THE LYSINE RESPONSE OF THE TURKEY

BY

CLIFFORD NIXEY, B.Sc (Agric.), M. Agr. Sc.

THESIS SUBMITTED TO THE
UNIVERSITY OF NOTTINGHAM
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY,
OCTOBER 1991

ACKNOWLEDGMENTS

I wish to record my sincere appreciation of all those people and organisations who have helped to make the study reported in this thesis possible. I wish to particularly thank the following:-

Dr. K. N. Boorman for his patient encouragement and expert advice. His unobtrusive guidance has kept the project moving and on course. His painstaking examination of the many handwritten drafts is greatly appreciated. His apparent confidence that the project would be completed contributed greatly to its ultimate completion.

My employers British United Turkeys Ltd for allowing me to undertake the project and for the use of their experimental facilities.

Mrs M. Foscett (nee Beeston), Mrs D. Latham, Mr A. Hines and the staff at Kinnerton Farm for their help in carrying out the experiments in BUT facilities.

Miss C. Pass for her work in the two experiments carried out in the University of Nottingham School of Agriculture facilities.

L. Back and K. Gregson of the Biometry Section of the University of Nottingham School of Agriculture for their assistance.

Dr C. Fisher for supplying the Reading model.

Colborn-Dawes Ltd for the production of the experimental diets.

Carolyn Shepherd and her staff at The Wordsmith Group for the layout and typing of the thesis.

To embark on a project such as this while in full time employment demanded considerable sacrifice on the part of my family. My children, Paul and Clare, accepted the calls it made on my time without once complaining.

My wife, Norma, has been a continual source of encouragement, willing to forego numerous activities and postponement of household jobs in the cause of "the thesis". It is dedicated to her with all my love.

INDEX OF CONTENTS

INDEX OF TABLES

INDEX OF FIGURES

INDEX OF APPENDIX TABLES

Material from this thesis has been used by the author in the following publications or conference papers.

NIXEY, C. and BOORMAN, K.N. (1985). The lysine requirements of market turkeys. In : *Proceedings of the 5th European Symposium on Poultry Nutrition* pp 137-144.

NIXEY, C. (1987). The interdependance and response of amino acids in growing turkeys. In : *Proceedings of the 14th Carolina Poultry Nutrition Conference* pp 20-31.

NIXEY, C. (1988a). The nutritional requirements of turkeys to meet current market demands. In : *Recent Advances in Animal Nutrition*. Cole, D. J. A. and Haresign, W. (eds) pp 119-130. London, Butterworths.

NIXEY, C. (1988b). Feeding the modern high performance turkey. 1988 Pennsylvania Poultry Conference (no published proceedings).

NIXEY, C. (1989b). Feeding growing turkeys for maximum breast meat yield. 11th Technical Turkey Conference, Peebles, Scotland. In : *Turkeys* 37, No 2, 25-30.

NIXEY, C. (1989c). Nutritional responses of growing turkeys. In : *Recent Advances in Turkey Science*. Nixey, C. and Grey, T. C. (eds) pp 183-199. London, Butterworths.

NIXEY, C. (1991). The influence of factors affecting food intake on turkey production. In : *Proceedings of XXVIII Europea De Congress De Avicultura Cientua*, Valencia, Spain. (In press).

ABSTRACT

THE LYSINE RESPONSE OF THE TURKEY

By

CLIFFORD NIXEY, B.Sc.(Agric.), M.Agr.Sc.

After reviewing the literature, it was found that there was a paucity of information on the subject. Examination of quantitative models of nutritional responses of a turkey did not clarify the situation. Analysing suitable published data by the Reading flock response model (Fisher, Jennings and Morris, 1973), which derives the two constants a and b in the equation:-

Lysine requirement = a x body-weight gain + b x body-weight

showed some agreement in a values among different experiments, although b values varied greatly.

Using the diet dilution technique, fifteen experiments were performed to generate lysine response data. These were analysed by the Reading model. Eleven experiments covered a range of ages from 4 days to 20 weeks, two experiments were concerned with the genetic potential for gain and two experiments examined the influence of the previous plane of nutrition.

For males the mean value ($\pm$SEM) for a was 21.4 ± 2.0 g lysine/kg gain. There was no indication of the value reducing until at least 120 days of age. The a value for females was similar to that of males until 84 days in a fast-growing strain, decreasing thereafter. In a slow-growing strain, this divergence occurred at an earlier age. The b values averaged 6.0×10^{-3} for males and 7.0×10^{-3} for females.

It was shown that compensatory growth is possible, but that the extent to which it takes place will be dependent on the degree of previous growth depression.

Optimum ratios of lysine:energy (g lysine per MJ ME) decreased with age. It is recommended that these are used in conjunction with tables of lysine input and body-weight output produced from the experimental data. These tables could also provide the basis of a method of computer simulation of turkey nutritional responses.

CHAPTER ONE

Literature Review of the Lysine Response of the Turkey

INTRODUCTION

Knowledge of the amino acid needs of turkeys is considerably less than that for broilers and laying hens. The longer growth period of turkeys and the consequent increased cost of research are largely responsible for the lack of research, particularly beyond the first three or four weeks of age. The longer growth period also involves several changes of diet which complicates experimental work.

The amino acid requirements for optimal growth will be of prime importance in turkeys because of their fast growth rates, high meat yield and low fat content. Lysine is likely to be one of the most commonly limiting amino acids in turkey diets based, as they usually are, on cereals. It is also a reliable marker amino acid on which to base any calculations of the ideal amino acid pattern because its primary use in the body is for protein synthesis whereas methionine, for example, is involved in a relationship with cystine (Behrends and Waibel, 1980) and, because of an involvement with methyl groups, interacts with choline (Quillin, Combs, Creek and Romoser, 1961).

There are currently several attempts to unify data on amino acid requirements of poultry in order to make generally applicable statements. By such means, it should be possible to avoid further proliferation of empirical experimentation. With the turkey, there is the chance to introduce such unifying statements at this relatively early stage. A thorough quantitative analysis of existing data together with collection of further data and examination of such fundamental models as exist would seem to be logical at this stage.

This examination is the subject of this thesis. The analysis largely concerns lysine and the experimental work solely concerns lysine.

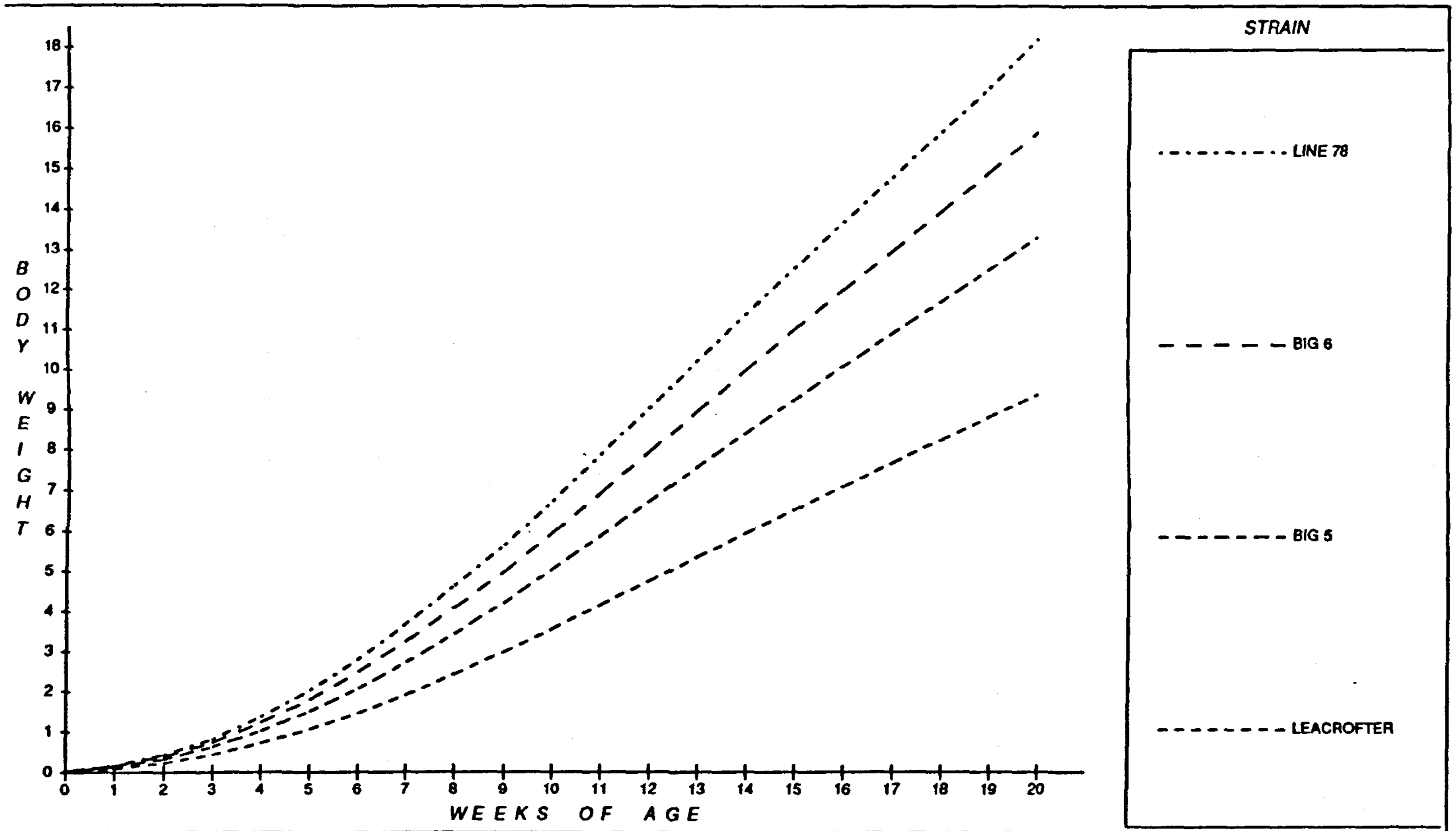

FIGURE 1. BODY WEIGHTS AND GROWTH PATTERNS(kg) OF VARIOUS TYPES OF MALE TURKEYS (BRITISH UNITED TURKEYS LTD 1986)

LITERATURE REVIEW

It has been forecast that the turkey industry will be a major growth area in the livestock industry in the last quarter of the 20th century (Richardson, 1980). A major reason for this is the versatility of the turkey, which can be used to produce small oven-ready birds of 2.5kg, catering-sized birds of 25kg oven-ready and all sizes in between. In addition the turkey can be used solely as a source of meat for further processed products. To cater for these markets, a number of different types of turkey have been developed with different growth characteristics. This is illustrated by the published standards for 20 weeks of age body weight for some of the various types of male turkeys available from British United Turkeys Ltd (Figure 1).

It will be seen that the largest turkey, Line 78, achieves twice the weight of the smallest, the Leacrofter, in 20 weeks. There are also considerable differences between the sexes. The extent of these differences changes with age (Table 1).

TABLE 1	GROWTH RATES (g/bird.day) AT DIFFERENT AGES (BRITISH UNITED TURKEYS, 1981)		
AGE (WEEKS)	BIG 6 FEMALE	BIG 6 MALE	% INCREASE OF THE MALE OVER THE FEMALE
0-4	27.5	30.7	12
4-8	70.0	84.3	20
8-12	96.8	131.4	36
12-16	87.1	145.7	67
16-20	62.1	120.7	94
20-24	35.0	98.6	182

The composition of the weight gained also differs, females starting to deposit fat earlier than males (Hurwitz, Frisch, Bar, Eisner, Bengal and Pines, 1983). Within a sex, strains also differ in the rate at which they mature and the rate of fat deposition (Moran, 1983). To complicate matters still further, rapid genetic gains in growth rate have been achieved in the past and are likely to continue. The extent of the improvement has been illustrated by Nixey (1989a) and is shown in Table 2.

TABLE 2	AN EXAMPLE OF GENETIC PROGRESS		
YEAR	BRAND NAME	18 WEEK BODY WEIGHT (kg)	
		MALES	FEMALES
1966	TRIPLE 6	9.45	6.75
1969	TRIPLE 6	9.77	6.92
1972	BUT 6	10.27	7.27
1974	BUT 6	10.68	7.56
1977	BUT 6	10.96	7.80
1981	BIG 6	12.67	8.78
1982	BIG 6	12.80	8.84
1984	BIG 6	13.40	9.13
1986	BIG 6	13.96	9.88

It will be seen that in 1986 the large strain females were heavier than the males of 1969. In 1986 strains had a growth potential approaching 50% greater than the bird of 20 years earlier. The older the research, therefore, the less its findings may be applicable to the modern strains of turkeys.

A primary question with regard to the individual amino acid requirements of animals is "how should the requirement be expressed?" Early workers expressed the lysine requirement as a percentage of the protein. Kratzer, Davis and Marshall (1956) concluded that the lysine requirement was approximately 4.75% of the protein for poults from hatching to 4 weeks and decreased thereafter to about 4%. Balloun (1962) however, proposed a value of at least 5%. This method of assessing the lysine requirement has a serious weakness in that the quality of the protein as judged by the lysine content will influence the recommendation. For example, two diets could both be identical in the proportion of lysine in the total diet eg. 1.38%, but the total protein percentage in the diets could differ eg. 29% and 25%. In such an example the recommended lysine level expressed as a percentage of the protein would be very different according to the diet used ie. 4.75% in the 29% protein diet and 5.5% in the 25% protein diet.

Later workers have expressed lysine requirements as a proportion of the diet. While a more general expression of the requirement, it will be influenced by factors which affect food intake. Three major factors which affect food intake are the metabolizable energy content of the diet (Booth, 1979), the form of the feed, be it mash or pellets (Britzman, 1976) and the ambient temperature (De Albuquerque, Leighton, Mason and Potter, 1978). The latter two factors can be specified when the requirements are stated, while to overcome the influence of the metabolizable energy content of the diet, the lysine requirement can be stated in proportion to metabolizable energy content of the diet. The lysine content of a diet should be expressed as grams of lysine per kilogram of diet and the metabolizable energy (ME) content as megajoules (MJ) per kilogram of diet. The lysine requirement therefore, can be expressed as grams of lysine per MJ of ME. In the review of work which follows, the conclusions have all been converted where possible to this method of expressing the lysine requirement. In the chapter which follows on calculated methods of lysine requirements, it is possible to express the requirements in grams of lysine per bird day when related to a known growth rate. However, the relevant information is not always available when reviewing experiments in the literature.

How are lysine requirements best assessed? It has been traditional to assess them directly by empirical experimentation. It has been shown that turkeys can differ greatly in growth rates and growth patterns. Fisher and Emmans (1983) argued the case for assessing amino acid requirements indirectly by calculation rather than by empirical experimentation to accommodate the widely differing situations and quickly fill the large gaps in the present state of knowledge. Any predictive model must take account of potential growth rate, carcass composition, temperature, dietary energy content, form of the diet and several other factors. The advantage of such a method is that it has the flexibility necessary for a variety of situations and a changing genetic potential, while empiricism will require constant and continuing experimental work. However, the requirements arrived at by calculation have to be validated by empirical experimentation.

The case for empirical experimentation has not been furthered by the efforts of workers to determine the lysine requirements of the turkey. Most of the experiments to date are open to criticism which makes the conclusions drawn unreliable. In reviewing the current state of the knowledge of the lysine requirements of the turkey, experiments have been categorised under the headings which indicate the main area of concern in the experiments.

a. Added Synthetic Lysine

Most investigations have involved the adding of free (commonly known as synthetic) lysine incremently to a basal diet deficient in lysine to achieve a range of lysine concentrations for the development of a dose-response relationship. The supplementation technique can be criticised on two bases. The first is that variation occurs in the amino acid balance of successive diets within a supplementary series. The second criticism is that another amino acid may become limiting before the maximum response to the amino acid under test is achieved. The limitations of the supplementation technique are illustrated by work on 8 to 24 week old turkeys by Potter, Shelton and McCarthy (1981). They used 9 dietary treatments comprising 3 protein concentrations with 3 lysine concentrations (0, 1 or 2g added lysine/kg) in a complete 3 x 3 factorial design. While there was a response to increasing dietary protein, added lysine had only small effects. For example, increasing the protein by 30 or 60g/kg, which provided additions of 2.2 or 4.4g lysine/kg respectively, at 8 to 20 weeks of age increased body-weight gain by 18.3 and 24.7% respectively, while additions of 1 or 2g synthetic lysine/kg produced increases of only 2.2 and 3.6% respectively. Thus the almost equivalent additions of 30g protein (2.2g lysine/kg) and 2g synthetic lysine/kg produced grossly disparate (18.3 and 3.6%) responses. A similar marked effect was evident in males in the 20 to 24 week period. These results indicate that the response to protein was to an amino acid equally or more limiting than lysine, which must have been deficient in the basal diet. This diet was formulated from maize, dehulled soya bean meal, meat and bone scraps, animal and vegetable fat, corn distillers dried grains with solubles, DL-methionine and normal minerals and vitamins. On the basis of the NRC (1977) recommendations however, lysine was calculated to be the most deficient amino acid by at least 16% compared with the next limiting amino acid. Without the benefit of the protein comparison, it would have been concluded that there was no significant response to added lysine and that the requirement was near to the lysine provided by the basal diet. Results obtained from work involving the added synthetic lysine technique will therefore lack an element of credibility because of the possible effect of a second amino acid becoming limiting.

Using the lysine data in the added protein treatments, Potter et al (1981) concluded that the lysine requirements from 8 to 12, 12 to 16 and 16 to 20 weeks of age were 1.076, 0.885 and 0.717g of lysine per MJ of ME respectively. This conclusion is open to debate because there was no clear indication that the response to lysine had reached its limit in each case. This problem occurs in other work and is covered in a following section.

It should be pointed out that while Potter et al (1981) failed to achieve lysine limitation in the basal diet, other workers, using the supplementation technique have found a response to added lysine, at least among the increments at the lower end of the range. This indicates that lysine was the first limiting amino acid in their diets. Tuttle and Balloun (1974) using male turkeys from 0 to 4 weeks, 4 to 8 weeks and 8 to 12 weeks, added synthetic lysine to diets of various protein contents to give a range of protein and lysine concentrations. The diets were 'supplemented with leucine, cystine, arginine and threonine to ensure adequacy of all essential amino acids except lysine'. As added synthetic lysine in several treatments accounted for more than 30% of the total lysine content, and in one treatment 52%, it would be extremely surprising if, in such diets, lysine was the first limiting amino acid. For this to have been the case, it would have required the other ingredients in the diet to have grossly imbalanced amino acid profiles, with lysine deficiencies of a similar magnitude to the proportions of added synthetic lysine to total lysine used.

Despite clear lysine deficiency, the inadequacies of using this type of factorial approach to determine the lysine requirement are illustrated in Figure 2. If points of similar total lysine are compared, the higher the contribution of synthetic lysine the lower the growth rate. In the comparison the higher the contribution from added synthetic lysine, the lower the protein level of the diet, so the most likely explanation is that an amino acid other

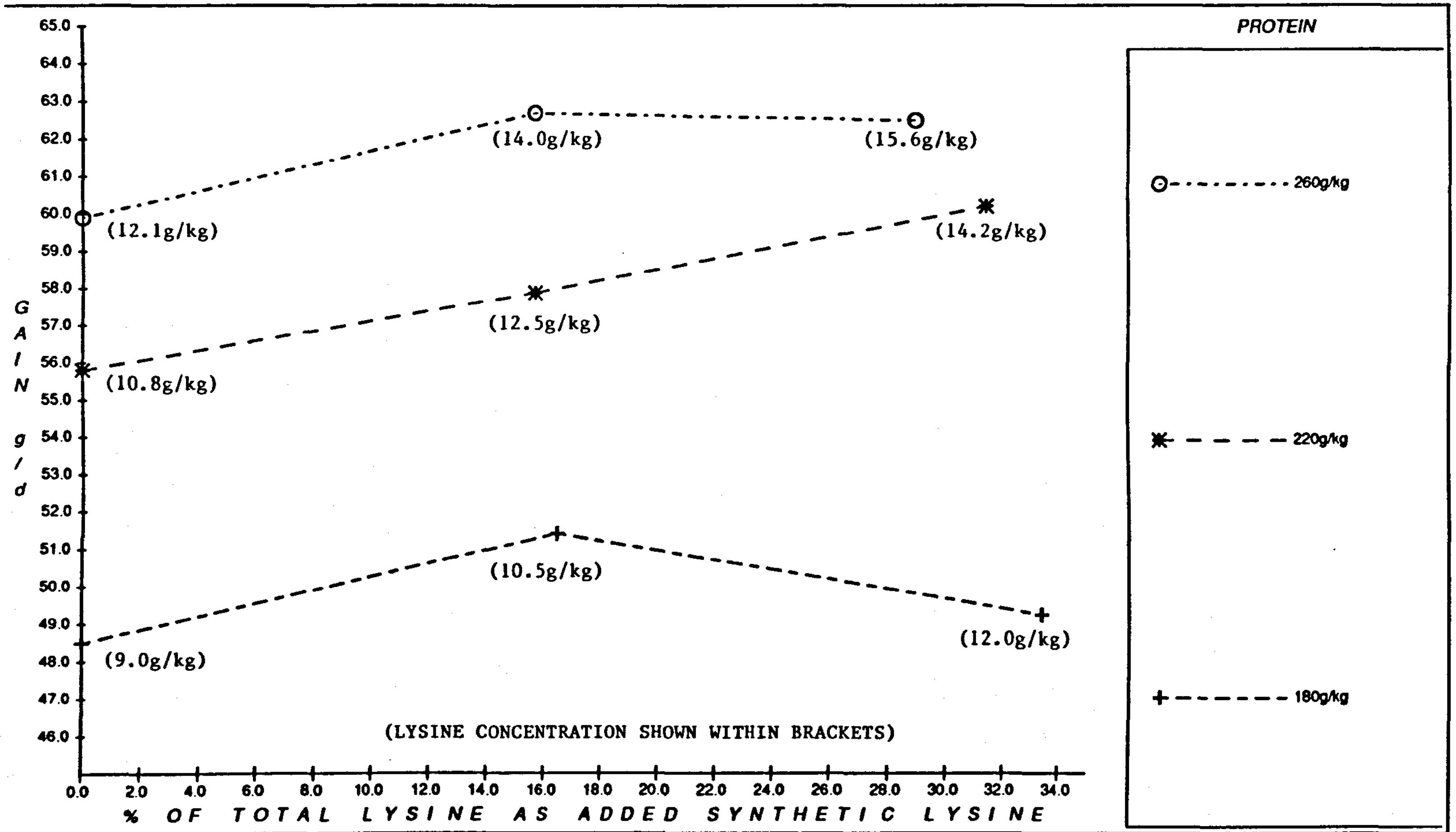

FIGURE 2. THE INFLUENCE OF DIETARY PROTEIN CONCENTRATION ON PERCEIVED LYSINE REQUIREMENT OF TURKEYS(Tuttle and Balloun,1974,exp.3:4to8 weeks)

than lysine is limiting in the diets involving higher levels of added synthetic lysine, preventing full expression of the total lysine content of the diet.

b. Amino Acid Relationships

An alternative method of achieving different doses of lysine is to formulate a series of diets of different lysine contents from feedingstuffs, such that lysine is the first limiting amino acid of each diet. The weakness of this method is that each diet will tend to have a different amino acid pattern. D'Mello and Lewis (1970a) showed that, in the chick, amino acids do not act independently of each other. They demonstrated that at a dietary lysine concentration of 11g/kg, the arginine requirement was 8g/kg, whereas at lysine concentrations of 13.5, 16.0 and 18.5g/kg, the arginine requirements were 9.2, 10.4 and 11.5g/kg respectively. They demonstrated a similar interdependence between leucine and isoleucine and, between leucine and valine (D'Mello and Lewis, 1970b) and between threonine and tryptophan (D'Mello and Lewis, 1970c). D'Mello and Emmans (1975) reported the same interdependence between lysine and arginine in turkeys and D'Mello (1975) confirmed the leucine-isoleucine and leucine-valine relationships in turkeys. Excesses of both lysine and total sulphur amino acids have been reported to depress weight gains in the chick (Boorman and Fisher, 1966). Clearly the interdependence of amino acids should not be ignored in experimental design. Where differing lysine concentrations are achieved by using different feedingstuffs, the diets will differ in their amino acid patterns. The effects of changes in the relationship between amino acids cannot yet be calculated and could influence the apparent responses to lysine.

The effects of amino acid imbalances can be seen in a response surface analysis reported by Kummero, Jones and Loadholt (1971) to determine the optimum combination of lysine and total sulphur amino acids. One experiment comprised a complete factorial design of five lysine and five total sulphur amino acid concentrations and in another a similar design comprising four concentrations of each was used. All diets were of equal energy content. Sand was included in the basal diet to allow substitution of lysine and DL-methionine to produce the different concentrations. The technique however did not take into account the balance of other amino acids, with the result that the contours produced show growth depressions with increasing lysine concentration when the sulphur amino acids remained constant. Other amino acids will also be remaining constant so a possible explanation of the growth depression is the lysine and arginine interrelationship, which would mean that as lysine levels were increased, the arginine requirement was also increased.

Waldroup, Maxey, Luther, Morrow and Johnson (1979) investigated the lysine requirements of the turkey at various ages in an extensive series of studies using both supplementation of a deficient basal diet and the complete formulation approach. The diets used were very dependent on soya bean meal and maize to achieve the lysine differences. As the protein in these two ingredients differs markedly in amino acid content (see Table 3) the diets change significantly in amino acid patterns as formulations are changed to achieve different lysine contents.

TABLE 3 AMINO ACID CONTENTS OF MAIZE AND SOYA BEAN (NATIONAL RESEARCH COUNCIL, 1977)

	MAIZE		SOYA BEAN (DEHULLED)	
	g/100g protein	In proportion to Lysine = 100	g/100g protein	In proportion to Lysine = 100
Arginine	5.68	208	7.59	116
Glycine	4.20	145	4.72	72
Histidine	2.27	83	2.72	42
Leucine	12.50	458	7.88	120
Isoleucine	4.20	154	5.30	81
Lysine	2.73	100	6.56	100
Met + Cys	3.98	146	2.99	46
Phe + Tyr	10.45	383	8.49	130
Threonine	4.43	162	3.94	60
Tryptophan	1.02	37	1.38	21
Valine	5.91	217	5.61	86

The higher arginine content relative to lysine in maize compared to that of soya could be of particular significance in view of the interdependence between these two amino acids.

Methionine and cystine may be next limiting amino acids. Maize has high contents of these amino acids relative to lysine whereas the reverse is the situation in soya bean.

The weaknesses of the supplementation technique have been discussed previously. They may explain the conclusion of the work by Waldroup et al (1979) that turkeys may require no more than 90% of the lysine requirement suggested by the recommendations of the National Research Council (NRC, 1971) which were themselves lower than their later recommendations (NRC, 1977).

Because of differences in ingredient price relationships, the ingredients used in European nutritional experiments e.g. Geraedts and Kan (1981), D'Mello and Emmans (1975), differ considerably from those used in North America e.g. Waldroup et al (1979). European diets are based on wheat and barley for the cereal content and fishmeal, meat and bone meal, wheat middlings and soya bean meal for much of the protein content. In North American diets, the cereal is mostly provided by maize and the protein almost solely by soya bean meal. The amino acid patterns will therefore differ between the diets used in each continent. The effect of such differences has not been investigated as yet.

c) Problems of Interpretation

The primary objective of an experiment is to draw a conclusion. The validity of the conclusion depends upon the quality of the work as judged by method, size etc and also on how the information so obtained is interpreted. The interpretation of some of the work on the lysine requirements can be criticised. The criticism is of two kinds.

i) Lack of plateau

To be sure that the full potential response to lysine in a particular circumstance has been reached, the data obtained should give a clear indication of a "plateau" or upper limit. This criterion has not been met in several experiments where conclusions have been drawn by the authors. Tuttle and Balloun (1974) investigated the lysine requirements of male turkeys during the periods 0 to 4, 4 to 8 and 8 to 12 weeks. The results for 4 to 8 weeks have already been described in the context of limitation in an amino acid other than lysine. At the other two ages, the highest level of lysine gave the best weight gain, so the conclusion that the highest concentration of lysine used is the requirement for maximum growth is not proven. The only safe conclusion is that the requirement is at least as high as the highest lysine level used in the experiment.

Similarly Jensen, Manning, Falen and McGinnis (1976) drew conclusions on the lysine needs of 12 to 16 week old turkeys from data in which the highest lysine concentration used in two experiments produced the highest weight gains. The work also highlighted another important facet of interpretation. The absolute lysine requirement for maximum growth rate is a rate of supply of lysine, not a proportion of the diet. The latter is for the convenience of the nutritionist. In the two experiments of Jensen et al (1976), if weight gain is plotted against proportion of lysine in the diet (Figure 3), the two experiments seem to show very different relationships between weight gain and lysine in the diet. However when converted into intake of lysine (Figure 4) the overall relationship between weight gain and lysine intake underlying the two experiments becomes evident. Part of the remaining variation may be due to the very different protein ingredient sources used in the two experiments with their different amino acid patterns and perhaps availability of lysine. Two separate lines have been fitted to the data. Alternatively a single line could describe the data concluding that the three highest lysine intakes of Experiment 2 are on the plateau section of the response curve.

D'Mello and Emmans (1975) in their investigation of the effect of the specific interaction between lysine and arginine on the requirement for lysine in the young turkey also compared weight gains and lysine intakes. They concluded that the arginine and lysine requirements for maximum growth of the 3 week old turkey

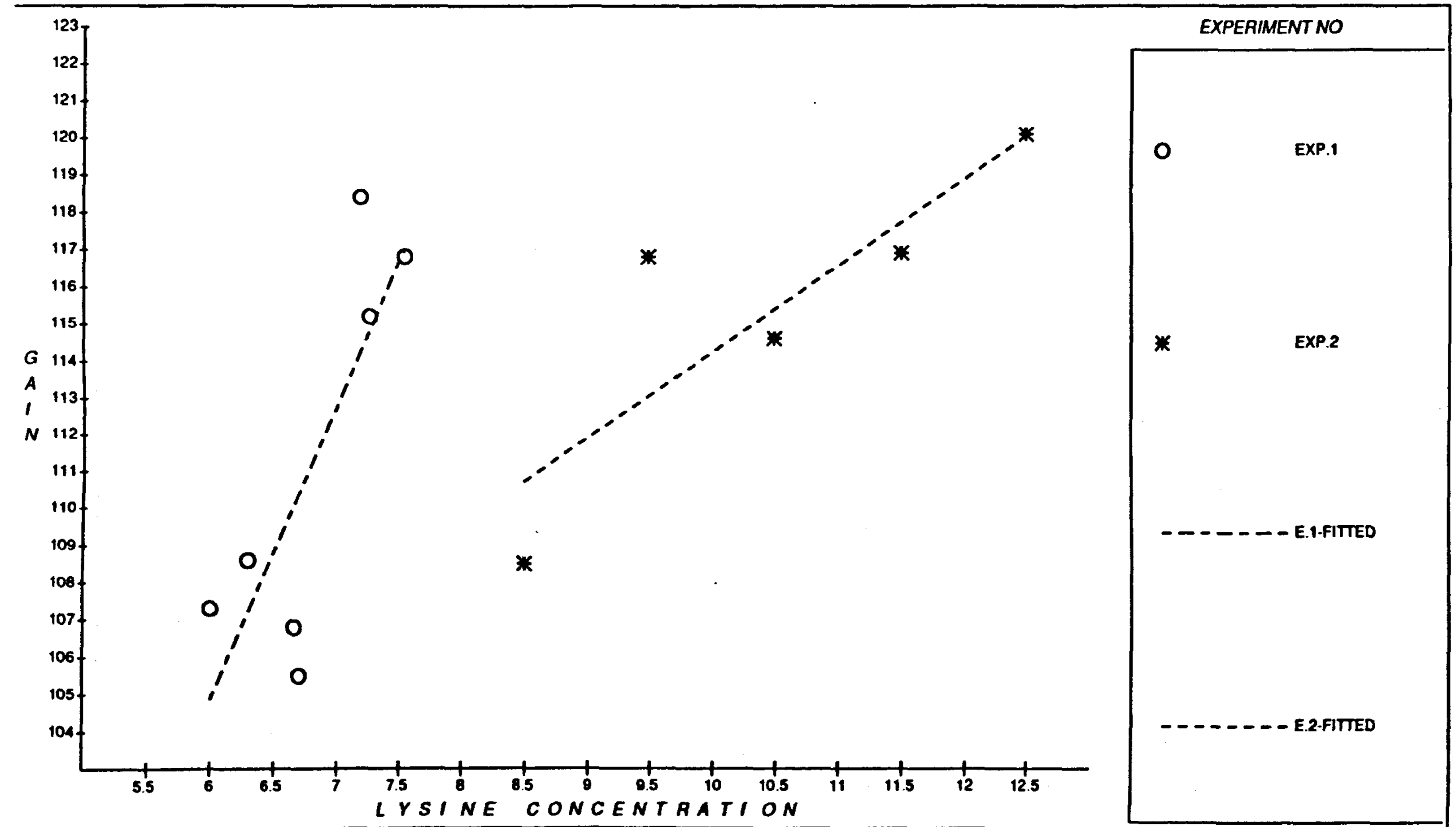

FIGURE 3.DIETARY LYSINE CONCENTRATION(g/kg) AND BODY-WEIGHT GAIN(g/d) OF TURKEYS (Jensen et al,1976,Expts.1 and 2:16 to 20 weeks)

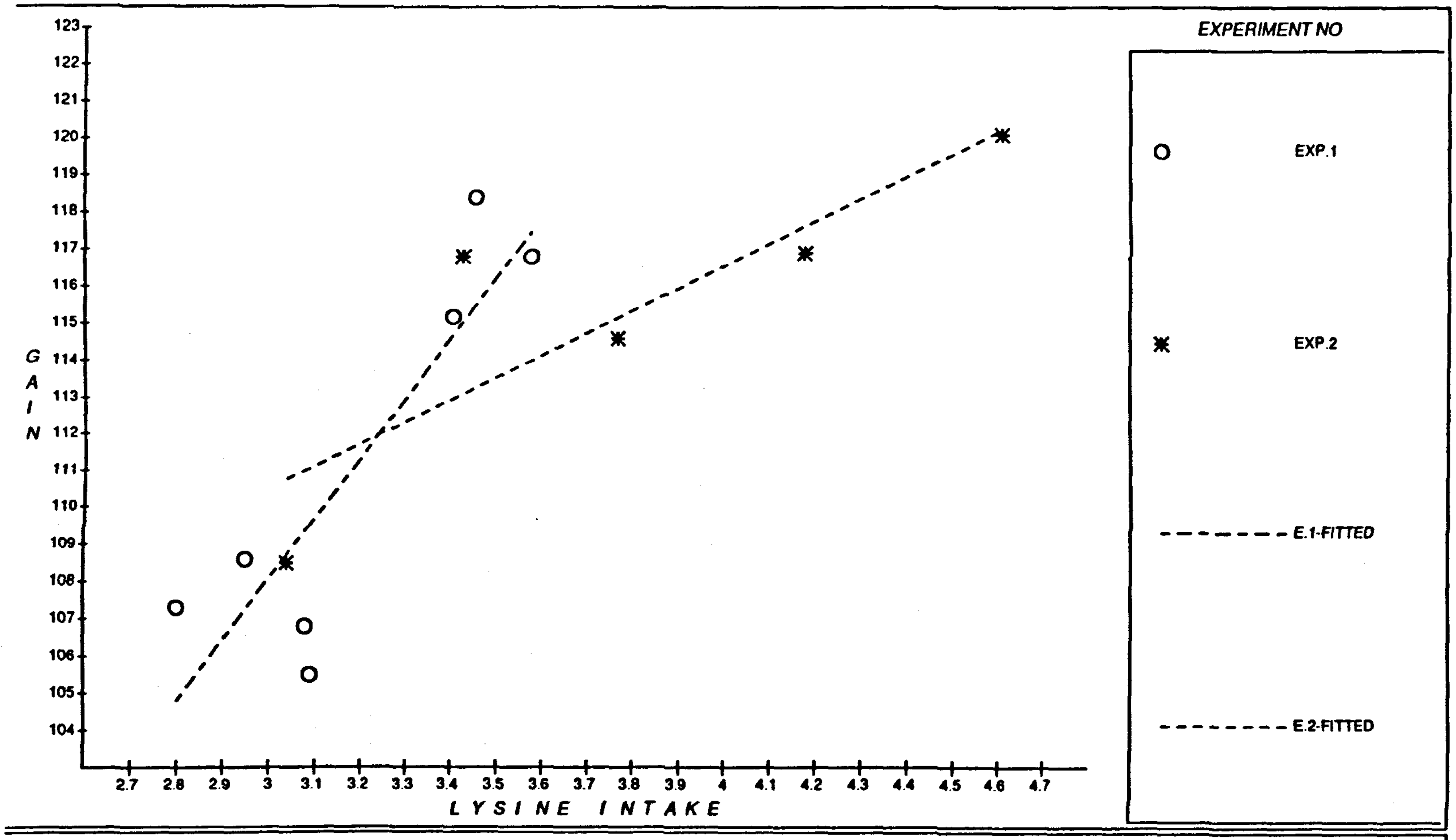

FIGURE 4.LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d) OF TURKEYS
(Jensen et al,1976,Expts.1 and 2:16 to 20 weeks)

were 1.389g/MJ for arginine and 1.230g/MJ for lysine. Their conclusions however also suffer from the weakness that these levels were the highest used and the response curve was showing no sign of a limit. The justification they offered that a limit in response had been reached was that the performance of the highest treatment level was the same as that achieved on a standard maize/soya bean diet which contained 1.627g arginine and 1.429g lysine/MJ. This does not preclude the possibility that the standard diet was limiting in another amino acid.

ii) Method of curve fitting

The theoretical growth response curve in an individual bird to an amino acid input would consist of three sections (see Figure 5).

A. An initial section where the amino acid is limiting and any increase in amino acid intake is used for maintenance requirements, leaving no excess for a growth response.

B. A section where the amino acid is still limiting and where the increased amino acid intake promotes increased growth rate in a linear fashion.

C. A plateau section where the amino acid needed to satisfy the bird's growth rate potential has been supplied and increased amino acid intake does not result in increased growth rate.

This theory is utilised in the 'broken line' least squares method (Robbins, Norton and Baker, 1979) for determining the requirement of a nutrient from a set of response data. The broken line method determines the requirement point (break-point) as the intersection of the sloping line fitted to the growth response or incremental section of the curve (B) with the line fitted to the plateau section (C).

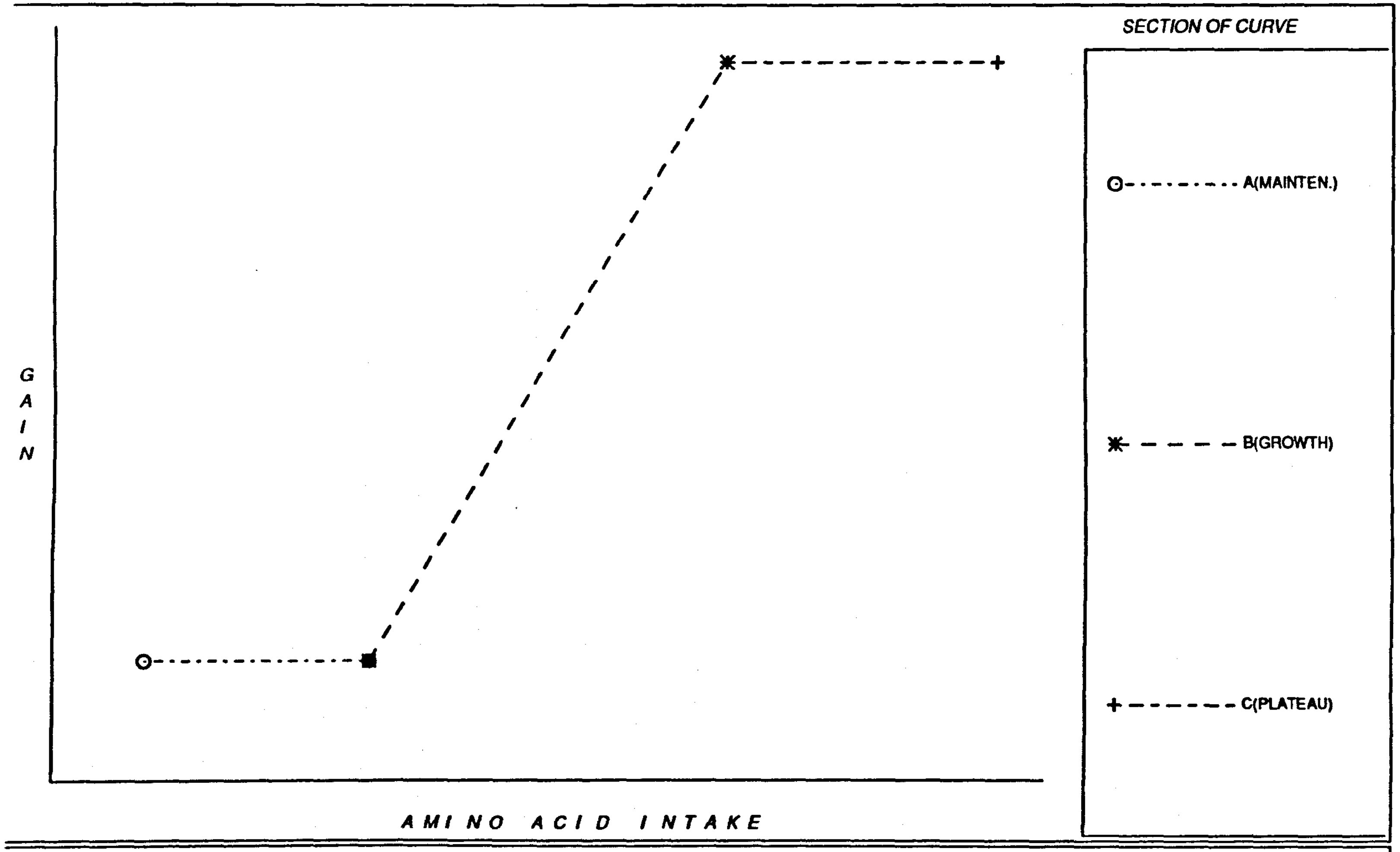

FIGURE 5. THE RESPONSE CURVE OF AN INDIVIDUAL BIRD

In practice the response for the whole flock or population almost invariably appears as a line or incremental response leading through a curved or 'diminishing returns' zone to a flat plateau. There is a logical explanation for this pattern which is illustrated in Figure 6. The explanation was first put forward by Fisher, Morris and Jennings (1973) to describe the response of laying hens to amino acid intake. The explanation is equally applicable to growth rate response. Individuals will vary in their maintenance requirement (especially as a result of variation in body weight) and in their genetic potential for growth rate. Thus response curves for individuals will show variation in respect of the maintenance section (A) and the plateau (C) with the consequent movement of the incremental section (B), although not necessarily variance of the slope itself. The mean response for the flock is therefore curvilinear throughout with maximum curvature at the ends of the incremental sequence.

In experiments where the lysine requirement has been determined by the broken-line method, there will be a tendency to underestimate the requirement. This is illustrated by Figure 7 which has been taken from a paper by Noll and Waibel (1982) on the turkey's lysine requirement at different temperatures. It shows a quadratic line and a broken line fitted to the 75°F (24°C) treatment points. If the broken-line method is used to fit the points, as it was by the authors, the indicated requirement level occurs at a lower level than that required to reach the plateau section indicated by the quadratic line. In addition the indicated requirement does not lie on the line indicated by the data points approaching the plateau.

Fisher et al (1973) produced a model, now known as the Reading model, to analyse and describe the flock response of laying hens. It has since been proposed for use with growing birds by Clark, Gous and Morris, (1982) and Fisher and Emmans, (1983). The model is described in detail in the following chapter and used to analyse available data.

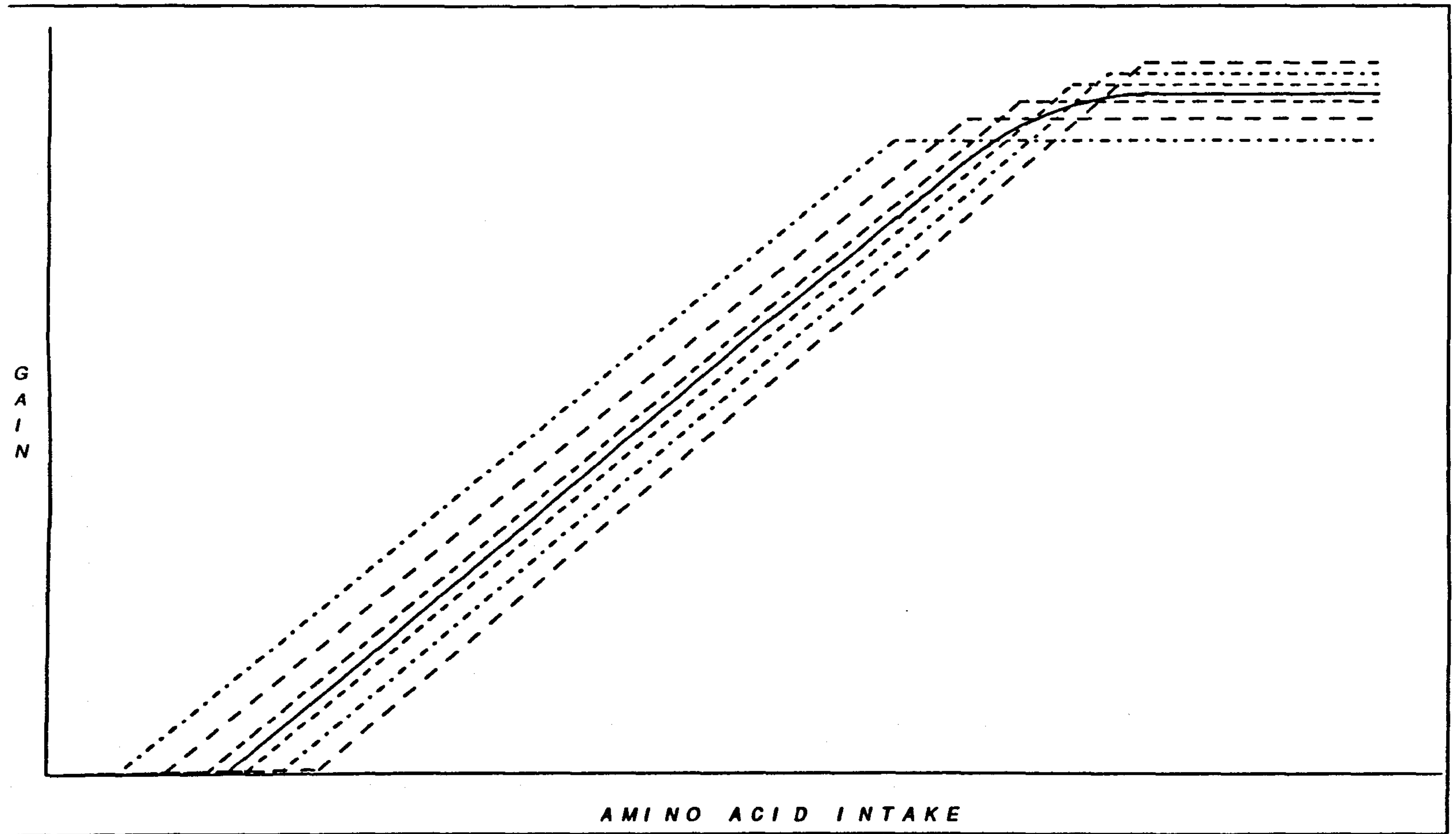

FIGURE 6. THE RESPONSE CURVE OF A GROUP OF BIRDS
(Broken Lines=Individuals, Solid Line=Flock Mean)

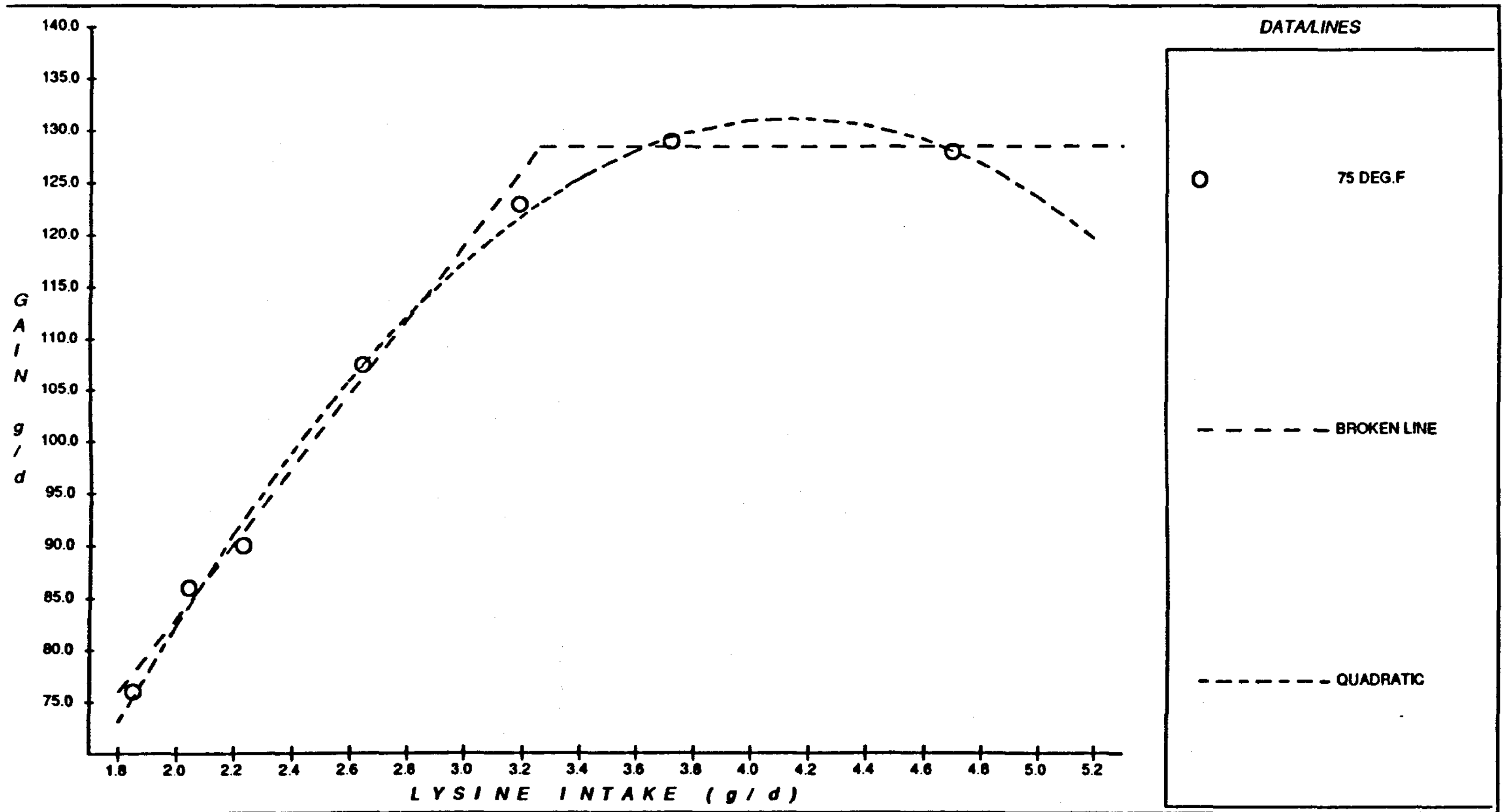

FIGURE 7. A COMPARISON OF THE "BROKEN LINE" AND "THE QUADRATIC LINE" METHOD FOR ASSESSING LYSINE REQUIREMENTS (Data from Noll and Waibel,1982)

d) **Previous Plane of Nutrition**

It was shown by Auckland, Morris and Jennings (1969) that the previous nutrition could influence the utilisation of protein in the subsequent growth period. Poults fed on a low protein diet from 0 to 6 weeks were able to catch up in body weight, when subsequently given adequate amounts of protein from 6 to 14 weeks, with poults fed on a high protein diet throughout. The undernourished poults ate more food at any body weight when catching up than did controls when they were at the same weight. Food conversion into body weight was better in undernourished birds than in the controls, and significantly as far as work on lysine requirements is concerned, there was a large increase in the efficiency of conversion of dietary protein to body weight in favour of the poults which had been undernourished to 6 weeks of age. An explanation for this, either in part or wholly, is that over the total growing period less protein is required for body maintenance as more of the body-weight gain occurs at a later stage with the undernourished birds. Sholtyssek (1981) has shown similar changes in efficiency of protein utilisation using the compensatory growth principle with turkeys.

In a number of the trials reported on the lysine requirements of the turkey, the requirements were determined for two or more consecutive periods without randomised remixing of the birds. In such a situation the growth rates and efficiencies of utilisation of lysine during the last period under test will be influenced by the treatments previously received by the turkeys. An extreme example of this is a trial by Geraedts and Kan (1981) in which very good growth rates were achieved. Three feeding periods were investigated, 0 to 6 weeks, 6 to 12 weeks and 12 to 24 weeks with measurements made every 3 weeks. The diets were redistributed between pens at the end of each period. However the birds within a pen remained together throughout the trial so there will have been carry over effects from one period to the next. To prevent this, randomised remixing of the birds should have taken place at the start of each period. It would have been far preferable if all the birds had received the same plane of nutrition prior to the start of the experimental period. At 18 weeks of age, the body weight of birds assigned to the low lysine programme was noticeably below that of those assigned to the high lysine programme. From 18 to 24 weeks, the body-weight gain of the birds receiving high lysine slowed down as they approached mature size, while the low lysine group exhibited compensatory or catch up growth similar to that demonstrated by Auckland et al (1969). Thus the low lysine group gained 134g/bird d on an intake of 3.3g lysine/bird d from 21 to 24 weeks while the high lysine group only gained 117g on an intake of 5.5g. In such a situation the results for a period can be misleading.

e) **Factors Affecting Food Intake**

The turkey's requirement for lysine is most accurately defined as grams per bird per day as this eliminates the effect of food intake. This has not always been done in studies, where the requirement was stated as a proportion of the diet and where food intake differences may have had a very important influence. The food intake is obviously very influential on the achievement of the requirement. In turn food intake is influenced by several factors, the most important of which are the energy content of the diet, the form of the diet, be it mash, crumbs or pellets and the environmental temperature that the bird is subjected to. The influence of energy is allowed for by stating the requirement in terms of g lysine/MJ of ME.

Pelleting has been shown to give better growth rates and/or better food conversion in a number of trials. Heidebrecht (1973) reviewed research comparing pellets and mash for turkeys. Combining 29 comparisons, the average improvement in food conversion due to pelleting was 4.621%. The main benefit of pelleting would appear to be through promoting a greater food intake than on mash (Hamm, Jaen, Tollet and Stephenson, 1960, Jensen, Merrill, Reddy and McGinnis, 1962, and Moran, 1983). Jensen, Ranit, Wagstaff and McGinnis (1965) found that, at critical lysine or protein concentrations, pelleting accentuated differences in growth due to deficiency. If protein was adequate, pelleting did not improve growth rate but food conversion was improved. The form of the food therefore must be taken into account when reviewing previous work where conclusions are drawn as to the lysine requirement when expressed as a proportion of the diet. With mash feeding the g lysine per kg food requirement should be higher than if pellets are fed, to make allowance for the reduced food intake on mash.

Environmental temperature has been shown to influence growth and food consumption of turkeys (de Albuquerque, et al 1978, Waibel, El Halawani and Behrends, 1976). Noll and Waibel (1982) investigated the influence of the environmental temperature on the lysine requirements of growing turkeys in two experiments. In one experiment 16- to 20-week-old turkeys showed average gain and food intakes at 24°C which were only 81 and 79% respectively of those achieved by turkeys kept at 7°C. In a second experiment for 8- to 12-week-old birds, gains at 21°C and 27°C were depressed to 91 and 84% of those seen at 7°C while food intake was depressed to 88 and 82% respectively. For the 16 to 20 week period,gains at 15°C and 24°C were depressed to 94 and 82% of those seen at 7°C while food intake was depressed to 92 and 84%. These results indicate a similarity between growth depression and food intake depression. The influence of temperature is a major cause of weakness in stating the requirement in terms of g lysine/MJ ME. The requirement will change according to the environmental temperature, with the g lysine required being increased as the temperature increases to counteract the reduced food intake resulting from the lowered ME requirement to maintain body temperature.

REVIEW OF LYSINE REQUIREMENTS AS ASSESSED BY EMPIRICAL METHODS

In view of the possible areas for criticism, the published research has been reviewed and technical comments made on the following four questions:

A. Does the growth response indicate a plateau has been reached?

B. Are the differing lysine levels achieved by the addition of synthetic lysine?

C. Are the amino acids other than lysine in similar proportions in all treatments?

D. Does the assessed requirement take into account the curvilinear response near the plateau?

The indicated lysine requirements from published papers have been converted to a grams of lysine per MJ of ME base, using the original author's value for ME, and are summarised in approximately 4 weekly age groups in Tables 4 to 9. In the tables, the questions outlined above are identified by the appropriate code letter. Variations in the ME values used for ingredients by different authors constituted a problem which could not be overcome because of incomplete descriptions of ingredients.

TABLE 4	A REVIEW OF THE RESEARCH ON THE LYSINE REQUIREMENTS OF THE TURKEY AGED APPROXIMATELY 0 TO 4 WEEKS OF AGE						
SET[1]	AGE RANGE (d)	SEX[2]	INDICATED LYSINE REQUIREMENT (g/MJ)	TECHNICAL COMMENT CODE[3]			
				A	B	C	D
1	1-42	B	1.484	Y[4]	N[4]	N	N
2	1-21	B	1.349	Y	N	N	N
3	1-21	B	1.392	Y	N	N	N
4	5-17	B	1.317	Y	Y	Y	N
5	1-28	M	1.328	N	Y	Y	-
6	7-28	M	1.278	Y	Y	Y	N
7	7-35	M	1.135	N	Y	Y	-
8	7-21	M	1.230	N	Y	Y	N
9	1-42	B	1.438	Y	Y	Y	N
10	1-28	M	1.311	N	Y	Y	-
11	7-21	M	1.136	Y	Y	Y	N
12	7-28	B	1.338	N	N	Y	Y

TABLE 5	A REVIEW OF THE RESEARCH ON THE LYSINE REQUIREMENTS OF THE TURKEY AGED APPROXIMATELY 4 TO 8 WEEKS OF AGE						
SET[1]	AGE RANGE (d)	SEX[2]	INDICATED LYSINE REQUIREMENT (g/MJ)	TECHNICAL COMMENT CODE[3]			
				A	B	C	D
13	42-84	B	1.130	Y[4]	N[4]	N	N
14	28-56	M	1.219	Y	Y	Y	N
15	28-56	M	1.278	Y	Y	Y	N
16	28-56	M	1.280	Y	N	Y	Y
17	28-56	F	1.200	Y	N	Y	Y
18	28-56	M	1.280	Y	N	Y	Y
19	28-56	F	1.171	Y	N	Y	Y

TABLE 6	A REVIEW OF THE RESEARCH ON THE LYSINE REQUIREMENTS OF THE TURKEY AGED APPROXIMATELY 8 TO 12 WEEKS OF AGE						
SET[1]	AGE RANGE (d)	SEX[2]	INDICATED LYSINE REQUIREMENT (g/MJ)	TECHNICAL COMMENT CODE[3]			
				A	B	C	D
20	56-84	B	0.860	Y[4]	Y	Y	N[4]
21	56-84	B	1.076	Y	Y	Y	N
22	56-84	M	1.110	N	Y	Y	N
23	56-84	M	0.765	Y	Y	Y	N
24	56-84	M	1.837	Y	Y	Y	N
25	56-84	M	0.736	Y	Y	Y	N
26	56-84	M	0.729	Y	Y	Y	N
27	56-84	M	0.826	Y	Y	Y	N
28	56-84	M	0.898	N	N	N	-
29	56-84	M	0.911	Y	N	N	N
30	56-84	M	1.105	N	N	N	-
31	56-84	M	1.034	Y	N	Y	Y
32	56-84	F	0.774	Y	N	Y	Y

TABLE 7	A REVIEW OF THE RESEARCH ON THE LYSINE REQUIREMENTS OF THE TURKEY AGED APPROXIMATELY 12 TO 16 WEEKS OF AGE						
SET[1]	AGE RANGE (d)	SEX[2]	INDICATED LYSINE REQUIREMENT (g/MJ)	TECHNICAL COMMENT CODE[3]			
				A	B	C	D
33	84-112	B	0.672	Y[4]	Y	Y	N[4]
34	84-112	M	0.978	N	Y	Y	-
35	84-112	M	0.885	Y	Y	Y	N
36	84-112	M	0.646	Y	Y	Y	N

TABLE 8	A REVIEW OF THE RESEARCH ON THE LYSINE REQUIREMENTS OF THE TURKEY AGED APPROXIMATELY 16 TO 20 WEEKS OF AGE						
SET[1]	AGE RANGE (d)	SEX[2]	INDICATED LYSINE REQUIREMENT (g/MJ)	TECHNICAL COMMENT CODE[3]			
				A	B	C	D
37	112-140	B	0.617	Y[4]	Y	Y	N[4]
38	112-133	M	0.526	Y	Y	Y	N
39	112-140	M	0.648	N	Y	Y	-
40	112-140	M	0.576	Y	Y	Y	N
41	112-140	M	0.717	Y	Y	Y	N
42	112-140	M	0.478	Y	Y	Y	N
43	112-140	M	0.550	Y	Y	Y	N
44	112-140	M	0.499	Y	Y	Y	N
45	112-140	M	0.485	Y	Y	Y	N
46	112-140	M	0.533	Y	Y	Y	N
47	112-140	F	0.470	Y	Y	Y	N

TABLE 9	A REVIEW OF THE RESEARCH ON THE LYSINE REQUIREMENTS OF THE TURKEY AGED APPROXIMATELY 20 TO 24 WEEKS OF AGE						
SET[1]	AGE RANGE (d)	SEX[2]	INDICATED LYSINE REQUIREMENT (g/MJ)	TECHNICAL COMMENT CODE[3]			
				A	B	C	D
48	140-168	M	0.470	Y[4]	Y	Y	N[4]
49	140-168	M	0.569	Y	Y	Y	N
50	140-168	F	0.392	Y	Y	Y	N
51	140-168	F	0.533	Y	Y	Y	N

Footnotes on Tables 4 to 9

1 1,13 13: Balloun and Philips (1957); 2, 3: Kummero et al (1971); 4: Warwick and Anderson (1968); 5, 6, 7, 14, 22: Tuttle and Balloun (1974); 8: D'Mello and Emmans (1975); 9: Potter and Shelton (1976); 10, 15, 20, 33, 37, 49, 51: Waldroup et al (1979); 11, 36, 38: Hurwitz et al (1983); 12, 16, 17, 18, 19, 31, 32: Fisher (1984); 21, 35, 41: Potter et al (1981); 23, 24, 25, 26, 27, 42, 43, 44, 45, 46: Noll and Waibel (1982); 28, 29, 30: ADAS (1983); 34, 39: Jensen et al (1976); 40, 47, 48, 50: Summers et al (1966).

2 M: Male, F: Female, B: Both.

3 A: Does the growth response indicate a plateau has been reached?

B: Are the differing lysine levels achieved by addition of synthetic lysine?

C: Are the amino acids other than lysine in similar proportions in all treatments?

D: Does the assessed requirement take into account the curvilinear response near the plateau?

4 Y = Yes
N = No

When an experiment has investigated two or more age periods without the birds being re-randomised between periods, only the initial period result has been shown. Other periods may have been affected by the compensatory growth effect described above. When no interpretation of an individual experiment has been made by the authors, the level giving the maximum growth rate has been used in the tables.

Most work has been reported for the 0 to 4 week and the 8 to 12 week ages. It will be seen that there is a considerable range in the optimum levels reported. This is illustrated in Figure 8 where the indicated lysine requirements have been plotted against age. It will be seen that the range of requirements at each age is such that these ranges overlap for different ages. Figure 8 does however indicate a steady reduction in lysine requirement per unit of dietary energy with age. Linear regression analysis indicates that for each week of life to 24 weeks, the lysine requirement decreases by 0.0448g per MJ ME, the equation being:

$$R_L = -0.0448\ (\pm 0.0037)\ A + 1.376\ (\pm 0.052)\ (r = -0.908,\ n = 34,\ P < 0.001)$$

R_L = Requirement in g lysine per MJ ME

A = Age in weeks

It is unlikely that the true relationship with age will be exactly linear as it will be dependent on the relative growth rates of muscle and fat which are not linear (Hurwitz, Frisch, Bar, Eisner, Bengal and Pines, 1983), but as indicated above a linear relationship describes the data adequately.

Most work used the addition of synthetic lysine to a deficient basal diet to achieve the various lysine levels. The disadvantages of this method have already been discussed. Only Fisher (1984) has taken into account the curvilinear response nearing the plateau when assessing the requirement. The other interpretations might be expected therefore to underestimate requirements for maximum growth. The same comment applies when a clear plateau in response was not achieved.

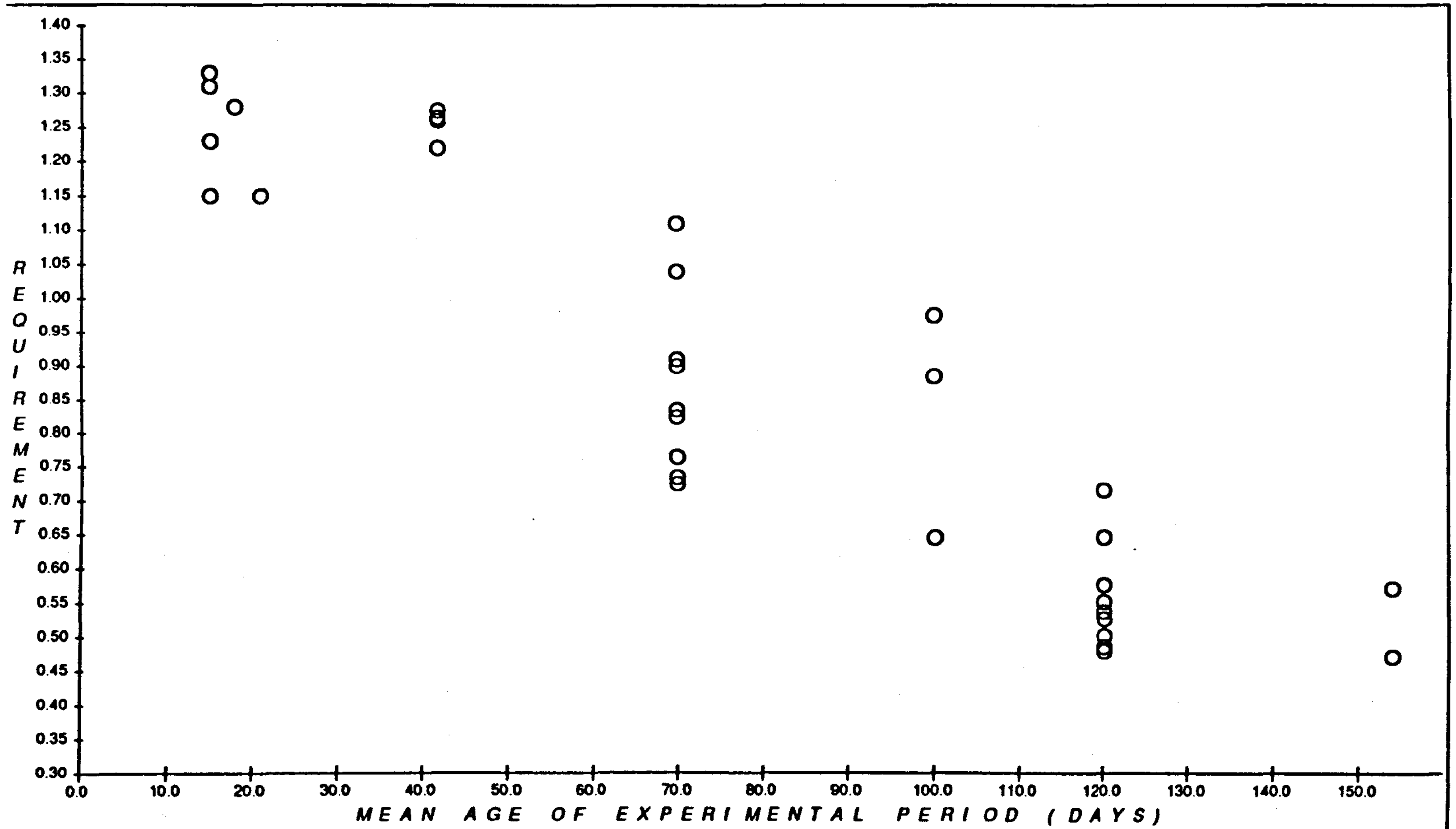

FIGURE 8. THE RANGE OF INDICATED LYSINE REQUIREMENTS OF MALE TURKEYS EXPRESSED AS g LYSINE PER MJ ME (Data from tables 4 to 9)

Several countries issue recommendations for the feeding of farm animals in booklets published by Government Agricultural Departments or Councils.

TABLE 10	A REVIEW OF THE LYSINE RECOMMENDATIONS FOR TURKEYS IN VARIOUS COUNTRIES		
A) APPROX 0 - 4 WEEKS OF AGE			
COUNTRY	AGE FED (MALES)	AGE FED (FEMALES)	RECOMMENDED REQUIREMENT (g/MJ)
USA	0-4	0-4	1.452
CANADA	0-4	0-4	1.405
UK	0-8	0-8	1.032
FRANCE	0-4	0-4	1.435
B) APPROX 4 - 8 WEEKS OF AGE			
USA	4-8	4-8	1.319
CANADA	4-8	4-8	1.117
UK	0-8	0-8	1.032
FRANCE	4-10	4-10	1.145
C) APPROX 8 - 12 WEEKS OF AGE			
USA	8-12	8-11	1.076
CANADA	8-14	8-10	0.888
UK	8-12	8-12	0.846
FRANCE	10-16	10-16	0.865
D) APPROX 12 - 16 WEEKS OF AGE			
USA	12-16	11-14	0.771
CANADA	14-16	10-14	0.694
UK	12-18	12-18	0.756
FRANCE	10-16	10-16	0.865
E) APPROX 16 - 20 WEEKS OF AGE			
USA	16-20	14-17	0.598
CANADA	16-20	14-18	0.588
UK	12-18	12-18	0.756
FRANCE	NO RECOMMENDATIONS		
F) APPROX 20 - 24 WEEKS OF AGE			
USA	20-24	17-20	0.471
CANADA	20-22	18-20	0.458
UK	18-24	18-20	0.715
FRANCE	NO RECOMMENDATIONS		

REFERENCES: USA - NRC (1977); CANADA - SUMMERS & LEESON (1976); UK - ARC (1975); FRANCE - AEC (1978)

The published recommendations for the turkey's lysine requirements are shown for the four countries with the largest turkey populations (Table 10). All were published in the late 1970's and when updated might be expected to show alterations. At present Table 10 indicates that there is little agreement between the sets of recommendations. The ultimate objective of both research and advisory recommendations is to improve the diets fed commercially. In the course of the author's employment, he is given access to turkey diet formulations in various countries. A wide range in the amount of lysine per MJ of ME fed at a similar age is seen among countries (personal observations). This is illustrated in Table 11.

