

Table 1.

Vitamin-Mineral Supplements * (Ingredients/lb)

		Grower	Layer
Vitamin A	(I.U.)	3000	5000
Vitamin D_3	"	625	625
Vitamin E	"	-	1.25
Riboflavin	(mg.)	1.5	2
Vitamin B_{12}	"	-	0.00025
Calcium Pantothenate	"	4	4
Nicotinic Acid	"	7.5	10
Folic Acid	"	-	0.25
Choline Chloride	"	-	80
Menadione Sodium Bisulphite	"	1.0	1.0
Selenium	"	0.068	0.068
Zinc Oxide	"	15.2	15.2
Ferrous Fumarate	"	10.0	10.0
Potassium Iodate	"	0.65	0.65
Copper Carbonate	"	2.25	2.25
Cobalt Carbonate	"	0.3	0.3
Manganese Sulphate	"	85.2	110.6

* The cost of the grower supplement adds $1.60 to the price per ton of the mash. The layer supplement adds $2.00 per ton.

Table 2.

Nutrient values used in compounding the rations.
(air dry basis)

	Protein %	Energy kcs ME/lb	Calcium %	Phosphorus %
Barleymeal	11.0	1200	0.07	0.4
Pollard	15.0	1200	0.08	0.8
Meatmeal	51.5 *	1250	9	4.5
Lucernemeal	17.0	600	1.9	0.3
Buttermilk Powder	34.0	1300	1.6	1.0
Limestone	0	0	38.0	0
Bonemeal	10.0	800	29.0	13.0

* Protein values are based on previous ingredients analyses at the P.R.C. Values for energy, calcium and available phosphorus were derived using published tables (Scott, Nesheim and Young (1969), McClymont and McDonald (1958)).

Table 3.

Layer ration ingredients and chemical analysis.
(air dry basis)

	(% of ration)	Theoretical Requirements ***
Barleymeal	48	
Pollard	10	
Meatmeal	10	
Maizemeal	20	
Buttermilk Powder	1.5	
Lucernemeal	4	
Limestone	4	
Bonemeal	2	
Iodised Salt	0.25	
Vitamin-mineral Supplement *	0.25	
Kjeldhal Crude Protein	16.8	
Calculated Protein	15.5	
Energy (kcs ME/lb)	1181	
Energy (kcs ME/kg)	2601	
Cal.(per lb)Protein Ratio	76	
Protein-Megacalorie Ratio	13.1	
Calcium	3.1	
Phosphorus	1.07	
Ash	8.7	
Water	11.4	
Lysine	0.70 **	0.55
Histidine	0.25	0.28
(Ammonia)	(0.26)	-
Arginine	0.86	0.8
Aspartic Acid	1.20	-
Threonine	0.60	0.45
Serine	0.70	-
Glutamic Acid	3.33	-
Proline	1.64	-
Glycine	1.15	-
Alanine	0.90	-
Cysteine ****	0.24	0.24
Valine	0.75	0.65
Methionine	0.23	0.28
Isoleucine	0.54	0.60
Leucine	1.40	1.4
Tyrosine	0.48	0.3
Phenylalanine	0.67	0.45
TOTAL PROTEIN:	15.64	15.0

...continued...page(5)

Table 3 (continued)

* The vitamin-mineral layer supplement formula can be seen in Appendix I table 1.

** A Beckman amino acid analyser (Model 120C) was used to obtain the amino acid levels.

*** Compiled from Agricultural Research Council (U.K.) (1963), and National Research Council (U.S.A.) (1966) publications; and Scott, Nesheim and Young (1969).

**** The sulphur amino acids cysteine and cystine are estimated together in this analysis. The cystine molecule is split into 2 cysteine molecules during acid hydrolysis of the sample. The amino acid tryptophan is destroyed by this acid hydrolysis, and can only be estimated by a separate alkaline hydrolysis.

Table 4.

Analysis of Variance of Body Weight Data.

Column Code.

(1) Hatch to 2 weeks weight gain (grams).

(2) 2 to 4 " " " "

(3) 4 to 12 " " " "

(4) 12 to 16 " " " "

(5) 16 to 20 " " " "

(6) Body weight at 20 weeks (grams)

M S = Mean Square df. = degrees of freedom

* Significant at 5% level of probability

** " 1% "

*** " 0.1% "

N S = Not Significant

Source	df.						M S					
(Code)	1	2	3	4	5	6	1	2	3	4	5	6
Total	361	358	282	276	274	274						
Treatments (T)	8	8	8	8	8	8	4529***	40899***	193127***	24817**	13615**	199788**
Blocks (B)	2	2	3	3	3	3	124	1002	10489	7454	2402	19592
T x B	16	16	24	24	24	24	100	555	3964	2433	2725	15621
Error	335	332	247	241	239	239	191	914	6359	1998	3275	16443

Table 5.

Comparison of Treatment Means for Body Weight Data using the same column code as Table 4.

M.S.D. = Minimum Significant Difference
5% levels underlined.

