EVALUATION OF MEAT-AND-BONE MEALS IN RATIONS FOR GROWING CHICKENS

1. EFFECT OF VARYING LEVELS OF BLOOD AND BONE

By R. J. W. GARTNER, B.Sc.*, and H. W. BURTON, H.D.A.†

SUMMARY

Meat-and-bone meals prepared by blending in various proportions the three ingredients in commercial products, namely blood, soft tissues and bone, were tested in practical rations for growing chickens. All rations were balanced for crude protein, calcium and phosphorus. Chickens were reared for 53 days.

In the first experiment the amount of predominantly blood meal in the meat-and-bone meals ranged from 0 to 12 per cent. There was a significant tendency for body-weight to increase and food conversion ratio to fall as percentage of blood meal increased.

In a second experiment the proportion of bone in the meat-and-bone meals was varied to provide a range in ash content of 22·7 to 32·7 per cent. There was a significant tendency for body-weight to decrease and food conversion ratio to increase as the percentage of bone increased.

I. INTRODUCTION

The tonnage of chilled and frozen meat exported from Australia to the United States of America increased 34-fold from 1958 to 1963 (Anon. 1958 a, 1963). Whereas in 1958 this represented only 5 per cent. of the total beef and veal export, this figure increased to 82 per cent. in 1963. This trade consists mainly of boneless beef and there has been a consequential increase in the amount of bone available as a by-product. Over this period there has not been a proportional increase in the production of animal fertilizer or bone meal

---

* Senior Chemist, Animal Research Institute, Yeerongpilly.

† Senior Adviser, Animal Husbandry Research Farm, Poultry Section, Rocklea.

---

either in Australia as a whole or in Queensland in particular; in fact, the production of these products as recorded by the Bureau of Census and Statistics (Anon. 1957–1962 *a, b*) has decreased. An increasing proportion of bone is being diverted to meat-and-bone meal. This has a particular application in Queensland, as this State has provided 50–70 per cent. of the total beef exported during the years mentioned. Another major influence in the manufacture of animal by-products has been the increasing mechanisation in some abattoirs. Under such a system it is less convenient to segregate raw materials. The result is the production of meat-and-bone meal rather than a range of animal by-products such as meat meal, liver meal, blood meal and bone meal.

The composition of meat-and-bone meals produced in Queensland is variable. From June 1957 to December 1960, 134 samples representing 32 products were analysed for legislative control purposes. The crude protein percentage of these ranged from 37·1 to 66·6 (mean 48·6 ± 5·3). Percentage ash was determined in 34 of these samples and ranged from 13·6 to 42·6 (mean 29·2 ± 7·2) (unpublished records of the Queensland Department of Agriculture and Stock, now Department of Primary Industries).

Variable growth responses have been obtained with Australian meat-and-bone meals. Underwood, Conochie, Reed, and Smyth (1950) found with a series of meat-and-bone meals that the protein in the worst samples had less than half the nutritive value of that in the best, as judged by feeding tests with rats. They suggested that the lower biological values found for later products (1947–1949) compared with values found for samples tested in 1939–1940 were due largely to the inclusion of increased proportions of "offal" and smaller amounts of "meat" rather than to changes in the methods of processing. Experiments conducted at the Poultry Section of the Animal Husbandry Research Farm at Rocklea have shown variable performance in growing chickens receiving rations containing different meat-and-bone meals (Anon. 1958*b*). McDonald and Beilharz (1959) reported considerable variation in the ability of commercial meat-and-bone meals to support growth of chickens and suggested a toxic factor in the ash fraction of low-quality meat-and-bone meals. McArdle, Jones, and Lowe (1960) found a lower growth rate in chickens receiving a ration containing meat-and-bone meal of 40 per cent. crude protein compared with an isoproteinic ration containing a meat-and-bone meal of 50 per cent. crude protein content. Sathe, Cumming, and McClymont (1964) observed wide variation in nutritional value of Australian meat-and-bone meals, with all samples inferior in value to imported fish meal. These workers found no relationship between crude protein and fat content of the meals and performance of chickens; in rations balanced for crude protein only, small variations in growth response were significantly associated with the amount of ash contributed by meat-and-bone meals to diets; however, ash was not the major cause of the differences between high and low quality meals.