TABLE 11	THE LYSINE TO ME RATIOS IN PRACTICAL USE IN VARIOUS PARTS OF THE WORLD				
COUNTRY	USA	ISRAEL	ITALY	GERMANY	UK
AGE FED (WEEKS)	0-4	0-4	0-4	0-6	0-3
g LYSINE PER MJ	1.453	1.464	1.569	1.417	1.613
AGE FED (WEEKS)	20-24	20-24	19-24	18-24	18-24
g LYSINE PER MJ	0.471	0.471	0.575	0.637	0.668

It is the author's impression that the differences shown have arisen because of economic factors rather than experimental work. In EC countries, the cereal prices are increased by imposing tariffs on imported cereals. As there is no EC soya production to protect, imports of soya are allowed almost at world prices. The effect is to distort the price relationships between energy and protein (and therefore lysine) costs in the EC compared to the world market. Table 12 gives comparative ingredient costs.

TABLE 12	COMPARISON OF NORTH AMERICAN AND UK INGREDIENT PRICES IN DECEMBER 1982 (NIXEY, 1983)		
	USA	CANADA	UK
MAIZE	58	79	150
WHEAT	89	71	120
BARLEY	83	50	114
SOYA (44%)	118	151	141
FISH (66%)	252	277	266

Prices in pounds sterling based on 1.63 U.S Dollars and 2.09 Canadian Dollars to one pound

As a result in the USA where maize is only half the price of soya, protein units are much more expensive relatively than energy, whereas in the UK the cereals are almost as expensive as soya so that energy is relatively the more expensive part of the diet. The formulations and lysine to energy levels reflect these economic factors. In the UK high lysine levels and relatively low energy levels are used whereas in the USA the opposite is the case.

The published research work on the optimum lysine to energy ratios can be used to support either case. When this work was started therefore the situation was badly in need of clarification so that more rational formulating decisions could be made in differing economic situations.

CHAPTER TWO

Lysine Requirements of the Turkey by Calculation

INTRODUCTION

In the previous chapter the lysine requirements of the turkey as determined by empirical experimentation were reviewed. An alternative means of determining the requirements is indirectly by calculation.

Determining the requirements by calculation has a number of advantages. The turkey has a long growing cycle with continually changing nutritional needs. It has been shown in the previous chapter that existing data on the nutritional needs are incomplete and inconsistent. By using suitable theoretical models to calculate requirements at different stages of growth, it may be possible to clarify the situation, which can then be verified later by experimentation. Good data are available on some of the factors which influence the requirements such as growth rate potential, body composition and energy requirements. Using these data, allied to sound principles to calculate the lysine requirement, should then give a more exact estimate of the turkey's lysine requirements. The calculation should be able to estimate the different requirements at different ages under different conditions such as temperature, form of the feed, energy level of the feed etc., for turkeys with different genetic potentials for growth rate. For the turkey which is capable of a diversity of potential growth rates, which are themselves being changed by genetic progress, the latter is particularly relevant. The cost and time involved in trying to determine requirements by empirical experimentation for such diverse circumstances would be prohibitive. Furthermore, experiments would need repeating regularly as production characteristics were changed by genetic progress. A method of calculating requirements is the only practical answer to this problem. Two groups of workers have attempted to calculate the lysine requirements of the turkey. Fisher and Emmans (1983) have produced a model which will be referred to hereafter as the Edinburgh model and Hurwitz, Frisch, Bar, Eisner, Bengal and Pines (1983) have produced a model which will be referred to as the Israel model. The two groups have tackled the problem in different ways, using different combinations of empirical and analytical data to produce their models of the turkey. For comparison, the models have been split into segments and the alternative methods of solving the problems in each segment are discussed.

The protein requirements and individual amino acid requirements for growing birds can be defined as the sum of the requirements for maintenance, carcass gain and feather gain.

POTENTIAL BODY WEIGHT AND BODY-WEIGHT GAIN

A turkey has a genetic potential for growth rate and mature body weight. In the Israel model, the body weight curve used is the results of measurements made on 25 male BUT Large White turkeys, held at 24°C, so that the calculations relate specifically to that type of bird and temperature.

In the Edinburgh model growth is predicted using the Gompertz function (Gompertz, 1825), a well-established growth equation which gives an estimate of body weight at time t (W_t). It requires the definition of two parameters; A, the body weight at maturity and B, the rate of decline in relative growth rate which is a measure of the degree of maturity.

$$W_t = A \exp(-\exp(B(t-t^*))) \qquad \text{kg (1)}$$

Where W_t = body weight W at time t (days after hatching)

A = body weight at maturity (t = infinity)

exp = *e* to the power of (*e* is the base of natural logarithms)

B = rate of decline of relative growth rate

t^* = time (days after hatching) at which $W_t/A = 1/e = 1/2.72 = 0.37$

Growth rate dW/dt is given by:

$$dW/dt = B.W_t.\log e\,(A/W_t) \qquad \text{kg/day (2)}$$

More research is required into the parameter values used in the equations. For example body weight at maturity needs to be defined more precisely. In the author's experience, while the growth rate slows down markedly in the 28 to 32 week age period in males, the birds continue to gain weight slowly even beyond 40 weeks of age. Fisher Emmans (1983) suggested the following values for the present.

Type	Sex	A (kg)	B	t* (d)
Large	M	21.5	0.017	91.0
	F	12.9	0.020	79.3
Medium	M	16.0	0.018	84.0
	F	9.6	0.021	73.2

Equation (1) represents potential growth. In practice actual growth will usually be less than this. Ultimately a "catch-up" period of growth will usually occur so that the birds reach the same mature body weight. The Edinburgh model does not yet accommodate or describe this phenomenon. Ultimately the solution would be to use body protein at maturity.

MAINTENANCE REQUIREMENTS

Fisher and Emmans (1983) estimated, using values taken from adult cockerels, the maintenance requirement of the turkey for lysine to be 69 mg per kg body weight per day. Hurwitz et al (1983) calculated the maintenance requirements from first principles. Classically, the energy requirement for maintenance has been considered to be proportional to body surface area. Empirically, surface area has been taken as a function of body weight raised to a power of less than unity. For mammals Kleiber (1947) used the power of 0.75 but for birds Brody (1945) concluded that a power of 0.66 was a more suitable value. This value was used in the Israel model.

Obviously the loss of skin particles must be proportional to the skin surface. Also intestinal losses are probably related to the body surface since, in the turkey, intestinal length varies with body weight (Hurwitz unpublished) and body surface will be correlated with body weight. In the Israel model, these two items, skin losses and intestinal losses, were regarded as major components in determining the protein needs for maintenance. This model uses the following equation for protein required for maintenance (P):

$$P = M \cdot W^{2/3}/0.85$$

where M is the coefficient of protein needed for maintenance and W is the body weight. The net requirement is divided by 0.85, the coefficient of protein absorption in the young turkey (Hurwitz, Eisner, Dubrov, Sklan, Riesenfeld and Bar, 1979).

For determination of the maintenance requirements of individual amino acids, the Israel model assumes that tissue renewal does not involve any significant net loss of essential amino acids, except for specific amino acids which are catabolised irreversibly. Examples of these are proline, some of which is hydroxylated into hydroxyproline, and histidine, some of which is methylated. A net loss of amino acid is presumed to occur via

1) The intestine, the result of unabsorbed digestive secretions and of epithelial breakdown. This was determined by analysing the amino acid excretion of birds consuming a protein-free diet.

2) Continuous loss of skin particles. For the measurement of the loss of protein and amino acids in the sloughed off skin particles, it was assumed that in the non-growing adult bird with an unchanged nitrogen concentration in its carcass, nitrogen retention must equal zero. When feeding an adequate protein diet, a positive nitrogen retention value is obtained which must be equivalent to the loss of skin integuments to the environment. It was noted by Leveille, Shapiro and Fisher (1960) that the amino acid pattern required for maintenance was similar to that of feather protein so the same assumption was made in the Israel model.

3) Catabolism of equivalent amounts of methionine, glycine and arginine involved in the obligatory synthesis of creatine (Narayanan and Appelton, 1980) which is subsequently lost in the urine as creatinine. Creatinine excretion was measured experimentally.

Using data obtained as above, the coefficient (M) of protein required for maintenance by the turkey was calculated to be 31.9mg/g $W^{2/3}$ per day. Using a lysine content similar to that of feather protein (24mg/g protein) the equation indicates a lysine requirement of 76.6mg/kg $W^{2/3}$ per day. The Edinburgh model used a value for lysine requirement directly related to body weight i.e. 69mg/kg W per day. The two models therefore use a similar prediction for lysine requirement in the body weight range 1.3 to 1.5kg. As the body weight increases thereafter the Israel model predicts progressively less lysine required by kg W per day. At 10kg body weight, the Israel model predicts a lysine requirement for maintenance which is almost half the figure used in the Edinburgh model.

THE REQUIREMENT FOR WEIGHT GAIN

The Edinburgh model calculations are based on the assumption that the protein content of weight gain will depend on the degree of maturity. The following formula is used to calculate the protein content of the gain:

$dP/dW = d\mathring{p}/d\mathring{w}.u^{p}$

where dP/dW = protein gain/body-weight gain

$d\mathring{p}/d\mathring{w}$ = dP/dW at maturity

u = degree of maturity = W_t/A

where W_t = body weight W at time t and

A = mature body weight

p = a constant

A value of 240g protein/kg is suggested for maturity and 0.06 for the constant p. These figures give whole body (including feathers) protein of 170, 215 and 234g/kg at 0 and about 56 and 140 days. Fisher and Emmans (1983) suggested that each gram of protein growth (dP/dt) requires 86mg dietary lysine. Analysis of whole turkey bodies (Fisher and Scougall, 1982) has shown that the mixed protein contains 54.9mg lysine per g. An efficiency of utilisation of 64% was assumed giving a calculated requirement of 54.9/64 = 86mg dietary lysine for each gram of protein growth.

The Israel model does not use any term for total biological utilisation but contains a term for the efficiency of intestinal absorption, which is a function of the digestibility of the protein. The efficiency of absorption is taken as 85% (Hurwitz et al, 1979). There is therefore no efficiency term for utilisation of absorbed amino acids and if all other calculations were similar the Israel model would arrive at a dietary lysine requirement considerably lower than the Edinburgh model because it assumes 85% of dietary lysine is utilised for body lysine whereas the Edinburgh model assumes only 64%.

To calculate the protein requirement for weight gain in the Israel model, the protein content of the turkey at various ages was first measured. To do this birds were killed at various ages and their weight distribution in terms of carcass, viscera and feathers was then determined. Protein deposition in the tissues and in the body can then be calculated.

Hurwitz et al (1983) stated that "the result of this calculation did not show any consistent changes in protein composition with age nor any consistent differences between sexes". From examining the data presented in the paper, this surprising statement does not appear to be correct. The stages made in the examination were as follows:

Stage 1 - The body composition in terms of body weight, carcass weight, viscera weight and feather weight at various ages (Table 13).

TABLE 13	BODY COMPOSITION OF B.U.T MALE TURKEYS AS CALCULATED FROM HURWITZ ET AL (1983) TABLES 2 AND 8				
AGE (DAYS)	ITEM	BODY WEIGHT (g)	CARCASS (g)	VISCERA (g)	FEATHERS (g)
8	g/kg body		765	210	25
	weight (g)	151	115	32	4
15	g/kg body		754	216	30
	weight (g)	338	255	73	10
23	g/kg body		763	206	31
	weight (g)	628	480	129	19
37	g/kg body		796	161	43
	weight (g)	1499	1194	241	64
51	g/kg body		808	143	49
	weight (g)	2755	2227	394	134
72	g/kg body		823	126	51
	weight (g)	5195	4275	655	265
99	g/kg body		844	105	51
	weight (g)	8052	6797	845	410
133	g/kg body		876	79	45
	weight (g)	12262	10741	969	552
154	g/kg body		858	102	40
	weight (g)	14200	12184	1448	568
168	g/kg body		876	87	37
	weight (g)	15270	13377	1328	565

Stage 2 - The protein content (g) of the carcass, viscera and feathers at various ages (Table 14).

TABLE 14 — PROTEIN CONTENT OF THE CARCASS, VISCERA AND FEATHERS OF B.U.T MALE TURKEYS AS CALCULATED FROM HURWITZ ET AL (1983) USING TABLES 2, 3 AND 8

	CARCASS			VISCERA			FEATHERS		
AGE (DAYS)	WEIGHT (g)	g PROTEIN/kg	PROTEIN (g)	WEIGHT (g)	g PROTEIN/kg	PROTEIN (g)	WEIGHT (g)	g PROTEIN/kg	PROTEIN (g)
8	116	192	22.2	32	208	6.6	4	870	3.3
15	255	187	47.7	73	186	13.6	10	871	8.8
23	480	187	89.8	129	178	23.0	19	875	17.0
37	1194	207	247.0	241	166	40.1	64	879	56.7
51	2227	200	445.2	394	179	70.5	134	884	118.3
72	4276	222	949.2	655	170	111.3	265	890	235.8
99	6797	228	1549.5	845	179	151.3	410	895	367.5
133	10741	202	2169.8	969	174	168.6	552	895	793.9
154	12184	210	2558.6	1448	157	227.4	568	892	506.7
168	13377	206	2755.8	1328	144	191.3	565	888	501.7

Stage 3 - The protein content as a proportion of the body weight (Table 15).

TABLE 15 CALCULATION OF THE PROTEIN CONTENT (g/kg) OF THE BODY OF B.U.T MALE TURKEYS AS CALCULATED FROM TABLES 2,3 AND 8 OF HURWITZ ET AL (1983)

AGE (DAYS)	WEIGHT (g)	CARCASS PROTEIN (g)	VISCERA PROTEIN (g)	FEATHER PROTEIN (g)	TOTAL PROTEIN (G)	g PROTEIN PER kg WEIGHT
8	151	22.2	6.6	3.3	32.1	213
15	338	47.7	13.6	8.8	70.1	207
23	628	89.6	23.0	17.0	129.6	206
37	1499	247.0	40.1	56.7	343.8	229
51	2755	445.2	70.5	119.3	635.0	230
72	5195	949.2	111.4	235.8	1296.3	250
99	8051	1549.5	151.3	367.5	2068.3	257
133	12262	2169.8	168.6	493.9	2832.3	231
154	14200	2558.6	227.4	506.7	3292.7	232
168	15270	2755.6	191.3	501.7	3448.6	226

Stage 4 - The protein content of the body-weight gain (Table 16).

TABLE 16 CALCULATION OF THE PROTEIN CONTENT OF THE BODY WEIGHT GAIN (g/kg) OF B.U.T MALE TURKEYS AS CALCULATED FROM TABLES 2, 3 AND 8 OF HURWITZ ET AL (1983)

AGE (DAYS)	BODY WEIGHT GAIN (g)	CARCASS PROTEIN GAIN (g)	VISCERA PROTEIN GAIN (g)	FEATHER PROTEIN GAIN (g)	TOTAL PROTEIN GAIN (G)	g PROTEIN PER kg WEIGHT GAIN
8-15	187	25.5	7.0	5.5	38.0	203
15-23	290	41.9	9.5	8.2	59.6	206
23-37	871	157.4	17.0	39.6	214.0	246
37-51	1256	198.2	30.5	62.7	291.4	232
51-72	2440	504.0	40.8	116.5	661.3	271
72-99	2856	600.0	40.1	131.7	771.8	270
99-133	4211	620.6	17.2	126.3	764.1	181
133-154	1938	388.9	59.9	12.8	460.6	238
154-168	1070	196.9	-36.1	-4.9	155.9	146

In the Israel model, a constant average coefficient of 0.1977 of crude protein in the weight gain was used. According to Table 16, this coefficient will underestimate the protein content of the gain between 23 and 99 days and tend to overestimate the protein content of the gain after 99 days for male turkeys based on the data from which the coefficient was derived. Body weight data for females are not given in the paper so the correctness of the coefficient for calculating the requirement for females cannot be assessed. As fat is laid down earlier in the female (Table 4 of Hurwitz et al, 1983) the protein content of gain is likely to decrease at an earlier age for the female than for the male. To correct for the changing protein content of the weight gain with age, a different coefficient is required for each age period. Alternatively the protein contents of the components at each age can be used to compute the protein content of the gain. This latter method is now being incorporated in the Israel model (Hurwitz, personal communication).

Despite the apparent error, subsequent experiments were found to validate the Israel model (Hurwitz, Plavnik, Bengal, Talpaz and Bartov 1983). This is probably because the method used to vary lysine dose was the addition of synthetic lysine to a lysine deficient basal diet. Another amino acid may have become deficient at the higher lysine doses giving a spuriously low estimate of lysine requirement, consistent with low estimates of protein growth.

In the Edinburgh model the protein content of the body is calculated by a theoretical formula related to the degree of maturity of the turkey. In the Israel model, the protein content of the body is calculated from actual analysis at various ages. A comparison of the values given for protein content is shown in Table 17.

TABLE 17	A COMPARISON OF THE TOTAL PROTEIN CONTENT (g/kg) OF BODY WEIGHT USED IN THE ISRAEL AND EDINBURGH MODELS	
AGE (DAYS)	ISRAEL MODEL	EDINBURGH MODEL
37	229.3	206.4
51	230.5	213.0
72	249.5	220.9
99	256.8	227.8
133	231.0	233.1
154	231.9	235.1
168	225.8	236.1

The assumption in the Edinburgh model of a gradual increase in whole body protein content from day old to maturity would not appear to be correct. It is not clear why this was assumed since animals deposit more fat as they mature. The proportion of protein in the mature turkey would therefore be expected to be lower than that of a slightly less mature bird which had not deposited as much fat.

To predict the crude protein required for growth, the Israel model uses the following equations:

1) crude protein required for carcass growth (PRC) = $CP.\Delta W/0.85$

2) crude protein required for feather growth (PRF) = $FP.\Delta W/0.85$

where CP is the protein concentration in carcass gain (including muscle and viscera), FP is the protein concentration in the feather gain and ΔW is the rate of weight gain. As explained before, the net requirement is divided by 0.85, the coefficient of protein absorption in the young turkey (Hurwitz et al, 1979).

CALCULATION OF AMINO ACID REQUIREMENTS

In the Edinburgh model, the amino acids required for weight gain are presumed to be in the same proportions as found in analysis of whole turkey bodies, including feathers (Fisher and Scougall 1982). The analysis was only made at 28 and 56 days of age so the age effect has not been fully allowed for in the model. The Hurwitz model used the data from analysis of soft tissue gain and feather gain. The resulting sets of amino acid profiles do not show very much similarity (Table 18) numerically although there is close agreement if the amino acids are ranked in order of quantities required.

TABLE 18	A COMPARISON OF THE ISRAEL AND EDINBURGH MODEL AMINO ACID PROFILES FOR TURKEY WEIGHT GAIN (Amino Acid profile based on Lysine = 100)			
	28 days		56 days	
	ISRAEL	EDINBURGH	ISRAEL	EDINBURGH
Arginine	98	121	101	117
Histidine	38	44	38	35
Lysine	100	100	100	100
Phe + Tyr	107	130	111	134
Methionine	34	38	34	33
Met + Cys	54	64	60	63
Threonine	65	72	67	71
Leucine	125	134	128	126
Isoleucine	63	72	66	71
Valine	81	89	85	89

The differences between the ages are relatively small in both sets of data. Perhaps this should not be too surprising as feather protein represents less than 20 per cent of the total protein at any age Hurwitz et al (1983) and the amount of feather protein relative to carcass and viscera protein will be the main source of variation in amino acid ratios with age.

The amino acid requirement expressed as g/d is calculated from the amount of protein in the daily gain and the percentage of the amino acid in the protein gained.

CALCULATION OF METABOLIZABLE ENERGY REQUIREMENTS

The protein and amino acid requirements calculated above on the basis of mass/time (i.e. g/d) must be converted into proportions of the diet for formulation purposes. For this the food intake must be calculated. Since "food" may vary, metabolizable energy intake is a more unifying expression and amino acid requirements can be expressed as g amino acid per MJ ME.

The food intake is determined by a number of factors, which are themselves not clearly defined, so the food intake prediction of any model is likely to be complicated and also to contain the greatest error.

In the simplest situation where the turkeys are at thermoneutrality receiving a diet which allows minimum fat growth, the intake of which is not limited by bulk, the Edinburgh model states that the birds will have a voluntary ME intake (dME/dt,kJ/d) of:

$$dME/dt = M.W_t + g.u.^{0.08}.dW/dt$$

M, kJ/kg day = maintenance requirement = $600A^{0.73}/A$.

A, kg = body weight at maturity

W_t, kg = body weight W at time t

g, kJ/g = growth requirement,

u = degree of maturity = W_t/A

dW/dt = body-weight gain per day at time t

Where the turkeys are not at thermoneutrality, the situation is much more complex and the full facilities of the Edinburgh model are required to obtain reasonable predictions. The designers of the Edinburgh model admit that in practice it might be just as accurate to predict food intake on the basis of experience of a given strain on a given farm (Fisher and Emmans, 1983) provided food wastage is not included.

In the Israel model, the energy requirements are predicted by the following equations:

(1) $EC = M.W^{2/3} + D.\Delta W$

(2) $M = f(T)$

(3) $D = 0.6 + 9.3\ F$

where EC is the metabolizable energy intake (kcal/d); W is the average body weight (g) for the period; ΔW is weight gain (g/d); M is the metabolizable energy requirement for maintenance (kcal/g d); D is the metabolizable energy requirement for weight gain (kcal/g); T is the environmental temperature in °C; and F is the lipid fraction in the body weight gained per day.

f values for M were determined experimentally at various temperatures by Hurwitz, Weiselberg, Eisner, Bartov, Riesenfield, Sharvit, Niv and Bornstein (1980). As an example at 12°C the requirement was 2.70kcal/$g^{2/3}$. For the weight gain calculation, observed lipid contents of the birds at various ages were determined experimentally and used in equation 3 above. These values might vary among strains at any age. The lipid variation in the males examined by Hurwitz et al (1983) has been calculated for the various age periods (Table 19).

TABLE 19	THE VARIATION IN LIPID GAIN WITH AGE IN MALE TURKEYS (HURWITZ ET AL 1983)
AGE (DAYS)	LIPID (g/kg) OF BODY WEIGHT GAIN
8-22	12
22-71	22
71-99	76
99-134	209

THE CALCULATED REQUIREMENTS

As argued earlier the optimum method of stating lysine requirements is in terms of g lysine per MJ ME. The requirements decrease with age. It is usual to state the requirements for 4-week periods. In Table 20 the calculated requirements obtained by the Edinburgh model and the Israel model are compared with the range of requirements indicated by empirical experimentation shown in Tables 5 to 10.

Fisher and Emmans (1983) stated that the expressions used in the Edinburgh model give unrealistic estimates of growth and food intake prior to 4 weeks of age. The calculated lysine requirement for the Edinburgh model for 4 to 8 weeks is noticeably smaller and outside the range of requirements obtained by empirical experimentation. Thereafter the calculated requirements fall within the range indicated experimentally, with a trend towards the calculated requirements falling nearer the high limit of the experimental range of requirements as the turkeys become older.

TABLE 20	THE LYSINE REQUIREMENTS OF LARGE MALE TURKEYS (g LYSINE/MJ ME)		
AGE (WEEKS)	CALCULATED REQUIREMENTS		RANGE IN REQUIREMENTS INDICATED BY EMPIRICAL EXPERIMENTATION (SEE TABLES 5 - 10)
	1 EDINBURGH MODEL	2 ISRAEL MODEL	
0-4	NA	1.210	1.135 - 1.328
4-8	0.990	0.925	1.219 - 1.264
8-12	0.887	0.646	0.729 - 1.105
12-16	0.775	0.485	0.646 - 0.978
16-20	0.660	0.363	0.478 - 0.717
20-24	0.552	NA	0.470 - 0.569

NA - not available (see text)

With the exception of the 0-4 week calculated requirements, the Israel model suggests requirements that are noticeably lower than those within the range indicated by empirical experimentation. The Israel model does not show calculated values beyond 21 weeks. As noted, the Israel model used a method for predicting the lysine required for maintenance which predicts progressively less lysine than the Edinburgh model for this purpose as body weight increases. In addition the Israel model assumes 85% of dietary lysine is utilised for body lysine whereas the Edinburgh model presumes only 64% utilisation.

On the available empirical experimental evidence, it would appear that the Edinburgh model arrives at a better prediction of the lysine requirements at the older ages than does the Israel model. The fact that the Israel model has been validated by empirical experiments (Hurwitz et al 1983) can be explained by the method of validation. The method of varying the lysine dose was by the addition of synthetic lysine doses probably giving a spuriously low estimate of lysine requirement.

AN ALTERNATIVE METHOD OF CALCULATING LYSINE REQUIREMENT

An alternative method to the complete model approach of assessing the requirement for lysine or any amino acid is to analyse the acceptable published data to produce a predictive equation for input of amino acid and subsequent weight gain.

A suitable flock response model, known as the Reading model, was developed originally for description of output responses in laying hens (Fisher et al, 1973, Curnow, 1973) but has since been considered plausible for the growing bird (Clark, Gous and Morris 1982, Fisher and Emmans 1983). The Reading model will produce a best fit line to the data available, taking into account the curvilinear effect seen near the plateau, already described on page 10. The mean lysine requirement for a defined weight gain can then be calculated. In a situation where the most economic weight gain is less than the maximum growth rate the flock is genetically capable of producing, the optimum economic lysine intake level can be calculated from the cost of a unit of lysine and the value of the expected weight gain resulting from that lysine input.

The Reading model calculates the optimum dose of amino acid using the following equation:-

$$AA1(oPT) = \underline{a}\Delta w + \underline{b}w + x\sqrt{\underline{a}^2\sigma_{\Delta w}^{\ 2} + \underline{b}^2\sigma_w^{\ 2} + 2\underline{a}\underline{b}.r.\sigma_{\Delta w}.\sigma_w}$$

where AA1(oPT) = amino acid dose which equates marginal costs and marginal income

ΔW = body-weight gain

W = mean body weight

$\underline{a}$ = amino acid (g) per kg ΔW

$\underline{b}$ = amino acid (g) to maintain kg W x = the deviation from the mean of a standard normal distribution which is exceeded with probability ak in one tail; a being defined as above, k being the ratio of cost per g amino acid/value per kg W

σ = standard deviation of ΔW and W

r = correlation between ΔW and W

The use of the Reading model to describe published data results for lysine intake and weight gain at one age range presumes that common a and b values can be used to describe turkeys of different sex and strain, kept under different conditions. The fact that the maximum weight gains achieved and mean body weights will vary between experiments is accommodated by the fact that the model is seen as describing the data in the form of a common slope 1/a at limiting intakes of lysine, with a series of intercepts related to a common value of b and a series of parallel asymptotes related to the maximum weight gains achieved in the experiments (see Figure 6 on page 12).

The Reading model can be used to analyse previously published work on the lysine requirements of the turkey, provided there are sufficient data in the paper to supply the parameters required by the model. An analysis of suitable data has been carried out and is reported in this section.

The Reading model is most accurate if the weight gain is described in terms of protein gain. None of the experiments reviewed provided this information. Since the proportion of protein in the weight gain decreases conversely as the fat content increases, it might be expected that the value for a would change with age when calculated for body weight alone.

The parameters of the model used in this analysis were as follows:

Mean body weight of flock (W)

$$W=\frac{Wo+\frac{1}{2}(W1+W2)}{2}$$

Where W_o is starting weight, W1 is final weight of birds achieving highest weight gain and W2 is final weight of birds achieving lowest weight gain.

Correlation between W and ΔW (r) = 0.8

Variance in body weight (σ^2W) = 0.1W

Variance in gain ($\sigma^2\Delta$W) = 0.1ΔW

The above are based on values from a paper by Boorman and Burgess (1986), who derived them from data from experiments with poultry. ΔW is the mean of all growth rates for each separate data set. The original Reading model was designed for predicting egg output (Fisher et al, 1973) and used a variance figure based on the maximum egg output. However in growth trials, the differences seen in one response experiment between deficient and adequate treatments are often of a much larger magnitude than seen in egg output experiments, with the maximum growth rate sometimes being as much as four times greater than the lowest. In such a situation, to have based the variance on a proportion of the maximum growth rate would therefore imply a variance four times greater for the slowest growth rate. In the author's experience, in a flock achieving good growth rates the variance could be expected to be less than 10% of the mean growth rate whereas in a flock achieving poor growth rates, the variance may exceed 10% of the mean growth rate. It was felt therefore that the estimate of variance in gain would have more validity if it was based on the mean of all growth rates in each separate data set. To test the influence of using different methods of estimating $\sigma\Delta$W, both methods of estimating the variance were applied to the suitable data. Using the lower value based on the mean of all growth rates as opposed to the maximum growth rate had the effect of lowering the estimated maximum gain by less than 0.1%, increasing the a value by 1.7% and decreasing the b value by 16%. The apparent large change in the b value from which the maintenance requirement is calculated, is of little significance for the young turkey where maintenance requirement for lysine represents less than 5% of the total lysine required. However it is of more significance for the large turkey where, for example, the maintenance requirement for lysine of a 10kg turkey may represent 20% of its total requirement. As was explained earlier, a variance expressed as a proportion of the maximum growth rate will imply a very much greater variance for the slower growth rates. In view of this the variance in gain estimate based on the mean of all growth rates would appear to be more accurate than a value based on the maximum gain and has been used in the following analysis.

Data sources. Data have been analysed from reports which showed suitable response to lysine. A suitable response was defined as comprising the essentially linear phase at limiting intakes of lysine and the plateau or asymptote at maximum response. These criteria excluded experiments in which four or less concentrations of lysine had been used and which therefore failed to define one or other of the two phases adequately. Several of the published papers on lysine failed to include either sufficient information to allow calculation of food consumption, and hence lysine consumption, for the period or initial starting weight (W_0) necessary to calculate W. It has been possible to obtain these data for some experiments by personal correspondence.

The lysine intakes used were calculated from the concentrations stated by the authors. It has not been possible to recalculate the contents on the basis of a standard ingredient data base because of insufficient description of some of the ingredients used. The lysine values are total lysine values and no attempt has been made to correct for digestibility or availability.

Data sets. The data sets deemed suitable and their analysis by the Reading model are summarised in Table 21. It will be seen that less than half of the papers reviewed in

Chapter 1 (Tables 4 to 9) have proved suitable for analysis. The twenty-three suitable data sets have been contributed by only five of the fourteen papers reviewed in Chapter 1.

TABLE 21	READING MODEL ANALYSIS OF SUITABLE DATA SETS TO PREDICT THE LYSINE REPONSE OF TURKEYS					
SET[1]	AGE RANGE (d)	SEX[2]	W[3]	ΔW (g/bird.d)	a[4]	b[4] (x10[3])
1	1-28	M	301	23.21	25.26	22.6
2	7-21	M	286	29.56	19.38	23.0
3	1-42	B	555	25.56	23.55	83.5
4	7-28	B	273	20.14	18.99	4.8
5	28-56	M	1388	61.13	21.02	32.0
6	28-56	M	1213	76.64	19.25	8.5
7	28-56	M	1592	87.00	19.47	11.1
8	28-56	F	1004	60.65	18.99	14.5
9	28-56	F	1261	67.17	18.76	8.6
10	42-84	B	1998	55.70	24.53	24.2
11	56-84	M	2470	94.19	15.32	45.8
12	56-84	M	3635	102.04	21.81	5.4
13[5]	56-84	M	3805	107.07	21.69	10.9
14[6]	56-84	M	3715	103.07	20.97	7.4
15[7]	56-84	M	4313	117.86	23.56	7.3
16[8]	56-84	M	4120	107.61	21.37	43.8
17[9]	56-84	M	4028	98.02	23.42	14.7
18	56-84	F	2859	75.29	19.21	18.7
19[10]	112-140	M	9948	128.57	22.88	10.0
20[11]	112-140	M	9655	107.68	24.77	8.3
21[12]	112-140	M	10888	153.00	22.93	10.2
22[13]	112-140	M	10800	143.64	21.19	12.1
23[14]	112-140	M	10548	128.11	23.02	12.1

1
1,5,11: Tuttle and Balloun (1974); 2; D'Mello and Emmans (1975); 3,10: Balloun and Philips (1957); 4,6,7,8,9,12,18: Fisher (1984); 13,14,15,16,17,19,20,21,22,23: Noll and Waibel (1982).

2
M: Male, F: Female, B: Both sexes

3
From initial weight and maximum and minimum final weights as described in text (σ^2W taken as 0.1W).

4
a = amino acid (g) per kgΔW b = amino acid (g) to maintain kg W

Generated from the fitted response in each case.

5 6.1°C Treatment
6 23.3°C "
7 7.4°C "
8 20.1°C "
9 26.4°C "
10 8.0°C "
11 23.7°C "
12 7.2°C "
13 15.5°C "
14 24.3°C "

The flock response model was originally developed for use in conjunction with the dietary dilution procedure (Fisher and Morris, 1970) for producing a response. This procedure was used to produce only seven data sets (sets 4,6,7,8,9,12 and 18). The other responses were obtained with the traditional procedure, in which different lysine inputs are produced by additions of lysine to a basal diet limiting in lysine. On the limited data available, there is no indication that the two procedures produced different response curves, resulting in different estimates of a and b.

There are insufficient data sources at each age period to attempt to draw any conclusions on the effect of age. Most of the data refer to males, with only three data sets referring specifically to females so no view on the sex effect is possible, although results from females do indicate lower a values. It is encouraging that there is some agreement in the values for a although the values for b vary greatly between experiments.

The Reading model can also be used to predict from the data of an experiment, the least quantity of lysine per bird day required to produce the maximum growth rate attained by that strain and sex for that age period in that situation. As the ME content of the diets is known, the ratio of lysine to ME (g/MJ) required in the diet to provide that quantity of lysine can then be assessed. Applying this technique to the suitable experiments in the literature, the assessed requirement is often noticeably different from that found by the authors of the experiments. (Table 22). This difference is particularly evident at the older ages. This is usually a consequence of the author using the "broken line" method of determining the requirement point. As already discussed, this will underestimate the requirement as it fails to take into account the curve or "diminishing returns" zone near the plateau.

TABLE 22		A COMPARISON OF ALTERNATIVE METHODS OF ASSESSING THE LYSINE REQUIREMENT USING IDENTICAL EXPERIMENTAL DATA		
SET[1]	AGE RANGE (d)	SEX[2]	LYSINE REQUIREMENT AUTHOR'S ASSESSMENT	(g LYSINE/MJ ME) READING MODEL ANALYSIS
1	1-28	M	1.328	1.227
2	7-21	M	1.230	1.278
3	1-42	B	1.484	1.398
4	7-28	B	NA[3]	1.338
MEAN			1.347	1.301
5	28-56	M	1.219	1.281
6	28-56	M	NA[3]	1.280
7	28-56	M	NA[3]	1.280
8	28-56	F	NA[3]	1.171
9	28-56	F	NA[3]	1.200
MEAN			1.219	1.281
10	42-84	B	1.130	1.103
11	56-84	M	1.110	1.088
12	56-84	M	NA[3]	1.034
13	56-84	M	0.765	0.911
14	56-84	M	0.837	0.950
15	56-84	M	0.736	1.006
16	56-84	M	0.729	0.956
17	56-84	M	0.826	0.897
18	56-84	F	NA[3]	0.774
MEAN			0.876	0.987
19	112-140	M	0.478	0.562
20	112-140	M	0.550	0.648
21	112-140	M	0.499	0.617
22	112-140	M	0.485	0.605
23	112-140	M	0.533	0.657
MEAN			0.509	0.618

1 - 1, 5, 11: Tuttle and Balloun (1974); 2: D'Mello and Emmans (1975); 3, 10: Balloun and Philips (1957); 4, 6, 7, 8, 9, 12, 18: Fisher (1984); 13, 14, 15, 16, 17, 19, 20, 21, 22, 23: Noll and Waibel (1982)

2 - M: Male, F: Female B: Both sexes.

3 - NA: Assessment not available as obtained by personal correspondence before publication of research work.

A COMPARISON OF THE PREDICTIONS OF THE THREE MODELS

As has been explained the three models, the Edinburgh, the Israel and the Reading, have different methods of arriving at estimates for the lysine requirements for maintenance and weight gain. The Edinburgh model, the authors state, is not suitable at ages younger than 4 weeks so a comparison has been made of the three models' predictions for three age periods, i.e. 28-56 days, 56-84 days and 112-140 days. A turkey with the same growth pattern as described in the Israel model (see table 13) was used for the comparison. The model predictions are shown in Table 23.

TABLE 23	A COMPARISON OF THE EDINBURGH, ISRAEL AND READING MODELS' PREDICTIONS FOR LYSINE REQUIREMENTS		
	LYSINE REQUIREMENT (g/bird)		
1 28-56 DAYS			
ROLE OF LYSINE	EDINBURGH	ISRAEL	READING
MAINTENANCE	4.23	3.13	1.05
WEIGHT GAIN	47.14	43.62	49.72
TOTAL	51.37	49.45	50.47
2 56-84 DAYS			
MAINTENANCE	10.29	5.01	2.81
WEIGHT GAIN	63.84	59.15	67.06
TOTAL	74.13	64.16	69.87
3 112-140 DAYS			
MAINTENANCE	22.48	7.44	3.42
WEIGHT GAIN	70.24	62.33	76.78
TOTAL	92.72	69.77	80.20

There was a wide disparity in initial body weights and subsequent weight gains resulting from the genetic progress achieved over the period covered by the experiments reviewed in Table 21. The validity of a composite Reading model run with such data is suspect. Therefore, the Reading model predictions are based on a and b values which were the arithmetical means of the relevant age data for males reported in Table 21. The values were

AGE RANGE	a	b(X10³)
28 - 56	19.91	17.2
56 - 84	21.16	19.3
112 -140	22.96	10.5

Earlier in this chapter, criticisms and areas of difference were identified in both the Edinburgh and Israel models. For example the Israel model assumes that 85% of dietary lysine is utilised whereas the Edinburgh model is based on 64%. The assumption in the Edinburgh model of a gradual increase in whole body protein content from day old to maturity would not appear to be correct and will overestimate the protein requirements at the older ages. Taking such alterations into the calculations would have the effect of increasing the Israel model predictions and decreasing the Edinburgh model predictions. This would result in both predictions moving nearer to the prediction obtained by applying the Reading model predictions to existing suitable experimental data, which were intermediate between the predictions of the two other models. At the youngest age, 28-56 days there is good agreement between the three models in total requirement although the components of the totals may differ considerably. At all three ages the maintenance prediction from the Reading model was the lowest of the three and its weight gain prediction the highest. The Reading model predictions are based on very inadequate data which themselves show considerable variation in the b value, from which the maintenance requirement is calculated. The initial comparisons are therefore encouraging, indicating that if the experimental information is strengthened for various ages for both sexes and a comparison is made of different genetic potential growth rates, predictions from the Reading model can be used to assess turkey's lysine requirements in different situations relating to age and strain and different growth patterns.

A series of experiments was therefore conducted to provide lysine input data and resulting body weight output at various ages for both sexes and also comparisons involving birds with different growth potentials. These experiments are reported in the next chapter.

CHAPTER THREE

Experimental Section

EXPERIMENTAL TECHNIQUE

The experiments in this section were designed to provide lysine input and resulting body weight output data which could be analysed by the Reading model to provide predictions of the lysine response of turkeys.

The review of the literature showed that the available information is deficient in most areas. In an attempt to remedy the situation, two sets of experiments were carried out. The first set (experiments 1-11) investigated the influence of the age of the turkey between 0 and 20 weeks and differences between the sexes during this period on the lysine requirement. The second set of experiments (experiments 12 to 15) looked at the other two main influences on the lysine requirements, the bird's genetic potential for growth and its previous plane of nutrition and hence growth.

From the analysis of these results, it was hoped to be able to predict the lysine response in the situations met in normal commercial practice, where the turkeys may differ in respect of their sex, age, genetic potential for growth and previous plane of nutrition.

Materials and Methods

1) Housing

Experiments 1 and 2 were concerned with the brooding stage. They were conducted at the University of Nottingham, School of Agriculture, Sutton Bonington, Loughborough, Leicestershire. The turkey poults were housed in metal metabolism cages at 1 day of age in a windowless room with facilities for lighting, heating and ventilation.

Experiments 3 to 15 were carried out in an experimental house owned by British United Turkeys Ltd at Kinnerton Turkey Farm, Kinnerton, Clwyd. The house, windowless with a concrete floor, consisted of four experimental rooms with an ante-room used to store the experimental diets. Each room contained 24 pens, each of 0.84 m^2 (96 pens in total). The pens were constructed of galvanised weld-mesh steel standing 0.91 m high with a weld-mesh lid which could be opened to give access to the turkeys. Around the base of the sides of each pen, there was a 15 cm galvanised sheet which enclosed the wood shavings used as litter.

In experiments 3 and 4, which involved 4 to 7 week old turkeys, a hanging tubular plastic feeder was placed in each pen. In subsequent experiments which involved older birds, the feed was placed in plastic trough on the outside of the front of each pen, birds having access to the feed through holes cut in the weld-mesh front. The feeding troughs could be removed easily for weighing. Adjoining pens shared a water trough which was also placed outside the pen.

Rooms 1 and 4 had different dimensions to those of rooms 2 and 3. This necessitated different pen layouts within the two types of room. As the temperature and conditions in pens situated on outside walls could be expected to be different from those in the middle of the room, the pens of a room were divided into three blocks when allocating experimental treatments, to try to accommodate each of the biases.

The house was naturally ventilated with air entering via the ante-room and exiting through air ducts in the centre of each room. The amount of air entering each room was adjusted by varying the extent to which the sliding door, which gave access to each room, was opened. Probably because of the low stocking rates within a room, the atmosphere and litter conditions within each room during the experiments were good both in winter and in summer.

In experiments 3 to 15, a 14 hour light period was used, light being provided from fluorescent tubes. In experiments 1 and 2, 23 hours light provided by 60w tungsten bulbs was given.

The water troughs were replenished by hand each day and periodically emptied and cleaned out. The experimental diets were weighed out by hand into plastic buckets before being tipped into the feed trough. In experiments 3 and 4, any food spilled was lost in the litter within the pen, but in subsequent experiments where the feed trough was outside the pen any food spilled was easily seen on the concrete floor. If there was a noticeable amount, it was collected and returned to the trough.

2) Experimental Diets

The disadvantages of using the graded supplementation technique to assess the response to lysine were discussed in Chapter 1.

The Reading model was designed to analyse data resulting from experiments which used the diet dilution technique developed by Fisher and Morris (1970). This technique makes the amino acid of interest limiting in the protein mix and then achieves different concentrations of the amino acid by dilution. In the experiments reported in this thesis, a modified version of the diet dilution technique was used. The classical dilution procedure involves using a protein-free basal or dilution mixture, which is used to dilute a 'summit' (high protein) mixture in various combinations. The formulation of this dilution mixture entails using unusual ingredients such as maize starch, pure cellulose and oat hulls, which are not normally fed to turkeys and the effect of which is largely unknown. As the turkey is especially susceptible to dietary disorders which result in diarrhoea, it was decided to use a basal mixture formulated from ingredients low in protein content, which are commonly used in commercial turkey diets.

The turkey's lysine requirements for maximum growth rate expressed as grams per kilogram of diet decreases markedly with age. Thus a diet deficient at one age may not be deficient at another. This is important because it is essential to produce a satisfactory response curve ("slope" and "plateau") at each age. Therefore one set of diets could not be used for all ages. The older birds demanded a lower range of lysine concentrations, while for the youngest birds (4 to 22 days), it was eventually found necessary to design a third series of diets, higher in lysine to clarify the response curve at the higher lysine intakes.

The compositions of the various summit and basal mixtures and their calculated analyses are shown in Appendix Tables 1, 2, 3, 4, 5, 6, 7 and 8. The vitamin and mineral mixture which was common to all mixtures is shown in Appendix Table 9.

In deciding on the required amino acid levels of the mixtures, a theoretical ideal amino acid pattern was first estimated. To do this, the requirements for each amino acid as indicated by National Research Council of the U.S.A. (N.R.C., 1977), the Canadian Department of Agriculture (Summers and Leeson, 1976), the Agricultural Research Council of the U.K. (A.R.C., 1975) and Nottingham University (unpublished) were averaged. These requirement arrays are shown in Appendix Table 10. For each array, requirements for amino acids other than lysine were expressed as a percentage of the lysine requirement to derive an amino acid pattern in which lysine was designated 100. The arrays were then averaged for each amino acid to produce the "ideal" amino acid pattern.

The experimental diets containing a range of lysine levels were obtained by first formulating a mixture (the summit mixture) of high lysine concentration and a mixture of low lysine concentration (the basal mixture). The range of lysine concentrations was then obtained by different combinations of summit and basal mixtures. The lysine concentration of the summit mixture was set to be a level which should on available evidence be in excess of requirements and so on the "plateau" part of the response curve. The lysine concentration of the basal mixture was set to be sufficiently below the turkey's requirements to enable the response of more than half the range of lysine concentration to fall on the "slope" part of the response curve. Both the summit and basal mixtures could be used as diets in a range as well as for producing intermediate lysine concentrations by mixing.

To ensure that lysine was the limiting amino acid in the ingredient mixture used and that the response was therefore to lysine, having first decided upon the lysine concentrations of the summit and basal mixtures, the minimum levels of the other essential amino acids were derived by calculating the "ideal" amino acid pattern for that mixture with the lysine concentration being designated 100. The minimum levels of the other essential amino acids were then set by multiplying the concentrations indicated from their respective concentrations in the "ideal" amino acid pattern by 1.3. This should have ensured that lysine was the most deficient (first limiting) amino acid in all diets and that the pattern of the other amino acids was similar in all diets of a particular range. However an excess of some amino acids over the recognised pattern was unavoidable. The summit and basal mixtures both contained much more protein than would be normal for their lysine concentrations. The excess of some amino acids over that required was kept to a minimum by arriving at the lowest protein content in the mixtures which would supply the minimum levels of the other essential amino acids required.

An additional diet was fed in each experiment in which synthetic or free lysine was added to one of the experimental diets so that its lysine concentration was equivalent to that of the next diet in the series. The diet chosen for supplementation was one which was expected to be on the "slope" of the response curve so that the limiting nature of lysine could be verified by a growth response. As the synthetic or free lysine was added to the diet to verify that the growth response seen was due to lysine contained in natural ingredients, it was thought necessary to give synthetic lysine an equivalent potency which took into account that the lysine in synthetic lysine is fully absorbed at the intestinal level whereas the lysine in natural ingredients is not (Larbier, 1979).

While pure L-lysine hydrochloride contains 800g lysine/kg, the commercial product contains impurities, mainly moisture, with the result that the minimum guaranteed L-lysine in commercial synthetic lysine HCl is 784.4/g/kg.There is variation in the proportion of lysine in natural ingredients which is absorbed at the intestinal level, depending on the ingredient and the age of the animal (Robel and Frobish, 1977, Sauer, Kennelly, Aherne and

Cichon, 1981). An average absorbability of 870g/kg in natural ingredients has been assumed in this case. To correct for the higher absorption of synthetic lysine, the lysine content of synthetic lysine should be multiplied by a correction factor equal to the inverse function of the coefficient of lysine absorption from natural ingredients. If the coefficient of lysine absorption from natural ingredients is taken to be 0.87, this gives a correction factor of $1/0.87 = 1.149$ which, when applied to a lysine content of 784.4g/kg in synthetic lysine gives an equivalent total lysine to that in natural ingredients of 901g/kg. A value of 900g lysine/kg has been used for synthetic lysine HCl when calculating the lysine content of the diet containing synthetic lysine, to allow for the higher absorption of lysine relative to that in natural ingredients. This value is generally used in commercial practice.

All diets were of identical nutrient content other than the amino acids.

The experimental diets were fed in mash form for the starter experiment (4 to 22 days of age) and as 3 mm pellets in the other experiments.

The details of the proportions of summit and basal mixtures used in each experiment and their resulting lysine concentrations will be given when each experiment is described in detail. All the diets were chemically analysed for protein, oil, calcium, phosphorus, manganese, salt and total lysine to ensure that the summit and basal diets had been mixed individually correctly, and then combined in the correct proportions. In addition the summit and basal diets were analysed for the main amino acids. The data are shown in Appendix Tables 6 and 8.

3. Statistical Analysis

For each experiment, an analysis of variance for a randomised block design was carried out on the data for body-weight gain, food intake, gain:food ratio, lysine intake and gain:lysine ratio.

The relevant data were then used for analysis by the Reading model. The dietary lysine requirement of the average individual in a flock can be expressed in terms of its mean body weight and its body-weight gain:

$$L = \underline{a}\,\Delta W + \underline{b}\,W$$

where L = lysine intake (g/d), ΔW is the body-weight gain (kg/d), W is the mean body weight (kg), a is the g lysine required per kg body-weight gain, and b is the g lysine required to maintain a kg of body weight for a day. From this simple model, Curnow (1973) and Fisher et al (1973) have produced a computer model which derives a curve representing a flock of individuals based on this average individual, provided that appropriate variances are given. Data may be fitted to the curve by the exact procedure (Fisher, et al, 1973) to generate values for a and b, given response data and estimates of standard deviations of body-weight gain ($\sigma\Delta W$,) body weight (σW) and the correlation between the two ($r\Delta W.W$)

This has come to be termed the Reading model. The exact method of fitting the curve, as described by Curnow (1973), was used to analyse the experiments reported in this section. In the analysis, the standard deviations for body-weight gain and the mean body weight used were those seen in each experiment. In the analysis of published data discussed in Chapter 2, the standard deviations used were $0.1\Delta W$ and $0.1W$. As previously (page 41 of this text), the mean body weight of a flock (W) was calculated from the equation below

$$W = \frac{Wo + \frac{1}{2}(W1 + W2)}{2}$$

where Wo is the starting weight, W1 is the final weight of birds achieving the highest weight gain and W2 is the final weight of birds achieving the lowest weight gain. The standard deviation for W was calculated as follows

$$\sigma W = \sigma Wo + ((W - Wo) \times CV/100)$$

where CV is the coefficient of variation of body-weight gain during the experiment. In most experiments, the birds chosen for the trial were selected to be much more uniform in body weight at the start of the experiment than those of an unselected flock. This was thought desirable because facilities only allowed the use of relatively few birds in each experiment and unnecessarily large variances would have reduced precision.

The correlation between gain and body weight was taken to be 0.8, which is the value used by Boorman and Burgess (1986) for chickens. In most of the experiments, data from all replicates were used in the Reading Model rather than the mean treatment values. Using the data from all replicates usually resulted in a Reading Model predicted input and output line that fitted the data better than that seen using only the treatment means. However, in a few analyses, the configuration of the data points at the lower input greatly influenced the slope of the response and caused a solution which clearly did not fit the rest of the data satisfactorily. In those instances, the treatment means were used. Unless otherwise stated in the text, data from replicates were used in the Reading Model analysis.

In what is termed the A run of the computer model, fitted values of the constants a̲ and b̲ are calculated together with ΔW_{MAX} the fitted maximum body-weight gain. These data together with W are then used in the B run of the computer model to calculate the expected body-weight gain for each increment of lysine intake over the range specified. The range specified should include the approach to and beyond the plateau section of the response curve. This procedure was carried out on data from each experiment.

EXPERIMENTAL SECTION A

THE INFLUENCE OF AGE AND SEX

This section reports experiments designed to investigate the influence of the age and sex of the turkey on its lysine requirements.

The most usual feed programme commercially involves changing diets every four week of life. In determining the lysine requirement at a stated age, it was felt that a four week experimental period would be too long as it would give the opportunity for some catch-up growth to take place in diets marginally deficient in lysine at the start of the experimental period. Conversely if the experimental period was very short, ie one or two weeks, the unavoidable error in the accuracy of weighting live turkeys on a spring balance graduated into 0.1kg units, would make the detection of differences and the assessment of their statistical significance more difficult. An experimental period of three weeks was therefore decided upon, at intervals over the normal twenty week growing period.

1. The Lysine Response of the Starting Turkey

It is normal to feed the young turkey a mash or crumb diet, often called pre-starter or starter, for the first three or four weeks of life. Although at this age, it is usual to rear the sexes together, or at least on the same diet, the response was assessed using the male as, being the faster growing sex, its lysine demands are likely to be greater. Experiments 1 and 2 were concerned with assessing the lysine response over the first three weeks of life.

Experiment 1

Objective

To describe the lysine response of the 4 to 22 day old male turkey.

Materials and Methods

Medium to heavy strain (BUT 6 Female Line Cross) male poults were used. They were placed in metal metabolism cages at 1 day of age in a windowless room with facilities for control of lighting and ventilation. The photoperiod was 23 hours a day and provided by 60w tungsten bulbs. The temperature was maintained at 35 ± 1 °C for the first 4 days, after which it was gradually decreased by about 1° per day to 27°C, after which it was maintained constant.

The turkey is hatched with remnants of the yolk sac remaining. This provides nutrients for the first few days of life. The experiment was therefore not started until 4 days of age. For the first four days, the birds were fed a standard turkey starter crumb diet containing 280g protein/kg and 11.96 MJ ME.

At 4 days of age, the birds were allocated to their experimental cages and diets. Only poults which appeared normal and were eating were used. Three birds were allocated to each cage and each of eight diets was fed to eight cages in a randomised complete-block design, so that a total of 192 birds was used. Any cages in which a bird died or was culled were omitted from the analysis and a missing plot technique was used in the statistical analysis. The birds were weighed at 4, 13 and 22 days of age. The food fed was recorded and weighed back at 13 and 22 days of age.

The eight diets fed were produced by combining summit mixture A with basal mixture A, details of which are shown in Appendix Tables 5, 6, 7 and 8, in differing proportions. These proportions and the resulting level of lysine were decided upon with the aim of exceeding the likely requirement with at least one diet but ensuring that at least three diets would be on the slope part of the response curve. The levels of lysine required were decided upon as a result of a review of the literature. The proportions of the summit and basal mixtures and the resulting level of lysine are shown in Appendix Table 1. Diets included one (Diet 8) with free lysine added to test for lysine deficiency. The addition was equivalent to the calculated difference in lysine content of adjacent diets of the dilution series.

Results

The mortality and culling during the experiment was 8 birds of the 192 started. In this experiment, the birds were not beak-trimmed because they were to be fed mash diets. This resulted in some pecking damage, some of which was severe enough to necessitate culling and which probably depressed body-weight gain in other individuals. This problem appeared to be random with respect to dietary treatment.

The mean body-weight gain, food intake, gain:food ratio, lysine intake and gain: lysine ratio data are shown in Tables 24 and 25.

TABLE 24 RESPONSE OF 0 TO 3-WEEK OLD MALE TURKEY POULTS TO LYSINE (EXPERIMENT 1)

1) 4 - 13 DAYS OF AGE

DIET NO	LYSINE CONCEN-TRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	19.00	18.21	22.89	0.7955	0.435	41.86
2	17.75	15.68	21.29	0.7365	0.378	41.18
3	16.50	15.80	20.98	0.7531	0.346	45.66
4	15.25	14.72	20.24	0.7273	0.309	47.64
5	14.00	11.94	17.30	0.6902	0.242	49.34
6	11.50	7.49	14.03	0.5339	0.161	46.52
7	9.00	4.88	12.20	0.4000	0.110	44.36
8	11.50	9.88	16.69	0.5921	0.192	51.46
SE		0.77	0.85	0.0224	0.013	1.73

THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 8 REPLICATES OF 3 BIRDS EACH

READING MODEL ANALYSIS

4-DAYS BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE /kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)
0.0855	0.137	18.80	21.31	0.0155

TABLE 25	RESPONSE OF 0 TO 3-WEEK-OLD MALE TURKEY POULTS TO LYSINE (EXPERIMENT 1)					
2) 4 - 22 DAYS OF AGE						
DIET NO	LYSINE CONCEN-TRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird.d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	19.00	21.73	31.54	0.6890	0.599	36.28
2	17.75	20.17	29.39	0.6863	0.522	38.64
3	16.50	20.13	29.09	0.6920	0.480	41.94
4	15.25	19.06	28.57	0.6671	0.436	43.72
5	14.00	16.96	25.79	0.6576	0.631	46.98
6	11.50	11.38	20.46	0.5562	0.235	48.43
7	9.00	6.79	15.72	0.4319	0.142	47.82
8	11.50	13.72	23.45	0.5851	0.270	50.81
SE		0.89	1.14	0.0164	0.018	1.25

THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 8 REPLICATES OF 3 BIRDS EACH

READING MODEL ANALYSIS

4-DAYS BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE /kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)
0.0855	0.214	21.30	21.41	0.0086

When the body-weight gain was plotted against lysine intake shown in Figures 9 and 10 (Appendix Tables 11 and 12), it was found that the added free lysine treatment (Diet 8 formulated as Diet 7 with 2.5g lysine added/kg) gave a result similar or even slightly higher, than that to be expected from the results of the other diets, indicating that lysine was indeed the first limiting amino acid even at the level achieved by the supplementation treatment. It will be seen from Figures 9 and 10 that there was a clear response to lysine.

The values for the coefficients and the estimate of maximum body-weight gain were obtained by processing the data in the A run of the Reading model as described in the Statistical Analysis section earlier in this chapter. The numbers obtained were then used in a B run of the Reading model to produce lysine input and body-weight gain output predictions. These are given in tabular form in Appendix Tables 11 and 12, and illustrated in Figures 9 and 10. It will be seen that the continuing upward trend in the data at intakes of 0.4 and more g lysine/bird d, when fitted to the model appears as variance around a plateau value of about 18.8 or 21.3g body-weight gain/bird d at 4 to 13 and 4 to 22 days

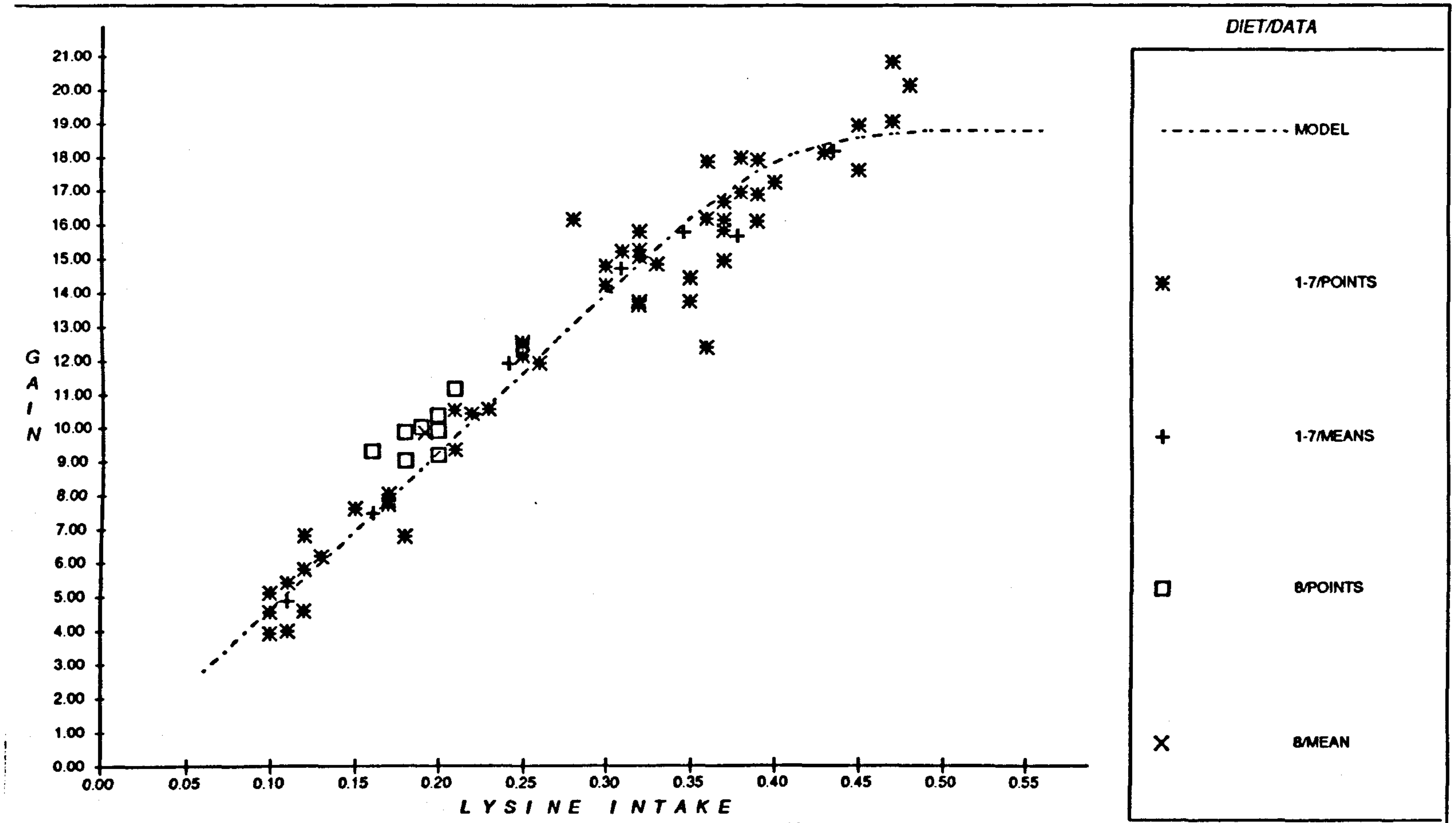

FIGURE 9. EXPERIMENT 1. 4 TO 13 DAYS,
LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

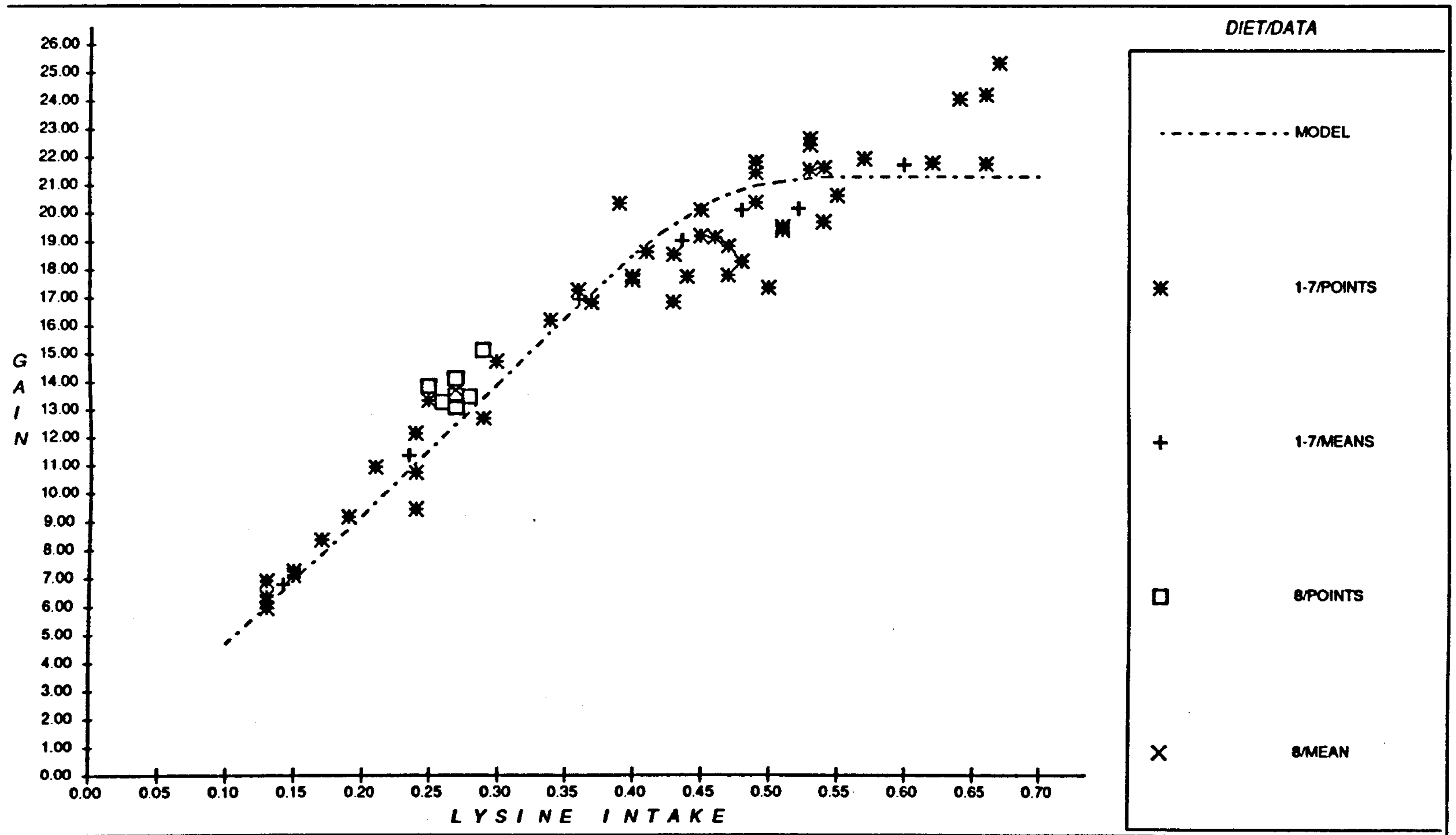

FIGURE 10. EXPERIMENT 1. 4 TO 22 DAYS,
LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

respectively. This is an interpretation due to the characteristics of the model used and it is not clear whether a plateau really was established. Clarification of this area of doubt is important to the interpretation of the requirement for maximum growth rate of the young turkey poult. It was decided therefore that a second experiment was required concentrating on the lysine inputs around the plateau of growth response.

Experiment 2

Objective

To clarify the response of the 4 to 22 day old turkey to the lysine inputs giving maximum or near maximum growth responses indicated by Experiment 1.

Materials and Methods

The same strain and sex of poults as those used in Experiment 1 were used in Experiment 2 (BUT 6 Female Line Cross Males). They were housed in the same metabolism cages at 1 day of age and given the same pre-experimental diet and management conditions as in Experiment 1, with the exception that in Experiment 2 the beaks of the poults were trimmed at the start of the trial (4 days of age) as it was felt that any problems with eating mash were preferable to pecking among birds.

The method of allocating birds to cages and diets and their numbers was the same as in Experiment 1. Any birds dying or culled were weighed and included in the total cage weight gain, which with the total food was used to calculate the gain:food ratio for the cage. This ratio was then used with the actual gain of the survivors at the end of the period to calculate the food eaten by the survivors. If two birds died in a cage, the cage was omitted and a missing plot technique used in the statistical analysis. The birds were weighed at 4, 13 and 22 days of age. The food fed was recorded and uneaten food weighed at 13 days and 22 days of age.

As the objective of the experiment was to clarify the situation at the higher lysine inputs, summit and basal mixtures with higher lysine concentrations had to be used. To extend the lysine intakes further past the point of any plateau, the lysine content of the summit mixture B was increased from 19.0g/kg (as in Experiment 1) to 20g/kg. To increase the number of data points around the area approaching the plateau entailed raising the lysine level of the basal mixture B from 4g/kg (as in Experiment 1) to 13g/kg. Details of each are shown in Appendix Tables 5, 6, 7 and 8. The proportions of each that were used and the resulting levels of lysine are shown in Appendix Table 2. In one diet (Diet 8), free lysine was added in the same way as previously to test for lysine deficiency in the dilution series.

Results

The beak trimming prevented the pecking damage seen in Experiment 1. However, the poults suffered an outbreak of turkey hepatosis or oedema disease with a peak in mortality at 9 and 10 days. During the experiment 25 birds out of 192 birds started, died or were culled. The cause of turkey hepatosis is not known. It has been suggested that high protein diets may be a factor involved. Although the pattern seen among treatments would suggest that there was no difference between the diets which varied in lysine and protein levels in the incidence of the disease, the level of protein even in the lowest diet was high by commercial standards. This could have predisposed birds on all diets in the experiment to hepatosis. The high levels of protein arose because of the need for the amino acids other than lysine to be at least 30% higher than requirements in order to ensure lysine deficiency.

The mean body-weight gain, food intake, gain:food ratio, lysine intake and gain:lysine ratio data are shown in Tables 26 and 27.

TABLE 26	RESPONSE OF 0 TO 3-WEEK-OLD MALE TURKEY POULTS TO LYSINE (EXPERIMENT 2)

2) 4 - 13 DAYS OF AGE

DIET NO	LYSINE CONCEN-TRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	20.00	16.66	22.03	0.7562	0.441	37.78
2	19.00	18.45	23.06	0.8001	0.438	42.12
3	17.75	16.59	21.81	0.7607	0.387	42.87
4	16.50	15.02	20.85	0.7204	0.344	43.66
5	15.25	16.50	21.63	0.7628	0.330	50.00
6	14.00	12.72	18.24	0.6974	0.255	49.88
7	13.00	11.77	18.28	0.6439	0.238	49.45
8	14.00	14.35	20.02	0.7168	0.280	51.25
SE		0.79	1.00	0.0229	0.016	1.49

THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 8 REPLICATES OF 3 BIRDS EACH

READING MODEL ANALYSIS

4-DAYS BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE /kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)
0.0930	0.161	17.90	20.97	0.0109

TABLE 27	RESPONSE OF 0 TO 3-WEEK OLD MALE TURKEY POULTS TO LYSINE (EXPERIMENT 2)					
2) 4 - 22 DAYS OF AGE						
DIET NO	LYSINE CONCEN-TRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	20.00	21.72	31.78	0.6834	0.636	34.15
2	19.00	23.28	33.28	0.6995	0.632	36.84
3	17.75	22.19	32.14	0.6904	0.571	38.86
4	16.50	20.86	31.12	0.6703	0.514	40.58
5	15.25	21.88	32.36	0.6782	0.492	44.47
6	14.00	18.43	27.91	0.6603	0.391	47.14
7	13.00	17.03	26.62	0.6397	0.346	49.22
8	14.00	20.90	30.67	0.6814	0.429	48.72
SE		1.09	1.50	0.0170	0.025	1.06
THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 8 REPLICATES OF 3 BIRDS EACH						
READING MODEL ANALYSIS						
4-DAYS BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE/ kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)		
0.0930	0.274	22.40	20.97	0.0047		

As will be seen in Figures 11 and 12 (Appendix Tables 13 and 14), the added free lysine diet gave a body-weight gain very similar to that which would have been expected from the prediction resulting from lysine intakes of the other diets, confirming that lysine was the first limiting amino acid in the experimental diets, to the extent of the full supplementation of the added free lysine.

The data were used in an A run of the Reading model to produce values for the constants a and b, together with an estimate of ΔW_{MAX} the maximum body-weight gain. These data together with W were then used in the B run of the Reading Model to produce lysine input and body-weight gain output predictions. These are given in tabular form in Appendix Tables 13 and 14 and illustrated in Figures 11 and 12.