(1)

Ranked Means.		B-All	A-	D-	C-	E-	F-	G-	H-
B	31.33	-							
A	31.64	0.31	-						
D	39.67	8.34	8.03	-					
C	41.44	10.11	9.80	1.77	-				
E	46.02	14.69	14.38	6.35	4.58	-			
F	48.64	17.31	17.00	8.97	7.20	2.62	-		
G	53.10	21.77	21.46	13.43	11.66	7.08	4.46	-	
H	59.00	27.67	27.36	19.33	17.56	12.98	10.36	5.90	-
I	60.74	29.41	29.10	21.07	19.30	14.72	12.10	7.64	1.74

M.S.D. (5%) = 7.92; (1%) = 9.80 gm. gain.

(2)

		A-All	B-	D-	C-	E-	F-	G-	H-
A	62.44	-							
B	80.89	18.45	-						
D	102.33	39.89	21.44	-					
C	106.35	43.91	25.46	4.02	-				
E	126.34	63.90	45.45	24.01	19.99	-			
F	136.62	74.18	55.73	34.29	30.27	10.28	-		
G	143.05	80.61	62.16	40.72	36.70	16.71	6.43	-	
H	151.88	89.44	70.99	49.55	45.53	25.54	15.26	8.83	-
I	153.27	90.83	72.38	50.94	46.92	26.93	16.65	10.22	1.39

M.S.D. (5%) = 18.76; (1%) = 23.20 gm. gain.

...continued...page (8)

Table 5 (continued).

(3)

		A-All	B-	C-	D-	G-	E-	F-	I-
A	532.17	-							
B	656.50	124.33	-						
C	716.16	183.99	59.66	-					
D	729.26	197.09	72.76	13.10	-				
G	744.31	212.14	87.81	28.15	15.05	-			
E	762.59	230.42	106.09	46.43	33.33	18.28	-		
F	765.41	233.24	108.91	49.25	36.15	21.10	2.82	-	
I	771.66	239.49	115.16	55.50	42.40	27.35	9.07	6.25	-
H	785.01	252.84	128.51	68.85	55.75	40.70	22.42	19.60	13.35

M.S.D. (5%) = 54.12; (1%) = 65.37 gm. gain.

(4)

		H-All	I-	G-	F-	E-	D-	B-	C-
H	239.77	-							
I	249.02	9.25	-						
G	263.81	24.04	14.79	-					
F	275.75	35.98	26.73	11.94	-				
E	283.50	43.73	34.48	19.69	7.75	-			
D	300.54	60.77	51.52	36.73	24.79	17.04	-		
B	303.17	63.40	54.15	39.36	27.42	19.67	2.63	-	
C	304.16	64.39	55.14	40.35	28.41	20.66	3.62	0.99	-
A	326.93	87.16	77.91	63.12	51.18	43.43	26.39	23.76	22.77

M.S.D. (5%) = 42.76; (1%) = 51.65 gm. gain.

...continued...page (9)

Table 5 (continued).

(5)

		D-All	I-	H-	C-	B-	E-	F-	G-
D	187.79	-							
I	194.26	6.47	-						
H	199.43	11.64	5.17	-					
C	200.16	12.37	5.90	0.73	-				
B	209.55	21.76	15.29	10.12	9.39	-			
E	219.84	32.05	25.58	20.41	19.68	10.29	-		
F	223.50	35.71	29.24	24.07	23.34	13.95	3.66	-	
G	223.63	35.84	29.37	24.20	23.47	14.08	3.79	0.13	-
A	258.48	70.69	64.22	59.05	58.32	48.93	38.64	34.98	34.85

M.S.D. (5%) = 45.42; (1%) = 54.86 gm. gain.

(6)

		A-All	B-	D-	C-	I-	G-	E-	H-
A	1212.45	-							
B	1331.21	118.76	-						
D	1392.93	180.48	61.72	-					
C	1413.29	200.84	82.08	20.36	-				
I	1465.97	253.52	134.76	73.04	52.68	-			
G	1476.34	263.89	145.13	83.41	63.05	10.37	-		
E	1479.00	266.55	147.79	86.07	65.71	13.03	2.66	-	
H	1488.20	275.75	156.99	95.27	74.91	22.23	11.86	9.20	
F	1502.34	289.89	171.13	109.41	89.05	36.37	26.00	23.34	14.14

M.S.D. (5%) = 108.75; (1%) = 131.36 gm. gain.

Table 6.

Analysis of Variance of Shank Length Gains.

Column Code.

(1) Hatch to 4 weeks length gain (centimetres).

(2) 4 to 8 " " " "

(3) 8 to 12 " " " "

(4) 12 to 16 " " " "

Source.	df.				MS			
(Code)	1	2	3	4	1	2	3	4
Total	81	80	78	77				
Treatments	8	8	8	8	0.4554*	0.3723**	0.2665**	0.6846**
Error	73	72	70	69	0.1681	0.0706	0.0831	0.1132

Table 7.

Comparison of Treatment Means for Shank Length Gains, using code as in table 6.

(1) Ranked Means.