The evidence that the quality of meat-and-bone meals is variable and has in general deteriorated in recent years emphasizes the need to evaluate commercial products in Australia. A similar deterioration in quality of meat-and-bone

meals in the United States of America has been described by F. B. Morrison (1959). Quality must be related to the materials composing the meals and to the processing procedure.   Initially it was considered that biological testing with chickens would be the desirable experimental approach, as this would evaluate the influence of both composition and processing.   It was appreciated that some variation in performance of chickens could be genetical and that this would have to be examined later.   Because biological tests are time-consuming, a practical approach to subsequent routine testing would be to establish a correlation between biological tests and certain entities of meat-and-bone meals which could be determined by chemical analysis.

One biological method of evaluating proteins is the measurement of Gross Protein Value (G.P.V.).   The procedure was first described by Heiman, Carver, and Cook (1939), recalculated by Robertson, Carver, and Cook (1940) and modified by Carpenter, Ellinger, and Shrimpton (1955).   Because lysine is a critical amino acid under the conditions of the G.P.V. test, it is not surprising that a high correlation has been found between G.P.V. and 'available lysine' in animal proteins (Carpenter and Ellinger 1955 a, 1955 b; Bruno and Carpenter 1957; Carpenter, Ellinger, Munro, and Rolfe 1957; Carpenter 1958 a; Boyne, Carpenter, and Woodham 1961; Anwar 1962).   On the other hand, it is not surprising that no correlation has been found between 'available lysine' and biological tests which are less dependent on the lysine contribution of the protein supplement.   Bunyan and Price (1960) found no correlation between 'available lysine' in meat-and-bone meals and Biological Value.   Boyne, Carpenter, and Woodham (1961) found no correlation between 'available lysine' and Net Protein Utilization.

The G.P.V. of four Australian meat-and-bone meals was determined by J. W. C. Morrison (1959) and ranged from 63 to 67.   The G.P.V. of a further four Australian meat-and-bone meals was measured in the United Kingdom and ranged from 56 to 73 (Duckworth, Woodham, and McDonald 1961).   Experiments were carried out at the Poultry Section of the Animal Husbandry Research Farm at Rocklea to examine this biological test.   Using the procedure of Carpenter, Ellinger, and Shrimpton (1955), high G.P.V.s of 90 and 105 were found in two Queensland meat-and-bone meals (Anon. 1959) and were associated with high 'available lysine' levels of 4·06 and 5·25 respectively as determined by the method of Carpenter (1958 b).   From the above values it can be seen that the meat-and-bone meal richer in 'available lysine'· gave a higher chick response, but not in full proportion to its 'available lysine' content.   This may be due to a different amino acid limiting performance when the lysine value is high (K. J. Carpenter, personal communication).   Alternatively, it may have been due to a higher level of blood in the meat-and-bone meal with the higher content of 'available lysine', for the relation of 'available lysine' and G.P.V. does not extend to blood meals (Carpenter and Ellinger 1956). B. S. Sathe (personal communication) found a significant correlation between 'available lysine' and chick growth for six Australian meat-and-bone meals fed

in diets containing wheat, skim-milk and meat-and-bone meals as the major source of protein. However, the range of 'available lysine' (determined by K. J. Carpenter) was narrow ($4 \cdot 11$–$4 \cdot 81$).