The Reading model analysis of the two experiments indicated a close similarity in the results as summarised below (from Tables 24, 25, 26 and 27):

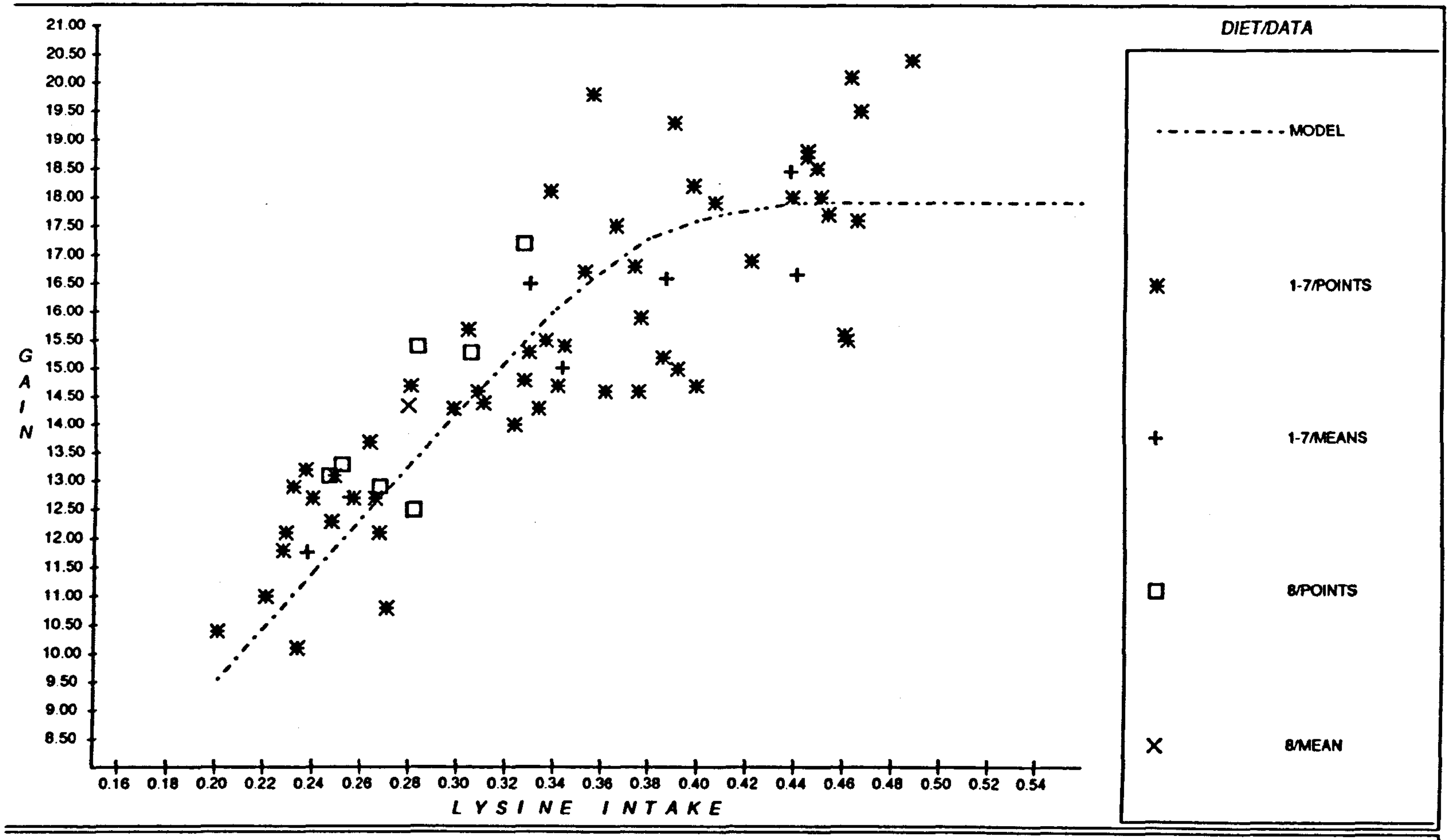

FIGURE 11. EXPERIMENT 2. 4 TO 13 DAYS,
LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

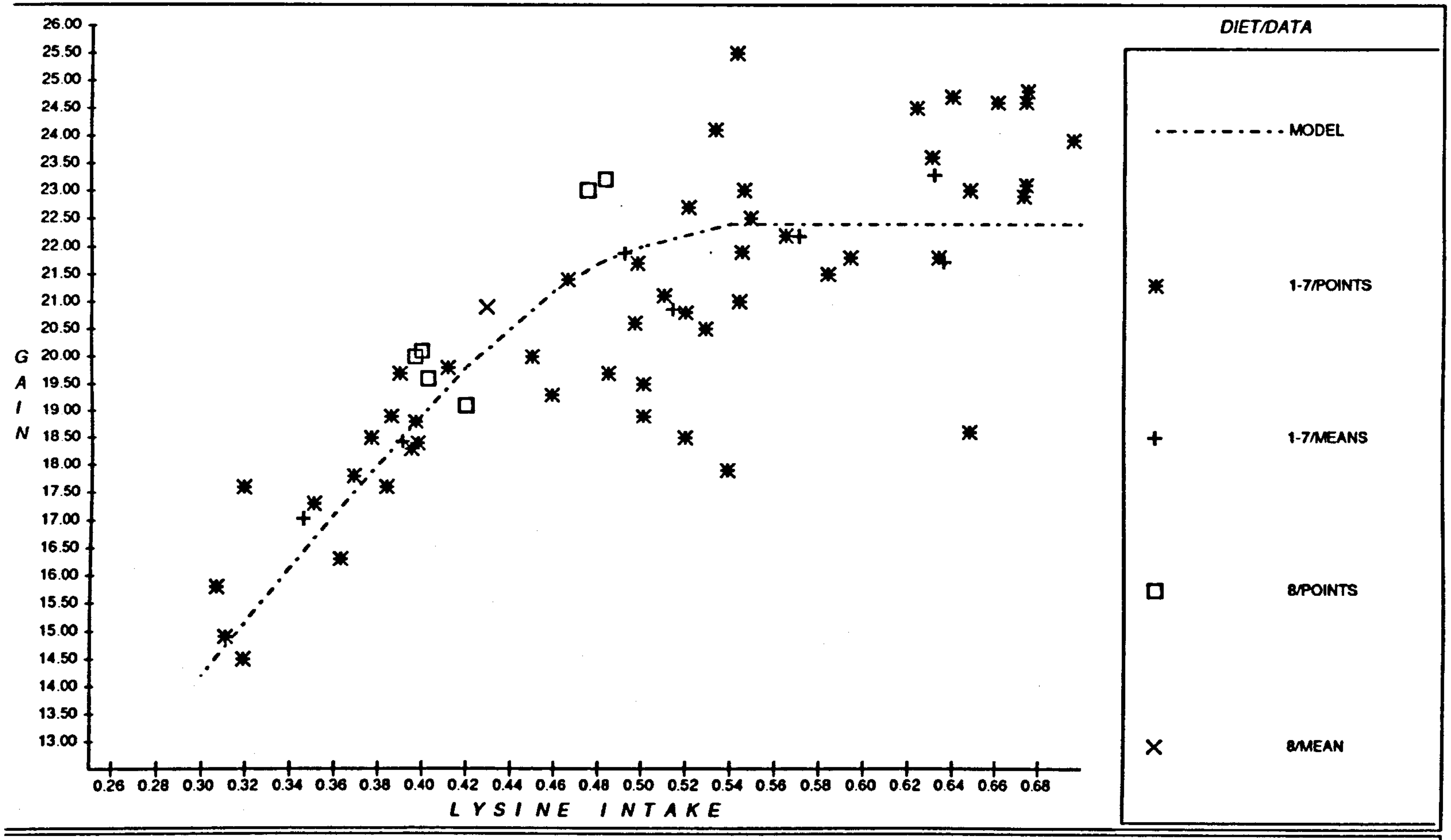

FIGURE 12. EXPERIMENT 2. 4 TO 22 DAYS,
LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

	a VALUES		b VALUES	
	EXP. 1	EXP. 2	EXP. 1	EXP. 2
4 - 13 days	21.31	20.97	0.0155	0.0109
4 - 22 days	21.41	20.97	0.0086	0.0047

Figure 13 demonstrates the close similarity of the Reading model predicted response curves. In the period 4 to 13 days of age, the asymptote of experiment 1 is higher than that of experiment 2. However, in the period 13 to 22 days of age, in Experiment 2, a greater maximum body weight was achieved than in Experiment 1. This was almost certainly the result of the pecking problem which occurred at this time in Experiment 1, which probably depressed the body weight of some individuals on all diets. An alternative possibility is that the oedema problem seen in Experiment 2 at 9 and 10 days of age had eliminated some of the smaller birds, have the effect of selecting birds of higher body-weight gain which influenced the mean in the period 13 to 22 days. This seems the less likely possibility because the veterinary opinion is usually that the oedema problem affects the fastest growing birds in a flock. Whatever the cause, the result was that the asymptote for Experiment 2 for the period 4 to 22 days of age was higher than that of Experiment 1. The highest dietary lysine concentration in Experiment 1 produced a gain in body weight very similar to the asymptote prediction of Experiment 2, indicating that it was a reliable result and not just variance around the lower predicted plateau.

The b values calculated from the two experiments indicate that less than 3% of the total lysine required for birds growing at the maximum rate is needed for maintenance, with the remainder required for gain. As discussed in Chapter 2, the calculated lysine requirement for maintenance purposes is much higher than indicated by the Reading model. Analysis of the data from these experiments suggests that while the total lysine prediction of the Reading model fits the data well, its apportionment into that required for maintenance (b value) and that required for body-weight gain (a value) is incorrect. This is confirmed by examination of Figure 13 where it will be assessed that an extension of the

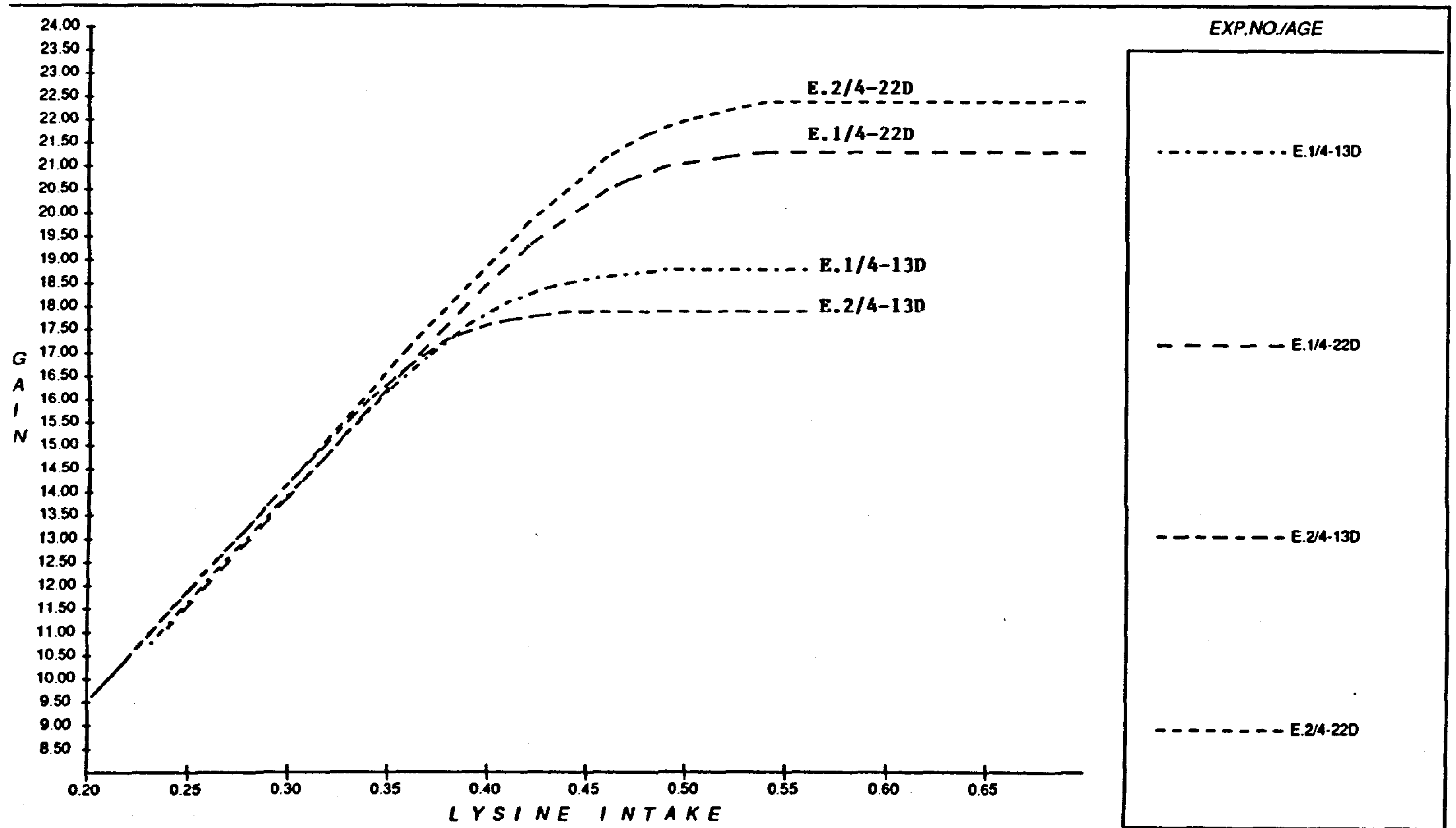

FIGURE 13. READING MODEL PREDICTIONS FOR LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d) FOR EXPERIMENTS(E) 1 AND 2 (1 TO 22 DAYS)

body-weight gain prediction line would give an intercept with the lysine intake axis (abscissa) showing no indication of a requirement for maintenance before body-weight gain can commence. Errors in slope are generally reflected in the intercept. In this instance the value of the intercept is likely to be small which will therefore be liable to large error relatively. While the Reading model will give good predictions of the relationship between lysine inputs and expected body-weight gain outputs, it is apparent that it cannot be used to apportion the requirement into body-weight gain and maintenance requirements. To be able to do this accurately, the body-weight gain measurement would need to be replaced by total body protein gain. This would entail much greater work and expense which will often be prohibitive.

By using the lysine consumptions and body-weight gain predictions together with the lysine and ME content of the diet, it is possible to estimate the lysine requirement for maximum body-weight gain of a flock in relation to the ME consumed. To do this, the least amount of lysine per bird day to achieve maximum body-weight gain must be ascertained from the Reading model input and output predictions shown in the appropriate Appendix table. Very rarely will this equate exactly with the consumption level achieved on one of the experimental diets so the experimental diets giving lysine consumptions immediately above and below the requirement are used as reference points to calculate the level of lysine required in the diet (g/kg) to give the target g lysine intake per bird day to achieve maximum body-weight gain. This is calculated using the Reading Model lysine input and body-weight gain output predictions by first calculating the difference in g lysine per bird day consumed between the two reference diets. The difference between the target g lysine per bird day to achieve maximum body-weight gain and that of the lower of the two reference diets is then calculated. This difference is then expressed as a percentage of the difference in lysine consumption between the two reference diets and applied to the difference in lysine concentration (g/kg) between the diets to arrive at the concentration (g/kg) required to achieve the target lysine intake required for maximum body-weight gain. As all the diets had the same calculated ME content, ie. 11.96 MJ ME/kg, the g lysine/MJ ME for maximum body-weight gain can be calculated. It may be argued that the value calculated will depend on the ME content of the diet. However, it has been shown by MacLeod and Jewitt (1985) that the growing turkey is sensitive to the ME content of the diet and will adjust its intake accordingly to meet its requirements. If the ME content of the diet is increased, the food intake will be reduced and the g of lysine required in the diet (g/kg) to achieve maximum body-weight gain will consequently be increased. It is presumed that the ratio between g lysine and MJ ME required for maximum body-weight gain will remain the same. This would not be so if the composition of the body-weight gain was changed, i.e. if a higher ME content of the diet induced the bird to deposit greater quantities of fat. The optimum ratio will also be influenced by the environmental temperature. In the absence of more information, the ratio calculated as described offers a guide for nutritionists when formulating turkey diets.

The calculations for these two experiments using data in Appendix Tables 11,12,13 and 14 indicate the following lysine to ME relationships to achieve maximum body-weight gain of a flock:

g lysine/MJ ME requirement to achieve maximum body-weight gain (ΔW_{MAX})

AGE	4-13 days		4-22 days	
	g lys/kg	g lys/MJ ME	g/lys/kg	g lys/MJ ME
EXP.1			18.06	1.510
EXP.2	19.00	1.589	17.12	1.431

The Reading model indicated a requirement higher than the highest concentration used in Experiment 1 for 4 to 13 days so the calculation could not be carried out for that period.

The requirement for maximum body-weight gain of a flock may not be the optimum economic requirement. The lysine intake level at which ΔW_{MAX} is achieved by a flock of turkeys is that level which satisfies every individual in the flock. Some individuals within the flock will have a lower genetic potential body-weight gain and hence lower lysine requirement. As the average intake level of a flock increases, progressively the requirement for maximum gain of more individuals within the flock is satisfied. This results in a marked diminishing return, seen in Figures 9, 10, 11 and 12, in body-weight gain of the flock for each mg of lysine consumed as more individuals achieve their maximum gain. As lysine has a cost and body-weight gain a value, a point is reached in the diminishing returns section of the response curve when the marginal cost equals marginal return, which is the optimum amino acid intake for a flock of birds. The Reading Model contains an equation to calculate this point as shown below:

$$L_{OPT}(mg/d) = \underline{a}\Delta W + \underline{b}W + x\sqrt{\underline{a}^2\sigma^2\Delta W \underline{b}^2\sigma^2 W + 2.\underline{a}.b\sigma\Delta W.\sigma W.r}$$

where ΔW = mean potential body-weight gain

W = mean body weight

σ = standard deviation

r = correlation between ΔW and W

x = the deviation from the mean of a standard normal distribution which is exceeded in one tail with probability ak, where k = cost per mg amino acid/value per g body-weight gain.

While the cost of the extra lysine can be calculated, it is impossible to put an accurate value on the extra body weight gained because the turkeys are not at a marketable age. Indirectly the extra body weight may have a beneficial effect on subsequent performance. There is a correlation between 4 week body weight and 20 week body weight (Nixey, 1989a) so it is likely that a similar correlation exists between 3-week body weight and 12-week body weight. As the food consumed in the first three weeks of life only represents less than 8% of the total consumed to 12 weeks, it is reasonable to assume that it is economic to aim to feed to the requirement of individuals with the greater requirement in the flock for the first three weeks of life if it is planned to kill the flock at young ages. If the turkeys are future breeding stock, the optimum economic requirement will be something less than that required for maximum body-weight gain. As will be described in Chapter 5, the Reading model predictions can be used to help when formulating to achieve a desired body-weight gain.

2. The Lysine Response of the Growing Turkey

The commercial turkey is grown to various ages depending on the type of product required. If small oven-ready birds are required, either sex may be killed as early as 9 weeks of age. If however larger birds are required or the birds are being used for further processing, they may be killed at ages up to 20 weeks on occasions. A series of experiments are now reported for various age periods between 4 and 20 weeks for each sex reared separately.

Experiment 3

Objective

To assess the lysine response of the 4- to 7-week-old male turkey.

Materials and Methods

Males of a medium-to-heavy strain, BUT 6 Female Line Cross, were used. Prior to the experiment, they were reared in tier brooders and fed ad Libitum on a standard starter diet containing 280g crude protein and 11.96 MJ ME/kg. They were moved into 96 pens in the experimental house at Kinnerton Farm at 3 weeks 3 days to acclimatise to their experimental surroundings. The birds were fed on the commercial starter diet until treatment diets were allocated. The birds were randomly assigned to the 96 pens but any found to be unusually small were excluded from the experiment because of the possibility that they might have been females. Five birds were placed in each pen. At 4 weeks of age, the birds were weighed by placing all the birds from one pen into a weighed small wooden crate. The hanging plastic tubular feeders could be removed for weighing purposes, when recording the food remaining at the end of the period.

As the birds had been in heated brooders previously and when they were moved to the experimental rooms, the outside temperature was cold especially at night, it being November, it was felt that supplementary background heat was necessary, this was provided by gas brooders hung near the ceiling. It was unavoidable that the temperature directly below the brooders was higher than in areas further from the brooder. It was therefore necessary to allocate pens within the room to experimental blocks within which treatment diets were randomised. The eight treatment diets were thus allocated to 12 replicate blocks, the blocks being in 4 rooms, each room containing 3 blocks.

Any pen in which a bird died was omitted from the data when analysed and a missing plot technique was used. The birds were weighed at 4 weeks and 7 weeks of age, diets being fed for 3 weeks. The food fed over the period was recorded and the amount remaining at 7 weeks weighed to allow calculation of food consumption.

The eight diets fed were produced by combining summit mixture A with Basal mixture A (Appendix Table 3). It will be seen that the summit and basal mixtures were also used as individual diets. Unfortunately due to an error in the feed mill, Diet 8, the diet to which free lysine was added, was supplemented with L-lysine (as HCl) at twice the intended addition. Thus instead of the supplementation increasing the lysine content to that of the next diet in the series (Diet 4), i.e. from 9.00 to 11.50g lysine/kg as shown in Appendix Table 3, the content was increased to that of Diet 3 (from 9.00 to 14.00 g/kg). At this level of supplementation, there was the possibility that an amino acid other than lysine would become limiting, although proof of lysine deficiency in the mixtures would still be evident.

Results

Of 480 birds started, only 3 birds died during the experiment; data are summarised in Table 28.

TABLE 28		RESPONSE OF 4 TO 7-WEEK OLD MALE TURKEY POULTS TO LYSINE (EXPERIMENT 3)				
DIET NO	LYSINE CONCEN-TRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	19.00	74.9	195.0	0.3841	3.705	20.22
2	16.50	72.2	231.5	0.3119	3.820	18.90
3	14.00	70.0	241.3	0.2902	3.377	20.73
4	11.50	56.1	195.7	0.2867	2.251	24.92
5	9.00	41.3	167.9	0.2460	1.211	27.33
6	6.50	27.9	109.3	1.2553	0.710	39.30
7	4.00	23.9	76.1	0.3141	0.304	78.62
8	14.00	72.7	197.1	0.3688	2.759	26.35
SE		2.0	17.00	0.0318	0.218	4.42
THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 12 REPLICATES OF 5 BIRDS EACH						
READING MODEL ANALYSIS						
4-DAYS BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE /kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)		
0.804	1.323	72.2	35.13	0.0010		

Unfortunately the feeding system, involving a hanging plastic feeder within the crowded pen, resulted in feed wastage which could not be estimated, as the feed was lost in the shavings. The wastage was not noticed in the pens receiving low lysine diets but was apparent in those receiving high lysine diets where feed consumptions were highest. The effect of this differential wastage, presumably related to the amount of feeding activity, became apparent when the data were used in an A run of the Reading model. This indicated an extremely high a value,35.13, compared with the earlier experiments with a values around 20. The effect of increased feed wastage on the high lysine diets will have had the effect of decreasing the slope of the response (1/a) and so increasing the value of a and indirectly reducing the b value.

It will be seen in Figure 14 (Appendix Table 15) that birds receiving the two most limiting diets achieved noticeably better body-weight gains than were predicted by the Reading model when analysing the total data. Feeding activity was low in the pens receiving these diets and no apparent feed wastage occurred. As a result these pens have achieved higher gains per g intake of lysine than pens where a proportion of the food was wasted.

The error in the feed mill which meant that diet 8 received twice the intended addition of L-lysine HCl, did not prevent diet 8 showing a body-weight gain response to the extra lysine, to the equivalent lysine level produced by mixing the summit and basal mixtures (diet 3, see Table 28). Thus the mixtures were lysine deficient equivalent to two stages in the diet sequence.

Using the method of calculation outlined for experiments 1 and 2, a concentration of 14.0g/kg lysine was required to promote maximum body-weight gain for 4- to 7-week old male turkeys. This equates to a ratio of 1.170g lysine/MJ ME. The problem of the feed wastage described earlier should have little influence on this calculation as that affected quantities whereas this calculation is based on concentrations. The experiment therefore is of value.

Experiment 4

Objective

To assess the lysine response of the 4- to 7-week old female turkey.

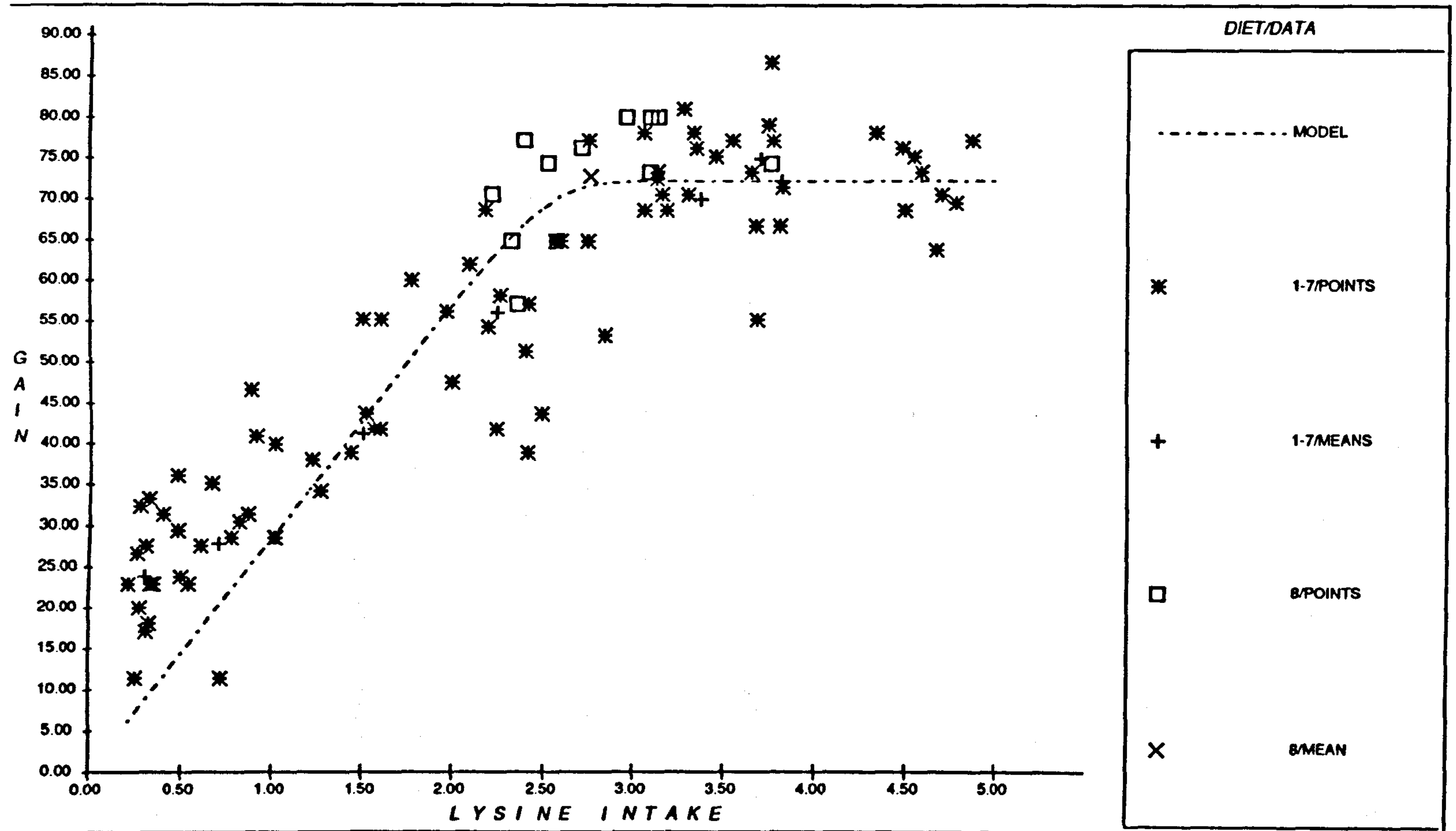

FIGURE 14. EXPERIMENT 3. 4 TO 7 WEEKS - MALES, LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

Materials and Methods

Females of the same strain as in experiment 3 were used. The arrangements for the experiment were the same as those detailed for experiment 3, with the exception that unusually large turkeys were excluded from the experiment because of the possibility that they have might been males. The food used was from the same batch mix as used in experiment 3. This meant that diet 8 received twice the intended addition of L-lysine HCl; however the lysine deficiency had been confirmed in experiment 3 and was reconfirmed in this experiment.

Results

Survival was good with only 3 birds out of 480 dying during the experiment. One bird escaped and became mixed with another pen so invalidating results from two pens.

A slight shortage of experimental diets occurred. To overcome a shortage of diet 3, it was reproduced by mixing proportions of diets 1 and 7 in pellet form to give the required lysine level. A shortage of diet 8 could not be overcome in this way as it was the diet to which L-lysine HCl had been added. In the final week, three pens on this diet were taken out of the experiment so that the remaining pens could last the full period. A missing plot technique was used in the statistical analysis. Data are summarised in Table 29.

TABLE 29		RESPONSE OF 4 TO 7-WEEK-OLD FEMALE TURKEY POULTS TO LYSINE (EXPERIMENT 4)				
DIET NO	LYSINE CONCEN-TRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	19.00	46.9	124.2	0.3776	2.360	19.87
2	16.50	45.2	134.7	0.3356	2.223	20.33
3	14.00	43.1	124.9	0.3451	1.749	24.64
4	11.50	35.4	128.9	0.2746	1.482	23.89
5	9.00	24.4	98.8	0.2470	0.889	27.45
6	6.50	16.3	80.1	0.2035	0.521	31.29
7	4.00	14.4	60.6	0.2376	0.242	59.50
8	14.00	44.2	126.3	0.3500	1.768	25.00
SE		1.2	7.2	0.0188	0.093	2.65

THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 12 REPLICATES OF 5 BIRDS EACH

READING MODEL ANALYSIS

4-DAYS BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE /kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)
0.712	1.034	44.5	35.22	0.0036

The food wastage reported in experiment 3, resulting from the feeding system was also noticed in this experiment, even though the birds were female and smaller. As explained before, this would have the effect of decreasing the slope of the response (1/a) and so increasing the value of a and decreasing the value of b.

Figure 15 (Appendix Table 16) shows that, as happened in experiment 3, the two lowest lysine intakes achieved noticeably better body-weight gains than were predicted from the total data. As explained in experiment 3, this was because of low food wastage in pens fed these diets.

A concentration of 14.3g/kg lysine was required to achieve maximum body-weight gain, equating to a ratio of 1.196g lysine/MJ ME. This is very similar to that determined for males (1.170g) in Experiment 3.

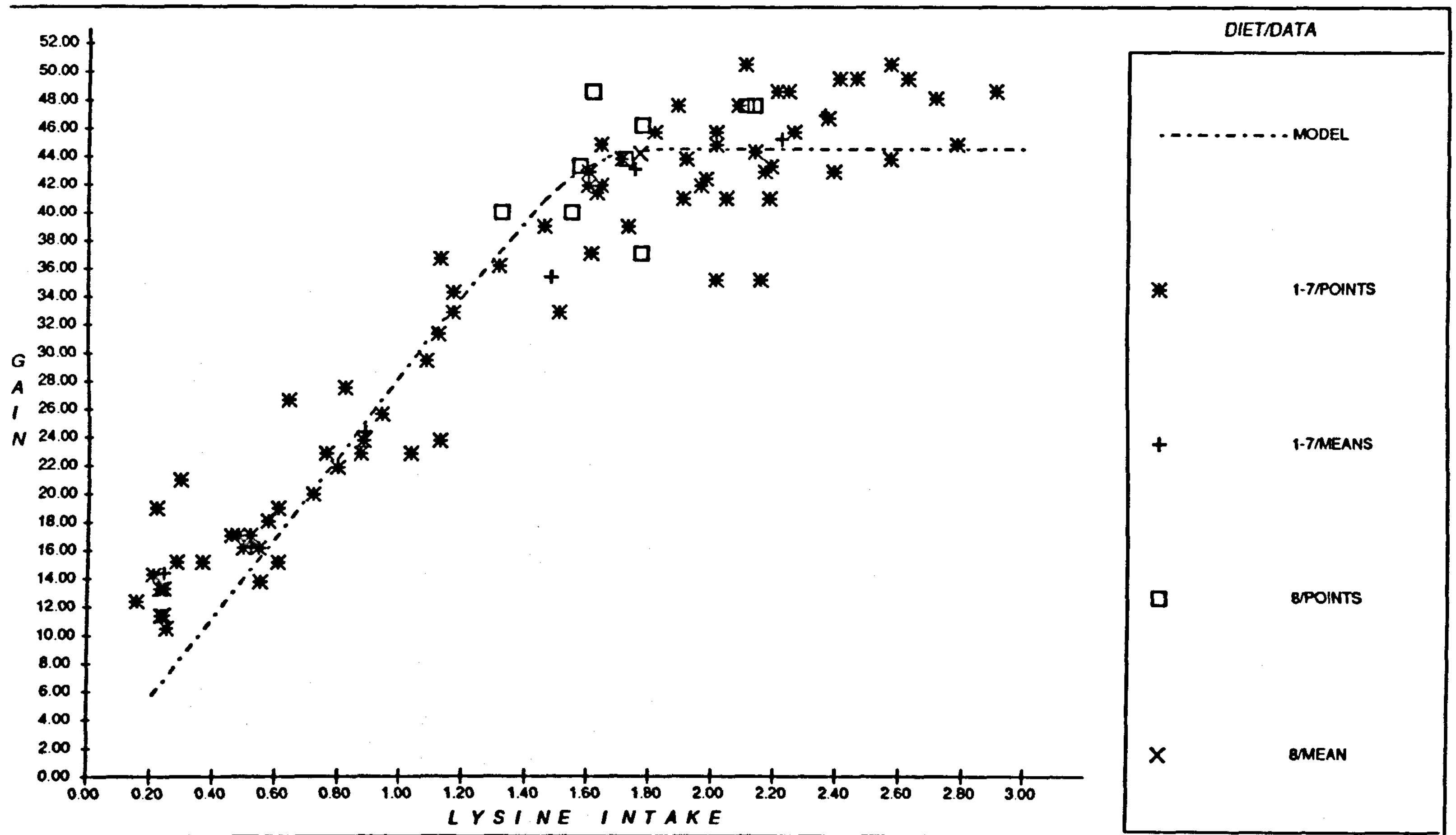

FIGURE 15. EXPERIMENT 4. 4 TO 7 WEEKS - FEMALES, LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

Figure 16 illustrates that the males and females at this age had very similar body-weight gain responses to lysine input until the females approached their genetic potential for gain which was lower than that for the males. That similar concentrations of lysine/MJ ME are required to achieve maximum gain in both sexes is an indication that the appetite is adjusted according to potential for gain. Experiments 3 and 4 indicate that both sexes should be fed the same concentration of lysine in the diet from 4 to 7 weeks of age.

Experiment 5

Objective

To assess the lysine response of the 9- to 12- week-old male turkey.

Materials and Methods

Males of the same strain of turkey as used in previous trials, the BUT 6 Female Line Cross, were used. Prior to the experiment, they were reared on a standard feeding programme which consisted of a 280g/kg protein diet and 11.9 MJ ME/kg from 0 to 4 weeks and 250g/kg protein and 12.0 MJ ME/kg from 4 to 9 weeks. At 8 weeks 4 days of age, the turkeys were moved into 96 pens in the experimental house at Kinnerton Farm and fed the same diet as previously until the start of the experiment at 9 weeks. Only normal, healthy turkeys were used. They were also screened before moving, to reject birds at the extremes of the weight range. In this experiment two birds were placed in each pen. The 96 pens were allocated to 8 treatments in each of the 3 blocks in each of the 4 rooms, giving 12 replicates of each treatment.

Each bird was weighed at 9 weeks and 12 weeks. One bird in each pen was identified by a wing band to prevent the subsequent error of weighing the same bird twice. The method of weighing was to place the turkey's legs as it hung upside down, in shackles attached to a spring balance capable of weighing to 0.1kg accuracy.

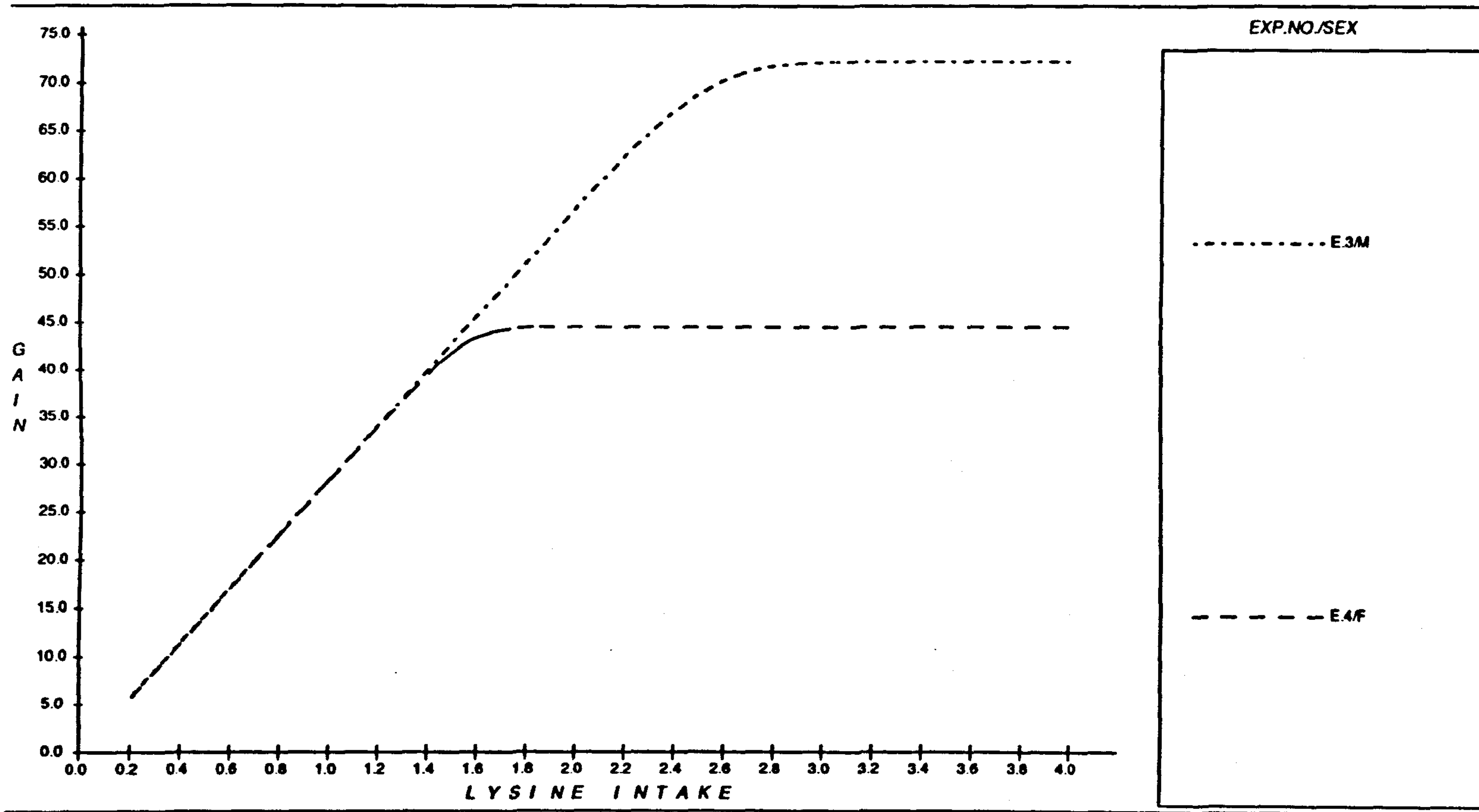

FIGURE 16. READING MODEL PREDICTIONS FOR LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d) FOR MALE(M) AND FEMALE(F) TURKEYS IN EXPERIMENTS(E) 3 AND 4 (4 TO 7 WEEKS)

For this experiment and all subsequent experiments, a plastic trough feeder was hung outside the pen with access to the food through holes cut in the weld mesh. Having the feed placed outside the pen reduced the feed wastage in the majority of pens to apparently nil. Some pens showed a little wastage, but this was easily seen on the concrete floor and collected and returned to the feed trough. Data from pens in which a bird died were omitted and a missing plot technique used in the statistical analysis. The food fed over the period was recorded and the amount remaining at 12 weeks weighed to allow calculation of food consumption. The 8 diets fed were produced by combining Summit mixture A with Basal mixture A (Appendix Tables 5, 6, 7 and 8) in differing proportions (Appendix Table 3). Diet 8, the diet containing added L-lysine HCl was mixed correctly taking the lysine level equivalent to that of diet 5 (9.00g/kg) up to that equivalent to diet 4 (11.5g/kg).

Results

Only one bird died during the experiment; data are summarised in Table 30.

TABLE 30	RESPONSE OF 9 TO 12-WEEK-OLD MALE TURKEY POULTS TO LYSINE (EXPERIMENT 5)					
DIET NO	LYSINE CONCEN-TRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	19.00	98.6	294.8	0.3345	5.601	17.60
2	16.50	96.0	274.3	0.3536	4.526	21.43
3	14.00	98.6	278.9	0.3535	3.905	25.25
4	11.50	98.6	272.6	0.3617	3.135	31.45
5	9.00	93.1	275.8	0.3376	2.482	37.51
6	6.50	68.7	249.6	0.2752	1.622	42.36
7	4.00	42.0	209.3	0.2007	0.837	50.18
8	11.50	99.8	276.6	0.3608	3.181	31.37
SE		7.6	16.9	0.0254	0.202	3.14

THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 12 REPLICATES OF 2 BIRDS EACH

READING MODEL ANALYSIS

9 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE /kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)
3.567	4.305	97.5	22.91	0.0040

The data when used in an A run of the Reading model produced a and b values of 22.91 and 0.0040 respectively, which were similar to those obtained in experiments 1 and 2 using birds from 4 to 22 days. The Reading model B run produced lysine input and body-weight gain output predictions (Appendix Table 17) and when plotted against actual observed results (Figure 17) a good fit between actual and predicted results can be seen.

Using data in Appendix Table 17, a concentration of 9.5g lysine/kg was calculated to be required to achieve the maximum body-weight gain of 97.5g bird d. This equated to a ratio of 0.794g lysine/MJ ME. The decrease in the concentration required to achieve maximum growth rate compared to trials with younger birds meant that only three of the treatments produced data points on the response section of the curve. Nevertheless the close fit of these data points to the predicted response line gives confidence in the coefficients calculated. The added L-lysine HCl gave a body-weight gain not significantly

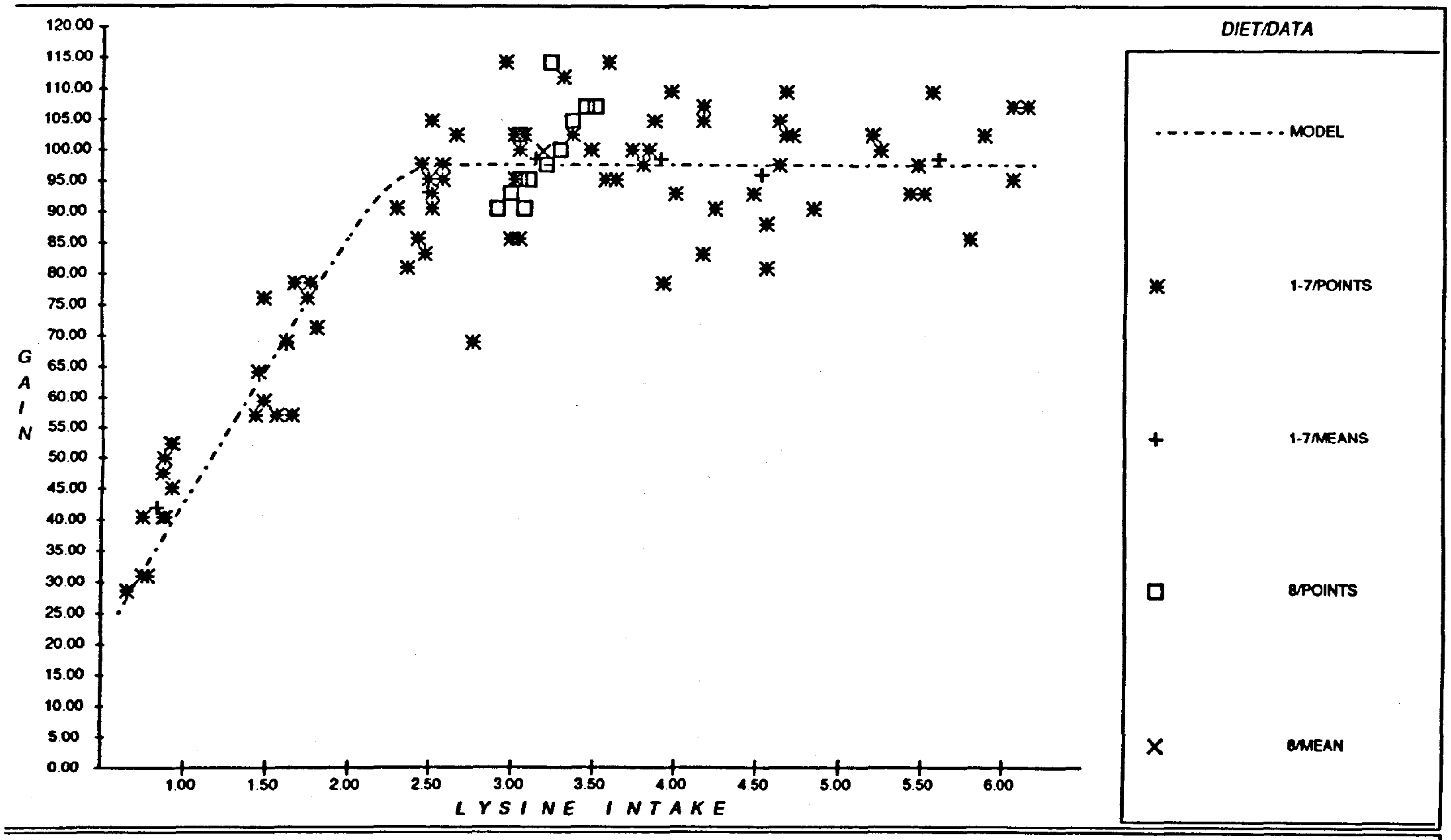

FIGURE 17. EXPERIMENT 5. 9 TO 12 WEEKS - MALES, LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

different from the diet of the same lysine content, indicating that lysine was the first limiting amino acid in the experimental diets at this age.

Experiment 6

Objective

To assess the lysine response of the 15- to 18-week-old male turkeys, with particular attention to the level required in the diet for maximum body-weight gain. As indicated in the previous experiment, as larger (older) birds are used in response trials, the lysine concentrations needed in the diets decreases. The requirement as a proportion of the diet decreases as body size increases, because gain diminishes in relation to body weight with increasing age while food intake continues to increase. Thus at this stage, it was necessary to consider the range of dietary lysine concentrations to be used for the older birds. The information obtained was then used for formulating the experimental diets involving birds between 15 and 20 weeks of age, to try to ensure that sufficient diets would give body-weight gains within the incremental ("slope") part of the response curve, to enable the slope ($1/\underline{a}$) to be calculated satisfactorily.

Materials and Methods

Males of the same strain as used previously (BUT 6 Female Line Cross) were used. Because of their large size, only one bird could be housed per pen. The 96 males used were selected from a flock of 300 birds to be similar in weight to the mean body weight of the flock. The 8 diet treatments were then allocated within the 3 blocks of pens within each of 4 rooms giving 12 replicates. The turkeys were housed in the experimental pens at 14 weeks 4 days of age and fed a standard diet (180g protein and 12.1 MJ ME/kg) until the start of the experimental period at 15 weeks.

The 8 diets fed were produced by combining summit mixture A with Basal mixture A (Appendix Tables 5,6,7 and 8) in differing proportions as shown in Appendix Table 3. It would have been preferable to formulate new mixtures. However these mixtures were remaining from the earlier experiments, and in view of the expense of experimental diets and the preliminary nature of the experiment, it was decided to use those already available.

Results

Of the 96 males which started, 4 died during the experiment, their results were excluded and a missing plot technique used in the statistical analysis; data are summarised in Table 31.

TABLE 31 RESPONSE OF 15 TO 18-WEEK-OLD MALE TURKEY POULTS TO LYSINE (EXPERIMENT 6)

DIET NO	LYSINE CONCENTRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	19.00	78.9	420.9	0.1872	8.001	9.86
2	16.50	85.3	424.8	0.2007	7.013	12.01
3	14.00	75.8	407.9	0.1846	5.711	13.19
4	11.50	87.7	421.6	0.2054	4.849	17.86
5	9.00	89.3	425.0	0.2080	3.825	23.11
6	6.50	90.1	429.8	0.2079	2.793	31.98
7	4.00	70.2	409.1	0.1704	1.637	42.60
8	11.50	88.5	427.8	0.2040	4.919	17.74
SE		8.2	15.0	0.0157	0.149	1.75

THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 12 REPLICATES OF 1 BIRDS EACH

READING MODEL ANALYSIS (See Appendix Table 8)*

15 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE /kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)
7.234	8.079	85.1	18.26	0.0435

* Based on analysis of Treatment Means

The Reading model was used to analyse the data as previously described. Using individual replicate data produced a very low a value (7.75). Examination of the position of the replicate data shown in Figure 18 gives the explanation. The position of the individual replicates of the diet with the lowest concentration lie almost on a straight line of positive

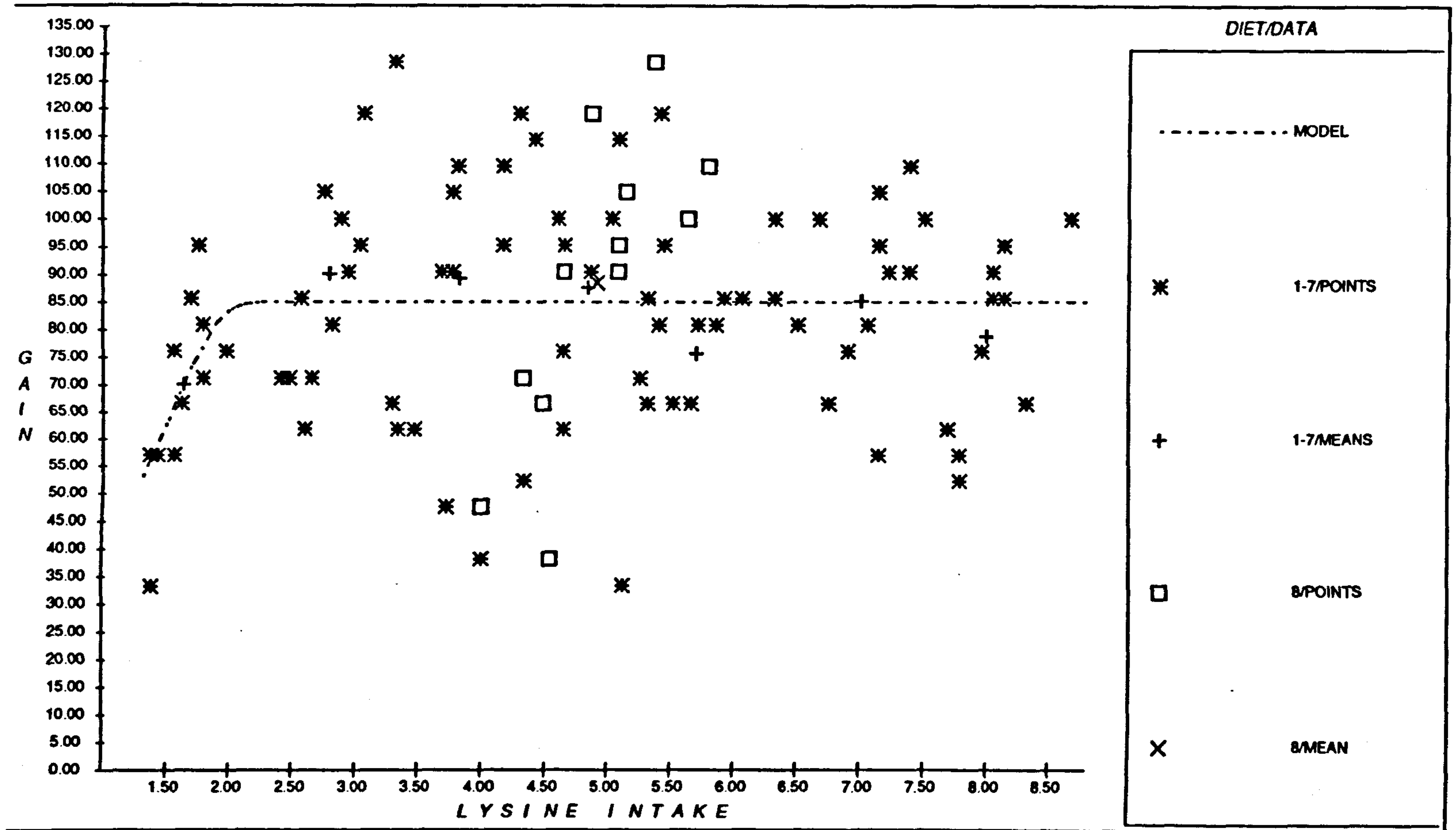

FIGURE 18. EXPERIMENT 6. 15 TO 18 WEEKS - MALES, LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

slope and these points alone were probably interpreted by the Reading Model to represent the slope of the response. Using the treatment mean data produced a more realistic a value (18.26) but Figure 18 indicates that the distribution of the data is such that a Reading model analysis is inappropriate as insufficient data lie on the slope (incremental) section of the response curve.

The information however satisfies the objective of the experiment to determine the lysine concentrations required in experimental diets to be used for this age range. It indicates that to achieve two or preferably three data points on the plateau of the response curve of 15- to 18-week-old male turkeys, lysine intakes in excess of 2.5g per day are required. In this experiment, this would have been achieved by diets containing a lysine concentration of 6g/kg and above. The other diets should be formulated to contain less than 6 lysine/kg in as many steps as possible to the lowest level of lysine that can be formulated using normal ingredients.

The variation among the body-weight gains of individual replicates lying on the plateau section of the response curve is considerable. If the replicates from less than 2g of lysine per bird day are omitted as they may lie on the slope (1/a) of the lysine response, there is a significant ($P<0.001$) correlation between body-weight gain and ME intake. The regression coefficient was 37.0g change in body-weight gain for each MJ of ME change in intake. Figure 19 illustrates the data and the regression line.

The extra body-weight gain in response to increased ME intake would most logically be made up of increased fat deposition. The bird's capacity to deposit fat will depend, amongst other things, upon its stage of maturity and genetic propensity to lay down body fat. These factors could be expected to vary between individuals and result in the ME response indicated.

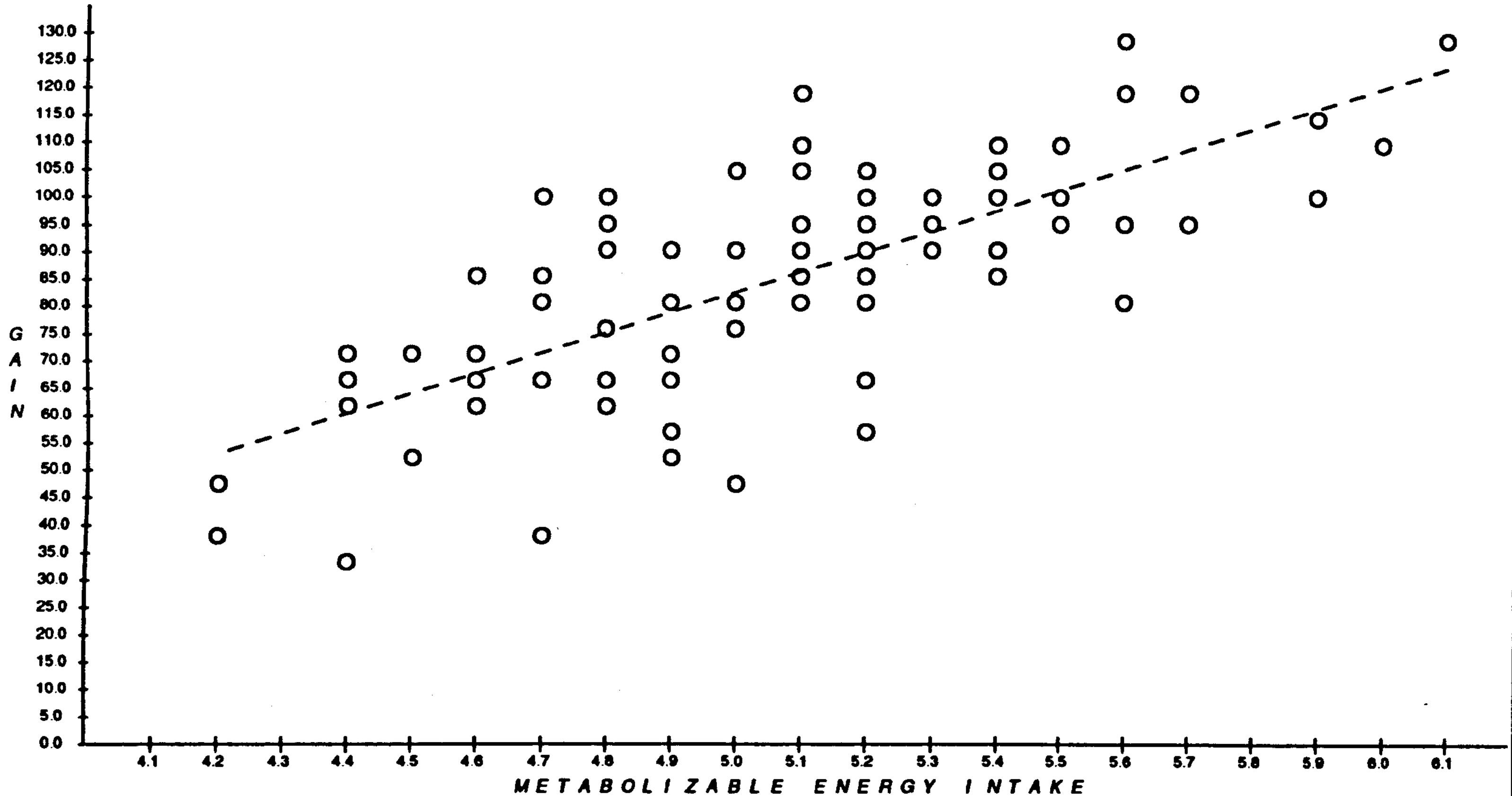

FIGURE 19. EXPERIMENT 6. 15 TO 18 WEEKS-MALES, METABOLIZABLE ENERGY INTAKE (MJ/d) AND BODY-WEIGHT GAIN (g/d) OF INDIVIDUALS AT NON-DEFICIENT AMINO ACID INTAKES (FITTED LINE, GAIN=37.0 ME-102.2, r=0.726, n=70, P<0.001)

The mean treatment values show an apparent decline in gain with increasing intakes of lysine in the plateau range. The corollary of this would be decreased fat deposition with increasing intakes of lysine.

As surplus experimental diets were available, the experiment was repeated (as experiment 7) to confirm or otherwise, the responses seen.

Experiment 7

Objective

To repeat experiment 6 to ensure that responses to lysine and metabolizable energy intakes were reproducible.

Materials and Methods

The procedure and numbers were identical to those of experiment 6. The same batch of experimental diets was used.

Results

Of the 96 males which started, 2 died during the experiment. Their results were excluded and a missing plot technique used in the statistical analysis; data are summarised in Table 32 and in Figure 20.

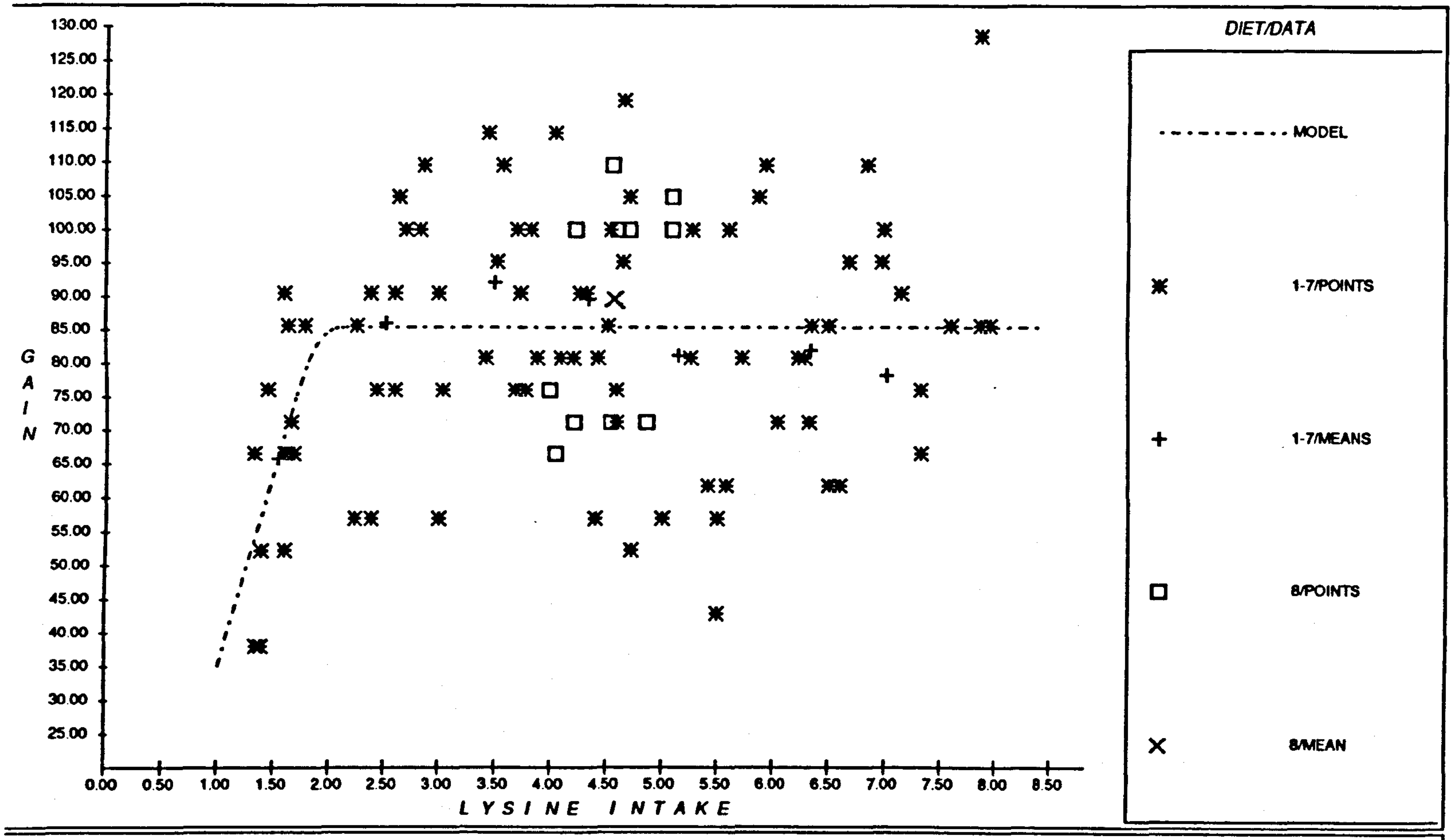

FIGURE 20. EXPERIMENT 7. 15 TO 18 WEEKS - MALES,
LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

TABLE 32		RESPONSE OF 15 TO 18-WEEK-OLD MALE TURKEY POULTS TO LYSINE (EXPERIMENT 7)				
DIET NO	LYSINE CONCEN-TRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	19.00	78.4	369.8	0.2126	7.021	11.29
2	16.50	82.1	384.9	0.2096	6.351	12.70
3	14.00	81.3	369.2	0.2185	5.166	15.58
4	11.50	89.7	378.2	0.2368	4.349	20.59
5	9.00	92.1	388.1	0.2368	3.493	26.31
6	6.50	86.0	389.7	0.2196	2.525	33.78
7	4.00	65.9	384.9	0.1700	1.540	42.49
8	11.50	89.0	397.0	0.2240	4.568	19.48
SE		7.0	14.2	0.0144	0.176	1.85
THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 12 REPLICATES OF 1 BIRDS EACH						
READING MODEL ANALYSIS*						
15 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE /kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)		
7.652	8.482	85.5	16.88	0.0503		

* Based on analysis of Treatment means

The results were very similar to those obtained in experiment 6. The experiment took place in late April and early May, four weeks later than experiment 6. The warmer seasonable temperatures would explain the reduction in food intake and reduced lysine intakes on all diets. In this experiment a concentration of 6.5g lysine/kg resulted in an intake of 2.52g/bird d whereas the same diet in experiment 6 resulted in 2.79g lysine/bird d. This is an illustration of the inadequacy of stating requirements in terms of concentration in a diet or as discussed on page 15 as a ratio to dietary energy. The requirement is best stated as a quantity not a concentration.

In view of the few data points on the incremental ("slope") part of the response curve in experiments 6 and 7, the predictions from the Reading model for body-weight gain per unit of lysine or the maximum body-weight gain(ΔW_{MAX}) indicated in Appendix Tables 18 and 19 are of little value.

The maximum body-weight gain (ΔW_{MAX}) indicated by the Reading model analysis was noticeably less than that achieved on some diets and noticeably more than that achieved on others (Figure 20). These departures were the results of the growth depression occurring at lysine intakes above that required for maximum body-weight gain. The growth depression on high lysine intakes seen in experiment 6 thus also occurred in experiment 7.

The Reading model assumes a constant plateau, which is a best fit to the values. As a result, if high lysine diets cause depression in growth rate, the data points beyond the first diet giving maximum body-weight gain are interpreted as variation around a lower plateau in body-weight gain. This results in a lower prediction for gain. If an analysis was performed omitting the data points resulting from the excessive lysine intakes, higher maximum body-weight gains, more consistent with the data, i.e. 89.4g per bird d in experiment 6 and 89.2g per bird d in experiment 7 compared to 85.1g and 85.5g respectively, were obtained. The derived a and b values were barely affected because they are derived from the data points on the slope (1/a) of the body-weight gain response. The increase in indicated body-weight gain (ΔW_{MAX}) also results in an increase in the indicated lysine intake required to achieve it, increasing to 2.7g per bird d in experiment 6 and 3.0g per bird d in experiment 7. This in turn increases the indicated ratio required in the diet to 0.527g lysine per MJ ME in experiment 6 and 0.644g lysine per MJ ME in experiment 7 compared to 0.458g and 0.492g respectively. The differences between experiments will relate to the temperature differences resulting in different ME requirements for maintenance. The values related to the higher maximum body-weight gains fit the results better and are preferred. However the poor range of diets for these responses requires that these estimates be treated as a preliminary estimate.

The depression in gain at lysine intakes higher than that required for maximum gain seen in experiment 6, was repeated in experiment 7. The large variation between the body-weight gains of individual replicates lying on the plateau section of the response curve was also seen. If the replicates from less than 2g of lysine per bird day are omitted, as they may lie on the slope (1/a) of the lysine response, there is, as in experiment 6, a significant ($P<0.001$) correlation between body-weight gain and ME intake. The regression coefficient was 28.42g change in body-weight gain for each MJ of ME change in intake compared to a value of 36.98g in experiment 6. Figure 21 illustrates the data and the regression line.

If the ME intakes and body-weight gains of experiment 6 and 7 are plotted together (Figure 22), it can be seen that for the same ME intake, the body-weight gains tended to be higher in experiment 7 than in experiment 6. The difference between the slopes is not significant ($P>0.05$)

The major difference between the experiments which might be expected to change the response to ME is temperature. Experiment 7 took place in late April and early May, four weeks later than experiment 6. It is regretted that the room temperatures were not recorded. The mean of the maximum and minimum daily air temperatures for the experimental periods were obtained from the local meteorological station. They were 6.1°C and 10.6°C for experiments 6 and 7 respectively. The temperatures inside the experimental house will have been higher than these, but it might be expected that a difference of this order would have occurred inside, a difference sufficient to explain the apparent differences in response between the experiments.

The influence of the lower temperatures in experiment 6 is presumed to be to increase the maintenance requirement for ME, leaving less surplus ME available for fat deposition resulting in a lower gain at the same ME intake. The weakness of this explanation is that it presumes that the turkey at this age does not regulate its energy intake accurately to its requirements. It may be that the drive to deposit body fat does not have a strong influence on the turkey's perceived ME requirement at this age and may be over-ridden by appetite depressant factors such as time and energy required to be spent eating and crop capacity.