		A-All	B-	C-	D-	E-	G-	I-	F-
A	1.56	-							
B	1.56	0	-						
C	1.79	.23	.23	-					
D	1.79	.23	.23	0	-				
E	1.87	.31	.31	.08	.08	-			
G	2.07	.51	.51	.28	.28	.20	-		
I	2.16	.60	.60	.37	.37	.29	.09	-	
F	2.27	.71	.71	.48	.48	.40	.20	.11	-
H	2.36	.80	.80	.57	.57	.49	.29	.20	.09

M.S.D. (5%) = 0.621; (1%) = 0.731 cm. gain.

(2)

		A-All	D-	B-	C-	F-	G-	I-	E-
A	1.37	-							
D	1.92	.55	-						
B	1.94	.57	.02	-					
C	1.95	.58	.03	.01	-				
F	1.96	.59	.04	.02	.01	-			
G	2.04	.67	.12	.10	.09	.08	-		
I	2.05	.68	.13	.11	.10	.09	.01	-	
E	2.10	.73	.18	.16	.15	.14	.06	.05	-
H	2.11	.74	.19	.17	.16	.15	.07	.06	.01

M.S.D. (5%) = 0.40; (1%) = 0.47 cm. gain.

...continued...page(12)

Table 7 (continued).

(3)

		H-All	G-	I-	A-	E-	F-	B-	D-
H	1.30	-							
G	1.52	.22	-						
I	1.57	.27	.05	-					
A	1.62	.32	.10	.05	-				
E	1.66	.36	.14	.09	.04	-			
F	1.68	.38	.16	.11	.06	.02	-		
B	1.74	.44	.22	.17	.12	.08	.06	-	
D	1.84	.54	.32	.27	.22	.18	.16	.10	-
C	1.87	.57	.35	.30	.25	.21	.19	.13	.03

M.S.D. (5%) = 0.44; (1%) = 0.51 cm. gain.

(4)

		H-All	E-	I-	G-	D-	F-	C-	B-
H	0.31	-							
E	0.34	.03	-						
I	0.37	.06	.03	-					
G	0.48	.17	.14	.11	-				
D	0.51	.20	.17	.14	.03	-			
F	0.56	.25	.22	.19	.08	.05	-		
C	0.58	.27	.24	.21	.10	.07	.02	-	
B	0.74	.43	.40	.37	.26	.23	.18	.16	-
A	1.31	1.00	.97	.94	.83	.80	.75	.73	.57

M.S.D. (5%) = 0.51; (1%) = 0.60 cm. gain.

Table 8.

Analysis of Variance of Hen-Day Food Consumption Data.

Column Code.

(1) Hatch to 4 weeks consumption (lbs.)

(2) 4 to 8 " "

(3) 8 to 16 " "

(4) 16 to 20 " "

(5) Hatch " " " "

(6) 20 " 32 " "

Source.	df.						M S					
(Code)	1	2	3	4	5	6	1	2	3	4	5	6
Total	26	35	35	35	35	26						
							***	***	**	**	**	N S
Treatments	8	8	8	8	8	8	0.1593	1.8286	4.9529	0.7017	22.6644	0.58[illegible]
Blocks	2	3	3	3	3	2	0.0032	0.0358	0.5451	0.0136	0.7016	0.15[illegible]
Error	16	24	24	24	24	16	0.0028	0.0392	0.2166	0.0803	0.5361	0.83[illegible]

Table 9.

Comparison of Treatment Means for Hen-day Food Consumption, using code as in table 8.

(1)	Ranked Means.	A-All	B-	C-	D-	E-	F-	G-	H-
A	0.839	-							
B	0.899	.060	-						
C	1.007	.168	.108	-					
D	1.015	.176	.116	.008	-				
E	1.180	.341	.281	.173	.166	-			
F	1.299	.460	.400	.292	.284	.119	-		
G	1.317	.478	.418	.310	.302	.137	.018	-	
H	1.414	.575	.515	.407	.399	.234	.115	.097	-
I	1.475	.636	.576	.468	.460	.295	.176	.158	.061

M.S.D. (5%) = 0.157 lb; (1%) = 0.191 lb.

(2)		A-All	B-	C-	D-	E-	F-	G-	H-
A	1.672	-							
B	2.488	.816	-						
C	2.671	.999	.183	-					
D	2.918	1.246	.430	.247	-				
E	3.153	1.481	.665	.482	.235	-			
F	3.334	1.662	.846	.663	.416	.181	-		
G	3.512	1.840	1.024	.841	.594	.359	.178	-	
H	3.661	1.989	1.173	.990	.743	.508	.327	.149	-
I	3.830	2.158	1.342	1.159	.912	.677	.496	.318	.169

M.S.D. (5%) = 0.476; (1%) = 0.575 lb.