Biological tests such as the G.P.V. are not ideal for routine use, being time-consuming and requiring extensive facilities. Further, there is an inherent error in the determination of G.P.V. and difficulty in reproducing results (Duckworth, Woodham, and McDonald 1961; Boyne, Carpenter, and Woodham 1961; Butterworth 1962). Experiments at the Poultry Section of the Animal Husbandry Research Farm showed that both the method of calculating G.P.V. and the breed of chickens appeared to exert a considerable influence on the results. Depending on the method of calculation, this breed difference in G.P.V. could be in favour of either the White Leghorn or the Australorp breed. Anwar (1960) also found that the food eaten by the negative control chickens should be taken into account in calculating G.P.V. However, Duckworth, Woodham, and McDonald (1961) maintained that while the theoretical figure for G.P.V. is improved by an alternative method of calculation, there is no significant difference in the resultant ranking of the individual meals. A final criticism of the G.P.V. test is that differences found between meat-and-bone meals tested in 11 per cent. protein rations where they contribute about 27 per cent. of the total crude protein may not be apparent when these meals are used in practical chicken rations containing from 18 to 24 per cent. protein, of which 20–50 per cent. is contributed by meat-and-bone meals. Since the level of protein intake is of critical importance in the evaluation of proteins (Harris and Buress 1959), it is suggested that proteins intended for poultry production should be evaluated in practical diets whenever possible. A similar suggestion related to the evaluation of fish meal has been made by Waterhouse and Scott (1962). Other factors to be considered in the evaluation of protein supplements have been reviewed by Summers, Slinger, Sibbald, and Pepper (1964).

Two experiments were made in 1960 as the first part of an evaluation of meat-and-bone meals in rations for growing chickens. Experiment 1 was designed to test the effect of different levels of blood meal in a meat-and-bone meal containing a constant amount of bone. Experiment 2 was designed to test the effect of different levels of bone in a meat-and-bone meal containing a constant amount of blood meal. The performance of chickens receiving these meat-and-bone meals in practical rations was used as the index of quality. All ration ingredients were analysed for crude protein, calcium and phosphorus and all rations were balanced for these constituents.

II. MATERIALS AND METHODS

(i) *Chickens.*—White Leghorn x Australorp crossbred cockerels were used.

(ii) *Basal Mixture.*—The basal mixture in both Experiments 1 and 2 is given in Table 1. When comprising about 80 per cent. of the experimental

rations, this mixture provided a blend of cereal grains, mill offals and lucerne meal comparable with that found in chicken starter mashes in Queensland in 1959.

TABLE 1

COMPOSITION OF BASAL MIXTURE USED IN EXPERIMENTS 1 AND 2

Ingredient	Percentage of Total	Crude Protein (%)	Ca (%)	P (%)
Sorghum meal ..	40	8·7	0·01	0·27
Wheat meal	22	13·4	0·02	0·40
Maize meal	9	8·3	0·02	0·21
Barley meal	5	10·2	0·06	0·30
Pollard	13	16·1	0·11	0·73
Bran	9	16·8	0·11	1·00
Lucerne meal	2	18·9	1·55	0·23
Total	100	11·7	0·07	0·42

(iii) *Meat-and-bone Meal Components.*—All components were obtained from the Brisbane Public Abattoir, operated by the Queensland Meat Industry Board. Mr. T. N. Grace, Plant Chemist at the Abattoir, described these ingredients (personal communication) as follows:

"Vomit", which will be referred to as predominantly blood meal. This material is blood containing a small quantity of undigested material which, during the bleeding process, unavoidably becomes mixed with blood. It is coagulated by the injection of live steam, drained and dried in steam-jacketed driers, which are fitted with rotating beater arms. The average drying time is 5–7 hr and the maximum temperature reached during this period is approximately 250°F.

"Protein", which will be referred to as soft tissues and bone meal. This consists of cleanly washed, inedible material from all classes of livestock and includes all gut material, sheep heads and feet. All this material is dry-rendered. Sheep heads are processed in pressure cookers, the other material in atmospheric cookers. With the pressure cookers, initial internal pressure is 40 lb/in.² and jacket pressure 60 lb/in.². The cooking time is 3½–4 hr and the maximum temperature reached in approximately 280°F. With atmospheric dry-rendering, cooking time is 3½–4 hr and temperature reached is 250–270°F. All protein material is expelled by screw press to reduce fat content.