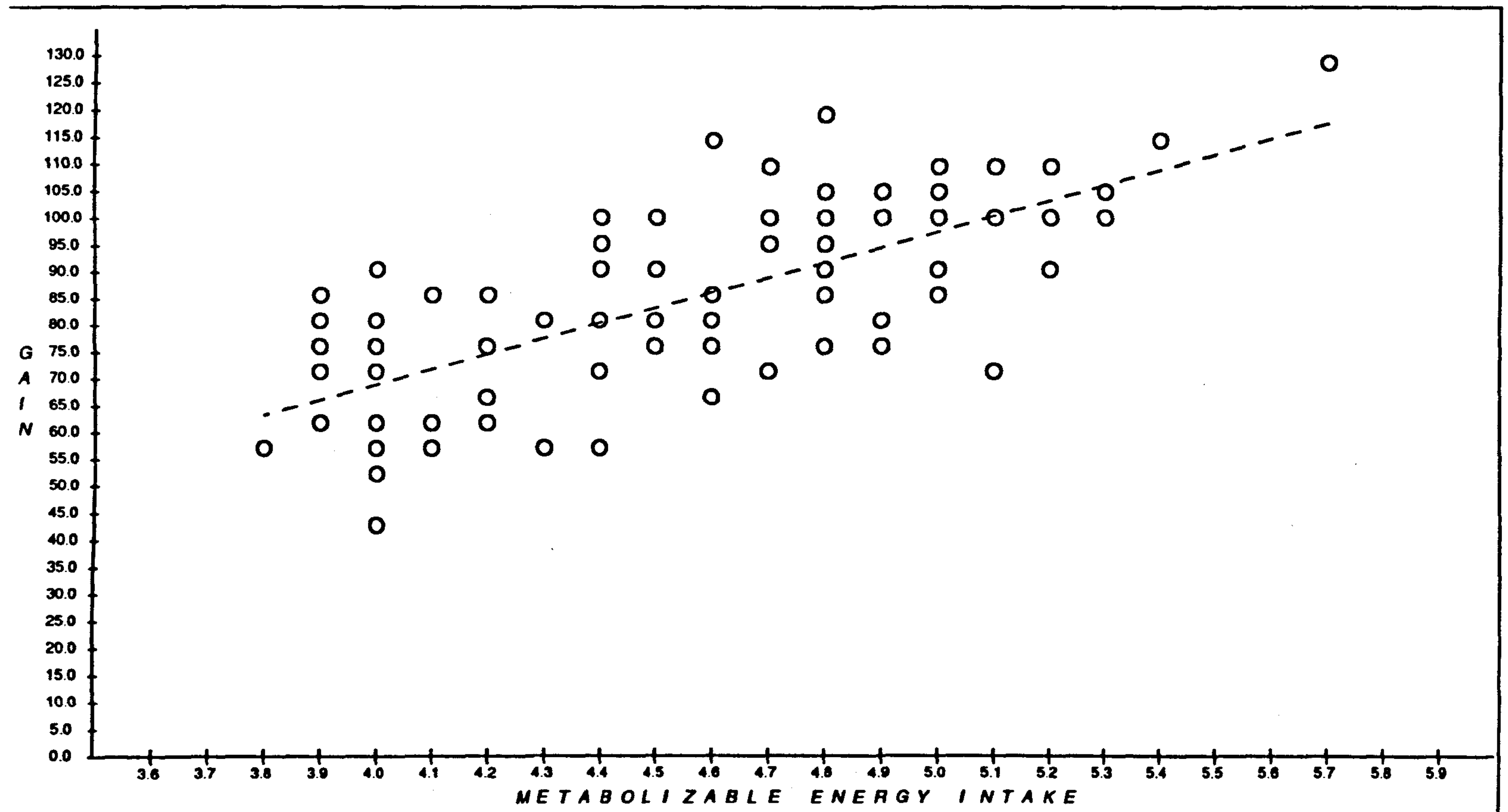

FIGURE 21. EXPERIMENT 7. 15 TO 18 WEEKS-MALES, METABOLIZABLE ENERGY INTAKE(MJ/d) AND BODY-WEIGHT GAIN(g/d) OF INDIVIDUALS AT NON-DEFICIENT AMINO ACID INTAKES (FITTED LINE,GAIN=28.4 ME-44.5,r=0.698,n=68,P<0.001)

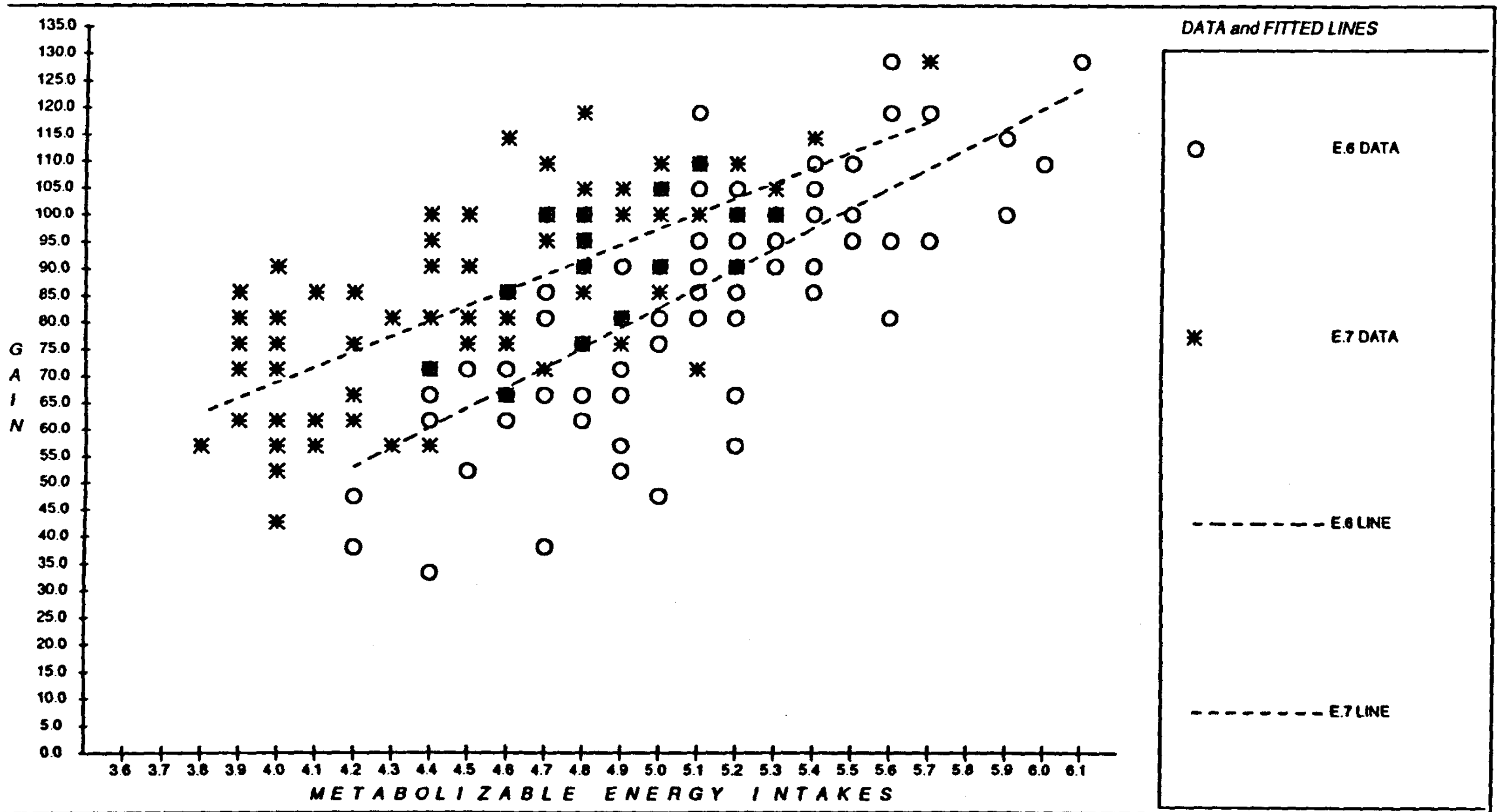

FIGURE 22. EXPERIMENTS(E) 6 AND 7 METABOLIZABLE ENERGY INTAKE(MJ/d) AND BODY-WEIGHT GAIN (g/d) OF TURKEYS AT NON-DEFICIENT AMINO ACID INTAKES (FITTED LINES E.6=37.0 ME-102.2, r=0.726 : E.7=28.4 ME-44.5, r=0.698)

In experiment 5, an excess of lysine and protein intake beyond that required for maximum body-weight gain, did not depress body-weight gains. That experiment was concerned with 9- to 12-week old males which even in favourable nutritional circumstances do not lay down significant quantities of body fat (Hurwitz et al 1983). This may be an additional indication that the body-weight gain depression seen in experiments 6 and 7 involved differences in body fat gain. It is a further indication that analysis of the body tissues laid down would greatly strengthen the interpretation of the results. Analysis of the body-protein gain might have shown no reduction at high lysine intakes.

If high lysine or protein intakes in excess of that required for maximum body-weight gain alter the body tissue proportions, this would have commercial significance. Body fat is a desirable characteristic in traditional farm fresh turkeys but undesirable in turkeys for further processing.

The body-weight gain depression at excess lysine and perhaps other amino acid intakes should be borne in mind when designing experimental diets and in the interpretation of data, particularly by the Reading model. This subject is discussed later.

Experiment 8

Objective

To assess the lysine response of the 15- to 18-week-old male and female turkeys.

Materials and Methods

As females mature earlier than males, and will therefore commence to lay down body fat earlier, the lysine requirements of the sexes might be expected to diverge with increasing age. For the 15- to 18-week age period therefore both sexes of turkey were used. As this doubled the number of experimental units it was necessary to use a different experimental design to that used in experiments 3 to 7. Instead of 4 experimental rooms, it was necessary to combine the two outside rooms as one experimental area, and the two inner rooms as another. The similar 8 pens which constituted an experimental block within each of the two rooms were treated as an experimental block of 16 pens within the experimental area, within which the 8 diets and the 2 sexes were allocated at random such that each sex received each diet. Because of the size of the males, only one bird was allocated to each pen. The experiment was therefore a 96 pen factorial experiment consisting of 8 treatments x 2 area x 3 blocks x 2 sexes (6 replicates of each sex on each treatment). It was also intended to repeat the experiment provided that no problems emerged.

Males and females of the same strain as previously (BUT 6 Female Line Cross) were used. Prior to the experiment, they were reared on a standard feed programme consisting of 280g protein and 11.9 MJ ME/kg from 0 to 4 weeks, 250g/kg protein and 12.0 MJ ME/kg from 4 to 8 weeks, 220g and 12.0 MJ ME/kg from 8 to 12 weeks, and 180g and 12.1 MJ ME/kg after 12 weeks, and had achieved normal growth rates.

They were moved into their pens in the experimental house at Kinnerton Farm at 14 weeks 4 days and fed a commercial diet consisting of 180g/kg and 12.1 MJ ME/kg until the start of the experiment at 15 weeks of age. The birds of each sex used were selected from within larger flocks to be of similar weight close to the mean weight of the respective flock. The birds were weighed at 15 weeks and 18 weeks and food intake recorded. Any pens in which a bird died were omitted from the statistical analysis as were any obviously sick birds. One pen contained a male which wasted large quantities of food by flicking it out of the trough. Not all of this could be collected so data from this pen were omitted from the analysis.

Experiments 6 and 7 indicated that for 15- to 18-week-old males, three lysine concentrations between 6 and 11g/kg would be required with the other diets containing less than 6g/kg to the lowest level of lysine that could be formulated using normal ingredients. Using normal ingredients, it proved difficult to formulate to a concentration as low as 2g/kg. As it was anticipated that a level as low as this would be necessary, particularly as it was hoped that these diets might also be used for 18- to 21-week-old turkeys, it was decided to allow the use of an abnormal ingredient, ground barley straw, in the formulation of the basal mixture to allow a level of 2g lysine/kg to be achieved. The formulation of the basal mixture C together with the Summit mixture C (11.0g lysine/kg) from which the eight diets were produced by combining in differing proportions (Appendix Table 4), are shown in Appendix Tables 5, 6, 7 and 8.

Results

Three pens of females and two pens of males were omitted from the statistical analysis because of mortality, morbidity or food wastage, and missing plots were used instead; data are summarised in Tables 33 and 34.

TABLE 33 — **RESPONSE OF 15 TO 18-WEEK-OLD MALE AND FEMALE TURKEYS TO LYSINE (EXPERIMENT 8)**

a) Males

DIET NO	LYSINE CONCENTRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	11.0	96.8	460.3	0.2109	5.063	19.2
2	8.5	84.1	452.4	0.1848	3.845	21.7
3	6.0	88.1	460.3	0.1889	2.762	31.5
4	5.0	80.2	457.9	0.1752	2.291	35.0
5	4.0	56.8	414.7	0.1369	1.636	34.4
6	3.0	69.8	446.8	0.1555	1.340	51.8
7	2.0	42.1	424.6	0.0988	0.849	49.4
8	3.0	57.1	412.7	0.1358	1.238	45.3
SE		10.8	31.1	0.0201	0.142	4.4

THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 6 REPLICATES OF 1 BIRDS EACH

READING MODEL ANALYSIS

15 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE /kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)
7.785	8.517	88.5	22.23	0.0019

TABLE 34	RESPONSE OF 15 TO 18-WEEK-OLD MALE AND FEMALE TURKEYS TO LYSINE (EXPERIMENT 8)					
b) Females						
DIET NO	LYSINE CONCEN-TRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	11.0	62.7	327.0	0.1926	3.597	17.5
2	8.5	51.6	310.3	0.1661	2.638	19.5
3	6.0	70.6	354.6	0.2042	2.127	34.2
4	5.0	61.1	368.3	0.1666	1.841	33.3
5	4.0	66.7	373.8	0.1813	1.495	45.3
6	3.0	54.0	392.9	0.1377	1.179	45.9
7	2.0	46.8	374.6	0.1258	0.749	62.9
8	3.0	47.6	361.9	0.1326	1.086	44.2
SE		6.9	29.5	0.0180	0.154	4.9
THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 6 REPLICATES OF 1 BIRDS EACH						
READING MODEL ANALYSIS						
15 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE /kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)		
5.158	5.775	62.2	19.65	0.0032		

This was the third experiment involving 15- to 18-week old males. In the previous two experiments, 6 and 7, the slope (1/a) was based on only one or two data points, whereas in this experiment six data points fell on the slope, indicating the correct choice of lysine concentrations in the experimental diets. The a value indicated for males by this experiment was higher than in the two previous experiments i.e. 22.23 compared with 18.26 and 18.88 and conversely the b value lower i.e. k0.0019 compared with 0.0435 and 0.0503. As the values from experiment 8 are based on 6 data points, these should be the more reliable estimates.

Lysine input and body-weight gain output predictions derived from the Reading model (Appendix Tables 20 and 21) are plotted against observed results in Figures 23 and 24. The lower body-weight gain achieved on diet 8, the diet containing added L-lysine HCl compared to the diet with the same concentration of Lysine (diet 6) is explained by the lower food intake on diet 8, resulting in lower lysine intakes. Why food intake was reduced

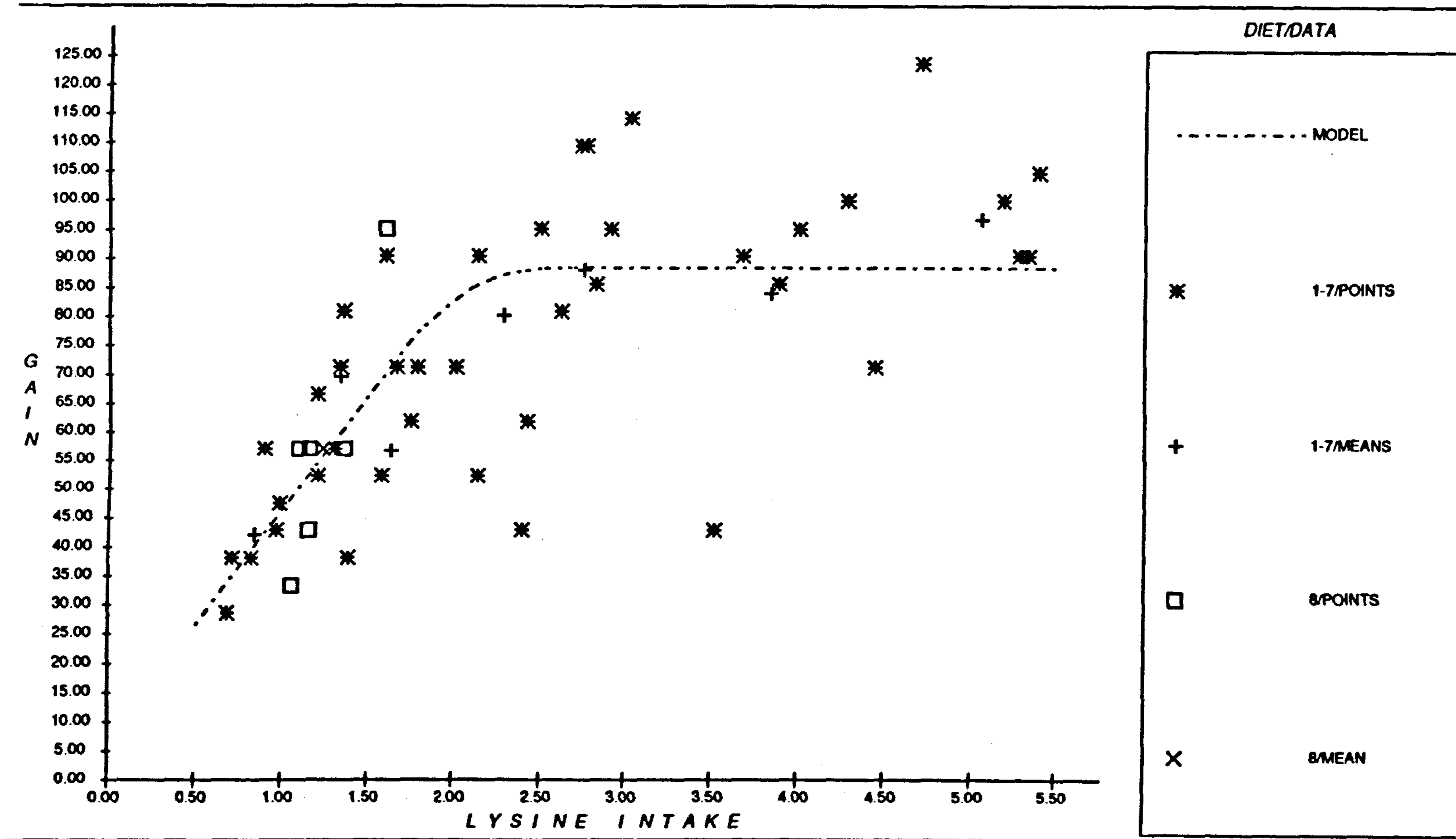

FIGURE 23. EXPERIMENT 8. 15 TO 18 WEEKS - MALES, LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

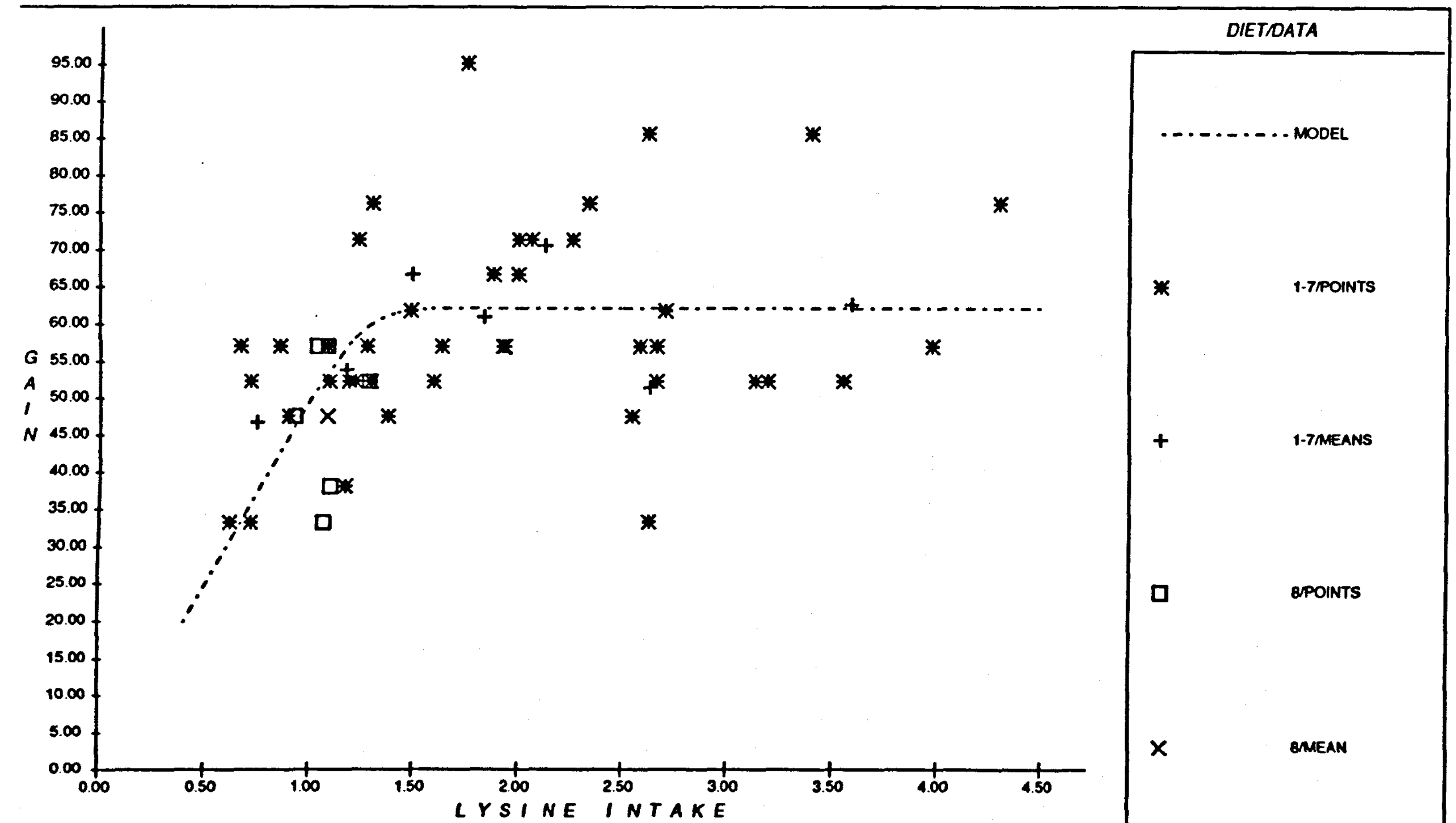

FIGURE 24. EXPERIMENT 8. 15 TO 18 WEEKS - FEMALES, LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

is not known. Lysine intakes were increased above those of diet 7 and a growth response seen.

It will be seen in Tables 33 and 34 and Figure 25 that there was a noticeable difference in the response of the two sexes. An obvious difference expected was in maximum body-weight gain. The Reading model analysis indicates a maximum body-weight gain for the males of 88.5g and for the females of only 62.2 g. The Reading model analysis indicated the grams lysine required to achieve 1 kilogram body-weight gain (a value) appeared to be was slightly less for females than males, i.e. 19.65 compared with 22.23. This may reflect differences in the composition of the body-weight gain between the sexes, with more body fat being laid down in females than in males. Unlike the muscle, body fat does not contain lysine so that more weight gain that does not require lysine is erroneously ascribed to increments in lysine intake in the case of females. The lower a value for females, together with their increased requirement for ME to lay down body fat resulted in a lower indicated lysine requirement per MJ of ME for the females (0.360g compared to 0.487g for males) using data in Appendix Tables 20 and 21 as outlined earlier.

The lower requirement for females resulted in body-weight gain depression on the higher lysine diets as seen in males in experiments 6 and 7. Also as in experiments 6 and 7, food intake was depressed on the two highest lysine diets with the result that the body-weight gain had a close relationship with ME intake rather than lysine intake, indicating again that body fat differences may be involved in the body-weight gain differences.

In view of the small number of birds of each sex on each diet, it was considered useful to repeat the experiment.

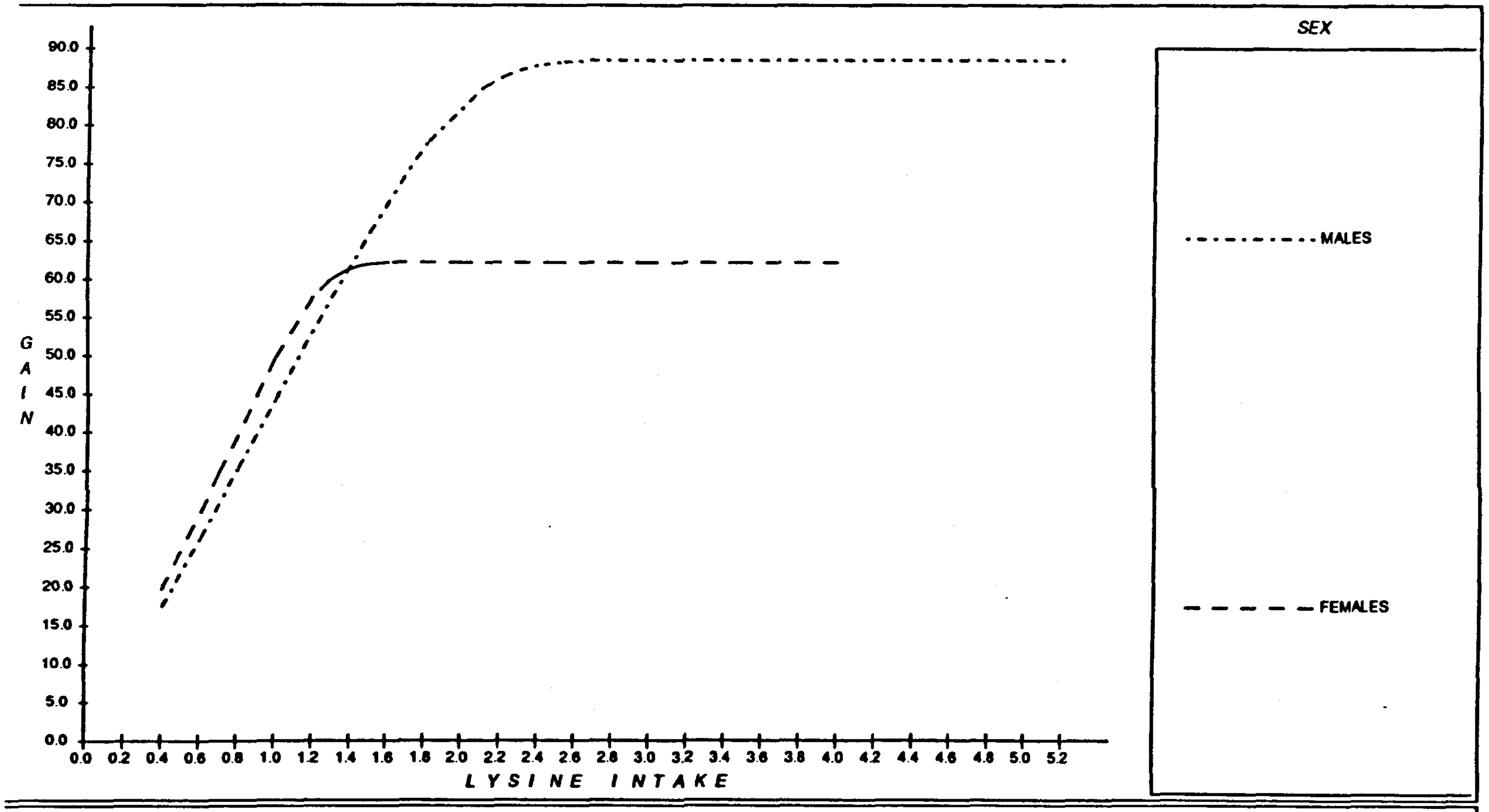

FIGURE 25. READING MODEL PREDICTIONS FOR LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d) FOR MALE AND FEMALE TURKEYS IN EXPERIMENT 8 (15 TO 18 WEEKS)

Experiment 9

Objective

To repeat experiment 8 to confirm the lysine response of the 15- to 18-week-old male and female turkeys.

Materials and Methods

The same procedures and diets as used in experiment 8 were used in this experiment. This experiment was carried out in March whereas experiment 8 was carried out in January so the environmental temperatures will have been higher in experiment 9 than in experiment 8.

Results

Missing plots were not necessary for any females and only for two males; data are summarised in Tables 35 and 36.

TABLE 35	RESPONSE OF 15 TO 18-WEEK-OLD MALE AND FEMALE TURKEYS TO LYSINE (EXPERIMENT 9)

b) Males

DIET NO	LYSINE CONCEN-TRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	11.0	99.2	403.5	0.2464	4.435	22.4
2	8.5	100.8	391.3	0.2566	3.326	30.2
3	6.0	99.4	420.1	0.2289	2.531	36.4
4	5.0	59.5	351.6	0.1657	1.758	33.1
5	4.0	58.7	354.8	0.1640	1.419	41.0
6	3.0	50.5	357.8	0.1367	1.093	45.8
7	2.0	32.5	319.0	0.0999	0.638	50.0
8	3.0	51.6	354.0	0.1428	1.062	47.6
SE		12.1	23.1	0.0268	0.121	7.2

THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 6 REPLICATES OF 1 BIRDS EACH

READING MODEL ANALYSIS

15 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE /kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)
8.249	8.949	102.7	23.67	0.0022

TABLE 36	RESPONSE OF 15 TO 18-WEEK-OLD MALE AND FEMALE TURKEYS TO LYSINE (EXPERIMENT 9)

b) Females

DIET NO	LYSINE CONCEN-TRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	11.0	64.7	258.2	0.2546	2.787	22.4
2	8.5	78.6	266.7	0.2919	2.267	34.3
3	6.0	65.9	260.3	0.2523	1.562	42.1
4	5.0	73.5	277.7	0.2623	1.390	52.3
5	4.0	74.6	296.0	0.2525	1.184	63.1
6	3.0	57.9	288.1	0.2006	0.864	66.9
7	2.0	55.6	269.8	0.2110	0.540	105.5
8	3.0	53.2	242.1	0.2160	0.726	72.0
SE		8.4	20.1	0.0254	0.102	6.4

THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 6 REPLICATES OF 1 BIRDS EACH

READING MODEL ANALYSIS

15 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE /kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)
5.221	5.913	71.8	12.92	0.0006

The Reading model was used to analyse the data as previously described. Despite the fact that the same strain of turkey was used in both experiments, the maximum body-weight gain achieved by both males and females in experiment 9 was higher than that achieved in experiment 8, i.e. 102.7g compared with 88.5g for males and 71.8g compared with 62.2g for females. The body weights at the start of the experiment were higher in experiment 9 than those in experiment 8 which may have been a factor involved in the difference in body-weight gain.

When the lysine input and body-weight gain output predictions derived from the Reading model (Appendix tables 35 and 36) were plotted with observed results (Figures 26 and 27), it was apparent that there was a good fit between predicted and observed for males and less so for females. As in previous experiments using birds of this age (experiments 6, 7 and 8), the replicates falling on the plateau section of the response curve show a wide variation in body-weight gain, reflecting probable difference in ME intake and fat deposition already discussed in experiments 6 and 7.

While the response for males shows an ideal distribution of treatment means with three on the plateau and the rest on the incremental section of the curve, the females because of their apparent lower lysine requirement at this age, have the reverse distribution with insufficient treatments falling on the incremental section for the slope to be assessed accurately. The use of individual replicates does improve the situation. Figure 28 compares the Reading model predictions for lysine intakes and body-weight gain for experiments 8 and 9. The males show very similar response slopes with differing maximum body-weight gains. The two groups of males also differed markedly in their initial 15-week body weights, so the maximum body-weight gains may be a reflection of the stage of the growth curve that the birds had reached, i.e. although both groups were 15-weeks-old, the heavier group (experiment 9) was at a later stage in its growth curve than the lighter group and so had a higher potential maximum body-weight gain. At an even later stage in the growth curve, the reverse would be the case, i.e. potential maximum body-weight gains reducing with age. The females in the two experiments show a large difference with

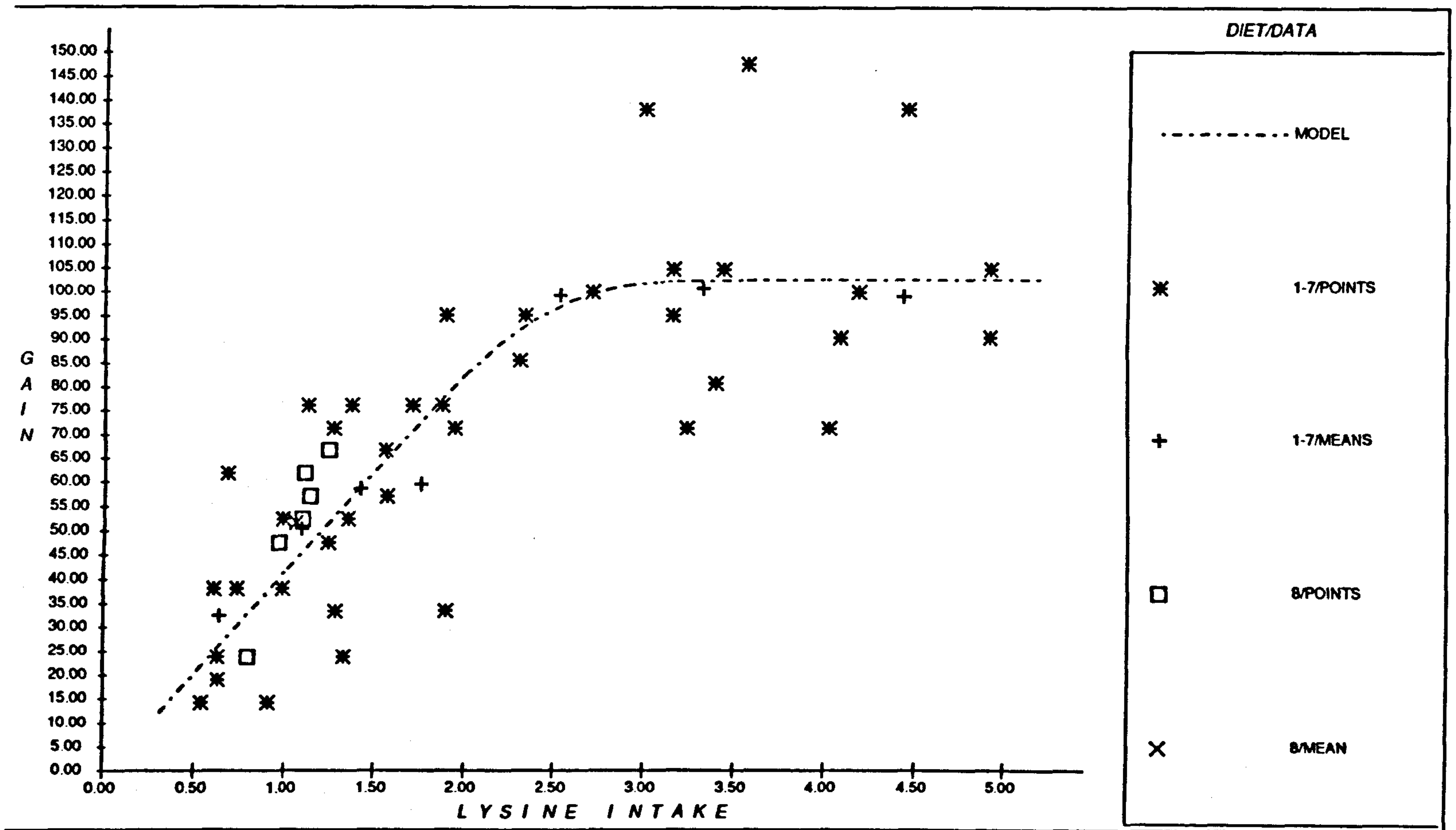

FIGURE 26. EXPERIMENT 9. 15 TO 18 WEEKS - MALES, LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

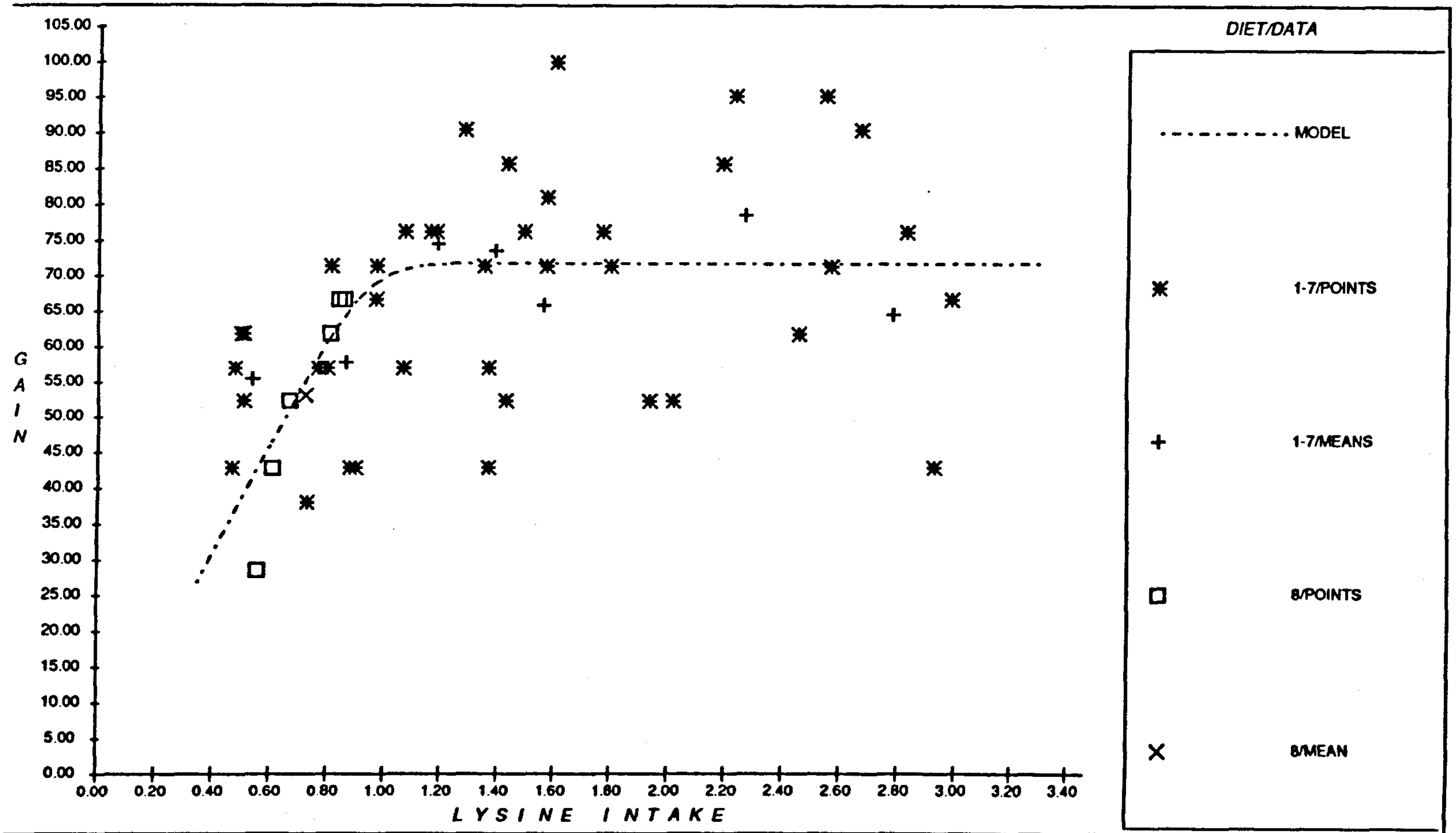

FIGURE 27. EXPERIMENT 9. 15 TO 18 WEEKS - FEMALES,
LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

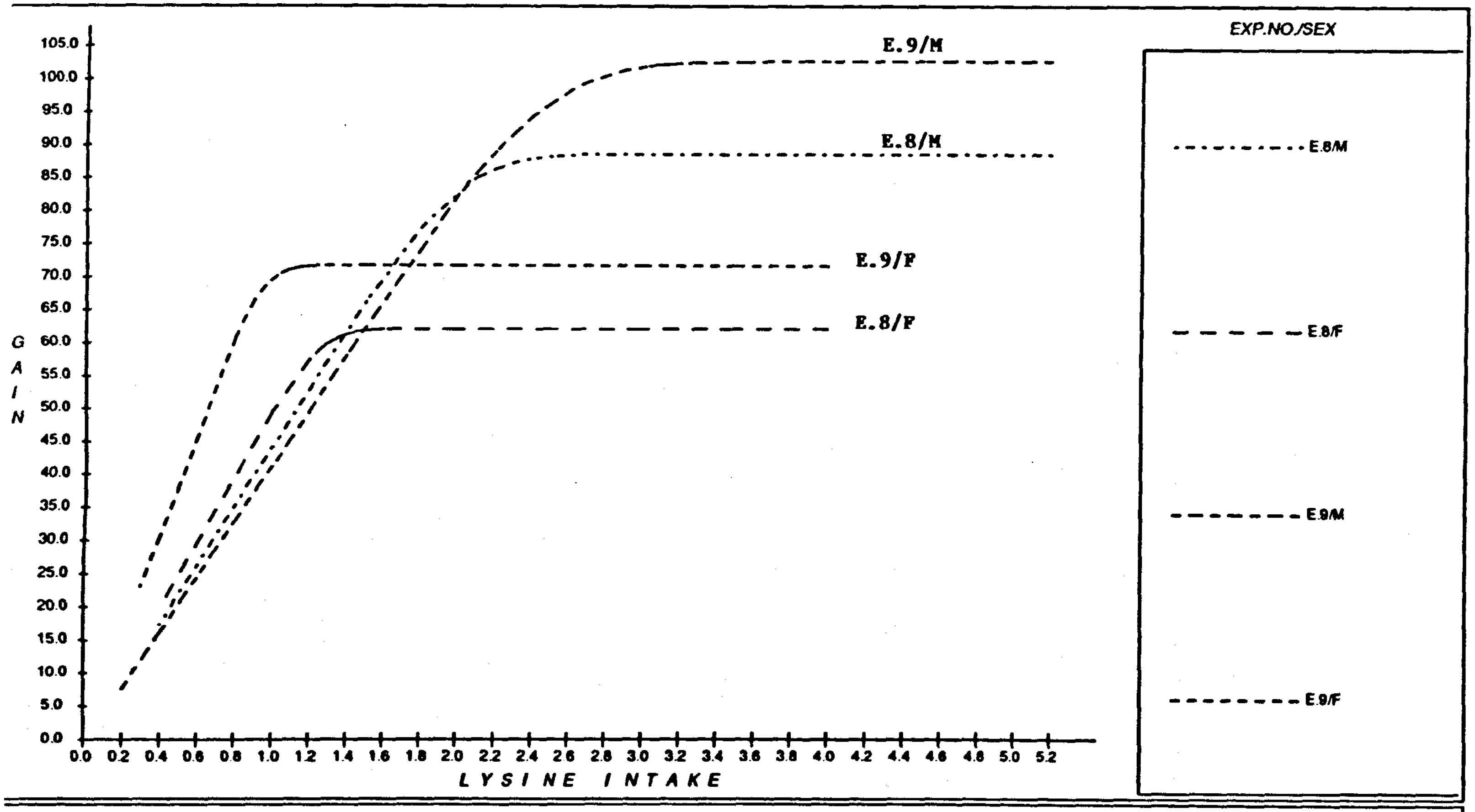

FIGURE 28. READING MODEL PREDICTIONS FOR LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d) FOR MALE(M) AND FEMALE(F) TURKEYS IN EXPERIMENTS(E) 8 AND 9 (15 TO 18 WEEKS)

differing response slopes and a values which may be a reflection of the quality of the data with insufficient data points falling on the incremental section of the curve. The predictions would indicate a greater body-weight gain per gram of lysine with females than males. This could be expected at this age as the females will be depositing more body fat per unit of body-weight gain than the males which are later maturing.

The differences in the maximum body-weight gains between the experiments could also be the result of differences in body fat deposition. It may be that in experiment 8 during January, there was less surplus metabolisable energy for body fat production because of the elevated maintenance requirement for energy, resulting from the lower ambient temperatures. In March, when experiment 9 was carried out, maintenance requirements would have been less. It would obviously have been very desirable in this situation to separate body-weight gain into protein, fat and skeletal tissue. However, it is prohibitively expensive both in terms of labour and lost income from carcasses to carry out this analysis of large turkeys. Its importance however should be realised and in future, workers should investigate ways of overcoming the problem. Even analysis of a small sample of birds could be indicative and help understanding of differences seen.

If differences between body-fat levels may be present between experiments, it is even more likely that such differences exist between treatments within an experiment. Differences between treatments on the incremental (slope) part of the response curve will be expressed in the coefficient a. Treatments falling on the plateau section of the response curve may also vary in body fat and could help to explain the differences seen in this section of the response curve already discussed.

Ignoring experiments 6 and 7 where the slope (1/a) was based on only two data points, the a and b values for 15 to 18 week-old male turkeys can be assessed with some confidence to be around the mean of the values for experiments 8 and 9 i.e. 22.95 and 0.0020 respectively. These values are very similar to those for 9 to 12 week old male turkeys in experiment 5, i.e. 22.91 and 0.0040.

The a and b values for the females, as already discussed, show variations between the experiments, but with a values of 19.65 and 12.92 and b values of 0.0032 and 0.0006 for experiments 8 and 9 respectively, the a values were noticeably lower and the b values similar for the females when compared with the males. This results in different indicated g lysine per MJ ME for maximum body-weight gain for the two sexes using data from Appendix Tables 20, 21, 22 and 23 as outlined previously. For the males the indicated values from experiments 8 and 9 were 0.487g and 0.778g respectively with a mean of 0.633 g, compared with 0.360g and 0.359g in the females. The two sexes clearly have different diet requirements at this age and should be reared and fed separately.

Experiment 10

Objective

To assess the lysine response of the 17- to 20-week-old male and female turkeys.

Materials and Methods

The original intention was to assess the lysine response of the 18- to 21-week-old male and female turkeys. The diets available for the experiment were the same formulation and mixing as used in experiments 8 and 9. In view of the response curve for females seen in the 15-to- 18-week period and the need for at least three data points on the slope section of the response curve, it was decided to advance the age period for the experiment by one week. Even with this advancement, it was still likely that fewer data points would fall on the "slope" than was desirable.

Males and females of the same strain of turkey as used previously (BUT 6 Female Line Cross) were used. Prior to the experiment, they were reared on a standard feed programme which was the same as that used in experiment 8 and had achieved normal growth rates. They were moved into their pens in the experimental house at Kinnerton

Farm at 16 weeks 4 days and fed a standard diet containing 180g/kg protein and 12.1 MJ ME/kg until the start of the experiment at 17 weeks of age. The experimental design and the eight diets fed were identical to those used in experiments 8 and 9. The birds were weighed at 17 weeks and 20 weeks of age and food intake recorded.

Results

Only one female died in the experiment for which a missing plot technique was used; data are summarised in Tables 37 and 38.

TABLE 37 RESPONSE OF 15 TO 20-WEEK-OLD MALE AND FEMALE TURKEYS TO LYSINE (EXPERIMENT 10)

a) Males

DIET NO	LYSINE CONCEN-TRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	11.0	112.7	483.3	0.2341	5.317	21.28
2	8.5	111.9	519.8	0.2128	4.419	25.04
3	6.0	118.3	488.1	0.2423	2.929	40.38
4	5.0	99.2	469.0	0.2118	2.345	42.36
5	4.0	85.7	443.7	0.1937	1.775	48.48
6	3.0	70.6	432.5	0.1652	1.298	55.06
7	2.0	55.6	396.8	0.1402	0.794	70.08
8	3.0	52.4	383.3	0.1374	1.150	45.79
SE		12.1	32.0	0.0223	0.187	4.67

THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 6 REPLICATES OF 1 BIRDS EACH

READING MODEL ANALYSIS

17 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE /kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)
9.506	10.402	111.8	19.62	0.0019

TABLE 38	RESPONSE OF 17 TO 20-WEEK-OLD MALE AND FEMALE TURKEYS TO LYSINE (EXPERIMENT 10)					
b) Females						
DIET NO	LYSINE CONCENTRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	11.0	81.0	392.9	0.2053	4.321	18.66
2	8.5	76.2	374.6	0.2041	3.184	24.01
3	6.0	77.8	403.2	0.1926	2.419	32.10
4	5.0	67.5	360.3	0.1862	1.802	37.24
5	4.0	83.3	427.0	0.1967	1.708	49.19
6	3.0	58.7	373.8	0.1579	1.121	52.64
7	2.0	57.9	385.7	0.1493	0.771	74.63
8	3.0	68.8	379.9	0.1805	1.124	60.14
SE		6.7	22.0	0.0143	0.116	4.42
THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 6 REPLICATES OF 1 BIRDS EACH						
READING MODEL ANALYSIS						
17 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE /kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)		
5.998	6.740	76.9	16.18	0.0024		

Lysine input and body-weight gain output predictions derived from the Reading model (Appendix Tables 24 and 25) when plotted against observed results (Figures 29 and 30) show a good response curve and fit for the males, with the exception of the added free lysine treatment (diet 8) on which birds did not achieve the body-weight gain of those on diet 6 with the equivalent lysine content. The food intake of males on diet 8 was also lower than that of males on diet 6, resulting in differences in lysine intakes. The body-weight gains achieved by males on diet 8 were in most cases lower than those predicted by the Reading model for the lysine intakes of those birds. The results for the females were less satisfactory in that less data fell on the incremental section of the curve. There must therefore be reservations about any conclusions drawn from the data for females. The data in Appendix Tables 24 and 25 would indicate the lysine requirement for females was lower in relation to the ME requirement as evidenced by the g lysine per MJ ME required for maximum body-weight gain (ΔW_{MAX}), i.e. 0.310 for females and 0.472 for males. The a values would indicate that the tissues constituting the body-weight gain are

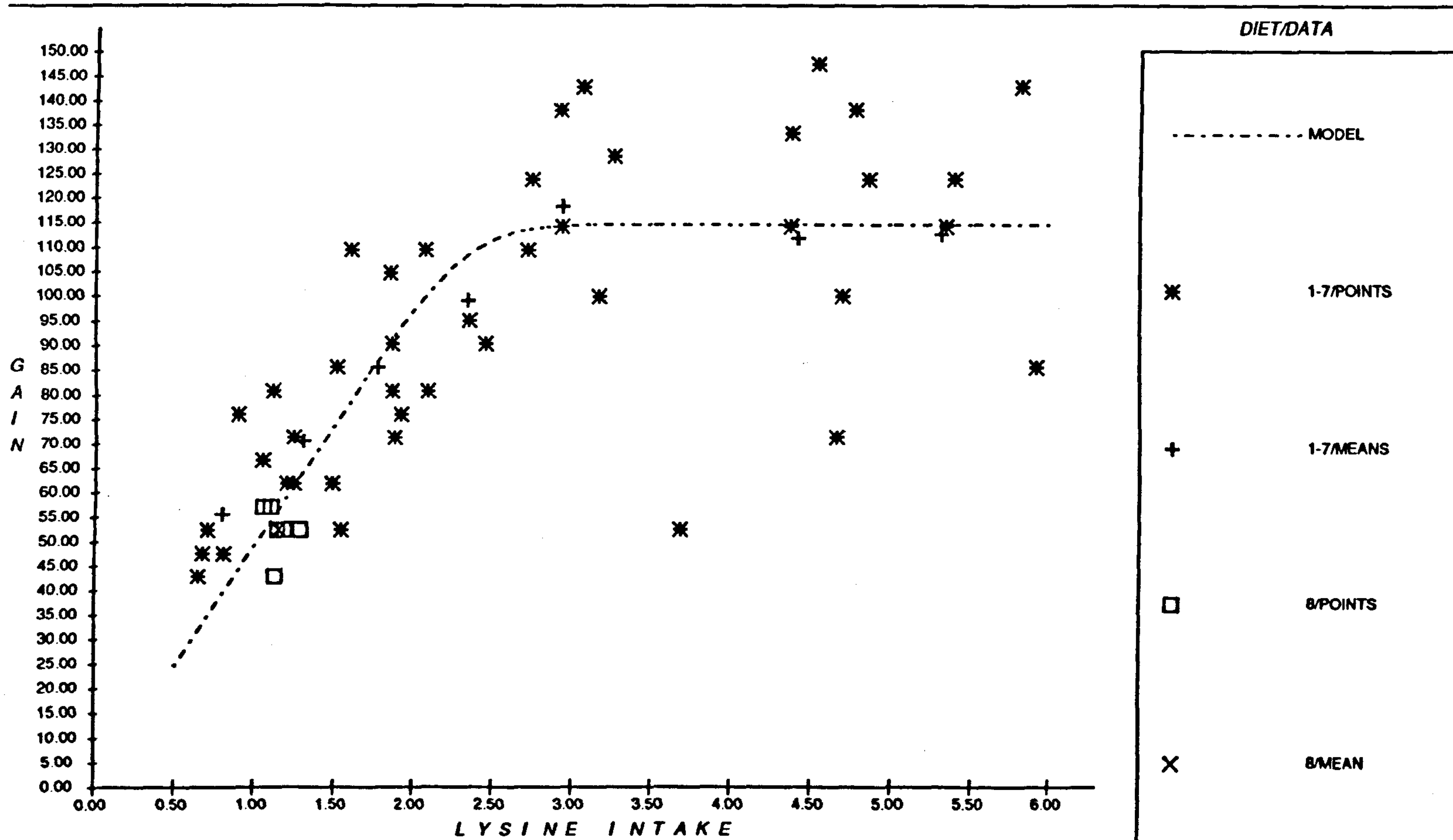

FIGURE 29. EXPERIMENT 10. 17 TO 20 WEEKS - MALES,
LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

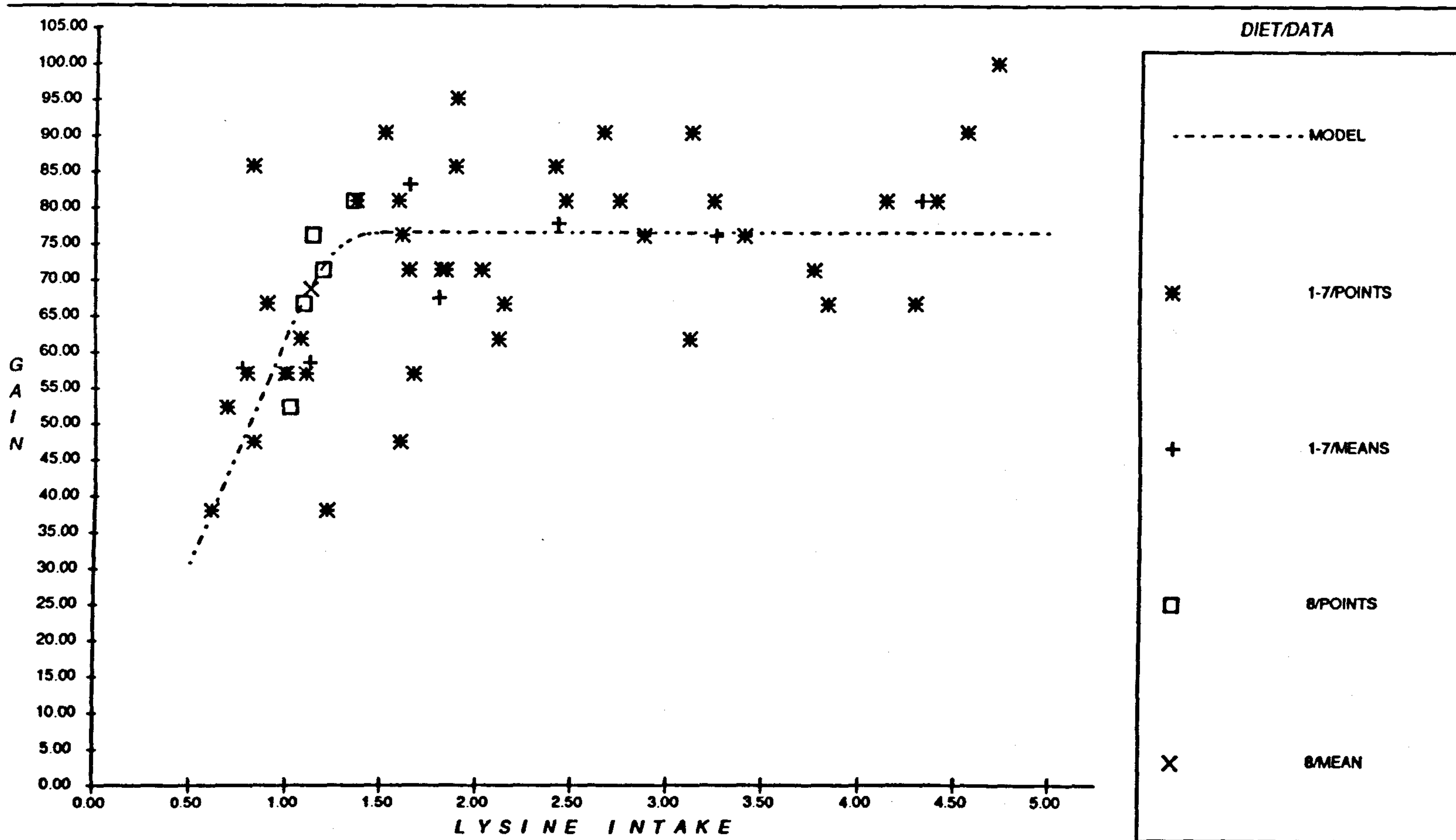

FIGURE 30. EXPERIMENT 10.17 TO 20 WEEKS - FEMALES, LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

different between the sexes at this age (*a* for males was 19.62 and 16.18 for females). Thus at lysine intakes which were severely limiting for the male, the females, presumably because they were laying down body fat and had a smaller body weight to maintain, produced noticeably more body-weight gain. For example Figure 31 would indicate that for a daily lysine intake of 1 gram, a 17 to 20 week old female turkey will produce a daily body-weight gain of 65g while on the same intake a male of the same age would only produce 50g per day. The males have a higher maximum body-weight gain and so require more lysine per day in total to achieve their maximum body-weight gain.

Although in the experiments involving 15- to 18- week-old birds, diet 8, containing free lysine showed a response compared with the unsupplemented diet for males but not females, the same mixes of diet in this experiment showed a response with females but not males. At the outset it was anticipated, because of the small number of birds on each treatment, that the variation present could create questionable results. Sufficient quantities of each diet had however been made to repeat the experiment. The results indicate the desirability of doing this.

Experiment 11

Objective

To repeat experiment 10 which assessed the lysine response of the 17-to 20-week old male and female turkeys.

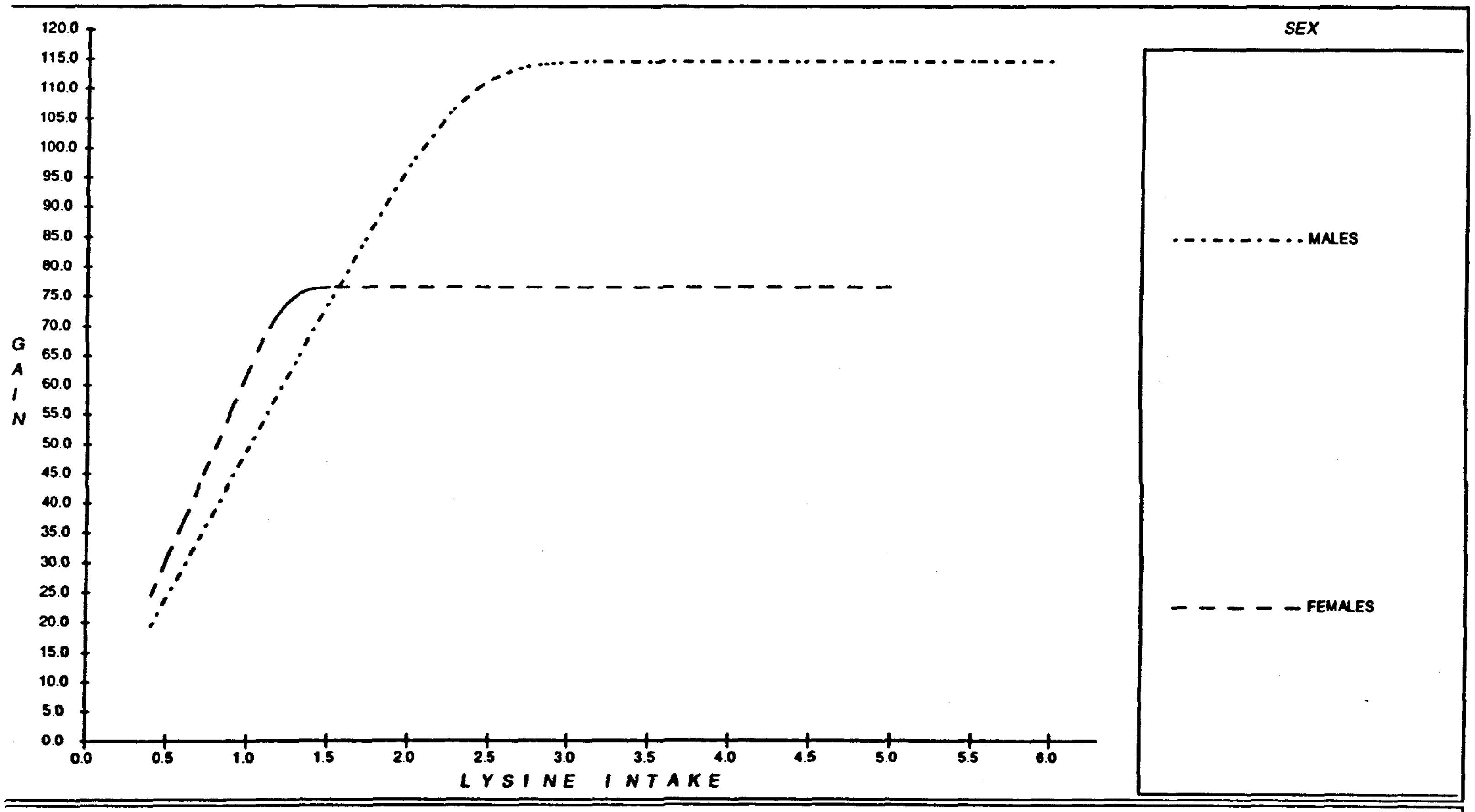

FIGURE 31. READING MODEL PREDICTIONS FOR LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d) FOR MALE AND FEMALE TURKEYS IN EXPERIMENT 10 (17 TO 20 WEEKS)

Materials and Methods

The same procedures and diets as used in experiment 10 were used in this experiment. This experiment was carried out at the end of April and early May whereas experiment 10 was carried out from the middle of February to the start of March when the environmental temperature was lower.

Results

Four females and one male died during the experiment and the missing plot technique used in the statistical analysis; data are summarised in Table 39 and 40 and illustrated in Figures 32 and 33.

As in some previous experiments, the use of individual replicate data in the Reading model produced prediction response lines for both males and females which did not fit the data satisfactorily, interpreting the slope of the very low lysine intake data points as that of the total experiment. Using treatment mean data produced more realistic a and b values and prediction lines which fitted the total data more satisfactorily. It will be seen that for both males and females, the values are very similar to those found in experiment 10, as shown below:

		a VALUE	b VALUE
MALES	EXPERIMENT 10	19.62	0.0019
	EXPERIMENT 11	20.48	0.0020
FEMALES	EXPERIMENT 10	16.18	0.0024
	EXPERIMENT 11	15.91	0.0012

TABLE 39	RESPONSE OF 17 TO 20-WEEK-OLD MALE AND FEMALE TURKEYS TO LYSINE (EXPERIMENT 11)					
a) Males						
DIET NO	LYSINE CONCEN-TRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	11.0	89.7	514.3	0.1787	5.657	16.24
2	8.5	88.9	438.9	0.1987	3.731	23.37
3	6.0	98.4	462.9	0.2206	2.808	35.04
4	5.0	108.5	454.7	0.2402	2.263	47.95
5	4.0	74.6	428.6	0.1740	1.753	42.56
6	3.0	70.5	476.5	0.1477	1.418	49.72
7	2.0	46.8	403.2	0.1170	0.806	58.48
8	3.0	54.0	145.1	0.1301	1.245	43.37
SE		11.9	30.8	0.0252	0.208	5.51
THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 6 REPLICATES OF 1 BIRDS EACH						
READING MODEL ANALYSIS						
17 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE/kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)		
10.310	11.125	95.5	20.48	0.0020		

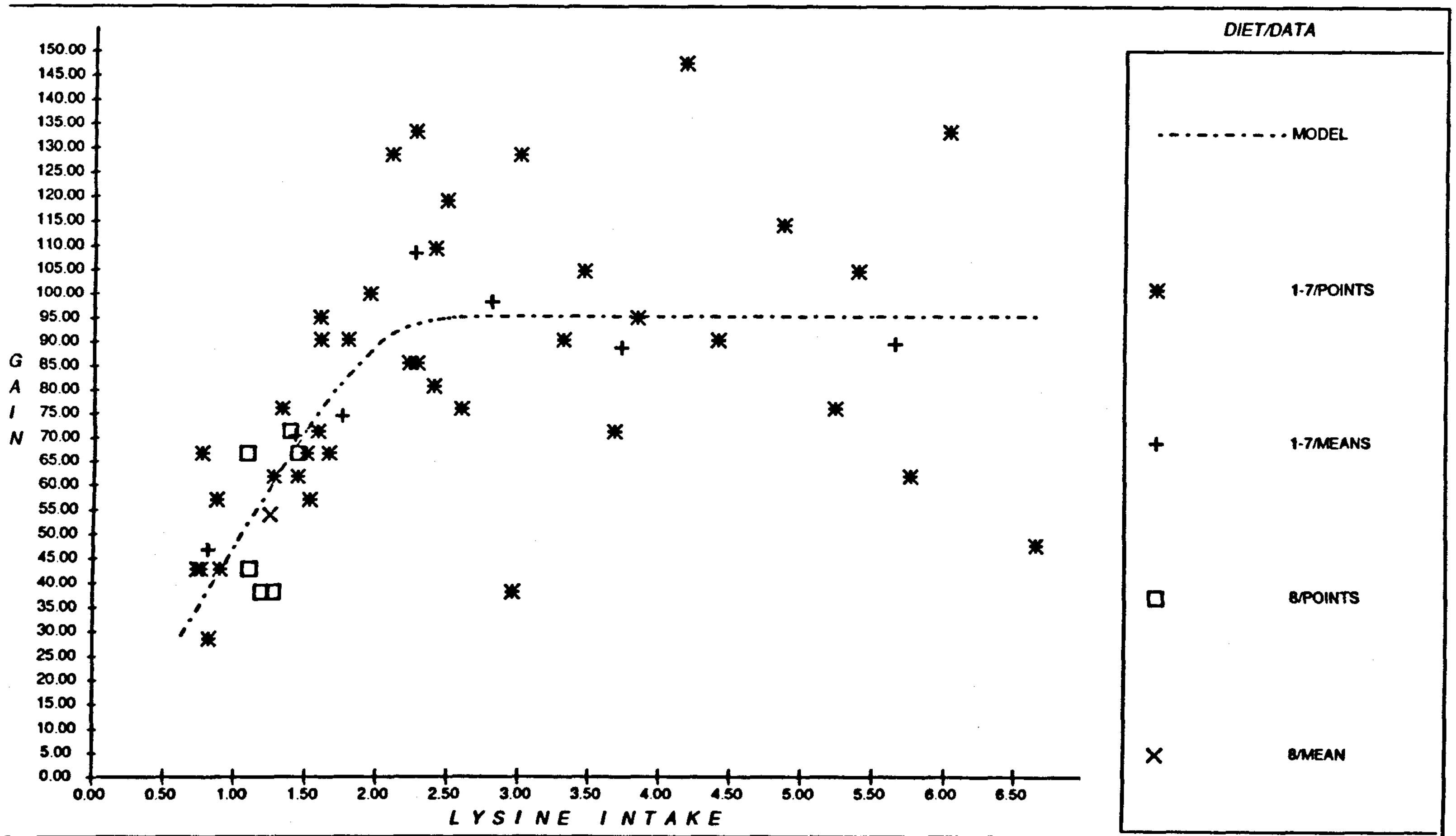

FIGURE 32. EXPERIMENT 11. 17 TO 20 WEEKS - MALES,
LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

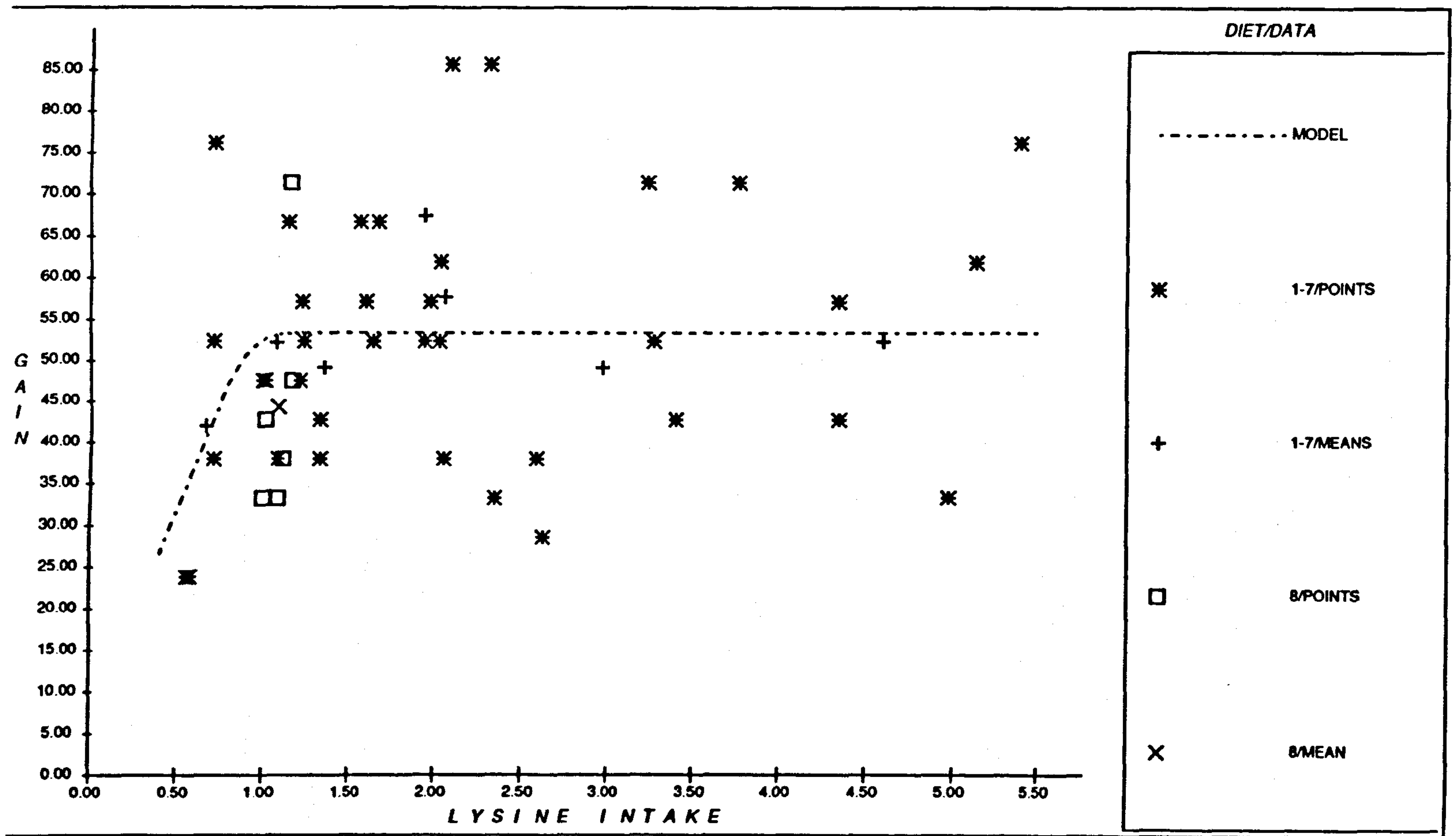

FIGURE 33. EXPERIMENT 11. 17 TO 20 WEEKS - FEMALES, LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

TABLE 40	RESPONSE OF 17 TO 20-WEEK-OLD MALE AND FEMALE TURKEYS TO LYSINE (EXPERIMENT 11)					
b) Females						
DIET NO	LYSINE CONCENTRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	11.0	52.4	418.3	0.1255	4.601	11.41
2	8.5	49.2	350.0	0.1371	2.975	16.51
3	6.0	57.7	344.0	0.1675	2.062	27.31
4	5.0	67.4	385.9	0.1750	1.938	34.64
5	4.0	49.2	339.7	0.1443	1.359	36.08
6	3.0	52.2	369.8	0.1417	1.076	47.54
7	2.0	42.1	333.3	0.1233	0.667	61.67
8	3.0	44.4	363.5	0.1214	1.090	40.48
SE		7.4	26.7	0.0157	0.208	5.69
THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 6 REPLICATES OF 1 BIRDS EACH						
READING MODEL ANALYSIS*						
17 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE/k g BODY-WEIGHT GAIN (a)	g LYSINE TO MAINT AIN 1kg W FOR 1 day (b)		
6.783	7.358	53.4	15.91	0.0012		

* Based on analysis of treatment means.

The maximum body-weight gains (ΔW_{MAX}) achieved differed markedly between the experiments, as can be seen in Figure 34. The 17-week body weights at the start of each experiment also differed, those of experiment 10 being lower than those of experiment 11 being 9.506kg for males and 5.998kg for females in experiment 10 and 10.310kg and 6.783kg respectively in experiment 11. As in both experiments the same strain of turkey with the same genetic potential for body weight at maturity was involved, the explanation for the lower gain in experiment 11 may be that, being nearer their mature body weight and so physiologically more mature, their potential for growth rate would be lower than that for the turkeys used in experiment 10.