...continued... Page (15)

Table 9 (continued)

(3)		A-All	B-	C-	D-	E-	G-	F-	H-
A	8.842	-							
B	9.477	.635	-						
C	10.077	1.235	.600	-					
D	10.621	1.779	1.144	.544	-				
E	10.932	2.090	1.455	.855	.311	-			
G	11.088	2.246	1.611	1.011	.467	.156	-		
F	11.178	2.336	1.701	1.101	.557	.246	.090	-	
H	11.872	3.030	2.395	1.795	1.251	.940	.784	.694	-
I	12.361	3.519	2.884	2.284	1.740	1.429	1.273	1.183	.489

M.S.D. (5%) = 1.119; (1%) = 1.352 lb.

(4)		C-All	A-	B-	D-	F-	E-	H-	G-
C	5.852	-							
A	6.148	.296	-						
B	6.159	.307	.011	-					
D	6.260	.408	.112	.101	-				
F	6.510	.658	.362	.351	.250	-			
E	6.557	.705	.409	.398	.297	.047	-		
H	6.614	.762	.466	.455	.354	.104	.057	-	
G	6.715	.863	.567	.556	.455	.205	.158	.101	-
I	7.300	1.448	1.152	1.141	1.040	.790	.743	.686	.585

M.S.D. (5%) = 0.682; (1%) = 0.823 lb.

...continued...page (16)

Table 9 (continued)

(5)		A-All	B-	C-	D-	E-	F-	G-	H-
A	17.501	-							
B	19.023	1.522	-						
C	19.607	2.106	0.584	-					
D	20.814	3.313	1.791	1.207	-				
E	21.821	4.320	2.798	2.214	1.007	-			
F	22.321	4.820	3.298	2.714	1.507	0.500	-		
G	22.632	5.131	3.609	3.025	1.818	0.811	0.311	-	
H	23.560	6.059	4.537	3,953	2.746	1.739	1.239	0.928	-
I	24.966	7.465	5.943	5.359	4.152	3.145	2.645	2.334	1.406

M.S.D. (5%) = 1.761; (1%) = 2.127 lb.

Table 10.

Mortality over the period hatch to 52 weeks.
(Causes and number per treatment)

	A	B	C	D	E	F	G	H	I	Total
Growing Period (Hatch to 20 wks.)										
Rickets	2	1	1	0	0	0	0	0	0	4
Coli septicaemia	0	0	0	0	0	1	0	0	0	1
Air sacculitis	0	1	0	0	0	0	0	0	0	1
Omphalitis	0	1	0	0	0	0	0	0	0	1
F L K *	0	1	1	0	0	0	0	0	1	3
Marek's Disease	1	0	0	2	0	0	0	2	1	6
Colon Impaction	0	1	0	0	0	0	0	0	0	1
Culls (Runts)	0	1	0	1	0	0	0	0	0	2
N.D.D. **	0	1	1	1	0	0	0	0	0	3
Handling Shock	1	1	0	1	0	0	0	1	0	4
Total	4	8	3	5	0	1	0	3	2	26
Laying Period (20 to 52 wks.)										
Marek's Disease	1	0	1	0	1	0	0	1	2	6
Prolapsed Uterus	0	1	1	0	3	0	0	2	0	7
Egg Bound	0	0	0	0	0	0	0	1	0	1
Peritonitis	0	0	1	0	0	0	0	0	0	1
Coli septicaemia	0	0	0	0	0	0	0	0	1	1
Lymphoid Leucosis	1	0	0	0	0	0	0	0	0	1
N.D.D. **	0	1	0	0	1	0	2	1	2	7
Total	2	2	3	0	5	0	2	5	5	24
Total (Hatch to 52 wks.)	6	10	6	5	5	1	2	8	7	50

* Fatty Liver Kidney Syndrome
** No Definite Diagnosis.

Table 11.

Analysis of variance of mortality differences between treatments for several time periods(%).

Column Code.

(1) Hatch to 4 weeks

(2) 4 to 20 "

(3) 20 to 52 "

Source.	df.			MS		
(Code)	1	2	3	1	2	3
Total	26	35	26			
Treatments	8	8	8	NS 41.58	NS 69.45	NS 141.7
Error	18	27	18	22.67	62.21	107.4

Table 12.

Analysis of variance of age at first egg (days).

Source	df.	MS	F-test.
Total	262		
Treatments	8	611.52	3.52 **
Error	254	173.94	

Table 13.

Comparison of treatment mean age at first egg (days).

Ranked Means.		A-All	D-	B-	E-	F-	G-	C-	H-
A	174.9	-							
D	170.7	4.2	-						
B	169.9	5.0	0.8	-					
E	164.9	10.0	5.8	5.0	-				
F	164.6	10.3	6.1	5.3	0.3	-			
G	164.5	10.4	6.2	5.4	0.4	0.1	-		
C	164.2	10.7	6.5	5.7	0.7	0.4	0.3	-	
H	162.6	12.3	8.0	7.3	2.3	2.0	1.9	1.6	-
I	160.2	14.7	10.5	9.7	4.7	4.4	4.3	4.0	2.4

M.S.D. (5%) = 10.7; (1%) = 12.3 days.

Table 14.

Analysis of Variance of Body Weight at age at first egg.

Source.	df.	M.S.	F-test.
Total	26		
Treatments	8	0.0754	5.81 **
Blocks	2	0.0017	
Error	16	0.0130	

Table 15.