The apparently lower a values for females than for males in both experiments although based on poor response data are consistent with the earlier maturing of females than males. Thus deposition of fat occurs earlier in females which would have a negligible

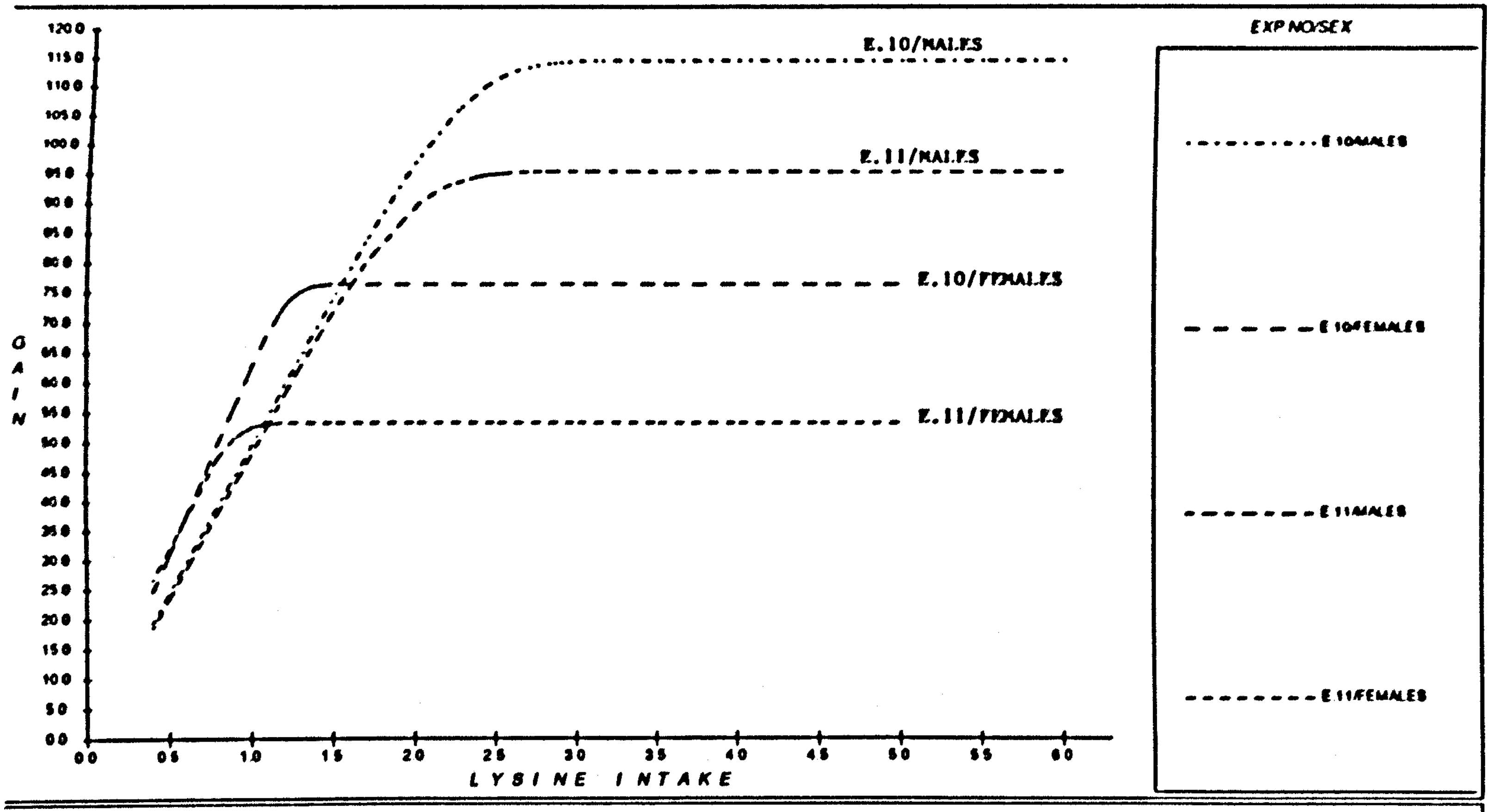

FIGURE 34. READING MODEL PREDICTIONS FOR LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d) FOR MALE AND FEMALE TURKEYS IN EXPERIMENTS(E) 10 AND 11 (17 TO 20 WEEKS)

requirement for lysine compared to the requirement for laying down muscle as explained previously.

As in previous experiments involving birds older than 15 weeks, the replicates falling on the plateau section of the response curve show a wide variation in body-weight gain, reflecting differences in ME intake and probably fat deposition discussed in experiments 6 and 7.

The relationship between predicted responses derived from the Reading model (Appendix 26 and 27) and observed results (Figures 32 and 33) show strong similarities with patterns seen in experiment 10 for males and females. One of the questions posed by the results in experiment 10 was the food intake and body-weight gain response of diet 8, which consisted of diet 7 supplemented with L-lysine HCl to equal the lysine concentration of diet 6. In experiment 10, neither the food intake or body-weight gain of the males on diet 8 equalled that of diet 6. In experiment 11, some body-weight gain response was seen with both males and females. The extent of this response was not, however, sufficient to equal the body-weight gain achieved by birds receiving diet 6.

Re-examination of the theory used to design the experimental diets for confirmation of lysine deficiency revealed a flaw when it was applied to the low-lysine series of diets for the older ages. Summit mixture C (Appendix Tables 5 and 6) and Basal mixture C (Appendix Tables 7 and 8) were both designed so that essential amino acids other than lysine would be present at concentrations at least 1.3 times greater than indicated by the "ideal" amino acid profile for this protein content. This should have ensured that lysine was the first limiting amino acid by a margin of 30%. Because of uncertainty about how many data points would fall on the slope of the response curve, the diet chosen for supplementation with added free lysine in experiments 8, 9, 10 and 11 was the diet with the lowest lysine concentration, diet 7, which contained 2g lysine/kg. Using added free lysine to increase the lysine concentration to 3g/kg in diet 8 was intended to confirm lysine deficiency by demonstrating a body-weight gain response similar to that of diet 6. By increasing the lysine concentration from 2 to 3g/kg the lysine concentration was increased by 50%. As the other amino acids had only an intended 30% safety margin, it does not seem likely that lysine was the first limiting amino acid in diet 8. The added free lysine however would allow a body-weight gain response to the extent allowed by the first limiting amino acid in reality. As some body-weight gain response was seen for both females and males, this is an indication that the response seen in the other diets was indeed due to lysine.

A further complication is that no work has been done on the arginine to lysine relationship in the diet of older turkeys. Increasing the lysine concentration by 1.5 times may have altered the relationship adversely. As this relationship may differ between the sexes at older ages, it may help to explain the variation seen in the body-weight gain response seen for diet 8 in experiments 8 to 11.

Figure 34 compares the Reading model predictions for lysine intakes and body-weight gain for Experiments 10 and 11. Experiment 11 was carried out when the outside environmental temperatures were higher than those prevailing during experiment 10. However the expected reduced food intake resulting from a lower energy requirement did not have the effect of greatly increasing the g lysine per MJ ME required for maximum body-weight gain (W_{MAX}) for the males in experiment 11, (0.533g compared with 0.526g in experiment 10). The explanation may lie in the fact that the initial 17-week body weight of the males in experiment 11 was noticeably greater than that in experiment 10 i.e. 10.31kg and 9.51kg respectively. As the males of experiment 11 were nearer their ultimate mature body weight, their expected maximum body-weight gain might be expected to be less than in experiment 10, as indeed it was, (95.5kg per bird day and 114.6g respectively). Additionally more of the body-weight gain might be expected to be fat than that of a less mature bird. Both these aspects would reduce the g lysine required per MJ ME, helping to offset the influence of high temperatures on food intake.

In the females in experiment 11, 0.291g lysine per MJ ME was apparently required for maximum body-weight gain compared with 0.305g in experiment 10. Since in experiment 11 females were also bigger than their counterparts in experiment 10 at 17 weeks and therefore more mature, the same explanation as for the males appertains.

The mean of the two experiments would indicate 0.530g and 0.298g lysine per MJ ME are required for maximum body-weight gain of males and females of this age respectively. Diets differing distinctly in protein and ME content are required by each sex during this age period.

EXPERIMENTAL SECTION B

THE INFLUENCE OF GENETICAL POTENTIAL AND PREVIOUS PLANE OF NUTRITION

The previous experimental section described investigations into the influence of the age and sex of the turkey on lysine requirements. The experiments described in this section investigated the influence on the lysine requirements of two other factors which affect body-weight gain. These are the turkey's genetic potential for body-weight gain and the turkey's previous plane of growth relative to its potential growth rate.

1. The Turkey's Potential for Body-weight Gain

In order to meet different market requirements, different types of turkey have been developed. One of the major differences is with respect to growth rate. As was illustrated in Figure 1, some strains may have the potential to grow twice as fast as other strains. The growth rate variations are such that the females of a fast growing strain may grow as quickly as males of a slower growing strain. Two important questions may be asked. First, does the genetic potential for growth rate influence the lysine response? Second, does the greater potential for growth rate improve the efficiency of lysine utilisation for growth rate? Two experiments, experiments 12 and 13 were conducted to attempt to answer these questions.

Experiment 12

Objective

To assess if the genetic potential for growth rate influences the lysine response of both sexes of two strains of turkey which differed greatly in their genetic potential for body-weight gain from 9- to 12-weeks of age.

Materials and Methods

The fast growing strain used was the BUT Strain 81, a line kept in the BUT gene pool and not used commercially. From 9 to 12 weeks, the males would be expected to gain around 125g and the females 90g per bird day. The slow-growing strain used was the BUT Strain 32, a female line used in the production of the Big 5 Female Line Cross parent hen. The males of this strain would be expected to gain around 85g and the females 60g per bird day over the 9- to 12- week age period.

Prior to the experiment the birds of both strains were reared in normal commercial housing on a standard feed programme, the same as in experiment 5, and had achieved normal growth rates. Because of transport availability, they could not be moved into their pens in the experimental house at Kinnerton Farm until 9 weeks of age. To give the birds time to settle and find the feeders which were hung on the outside of the pens, they were fed a standard diet for 4 days and the experimental period commenced at 9 weeks 4 days. Before being accepted for the experiment, the birds were selected for uniformity of body weight within each strain and sex. One bird was housed per pen.

As the experiment involved 8 diets fed to two sexes of two strains of turkey, thirty-two experimental units were involved in one block. The Kinnerton experimental house contained 4 rooms each with 24 pens. The pens within each room were allocated to three blocks according to their situation within the room. To accommodate the thirty-two experimental units, the room identities were ignored and the ninety-six pens within the house, deemed to be in three blocks of thirty-two pens. The thirty-two pens in each block consisted on eight pens in each of the four rooms in similar positions within each room. The experiment therefore consisted of 8 diets x 2 strains x 2 sexes x 3 experimental blocks.

The eight diets fed were identical formulations but a different batch mix to those used in experiment 5, involving the same age of birds. In view of the small number of birds of each strain and sex on each diet, it was anticipated that the experiment would require repeating. Sufficient of each diet was therefore produced to allow for this.

The birds were individually weighed at 9 weeks 4 days and at 12 weeks 4 days. The food consumed over the period was recorded. Any pens in which a bird died were omitted and a missing plot technique used in the statistical analysis.

Results

Of the 96 pens, three birds died and one bird had to be culled with a broken wing; data are summarised in Tables 41, 42, 43 and 44.

TABLE 41 RESPONSE OF 9 TO 12-WEEK-OLD TURKEYS OF DIFFERENT GENETIC POTENTIAL FOR GROWTH RATE (EXPERIMENT 12)

a) Large Type Males

DIET NO	LYSINE CONCENTRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	19.00	107	344.4	0.3135	6.544	16.50
2	16.50	112	361.9	0.3137	5.921	19.01
3	14.00	117	350.8	0.3374	4.911	24.10
4	11.50	123	341.3	0.3649	3.925	31.73
5	9.00	115	321.0	0.3617	2.900	40.24
6	6.5	98	317.5	0.3111	2.063	47.86
7	4.00	55	276.2	0.2004	1.105	50.09
8	11.5	117	358.1	0.3236	4.106	28.13
SE		5	22.2	0.0227	0.303	2.91

THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 3 REPLICATES OF 1 BIRD EACH

READING MODEL ANALYSIS*

9 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE/kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)
4.092	5.034	115.7	20.33	0.0061

* Based on analysis of treatment means.

TABLE 42	RESPONSE OF 9 TO 12-WEEK-OLD TURKEYS OF DIFFERENT GENETIC POTENTIAL FOR GROWTH RATE (EXPERIMENT 12)					
b) Large Type Females						
DIET NO	LYSINE CONCEN-TRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	19.00	74.6	250.8	0.2978	4.765	15367
2	16.50	76.2	254.0	0.3008	4.190	18.23
3	14.00	93.7	281.0	0.3336	3.933	23.83
4	11.50	87.3	260.3	0.3363	2.994	29.25
5	9.00	85.7	260.3	0.3287	2.343	36.52
6	6.5	76.2	249.2	0.3037	1.620	46.72
7	4.00	52.4	203.2	0.2584	0.813	64.03
8	11.5	92.1	258.7	0.3552	2.975	30.89
SE		9.0	16.8	0.0278	0.208	5.46

THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 3 REPLICATES OF 1 BIRD EACH

READING MODEL ANALYSIS

9 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE/kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)
2.975	3.742	84.6	17.99	0.006

TABLE 43	RESPONSE OF 9 TO 12-WEEK-OLD TURKEYS OF DIFFERENT GENETIC POTENTIAL FOR GROWTH RATE (EXPERIMENT 12)					
c) Small Type Males						
DIET NO	LYSINE CONCEN-TRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	19.00	71.4	276.2	0.2599	5.248	13.68
2	16.50	68.3	247.6	0.2759	4.086	16.72
3	14.00	54.0	250.8	0.2116	3.511	15.12
4	11.50	71.4	254.0	0.2808	2.921	24.41
5	9.00	76.2	265.1	0.2888	2.386	32.09
6	6.5	65.1	242.9	0.2680	1.579	41.23
7	4.00	31.8	190.5	0.1653	0.762	41.33
8	11.5	66.7	257.1	0.2579	2.957	22.43
SE		9.7	16.2	0.0317	0.153	2.57

THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 3 REPLICATES OF 1 BIRD EACH

READING MODEL ANALYSIS

9 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE/kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)
2.950	3.517	68.0	18.16	0.0531

TABLE 44	RESPONSE OF 9 TO 12-WEEK OLD TURKEYS OF DIFFERENT GENETIC POTENTIAL FOR GROWTH RATE (EXPERIMENT 12)					
d) Small Type Females						
DIET NO	LYSINE CONCEN-TRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	19.00	34.9	176.2	0.1973	3.348	10.38
2	16.50	50.8	198.4	0.2514	3.274	15.24
3	14.00	42.9	179.4	0.2366	2.511	16.90
4	11.50	61.9	201.6	0.3075	2.318	26.74
5	9.00	44.4	188.9	0.2355	1.700	26.16
6	6.5	50.8	207.9	0.2438	1.352	37.51
7	4.00	38.4	184.3	0.2108	0.714	53.82
8	11.5	57.7	189.9	0.3046	2.190	26.37
SE		7.3	9.1	0.0311	0.148	3.09
THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 3 REPLICATES OF 1 BIRD EACH						
READING MODEL ANALYSIS						
9 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE/k g BODY-WEIGHT GAIN (a)	g LYSINE TO MAINT AIN 1kg W FOR 1 day (b)		
2.108	2.635	48.6	7.800	0.1492		

Lysine input and body-weight gain output predictions derived from the Reading model (Appendix Tables 28, 29, 30 and 31) when plotted against observed results (Figures 35, 36, 37 and 38) show a large variation in the number of data points on the slope of the response between the strains and sexes. Despite the fact that in experiment 5 which investigated the same age period for males, the range of experimental diets proved almost ideal, in this experiment, most of the diets resulted in lysine consumptions greater than were required for maximum body-weight gain for all of the four types of bird. This caused growth depression at the highest levels of lysine consumption as seen in previous experiments. As a result, in each case the Reading model analysis indicated a lower level of maximum body-weight gain (ΔW_{MAX}) than achieved by birds receiving several of the diets. Although the slope (1/a) was not greatly influenced, the lower ΔW_{MAX} resulted in a lower indicated g lysine per MJ ME. The results of only the data up to and including that

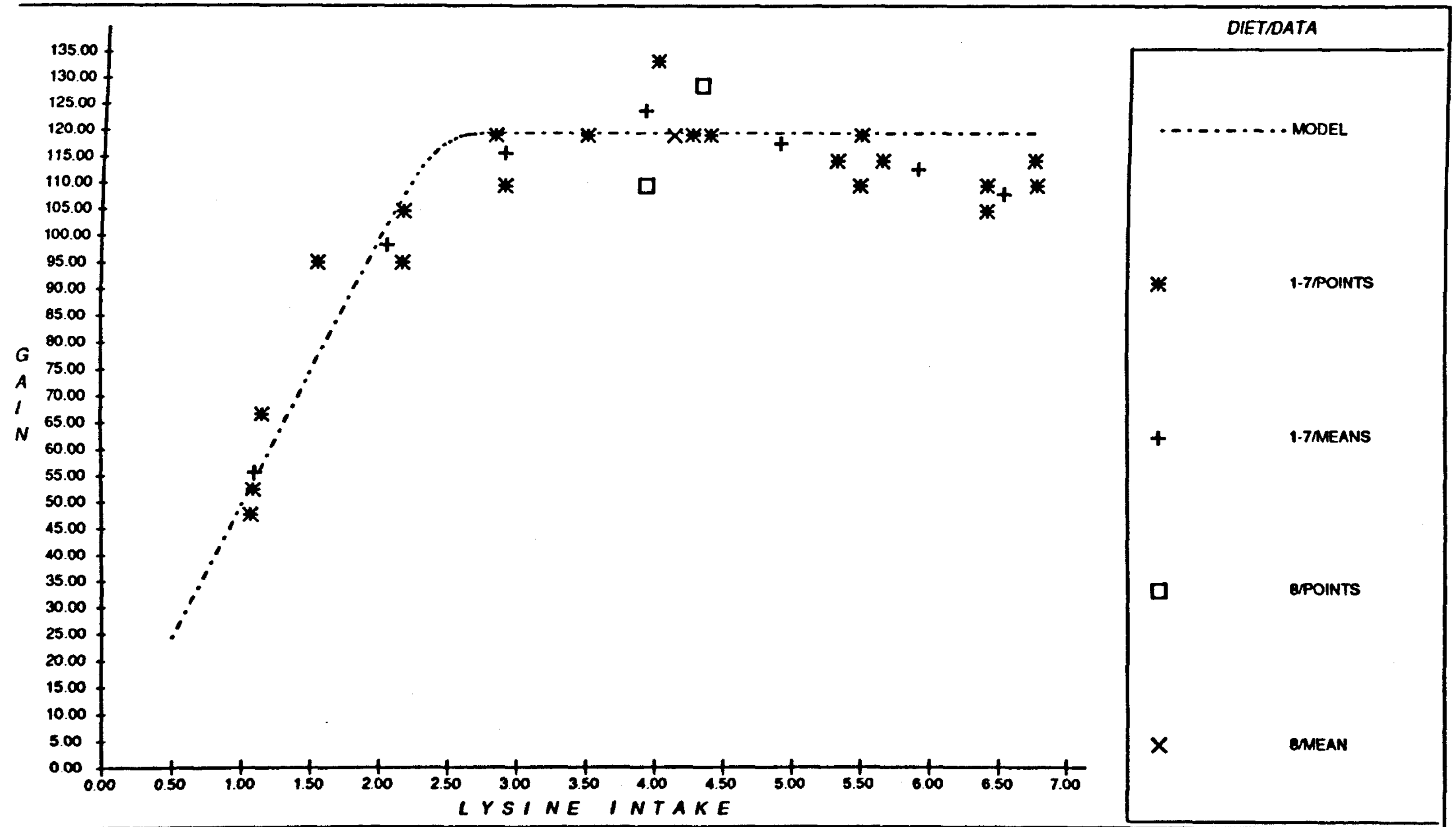

FIGURE 35. EXPERIMENT 12. 9 TO 12 WEEKS - LARGE TYPE MALES, LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

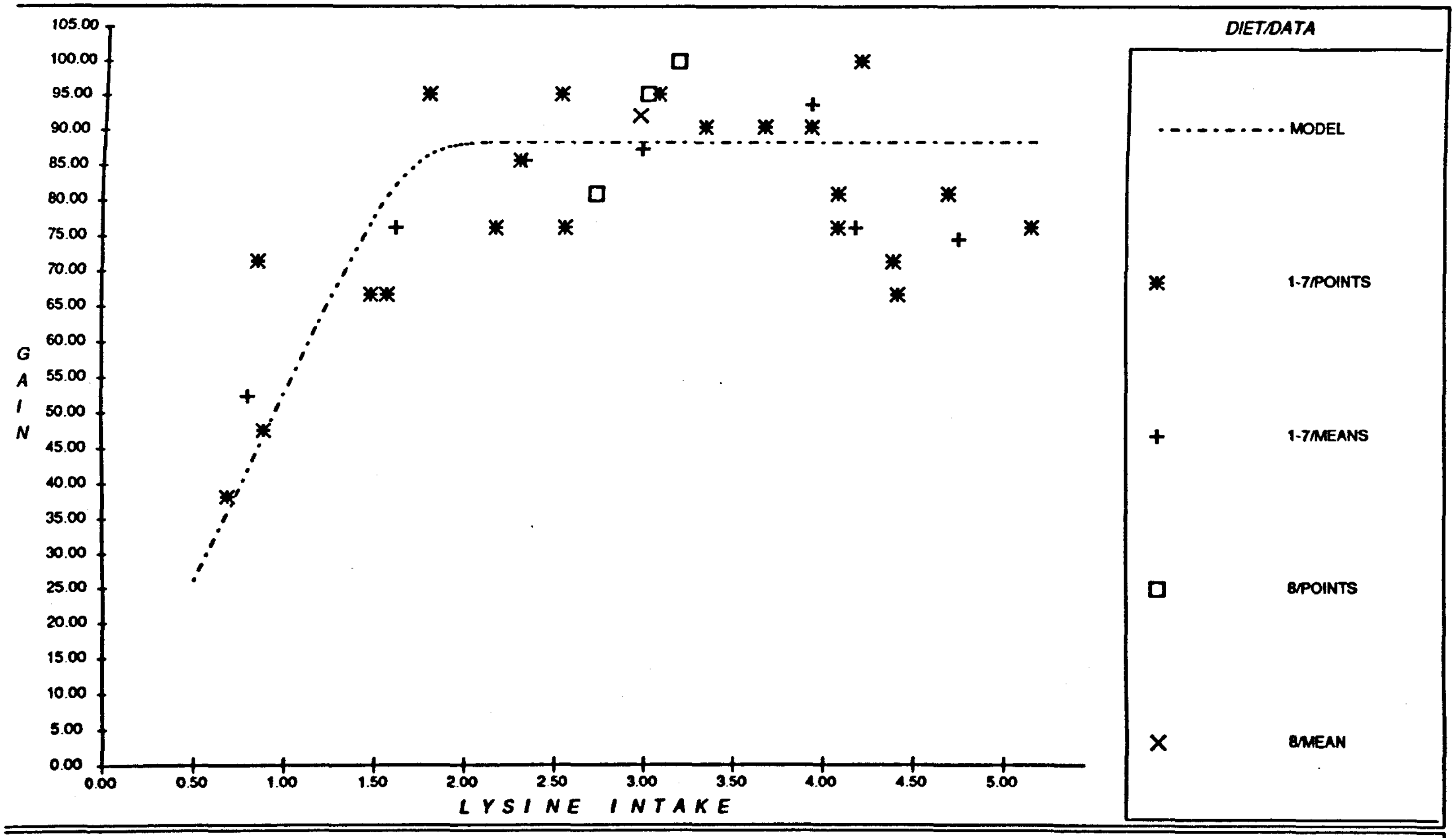

FIGURE 36. EXPERIMENT 12. 9 TO 12 WEEKS - LARGE TYPE FEMALES, LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

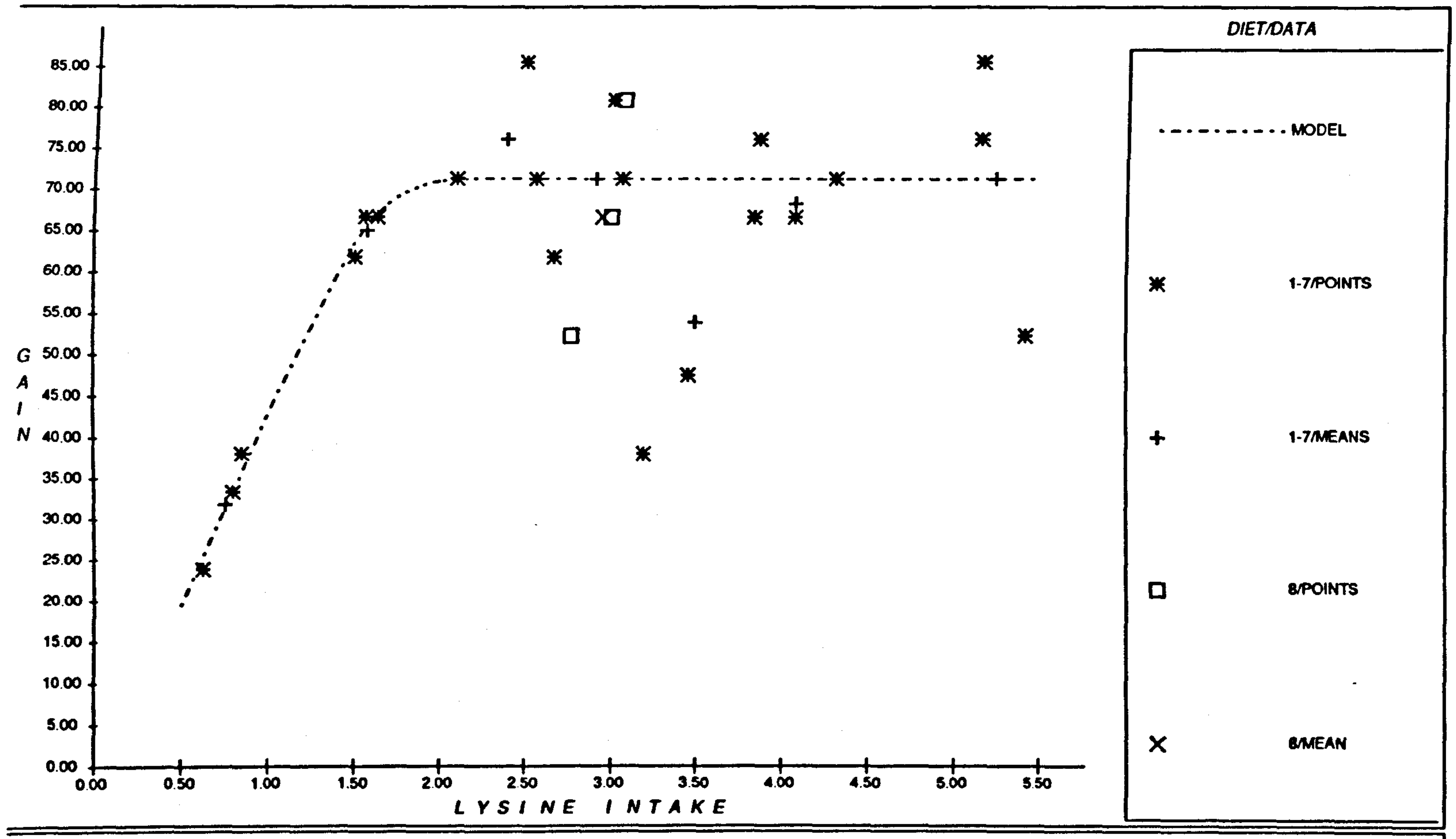

FIGURE 37. EXPERIMENT 12. 9 TO 12 WEEKS - SMALL TYPE MALES, LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

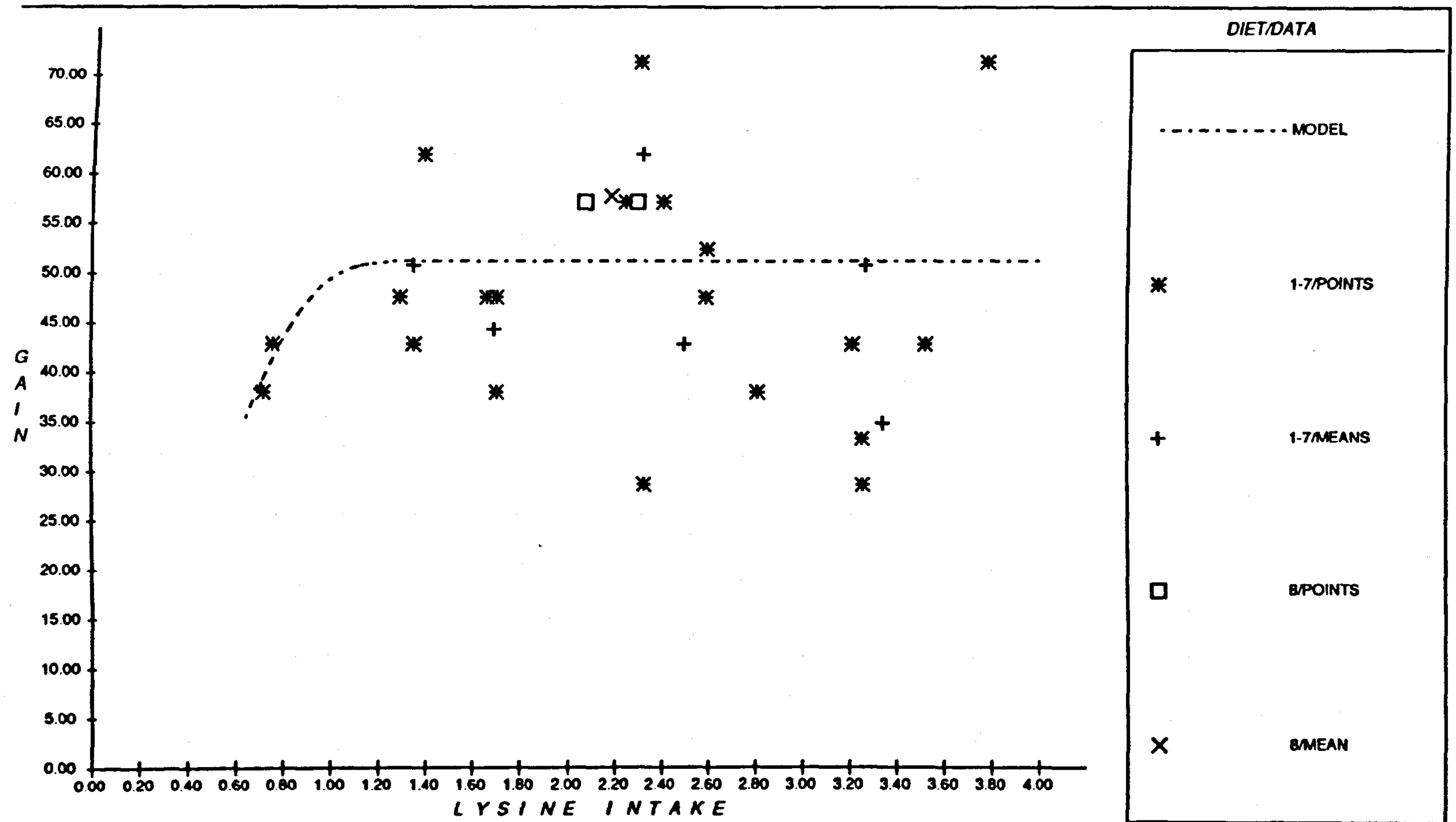

FIGURE 38. EXPERIMENT 12. 9 TO 12 WEEKS - SMALL TYPE FEMALES, LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

lysine intake giving the greatest body-weight gain for each strain were used in the Reading model analysis compared with the full data analysis are shown in Table 45.

TABLE 45	A COMPARISON OF FULL DATA ANALYSIS BY THE READING MODEL WITH PART DATA ANALYSIS* OF EXPERIMENT 12			
	LARGE TYPE MALES	LARGE TYPE FEMALES	SMALL TYPE MALES	SMALL TYPE FEMALES
MAX BODY-WEIGHT GAIN (g/bird d)				
FULL DATA	115.7	84.6	68.0	48.6
PART DATA	118.9	87.1	71.4	53.7
g LYSINE/kg BODY-WEIGHT GAIN (a)				
FULL DATA	20.33	17.99	18.16	7.80
PART DATA	19.98	19.00	21.56	17.18
g LYSINE TO MAINTAIN 1kg w FOR 1 d (b)				
FULL DATA	0.0061	0.0006	0.0531	0.1492
PART DATA	0.0031	0.0015	0.0234	0.0137
g LYSINE PER MJ ME FOR ΔW_{MAX}				
FULL DATA	0.717	0.642	0.634	0.436
PART DATA	0.718	0.692	0.703	0.517

* Part data analysis - this uses data up to and including that lysine intake giving the highest body weight gain in the trial.

It will be seen that excluding the data where the indications were that the body-weight gain had been depressed by an excess of protein or lysine, resulted in the Reading model interpreting the data differently. Not surprisingly a higher maximum body-weight gain was indicated. The a value increased slightly with two of the three largest types, while there was a marked increased in a value with the small type hens from 7.80 to 17.18. However, the data for small type hens are weakest, having the least clearly defined response section of the curve and the most severe body-weight gain depression from excess lysine intakes. When the Reading model input and output predictions are plotted (Figure 39), the females of both types are shown to gain more per g of lysine than the males. The most important change resulting from the higher indicated maximum body-weight gain was an increase in the amount of lysine required to achieve the maximum body-weight gain, and as a result the g lysine per MJ ME required for maximum body-weight gain was increased. This is the information of most use to commercial nutritionists. There is no means of testing the significance of differences seen in the g lysine required per MJ ME. The indications are that the three largest types have a similar requirement whereas the small type females would appear to be able to achieve their maximum body-weight gain with less lysine per MJ ME.

In view of the small number of birds of each type and sex on each experimental diet (three birds in individual pens), it is perhaps not surprising that the data were variable. This experiment was repeated to strengthen the information on the subject.

Experiment 13

Objective

To repeat experiment 12 in order to strengthen the information to assess if the genetic potential for growth rate influences the lysine response.

Materials and Methods

The same procedures and diets as used in experiment 12 were used in this experiment, including the same age at commencement i.e. 9 weeks 4 days. This

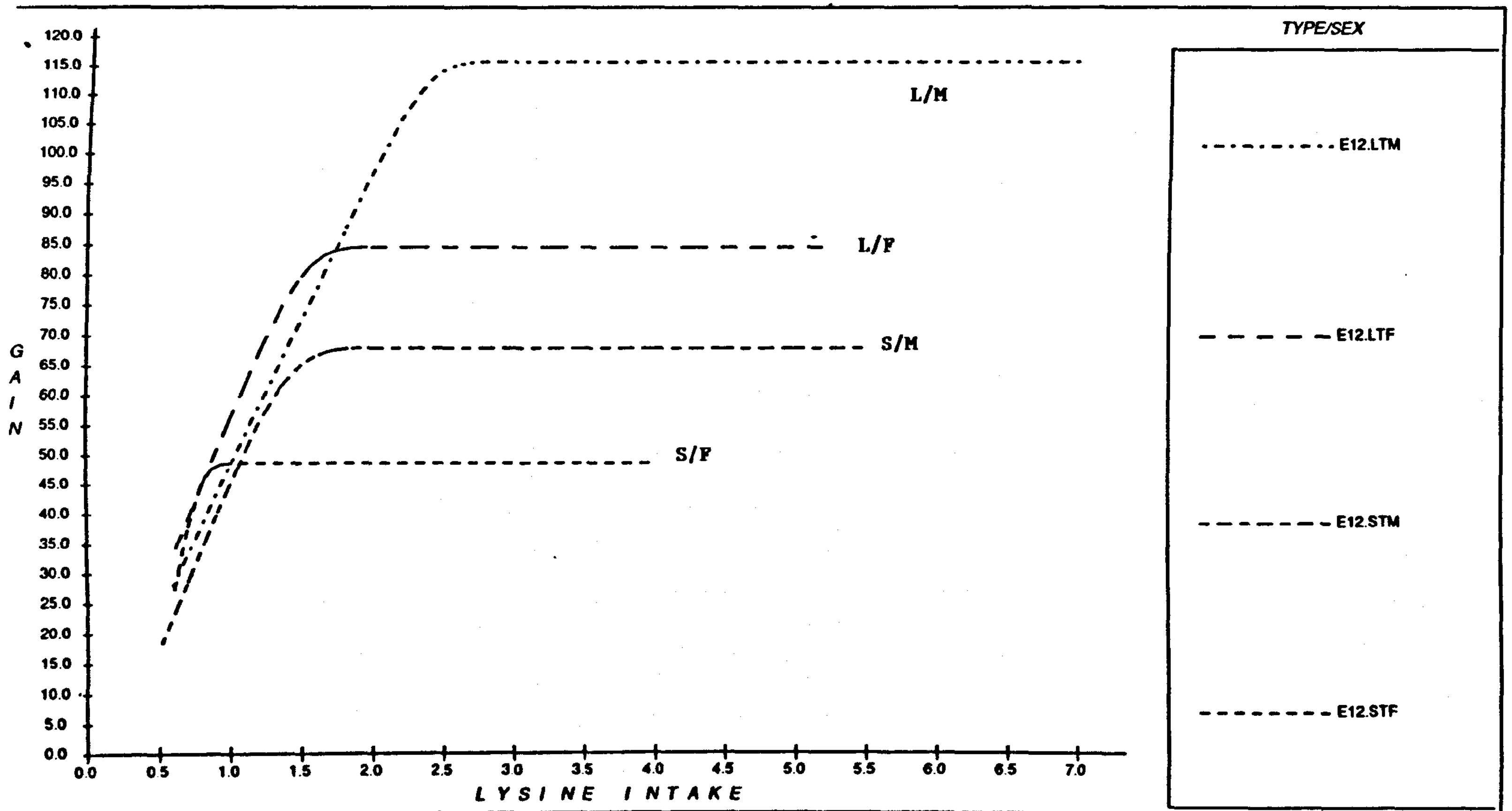

FIGURE 39. READING MODEL PREDICTIONS FOR LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d) FOR LARGE(L) AND SMALL(S) TYPE MALE(M) AND FEMALE(F) TURKEYS IN EXPERIMENT 12 (9 TO 12 WEEKS)

experiment was carried out in May under temperatures which would have been higher than those prevailing during experiment 12.

Results

Of the 96 pens, two were excluded because of broken wings and three because of mortality; data are summarised in Tables 46, 47, 48 and 49.

TABLE 46	RESPONSE OF 9 TO 12-WEEK-OLD TURKEYS OF DIFFERENT GENETIC POTENTIAL FOR GROWTH RATE (EXPERIMENT 13)					
a) Large Type Males						
DIET NO	LYSINE CONCEN-TRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	19.00	122.2	292.1	0.4183	5.549	22.02
2	16.50	119.1	296.8	0.4016	4.898	24.34
3	14.00	141.3	317.5	0.4457	4.444	31.83
4	11.50	125.4	260.3	0.4826	2.994	41.98
5	9.00	127.9	315.0	0.4024	2.837	44.85
6	6.5	117.5	285.7	0.4094	1.857	62.98
7	4.00	38.1	192.1	0.1981	0.768	49.54
8	11.5	87.3	249.2	0.3407	2.866	29.62
SE		14.5	30.6	0.0314	0.253	2.88
THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 3 REPLICATES OF 1 BIRD EACH						
READING MODEL ANALYSIS						
9 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE/kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)		
3.908	4.850	124.8	18.64	0.0053		

TABLE 47	RESPONSE OF 9 TO 12-WEEK-OLD TURKEYS OF DIFFERENT GENETIC POTENTIAL FOR GROWTH RATE (EXPERIMENT 13)					
b) Large Type Females						
DIET NO	LYSINE CONCENTRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	19.00	85.7	233.3	0.3670	4.433	19.32
2	16.50	82.5	241.3	0.3452	3.981	20.92
3	14.00	88.9	234.9	0.3792	3.289	27.08
4	11.50	94.5	198.4	0.4740	2.287	41.30
5	9.00	69.8	220.6	0.3147	1.986	34.96
6	6.5	73.0	222.2	0.3279	1.444	50.45
7	4.00	27.0	154.0	0.1778	0.616	44.45
8	11.5	90.5	242.9	0.3746	2.793	32.58
SE		8.8	23.5	0.0340	0.277	3.68

THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 3 REPLICATES OF 1 BIRD EACH

READING MODEL ANALYSIS

9 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE/kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)
2.867	3.505	86.9	22.05	0.0049

TABLE 48	RESPONSE OF 9 TO 12-WEEK-OLD TURKEYS OF DIFFERENT GENETIC POTENTIAL FOR GROWTH RATE (EXPERIMENT 13)					
c) Small Type Males						
DIET NO	LYSINE CONCENTRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	19.00	68.3	196.8	0.3471	3.740	18.27
2	16.50	77.8	198.4	0.3907	3.274	23.68
3	14.00	85.7	214.3	0.4001	3.000	28.59
4	11.50	79.4	220.6	0.3596	2.537	31.27
5	9.00	70.7	203.1	0.3432	1.829	38.28
6	6.5	68.3	207.9	0.3249	1.352	49.98
7	4.00	30.2	150.8	0.2012	0.603	50.29
8	11.5	80.5	212.7	0.3806	2.425	33.29
SE		9.3	15.3	0.0262	0.164	3.33
THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 3 REPLICATES OF 1 BIRD EACH						
READING MODEL ANALYSIS						
9 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE/k g BODY-WEIGHT GAIN (a)	g LYSINE TO MAINT AIN 1kg W FOR 1 day (b)		
2.792	3.400	78.0	19.54	0.0068		

TABLE 49	RESPONSE OF 9 TO 12-WEEK-OLD TURKEYS OF DIFFERENT GENETIC POTENTIAL FOR GROWTH RATE (EXPERIMENT 13)					
d) Small Type Females						
DIET NO	LYSINE CONCENTRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	19.00	42.9	158.7	0.2716	3.016	14.30
2	16.50	52.4	160.3	0.3250	2.645	19.70
3	14.00	57.1	166.7	0.3393	2.333	24.24
4	11.50	52.4	181.0	0.2931	2.081	25.48
5	9.00	46.0	152.4	0.3025	1.371	33.61
6	6.5	54.0	171.4	0.314	1.114	48.41
7	4.00	38.1	154.0	0.2452	0.616	61.31
8	11.5	47.6	144.4	0.3281	1.661	28.53
SE		6.7	17.9	0.0319	0.218	3.43
THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 3 REPLICATES OF 1 BIRD EACH						
READING MODEL ANALYSIS*						
9 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE/kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)		
2.150	2.618	50.3	13.72	0.0353		

* Based on analysis of treatment means.

Relationships between lysine input and body-weight gain (Appendix Tables 32, 33, 34 and 35, Figures 40, 41, 42 and 43) were similar to those seen with experiment 12. There was a slight reduction in food intake compared with experiment 12, presumably because of the higher environmental temperature which resulted in lower lysine intakes and more data points on the "slope" section of the body-weight gain curve. However the dangers inherent in having a small number of birds of each type on each diet is illustrated by diet 8 fed to the large type males. It will be seen in Figure 40 that body-weight gain on this diet was markedly out of line with expectations. Inspection of the individual pen (bird) data for the treatment, showed that one male ate very little food in the first week, perhaps because it had not learnt to use the feeder attached to the outside of the pen. For whatever reason, the result was that at the end of the experimental period, its body weight gain was less than half that of the other two pens representing the same treatment so depressing the

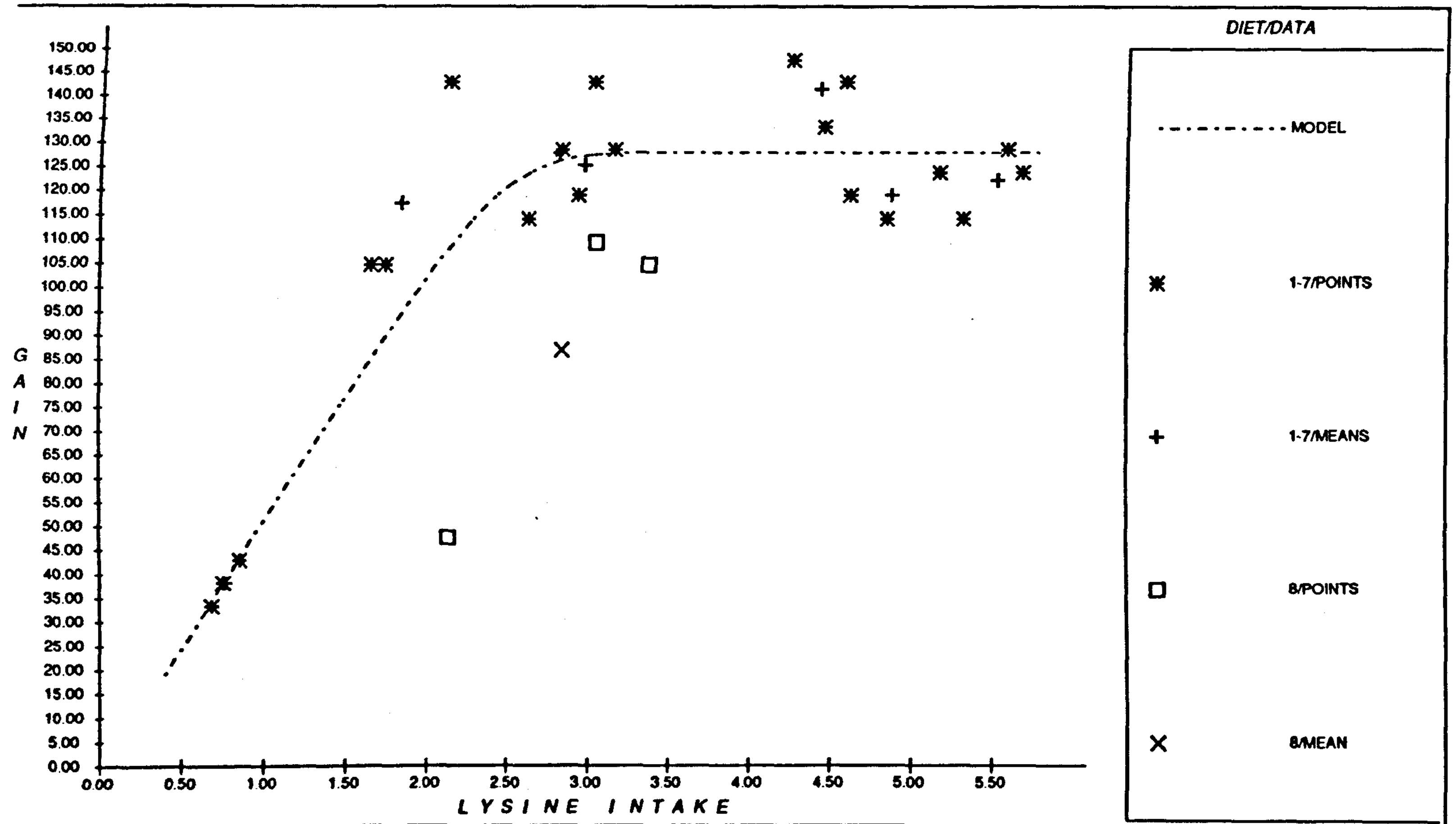

FIGURE 40. EXPERIMENT 13. 9 TO 12 WEEKS - LARGE TYPE MALES, LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

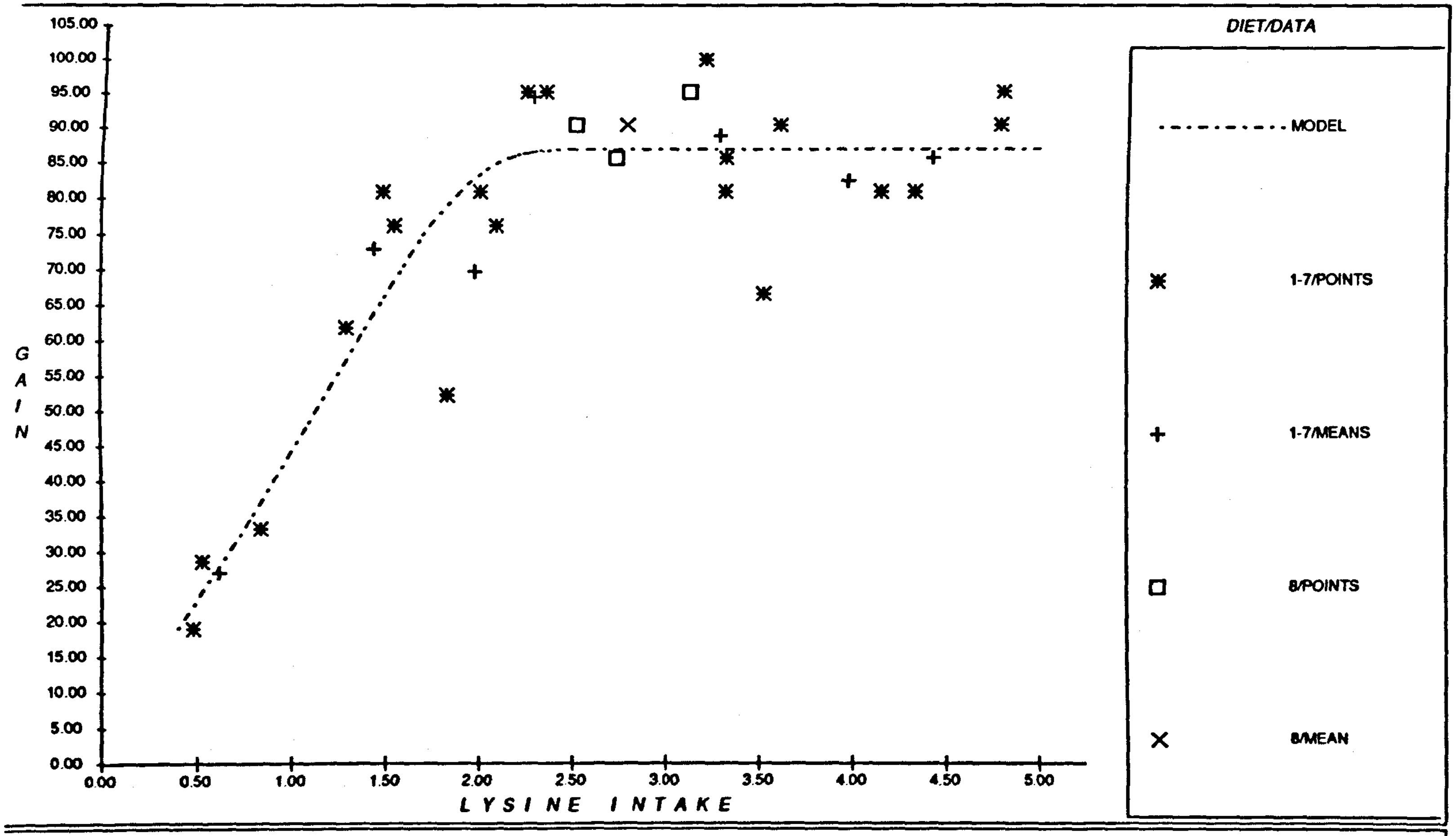

FIGURE 41. EXPERIMENT 13. 9 TO 12 WEEKS - LARGE TYPE FEMALES, LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

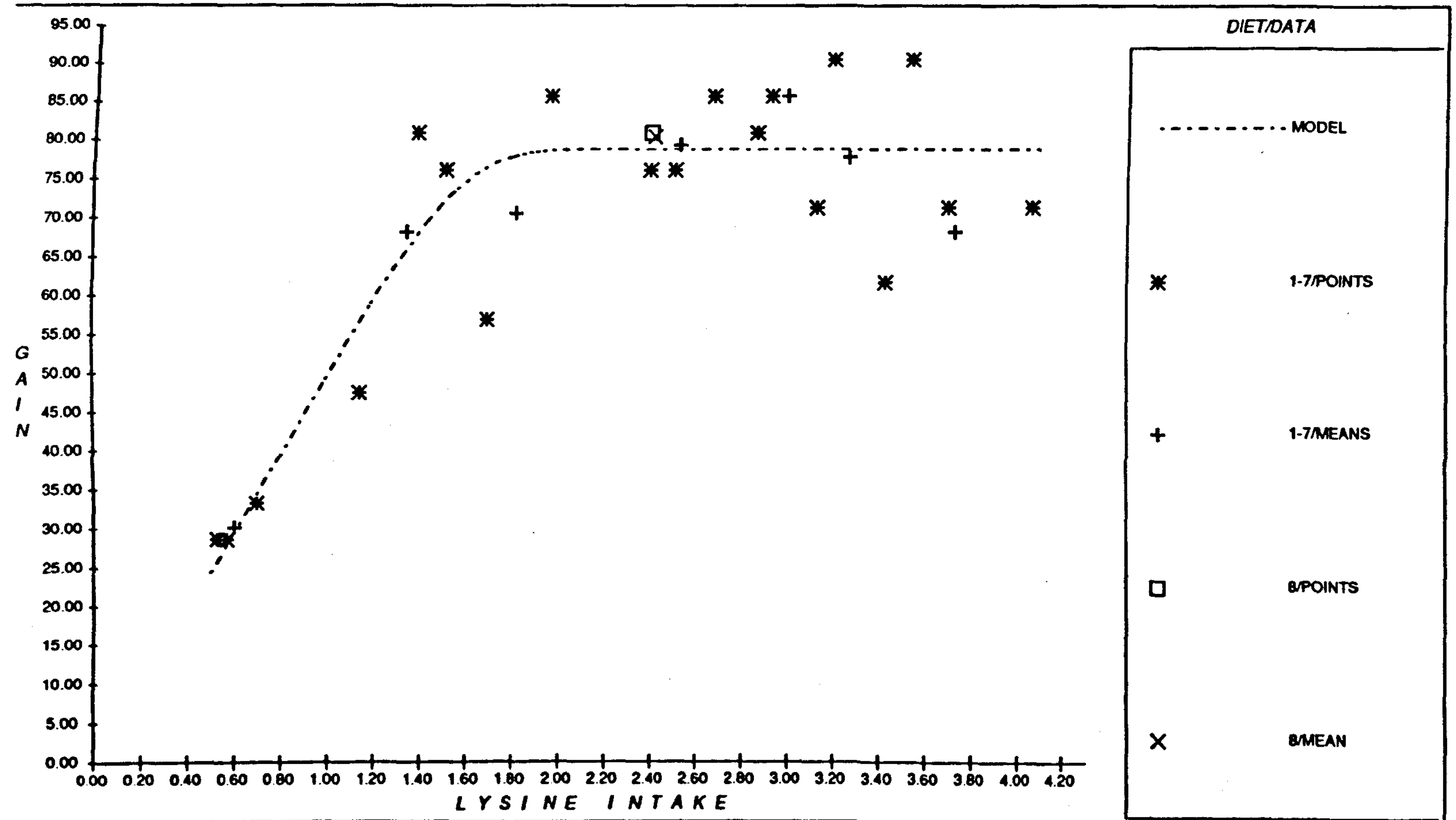

FIGURE 42. EXPERIMENT 13. 9 TO 12 WEEKS - SMALL TYPE MALES, LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

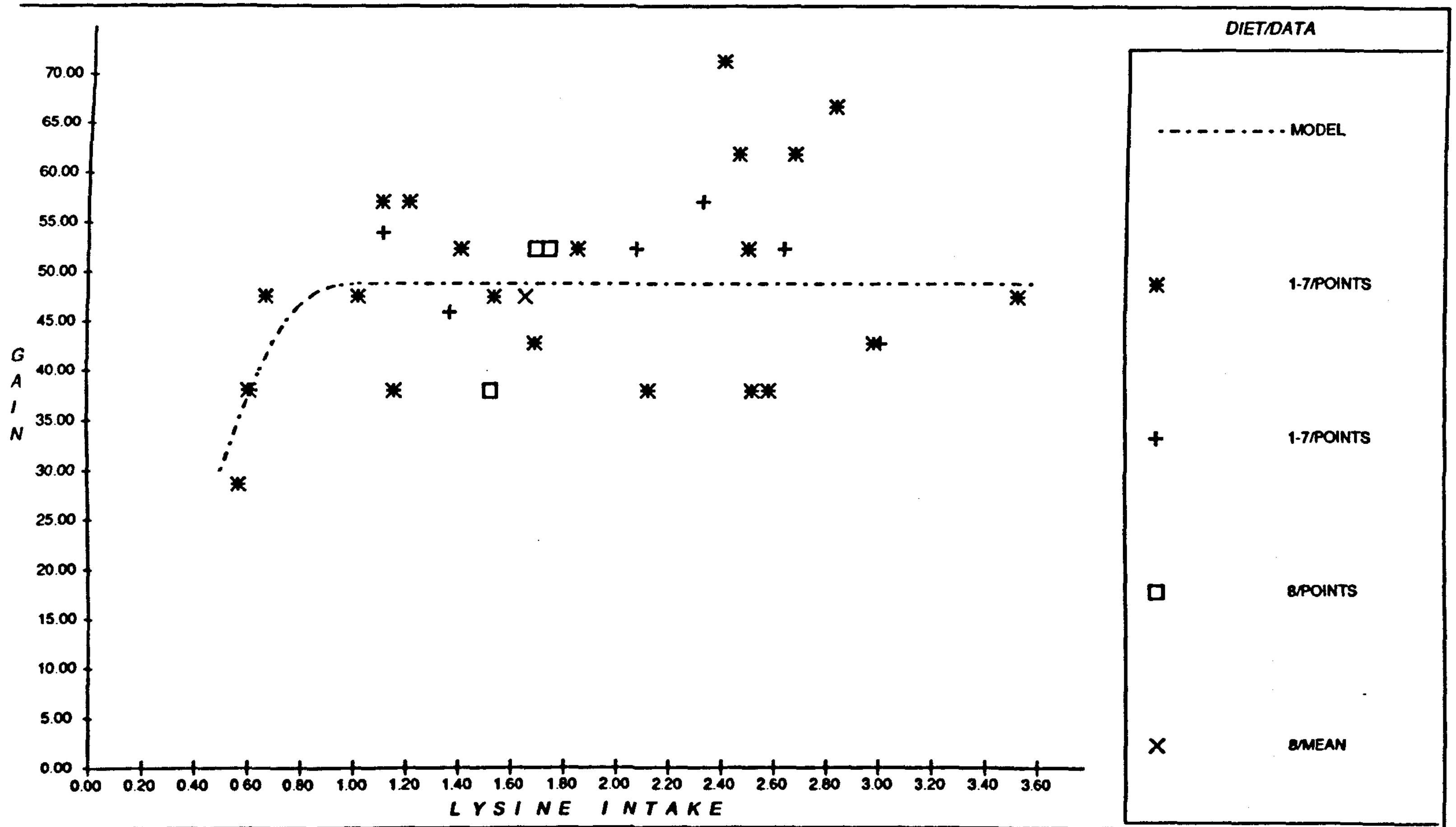

FIGURE 43. EXPERIMENT 13. 9 TO 12 WEEKS - SMALL TYPE FEMALES, LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

treatment mean considerably. Diet 8 fed to the other types of bird gave gains similar to those of diet 4, the diet with the same lysine content.

The same growth depression at the highest levels of lysine consumption was seen as in experiment 12, resulting in the Reading model indicating a lower level of maximum body-weight gain (ΔW_{MAX}) than achieved by birds on several of the diets. As in experiment 12, a Reading model analysis using data up to and including that lysine intake giving the greatest body-weight gain was carried out. The results compared to the full data analysis are shown in Table 50 following.

TABLE 50	A COMPARISON OF FULL DATA ANALYSIS BY THE READING MODEL WITH PART DATA ANALYSIS* OF EXPERIMENT 13			
	LARGE TYPE MALES	LARGE TYPE FEMALES	SMALL TYPE MALES	SMALL TYPE FEMALES
MAX BODY-WEIGHT GAIN (g/bird d)				
FULL DATA	124.8	86.9	78.0	50.3
PART DATA	128.0	87.0	78.9	48.9
g LYSINE/kg BODY-WEIGHT GAIN (a)				
FULL DATA	18.64	22.05	19.54	13.72
PART DATA	19.47	22.57	20.08	13.91
g LYSINE TO MAINTAIN 1kg w FOR 1 d (b)				
FULL DATA	0.0053	0.0049	0.0068	0.0353
PART DATA	0.0021	0.0019	0.0027	0.0313
g LYSINE PER MJ ME FOR ΔW_{MAX}				
FULL DATA	0.992	1.002	0.830	0.471
PART DATA	1.034	1.010	0.835	0.462

* Part data analysis - this uses data up to and including that lysine intake giving the highest body weight gain in the trial.

As in experiment 12, a higher maximum body-weight gain, a slightly higher a value and lower b values are indicated using the part-data analysis. Using the part data analysis, which fits the data more closely than the full data analysis, for Reading B Runs, produced predictions (Figure 44) for experiments 12 and 13 which show a close similarity in the predicted gain per g of lysine intake between the various types of bird.

There is an intriguing difference between the males, both large and small type, responses between experiments 12 and 13. Despite eating more food and hence nutrients,

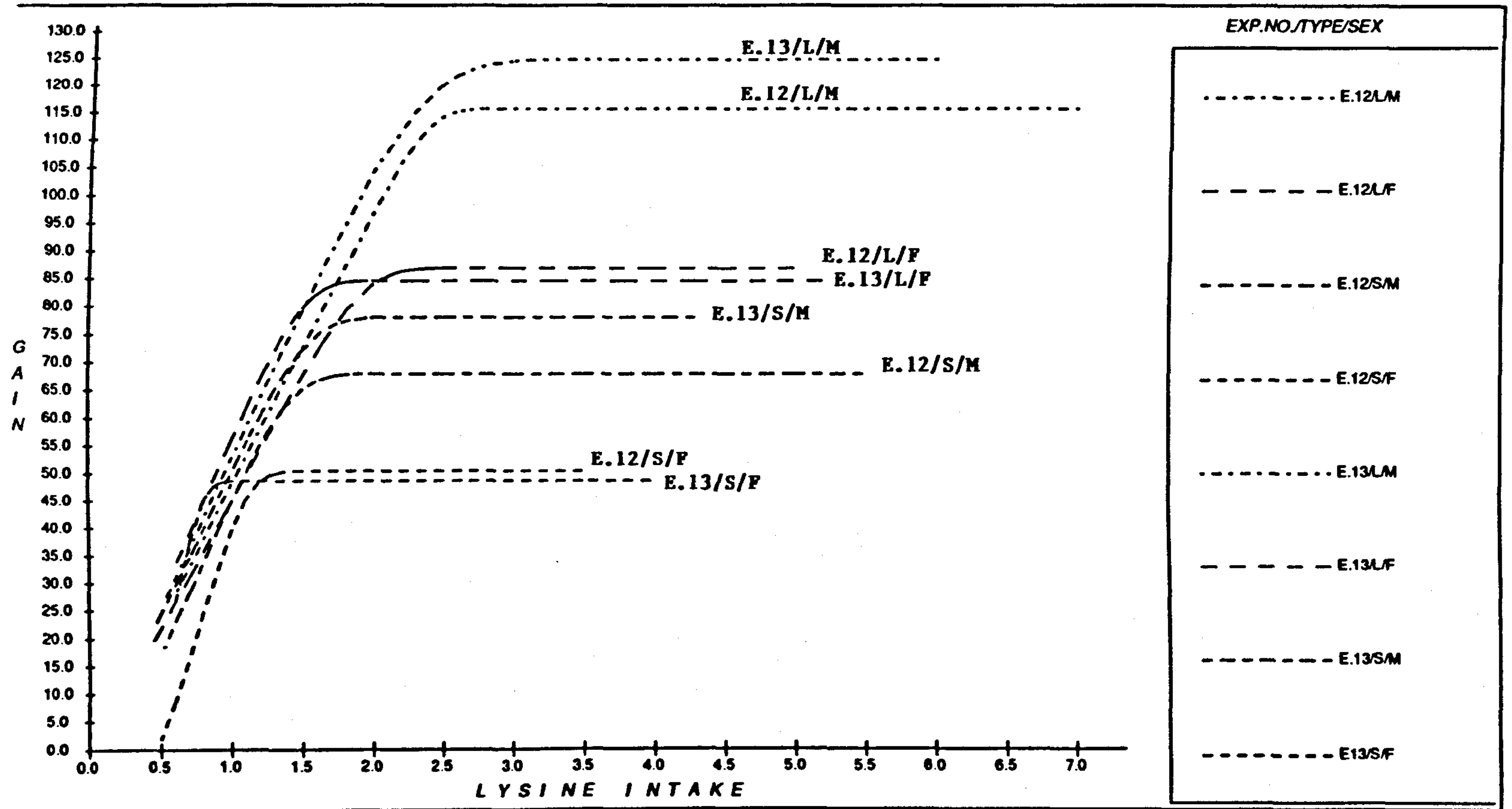

FIGURE 44. READING MODEL PREDICTIONS FOR LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN(g/d) FOR LARGE(L) AND SMALL(S) TYPE MALE(M) AND FEMALE(F) TURKEYS IN EXPERIMENTS(E) 12 AND 13 (9 TO 12 WEEKS)

the males in experiment 12 achieved a lower maximum gain and were less food efficient than those of experiment 13. Experiment 12 took place in February when ambient temperatures were much lower than in May when experiment 13 took place.

The explanation may be associated with fat deposition differences. At the lower temperatures there may have been less ME available for fat deposition because of the increased maintenance requirements for ME. This explanation would require there to be a limitation on ME consumption.

The g of lysine per MJ ME required to achieve maximum body-weight gain (ΔW_{MAX}) in experiments 12 and 13 and the means of the two experiments, based on part data analysis are shown in Table 51.

TABLE 51	THE LYSINE PER MJ ME IMPLICATED BY EXPERIMENTS 12 AND 13			
TYPE	SEX	g LYSINE PER MJ ME FOR ΔW_{MAX}		
		EXPERIMENT 12	EXPERIMENT 13	MEAN
LARGE	MALE	0.718	1.034	0.876
LARGE	FEMALE	0.692	1.010	0.851
SMALL	MALE	0.703	0.835	0.769
SMALL	FEMALE	0.517	0.462	0.490

At the start of this section, two important questions were posed. First, does the genetic potential for growth rate influence the lysine response? Second, does the greater potential for growth rate improve the efficiency of lysine utilisation for growth rate? The bird with the lowest growth potential, the small type female, was apparently the most efficient, judged by the a value, in converting lysine into body weight. It seems likely that the effect of speed of growth is being confounded by changes in body composition, to produce this result, with the small type female laying down more body fat which does not require lysine.

An interesting comparison can be made between the large type female and the small type male which have similar growth rates at this age. The mean a vales for the two experiments based on part data analysis was 20.79 and 20.82 for the large type females and the small type males respectively, indicating similar efficiency of lysine utilisation.

Judged by the g lysine per MJ ME required for maximum growth rate shown in Table 51, the genetic potential for growth does influence the lysine required for maximum response, with the required ranking the same as the growth potential ranking. It is reasonable to conclude that there is little justification in feeding diets differing in their lysine to ME ratio to the two sexes of the large type of turkey up to 12 weeks of age. The small type males would appear to have a similar requirement. Their sisters, however, the small type females, would seem to required less g of lysine per MJ ME from 9 to 12 weeks than their brothers to grow to their maximum body-weight gain. It is difficult to assess the statistical significance of the differences but a reduction of almost 40% seems likely to be a real difference. More data is needed for small type females as only the lowest lysine level (diet 7) in the range used was deficient in lysine for these birds.

There are large differences between the indicated requirements of the birds between experiments. The most likely explanation for the differences is the seasonal temperature with experiment 12 taking place in February and experiment 13 in May. There is a higher lysine requirement per MJ ME in the warmer temperature because of a reduced food intake resulting from a lower ME requirement for maintenance. Nevertheless, as shown in Figure 44, if the gain is expressed per g of lysine, the difference between experiments is small with predictions from experiment 13 indicating a slightly higher gain per g of lysine. It is a further indication of the importance of stating requirements ultimately as quantities rather than percentages or ratios.

2. <u>The Turkey's Previous Plane of Growth</u>

As explained earlier it has been shown (Auckland, <u>et al</u>, 1969) that if a turkey's growth is retarded early in life, it has the ability to catch up lost growth in a later growth phase. This is known as compensatory or catch up growth and it has been suggested that the efficiency of protein utilisation is improved when compensatory growth occurs. The "catching up" growth occurs mainly when the growth rate would have been slowing down if the birds had been growing normally. More information is required on the lysine requirements of growth retarded birds given the opportunity to catch up prior to the period of peak growth rate. Do the retarded birds have the same potential for growth? Do they have the same lysine conversion efficiency as normally grown turkeys? Can the retarded birds respond to higher levels of lysine than normally grown turkeys? In an attempt to answer these questions, two experiments, numbered 14 and 15, were carried out.

Experiment 14

Objective

To assess the lysine response from 6 to 9 weeks of male turkeys reared on two different planes of nutrition prior to 6 weeks of age.

Materials and Methods

Big 6 Female Line Cross male turkeys were used for the trial. This strain of turkey has a slightly higher growth potential than the BUT 6 Female Line Cross turkeys used in earlier trials. The change was unavoidable as the former cross had been replaced in the British United Turkey's breeding programme by the latter cross.

Two hundred and thirty four male poults were fed ad libitum a starter crumb (280g protein/kg and 11.96 MJ ME/kg) from 1 day old to 5 weeks 6 days of age to provide birds grown on a high plane of nutrition.

To provide birds grown on a low plane of nutrition, 234 male poults were fed a relatively low protein starter diet (250g protein/kg and 11.96 MJ ME/kg in crumb form until

26 days of age. They then went on to a low protein grower diet (220g protein/kg 11.96 MJ ME/kg) in pellet form until 5 weeks 6 days.

At 5 weeks 6 days, the birds were moved to the experimental house at Kinnerton Farm. One hundred and ninety two birds on each plane of nutrition were housed out of the two hundred and twenty eight birds available. To reduce the numbers, the smallest birds were rejected to avoid the risk of females being included in the trial.

In the experimental design, the two outside rooms were treated as one housing section and the two inner rooms treated as one housing section. The similar blocks of pens within the two rooms in each housing section were combined to provide 3 blocks of 16 pens within each housing section. Within the 16 pens, the eight diets of different lysine content were allocated at random among pens so that each was fed to one pen of birds of each pre-feeding treatment. Four birds were placed in each pen, so that there was 384 birds in all. The experiment therefore consisted on 8 diets x 2 previous planes of nutrition x 3 blocks x 2 housing sections spread over 96 pens.

The food was recorded and the birds individually weighed at the start and end of the three week experimental period. Any pens in which a bird died were omitted and a missing plot technique used in the statistical analysis.

The eight diets fed were identical formulations to those used in experiments 3 and 4 which covered similar ages to the birds used in this experiment but were made in a different batch.

Results

Of the 96 pens, 3 pens were omitted from the statistical analysis because of mortality. When birds died in two adjacent pens early in the trial, post mortem examinations were carried out and these indicated coccidiosis. As a result all birds in the experiment were treated with a coccidiostat drug, Saquadil, via the water for 4 days. No further problem was seen.

The pre-experimental period feeding was successful in producing two groups of birds which differed substantially in their 6 week body weights. The group fed on the standard feed programme weighed 1.458kg whereas those on the lower plane of nutrition weighed 1.232kg, a reduction of 15.5%. This is the equivalent of almost 1 week's difference in age, ie. the slow grown group were similar in body weight to normal 5-week-old birds although they were 6 weeks old.

With four birds in each pen, more excreta were produced in each pen than in previous trials. At the end of the trial, some pens were obviously wetter than others, with a frothy yellow scour being present. The contrast between wet and dry pens was so evident, it was decided to score the pens as dry or wet. This was carried out by two people working together. They did not know which treatments had been allocated to which pen. The scores are shown in Table 52.

TABLE 52 LITTER SCORES RESULTING FROM THE DIETARY TREATMENTS

DIET NO	1	2	3	4	5	6	7	8
Lysine k/kg	19.0	16.5	14.0	11.5	9.0	6.5	4.0	11.5
Protein g/kg	46.4	40.6	35.0	29.3	23.6	17.9	12.2	23.6
Number of dry pens	0	0	1	8	11	12	12	12
Number of wet pens	12	12	11	4	1	0	0	0
Wet pens as % of total pens	100	100	91.7	33.3	8.3	0	0	0

It would appear that the higher the protein level in the diet, the more likely was the occurrence of wet litter. Moran (1983) reported that diets higher in protein content produced wetter litter than diets of lower protein content. As the diets also differed in their ingredient content, the wet litter problem may have been associated with the level of one ingredient in the diet. The particular ones which must be suspected in this instance are soya bean meal and maize gluten meal, both of which increased as the protein level in the diet increased. As the excreta had a frothy characteristic, it seems likely that a fermentation process was involved presumably as a result of an alteration in the gut bacteria. While it seems likely that the cause of the frothy, yellow scour may have depressed body-weight gains, it would not have appeared to have altered the slope (1/a) of the lysine response curve. Pens of birds fed on diet 4 showed the highest body-weight gains in both groups and one third of these were classified as having wet litter. On average the body-weight gain of birds on this diet in pens where the litter was wet were 2.4g less than those birds from pens on diet 4 where the litter was classified as dry. Thus the plateau (maximum weight gain) will have been influenced slightly by this problem.

The body-weight gain and food intake data are summarised in Tables 53 and 54 and illustrated in Figures 45 and 46.

TABLE 53 RESPONSE OF MALE TURKEYS FROM 6 TO 9 WEEKS, REARED ON TWO DIFFERENT PLANES OF NUTRITION PRIOR TO 6 WEEKS OF AGE (EXPERIMENT 14)

a) High Plane of Nutrition Prior to 6 Weeks of Age

DIET NO	LYSINE CONCENTRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	19.00	63.9	155.3	0.4115	2.950	21.66
2	16.50	66.4	156.0	0.4256	2.573	25.81
3	14.00	69.0	162.5	0.4246	2.271	30.38
4	11.50	73.7	163.4	0.4510	1.879	39.22
5	9.00	48.3	139.7	0.3457	1.257	38.42
6	6.5	46.1	137.6	0.3350	0.894	51.57
7	4.00	15.7	93.1	0.1686	0.375	41.87
8	11.5	70.0	164.3	0.4260	1.889	37.06
SE		7.5	11.9	0.0298	0.150	4.44

THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 6 REPLICATES OF 4 BIRDS EACH

READING MODEL ANALYSIS

6 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE/kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)
1.458	1.928	68.5	22.86	0.0042

TABLE 54	RESPONSE OF MALE TURKEYS FROM 6 TO 9 WEEKS, REARED ON TWO DIFFERENT PLANES OF NUTRITION PRIOR TO 6 WEEKS OF AGE (EXPERIMENT 14)					
b) Low Plane of Nutrition Prior to 6 Weeks of Age						
DIET NO	LYSINE CONCENTRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	19.00	64.9	139.5	0.4352	2.659	24.41
2	16.50	71.6	149.6	0.4786	2.468	29.01
3	14.00	75.0	154.1	0.4867	2.157	34.77
4	11.50	75.9	158.6	0.4786	1.824	41.61
5	9.00	59.4	144.5	0.4111	1.301	45.66
6	6.5	44.4	125.2	0.3546	0.814	54.55
7	4.00	15.7	76.8	0.2044	0.307	51.14
8	11.5	77.6	157.8	0.4918	1.815	42.75
SE		7.1	11.6	0.0277	0.147	4.47
THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 6 REPLICATES OF 4 BIRDS EACH						

READING MODEL ANALYSIS

6 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE/kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)
1.232	1.721	73.4	20.29	0.0046

The data shows good response curves for both groups of birds. There is, however, as in some previous experiments, evidence of growth depression at the high lysine levels. There was no significant difference in body-weight gain in either group between the diet supplemented with added L-lysine (diet 8) and the diet containing the same amount of total lysine (diet 4) confirming that the diets were limiting in lysine. Lysine input and body-weight gain output predictions derived from the Reading model (Appendix Tables 36 and 37 when plotted against observed results (Figures 45 and 46) show that those birds previously on a low plane of nutrition reached a higher plateau in maximum body-weight gain (ΔW_{MAX}) than those birds previously on a high plane of nutrition, (73.4 v 68.5g per bird d). As a result, at 9 weeks of age there was little difference in body weight between the birds which had achieved maximum body-weight gain of the two groups. At 6 weeks of age those previously on a low plane of nutrition weighed 15.5% less than those previously

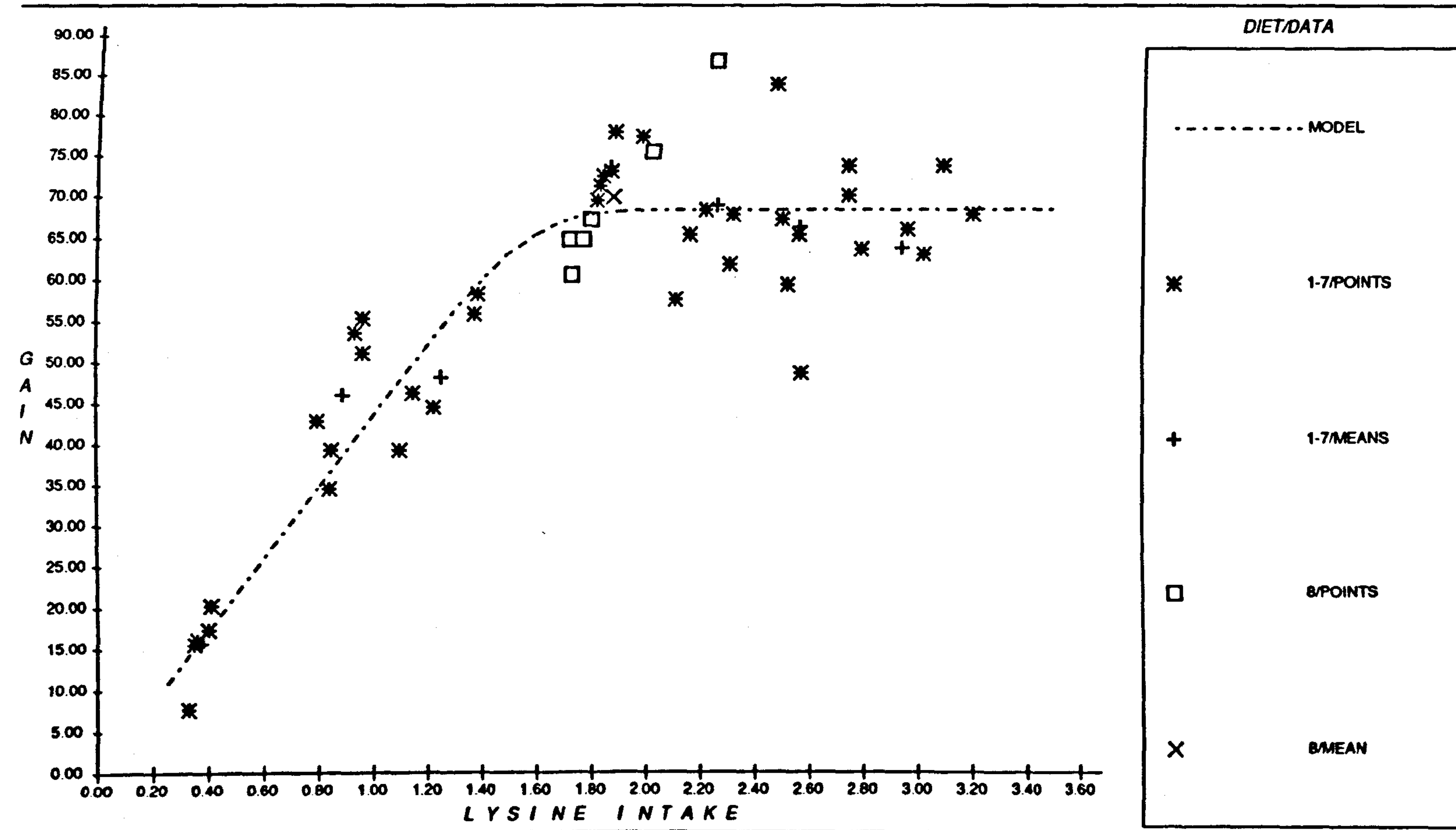

FIGURE 45. EXPERIMENT 14. 6 TO 9 WEEKS -PREVIOUS GROWTH : FAST, LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

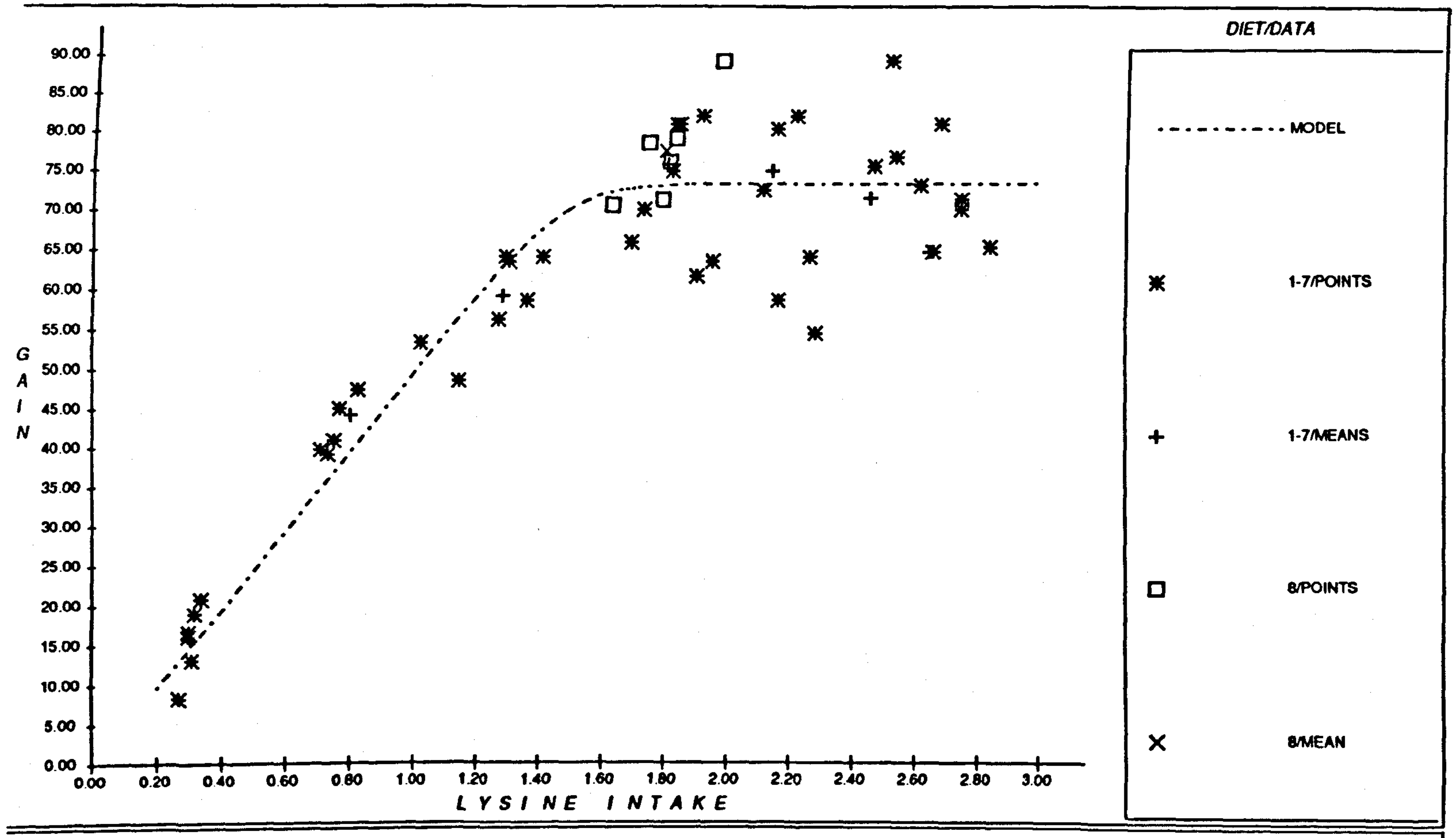

FIGURE 46. EXPERIMENT 14. 6 TO 9 WEEKS -PREVIOUS GROWTH : SLOW LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

on a high plane of nutrition (1.232kg v 1.458kg). By 9 weeks of age, the Reading model analysis, which fitted both sets of data closely, indicated that, between those groups grown to the maximum body-weight gain, the difference had decreased to 4.3% (2.773 v 2.896kg). It also indicated (see Figure 47) and the g values confirm that more body-weight gain was achieved per g of lysine intake by those birds previously on a low plane of nutrition than by those previously on a high plane.

If whole body analysis had been carried out on the birds, it may have explained most of the difference in lysine efficiency between the two groups. It would be explained if the birds on a low plane of nutrition at 6 weeks of age had a body composition lower in non-lysine requiring tissues i.e. skeletal and fat tissue. Even at 6 weeks of age, the male turkey would normally contain around 4.5% of its body weight as fat (Leeson and Summers, 1980b). In appearance, those previously on a low plane of nutrition had a smaller skeletal structure i.e. their legs were shorter and smaller as was their total body height and width. By 9 weeks of age this obvious difference had disappeared in the groups grown to their maximum body-weight gain. During the experimental period, therefore, in the low plane of nutrition group there must have been considerable "catch-up" skeletal growth. If a higher proportion of the body-weight gain was skeletal tissue in the birds previously on a low plane of nutrition, it would help to explain their apparent improved efficiency in lysine utilisation. An alternative or additional explanation may relate to differences in fat deposition. The birds previously on a low plane of nutrition may have had to overconsume energy relatively in order to satisfy their lysine requirements to enable them to develop normally. Unfortunately analysis of body tissue at the start and end of the experimental period was not possible. The possibility that the birds previously on a low plane of nutrition used the lysine more efficiently should not be ignored.

There is no indication that for this age period a higher lysine to ME ratio is required in the diet of birds previously on a low plane of nutrition. In fact the indicated ratio is slightly less for the low plane than the high plane birds i.e. 1.011 and 1.033g lysine per MJ ME, respectively. Again there was a trend towards reduced body-weight gain at lysine

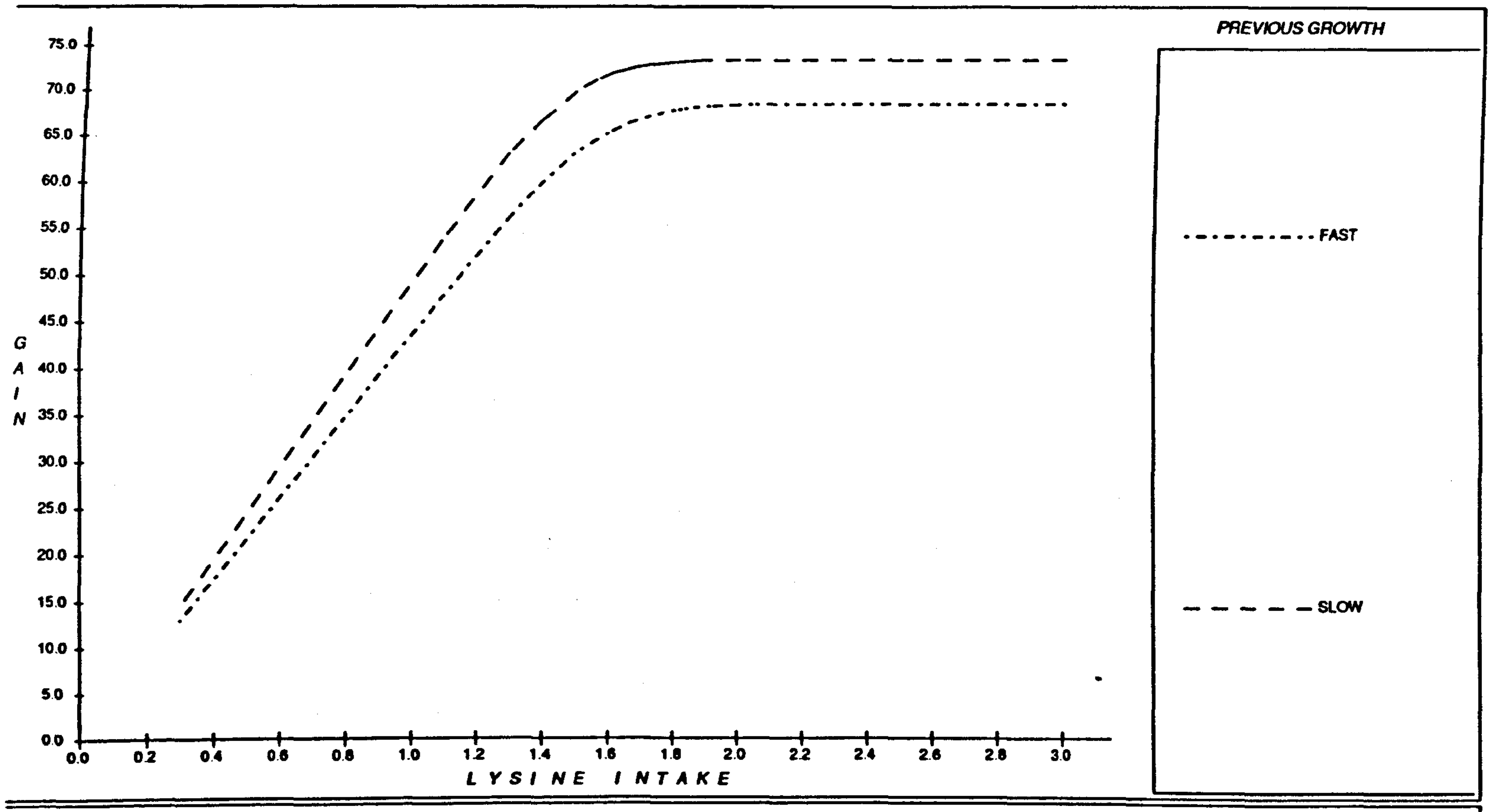

FIGURE 47. READING MODEL PREDICTIONS FOR LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d) FOR TURKEYS PREVIOUSLY GROWN FAST OR SLOW IN EXPERIMENT 14 (6 TO 9 WEEKS).

intakes higher than those required for maximum body-weight gain. This subject will be discussed further subsequently.

Experiment 15

Objective

To assess the lysine response from 9 to 12 weeks of male turkeys reared on two extremely different planes of nutrition prior to 9 weeks of age. In this experiment it was intended that the initial 9-week body weights would be sufficiently different so as to make it unlikely that those previously fed on the low plane could attain the same 12-week body weight as those previously fed on the high plane. The birds, therefore, while being the same age, would be at different physiological stages of development, even at the end of the experimental period.

Materials and Methods

Big 6 Female Line Cross male turkeys were used for the trial. The two planes of nutrition, high and low, were obtained by taking birds from the appropriate treatments at the end of experiment 14. The high plane treatments birds were obtained from the treatments giving the highest 9-week body weights. These were birds previously fed on a high plane of nutrition to 6 weeks of age and subsequently fed diets 1, 2, 3 or 4 (lysine contents 19.00, 16.50, 14.00 and 11.50g/kg respectively) plus some birds previously fed on diet 8 (11.50g lysine/kg) to make up numbers. The low plane treatment birds were obtained from the treatments giving the smallest 9-week body weights in experiment 14. These were birds previously fed on a low plane of nutrition to 6 weeks of age and subsequently fed diets 5, 6 and 7 (9.00, 6.50 and 4.00g lysine/kg respectively) and birds on diet 7 previously fed on a high plane of nutrition to 6 weeks of age. The numbers were made up with birds on diet 6 previously fed on a high plane of nutrition to 6 weeks of age. The resulting starting body weights of the two groups differed greatly, the high plane being

3.143kg and the low plane being 2.010kg. As the high plane groups were obtained from the plateau area of experiment 14, they were more uniform than the low plane birds obtained from the growth response area of experiment 14. The coefficient of variation of the high plane group was 6.9% while that of the low plane was 15%. The body weight of low-plane birds was the equivalent weight of a 7 weeks 1 day old turkey fed on a normal plane of nutrition.

Two birds were placed in each pen. Within each previous plane of nutrition treatment, birds were allocated to pens in such a way as to try to reduce the variation between total body weights per pen. The experimental design, procedures and diets were the same as those of experiment 14.

Results

Of the 96 pens, 4 pens were omitted from the statistical analysis because of mortality. With only 2 birds to a pen, the droppings load was much less than in experiment 14 and the litter remained dry in all pens. It was not therefore possible to assess the effect on the litter of different diets as in experiment 14.

The body-weight gain and food intake data are summarised in Tables 55 and 56. The data show good response curves (Figures 48 and 49) with a good balance between data on the incremental and plateau sections of the curve. Lysine input and body-weight gain output prediction derived from the Reading model (Appendix Tables 38 and 39) when plotted against observed results (Figures 48 and 49) show a different situation to that seen in experiment 14. In this experiment the birds previously on a high plane of nutrition reached a higher plateau in maximum body-weight gain (ΔW_{MAX}) than those previously on a low plane of nutrition, (115.6 and 107.2g per bird d respectively).

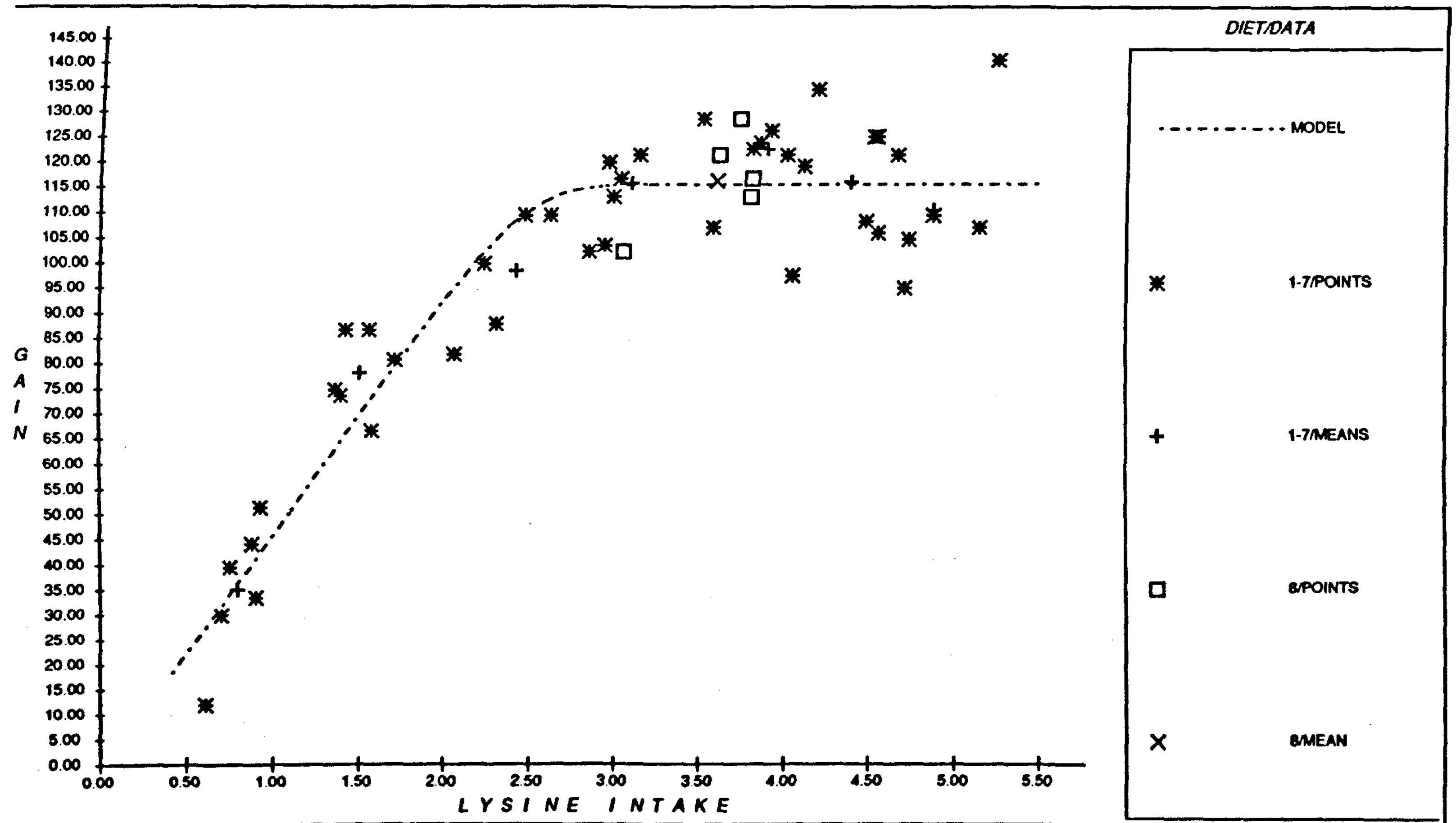

FIGURE 48. EXPERIMENT 15. 9 TO 12 WEEKS -PREVIOUS GROWTH :FAST, LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

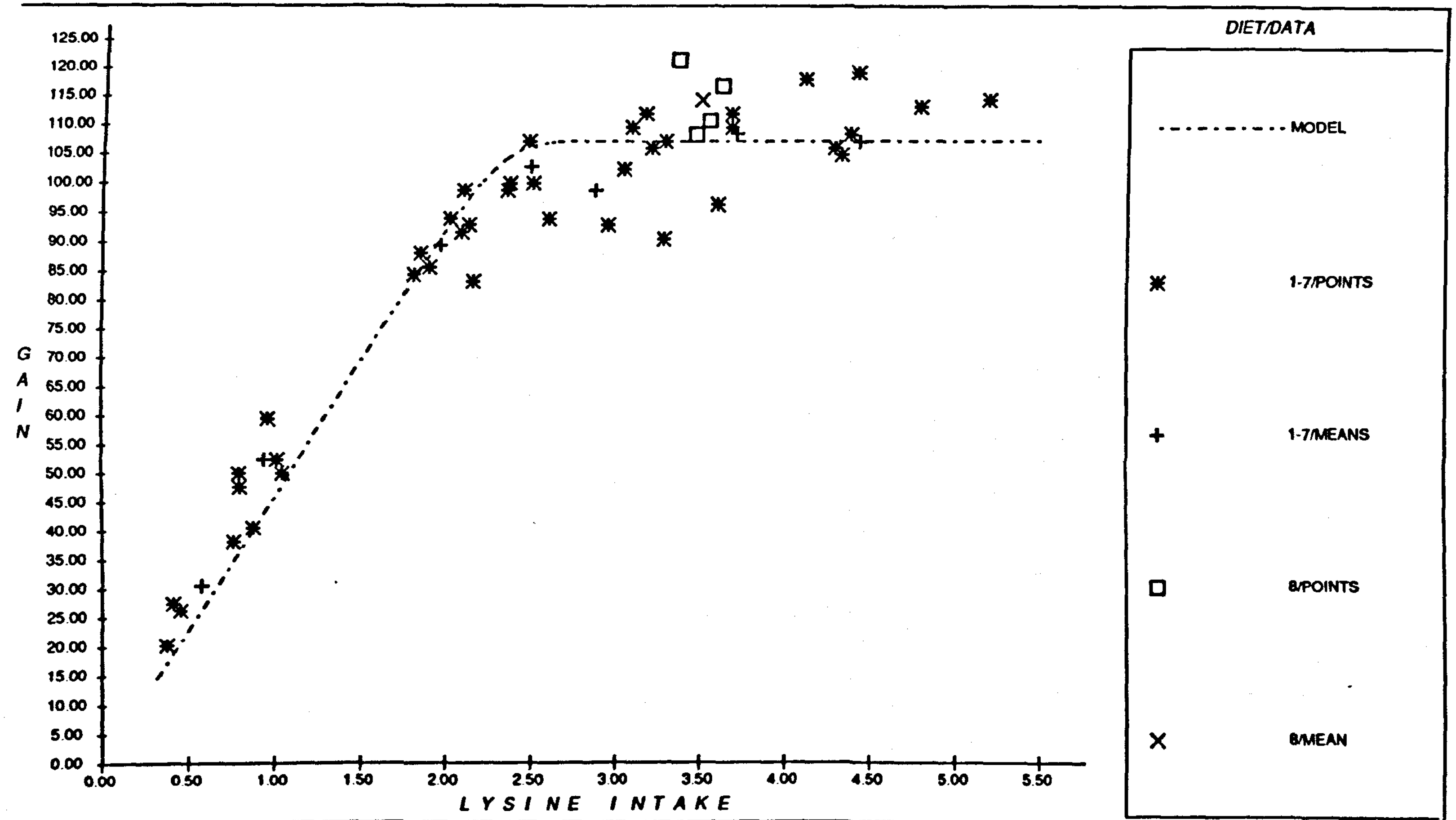

FIGURE 49. EXPERIMENT 15. 9 TO 12 WEEKS -PREVIOUS GROWTH :SLOW,
LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d)

TABLE 55	RESPONSE OF MALE TURKEYS FROM 9 TO 12 WEEKS, REARED ON TWO DIFFERENT PLANES OF NUTRITION PRIOR TO 9 WEEKS OF AGE (EXPERIMENT 15)					
a) High Plane of Nutrition Prior to 9 Weeks of Age						
DIET NO	LYSINE CONCEN-TRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	19.00	110.5	257.3	0.4295	4.889	22.60
2	16.50	116.1	267.3	0.4343	4.410	26.33
3	14.00	122.6	279.4	0.4388	3.911	31.35
4	11.50	115.9	271.0	0.4276	3.117	39.72
5	9.00	98.6	271.2	0.3636	2.441	40.39
6	6.5	78.4	234.1	0.3349	1.522	51.51
7	4.00	34.9	198.8	0.1756	0.759	43.90
8	11.5	116.3	315.2	0.3690	3.627	32.07
SE		11.1	23.3	0.0351	0.237	5.64
THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 6 REPLICATES OF 2 BIRDS EACH						
READING MODEL ANALYSIS						
9 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE/kg BODY-WEIGHT GAIN (a)	g LYSINE TO MAINTAIN 1kg W FOR 1 day (b)		
3.143	3.977	115.6	21.39	0.0063		

TABLE 56	RESPONSE OF MALE TURKEYS FROM 9 TO 12 WEEKS, REARED ON TWO DIFFERENT PLANES OF NUTRITION PRIOR TO 6 WEEKS OF AGE (EXPERIMENT 15)					
b) Low Plane of Nutrition Prior to 9 Weeks of Age						
DIET NO	LYSINE CONCEN-TRATION (g/kg)	BODY-WEIGHT GAIN (g/bird.d)	FOOD INTAKE (g/bird d)	GAIN: FOOD RATIO	LYSINE INTAKE (g/bird.d)	GAIN: LYSINE RATIO
1	19.00	107.1	233.7	0.4583	4.441	24.12
2	16.50	108.5	225.4	0.4814	3.719	29.17
3	14.00	98.8	206.7	0.4780	2.894	34.14
4	11.50	102.8	218.1	0.4713	2.508	40.99
5	9.00	89.5	219.6	0.4076	1.977	45.27
6	6.5	52.4	143.6	0.3649	0.946	55.39
7	4.00	29.8	141.5	0.2106	0.554	53.79
8	11.5	110.3	304.4	0.3623	3.489	31.52
SE		7.2	30.1	0.0340	0.360	4.00

THE VALUES ABOVE ARE MEANS (WITH POOLED SE) OF 6 REPLICATES OF 2 BIRDS EACH

READING MODEL ANALYSIS

9 WEEK BODY WEIGHT (kg)	MEAN BODY WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird.d) (ΔW_{MAX})	g LYSINE/k g BODY-WEIGHT GAIN (a)	g LYSINE TO MAINT AIN 1kg W FOR 1 day (b)
2.010	2.723	107.2	21.67	0.0033

This contrasts with experiment 14, where the birds previously on a low plane achieved a higher maximum gain. In experiment 14, the difference in body weight of birds on the low plane from those on the high plane was small at the end of the feeding period (9 weeks) compared with the difference in body weights at the start (6 weeks). In experiment 15, the difference between the body weights of these groups increased in absolute terms between 9 and 12 weeks. Rather than "catch-up" growth occurring, the reverse occurred.

It seems probable that this difference seen between the experiments is related to the difference in severity of the low plane of nutrition. In experiment 14, the low plane of nutrition had been applied in the first 6 weeks of life and resulted in a 15.5% reduction in body weight. In experiment 15, the low plane of nutrition was applied for the first 9 weeks and from 6 to 9 weeks had been severe. As a result, the body weight of those on the low plane of nutrition at 9 weeks was 36% below that of the birds on the high plane of nutrition.

In experiments 1, 2, 3, 4 and 5, it was demonstrated that the maximum body-weight gain increased with age up to 12 weeks. From the Edinburgh growth model (Fisher and Emmans, 1983) the stage of development may be calculated as W_t/A where W_t = body weight W at time $_t$ and A = body weight at maturity. On this basis, the turkeys on the low plane of nutrition will have been at a much earlier stage of maturity at 9 weeks of age than those previously on the high plane of nutrition. As such therefore, it seems likely that their maximum potential body-weight gain (ΔW_{MAX}) was less than that of birds on the high plane of nutrition, and this has been borne out by experiment 15. The same argument should have applied to the situation in experiment 14 but the reverse occurred. It may be that for the stage of maturity to be affected, the degree of body weight reduction must exceed a certain threshold which was not exceeded in experiment 14 but was in experiment 15.

Alternatively there may be a physical factor involved, viz the quantity (volume) of food that the bird may consume related to its body weight. There must be a limit to the amount of food that a crop can contain and it seems probable this is related to the body weight of the bird. The food consumed per bird day prior to the start of the experiment is known from the data obtained in experiment 14. Those birds previously on a high plane of nutrition had consumed on average 160g food per bird day for the three weeks prior to the start of the experiment, whereas those birds previously on a low plane of nutrition only consumed 110g per bird d, a reduction of 31%. The subsequent food intake at the start of the experiment will be related to the previous food intake. While the highest dietary lysine level would appear to be more than 31% higher than that required for maximum body-weight gain, all the diets were formulated to be iso-energetic, so it is likely there was approximately a third less ME consumed at the start of the experiment by the birds previously on a low plane of nutrition than those previously on a high plane of nutrition. While the birds might be expected to try to increase their ME intake to meet requirements, it is unlikely that the crop carrying capacity could be expanded by the required amount quickly. While the adjustment was taking place, those birds previously on the high plane of nutrition would have increased their body weight advantage which in turn would be causing their food intake to increase, further increasing their advantage over the low plane treatment. Whatever the explanation those birds previously on a high plane of nutrition to 9 weeks were able to attain a higher body-weight gain from 9 to 12 weeks than those birds previously on a low plane of nutrition. Beyond 12 weeks of age, the maximum potential body-weight gain (ΔW_{MAX}) decreases (Experiments 6, 7, 8, 9, 10 and 11) so that birds previously on a low plane of nutrition at that stage, being at a younger stage of maturity might be expected to have a greater potential for body-weight gain and so be able to demonstrate some "catch-up" growth, as reported by Auckland et al (1969).

Figure 50 shows that the lysine utilisation for body-weight gain was the same for both groups over the slope (1/a) section of the response curve. The birds previously on the high plane of nutrition reached a higher maximum body-weight gain. The indicated requirement of g lysine/MJ ME for the birds reared on two different planes of nutrition prior to 6 weeks was :

HIGH PLANE	0.941g lysine/MJ ME
LOW PLANE	0.972g lysine/MJ ME

The higher lysine requirement of the birds previously on a low plane of nutrition would support the proposition that they were at an earlier stage of maturity.

On the basis of experiments 14 and 15, the severity of the reduction in plane of nutrition will influence the ability of the birds to exhibit "catch-up" growth before 12 weeks of age. It will also influence the lysine requirement to achieve the potential body-weight gain. Figure 51 illustrates that in terms of g lysine required per g body-weight gain, experiment 15 indicated a similar efficiency for both treatments to that achieved by the average of the two treatments in experiment 14. However when the restriction is severe

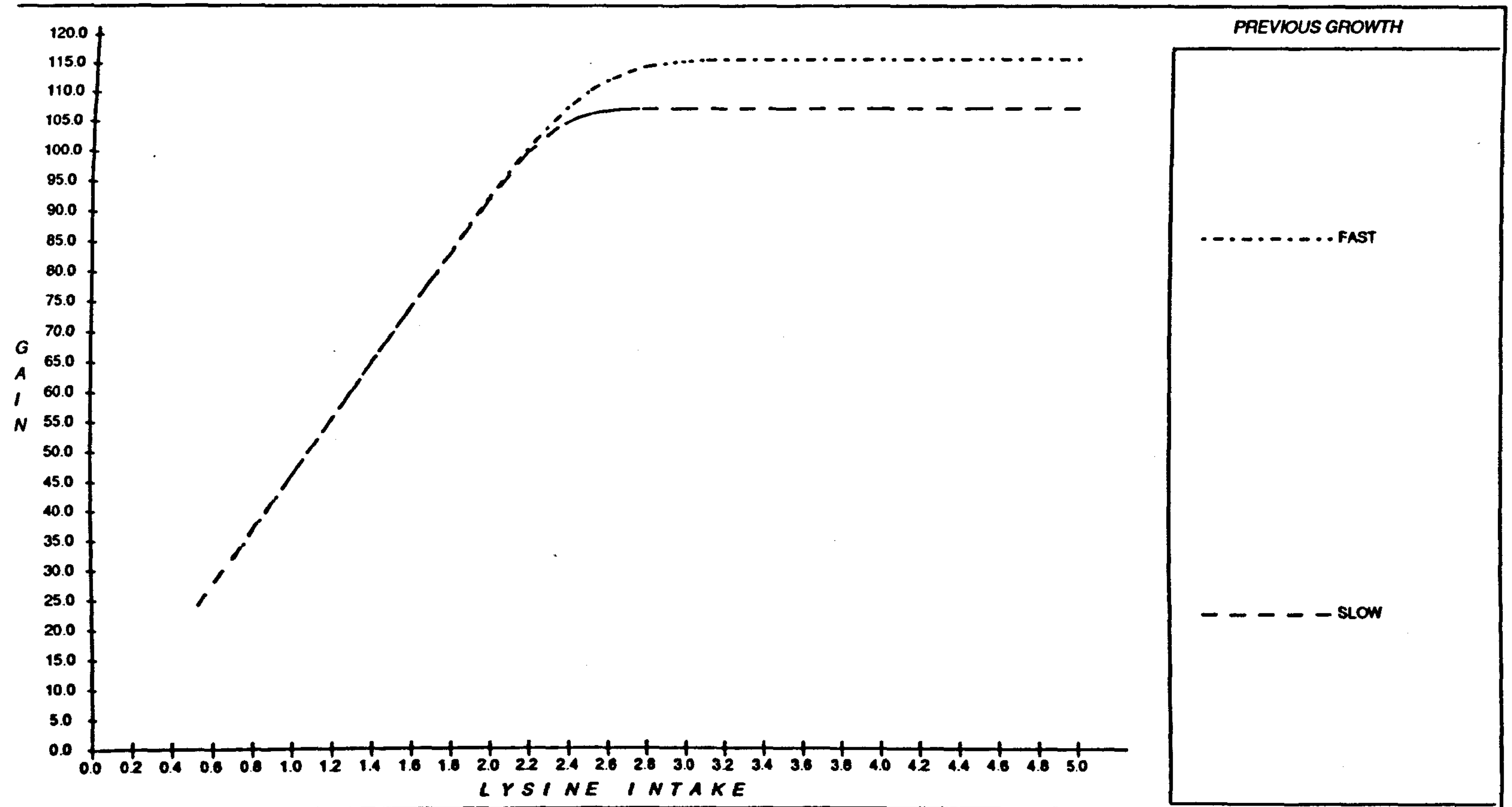

FIGURE 50. READING MODEL PREDICTIONS FOR LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d) FOR TURKEYS PREVIOUSLY GROWN FAST OR SLOW IN EXPERIMENT 15 (9 TO 12 WEEKS)

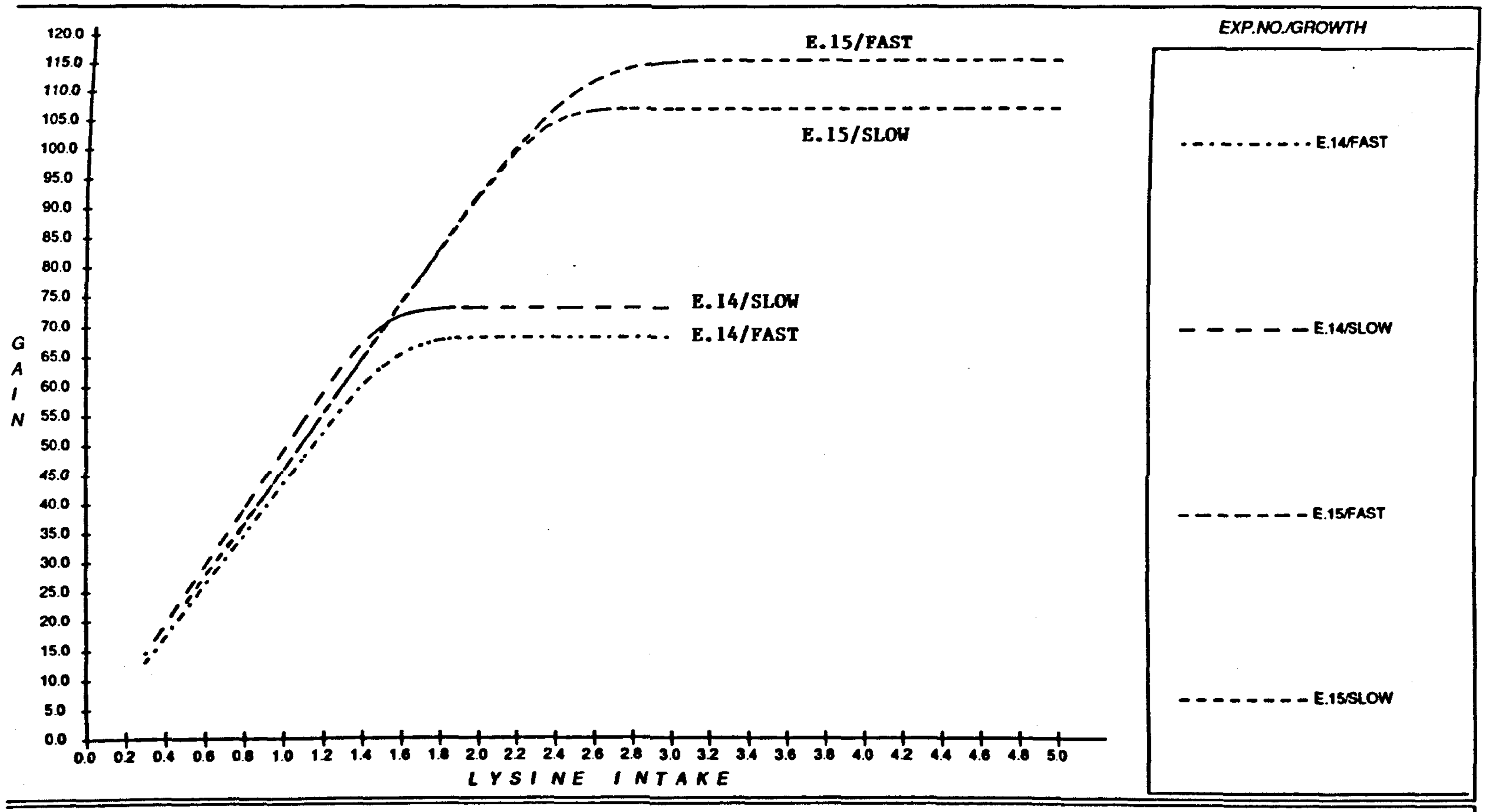

FIGURE 51. READING MODEL PREDICTIONS FOR LYSINE INTAKE (g/d) AND BODY-WEIGHT GAIN (g/d) FOR TURKEYS PREVIOUSLY GROWN FAST OR SLOW IN EXPERIMENTS(E) 14 AND 15

as in experiment 15, more g lysine per MJ ME are required by the restricted birds to exhibit maximum gain than is required by the normal birds. With a less severe restriction, as in experiment 14, the restricted birds did not require a higher lysine concentration than the normal birds to exhibit maximum gain.

CHAPTER FOUR

Discussion

THE EXPERIMENTAL TECHNIQUE

a) The length of the experimental period

The length of the experimental period will influence the results, particularly the curvature of the response line. Over the three-week period of the experiment, some diets initially providing inadequate quantities of lysine, will become adequate by the end of the experimental period, as the requirement decreases with age. This will produce curvature in the response to amino acid intake in addition to the curvature due to variation between individuals at a moment in time, discussed in Chapter 2 and illustrated in Figure 6.

The weighing of an individual live animal will contain an element of inaccuracy caused by the animal's movements. In addition crop fill may vary during the course of a day and may not have been identical at the start and end of the experimental period. There will also be an inaccuracy due to the method of recording the weight. This was less in experiments 1 and 2 when an electronic scale was used. However, in the other experiments, the size of the turkeys dictated that a spring balance was necessary. This meant that a judgement had to be made as to what weight the balance had settled at.

The summation of the areas of inaccuracy in weighing could therefore represent the equivalent of one day's body-weight gain by the bird in extreme incidences. As the length of the experimental period is increased, so the influence of this error is decreased. This must be counterbalanced by the problem of the bird's requirement changing with age discussed earlier. The coefficient of variation of body-weight gain in the experiments varied between 10 and 16% which is higher than one hoped for. This may in part be due to the weighing in accuracies discussed above. Nevertheless, to have extended the length of the experimental period beyond three weeks would have run the risk of the age affect influencing the curvature markedly. With the benefit of hindsight, the chosen experimental period of three weeks would appear to have been a suitable compromise.

b. The experimental diets

As a result of the lysine levels used in the experimental diets, the distribution of data points over the response curve was less than ideal in several of the experiments. In part, this can be explained by the economic necessity to use the same set of diets in several experiments scanning a range of ages. However, the situation was aggravated by the emphasis placed when designing the experimental diets on ensuring that a plateau in response could be clearly demonstrated, so avoiding the criticism made in the review chapter of some other research work on the subject. As a result often more diets than were necessary gave data points on the plateau section of the response curve and were in effect, wasted diets.

This became even more apparent when the data were analysed on the Reading model. By a succession of analysis runs omitting data points falling on the plateau section, it became apparent that the model takes little or no account of these data points in assessing the response slope (1/a) but the data points are used in assessing the maximum body-weight gain, (ΔW_{MAX}). As there was often growth depression as lysine intakes increased along the plateau section, the extra data points led to underestimation by the Reading model of (ΔW_{MAX}) judged by the highest level of gain, and the danger of underestimating the lysine intake necessary to achieve maximum gain which is a criticism of the broken line method of analysis.

A conclusion which can be drawn from these experiments when designing future experiments in which it is planned to analyse the data with the Reading model, is the value of trying to assess the likely level necessary to achieve ΔW_{MAX} quite accurately and then designing only two diets out of a series of seven or eight diets which might be expected to fall on the plateau. It is more preferable to assess the slope (1/a) accurately than to ensure that the plateau has been achieved beyond doubt because the extra data points apparently necessary to achieve this may be misleading.

c. The experimental design and analysis

Experimenters are often faced with the dilemma of either using large pens with more birds and fewer replications or an increased number of replications but each with fewer birds or even, on occasions, individual birds.

An analogy can be drawn in these experiments where either the mean treatment value derived from the sum of the replicates would be used in the Reading model or each individual replicate used as a data point. It will be appreciated by the reader that the experiments involved a large number of Reading model analyses with the data presented in a variety of ways. Using the mean treatment values often did not result in a good 'fit' of the model to these points which was even more apparent when contrasted with the individual replicate data points. If only a few data points, as in the case of the use of means, were available on the response section of the curve, it was very apparent that the data relating to the lowest lysine intake had a disproportionate effect on the resulting Reading model analysis of the response slope. The more data points falling on the response section of the curve, the less the influence of individual data points at the lower end of the response slope. It is concluded that if it is intended to analyse the resulting data on the Reading model, it is much preferable to use an increased number of replicates even at the expense of bird numbers rather than fewer replicates with more birds per replicate.

In defining the requirement level to achieve maximum body-weight gain, it is important to define the curvature approaching the plateau in response accurately. This can be defined more accurately if a large number of replicate data points are available. When only a few data points are available as in the case when a fewer number of large pens are used rather than many small pens, there is the ever present risk that the two treatments closest to the curvature area will straddle the area in such a way as to indicate a misleading curvature. An example of this would be if the first treatment lying on the plateau section of the curve fell at a point noticeably after the plateau had been achieved. Without the benefit of several data points lying in this area, the Reading model's definition of the curvature would be erroneous.

In view of possible variations within the experimental rooms and between rooms, the treatments were distributed among three block areas within each room. The analysis of variance indicated that only a small proportion of the variance seen could be attributed to these housing factors and that there were no significant differences between the rooms or between blocks within rooms. Most of the variance was attributed to the nutritional treatments. In experiments such as were carried out where large nutritional treatment differences are required in order to define the slope of the response, there would appear to be less need to be concerned about attributing other sources of variance as they will be of little account as a proportion of the total variation seen.

DIET FORMULATION AND ANALYSES

(a) The Diet Specification

For practical reasons, it was not possible to make less than one tonne of any summit or basal mixture. Due to the comparatively small amount of food required in each experiment, it was necessary for economic reasons to use the same experimental diets in several experiments. Since lysine requirements as a proportion of the diet decrease with increasing age of the turkey, when the diets were used over two age ranges eg. Experiments 12, 13, 14 and 15, the range of lysine concentrations covered by the diets included fewer in the deficient range (ie. on the response slope) in the older age than in the younger age period.

As stated earlier in this discussion, the experimental diets would have benefited from less emphasis on ensuring that sufficient diets gave data on the plateau region. The ideal spread of seven diet responses would appear to be four on the response slope, one around the point of inflection and two clearly on the plateau. Most experiments had at least three points on the plateau so at least one experimental diet was not used to its best potential. With hindsight, there was no need for the incremental steps between treatments to have been equal. By varying the size of the increment, diets could have been targeted to increase the number of diets in the more sensitive areas of the response curve i.e. the low intakes at the bottom of the curve and approaching the plateau.

(b) The response to the Added Free Lysine Diet

In each experiment an additional diet, diet 8, to those obtained from combinations of summit and basal diets was fed. This diet was one of the experimental diets to which free lysine was added such that its total lysine concentration was equivalent to that of the next diet in the series. The purpose of this diet was to verify that the growth response seen was in response to lysine rather than another nutrient.

In the diets used for experiments 3 and 4, by mistake free lysine was added at twice the intended concentration. Nevertheless, the data would indicate (Figures 14 and 15) that there was a growth response to the whole addition of free lysine, demonstrating the extent of the lysine deficiency in the diets.

In all responses except one, the data points for diets containing added free lysine were on the same response line as other diets in the same section of the response curve in the same experiment, confirming that the diets were first limiting in lysine. The exception, the large type males in experiment 13, consisted of only three individual replicate birds and was probably a chance occurrence, as the other types of birds and the large type males in experiment 12 on the same diet, all showed responses consistent with lysine deficiency as described above. To allow for the higher absorption in the intestine of synthetic or free lysine relative to that in natural ingredients, the added free lysine was given an equivalent total lysine value of 900g/kg in calculations, notwithstanding the fact that the minimum guaranteed L-lysine in commercial synthetic lysine is 784.4g/kg. Some confirmation of the value of the validity of this approach is evident from the fact that the data points for diets containing free lysine, when calculated using this value, were on the same response line as predicted from the other diets in all responses except one.

c. The Analysis

When the summit and basal diets were formulated, the analysed protein contents of the main ingredients were very similar to the calculated values. Nevertheless, subsequent analysis of the mixtures (Appendix Tables 6 and 8) showed more variation between calculated and determined protein and lysine levels than had been hoped for in some mixtures. This was especially so of the basal mixtures, for which values tended to be higher than calculated. Values for the other amino acids tended to be even higher than respective calculated values than was the case for lysine in all mixtures. Lysine should therefore have always been the first limiting amino acid. The growth responses seen with diet 8, the diet with added free lysine would confirm this.

There was also considerable variation between laboratories in the determined protein levels of the same mixture, e.g. the three laboratory results for summit and basal mixtures A, mix 1. Laboratory 2, also analysed all the blended diets using an ion-exchange procedure for amino acid analysis of the diets. The individual diets varied considerably in their comparison with calculated values.

The method of blending summit and basal mixes should have been accurate. The mixtures were first of all weighed into 25kg bags to an accuracy of 0.1kg. The required number of bags of each mixture were then tipped into the mixer. Empty bags were retained to check the count of each mixture. Despite these precautions, the variation between determined protein and lysine levels and those calculated for each diet was considerable. Variation due to sampling is a problem but it also seems likely that laboratory technique is a significant contributor to the variation seen between diets in their calculated and determined values. Evidence for this statement can be seen in Table 57.

TABLE 57	A COMPARISON OF THE DETERMINED VALUES OF TWO SETS OF SAMPLES FROM DIETS USED IN EXPERIMENTS 5, 6 AND 7 ANALYSED BY THE SAME LABORATORY (APPENDIX TABLE 3 GIVES CALCULATED LYSINE VALUES)					
	PROTEIN (g/kg)		LYSINE (g/kg)		CALCULATED	
DIET NO.	Pelleted Sample	Mash Sample	Pelleted Sample	Mash Sample	Protein (g/kg)	Lysine (g/kg)
1	433.9	436.2	18.8	17.6	468.0	19.0
2	402.7	396.2	15.6	16.4	411.0	16.5
3	349.5	321.8	14.3	14.2	353.4	14.0
4	300.8	286.9	11.9	11.9	294.9	11.5
5	242.4	246.0	9.6	10.3	236.7	9.0
6	195.6	192.4	7.2	7.4	179.0	6.5
7	138.6	135.0	5.3	5.5	121.8	4.0
8	239.7	245.7	9.4*	9.5*	236.7	11.5

* Added free lysine not detected by laboratory analysis technique.

The samples differed in that one was pelleted and the other was an unpelleted meal. They were obtained from the same mix of diets. It will be seen that while there was good agreement between some analyses, in others the variation was considerable. Often the lysine differences were not correlated with the protein differences.

There was usually a considerable time lag between submitting samples for analysis and receiving the completed analyses, and in some cases difficulties with technique produced incomplete analyses of sulphur amino acids. It was difficult to follow these up later. With hindsight, given that there is a limit to the number of analyses that can be carried out, the better solution would have been to accept that the correct proportions of each mixture were present in each diet on the evidence of the precautions taken. The effort could then be concentrated on the summit and basal mixtures, using more than one laboratory and have several analyses carried out by each laboratory on samples of the same mixture. The mean values could then have been used with some confidence to calculate the actual contents of the diets. These could then have been used in the Reading model in place of the calculated values.

Notwithstanding the above, it seems likely that while summit mixtures were close to calculated values, the basal mixtures were higher in lysine content than the calculated value (with the exception of basal B mixture). If so, this would have an influence on the slope of the response seen. This raises the question as to whether determined or calculated values should be used in fitting data to the Reading model.

Several factors must be taken into account in resolving the issue of which values to use. The mixtures were formulated to total lysine levels. The main source of the lysine in the summit mixtures was soya bean and maize gluten, while in the basal mixtures it was cereals. Sauer and Ozimek (1986) reported mean apparent ileal digestibilities in pigs for lysine of 86% in soya bean meal, and 72 and 74% in barley and wheat respectively. No values were given for maize gluten. The digestibility of the lysine in the basal mixtures, composed as they were of mainly cereals, will therefore have been lower than that in the summit mixture, having soya bean as a source of lysine. This will have tended to counterbalance the higher than intended total lysine levels in the basal mixtures. Furthermore, analyses inevitably use small samples and unless repeated analyses on several subsamples are possible, a reliable estimate of an amino acid concentration is difficult to obtain. For example, in basal A, mixes 2 and 3 (Appendix Table 8) there might seem to be a good case for using determined values. If this policy is adopted, is the 7.2g/kg value for mix 1 to be accepted? On the other hand, current ingredient values from a reliable source (Colborn Dawes, personal communication) have a background of use, confidence and general currency. They will be used for other formulatory exercises commercially and much published work is based on such values. In this case it was decided to use the values calculated from ingredient values taken from the Colborn Dawes ingredient nutrient matrix (Appendix Table 40). The analyses are therefore given in broad confirmation of these values and assumptions.

The summit and basal mixtures will always be derived from different ingredients. The influences of differences in digestibilities between ingredients will not arise if the basal mixture does not contain protein. When a protein containing basal mixture is used, it would seem to be important to use formulations based on digestible amino acids, to prevent the response slope being influenced by differences in digestibilities between those diets of high protein content and those of low protein content. This aspect appears to have been overlooked in previous work. For such formulations to be produced, good information on digestibilities of amino acids by poultry in various ingredients is required.

Of the nutrients other than amino acids, the sodium chloride levels were low in basal mixture A, mix 1 and in basal mixture C. Phosphorus levels generally were lower than intended in the basal mixtures. It is not envisaged that either nutrient will have influenced the utilisation of lysine. The low sodium chloride levels may have depressed appetites in the diets containing large quantities of basal mixture. It is not expected that this will have affected the slope of the response or the level of plateau.

READING MODEL

The experiments have relied heavily on analysis by the Reading model. The original reason was to enable predictive equations to be produced which would reduce the need for repetitive empirical experimentation as the genetical potential of the turkey changed with breeding progress. Retrospectively, it is apparent that the Reading model is a very good tool for fitting curves to data. No other system could have coped as consistently with the data in the experiments.

In the past, the 'broken line' method has been a popular system for analysing data. As discussed in Chapter One, such a system will tend to under-estimate the requirement for maximum growth rate, even using satisfactory data on the plateau region. A feature of the response curves in the current experiments was the irregular pattern of data at lysine intakes greater than the maximum needed for maximum gain. If three or more diet treatments exceeded the minimum required for maximum gain, the resulting data rarely indicated a flat plateau, necessary for analysis by the 'broken line' method.

The Reading model requires information on the standard deviations for maximum body-weight gain and body weight. When analysing data in published papers, this information is often lacking. In their analysis of published chicken data, Boorman and Burgess (1986) used values giving a coefficient of variation of 10% for both body-weight gain and body weight. The values obtained in the current experiments are plotted in Figure 52. It will be seen that in most experiments, the coefficient of variation for body weight was at or below 10%. This results from the birds being selected for uniformity before the start of the experiment. The exception was in experiment 15 when the birds with slow growth previous to the start of the experiment had to be obtained from the poorest treatments of experiment 14. This resulted in a coefficient of variation for body weight of almost 15% for this group of birds. On the other hand, the coefficients of variation for body-weight gain shown in Figure 52 were usually in excess of 10%. In most experiments they were between 10 and 15%.

In order to assess the possible significance of the values used for standard deviations in the Reading model, the experimental data were also analysed using standard deviation values which gave coefficients of variation of 10% for either or both gain and body weight. A comparison of the resulting a values with those obtained using the actual standard deviations is shown in Figure 53. It will be seen that, with one exception, the use of actual values for standard deviation of body-weight had little influence on the a value obtained compared to using a value equivalent to a coefficient of variation of 10% for body weight.

It will also be seen from Figure 53 that using actual values for standard deviation of body-weight gain compared to a value equivalent to a coefficient of variation of 10%, had little influence on the a value in the majority of cases. In six instances, the a value was noticeably influenced, in the extreme case by as much as 14%. All six instances were from experiments 12 and 13, involving the four types of bird with different growth potentials. In these experiments, the number of replicates per treatment had to be reduced to three, as opposed to twelve in most other experiments. From the distribution of the data points resulting from the same experiment in Figure 53 which can be identified by points at the same a value, it will be seen that when actual standard deviation values for both gain

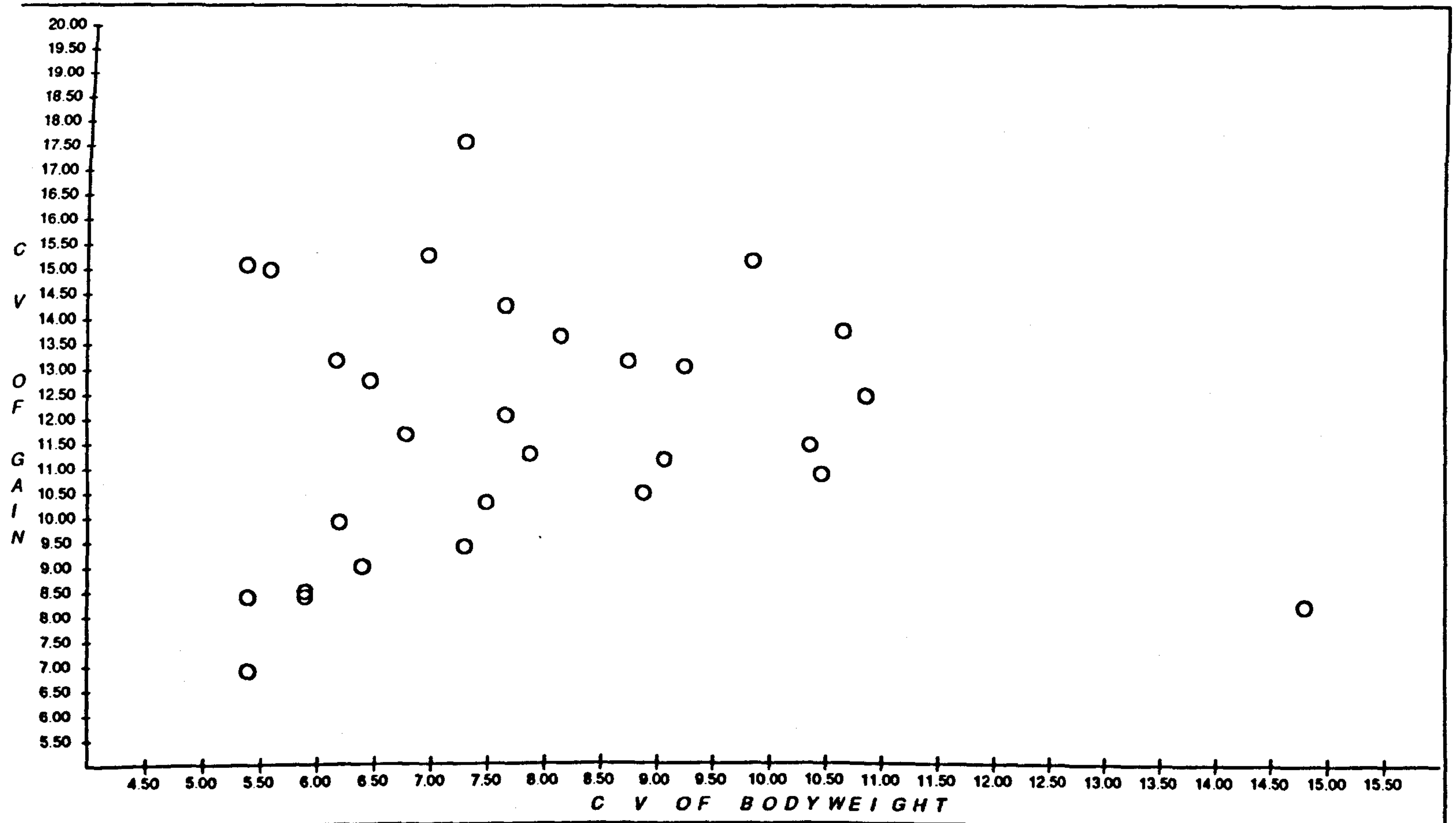

FIGURE 52. THE COEFFICIENTS OF VARIATION(%) FOR BODY-WEIGHT GAIN AND BODYWEIGHT IN THE EXPERIMENTS

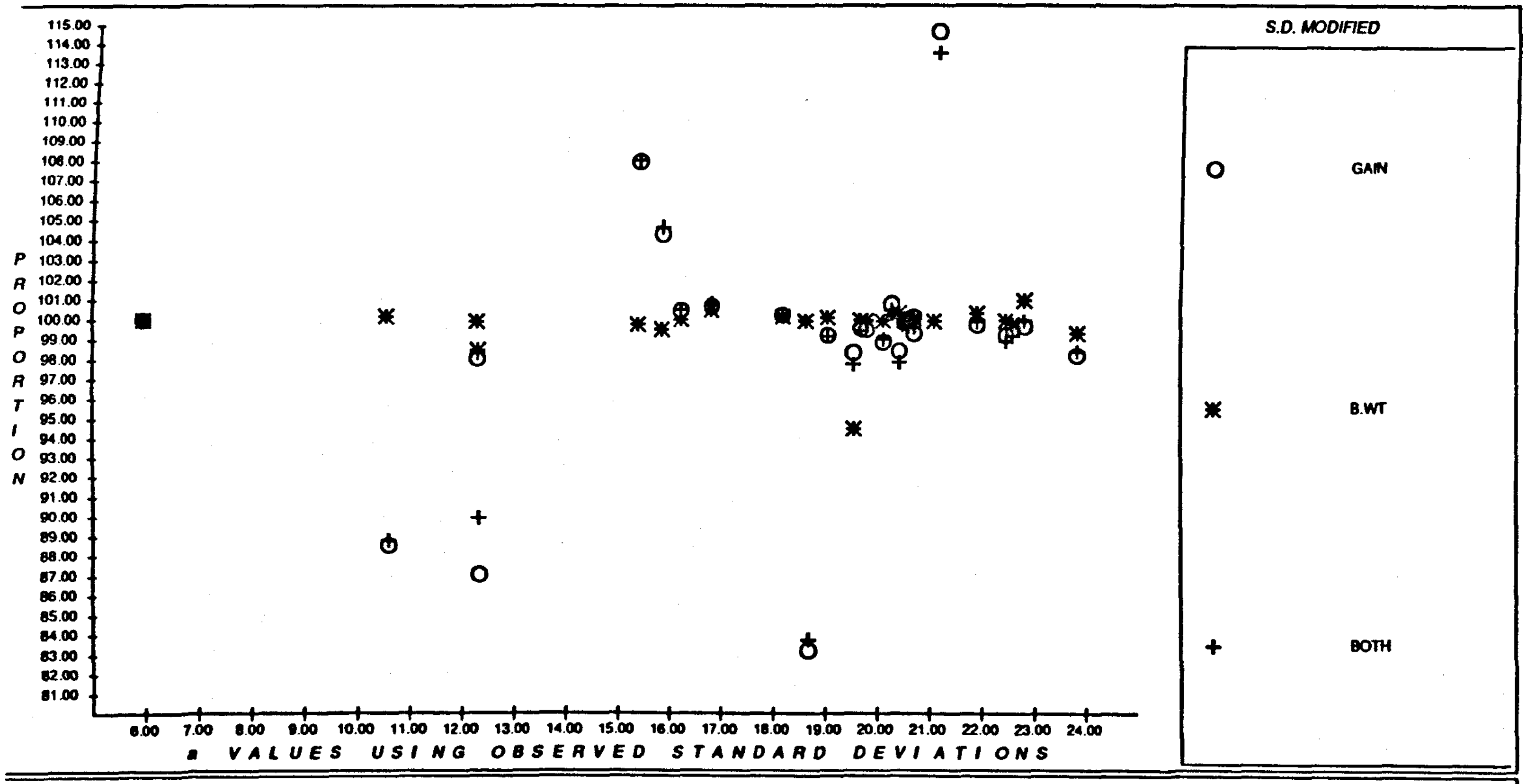

FIGURE 53. THE VALUE FOR COEFFICIENT a CALCULATED USING OBSERVED STANDARD DEVIATIONS FOR EITHER OR BOTH GAIN AND BODY WEIGHT EXPRESSED AS A PROPORTION OF THAT OBTAINED USING A STANDARD DEVIATION OF 10 % FOR BOTH

and body weight were used, the resulting a values were very similar to the value obtained when only the actual standard deviation for gain was used as opposed to the a value obtained when using only the actual standard deviation for body weight. It is therefore concluded that the use of arbitrary values for standard deviations equivalent to a coefficient of variation of 10% for both gain and body weight, when applied to data in the literature lacking actual values, does not carry a major risk of resulting in misleading a values. The possibility however exists. Actual values for standard deviation of gain are more valuable than those for body weight.

The Reading model also require a value for the correlation coefficient between maximum body-weight gain and body weight. Boorman and Burgess (1986) used a value of 0.8. The same value was used in the analysis of these experiments. To test the influence of the value used, all the experiments were re-run on the Reading model using a value for the correlation coefficient of 0.5. The effect on the resulting a and b values was minimal with the a values on average being 99.98% of those obtained using a correlation coefficient of 0.8 and the b values 101.87%. It is unlikely that the correlation coefficient will be below 0.5 so it can be concluded that the Reading model is not very sensitive to errors in the value given for this coefficient over the normal range of values seen in practice.

One of the weaknesses of the Reading model is indeed its robustness. It can be used to fit a curve to almost any set of data showing a response to an input. For individual coefficients, any conclusion is subject to wide limits of uncertainty. Errors associated with the coefficient a will influence the intercept and so increase the errors association with the coefficient b. Unfortunately, simple estimates of the errors associated with the value of a and b are not available (Curnow, 1973). Notwithstanding all this, an alternative system is not available which would have handled the available data as comprehensively as has the Reading model. While the value of individual coefficients a and b from a particular experiment may have an uncertain significance, the collection of coefficients obtained by this work, in which consistent trends can be identified, can be said to have a value greater than might be indicated by the errors attached to individual coefficients.

One aspect of the Reading model has been omitted in this analysis. This concerns the calculation of when the marginal cost of lysine equals the marginal return to calculate the optimum intake for a population of birds. Disregarding the unknown errors associated with the coefficients, there is a major problem in calculating the value of extra body weight. (Nixey, 1989b) illustrated that the breast meat yield as a percentage of the body weight is greatly influenced by body weight achieved at an age in relation to the birds' genetic potential for body weight at that age. Further, the time of any growth depression during the growing cycle will also influence subsequent breast meat yields. As at most times breast meat is worth at least double the value of other meats, any sophisticated calculation of when marginal cost equalled marginal yield, which could not incorporate differences in the breast meat yield in the calculation, had no value. In these experiments, no measurement of meat yields was made.

In commercial operations, rarely do the turkeys approach their maximum potential body-weight gain; usually still being on the linear response phase of the growth curve. In view of this and the benefits on breast meat yields from improved growth, the value of extra body-weight gain will usually exceed the extra cost of lysine. If desired, a decision can be made to satisfy the requirements of a known proportion of the flock by manipulating the value of x in the equation shown on page 39. A commercial solution to this situation is discussed in the next chapter.

PREDICTIVE EQUATIONS

The primary purpose of the experiments was to obtain values for the constants a and b in the equation:-

Lysine Requirement (g/d) $= a\Delta W + bW$

where ΔW = body-weight gain (kg)

W = mean body weight (kg)

This has been achieved for a wide range of ages and for a variety of types of turkey and will reduce the need for repetitive empirical experimentation.

Table 58 summarises the information obtained.