Comparison of Means of Body Weights at age at first egg. (lbs.)

Ranked Means.		A-All	B-	I-	G-	C-	D-	E-	F-
A	3.33	-							
B	3.58	.25	-						
I	3.69	.36	.11	-					
G	3.72	.39	.14	.03	-				
C	3.73	.40	.15	.04	.01	-			
D	3.75	.42	.17	.06	.03	.02	-		
E	3.82	.49	.24	.13	.10	.09	.07	-	
F	3.82	.49	.24	.13	.10	.09	.07	.00	-
H	3.83	.50	.25	.14	.11	.10	.08	.01	.01

M.S.D. (5%) = 0.33; (1%) = 0.49 lb.

Table 16.

H D Period Egg Production Analysis of Variance between treatments.

Column Code.

(1) 20 to 24 weeks

(2) 24 " 28 "

(3) 28 " 32 "

(4) 32 " 36 "

(5) 36 " 40 "

(6) 40 " 52 "

(7) 20 " 52 " (total H D egg number)

Source.	df.	M S						
(Code)	1 ... 7	1	2	3	4	5	6	7
Total	26							
Treatments	8	** 8.74	** 24.56	N S 2.86	N S 1.38	N S 2.76	N S 2.43	N S 4438.9
Blocks	2	3.90	11.85	0.32	0.19	0.23	3.56	389.8
Error	16	7.99	4.32	2.17	1.37	2.56	8.95	9897.0

Table 16a.

Average Treatment H D% egg production per 14-day period.

AGE (weeks)	A	B	C	D	E	F	G	H	I	5th * RST
20-22	0	0	0.92	2.42	5.83	3.33	12.08	2.25	3.58	4.57
22-24	8.11	11.57	17.36	18.36	25.21	28.79	32.00	32.14	28.79	24.14
24-26	42.12	52.43	51.79	49.50	59.07	65.93	61.86	70.21	56.43	52.00
26-28	75.64	53.25	70.64	73.21	70.50	76.93	69.95	69.08	70.00	73.57
28-30	78.36	76.71	68.64	78.29	70.71	73.36	69.07	70.56	70.71	82.57
30-32	75.49	78.86	76.04	70.14	70.71	70.50	69.07	67.34	72.51	84.83
32-34	76.00	78.86	75.93	71.71	74.58	73.36	70.64	70.93	77.29	84.94
34-36	72.21	73.79	71.93	75.29	75.38	68.07	69.86	68.00	70.93	82.64
36-38	71.69	75.46	74.08	69.77	70.62	69.77	64.08	67.76	70.08	82.68
38-40	67.87	73.07	72.25	67.40	69.49	74.67	65.40	62.69	66.80	83.09
40-42	70.64	66.43	72.79	72.43	73.57	71.93	63.21	66.57	66.79	81.06
42-44	72.43	67.71	67.97	65.79	66.93	63.36	61.64	63.43	62.43	79.50
44-46	62.50	64.00	57.43	63.00	60.86	53.79	55.74	57.43	56.29	78.78
46-48	70.64	68.00	63.43	71.43	66.93	63.07	63.21	61.43	65.93	76.58
48-50	67.86	62.43	61.43	62.21	61.93	63.79	62.64	60.29	62.93	73.44
50-52	63.46	63.79	60.86	62.21	63.17	65.50	59.86	57.14	61.29	71.00
20-52	61.92	61.95	60.42	61.34	62.29	62.03	58.86	60.24	60.60	73.58

* Average for all entries in 5th N.Z. Random Sample Test which includes the White Leghorn Control entry - which were the birds used in trial CN/50.

Table 17

Comparison of Treatment Means for H D Egg Production
20 to 28 weeks (same code as for table 16)

(1) Ranked Means.

		A-All	B-	C-	D-	E-	F-	I-	H-
A	1.17	-							
B	1.63	0.46	-						
C	2.57	1.40	0.94	-					
D	2.90	1.73	1.27	0.33	-				
E	4.23	3.06	2.60	1.66	1.33	-			
F	4.43	3.20	2.80	1.86	1.53	0.20	-		
I	4.47	3.24	2.84	1.90	1.57	0.24	0.04	-	
H	4.77	3.54	3.14	2.20	1.87	0.54	0.34	0.30	-
G	5.90	4.67	4.27	3.33	3.00	1.67	1.47	1.43	1.13

M.S.D. (5%) = 2.59; (1%) = 3.21 eggs.

(2)

		A-All	D-	C-	I-	B-	E-	G-	H-
A	10.13	-							
D	16.97	6.84	-						
C	17,20	7.07	0.23	-					
I	17.70	7.57	0.73	0.50	-				
B	17.77	7.64	0.80	0.57	0.07	-			
E	18.13	8.00	1.16	0.93	0.43	0.36	-		
G	18.20	8.07	1.23	1.00	0.50	0.43	0.07	-	
H	19.50	9.37	2.53	2.30	1.80	1.73	1.37	1.30	-
F	20.00	9.87	3.03	2.80	2.30	2.23	1.87	1.80	0.50

M.S.D. (5%) = 6.36; (1%) = 7.46 eggs.