TABLE 58	A SUMMARY OF THE READING MODEL ANALYSES OF THE EXPERIMENTS					
EXPERIMENT NO.	DESCRIPTION AGE (DAYS)	SEX	MEAN BODY-WEIGHT (kg) (W)	MAX. BODY-WEIGHT GAIN (g/bird d) (ΔW_{MAX})	g LYSINE/ kg BODY-WEIGHT GAIN (a)	mg LYSINE TO MAINTAIN 1 kg $\bar{W}$ FOR 1 DAY (b)
1	4-13	M	0.137	18.8	21.31	15.5
1	4-22	M	0.214	21.3	21.41	8.6
2	4-13	M	0.161	17.9	20.97	10.9
2	4-22	M	0.274	22.4	20.97	4.7
3	4-7	M	1.323	72.2	35.13	1.0
4	4-7	F	1.034	44.5	35.22	3.6
5	9-12	M	4.305	97.5	22.91	4.0
6	15-18	M	8.079	85.1	18.26	43.5
7	15-18	M	8.482	85.5	16.88	50.3
8	15-18	M	8.517	88.5	22.23	1.9
8	15-18	F	5.775	62.2	19.68	3.2
9	15-18	M	8.949	102.7	23.67	2.2
9	15-18	F	5.913	71.8	12.92	0.6
10	17-20	M	10.402	111.8	19.62	1.9
10	17-20	F	6.740	76.9	16.18	2.4
11	17-20	M	11.125	95.5	20.48	2.0
11	17-20	F	7.358	53.4	15.91	1.2
12	LARGE	M	5.034	118.9	19.98	3.1
12	LARGE	F	3.742	87.1	19.00	1.5
12	SMALL	M	3.517	71.4	21.56	23.4
12	SMALL	F	2.635	53.7	17.18	13.7
13	LARGE	M	4.850	128.0	19.48	2.1
13	LARGE	F	3.505	87.0	22.57	1.9
13	SMALL	M	3.400	78.9	20.08	2.7
13	SMALL	F	2.618	48.9	13.91	31.3
14	FAST	M	1.928	68.5	22.86	4.2
14	SLOW	M	1.721	73.4	20.29	4.6
15	FAST	M	3.977	115.6	21.39	6.3
15	SLOW	M	2.723	107.2	21.67	3.3

Figure 54 shows the a values, which are used to calculate lysine required for body-weight gain, against age for both sexes. Experiments 3 and 4 have been omitted because of food wastage problems. Data from the experiments are compared with the values indicated by analysis of data from the literature (see Table 21). It will be seen that there is, with a few exceptions, a strong similarity between the data for males from the two sources. Very few data have been published on requirements of females. The experimental data show an increasing divergence between the sexes with increasing age, with the value for females tending to be lower than that for males. There is no indication of the a value for males reducing until at least 120 days. Between 120 and 130 days of age, the experimental data

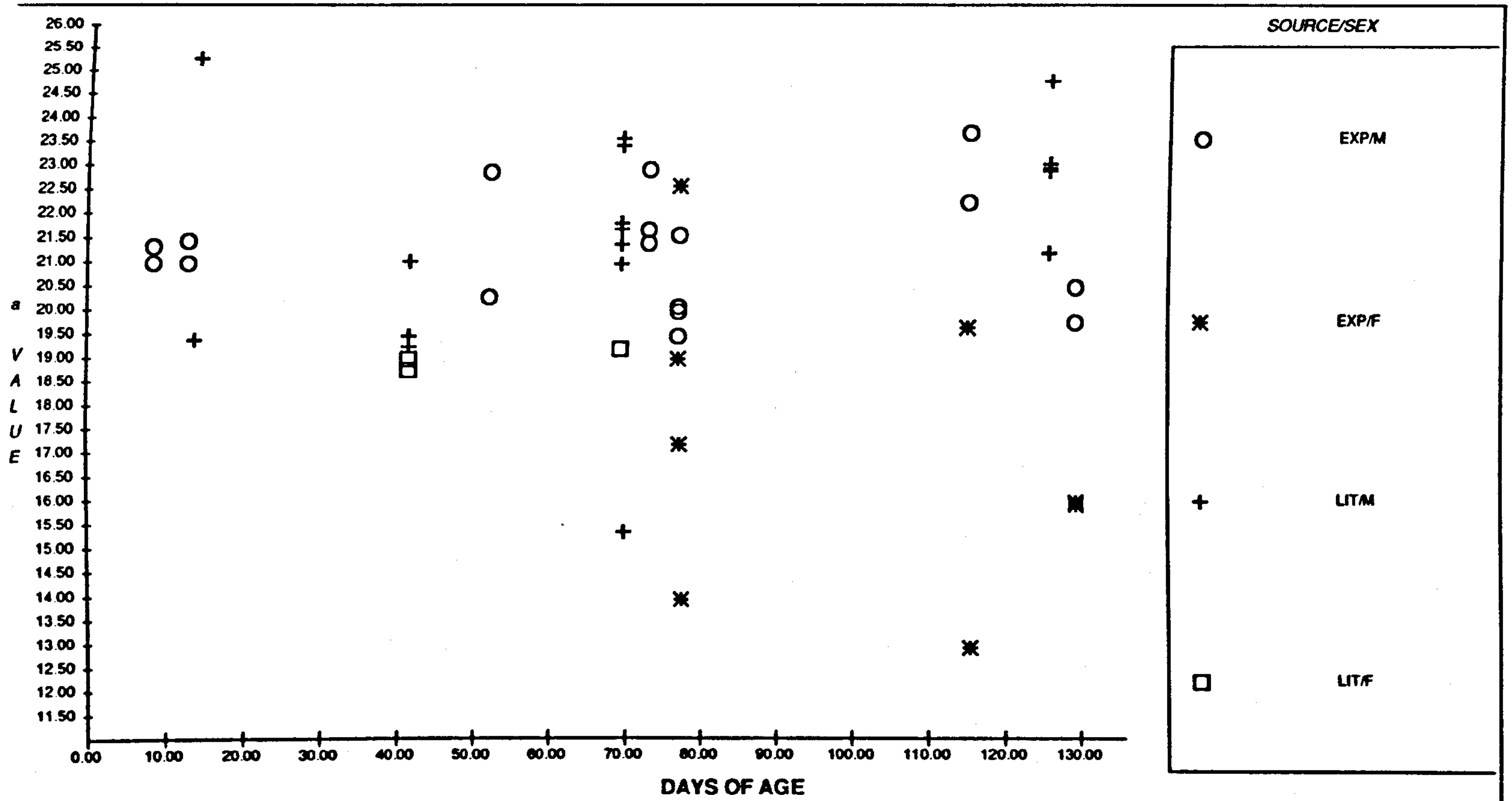

FIGURE 54. A COMPARISON OF THE VALUES FOR COEFFICIENT a (READING MODEL) INDICATED BY THE LITERATURE (LIT) (SEE TABLE 21) AND THOSE DERIVED EXPERIMENTALLY (EXP) FOR MALE (M) AND FEMALE (F) TURKEYS

indicated a slight reduction which was not in agreement with the published data. The mean (± S.E.M.) of the a values for males combining both published and experimental data over all the ages was 21.4 ± 2.0. With the a values for females tending to reduce with age, a mean value for females could be misleading and is of little value.

The b values for the published data show wide fluctuations (see Table 21) and average 16.8 x 10^3 for males and 13.9 x 10^3 for females. The experimental data show more consistency (Figure 55) but at a much lower level ie. 6.0 x 10^3 for males and 7 x 10^3 for females. No explanation for this difference can be given. Using body-weight gain data in the Reading model will produce an estimated maintenance value that is usually less than 5% of the total predicted lysine requirement. The difference seen in b values therefore has little overall quantitative significance.

Ideally, the Reading model is most correct when the output is measured in terms of protein gain as opposed to body-weight gain. However, it was beyond the scope of this project to undertake such work.

NETT EFFICIENCY OF UTILISATION

The predictive equations allow the nett efficiency of utilisation of dietary lysine consumed to be calculated and a comparison made with similar calculations for chickens. The nett efficiency of utilisation of lysine for growth (EG) is here defined as:-

$$EG = \frac{a_o}{a}$$

where a_o is the lysine content of the body-weight gain and a is the constant calculated by the Reading model as referred to previously. The lysine content of body-weight gain can be calculated from the protein content of the gain and the lysine content of the protein in the gain.

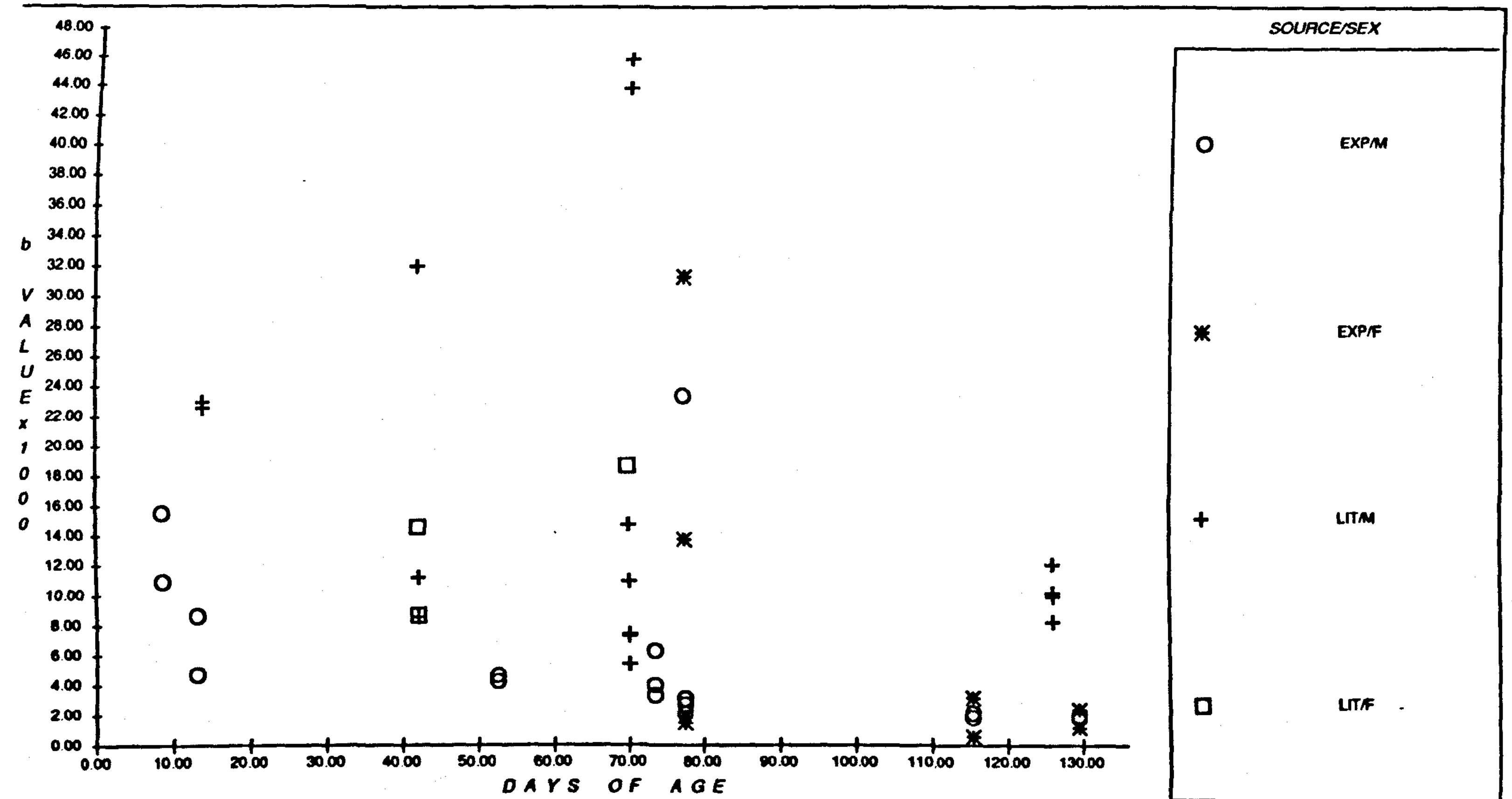

FIGURE 55. A COMPARISON OF THE VALUES FOR COEFFICIENT b (READING MODEL) INDICATED BY THE LITERATURE (LIT) (SEE TABLE 21) AND THOSE DERIVED EXPERIMENTALLY (EXP) FOR MALE(M) AND FEMALE(F) TURKEYS

The information on the protein content of body-weight gain of turkeys is not comprehensive. Hurwitz et al (1983) have produced data on large white turkeys (Tables 13 to 16). Leeson and Summers (1980 a and b) have published information on the carcass characteristics of both male and female turkeys at various ages, and also similar information on broiler chickens. Unfortunately, feathers were excluded from their analysis. As feathers will constitute only approximately 5% of the body weight and contain only about 17g lysine per kg (Hurwitz et al, 1983) the omission will have little effect on comparisons of ages, sexes or species of bird. These comparisons are illustrated in Figure 56. A comparison with Figure 54 shows that the a values indicate a similar pattern of change as that seen in protein content of body-weight gain. This is what might have been expected as lysine is required for protein gain and this increases the confidence to be placed in the results.

There is conflicting evidence on the lysine content of the protein in the gain. Data given in the Israel model (Hurwitz et al 1983) indicate that lysine has been presumed to be 6.6g/100g protein for all ages. Fisher and Scougall (1982) estimated the lysine content of turkey meat protein to be 5.42g/100g protein at 28 days and 5.57g at 56 days. Saunders, et al (1977) found a similar value, 5.41g lysine per 100g protein for young chicken meat protein. The lysine content of the protein presumed in the calculation will have a large influence on the calculation of nett efficiency of utilisation. As it would be surprising if there were large differences in the lysine contents of the proteins of chickens and turkeys, the lower level found by Fisher and Scougall (1982) of 5.42g/100g protein has been used in the calculation for young turkeys. Figure 56 indicates a protein content of 216g per kg body-weight gain for two week old male turkeys. Presuming a lysine content of 5.42g/100g protein, would indicate a lysine content of 11.72g/kg gain. .this would be the minimum lysine needed for gain if nett efficiency was 100%. Table 58 shows that Reading model analysis of the experiments carried out at this age indicated 21.2g lysine required per kg gain. This would result in a calculated nett efficiency of lysine utilisation of 55.2%.

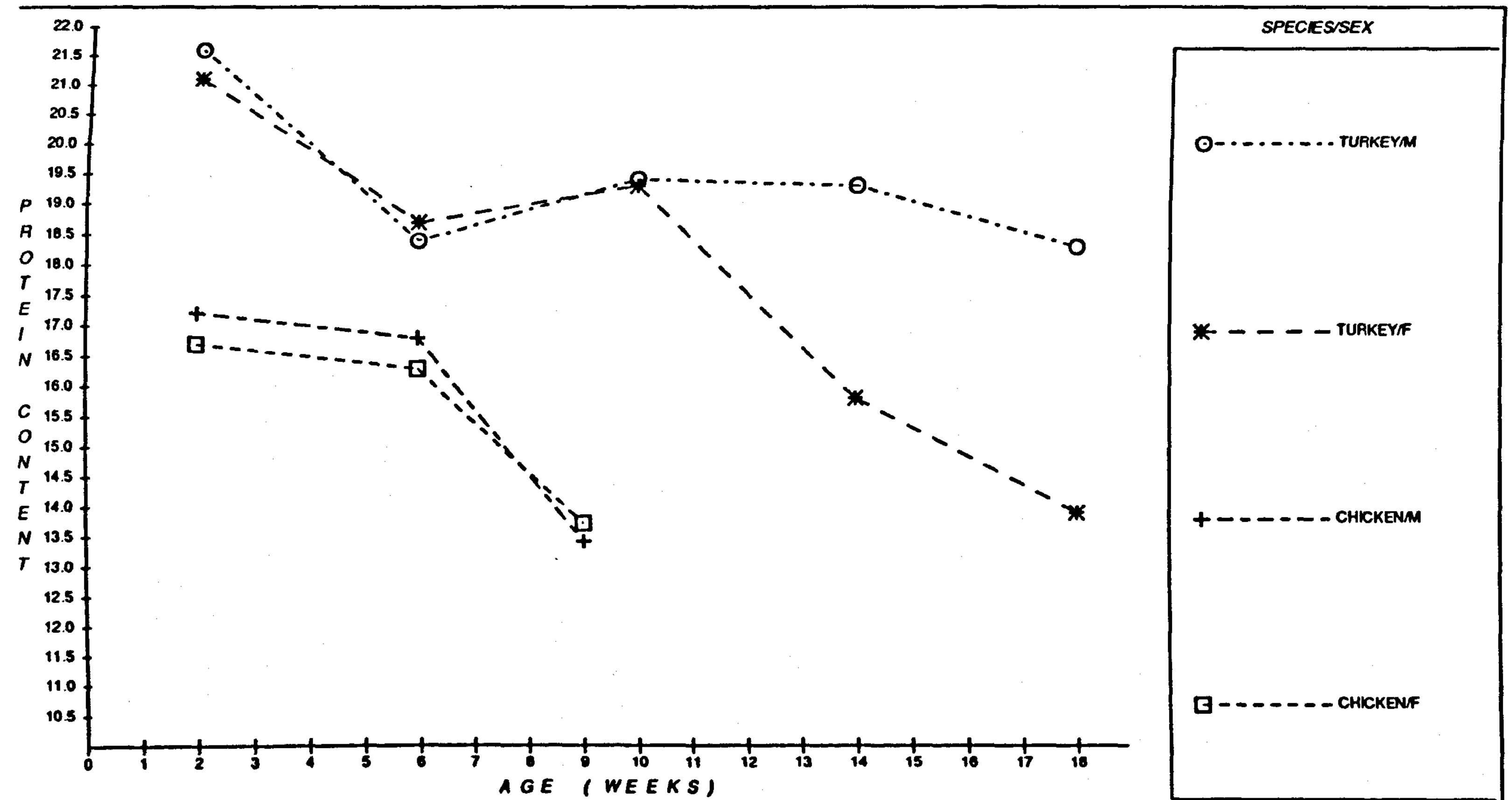

FIGURE 56. THE PROTEIN CONTENT (g/kg) OF BODY-WEIGHT GAIN OF MALE (M) AND FEMALE (F) TURKEYS AND CHICKENS AT DIFFERENT AGES CALCULATED FROM DATA OF LEESON AND SUMMERS (1980a,b)

At the older ages, the protein content of gain shown in Figure 56 is around 192g per kg body-weight gain. Using Fisher and Scougall (1982) data for 56 day old birds of 5.57g/100g protein indicates a lysine content of 10.69g/kg gain. The mean a value for all the experiments involving male turkeys was 21.4g lysine required per kg gain. This would result in a calculated nett efficiency of lysine utilisation of 50.0%

The same calculation can be carried out for chicken. Figure 56 indicates a protein content of about 170g per kg gain. Using a lysine content of 5.41g/100g protein would give (Saunders, et al 1977) a lysine content of 8.74g/kg gain. Boorman and Burgess (1986) analysed the suitable published data on the lysine requirements of broiler chickens using the Reading model. Combining the responses, they concluded that the a values for young (starter) chickens was 14.86g lysine/kg gain. This would produce a calculated nett efficiency of lysine utilisation for chicken of 58.8%. Boorman and Burgess (1986) when doing the identical calculation arrived at a higher value, 71%, as a result of using a higher protein content, 190g/kg gain, and a lysine content of 5.55g/100g protein.

Differences in lysine conversion rate to body-weight gain can be explained by differences in the composition of body-weight gain. Tissues such as fat and bone will have a negligible requirement for lysine. The greater the proportion of the body-weight gain such tissues represent, the lower will be the apparent requirement per kg gain. Differences in the composition of body-weight gain will explain not only the differences between turkeys and chickens but also the differences seen between sexes of turkeys. The large decrease in the protein content of the gain of females found by Leeson and Summers (1980 b) is the result of a marked increase in fat deposition. This is shown in Table 59, which is calculated from the data published by Leeson and Summers (1980 b). This shows a marked increase in fat content of gain in both sexes. The most likely explanation for the

TABLE 59	FAT CONTENT OF GAIN OF MALE AND FEMALE TURKEYS (AFTER LEESON AND SUMMERS, 1980b)	
AGE PERIOD (WEEKS)	g OF FAT/kg BODY-WEIGHT GAIN	
	MALES	FEMALES
0-4	32	37
4-8	40	39
8-12	84	188
12-16	107	325
16-20	209	410

protein content of gain in males remaining relatively constant over the later period (Figure 56) while the fat content is increasing, is the counter balancing decrease in skeletal gain. In females, the reduction in skeletal growth appears insufficient to balance the marked increase in fat deposition (Table 59), resulting in a marked reduction in the protein content of gain.

The comparison of chicken and turkey body compositions by Leeson and Summers (1980 a and b) showed the chicken to have a higher fat content at the same chronological age. The differences in the a values between chickens and turkeys and between sexes of turkeys can therefore be explained by differences in body compositions, particularly the deposition of fat.

While the comparisons of a values and calculated nett efficiencies may be valid, an effect of the non-lysine containing proportion of the gain ie. fat and skeletal tissues, is to increase the body-weight gain per g lysine. The increased gain response line has the effect of increasing the intercept point which represents the coefficient relating to lysine required for maintenance (b). Nevertheless, this should not influence the accuracy of the total lysine requirement for both maintenance and gain indicated by the Reading model.

A more accurate method of calculating the nett efficiency of utilisation of lysine for growth than the one outlined earlier would be to compare the amount of lysine deposited in the tissues with the lysine consumed in excess of maintenance requirements. To do this calculation an accurate estimation of maintenance requirements is needed. The Israel model (Hurwitz et al, 1983) estimated the lysine requirement for maintenance to be 76.6mg/kg $w^{2/3}$ per day. The Edinburgh model (Fisher and Emmans, 1983) used a value for lysine directly related to body weight, i.e. 69mg/kg w per day. These two models give a similar prediction for lysine maintenance requirements in the body weight range of 1.3 to 1.5kg. As the body weight increases thereafter, the Israel model predicts progressively less lysine required per kg weight per day.

Using total lysine requirements calculated from the a and b values indicated by the Reading model analysis of the experimental data and subtracting the maintenance values indicated by either the Israel or Edinburgh model, enables the lysine available for gain to be calculated. To calculate the nett efficiency of lysine utilisation for gain, a value for the lysine content of body-weight gain must be known. This has been calculated using the same principles as in the earlier calculation of nett efficiency. The protein content of the gain used was that indicated by Leeson and Summers (1980 b) and the lysine content of the turkey meat protein found by Fisher and Scougall (1982) using the value found at 56 days, 5.57g/100g protein, for ages greater than 56 days. Details of the calculations are shown in Table 60 and a comparison of the nett efficiencies indicated by the Edinburgh and Israel models illustrated in Figure 57. It will be seen that there is a good measure of agreement between the models for birds in the lower weight ranges but beyond 5kg body weight, the Edinburgh model indicates an increasing efficiency, so deviating from the predictions of nett efficiency by the Israel model which remain relatively constant in the range of 50 to 60 per cent. There would appear to be no logical explanation for the increasing nett efficiency with increasing weight predicted by the Edinburgh model.. the most obvious explanation is that the method of calculating the lysine required for maintenance in the Edinburgh model, being directly related to body weight, is over-estimating the lysine required for maintenance at the heavier weights. The effects of this would be to increase the apparent nett efficiency for gain at these weights.

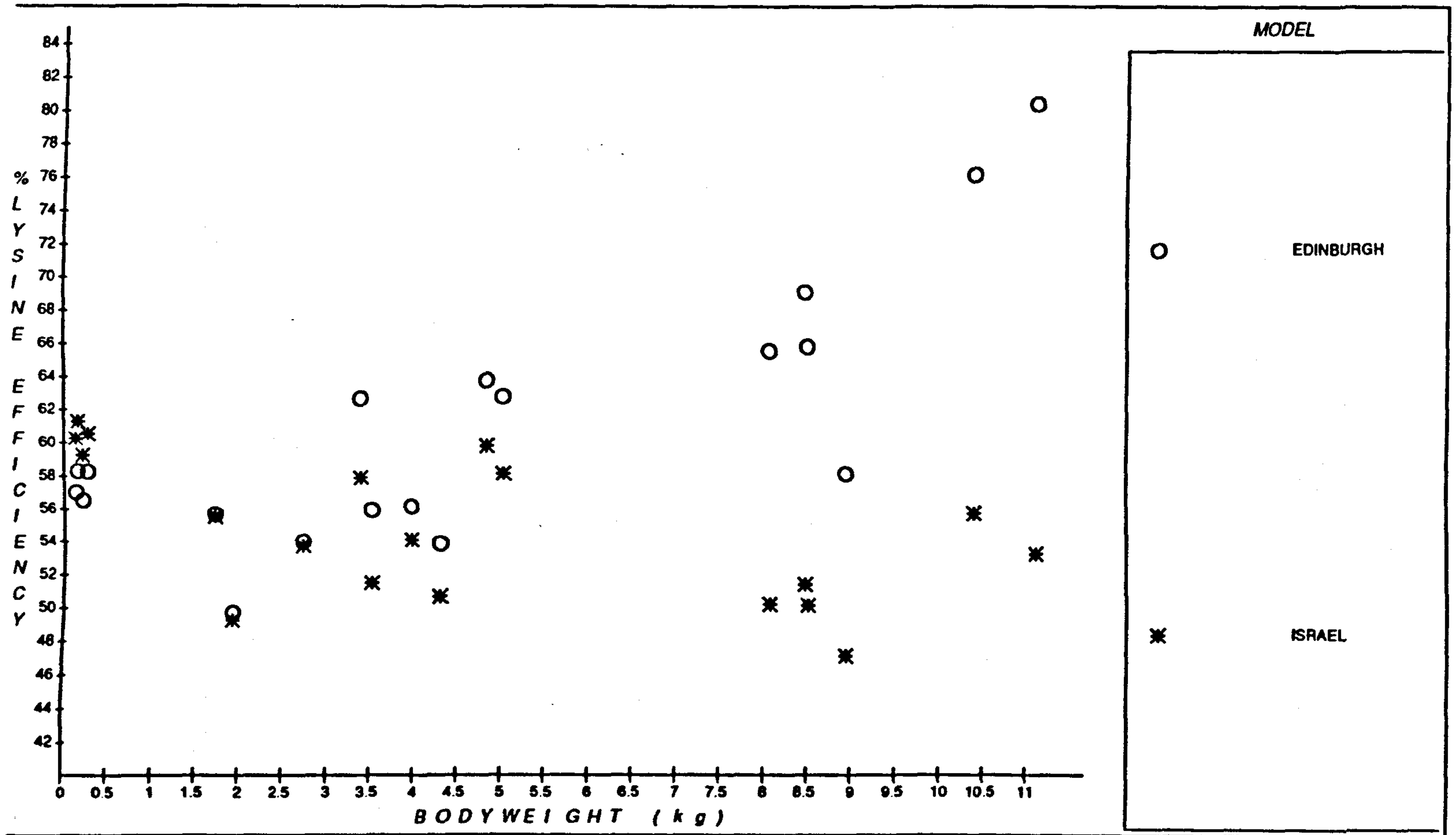

FIGURE 57. A COMPARISON OF NET EFFICIENCIES OF LYSINE UTILISATION (%) CALCULATED BY THE EDINBURGH AND ISRAEL MODELS.

TABLE 60	THE CALCULATION OF THE EFFICIENCY OF UTILISATION OF LYSINE FOR GROWTH BY MALE TURKEYS													
		The Total Lysine Requirement Per Bird Per Day					The Lysine Content of Body-weight gain			Maintenance Requirement for Lysine (g)		The Efficiency of Utilisation of Lysine for growth Edinburgh Model		Israel Model	
Exp. No.	Description	ΔW (kg)	W (kg)	a	b	g lysine requirement	Protein content of Gain[1] (g/kg)	g Protein Gain	g Lysine Gain[2]	Edinburgh[3]	Israel[4]	g lysine for gain	% efficiency	g lysine for gain	% efficiency
1	4-13D	0.0188	0.137	21.31	0.0155	0.4027	220	4.136	0.2242	0.0095	0.0204	0.3933	57.0	0.3719	58.6
1	4-22D	0.0213	0.214	21.41	0.0086	0.4579	217	4.622	0.2505	0.0148	0.0274	0.4431	56.5	0.4228	58.2
2	4-13D	0.0779	0.161	20.97	0.0109	0.3771	220	3.938	0.2134	0.0111	0.0227	0.3660	58.3	0.3482	60.2
2	4-22D	0.0224	0.274	20.97	0.0047	0.4710	217	4.861	0.2635	0.0189	0.0323	0.4521	58.3	0.4349	60.1
3	4-7W	0.0722	1.323	35.13	0.0010	2.5377	188	13.573	0.7561	0.0913	0.0923	2.4464	30.9	2.3433	30.9
5	9-12W	0.0975	4.305	22.91	0.0040	2.2510	194	18.915	1.0536	0.2970	0.2027	1.9539	53.9	2.0785	51.4
6	15-18W	0.0851	8.079	18.26	0.0435	1.9054	186.5	15.871	0.8840	0.5575	0.3084	1.3479	65.6	1.7594	55.4
7	15-18W	0.0855	8.482	16.88	0.0503	1.8699	186.5	15.946	0.8882	0.5853	0.3180	1.2846	69.1	1.7267	57.2
8	15-18W	0.0885	8.517	22.23	0.0019	1.9835	186.5	16.505	0.9193	0.5877	0.3195	1.3959	65.9	1.8316	55.2
9	15-18W	0.1027	8.949	23.67	0.0022	2.4506	186.5	19.154	1.0669	0.6175	0.3302	1.8331	58.2	2.2629	50.3
10	17-20W	0.1118	10.402	19.62	0.0019	2.2133	183	20.459	1.1396	0.7177	0.3650	1.4955	76.2	2.0437	61.7
11	17-20W	0.0955	11.125	20.48	0.0020	1.9781	183	17.476	0.9734	0.7676	0.3817	1.2105	80.4	1.8266	61.0
12	LTM	0.1189	5.034	19.98	0.0031	2.3912	194	23.067	1.2848	0.3474	0.2250	2.0439	62.9	2.2081	59.3
12	STM	0.0714	3.517	21.56	0.0234	1.6217	194	13.852	0.7715	0.2427	0.1772	1.3790	55.9	1.4975	53.4
13	LTM	0.1280	4.850	19.47	0.0021	2.5024	194	24.832	1.3831	0.3347	0.2195	2.1677	63.8	2.3107	60.6
13	STM	0.0789	3.400	20.08	0.0027	1.5935	194	15.307	0.8526	0.2346	0.1732	1.3589	62.7	1.4710	60.0
14	FP	0.0685	1.928	22.86	0.0042	1.5740	187.7	12.861	0.7164	0.1330	0.1187	1.4410	49.7	1.4534	49.2
14	SP	0.0734	1.721	20.29	0.0046	1.4970	187.7	13.781	0.7676	0.1188	0.1100	1.3785	55.7	1.3825	55.3
15	FP	0.1156	3.977	21.39	0.0063	2.4977	194	22.426	1.2492	0.2744	0.1923	2.2233	56.2	2.3064	54.2
15	SP	0.1072	2.723	21.67	0.0033	2.3320	194	20.797	1.1584	0.1879	0.1494	2.1441	54.0	2.1534	53.1

1 Using Data From Leeson and Summers (1980b)

2 Presuming a lysine content of 5.42g/100g protein in experiments 1 and 2 and 5.57g/100g protein in the other experiments (Fisher and Scougall 1982)

3 Based on 69mg/kg W

4 Based on 76.6mg/kg $W^{2/3}$

Little confidence can be placed in either set of calculations but the exercise is useful in clarifying the issues involved. Is the lysine nett efficiency for utilisation for protein growth the same at all ages? If it is, this would argue for a method of calculating the maintenance requirement similar to that used by the Israel model which relates the requirement to a power of the body weight to attempt to allow for the changing ratio between surface area and body weight. What is the protein content of gain at various ages? Does the lysine content of the protein gain change with age? The answers to these questions will have a marked effect on the calculated nett efficiency of utilisation for growth.

Using the data which are available and relating these to the results of the experiments gives rise to calculations which in general, indicate a nett efficiency of dietary utilisation for growth in the range of 50 to 60%. This is less than the figure used in the Edinburgh model of 64%, for which no specific experimental evidence was offered. As has been discussed previously, the Israel model uses an unrealistically high utilisation value of 85%, presuming that all the lysine digested is utilised at 100% efficiency.

There are clearly some interesting questions on nett efficiency posed by the calculations based on the results of the experiments. These require more information on carcass composition before further clarification.

GENETICAL DIFFERENCES

Experiments 12 and 13 compared two types of turkey of both sexes between 9 and 12 weeks of age. The mean coefficients obtained were:-

	a	b
Large type males	19.725	0.0026
Large type females	20.785	0.0035
Small type males	20.820	0.0130
Small type females	15.545	0.0225

Only for the small type females would the coefficients appear to differ from those for the other types. This conclusion must be qualified in that it is drawn within rather wide limits of confidence because simple estimates of the errors associated with the value of a and b are not available.

The most likely cause of any differences arising according to sex or genotype will be the carcass composition. The theoretical scope for improvement in nett utilisation, which is the other alternative, seems small. There is the example of unexplained variation in the utilisation of methionine by laying hens (McDonald, 1957, 1958). There is also the possibility of a complex metabolic inter-relationship affecting amino acid utilisation, as in the case of lysine and arginine (Nesheim, Christensen and Arnold, 1967).

Most commercial turkeys are derived from three major breeding companies and over the years, there has been an interchange of genetic material. The possibility that a major gene which affects lysine utilisation will be found to be segregating in one particular commercial genotype does not therefore seem likely. The possibility that such a gene exists or may be present at high levels in one of the unimproved coloured breeds of turkey cannot be dismissed. Therefore, in modern commercial breeds of turkey, it seems likely that the major explanation for differences in the coefficients a and b will arise from differences in carcass composition with variation in fat gain being a major reason for differences in a value. Differences in fat deposition may result from differences in rate of maturity or from a greater genetic propensity to deposit fat.

From personal experience, it appears that turkey breeds selected in the USA, on a high energy diet with a high energy to protein ratio, have a greater propensity to deposit fat than breeds selected in the UK on low energy, high protein diets. This difference also reflects itself in food conversion differences with the fatter strain having a less efficient conversion than the leaner strain. A comparison similar to that carried out in experiments 12 and 13 might find such USA breeds indicating a lower a value than the UK breeds in this trial, with perhaps a diet requirement lower in g lysine per MJ ME for maximum body-weight gain.

The mean requirements for g lysine per MJ ME for maximum body-weight gain in experiments 12 and 13 were:-

Large type males	0.876g lysine/MJ ME
Large type females	0.851g lysine/MJ ME
Small type males	0.769g lysine/MJ ME
Small type females	0.490g lysine/MJ ME

It should be noted that the requirement for the three larger types of bird is in inverse order to the mean a values calculated, which is not what might have been expected. The explanation probably lies in the relationship between body-weight gain and body-weight maintained. In the large type males daily gain represented 2.43% of the mean weight maintained. The figure for large type females was 2.36% and for small type males 2.11%. The relationship between these three percentages is very similar to that between the lysine requirement expressed per MJ ME. A major driving force on food intake is the

ME requirement for maintenance. The lower the body-weight gain is as a proportion of body-weight, the lower the ratio of g lysine per MJ ME might be expected to be.

The noticeably lower requirement of the small type female is of practical significance to the UK turkey industry as this type of bird is popular for the Traditional Farm Fresh (TFF) trade. It has been normal to feed these birds diets in similar feed-for-age programmes to those used for large type birds destined for the frozen oven-ready trade or the further processing trade. The current data indicates that the TFF bird could be fed diets much lower in lysine (and presumably other amino acids) than currently practised without detriment to growth rate. The cost saving would be substantial.

COMPENSATORY GROWTH

The theory of compensatory or 'catch-up' growth is the subject of controversy within the turkey industry. While Auckland et al (1969) and Sholtyssek(1981) have demonstrated the principle, other workers (Nixey, 1989a) have been unable to confirm the results. Experiments 14 and 15 were carried out to investigate the subject and the results help to explain the inconsistency in experimental results seen by other workers.

Experiment 14 gave similar results to those of Auckland et al (1969). Birds previously 15.5% less in body weight at six weeks of age gained at a greater maximum rate (73.4% v 68.5g per bird d) than birds grown normally to six weeks of age. This resulted in the differences in body weight at nine weeks of age diminishing to 4.3%. It seems likely that by 14 weeks of age, the difference would have disappeared.

Figure 58 illustrates that at the same calculated mid-experiment body-weight replicates of the undernourished birds were eating more food per day than the replicates of the controls. No body composition data were collected. As the undernourished birds had visibly less breast meat at the start of the experiment, most of the weight difference

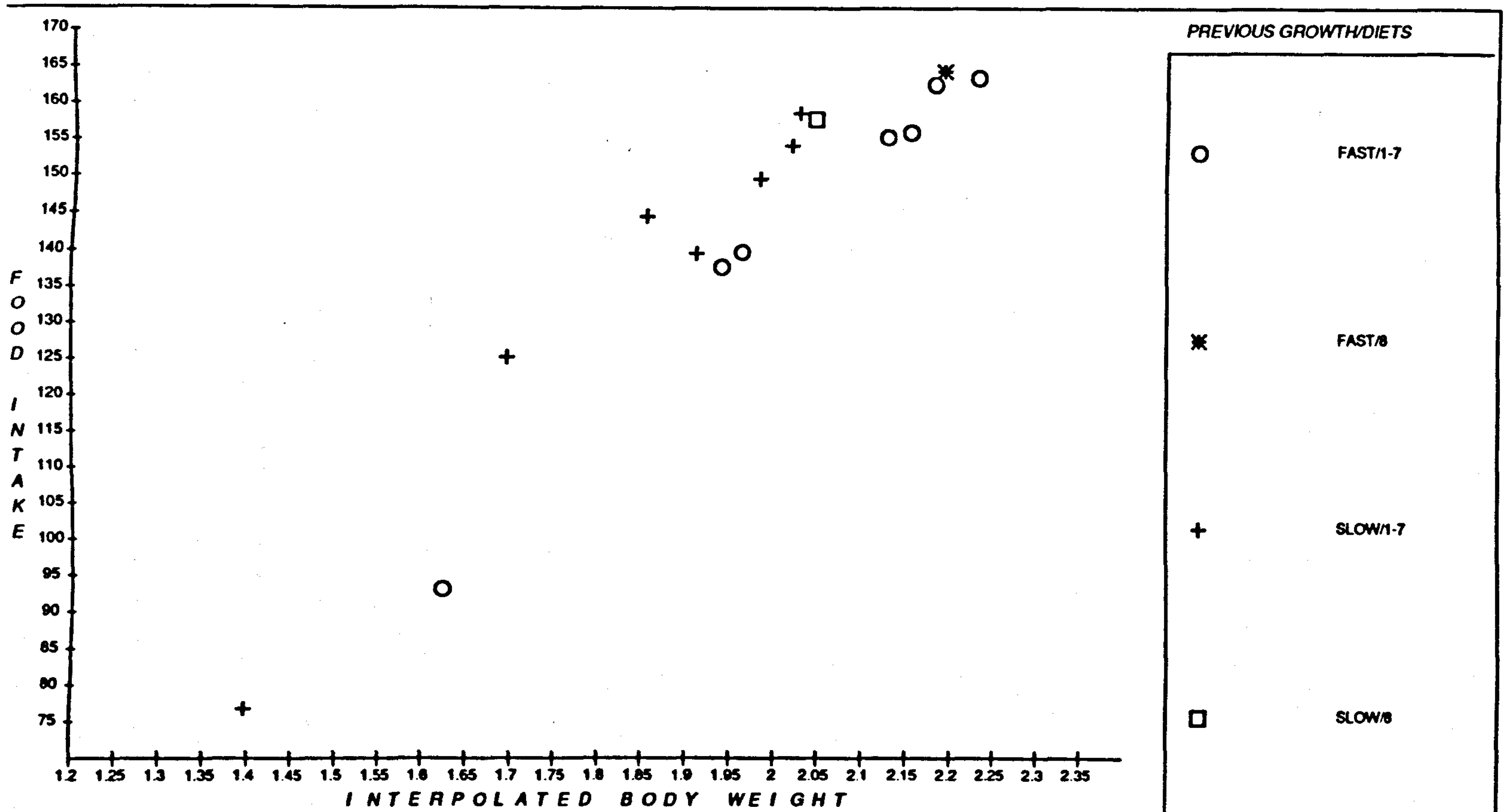

FIGURE 58. THE RELATIONSHIP BETWEEN THE INTERPOLATED BODY WEIGHT(kg) AT THE MID POINT OF EXPERIMENT 14 (7.5 WEEKS) AND THE MEAN FOOD INTAKE(g/d)

may have been related to the carcass meat weight, with the alimentary canal possibly being of more normal size. Food intake may be limited by the size of such organs as the crop and gizzard. If the gut of the undernourished birds was larger relative to body weight than that of the controls, it might explain the higher feed intake of the undernourished group at the same body weight compared to that of the controls. The higher food intake at the same body weight should make available more lysine for body-weight gain after the maintenance requirement has been met.

While the b values were similar for the two groups (0.0042 and 0.0046 on the controls and previously undernourished birds respectively) the a values were 22.86 for the controls and 20.29 for the previously undernourished birds. Although the latter difference cannot be tested for significance, it is not inconsistent with an improved efficiency of nett utilisation of lysine for growth and does represent over 10% improvement. Figure 47 does show the previously undernourished birds gaining at a greater rate per gram of lysine intake than did the controls. A contributing factor to the better efficiency of lysine utilisation is that the gain from six to nine weeks in the undernourished birds probably contained a greater proportion of skeletal growth which would be relatively non lysine requiring. It was observed that these birds attained normal stature by nine weeks of age.

Experiment 14 therefore confirmed the principles as outlined by Auckland et al (1969) for birds depressed in body-weight by as much as 15% at six weeks of age. A limiting factor on the ability to exhibit compensatory growth will be the diet. It will be seen from Tables 53 and 54 (pages 123 and 124) that on the most limiting diets, diets 6 and 7, there was no compensatory growth. The limitation will not be restricted to the formulation. Factors which prevent normal appetite from being expressed such as poor pellet quality, high temperatures, high stocking densities, lack of feeder and drink space could also be expected to inhibit the expression of compensatory growth.

Experiment 15 investigated the effect of very severe undernourishment such that the resulting body weights were 36% below those of the controls at the start of the experiment. The birds were also three weeks older than in Experiment 14 and so at a different stage of their growth curve.

In this experiment, during the period of potential catch-up growth the control birds attained a higher maximum body-weight gain, 115.6g per day, than did the undernourished birds whose maximum gain was only 107.2g per day. Thus rather than the difference in body weight between the two groups decreasing, it increased. This is the reverse of the situation in Experiment 14. Nevertheless, the relationship between food intake and body-weight (Figure 59) shows that although there was no overlap between the two groups in calculated mid-experiment body-weight, the trend of the data indicated that the intake of the diets fed to the undernourished birds would have been higher at the same mid-period body weight than that of the control birds. This suggests that whatever the mechanism of the 'drive' to eat more food after undernourishment which operated in experiment 14, there was also evidence of this in Experiment 15. Due however to the very low initial body-weights of the undernourished birds, the increase in food intake was insufficient to equal the normal food intakes of the much heavier control birds with the result that the difference between the groups increases rather than decreased.

In experiment 14. Figure 47 showed that the previously undernourished bird gained more per gram lysine intake than did the controls. Figure 50 illustrates that in Experiment 15, the gain responses per gram of lysine intake for the two groups were almost identical as were the a values (21.39 and 21.67). It seems unlikely that the composition of the gain in both groups was identical. It may have been that the two non-lysine requiring components of growth, i.e. skeleton and fat, were counterbalancing, with the former being more important in the undernourished birds and the latter in the controls.

Experiments 14 and 15 suggest that compensatory or "catch up" growth is possible in undernourished birds but that the extent to which it takes place will be very dependent on the level of growth depression. The importance of the extent of the growth depression has been overlooked in the controversy over the subject. The "catch up" growth occurs

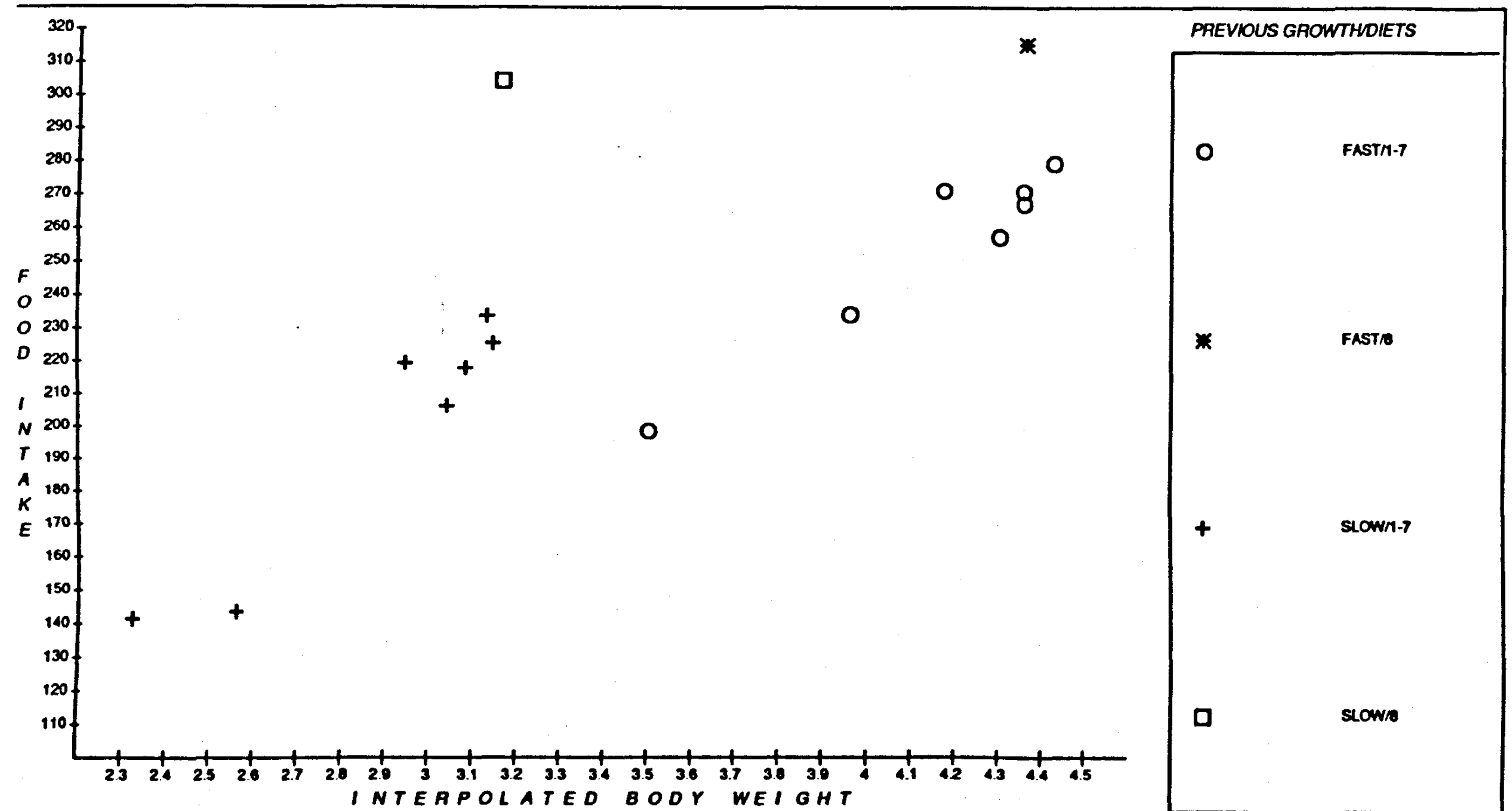

FIGURE 59.THE RELATIONSHIP BETWEEN THE INTERPOLATED MEAN BODY WEIGHT(kg) AT THE MID POINT OF EXPERIMENT 15 (10.5 WEEKS) AND THE MEAN FOOD INTAKE(g/d)

because, as was suggested by Auckland et al (1969), the undernourished birds will eat more food at any given body weight than birds of normal growth.

FOOD INTAKE AND BODY COMPOSITION

Attention has been focused on the body-weight gain response in the experiments. However, this response is an expression of the food intake response to the lysine concentration and the body composition resulting from the food intake.

The food intake is the major variable confronting scientists attempting to produce a computer simulation model of the turkey. It is also a major source of problems for nutritionists attempting to design diets for turkeys to produce the optimum economic performance.

It has been postulated by Emmans (1981) that, within limits, animals seek to eat for the first limiting nutrient rather than eating for their energy requirement unless energy is first limiting . .. If this is so, when an amino acid is marginally deficient, the animal will overconsume energy in an effort to obtain the deficient amino acid. The surplus energy consumed in excess of that which can be lost to the environment as heat must be stored as fat. The production of fat, with its lower water content than body protein, might be expected to result in a deterioration of the gain:food ratio. As a result, the intake of a nutrient necessary to optimise gain:feed ratio would be higher than that required for maximum body-weight gain. This has been demonstrated and reported for chickens by Lee, Gulliver and Morris (1971), Fisher (1976) and Gous and Morris (1985). It has not been shown experimentally yet for turkeys.

There are problems to be expected in attempting to demonstrate the existence of compensatory feeding to meet an amino acid deficiency. The compensatory increase in food intake may be small relative to the variation seen in the data. It may exist over a limited region of the curve which may not be well represented by data. There is insufficient knowledge of the process to be able to model a hypothesis against which the data could be tested. At this stage, the best that can be done is to examine the shape of the food intake and food utilisation curves for expected trends. The food intake curve could be expected to increase in slope relative to lysine concentration in diet as the maximum body-weight gain is approached. When maximum body-weight gain is achieved, food intake should decrease with increasing levels of lysine concentration. This should result in food utilisation efficiency improving beyond the lysine concentration necessary to achieve maximum body-weight gain. There is added complication with turkeys that their growing period extends over a larger period than chickens and the turkey has less propensity to deposit body fat.

In examining the data from the present study, some experiments were excluded. Experiment 1 suffered from a feather pecking problem which, judging from the results of experiment 2, may have depressed the gains and food intakes of the diets in the area of the onset of the plateau. In experiments 3 and 4, there was the differential feed wastage among treatments. In experiments 12 and 13, there were small numbers of birds of each type on each treatment. The experiments remaining have been examined in depth for confirmation or otherwise of the Emmans (1981) hypothesis. As might be expected with such a large amount of data, with no established method of analysis, a case can be made both in support of compensatory feeding or not, depending on the set of data chosen.

It was very difficult to find any evidence that the dietary intake of lysine necessary to optimise gain:feed ratio was higher than that required for maximum body-weight gain. A consistent pattern in almost all the experiments was of a depression in gain at lysine intakes higher than that achieving the maximum gain. Rarely did the data points on the plateau section of the curve fall in a near horizontal plane. More normally, at concentrations little more than necessary to achieve maximum gain, the data points would follow a downward trend.

A hypothesis has been constructed which would explain the shape of the body-weight gain response curve. Central to the hypothesis is variation in the body tissue components of the body-weight gain resulting from different lysine concentrations in the diet. This is illustrated diagrammatically in Figure 60.

It would seem logical that if an animal over-consumes energy in an effort to obtain the deficient amino acid necessary to obtain maximum protein gain and this results in increased production of body fat, the maximum body-weight gain would be achieved when the overconsumption of food, which achieves the desired intake of deficient amino acid necessary for maximum protein gain is at its maximum. This situation is identified by line A in Figure 60. Not only will protein gain be maximised, but also fat deposition. As the concentration of the deficient amino acid in the diet increases further, the amount of overconsumption of food and hence body fat deposition would decrease. As a result, the body-weight gains would also decrease with increasing concentration of amino acid in the diet. The majority of data in this thesis are consistent with this explanation, but no measurements of carcass composition were made. A surprising aspect of the data, however, is the wide range of lysine intakes over which the depression is occurring.

An explanation for this could be the variation to be expected between individuals in genetic potential for protein gain. Individuals with a lower potential protein gain might be expected to enter the overconsumption phase at a lower lysine intake level than birds with a higher genetic potential for protein gain. As a result of the overconsumption, more body fat would be deposited. In theory, this could result, at certain lysine intakes, in birds with lower genetic potentials for protein gain having a higher body-weight gain, because of body fat deposition, than similar birds with a higher potential for protein gain.

On diets with higher lysine concentrations resulting in higher lysine intakes, individuals with a lower potential for protein gain could be expected, if the theory is correct, to reduce their food intakes and hence body fat gains, with a resulting lower body-weight gain. On such diets, birds with a higher potential for protein gain would then enter

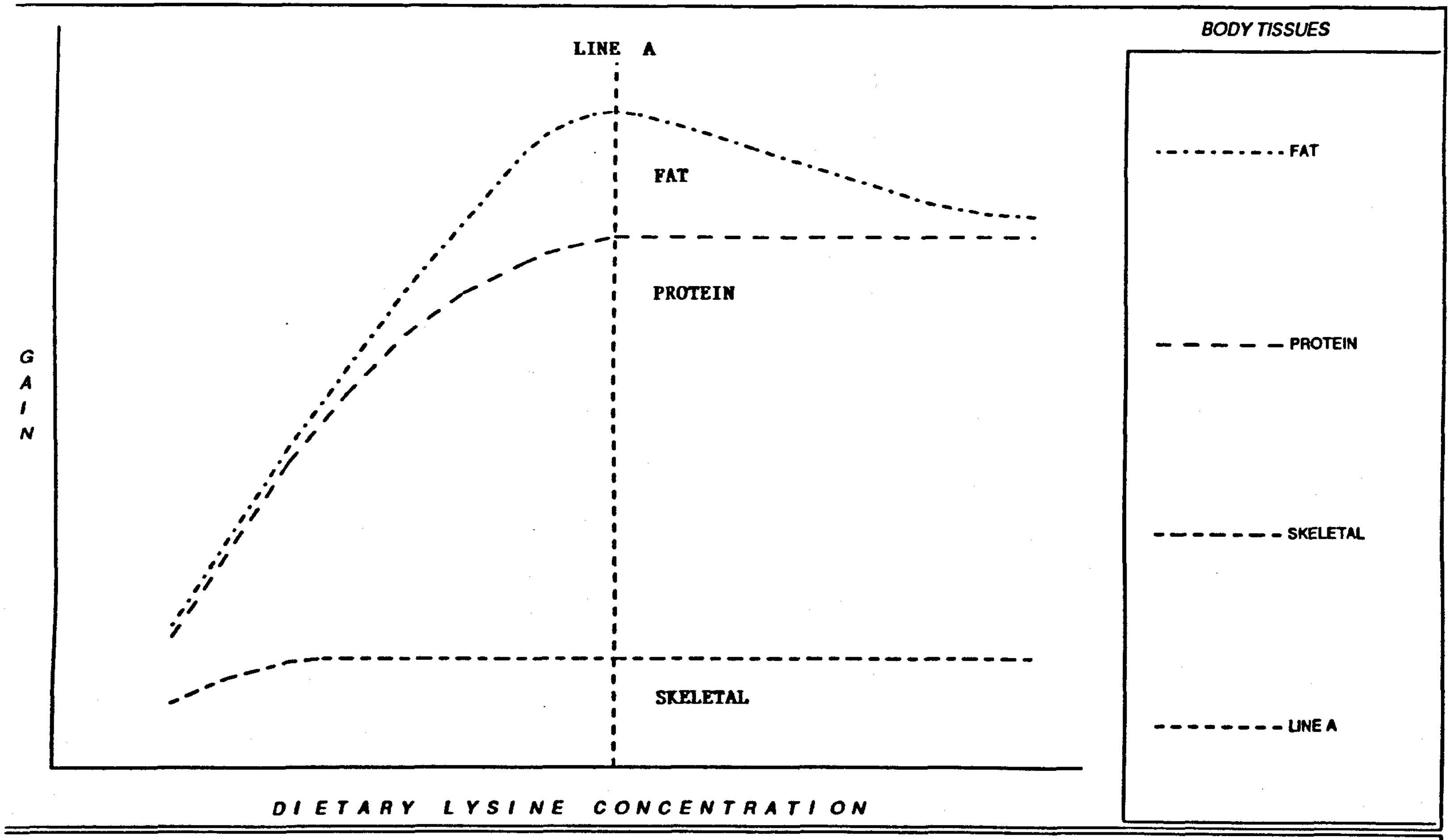

FIGURE 60. THE HYPOTHESIS PROPOSED TO EXPLAIN DECREASING BODY-WEIGHT GAIN WITH INCREASING LYSINE CONCENTRATION

the over-consumption phase, so laying down body fat and maximising body-weight gain. As lysine concentrations increase, more and more individuals would have their lysine demands satisfied without recourse to overconsumption of energy. As a result, mean body-weight gains could be expected to reduce at lysine intakes beyond those necessary for maximum flock body-weight gain. As stated earlier, this pattern would fit the majority of the experiments.

The hypothesis that the reduction in body fat is the explanation for reduced body-weight gains is not reliant on the theory of over-consumption of energy as birds seek to eat their first limiting nutrient as proposed by Emmans (1981). Other possibilities could be associated with the increased protein intake as lysine intake increases. The need to excrete more nitrogen could trigger an appetite depressing effect or the breakdown of excess protein into energy could be having a thermostatic effect, so reducing the bird's food intake.

Experiments 6 and 7 (Figure 22) demonstrated a correlation between ME intakes and body-weight gain for replicates lying on the plateau section of the curve. This would support the hypothesis that body fat was influencing body-weight gains as this would be the expected result of variations in energy intakes.

If this hypothesis is correct, it makes the task of producing a computer model of turkey responses to nutrient intakes very much more complicated. However in practice, the usage of such a model will be more concerned with the limiting response section of the curve than the situation at the plateau.

LYSINE TO ME RATIOS

Nutritionists require nutrient requirements to be made in a form of use in formulating diets. The industry has progressed from stating the recommended lysine level as a concentration (g/kg feed) to stating this as a ratio of g lysine per MJ ME in the feed. This is a recognition of the influence that dietary ME content has on food intake.

It may be hypothesised that the bird's primary need for food is to satisfy its energy requirement. Macleod and Jewitt (1985) found that growing turkeys responded to an increase in dietary energy concentration within 2 days by reducing food consumption. The sensitivity of the response to a dietary energy decrease was less, being between 4 and 10 days, depending on the magnitude of the decrease. They speculated that the slower response was because of the need for anatomical or physiological adaptation when an increased food intake is required to meet energy requirements.

To state the lysine requirement as a ratio of g lysine per MJ ME is to recognise the interaction between the ME content of the diet and food intake. The latter determines the lysine consumption which in turn will influence the growth rate.

In the experiments, all the experimental diets were formulated to be isoenergetic and therefore since lysine contents varied, represented a range of lysine to ME ratios. The ME content of the diet chosen was that prevailing most commonly in the UK at that time. If a higher ME content had been used, similar to that used in the USA and Italy, it might be thought that the lysine: ME ratios found as optima in this study would be different. However this is not expected to be the case. If diets of higher ME content had been used the food intake would have been less so the birds would have responded maximally to a diet of higher lysine concentration (g/kg diet). When this higher lysine concentration was expressed as a ratio to the higher dietary ME, it would seem reasonable to expect that the ratio would be the same as that determined with diets of a lower ME concentration in the current experiments. On the assumption that at lysine adequacy food intake is primarily being determined by the energy content of the diet and that the lysine required per day for maximum body-weight gain is the same regardless of the ME content of the diet, the ratio of lysine to ME required for maximum body-weight gain should be the same regardless of the dietary energy concentration. To confirm this an experiment involving several ME levels at each lysine concentration over a range of lysine concentrations is required, so that the effect of varying energy independently of lysine could be estimated. It has been presumed in the following analysis that the ratio is not influenced by the dietary energy concentration.

Using the data from the current experiments to produce predictions of the body-weight gain to be expected for a range of lysine consumptions, together with the diets used in the experiments, has enabled estimates to be made of the lysine requirement for maximum body-weight gain in relation to the ME consumed. The resulting ratios of g lysine per MJ ME have been calculated for all the experiments and types of bird. They are shown for males in Figure 61 and for females in Figure 62 and compared with the ratios indicated by published research (see Tables 4 to 9). The ratios indicated for males by the Israel and Edinburgh models are also included in Figure 61.

It will be seen that there is a good level of agreement between the experimental results and the published data for the males. Only in the initial weeks of life is there a divergence, with the experimental data indicating a much higher ratio than hitherto published. The published work tends to be older and much slower growing birds were used than those used for the current experiments. While the potential growth rate of turkeys has shown rapid improvements (Table 3), the egg size producing the initial poult has not shown the same increase (British United Turkeys Ltd, unpublished data). As the food intake capacity of the poult is likely to be related to its body size, and the poult size is related to egg size, the improvement in growth potential without an accompanying increase in initial poult size would suggest the need for a greater concentration of nutrients in the initial diet. This could explain the divergence between the current experimental data and published data in the past on very young turkeys.

The ratios suggested by the Edinburgh model decrease at a slower rate per day of age than that suggested by the experiments. The authors of the Edinburgh model accept that it is unsuitable for use before 28 days of age. Figure 61 suggests that even between 28 and 56 days, the model may underestimate requirements. There is quite close

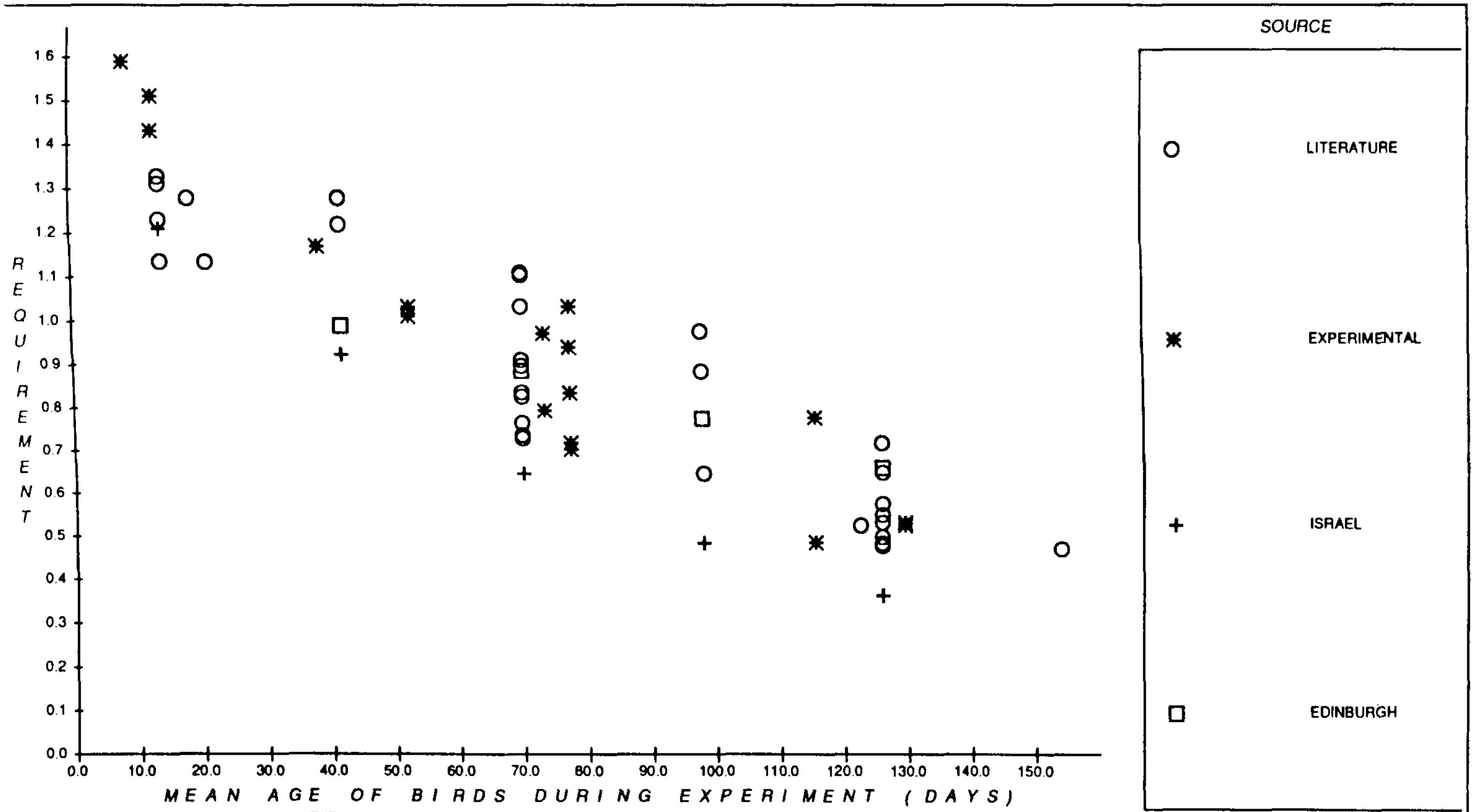

FIGURE 61. A COMPARISON OF LYSINE REQUIREMENTS (g per MJ ME) INDICATED BY THE LITERATURE, EXPERIMENTAL RESULTS AND CALCULATIONS FROM ISRAELI AND EDINBURGH MODELS FOR MALE TURKEYS

agreement between the Edinburgh model and the experimental results beyond 56 days of age.

An influence on the calculated ratios from the models will be the calculated ME requirements. There is close agreement between the predicted ME requirement from the two models from day-old through to around 10 weeks for male turkeys. Beyond 10 weeks the Edinburgh model predicts a lower ME requirement than the Israel model. This will have the effect of increasing the predicted g lysine per MJ ME in the Edinburgh model at ages beyond 10 weeks compared with requirements predicted from the Israeli model.

The Israel model consistently indicates lower levels of lysine than the experimental results at all ages. When discussing the Israel model in Chapter 2, it was pointed out that this model presumed that 85% of dietary lysine is utilised based on the efficiency of absorption. To assume that all the lysine which is absorbed by the intestine is utilised would appear very optimistic. There will be a minimum level of amino acid catabolism during protein synthesis and degradation. In addition there will be losses if the supply to the tissues does not correspond exactly with demand even though there are several "buffers" to avoid these losses. The assumption of 85% utilisation of dietary amino acids is the major cause of differences in the predictions of the Edinburgh and Israel models. The data from the experiments would confirm the view that the Israel model underestimates the lysine requirement. The rate of decrease in requirement with age is very similar to that indicated by the experiments. If the Israel model had assumed, as did the Edinburgh model, that only 64% of dietary lysine is utilised, there would have been close agreement between it and the experimental results.

Far less data are available for the females; there being none for the early weeks of life (Figure 62). There is good agreement for females around 40 days of age between the published data and experiment 4 ie. 1.2g lysine per MJ ME. This is almost identical to that indicated for the males suggesting that both sexes require the same diets at least until seven weeks of age. Clearly, the differences in growth potential are being compensated

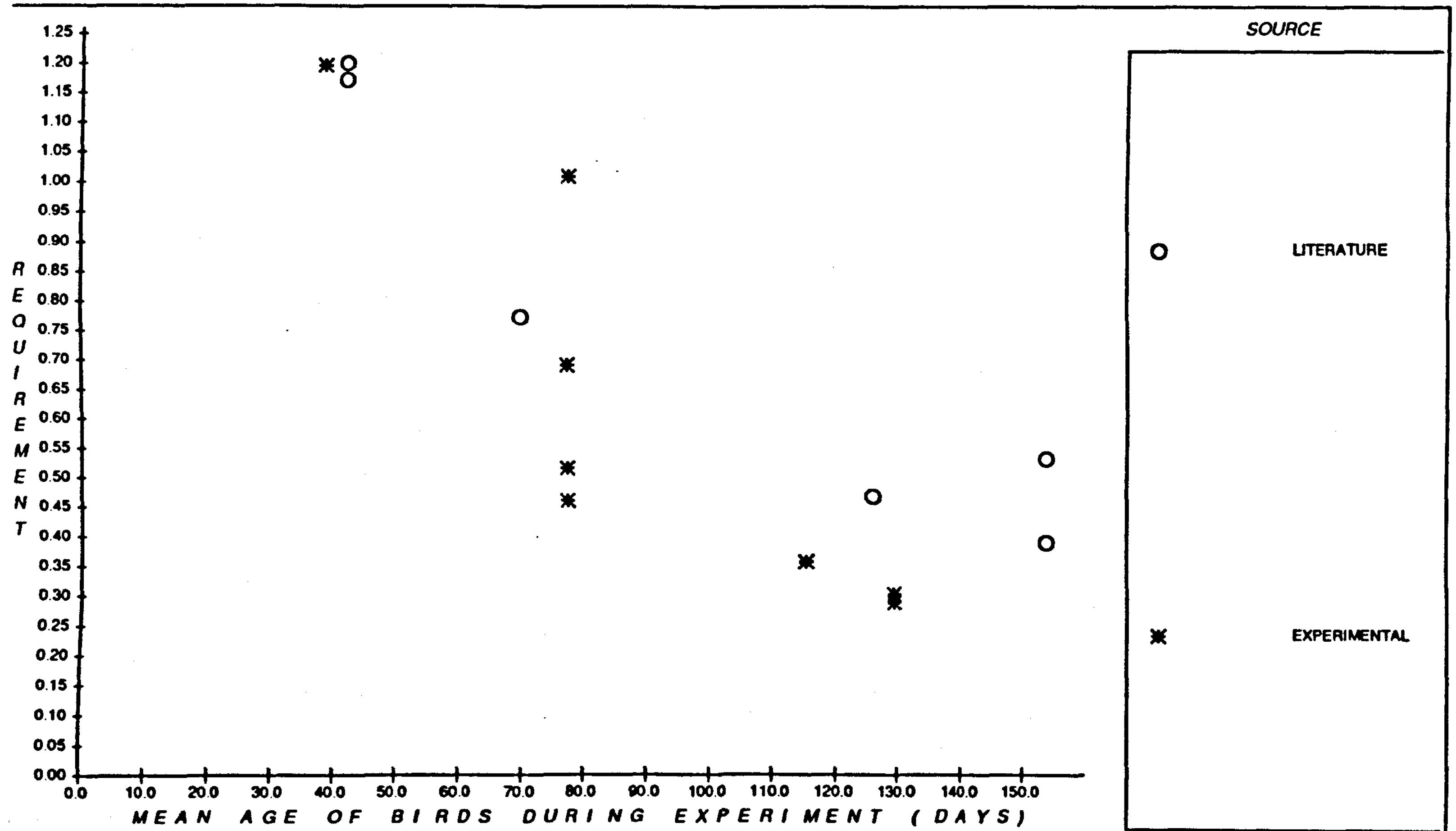

FIGURE 62. A COMPARISON OF LYSINE REQUIREMENTS (g per MJ ME) INDICATED BY THE LITERATURE AND EXPERIMENTAL RESULTS FOR FEMALE TURKEYS

for by differences in food intake up until this age. By nine to 12 weeks, the situation is complicated by genetic differences with a similar requirement being indicated for large type females to that indicated for males, while a distinctly lower requirement is indicated for small type females.

The experiments using 15 to 18 week females, experiments 8 and 9, gave identical ratios while those with 17 to 20 week females, experiments 10 and 11, produced slightly lower values which were also very similar to each other. At both these ages, the indicated ratios for females were distinctly lower than those indicated for males. The few published data for older females indicated higher ratios than those found from the experimental data.

The age when divergence occurs in the feeding programmes for males and females will depend on the strain involved. It may be as early as seven weeks for slow growing strains and as late as 12 weeks for late maturing, fast growing strains. It might be expected that the divergence will occur when the females commence to lay down significant amounts of fat while such deposition in the male is minimal.

In the experiments beyond nine weeks of age, there were sometimes large differences in the suggested ratios for birds of the same age. The major difference between such experiments was the time of year at which they were carried out. The experimental house had no supplementary heating and its temperature was related to the outside ambient temperature. Temperature will greatly influence the determined ratio of lysine to ME as increasing temperatures will reduce the bird's energy requirements for maintenance and so also reduce food intake. As a consequence, a higher concentration of lysine will be required at higher temperatures to achieve the same intake of lysine.

Even though large differences may be seen in g lysine per MJ ME required for maximum gain eg. between experiments 8 and 9, the differences between such experiments is small if the gain is expressed per g lysine intake as is illustrated in Figure 28.

This is good evidence for the need to express requirements ultimately as quantities rather than percentages or ratios.

The ratios indicated in this work can only be used as indications and should be modified according to the situation with regard to factors which affect food intake. Ideally, they should be used in conjunction with lysine input and body-weight gain output tables described in Chapter Five and modified according to the lysine intake achieved in practice.

CHAPTER FIVE

Commercial Utilisation

THE COMMERCIAL SITUATION AND NEEDS

The ultimate aim of nutritional research on turkeys must be to provide information which will be of use to nutritionists when formulating commercial turkey diets.

The work reported in this thesis indicated the lysine requirements of the turkey in terms of g lysine per MJ of ME energy at various ages. However under the conditions of the experiments, of small numbers or single bird pens with ample food space, food intake is likely to be near the bird's optimal requirements for ME with the bird able to eat to fully meet its requirements.

These conditions will not be present in commercial circumstances. Several factors which might be expected to reduce food intake below optimum requirements will be operative. These factors will include large flock sizes, limited feeder space, high stocking densities which in the microclimate surrounding the bird will also result in high temperatures, limited water access and dusty pellets. Individually each will have an influence but interactions between factors might also be expected, e.g. limited feeder space together with dusty pellets might be expected to have a combined effect greater than the effect of the sum of the two individual conditions, as dusty pellets will require more time at the feed trough which will be limited due to the competition for feeder space.

It will be impossible to predict accurately the result on food intake of these various conditions. The ultimate measurement must be the actual food intake resulting. Having assessed that, the nutritionist can then, given sufficient information, adjust his formulation accordingly. The work in this thesis is a major step forward in providing the commercial nutritionist with the information required to make adjustments to formulations.

The nutritionist needs to know the amino acid which is first limiting for growth rate in the diet. The thesis has not addressed itself to that aspect directly in experiments although it was discussed when deciding the experimental diet formulations and it is discussed later in this chapter. Given that lysine is the first limiting amino acid in the diet, the work reported in this thesis enables lysine input and body-weight gain output prediction tables to be constructed. If the results achieved in commercial practice are similar to those predicted, it confirms that lysine is the first limiting amino acid. If the results are not similar to the predictions, another amino acid must be suspected as being limited. If lysine is indicated as the limiting amino acid, the prediction tables will then enable the nutritionist to calculate the likely body-weight gain response to be expected from increasing lysine intake. The cost of achieving the increased lysine intake can be calculated, the value of the extra output in body-weight gain estimated, and a decision reached as to the desired level of lysine in the diet.

THE LYSINE RESPONSE TABLES

To construct the lysine response tables, it is necessary first to have a good estimate of the maximum genetic potential body-weight gain at various ages for the type and sex of turkey under consideration. In constructing lysine response tables for British United Turkeys' breeds with which the author is familiar, the maximum genetic potential body-weight gain has been judged to be that gain achieved in experimental pens with ideal conditions. As the most common feed programme is to change feed types every four weeks, the tables have been drawn up for four weekly age periods e.e. 0 to 4 weeks, 4 to 8 weeks, etc. Using the body weight data and the a and b values arrived at from the research reported in this thesis in the Reading model, using a Type B run, input and output predictions can be produced. The a and b values used to produce the predicitons are given in Table 61.

TABLE 61	THE a AND b VALUES USED TO PRODUCE LYSINE INPUT AND GAIN OUTPUT PRODUCTION TABLES			
	MALES		FEMALES	
	a	b (x10³)	a	b (x10³)
0 - 4	21.1	10.0	21.1	10.0
4 - 8	21.5	7.4	21.5	7.4
8 - 12	21.7	4.5	20.6	4.5
12 - 16	21.9	3.0	19.0	3.0
16 - 20	21.0	2.2	15.8	2.2

It must be said that some of the suggested values are based on weak information. Assumptions are drawn from the trends indicated where the information was strong. However the suggested values are a considerable advance on any other information, and the prediction tables already have been used in commercial practice both in Europe and North America. An example is shown in Table 62.

TABLE 62	B.U.T. BIG 6 MALES 4-8 WEEKS LYSINE INPUT AND GAIN OUTPUT PREDICTION TABLE
FLOCK LYSINE INTAKE (g/d)	FLOCK BODY-WEIGHT GAIN (g/d)
0.90	40.8
1.00	45.5
1.10	50.1
1.20	54.8
1.30	59.4
1.40	64.1
1.50	68.8
1.60	73.4
1.65	75.7
1.70	78.0
1.75	80.4
1.80	82.7
1.85	85.0
1.90	87.3
1.95	89.6
2.00	91.8
2.05	94.0
2.10	96.1
2.15	98.1
2.20	100.1
2.25	101.9
2.30	103.5
2.35	104.9
2.40	106.2
2.45	107.3
2.50	108.2
2.55	108.9
2.60	109.4
2.65	109.8
2.70	110.1
2.75	110.3
2.80	110.5
2.85	110.6
2.90	110.6
2.95	110.7
3.00 +	110.7

Assumptions:- Lysine to be the first limiting amino acid

Genetic potential 4 week body weight - 1.4kg

Genetic potential mean daily body-weight gain for period - 110.7g

AMINO ACID PROFILES

It is a fundamental principle of the response tables that lysine must be the first limiting amino acid in the diet. To check if this is indeed so, an indication of the ideal amino acid profile for each four weekly age period is required. It is an area that has received very little research attention. Indicated required amino acid profiles can be produced from both the Edinburgh and the Israel models.

The Edinburgh model bases its calculations on analysis of whole turkey bodies at 28 and 56 days of age (Fisher and Scougall, 1982) which gave values (mg/g Protein) of:

54.9mg Lysine

19.4mg Methionine

34.8mg Total Sulphur Amino Acids (TSAA)

9.9mg Tryptophan

39.2mg Threonine

It then uses a conversion of dietary to body lysine of 64% based on 86mg dietary lysine to provide 1 gram of protein growth (Fisher and Emmans, 1983) and 1 gram of protein containing 54.9mg of lysine. The same efficiency of conversion of dietary to body amino acid is used for the other amino acids. The Edinburgh model assumes a lysine maintenance requirement of 69mg/kg liveweight. Based on very little data, it uses a maintenance requirement per kilogram of bodyweight of 40mg methionine, 60mg total sulphur amino acids, 10mg tryptophan and 40mg threonine.

When this information is used in the Edinburgh model, it produces the following suggested profiles (Lysine = 100):

DAYS OF AGE	28	56	84	112	140
LYSINE	100	100	100	100	100
METHIONINE	36.0	36.5	37.4	38.6	40.4
T.S.A.A.	64.0	64.5	65.4	66.7	68.6
TRYPTOPHAN	17.3	17.2	17.1	17.0	16.7
THREONINE	70.3	70.0	69.5	68.8	67.9

In the Israel model as discussed in Chapter 2, the amino acid requirements are assessed by body composition analysis at various ages together with measurements of endogenous losses via the intestine and the skin. This method produced the following amino acid profile (Lysine = 100):

DAYS OF AGE	29	57	85	113	141
LYSINE	100	100	100	100	100
METHIONINE	36.2	36.7	38.7	38.7	44.0
T.S.A.A.	79.0	83.7	97.8	100.0	113.8
TRYPTOPHAN	15.2	15.5	16.4	16.0	18.4
THREONINE	82.3	84.2	90.2	85.9	97.3

It will be seen that there are striking differences between the Edinburgh and Israel profiles, both quantitatively e.g. total sulphur amino acid levels, and directionally with age e.g. the relative change in threonine levels with age.

Despite the fact that the Israel model is based on apparently better analytical data, the profiles it has produced indicate extraordinary diets in practice. Using common ingredients, the profiles would indicate that lysine should never be the first limiting amino acid. The first limiting amino acid would in all probability be the total sulphur amino acids with threonine the second limiting amino acid.

It is clearly a subject that warrants urgent research. Work on other amino acids similar to the work carried out for this thesis on lysine is required. This would produce a and b values for the other amino acids to enable the quantities of each to be calculated for a specific growth rate. This in turn would enable the ideal amino acid profile to be calculated at various ages.

In the meantime, it is suggested that the mean of the suggested profiles of the Edinburgh model and Israel model be used to assess the first limiting amino acid in a formulation. An addition that is required is a value for arginine which as shown by D'Mello and Emmans (1975) interacts with lysine. As the level of lysine is increased so the requirement for arginine is increased. For the 3-week-old turkey, the work by D'Mello and Emmans indicated that the arginine level should be in the region of 113% of the lysine level. In the high protein diets used early in life, it is normal to use fishmeal at levels of 10% or more in order to prevent a total reliance on soya-bean for the major protein fraction of the diet. In fishmeal, the arginine level is very similar to that of lysine and so it is difficult to formulate a diet in which the arginine level is 113% of that of the lysine, if substantial proportions of fishmeal are to be used in the diet. The reserve on the part of nutritionists to use high levels of soya-bean is because of the variability in its protein content, variability in the standard of processing, which may affect digestibility, and also the possibility that high levels of soya-bean may be implicated in the incidence of footpad dermatitis (Jensen, Martinson and Schumaier, 1970). Until more work has been done on the subject, it is suggested that in the ideal amino acid profile, the arginine level is set at 108% rising to 113% of the lysine content as the protein level in the diet decreases. In practice, the arginine level is only likely to be of significance in diets for young turkeys because in cereals which make up a major proportion of the diets for older birds, the arginine level will be approximately 150% of the lysine content.

THE OPTIMUM REQUIREMENTS

The optimum requirement will depend on how it is defined. One definition would be that level which gives the biological maximum growth rate. An alternative definition would be the optimum economic requirement, being that level which maximises the profitability of the turkey flock. This will depend upon the monetary cost of providing increasing levels of a nutrient, e.g. lysine, and the monetary value of the output so produced. Such a definition of requirement will be as transitory as the prices of feed ingredients or the value of turkey meat. As discussed in an earlier chapter, changes in growth rate will also affect body composition and the value of the body-weight gain.

The input and output tables as shown by the example in Table 62 enable such a calculation to be made. However there is difficulty in placing an accurate value on the output in terms of value per body-weight gain. No market exists for turkey meat in the first eight weeks of life. However the body weights attained over this period will have an influence on the subsequent body-weight gains, so they have an indirect value. This will depend on the age that it is planned to kill the turkeys, with the longer the period before killing, the greater the chance for "catch up" growth to take place.

To calculate the cost of lysine, a number of least cost formulations should be carried out on the computer with the lysine concentration increased in increments. Other amino acids should also be increased so that the suggested ideal amino acid profile is maintained. By dividing the cost per tonne by the number of grams of lysine in the tonne of feed, the cost of each gram of lysine can be estimated.

Obviously other nutrients will have contributed to the cost but with lysine being the first limiting nutrient, the calculation gives the relative cost of lysine compared to lysine in other diets. By formulating a number of diets with different levels of lysine, the cost of lysine at various concentrations can be estimated. Until more accurate data is available on body composition the likelihood of the increased cost being recouped by the value of the extra output must be judged by the nutritionist.

A value of the prediction tables such as that in Table 62 is that they enable an estimate of the increased output to be made. As already pointed out, in the early weeks of life, the value of this output must be a judgement of its subsequent long term value. At the older ages, the market value of a kilogram of dead turkey body-weight can be estimated if it is to be sold either in the feather, plucked or in oven-ready form. There is however a difficulty in estimating the value of the body weight if it is to be subsequently deboned and further processed. When the body weight at an age changes, the body proportions also change. Of most economic significance is that as the body weight compared to genetic potential at an age decreases, so the proportion of that body weight which is breast meat decreases (Nixey, 1989b). As breast meat is by far the most valuable meat being between 2 and 3 times more valuable than dark meat, there is a considerable incentive to maximise body-weight gains. It is estimated that for each 1% decrease in bodyweight compared to genetic potential, there will be a 12% decrease in breast meat weight (Nixey, unpublished). With this incentive to maximise body-weight gain, it is likely that the optimum economic requirement for lysine intake will be much nearer to the plateau in body-weight gain response when taking the meat off the bone than when the turkeys are being sold in the feather, plucked or oven-readied. The prediction table will enable decisions to be taken on a rational basis when formulating turkey diets.

Until good food intake and growth data are available, the commercial nutritionist must make a judgement which can be modified in the light of performance. In the Discussion Chapter, the indicated g lysine per MJ ME requirements for each sex from the experiments were illustrated in Figures 54 and 55 and discussed. It was pointed out that there was close agreement between previously published work and the experiments with the exception of the early weeks of life when the experimental work indicated a higher requirement. Using a best visually judged line through the experimental results at young ages and a combination of published and experimental data at older ages indicates the following requirements (Table 63). Based on the results of experiments 3 and 4, it is presumed that the females have the same requirement as males to 8 weeks of age. On the basis of experiment 12 and 13, the slow growing type females would appear to have lower requirement between 9 and 12 weeks.

It is recommended that commercial nutritionists initially use these values and then modify them in the light of the performance achieved in their situation.

TABLE 63	RECOMMENDED LYSINE:ME RATIOS	
	g lysine per MJ ME	
	Males	Females
0 - 4	1.50	1.50
4 - 8	1.26	1.26
8 - 12	1.15	0.94
12 - 16	0.80	0.63
16 - 20	0.60	0.32
20 - 24	0.33	

The information in this thesis on the turkey's lysine requirements should not become outdated, being capable of being adjusted as the bird's genetic potential changes. Further refinement would require more work on the influence of lysine intake on body composition.

THE BASIS OF A MODEL

The work in this thesis provides the basis upon which a predictive model can be constructed. The model would require input and output tables similar to those produced for lysine to be produced for other possible limiting amino acids. If the problem of predicting ME requirements can be overcome, this would enable food intake predictions to be made which are the necessary prerequisite to predicting amino acid intakes. Preliminary work by the author has indicated Reading Model analysis of ME intakes in existing published experiments and also the experiments in this thesis produces values for the a and b constants which when used in conjunction with published goals for different breeds' body-weight gains, predicts food consumptions very similar to those obtained in commercial practice.

In Chapter 2 the Israel and Edinburgh models were discussed. Both of these models require the body-weight gain to be specified either from previous work (Israel model) or based on the Gompertz equation (Edinburgh). A model based upon the Reading model equation for various nutrients would enable a prediction to be made of the daily body-weight gain likely from a known feeding programme. It would also identify the first limiting nutrient. This would considerably more value than the other two models as it could simulate experiments. It would also have considerable value for industrial companies as an aid for problem solving and as a demonstration tool.

REFERENCES

REFERENCES

AEC (1978). Alimentation animale - energie, acides amines, vitamines, mineraux. AEC, 03600, Commentry, France, 4

ADAS (1983). Personal communication with T. Bray. Gleadthorpe Experimental Husbandry Farm, Mansfield, Notts., NG20 9PF.

de ALBUQUERUE, K., LEIGHTON JR. A.T. MASON Jr, J.P. and POTTER, L.M. (1978). The effects of environmental temperature, sex and dietary energy levels on growth performance of Large White Turkeys. *Poultry Science*, 57, 353-362.

ARC (1975). The nutrient requirements of farm livestock. No 1 Poultry. London, Agricultural Research Council, 39-40.

AUCKLAND, J.N., MORRIS, T.R. and JENNINGS, R.C. (1969). Compensating growth after under-nutrition in market turkeys. *British Poultry Science*, 10, 293-302.

BALLOUN, S.L. (1962). Lysine, arginine and methionine balance of diets for turkeys to 24 weeks of age. *Poultry Science*, 41, 417-424.

BEHRENDS, B.R. and WAIBEL, P.E. (1980). Methionine and cystine requirements of growing turkeys. *Poultry Science*, 59, 849-859.

BOORMAN, K.N. and A.D. BURGESS (1986). Responses to amino acids, in : *Nutrient requirements of poultry and nutritional research*. Fisher, C. and Boorman, K.N. (eds), pp 99-123 London, Butterworths.

BOORMAN, K.N. and FISHER, H. (1966). The arginine-lysine interaction in the chick. *British Poultry Science*, 7, 39-44.

BOOTH, D.A. (1979). In : *Food Intake Regulation in Poultry*. Proceedings of Poultry Science Symposium No. 14 pp 13-62 Edinburgh. British Poultry Service Ltd.

BRITISH UNITED TURKEYS LTD. (1981). Published guides to performance. Chester, British United Turkeys Ltd.

BRITISH UNITED TURKEYS LTD. (1986). Published guides to performance. Chester, British United Turkeys Ltd.

BRITZMAN, D.G. (1976). Comparative performance with pelleted and meal diets for growing turkeys and egg producing chickens. *Proceedings of the 37th Minnesota Nutrition Conference*, pp 139-162.

BRODY, S. (1945). *Bioenergetics and growth*. Haffner Press, New York. 371.

CLARK, FELICITY A., GOUS, R.M. and MORRIS, T.R. (1982). Response of broiler chicken to well balanced protein mixtures. *British Poultry Science*, 23, 433-446.

CURNOW, R.N. (1973). A smooth population response curve based on an abrupt threshold and plateau model for individuals. *Biometrics*, 29, 1-10.

D'MELLO, J.P.F. (1975). Amino acid requirements of the young turkey: leucine, isoleucine and valine. *British Poultry Science*, 16, 607-615.

D'MELLO, J.P.F. and EMMANS, G.C. (1975). Amino acid requirements of the young turkey: lysine and arginine. *British Poultry Science*, 16, 297-306.

D'MELLO, J.P.F. and LEWIS, D. (1970a). Amino acid interactions in chick nutrition. 1. Interrelations between lysine and arginine. *British Poultry Science*, 11, 229-311.

D'MELLO, J.P.F. and LEWIS, D. (1970b). Amino acid interaction in chick nutrition. 2. Inter-relationships between leucine, isoleucine and valine. *British Poultry Science*, 11, 313-323.

D'MELLO, J.P.F. and LEWIS, D. (1970c). Amino acid interactions in chick nutrition. 3. Interdependence in amino acid requirements. *British Poultry Science*, 11, 367-385.

EMMANS, G.C. (1981). A model of the growth and feed intake of ad libitum fed animals, particularly poultry. *Computers in Animal Production*. 103-110. Occasional Publication No. 5 - British Society of Animal Production 1981 edited by E.M. Hillyer, C.T. Whittemore and R.G. Gunn.

FISHER, C. (1976). Protein in the diets of the pullet and laying bird. In : *Protein Metabolism and Nutrition*, pp 323-351, edited by Cole, D.J.A. Boorman, K.N. Buttery, P.J., Lewis, D., Neale, R.J. and Swan, H. London, Butterworths.

FISHER, C. (1984). Personal communication.

FISHER, C. and EMMANS, G.C.(1983). Calculated amino acid requirements for growing turkeys. *Turkeys*, 31, (No. 1), 39-43.

FISHER, C. and MORRIS, T.R. (1970). The determination of the methionine requirement of laying pullets by a diet dilution technique. *British Poultry Science*, 11, 67-82.

FISHER, C., MORRIS, T.R. and JENNINGS, R.C. (1973). A model for the description and prediction of the response of laying hens to amino acid intake. *British Poultry Science*, 14, 469-484.

FISHER, C. and SCOUGALL, R.K. (1982). A note on the amino acid composition of the turkey. *British Poultry Science*, 23, 233-237.

GERAEDTS, L.H.J. and KAN, C.A. (1981). The performance including compensating growth of male broiler turkeys on different energy and lysine levels in the diet. *Proceedings of 3rd European Symposium on Poultry Nutrition*, Edinburgh, pp 121-123.

GOMPERTZ, B. (1825). On the nature of the function expressive of the law of human mortality, and on a new method of determining the value of life contingencies. *Philosophical Transactions of Royal Society*, 115, 513-585.

GOUS, R.M. and MORRIS, T.R. (1985). Evaluation of a diet dilution technique for measuring the response of broiler chickens to increasing concentrations of lysine. *British Poultry Science*, 26, 147-161.

HAMM, D. JAEN, E., TOLLETTS, J. and STEPHENSON, E.L. (1960). Effect of pelleting, water soaking the grain, enzyme additions and limited feedings. *Arkansas Experimental Station Bulletin*, 631.

HEIDEBRECHT, A.A. (1973). Value of pelleted vs mash feed for growing finishing - turkeys. *American Food Manufacturers Association Nutrition Council 33rd Semi-Annual Meeting Proceedings.*

HURWITZ, S., EISNER, U., DURBROV, D., SK LAN, D., RIESENFELD, G. and BAR, A. (1979). Protein, fatty acids, calcium and phosphate absorption along the gastro-intestinal tract of the young turkey. *Comparative Biochemistry and Physiology*, 62A, 847-850.

HURWITZ, S., WEISELBERG, M., EISNER, U., BARTOV, I., RIESENFELD, G., SHARVIT, M., NIV, A., and BORNSTEIN, S. (1980). The energy requirements and performance of growing chickens and turkeys as affected by environmental temperature. *Poultry Science*, 59, 2290-2299.

HURWITZ, S., FRISCH, Y., BAR, A., EISNER, U., BENGAL, I. and PINES, M. (1983). The amino acid requirements of growing turkeys. 1. Model construction and parameter estimation. *Poultry Science*, 62, 2208-2217.

HURWITZ, S., PLAVNIK, I., BENGAL, I., TALPAZ, H. and BARTOV, I. (1983). The amino acid requirements of growing turkeys. 2. Experimental validation of model calculated requirements for sulphur amino acids and lysine. *Poultry Science*, 62, 2387-2393.

JENSEN, L.S.., MANNING, B., FALEN, L., and McGINNIS, J. (1976). Lysine needs of rapidly growing turkeys from 12-22 weeks of age. *Poultry Science*, 55, 1394-1400.

JENSEN, L.S., MARTINSON, R. and SCHUMAIER, G. (1970). A Foot Pad Dermatitis in the turkey poults associated with soybean meal. *Poultry Science*, 49, 76-82.

JENSEN, L.S., MERRILL, L.H., REDDY, C.V. and McGINNIS, J. (1962). Observations on eating patterns and rate of food passage of birds fed pelleted and unpelleted diets. *Poultry Science*, 41, 1414-1419.

JENSEN, L.S., RANIT, G.O., WAGSTAFF, R.K. and McGINNIS, J. (1965). Protein and lysine requirements of developing turkeys as influenced by pelleting. *Poultry Science*, 44, 1435-1441.

KLEIBER, M. (1947). Body size and metabolism rate. *Physiological Review*, 27, 511-541.

KRATZER, F.H., DAVIS, P.N. and MARSHALL, B.J. (1956). The protein and lysine requirements of turkeys of various ages. *Poultry Science*, 35, 197-202.

KUMMERO, V.E., JONES, J.E. and LOADHOLT, C.B. (1971). Lysine and total sulphur amino acid requirements of turkey poultry, one day to three weeks. *Poultry Science*, 50, 752-758.

LARBIER, M., (1979). The efficiency of L-lysine monohydrochloride as compared to the lysine of natural ingredients. *Eurolysine Bulletin* No. 3.

LEE, P.J.W., GULLIVER, A.L. and MORRIS, T.R. (1971). The quantitative analysis of the literature concerning the restricted feeding of growing pullets. *British Poultry Science*, 12, 413-437.

LEESON, S., and SUMMERS, J.D. (1980a). Production and carcass characteristics of the broiler chicken. *Poultry Science*, 59, 786-798.

LEESON, S., and SUMMERS J.D. (1980b). Production and carcass characteristics of the Large White Turkey. *Poultry Science*, 59, 1237-1245.

LEVEILLE, G.A., SHAPIRO, R. and FISHER, H. (1960). Amino acid requirements for maintenance in the adult rooster. iv. The requirements for methionine, lystine, phenylalanine, tyrosine and tryptophane; the adequacy of the determined requirements. *Journal of Nutrition*, 72, 8-15.

MacLEOD, M.G. and JEWITT, T.R. (1985), The rate of response of growing turkeys to changes in dietary energy concentration. *Proceedings Of Nutrition Society*, 44, 60a.

McDONALD, M.W. (1957). Methionine supplementation in chicken diets. 2. A breed difference in growth response to DL - methionine. *Australian Journal of Agricultural Research*, **8**, 587-594.

McDONALD, M.W. (1958). Methionine supplementation in chicken diets. 3. The biochemical difference in sulphur amino acid metabolism between White Leghorns and Australorps. *Australian Journal of Agricultural Research*, **9**, 161.

MORAN, E.T. (1983). N.R.C. recommendations may conflict with turkey strains developed outside North America. *Turkey World*, Nov-Dec 1983, 27-38.

NARAYANAN, S. and APPLETON, H.D. (1980). Creatine: A Review. *Clinical Chemistry*, **26**, No. 8, 1119-1126.

NESHEIM, M.C., CHRISTENSEN, D.A. and ARNOLD, D.L. (1967). Arginine deficiency in two strains of chickens selected for differences in dietary requirements for arginine. *Journal of Nutrition* **92**, 365.

NIXEY, C. (1983). The amino acid requirements of turkeys re-assessed. *Proceedings of 1983 Californian Animal Nutrition Conference*, 82-108.

NIXEY, C. (1989a). Nutritional responses of growing turkeys. In : Proceedings of 21st Poultry Science Symposium on *Recent Advances in Turkey Science*. Nixey, C. and Grey, T.C. (eds) pp 183-199 London, Butterworth.

NIXEY, C. (1989b). Feeding growing turkeys for maximum breast meat yield. *Turkeys* **37**, No. 2, 25-30.

NOLL, S.L. and WAIBEL, P.E. (1982). Influence of environmental temperature on the lysine requirements of growing turkeys. *Proceedings of 43rd Minnesota Nutrition Conference* (1982), 123-134.

N.R.C. (1971). National Research Council (1971) Nutrient requirements of domestic animals. 1. *Nutrient requirements of poultry*. Washington D.C., U.S.A. National Academy of Sciences.

N.R.C. (1977). National Research Council 1977. *Nutrient requirements of poultry.* Washington D.C., U.S.A., National Academy of Sciences.

POTTER, L.M. and SHELTON, J.R. (1976). Protein, methionine, lysine and a fermentation residue as variables in diets of young turkeys. *Poultry Science*, 55, 1535-1543.

POTTER, L.M., SHELTON, J.R. and McCARTHY, J.P. (1981). Lysine and protein requirements of growing turkeys. *Poultry Science*, 60, 2678-2686.

QUILLIN, E.C., COMBS, G.F., CREEK, R.D. and ROMOSER, G.L. (1961). Effect of choline on the methionine requirements of broiler chicken. *Poultry Science*, 40, 639-645.

RICHARDSON, D.I. (1980). Turkey production - a major growth industry. In *Proceedings of W.P.S.A. 6th European Poultry conference*, Hamburg, 295-305.

ROBBINS, K.R., NORTON, H.W. and BAKER, D.H. (1979). Estimation of nutrient requirements from growth data. *Journal of Nutrition*, 109, 1710-1714.

ROBEL, E. J. and FROBISH, L. T., (1977). Evaluation of the chick bio-assay for estimating sulfur amino acids, lysine and tryptophan availability in soybean meal. *Poultry Science*, 56, 1399-1404.

SAUER, W.C. and OZIMEK, L. (1986). The digestibility of amino acids in studies with swine and poultry. Bulletin No. 10, *Eurolysine Information*, Paris.

SAUER, W. C., KENNELLY, J. J., AHERNE, F. X. and CICHON, R.M., (1981). Availability of amino acids in corn, wheat and barley for growing pigs. *Canadian Journal of Animal Science*, 57, 585-597.

SAUNDERS, A.J., WESSELS, J.P.H. and GOUS, R.M. (1977). Carcass amino acid composition and utilisation of dietary amino acids by chickens. *South African Journal of Animal Science*, 7, 111-115.

SCHOLTYSSEK, S. (1981). Mast-und ausschlachturyserquebnisse schnerer puten nach futterung mit uhterschredlichen nubrstuffkonzentrationers. *Kraftfuttes*, 64, 2-4.

SUMMERS, J.D. and LEESON, S. (1976). *Poultry nutrition handbook*. Guelph, Canada; Ministry of Agriculture and Fisheries, 90-99.

TUTTLE, W.L. and BALLOUN, S.L. (1974). Lysine requirements of starting and growing turkeys. *Poultry Science*, 53, 1698-1704.

WAIBEL, P.E., EL HALAWANI, M.E. and BEHRENDS, B.R. (1976). Growth and efficiency of large white turkeys in relation to dietary protein and environmental temperatures. *Proceedings of 37th Minnesota Nutrition Conference* (1976), 119-127.

WALDROUP, P.W., MAXEY, J.F., LUTHER, L.W., MORROW, H.D. and JOHNSON, Z.B. (1979). *Amino acid needs of turkey poults*. Agricultural Experimental Station, University of Arkansas, Bulletin 834.

APPENDIX TABLES

APPENDIX TABLE 1	THE LYSINE CONCENTRATION AND THE SUMMIT AND BASAL MIXTURE PROPORTIONS IN THE DIETS USED IN EXPERIMENT 1.		
DIET NO	LYSINE CONCENTR-ATION (g/kg)	g/kg of SUMMIT A[1] MIXTURE	g/kg of BASAL A[1] MIXTURE
1	19.00	1000	0
2	17.75	916.7	83.3
3	16.50	833.4	166.6
4	15.25	750.0	250.0
5	14.00	666.6	333.3
6	11.50	500.0	500.0
7	9.00	333.3	666.6
8[2]	11.50	333.3	666.6

[1] Summit A contained 19g lysine/kg and basal A contained 4g lysine/kg

[2] Diet 8 was formulated as diet 7 and 2.5g lysine was added as L-lysine HCl. The L-lysine HCl was ascribed an equivalent total lysine content of 900g/kg (see page 53).

All diets contained 11.96 MJ ME/kg

APPENDIX TABLE 2	THE LYSINE CONCENTRATION AND THE SUMMIT AND BASAL MIXTURE PROPORTIONS IN THE DIETS USED IN EXPERIMENT 2.		
DIET NO	LYSINE CONCENTR-ATION (g/kg)	g/kg of SUMMIT B[1] MIXTURE	g/kg of BASAL B[1] MIXTURE
1	20.00	1000	0
2	19.00	857.1	142.9
3	17.75	678.6	321.4
4	16.50	500.00	500.0
5	15.25	321.4	678.6
6	14.00	142.9	857.1
7	13.00	0	1000
8[2]	14.00	0	1000

[1] Summit B contained 20g lysine/kg and basal B contained 13g lysine/kg.

[2] Diet 8 was formulated as diet 7 and 1.0g lysine was added as L-lysine HCl. The L-lysine HCl was ascribed an equivalent total lysine content of 900g/kg (see page 53).

All diets contained 11.96 MJ ME/kg.

APPENDIX TABLE 3	THE LYSINE CONCENTRATION AND THE SUMMIT AND BASAL MIXTURE PROPORTIONS IN THE DIETS USED IN EXPERIMENTS 3,4,5,6,7,12,13,14 AND 15.		
DIET NO	LYSINE CONCENTR-ATION g/kg	g/kg of SUMMIT A[1] MIXTURE	g/kg of BASAL A[1] MIXTURE
1	19.0	1000	0
2	16.5	833.4	166.6
3	14.0	666.7	333.
4	11.5	500.0	500.0
5	9.0	333.3	666.7
6	6.5	166.6	833.4
7	4.0	0	1000
8[2]	11.5	333.3	666.7

[1] Summit A contained 19g lysine/kg and basal A contained 4g lysine.kg.

[2] Diet 8 was formulated as diet 5 and 2.5g lysine was added as L-lysine HCl. The L-lysine HCl was ascribed an equivalent total lysine content of 900 g/kg (see page 53).

All diets contained 11.96 MJ ME/kg.

APPENDIX TABLE 4	THE LYSINE CONCENTRATION AND THE SUMMIT AND BASAL MIXTURE PROPORTIONS IN THE DIETS USED IN EXPERIMENTS 8,9,10 AND 11.		
DIET NO	LYSINE CONCENTR-ATION (g/kg)	g/kg of SUMMIT C[1] MIXTURE	g/kg of BASAL C[1] MIXTURE
1	11.0	1000	0
2	8.5	722.2	277.8
3	6.0	444.4	555.6
4	5.0	333.3	666.7
5	4.0	222.2	777.8
6	3.0	111.1	888.9
7	3.0	0	1000
8[2]	3.0	0	1000

[1] Summit C contained 11g lysine/kg and basal C contained 2g lysine/kg.

[2] Diet 8 was formulated as diet 7 and 1.0g lysine was added as L-lysine HCl. The L-lysine HCl was ascribed an equivalent total lysine content of 900g/kg (see page 53).

All diets contained 11.96 MJ ME/kg.

APPENDIX TABLE 5	COMPOSITION OF THE SUMMIT MIXTURES		
	SUMMIT CODE		
INGREDIENTS (g/kg)	A	B	C
MAIZE MEAL	-	-	370.2
MAIZE GLUTEN[1] MEAL	400.0	430.2	-
WHEATMEAL	-	-	233.0
SOYA BEAN MEAL[2]	427.2	460.7	259.9
SUNFLOWER[3] MEAL	56.3	-	-
MEAT AND BONE MEAL[4]	46.1	56.3	50.0
SKIM MILK AND GRASS[5] MEAL	-	-	25.0
DICALCIUM PHOSPHATE	18.3	16.1	21.2
CALCIUM CARBONATE	11.9	11.4	9.6
FAT	31.6	16.6	15.0
SODIUM CHLORIDE	1.6	1.5	1.1
BINDER	2.0	2.0	2.00
L-THREONINE	-	0.2	-
VITAMIN & MINERAL MIXTURE[6]	5.0	5.0	5.0

[1] contained 600g/kg protein
[2] contained 440g/kg protein
[3] contained 300g/kg protein
[4] contained 500g/kg protein
[5] contained 340g/kg protein
[6] composition given in Appendix 9

APPENDIX TABLE 6		ANALYSES OF SUMMIT MIXTURES (g/kg)							
		SUMMIT CODE A				B		C	
NUTRIENT	LABORATORY	CALCULATED	DETERMINED MIX1[a]	MIX 2[b]	MIX 3[c]	CALCULATED	DETERMINED	CALCULATED	DETERMINED
PROTEIN[d]	1	468.0	427.0	433.9	468.9			201.1	209.8
PROTEIN[d]	2	468.0	468.8	472.5		489.0	516.0		
PROTEIN[d]	3	468.0	402.5						
OIL	1	49.6	59.5	67.0	63.0	35.8		39.5	42.9
FIBRE		50.6				42.7		31.3	
ME (MJ/kg)		11.96				11.96		11.96	
LYSINE	1	19.0	15.9	18.8	19.8			11.0	11.2
LYSINE	2	19.0	22.3	18.5	15.1	20.0	17.0	11.0	10.8
METHIONINE	2	11.0	13.7	7.8	9.2	11.2	10.3	4.3	4.8
MET + CYS	2	16.4	21.8		15.9	16.8	18.9	7.6	8.1
TRYPTOPHAN	2	4.5				4.7		2.5	
THREONINE	2	16.7	20.9	16.4	17.6	17.6	18.2	7.6	8.1
ARGININE	2	25.1	40.0	23.7	23.0	25.8	25.1	13.5	12.9
HISTIDINE	2	10.5	17.7	9.8	11.4	11.1	10.6	4.9	5.3
TYR + PHE	2	44.5	78.2	43.4	45.4	47.2	53.1	17.0	22.3
ISOLEUCINE	2	21.0	22.4	17.7	17.1	21.8	21.6	8.8	8.4
LEUCINE	2	58.0	76.7	53.3	57.8	61.6	65.1	17.0	18.9
VALINE	2	22.9	22.5	19.8	19.2	23.8	21.1	10.7	12.3
CALCIUM	1	14.0	14.1	13.2	16.9	14.0		14.0	20.1
PHOSPHORUS	1	10.5	9.8	9.0	11.2	10.2		9.4	8.8
AVAIL. PHOS.		7.5				7.5		7.5	
SODIUM CHLORIDE	1	3.0	2.5	3.1	3.5	3.0		3.0	4.5

[a] mix for experiments 3 and 4

[b] mix for experiments 1, 5, 6, 7

[c] mix for experiments 12, 13, 14, 15

[d] Protein by gN x 6.25

Laboratory 1 - Colborn Dawes Ltd Heanor, Derby.

Laboratory 2 - Nottingham University Sutton Bonnington.

Laboratory 3 - Pritchard Laboratories Birkenhead.

APPENDIX TABLE 7	COMPOSITION OF THE BASAL MIXTURES		
	BASAL CODE		
INGREDIENTS (g/kg)	A	B	C
MAIZE MEAL			664.3
MAIZE GLUTEN[1] MEAL	36.0	259.9	
WHEAT MEAL	700.0	372.5	135.2
BARLEY MEAL	173.8		
BARLEY STRAW			120.0
SOYA BEAN MEAL[2]	29.8	302.5	
DICALCIUM PHOSPHATE	35.7	31.5	37.2
CALCIUM CARBONATE	12.4	14.0	11.6
FAT	3.2	10.4	15.0
SODIUM CHLORIDE	2.1	2.2	1.7
BINDER	2.0	2.0	10.0
VITAMIN AND MINERAL MIXTURE[3]	5.0	5.0	5.0

[1] contained 600g/kg protein
[2] contained 440g/kg protein
[3] composition given in Appendix 9

APPENDIX TABLE 8		ANALYSES OF BASAL MIXTURES (g/kg)							
		BASAL CODE A				B		C	
NUTRIENT	LABORATORY	CALCULATED	DETERMINED MIX 1[a]	MIX 2[b]	MIX 3[c]	CALCULATED	DETERMINED	CALCULATED	DETERMINED
PROTEIN[d]	1	121.8	152.0	138.6	143.7			75.0	92.6
PROTEIN[d]	2	121.8	159.4	166.6		323.6	342.3		
PROTEIN[d]	3	121.8	147.0						
OIL	1	19.7	17.6	2.4	2.16	26.6		45.0	47.8
FIBRE		30.3				37.0		57.0	
ME (MJ/kg)		11.96				11.98		11.96	
LYSINE	1	4.0	4.8	5.3	4.8			2.0	3.6
LYSINE	2	4.0	7.2	5.0	4.9	13.0	11.2	2.0	3.4
METHIONINE	2	3.1	4.3	2.9	2.9	7.8	7.2	2.4	2.9
MET + CYS	2	5.2	7.4		6.5	11.7	13.6	3.8	3.9
TRYPTOPHAN	2	1.4				3.4		0.5	
THREONINE	2	3.7	6.8	5.5	4.9	11.4	12.3	2.6	3.1
ARGININE	2	5.8		9.5	8.2	17.0	16.4	3.8	5.3
HISTIDINE	2	2.6	5.9	3.3	3.8	7.4	7.4	1.6	2.1
TYR + PHE	2	10.8	21.9	13.7	12.7	31.3	35.2	7.3	7.0
ISOLEUCINE	2	5.2	7.1	5.4	5.4	14.8	14.2	3.0	3.5
LEUCINE	2	10.0	19.0	14.8	14.5	39.1	42.3	9.1	9.5
VALINE	2	5.7	9.0	8.7	6.8	15.9	14.9	4.0	3.8
CALCIUM	1	14.0	13.4	12.4	14.9	14.0		14.1	21.3
PHOSPHORUS	1	10.5	8.4	7.7	9.8	10.0		9.1	8.5
AVAIL. PHOS		7.5				7.5		7.5	
SODIUM CHLORIDE	1	3.0	1.0	3.9	2.7	3.0		3.0	1.7

[a] mix for experiments 3 and 4

[b] mix for experiments 1, 5, 6, 7

[c] mix for experiments 12, 13, 14, 15

[d] protein calculated by g N x 6.25

Laboratory 1 - Colborn-Dawes Ltd Heanor, Derby

Laboratory 2 - Nottingham University Sutton Bonnington

Laboratory 3 - Pritchard Laboratories Birkenhead

APPENDIX TABLE 9	COMPOSITION OF VITAMINS AND MINERAL MIXTURE	
NUTRIENT	weight/kg SUPPLEMENT	mg/kg OF DIET
VITAMIN A (RETINOL)	72.00mg	0.36
VITAMIN D_3(CHOLECALCIFEROL)	25.00mg	0.125
VITAMIN E (a-TOCOPHERYL ACETATE)	7.00g	35
VITAMIN K (MENADIONE)	0.60g	3
FOLIC ACID	0.30g	1.5
NICOTINIC ACID	14.00g	70
PANTOTHENIC ACID	3.00g	15
RIBOFLAVIN (VIT B_2)	1.60g	8
VITAMIN B_{12}(CYANOCOBALAMIN)	2.00g	10
THIAMIN	0.20g	1
PYRIDOXINE	0.30g	1.5
BIOTIN	0.04g	0.2
SELENIUM	0.04g	0.2
IODINE	0.40g	2
COPPER	8.00g	40
IRON	50.00g	50
MANGANESE	20.00g	100
ZINC	20.00g	100
CHOLINE	80.00g	400
PANCOXIN (ANTI-COCCIDIAL)	100.00g	500
ZINC BACITRACIN	8.00g	40
ETHOXYQUIN	25.00g	125
DL-METHIONINE	180.00g	900

APPENDIX TABLE 10	VARIOUS RECOMMENDED DIETARY AMINO ACID CONCENTRATIONS AND PATTERNS RELATIVE TO LYSINE (-100) FOR TURKEYS								
	N.R.C. (1977)		SUMMERS & LEESON (1976)		A.R.C. (1975)		NOTTINGHAM UNIVERSITY		MEAN AMINO ACID
AMINO ACID •	g/kg	LYS = 100	g/kg	LYS = 100	g/kg	LYS = 100	g/kg	LYS = 100	LYS = 100
LYS	17.0	100	17.1	100	13.0	100	13.6	100	100
ARG	16.0	94	17.5	102	12.0	92	13.6	100	97
HIS	5.8	34	6.0	35	5.0	38	5.3	39	37
TRP	2.0	15	2.9	17	2.2	17	2.5	18	17
THR	10.0	59	11.0	64	9.0	69	9.9	73	66
PHE	10.0	59	10.8	63	8.0	62	9.5	70	64
P + T	18.0	106	19.4	113	14.0	108	16.0	118	111
MET	5.3	31	5.6	33	5.0	38	6.1	45	37
M + C	10.5	92	9.5	56	8.0	62	8.7	64	61
LEU	19.0	112	20.5	120	14.0	108	17.7	130	118
ILE	11.0	65	11.9	70	9.0	69	11.7	86	73
VAL	12.0	71	13.0	73	10.0	77	11.0	85	77
GLY	10.0	59	12.0	70	9.0	69	10.4	76	69
AGE (WEEKS)	0-4		0-4		0-8		0-4		

LYS, LYSINE; ARG, ARGININE; HIS, HISTIDINE; TRP, TRYPTOPHAN; THR, THREONINE; PHE, PHENYLALANINE; P + T, PHENYLALANINE PLUS TYROSINE; MET, METHIONINE M + C, METHIONINE PLUS CYSTINE; LEU, LEUCINE; ILE, ISOLEUCINE; VAL, VALINE; GLY, GLYCINE.

APPENDIX TABLE 11	EXPERIMENT 1 READING MODEL LYSINE INPUT AND BODY WEIGHT GAIN OUTPUT PREDICTIONS			
1) 4 TO 13 DAYS OF AGE				
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	9.00	0.11	4.9	5.1
6	11.50	0.16	7.9	7.4
8	11.50	0.19	9.9	8.8
5	14.00	0.24	11.9	11.2
		0.26		12.1
		0.28		13.0
		0.30		14.0
4	15.25	0.31	14.7	14.4
		0.32		14.9
		0.34		15.8
3	16.50	0.35	15.8	16.2
		0.36		16.6
2	17.75	0.38	15.7	17.3
		0.42		18.2
1	19.00	0.43	18.2	18.4
		0.46		18.7
		0.49		18.8

Based on $W = 0.137$kg $\sigma_{\Delta W} = 0.0023$
$\underline{a} = 21.31$ $\sigma W = 0.0149$
$\underline{b} = 0.0155$

APPENDIX TABLE 12	EXPERIMENT 1 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS			
1) 4 TO 22 DAYS OF AGE				
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	9.00	0.14	6.8	6.5
6	11.50	0.23	11.4	10.7
8	11.50	0.27	13.7	12.5
		0.30		13.9
		0.32		14.9
		0.34		15.8
5	14.00	0.36	17.0	16.7
		0.38		17.6
		0.40		18.5
		0.42		19.3
4	15.25	0.44	19.1	19.9
		0.46		20.5
3	16.50	0.48	20.1	20.8
		0.51		21.1
2	17.75	0.52	20.2	21.2
		0.54		21.3
1	19.00	0.60	21.7	21.3

Based on W = 0.214kg; $\underline{a}$ = 21.42; $\underline{b}$ = 0.0086; $\sigma_{\Delta W}$ = 0.0022; σW = 0.0225

APPENDIX TABLE 13	EXPERIMENT 1 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS			
1) 4 TO 13 DAYS OF AGE				
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	13.00	0.24	11.8	11.4
		0.25		11.8
6	14.00	0.26	12.7	12.3
		0.27		12.8
8	14.00	0.28	14.3	13.3
		0.30		14.2
		0.32		15.1
5	15.25	0.33	16.5	15.6
4	16.25	0.34	15.0	16.0
		0.36		16.7
		0.38		17.3
3	17.75	0.39	16.6	17.5
		0.40		17.6
		0.42		17.8
2	20.00	0.44	16.7	17.9
1	19.00	0.44	18.4	17.9

Based on $W = 0.161kg$ $\sigma_{\Delta W} = 0.0018$
$\underline{a} = 20.97$ $\sigma W = 0.0120$
$\underline{b} = 0.0109$

APPENDIX TABLE 14	EXPERIMENT 2 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS			
1) 4 TO 22 DAYS OF AGE				
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	13.00	0.35	17.0	16.6
		0.38		18.0
6	14.00	0.39	18.4	18.5
		0.40		18.9
		0.42		19.8
8	14.00	0.43	20.9	20.2
		0.44		20.6
		0.46		21.2
		0.48		21.7
5	15.25	0.49	21.9	21.9
		0.50		22.0
4	16.50	0.51	20.9	22.1
		0.52		22.2
		0.54		22.4
3	17.75	0.57	22.2	22.4
2	19.00	0.63	23.3	22.4
1	20.00	0.64	21.7	22.4

Based on $W = 0.274$kg $\sigma_{\Delta W} = 0.0023$
$\underline{a} = 20.97$ $\sigma W = 0.0240$
$\underline{b} = 0.0047$

APPENDIX TABLE 15	EXPERIMENT 3 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FOR MALE TURKEYS, 4 TO 7 WEEKS OF AGE			
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	4.0	0.30	23.9	8.5
6	6.5	0.71	27.9	20.2
5	9.0	1.51	41.3	43.0
		2.00		56.9
4	11.5	2.25	56.1	63.6
		2.50		68.9
		2.60		70.3
		2.70		71.2
8	14.0	2.76	72.7	71.6
		2.80		71.7
		2.90		72.0
		3.04		72.2
3	14.0	3.38	70.0	72.2
		3.60		72.2
2	19.0	3.71	74.9	72.2
1	16.5	3.82	72.2	72.2

Based on W = 0.323kg, $\sigma_{\Delta W}$ = 0.0068
$\underline{a}$ = 35.13, σW = 0.0845
$\underline{b}$ = 0.0010

APPENDIX TABLE 16	EXPERIMENT 4 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FOR FEMALE TURKEYS, 4 TO 7 WEEKS OF AGE			
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	4.0	0.26	14.4	7.3
6	6.5	0.52	16.3	14.7
5	9.0	0.89	24.4	25.2
		1.00		28.3
		1.20		34.0
		1.40		39.4
4	11.5	1.48	35.4	41.3
		1.60		43.3
		1.70		44.1
3	14.0	1.75	43.0	44.3
8	14.0	1.77	44.2	44.4
		1.83		44.5
		1.98		44.5
		2.03		44.5
2	16.5	2.22	45.2	44.5
1	19.0	2.36	46.9	44.5

Based on $W = 1.034$kg $\quad \sigma_{\Delta W} = 0.0039$

$\underline{a} = 35.22$ $\quad \sigma W = 0.0562$

$\underline{b} = 0.0036$

APPENDIX TABLE 17	EXPERIMENT 5 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FOR FEMALE TURKEYS, 9 TO 12 WEEKS OF AGE			
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	4.0	0.84	42.0	35.9
6	6.5	1.62	68.6	69.9
		1.80		77.8
		2.00		86.2
		2.30		95.1
		2.40		96.5
5	9.0	2.48	93.1	97.1
		2.50		97.2
		2.61		97.5
		2.70		97.5
		2.73		97.5
4	11.5	3.13	98.6	97.5
8	11.5	3.18	99.8	97.5
3	14.0	3.90	98.6	97.5
2	16.5	4.53	97.0	97.5
1	19.0	5.60	98.6	97.5

Based on $W = 4.305kg$ $\sigma_{\Delta W} = 0.0083$
$\underline{a} = 22.91$ $\sigma W = 0.2546$
$\underline{b} = 0.0040$

APPENDIX TABLE 18	EXPERIMENT 6 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FOR MALE TURKEYS, 15 TO 18 WEEKS OF AGE			
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	4.0	1.64	70.2	70.3
		1.70		73.4
		1.80		77.8
		1.90		81.3
		2.00		83.5
		2.10		84.5
		2.20		85.0
		2.24		85.0
		2.28		85.1
6	6.5	2.79	90.1	85.1
5	9.0	3.82	89.3	85.1
4	11.5	4.85	87.7	85.1
8	11.5	4.92	88.5	85.1
3	14.0	5.71	75.8	85.1
2	16.5	7.01	85.3	85.1
1	19.0	8.00	78.9	85.1

Based on $W = 8.079$kg, $\underline{a} = 18.26$, $\underline{b} = 0.0435$, $\sigma_{\Delta W} = 0.0082$, $\sigma W = 0.5032$

APPENDIX TABLE 19	EXPERIMENT 7 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FOR MALE TURKEYS, 15 TO 18 WEEKS OF AGE			
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	4.0	1.54	65.9	65.9
		1.70		75.0
		1.90		83.0
		2.00		84.7
		2.04		85.1
		2.06		85.2
		2.10		85.3
		2.16		85.4
		2.18		85.5
6	6.5	2.52	86.0	85.5
5	9.0	3.49	92.1	85.5
4	11.5	4.35	89.7	85.5
8	11.5	4.57	89.0	85.5
3	14.0	5.17	81.3	85.5
2	16.5	6.35	82.1	85.5
1	19.0	7.02	78.4	85.5

Based on $W = 8.482kg$ $\sigma_{\Delta W} = 0.0070$
$\underline{a} = 16.88$ $\sigma W = 0.4991$
$\underline{b} = 0.0503$

APPENDIX TABLE 20	EXPERIMENT 8 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FOR MALE TURKEYS, 15 TO 18 WEEKS OF AGE			
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	2.0	0.85	42.1	37.6
		1.00		44.3
8	3.0	1.24	57.1	55.0
6	3.0	1.34	69.8	59.4
		1.50		66.3
5	4.0	1.64	56.8	72.0
		1.80		77.7
		2.00		83.1
		2.15		85.8
4	5.0	2.29	80.2	87.2
		2.40		87.9
		2.58		88.4
		2.68		88.5
3	6.0	2.76	88.1	88.5
2	8.5	3.84	84.1	88.5
1	11.0	5.06	96.8	88.5

Based on W = 8.517kg $\sigma_{\Delta w}$ = 0.0144
<u>a</u> = 22.23 σW = 0.4757
<u>b</u> = 0.0019

APPENDIX TABLE 21	EXPERIMENT 8 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FOR FEMALE TURKEYS, 15 TO 18 WEEKS OF AGE			
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	2.0	0.75	46.8	37.2
		0.80		39.8
44.8		0.90		44.8
		1.00		49.7
8	3.0	1.09	47.6	53.7
6	3.0	1.18	54.0	57.0
		1.20		57.7
		1.24		58.8
		1.26		59.3
		1.30		60.1
5	4.0	1.49	66.7	61.9
		1.60		62.2
4	5.0	1.84	61.1	62.2
3	6.0	2.13	70.6	62.2
2	8.5	2.64	51.6	62.2
1	11.0	3.60	62.7	62.2

Based on W = 5.775kg; $\underline{a}$ = 19.65; $\underline{b}$ = 0.0032; $\sigma_{\Delta W}$ = 0.0085; σW = 0.4461

APPENDIX TABLE 22	EXPERIMENT 9 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FOR MALE TURKEYS, 15 TO 18 WEEKS OF AGE			
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	2.0	0.64	32.5	26.2
		0.80		33.0
8	3.0	1.06	51.6	43.9
6	3.0	1.09	46.0	45.2
		1.30		54.1
5	4.0	1.42	58.7	59.1
		1.60		66.6
4	5.0	1.76	59.5	73.1
		2.00		82.4
		2.25		90.5
3	6.0	2.53	99.4	97.2
		2.70		99.6
		2.90		101.4
		3.04		102.0
2	8.5	3.33	100.8	102.5
		3.68		102.7
1	11.0	4.43	99.2	102.7

Based on W = 8.949kg $\sigma_{\Delta W}$ = 0.0177
<u>a</u> = 23.67 σW = 0.6511
<u>b</u> = 0.0022

APPENDIX TABLE 23	EXPERIMENT 9 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FOR FEMALE TURKEYS, 15 TO 18 WEEKS OF AGE			
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	2.00	0.54	55.6	41.5
		0.60		46.1
		0.64		49.2
		0.68		52.3
		0.70		53.8
8	3.00	0.73	53.2	56.0
		0.76		58.1
		0.80		60.8
		0.84		63.3
6	3.00	0.86	57.9	64.4
		1.09		71.2
5	4.00	1.18	74.6	71.7
		1.24		71.8
4	5.00	1.39	73.5	71.8
3	6.00	1.56	65.9	71.8
2	8.50	2.27	78.6	71.8
1	11.00	2.79	64.7	71.8

Based on $W = 5.913kg$ $\sigma_{\Delta W} = 0.0101$
$\underline{a} = 12.92$ $\sigma W = 0.3862$
$\underline{b} = 0.0006$

APPENDIX TABLE 24	EXPERIMENT 10 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FOR MALE TURKEYS, 17 TO 20 WEEKS OF AGE			
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	2.00	0.79	55.6	38.8
		1.00		49.2
8	3.00	1.15	52.4	56.6
6	3.0	1.30	70.6	64.0
		1.50		73.8
5	4.00	1.77	85.7	86.9
		1.90		92.9
		2.10		101.1
		2.20		104.6
4	5.00	2.34	99.2	108.5
		2.40		109.8
		2.60		112.8
		2.72		113.7
3	6.00	2.93	118.3	114.4
		3.10		114.6
2	8.50	4.42	111.9	114.6
1	11.00	5.32	112.7	114.6

Based on $W = 10.402$kg $\sigma_{\Delta W} = 0.0162$
$\underline{a} = 20.24$ $\sigma W = 0.8547$
$\underline{b} = 0.0005$

APPENDIX TABLE 25	EXPERIMENT 10 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FOR FEMALE TURKEYS, 17 TO 20 WEEKS OF AGE			
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	2.0	0.77	57.9	47.8
		0.90		55.9
		1.00		62.1
6	3.0	1.12	58.7	68.9
8	3.0	1.12	68.8	68.9
		1.20		72.4
		1.28		74.8
		1.36		76.0
		1.40		76.3
		1.48		76.5
		1.50		76.6
5	4.0	1.71	83.3	76.6
4	5.0	1.80	67.5	76.6
3	6.0	2.42	77.8	76.6
2	8.5	3.18	76.2	76.6
1	11.0	4.32	81.0	76.6

Based on W = 6.740kg $\sigma_{\Delta W}$ = 0.0078
<u>a</u> = 15.97 σW = 0.4900
<u>b</u> = 0.0010

APPENDIX TABLE 26	EXPERIMENT 11 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FOR MALE TURKEYS, 17 TO 20 WEEKS OF AGE			
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	2.0	0.81	46.8	38.5
		1.00		47.7
8	3.0	1.24	54.0	59.4
6	3.0	1.32	71.4	63.2
		1.50		71.6
5	4.0	1.73	74.5	81.2
		2.00		89.5
		2.10		91.5
		2.20		93.0
4	5.0	2.27	108.4	93.8
		2.40		94.7
		2.42		94.8
3	6.0	2.61	98.4	95.3
		2.78		95.5
2	8.5	3.73	88.9	95.5
1	11.0	5.66	89.7	95.5

Based on W = 11.125kg; $\underline{a}$ = 20.48; $\underline{b}$ = 0.0020; $\sigma \Delta W$ = 0.0163; σW = 0.5974

APPENDIX TABLE 27	EXPERIMENT 11 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FOR FEMALE TURKEYS, 17 TO 20 WEEKS OF AGE			
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	2.0	0.67	42.1	41.0
		0.70		42.7
		0.74		44.7
		0.78		46.6
		0.82		48.2
		0.86		49.6
		0.90		50.7
		0.94		51.6
		0.98		52.2
6	3.0	1.08	52.2	53.1
8	3.0	1.09	44.4	53.2
		1.22		53.4
5	4.0	1.36	49.2	53.4
4	5.0	1.93	67.4	53.4
3	6.0	2.06	57.7	53.4
2	8.5	2.91	49.2	53.4
1	11.0	4.60	52.4	53.4

Based on W = 7.358kg, $\sigma_{\Delta W}$ = 0.0096
<u>a</u> = 15.91, σW = 0.55638
<u>b</u> = 0.0012

APPENDIX TABLE 28	EXPERIMENT 12 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FOR LARGE TYPE MALES, 9 TO 12 WEEKS OF AGE			
	LYSINE DATA		BODY WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	4.00	1.10	55.6	52.6
		1.50		72.3
		1.80		87.0
6	6.50	2.06	98.4	99.7
		2.20		106.1
		2.40		112.8
		2.50		114.5
		2.60		115.3
		2.68		115.6
		2.76		115.7
5	9.00	2.90	115.7	115.7
4	11.5	3.92	123.8	115.7
3	14.0	4.91	117.5	115.7
2	16.5	5.97	112.7	115.7
1	19.0	6.54	107.9	115.7

Based on W = 5.034kg $\sigma_{\Delta W}$ = 0.0082
a = 20.33 σW = 0.2696
b = 0.0061

APPENDIX TABLE 29	EXPERIMENT 12 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FOR LARGE TYPE FEMALES, 9 TO 12 WEEKS OF AGE			
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
		0.60		33.2
		0.70		38.8
7	4.00	0.81	52.4	44.9
		0.90		50.0
		1.00		55.5
		1.10		61.0
		1.20		66.3
		1.30		71.5
		1.54		80.8
6	6.50	1.62	76.2	82.5
		1.96		84.6
5	9.00	2.34	85.7	84.6
8	11.50	2.97	92.1	84.6
4	11.50	2.99	87.3	84.6
3	14.00	3.93	93.6	84.6
2	16.50	4.19	76.2	84.6
1	19.00	4.76	74.6	84.6

Based on $W = 3.742$kg $\sigma_{\Delta W} = 0.0105$
$\underline{a} = 17.99$ $\sigma W = 0.2940$
$\underline{b} = 0.0006$

APPENDIX TABLE 30	EXPERIMENT 12 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FOR SMALL TYPE MALES, 9 TO 12 WEEKS OF AGE			
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	4.00	0.76	31.7	31.6
		1.00		44.6
		1.20		54.3
		1.40		62.5
		1.50		65.0
6	6.50	1.58		66.3
		1.70		67.2
		1.78		67.7
		1.84		67.9
		1.93		68.0
5	9.00	2.39	76.2	68.0
4	11.50	2.92	71.4	68.0
8	11.50	2.96	66.7	68.0
3	14.00	3.51	54.0	68.0
2	16.50	4.09	68.2	68.0
1	19.00	5.25	71.4	68.0

Based on $W = 3.517$ kg, $\underline{a} = 18.16$, $\underline{b} = 0.0531$, $\sigma_{\Delta W} = 0.0116$, $\sigma W = 0.2452$

APPENDIX TABLE 31	EXPERIMENT 12 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FOR SMALL TYPE FEMALES, 9 TO 12 WEEKS OF AGE			
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
		0.50		
		0.56		
		0.62		
		0.68		
7	4.00	0.71		13.7
		0.80		21.3
		0.90		28.6
		0.96		35.3
		1.02		38.3
6	6.50	1.35	50.8	44.8
5	9.00	1.70	44.4	47.8
8	11.50	2.19	57.7	48.4
4	11.50	2.19	57.7	48.6
3	14.00	2.51	42.9	48.6
2	16.50	3.27	50.8	48.6
1	19.00	3.35	34.9	48.6

Based on $W = 2.635$kg $\quad \sigma_{\Delta W} = 0.0093$

$\underline{a} = 7.80 \quad \sigma W = 0.2624$

$\underline{b} = 0.1492$

APPENDIX TABLE 32	EXPERIMENT 13 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FOR LARGE TYPE MALES, 9 TO 12 WEEKS OF AGE			
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	4.00	0.77	38.1	39.9
		1.00		52.3
		1.20		63.0
		1.40		73.7
		1.60		84.4
6	6.50	1.86	117.5	97.7
		1.90		99.7
		2.00		104.4
		2.08		107.9
		2.16		111.1
5	9.00	2.84	127.8	124.1
8	11.50	2.87	87.3	124.2
4	11.50	2.99	125.4	124.5
		3.20		124.8
3	14.00	4.44	141.3	124.8
2	16.50	4.90	119.0	124.8
1	19.00	5.55	122.2	124.8

Based on W = 4.850kg, $\sigma_{\Delta W}$ = 0.0185

<u>a</u> = 18.64, σW = 0.4487

<u>b</u> = 0.0053

APPENDIX TABLE 33	EXPERIMENT 13 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FOR LARGE TYPE FEMALES, 9 TO 12 WEEKS OF AGE			
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	4.00	0.62	27.0	27.4
		1.00		44.5
		1.20		53.7
6	6.50	1.44	73.0	64.6
		1.60		71.5
		1.70		75.5
		1.80		79.3
		1.90		81.9
5	9.00	1.99	69.8	83.8
		2.00		84.0
		2.06		84.9
4	11.50	2.29	94.5	86.6
		2.40		86.9
8	11.50	2.79	90.5	86.9
3	14.00	3.29	88.9	86.9
2	16.50	3.98	82.5	86.9
1	19.00	4.43	85.7	86.9

Based on $W = 3.505kg$ $\sigma_{\Delta W} = 0.0108$
$\underline{a} = 22.01$ $\sigma W = 0.3652$
$\underline{b} = 0.0049$

APPENDIX TABLE 34	EXPERIMENT 13 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FOR SMALL TYPE MALES, 9 TO 12 WEEKS OF AGE			
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	4.00	0.60	30.2	29.5
		1.00		50.0
		1.20		59.9
6	6.50	1.35	68.2	66.7
		1.40		68.8
		1.50		72.2
		1.60		74.7
		1.70		76.3
		1.76		77.0
5	9.00	1.83	70.7	77.6
		2.05		78.0
8	11.50	2.42	80.5	78.0
4	11.50	2.54	79.4	78.0
3	14.00	3.00	85.7	78.0
2	16.50	3.27	77.8	78.0
1	19.00	3.74	68.2	78.0

Based on W = 3.400kg, $\underline{a}$ = 19.54, $\underline{b}$ = 0.0068, $\sigma_{\Delta W}$ = 0.0112, σW = 0.2995

APPENDIX TABLE 35	EXPERIMENT 13 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FOR SMALL TYPE FEMALES, 9 TO 12 WEEKS OF AGE			
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
		0.10		0.6
		0.20		7.8
		0.30		15.1
		0.40		22.4
		0.50		29.7
7	4.00	0.62	38.1	38.4
		0.70		43.9
		0.80		48.7
		0.94		50.3
6	6.50	1.11	54.0	50.3
5	9.00	1.37	46.0	50.3
8	11.50	1.66	47.6	50.3
4	11.50	2.08	52.4	50.3
3	14.00	2.33	57.1	50.3
2	16.50	2.64	52.4	50.3
1	19.00	3.02	42.9	50.3

Based on $W = 2.618$kg $\sigma_{\Delta W} = 0.0079$
$\underline{a} = 13.72$ $\sigma W = 0.2791$
$\underline{b} = 0.0353$

APPENDIX TABLE 36	EXPERIMENT 14 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FROM 6 TO 9 WEEKS, FOR MALE TURKEYS REARED ON TWO DIFFERENT PLANES OF NUTRITION PRIOR TO 6 WEEKS OF AGE			
A) HIGH PLANE OF NUTRITION				
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	4.00	0.37	15.7	15.8
6	6.50	0.89	46.1	38.6
		1.00		43.4
5	9.00	1.20	48.3	52.0
		1.30		56.1
		1.40		59.9
		1.50		63.1
		1.60		65.4
		1.70		67.0
		1.80		67.9
4	11.50	1.88	73.7	68.2
8	11.50	1.89	70.0	68.3
		2.02		68.5
3	14.00	2.27	69.0	68.5
2	16.50	2.50	66.4	68.5
1	19.00	2.95	63.9	68.5

Based on $W = 1.928$kg $\sigma_{\Delta W} = 0.0090$
$\underline{a} = 22.86$ $\sigma W = 0.1189$
$\underline{b} = 0.0042$

APPENDIX TABLE 37	EXPERIMENT 14 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FROM 6 TO 9 WEEKS, FOR MALE TURKEYS REARED ON TWO DIFFERENT PLANES OF NUTRITION PRIOR TO 6 WEEKS OF AGE			
B) LOW PLANE OF NUTRITION				
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	4.00	0.31	15.7	14.9
6	6.50	0.81	44.4	39.5
		1.20		58.6
5	9.00	1.30	59.4	63.1
		1.40		66.9
		1.50		69.6
		1.60		71.8
		1.65		72.4
		1.70		72.8
		1.73		73.0
		1.77		73.1
8	11.50	1.81	77.6	73.2
4	11.50	1.82	75.9	73.3
		1.90		73.4
3	14.00	2.16	75.0	73.4
2	16.50	2.47	71.6	73.4
1	19.00	2.66	64.9	73.4

Based on $W = 1.721$kg $\sigma_{\Delta W} = 0.0089$
$\underline{a} = 20.29$ $\sigma W = 0.1163$
$\underline{b} = 0.0046$

APPENDIX TABLE 38	EXPERIMENT 15 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FROM 9 TO 12 WEEKS, FOR MALE TURKEYS REARED ON TWO DIFFERENT PLANES OF NUTRITION PRIOR TO 9 WEEKS OF AGE			
A) HIGH PLANE OF NUTRITION				
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	4.00	0.79	34.9	35.7
6	6.50	1.52	78.4	69.9
5	9.0	2.44	98.6	108.6
		2.50		110.0
		2.60		112.1
		2.70		113.6
		2.80		114.5
		2.90		115.0
		3.00		115.3
		3.06		115.4
4	11.50	3.12	123.8	115.5
		3.20		115.6
8	11.50	3.63	116.3	115.6
3	14.00	3.91	122.6	115.6
2	16.50	4.41	116.1	115.6
1	19.00	4.89	110.5	115.6

Based on $W = 3.977$kg $\sigma_{\Delta W} = 0.0138$
$\underline{a} = 21.39$ $\sigma W = 0.3637$
$\underline{b} = 0.0063$

APPENDIX TABLE 39	EXPERIMENT 15 READING MODEL LYSINE INPUT AND BODY-WEIGHT GAIN OUTPUT PREDICTIONS FROM 9 TO 12 WEEKS, FOR MALE TURKEYS REARED ON TWO DIFFERENT PLANES OF NUTRITION PRIOR TO 9 WEEKS OF AGE			
B) LOW PLANE OF NUTRITION				
	LYSINE DATA		BODY-WEIGHT GAIN (g/BIRD D)	
DIET NO	g/kg OF DIET	g/BIRD D CONSUMED	OBSERVED	PREDICTED
7	4.00	0.58	25.4	26.4
6	6.50	0.94	52.4	89.0
5	9.00	1.98	89.5	90.8
		2.10		96.0
		2.20		99.8
		2.30		102.8
		2.40		105.0
		2.45		105.7
4	11.50	2.51	102.8	106.3
		2.55		106.6
		2.60		106.9
		2.76		107.2
3	11.50	2.89	98.8	107.2
8	14.00	3.50	110.3	107.2
2	16.50	3.72	108.5	107.2
1	19.00	4.44	107.1	107.2

Based on W = 2.723kg, $\sigma_{\Delta W}$ = 0.0089
<u>a</u> = 21.67, σW = 0.4042
<u>b</u> = 0.0033

APPENDIX TABLE 40 THE CALCULATED NUTRIENT VALUES OF INGREDIENTS (g/kg)

	INGREDIENT												
NUTRIENT	BARLEY	BARLEY STRAW	CALCIUM CARBONATE	DICALCIUM PHOSPHATE	FAT	MAIZE	MAIZE GLUTEN	MEAT & BONE	PRE-MIX	SKIM MILK & GRASS	SOYA BEAN	SUN-FLOWER	WHEAT
PROTEIN	100	25	-	-	-	88	600	500	-	340	430	300	100
OIL	19	15	-	-	1000	39	25	60	-	10	11	10	17
FIBRE	45	360	-	-	-	17	25	25	-	5	66	20	28
ME Kcalo/kg	2772	-	-	-	7276	3432	3663	2222	-	2470	2244	1850	3080
LYSINE	3.5	-	-	-	-	2.4	11.9	26.0	-	22.6	29.0	11.4	3.0
METHIONINE	1.7	-	-	-	-	1.9	15.8	7.0	180	9.6	6.7	10.2	1.6
MET & CYS	3.8	-	-	-	-	3.6	20.8	13.0	180	13.8	13.5	14.1	3.6
TRYPTOPHAN	1.4	-	-	-	-	0.5	3.0	2.6	-	4.4	7.0	3.9	1.2
THREONINE	2.9	-	-	-	-	3.4	20.	16.3	-	17.1	17.0	12.0	2.8
ARGININE	4.5	-	-	-	-	4.5	19.0	33.5	-	10.0	34.0	24.6	4.7
HISTIDINE	2.5	-	-	-	-	2.0	12.2	9.6	-	8.2	11.5	5.1	2.0
ISOLEUCINE	4.2	-	-	-	-	3.7	22.9	17.0	-	21.1	23.9	15.6	4.2
LEUCINE	6.9	-	-	-	-	11.0	101.1	32.0	-	31.7	35.2	18.6	5.9
PHEN & TYR	8.3	-	-	-	-	9.2	67.1	34.0	-	26.6	35.5	16.2	8.4
VALINE	5.3	-	-	-	-	5.2	27.4	22.5	-	22.6	23.4	15.6	4.4
CALCIUM	0.6	3.0	38.0	24.5	-	0.2	0.1	80	-	12.3	2.5	3.6	0.5
PHOSPHOROUS	4.0	0.7	-	18.0	-	2.9	5.4	40	-	9.8	6.0	11.0	3.0
AVAIL. PHOS	1.6	0.2	-	18.0	-	1.0	1.9	40	-	9.7	3.3	3.3	0.9