Table 18.

H H Period Egg Production, Analysis of Variance Table for the complete 222 day laying period.

Source.	df.	M S	F-test
Total	134		
Treatments	8	2,276.8	3.45 **
Blocks	2	115,786.1	
Error	124	660.1	

Table 19.

Comparison of H H Egg Production Treatment Means.

Ranked Means.		C-All	H-	G-	I-	B-	D-	A-	E-
C	119.1	-							
H	119.2	0.1	-						
G	119.6	0.5	0.4	-					
I	125.7	6.6	6.5	6.1	-				
B	127.0	7.9	7.8	7.4	1.3	-			
D	127.1	8.0	7.9	7.5	1.4	0.1	-		
A	129.7	10.6	10.5	10.1	4.0	2.7	2.6	-	
E	130.1	11.0	10.9	10.5	4.4	3.1	3.0	0.4	-
F	137.7	18.6	18.5	18.1	12.0	10.7	10.6	8.0	7.6

M.S.D. (5%) = 14.4; (1%) = 17.0 eggs.

Table 20.

Analysis of Variance of Period Egg Weights.

<u>Column Code</u>.

(1) 23 weeks of age.

(2) 29 " " "

(3) 52 " " "

Source.	df.	M S		
(Code)	1 ... 3	1	2	3
Total	26			
Treatments	8	N S 3.094	N S 5.504	N S 4.937
Error	18	4.209	3.226	2.584

Table 21.

Analysis of Variance of Weighted Egg Weight for the 222 day Production Period.

Source.	df.	M S	F-test
Total	26		
Treatments	8	1.996	2.33 N S
Error	18	0.857	

Table 22.

Analysis of Variance of Egg Quality Characteristics.

<u>Column Code</u>.

(1) Haugh Units

(2) Meat and Blood Spots (arcsin. root percentage transformed)

Source.	df.	M S	
(Code)	1 & 2	1	2
Total	26		
Treatment	8	N S 4.22	N S 140.88
Error	18	5.23	264.08

Table 23.

Amino acid analysis of 6 of the grower rations used. (% of ration). The requirements for the essential amino acids are based on the same sources quoted for Appendix I table 3.

Amino Acid	Theoretical Requirement **	Rations A	B	C	G	H	I
Lysine	1.0	0.70*	0.70*	0.62*	0.88*	0.92*	0.78*
Histidine	0.4	0.27*	0.28*	0.22	0.36	0.34*	0.29*
(Ammonia)	0	0.45	0.48	0.35	0.45	0.52	0.35
Arginine	1.0	0.80*	0.90*	0.92*	1.35	1.21	1.34
Aspartic Acid	0	0.91	1.05	1.14	1.27	1.38	1.54
Threonine	0.6	0.45*	0.64	0.56	0.74	0.81	0.73
Serine	0	0.68	0.81	0.75	0.85	0.86	0.85
Glutamic Acid	0	2.44	3.29	3.22	3.17	3.24	3.50
Proline	0	1.23	1.19	1.16	1.40	1.12	1.15
Glycine	1.0	0.50*	0.67*	0.68	1.02	1.09	1.19
Alanine	0	0.49	0.65	0.63	0.82	0.87	0.93
Valine	0.8	0.83	0.84	1.21	1.16	1.10	1.04
(½) Cystine	0.6	-	-	0.6	-	0.8	-
Methionine	0.4	0.20*	0.21*	0.22*	0.26*	0.25*	0.28*
Isoleucine	0.6	0.45*	0.52	0.63	0.60	0.61	0.61
Leucine	1.4	1.03*	1.07*	1.35	1.30	1.33	1.25
Tyrosine	1.3	0.45*	0.47*	0.54*	0.64*	0.67*	0.58*
Phenylalanine	0.7	0.69	0.75	1.03	0.91	0.94	0.77
Total Acids %	-	12.14	14.00	15.44	16.75	17.50	17.30

* More than 0.05% less than the theoretical requirement.

** Based on a high total protein (18-20%) and a high energy (1400 Kcal ME/lb) ration.

APPENDIX II.

Table 1.

% Composition of the Grower Ration used in LT/19

Maizemeal	35
Barleymeal	32
Pollard	15
Meatmeal *	7
Buttermilk Powder	3.5
Lucernemeal	3.0
Vitamin-mineral Supplement **	0.25
Coccidiostat Premix ***	0.25
	100.00%

* The meatmeal was a mixture of two meals rated at 50% and 60% crude protein. A ratio of 64:46 was used in the ration.

** The formula of the Vitamin-Mineral Supplement can be seen in Appendix 1, table 1.

*** The coccidiostat made up 0.006% of the ration, mixed in a pollard-base premix.

Table 2.

Analysis of Variance of Weight Gains.*

Source.	df.	M S	
Total	167		
Treatments (T)	13	0.04456	N S
Blocks (B)	3		
Tiers (Ti)	2	0.05137	N S
T x B	39	0.02503	
T x Ti	26	0.04150	N S
B x Ti	6	0.06144	
T x B x Ti	78	0.05139	

* Valid tests for significance are: (1) T/ (T x B)
(2) Ti/ (B x Ti)
(3) T x Ti/ (T x B x Ti)

Table 3.

Analysis of Variance of H D Food Consumption per bird per day (lb.)

Source.	df.	M S	
Total	167		
Treatments (T)	13	0.0004562	N S
Blocks (B)	3		
Tiers (Ti)	2	0.0007974	N S
T x B	39	0.0003554	
T x Ti	26	0.0002082	N S
B x Ti	6	0.0011609	
T x B x Ti	78	0.0003619	

Table 4.

Details of Mortality in the Laying Period (21-58 wks.)

Treatment	N.L.*	Marek's Disease	Prolapse	N.D.D. **	Total	% Treatment.
1	1	0	0	0	1	2.8
2	0	0	0	0	0	0
3	1	1	0	1	3	8.3
4	1	0	1	0	2	5.6
5	4	1	0	0	5	13.9
6	1	1	0	1	3	8.3
7	1	0	0	1	2	5.6
8	2	0	0	0	2	5.6
9	1	1	0	0	2	5.6
10	1	1	1	0	3	8.3
11	1	0	0	1	2	5.6
12	2	1	1	0	4	11.1
13	0	0	0	0	0	0
14	1	1	0	0	2	5.6
Total No.	17	7	3	4	31	-
% of all birds	3.37	1.39	0.60	0.79	6.15	6.2

* Non-Laying

** No Definite Diagnosis

Table 5.

Analysis of Variance for Differences between Treatment Mortality.

Source.	df.	M S	F-test
Total	55		
Treatments	13	57.71	0.66 N S
Error	42	87.27	

Table 6.

Analysis of Variance of H H Egg Production.

Source.	df.	M S	
Total	167		
Treatments	13	2337.37	N S
Blocks	3		
Tiers	2	4329.54	N S
T x B	39	4585.39	
T x Ti	26	3654.92	N S
B x Ti	6	7301.38	
T x B x Ti	78	12,426.54	

Table 7.

Analysis of Variance of H D Egg Production.

Source.	df.	M S	
Total	167		
Treatments	13	25.43	N S
T x B	39	63.10	

APPENDIX III.

(a) Derivation of the relationship between the level of pollard in rations used in trial CN/50, and price per ton delivered in bulk to the P.R.C. The computation includes a factor for overheads and mixing cost of 21.9%. Price per lb. of ration is given by :

$$\text{Price/lb.} = \frac{1.219}{100} (P_P\, P + P_B\, B + P_M\, M + P_{B'}\, B')$$

where P = % pollard.

B = % barley.

M = % meatmeal.

B' = % basal (constant at 5%).

P_P = price of pollard.

P_B = " " barley.

P_M = " " meatmeal.

$P_{B'}$ = " " basal mix.

For trial CN/50 we can express any two of the variables B, P, M as a function of the other one (see section 3.2.4). Using percentage pollard (P) as the explanatory variable and substituting in the above equation we obtain :

$$\text{Price/lb.} = \frac{1.219}{100} (P_P P + P_B(97.2 - 1.2\, P) + P_M\, (-2.2 + 0.2\, P) + P_{B'}\, 5)$$

$$= \frac{1.219}{100} ((P_P - 1.2\, P_B + 0.2\, P_M)\, P + 97.2\, P_B - 2.2\, P_M + P_{B'}\, 5)$$

where the prices are given as follows :

	Price per ton ($)	Price per lb. (c)
P_B	49.50	2.475
P_M	85.50	4.275
P_P	45.50	2.275
$P_{B'}$	138.68	6.934

we obtain for the price/lb. of ration, the following equation :

$$\text{Price/lb.} = 3.241 + 0.00195\, P \text{ cents.}$$

$$\text{or Price/ton} = 64.80 + 0.390\, P \text{ dollars.}$$

Table 1.

Data used to calculate Regression Coefficients for trial CN/50.

X	=	% Pollard
Y_1	=	Food consumption - hatch to 20 weeks (lbs.)
Y_2	=	18 week body weight (lbs.)
Y_3	=	20 week body weight (lbs.)
Y_4	=	31 week body weight (lbs.)
Y_5	=	Body weight gain from 20 to 47 weeks
Y_6	=	H H egg production
Y_7	=	H D egg production
Y_8	=	Mortality over period 20 to 52 weeks (%)
Y_9	=	Weighted egg weight over period 20 to 52 weeks (gms)

X	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8	Y_9
11	17.5	2.52	2.67	3.90	1.64	129.7	137.5	6.90	52.6
16	19.0	2.76	2.94	4.28	1.57	126.9	135.5	6.90	51.4
21	19.6	2.91	3.12	4.40	1.80	119.1	134.1	10.34	51.8
26	20.8	2.89	3.07	4.03	1.29	127.1	136.2	0	53.3
31	21.8	3.02	3.26	4.46	2.13	130.1	138.3	16.67	53.2
36	22.3	3.02	3.31	4.41	1.38	137.7	137.7	0	52.4
41	22.6	3.00	3.26	4.58	1.71	119.6	130.7	6.67	52.8
46	23.6	3.05	3.28	4.50	1.97	119.3	133.7	16.67	53.9
51	24.9	3.02	3.23	4.35	2.01	125.7	134.5	16.67	53.5

For each regression (calculated using least Squares Regression technique (Snedecor <u>et al</u> 1967)) coefficient calculated, an estimation of the standard error associated with the coefficient was made.

The sum of squares of deviations (Sdy. x^2) was used to derive the mean square deviation from regression (Sy. x^2) and the resulting sample standard deviation of the regression coefficient (S_b) as in table 3.2.1, from which a t-test of significance the regression coefficient (b) was derived using (n-2) degrees of freedom. This indicated the level of probability that the independent and dependent variables were related by chance. A 5% level was accepted as significant.

The value of r^2 (squared correlation coefficient) indicated the amount of variation explained for the relationship between Y and X by b, or the "goodness" of fit.

The estimated standard error of Y (estimated), (Sy) was also calculated. A table of these values for trial CM/50 is presented below:

Table 2.

	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8	Y_9
b	0.170	0.011	0.0126	0.0107	0.009	-0.09	-0.095	0.20	0.0404
$Sdy.x^2$	0.924	0.086	2.8862	0.226	0.539	290.56	36.713	292.41	2.888
$Sy.x^2$	0.132	0.012	0.4123	0.032	0.077	41.51	5.245	41.77	0.4127
Sy.x	0.363	0.110	0.6421	0.179	0.278	6.44	2.290	6.46	0.642
Sb	0.009	0.003	0.0166	0.0046	0.007	0.166	0.059	0.17	0.0166
t	18.89	3.667	0.7590	2.326	1.250	0.56	1.607	1.06	2.434
Prob	0.001	0.01	0.50	0.04	0.40	0.50	0.20	0.40	0.05
r^2	0.98	0.710	0.077	0.429	0.172	0.05	0.29	0.18	0.459
Sy	0.121	0.045	0.243	0.067	0.277	2.44	2.29	2.37	0.642

Table 3 : Data used to calculate Regression Coefficients for trial LT/19.

X = % Meatmeal.

Y_1 = H D egg number.

Y_2 = H H " "

Y_3 = Laying period mortality.

Y_4 = Food consumption per H D.

Y_5 = Average egg weight at 56 weeks age.

Y_6 = Body weight gain in the laying period.

Table 3.

n	X	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6
1	2.0	158.5	155.2	2.8	.279	56.38	.88
2	2.7	154.5	154.5	0	.275	55.45	.75
3	3.4	156.2	155.1	8.3	.270	56.91	.81
4	4.1	163.0	159.3	5.6	.270	56.48	.78
5	4.8	159.6	146.0	13.9	.265	56.37	.73
6	5.5	155.0	148.0	8.3	.274	56.88	.83
7	6.2	162.7	156.7	5.6	.279	56.56	.90
8	6.9	155.8	149.3	5.6	.270	56.94	.80
9	7.6	159.6	154.3	5.6	.278	57.41	.90
10	8.3	162.7	155.5	8.3	.270	55.57	.72
11	9.0	160.6	154.7	5.6	.278	54.96	.83
12	9.7	154.1	144.6	11.1	.285	56.84	.92
13	10.4	162.8	162.8	0	.284	56.59	.82
14	11.1	160.9	155.4	5.6	.278	57.[illegible]6	.78

Table 4.

A complete tabulation of Regression Data calculated for trial LT/19 using the variables in Appendix III, table 3. For an explanation of the terms used, see Appendix III, table 1.

Dependent Variable	b	$Sdy.x^2$	Sy.x	Sb	t	Prob.	r^2
Y_1	0.334	124.36	3.22	0.31	1.10	N S	.09
Y_2	0.08	328.69	5.23	0.50	0.166	N S	.00
Y_3	0.079	8.382	0.836	0.374	0.211	N S	.04
Y_4	0.001	0.0003	0.0053	0.0005	1.996	N S	.24
Y_5	0.034	3.613	0.5487	0.052	0.644	N S	.02
Y_6	0.003	0.051	0.065	0.006	0.45	N S	.02

Table 5.

Price received per dozen eggs (for each grade) C:V/50.

Large	Standard	Medium	Pullet	Undergrade	Period.
56	52	45	35	29	16/7 - 29/ 7/69
56	52	45	35	29	30/7 - 12/ 8/69
56	52	45	35	29	13/8 - 26/ 8/69
56	52	45	35	29	27/8 - 9/ 9/69
46	42	35	25	29	10/9 - 23/ 9/69
42	38	33	23	29	24/9 - 7/10/69
38	34	31	21	29	8/10 - 21/10/69
46	42	39	29	29	22/10 - 18/11/69
46	42	39	29	29	19/11 - 16/12/69
46	42	34	24	29	17/12 - 28/ 1/70
42	38	30	23	25	28/ 1 - 10/ 2/70

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