"Special", which will be referred to as predominantly bone meal. This consists mainly of boning-room bones and small amounts of slaughter-floor fat trimmings. It is cooked in water with direct steam, in digesters under pressure of 50 lb/in.². The cooking time is 3–3½ hr and the maximum temperature reached in the digester is approximately 300°F. Free oil is then floated off. The solid residues are allowed to drain and then dried in horizontal steam-jacketed driers for 2½–3 hr. The maximum temperature reached in the drying process is approximately 250°F.

Analyses of these three components are given in Table 2. They were blended in various proportions to give the meat-and-bone meals used in both experiments.

TABLE 2

ANALYSIS OF MEAT-AND-BONE MEAL INGREDIENTS

Ingredient		Crude Protein (%)	Ash (%)	Ca (%)	P (%)
Predominantly blood meal	..	63·7	10·2	1·85	0·98
Soft tissues & bone meal	..	57·1	23·7	7·90	3·84
Predominantly bone meal	..	28·3	47·6	19·70	8·52

(iv) *Battery Brooders.*—Chickens were reared in electrically heated battery brooders with wire floors. Each brooder measured 4 ft x 3 ft x 1 ft high and had attached two 3-ft feeding troughs and a 3-ft water trough. Brooders were stacked one upon the other in units containing four levels. Thus each unit accommodated four groups of chickens. Temperatures maintained were 90–95°F for the first week, 85–90°F for the second week, 75–85°F for the third week and approximately 70°F for the fourth week.

(v) *Follow-on Cages.*—Each follow-on cage was divided into two sections. Each section measured 2·5 ft x 2·5 ft x 1 ft high and had attached two feeding troughs and one water trough each 2·5 ft long. The cages were stacked in the same manner as adopted with the battery brooders. Ambient temperatures varied from 50 to 75°F.

(vi) *Sampling and Analysis of Ration Ingredients.*—Each ingredient was mixed separately in a horizontal mixer of 300-lb capacity, then bagged. A proportion of these bags relative to the total weight of each ingredient was remixed and a final sample of 2 lb was taken for analysis from the final mix. Proximate analysis was done essentially by the methods described by the Association of Official Agricultural Chemists (1955) with the following modifications: nitrogen was estimated by the method of Markley and Hann (1925), and $Mg(NO_3)_2$ was not used to fix phosphorus.

(vii) *Body-weight.*—The chickens were individually weighed on a physical balance calibrated in 1-g divisions.

(viii) *Husbandry of Chickens.*—All chickens were debeaked by having half the upper beak between the tip and the nostrils removed by an electric debeaker at four days of age. At the same time all chickens were vaccinated with pigeon pox vaccine by the follicular method. Feed and water were available *ad lib*.

(ix) *Allocation of Chickens to Treatments.*—At seven days of age chickens were randomly allocated to experimental groups by stratified random allocation on a body-weight basis. Group numbers were reduced from 50 to 30 at 28 days of age by a set of restricted random numbers which retained the same relative proportions of heavy and light chickens in each group.

III. EXPERIMENT 1

(a) Experimental Design

Four meat-and-bone meals were prepared containing proportions of blood meal, soft tissues and bone meal, and bone meal as shown in Table 3. The calculated composition of meat-and-bone meals is given on the basis of analyses from Table 2.

Four experimental rations (Table 4) were then prepared using each of these meat-and-bone meals and the basal mixture. All rations were equated for protein, calcium and phosphorus. A small amount of starch was required to balance the rations. The crude protein content of all rations was 18·9 per cent., of which 9·6 per cent. was contributed by the basal mixture and 9·3 per cent. by the animal proteins. The calcium content of all rations was 1·67 per cent. and the phosphorus content 1·10 per cent., giving a Ca:P ratio of 1:0·67. These values were calculated from individual analyses of ration ingredients (Tables 1 and 2). The metabolizable and productive energy contents of these rations were calculated from published data (Anon. 1957; F. B. Morrison 1959). The metabolizable energy was 1301 kcal/lb and the productive energy 909 kcal/lb. The kcal:protein ratios were therefore 69:1 and 48:1 respectively.

TABLE 3

COMPOSITION OF MEAT-AND-BONE MEALS IN EXPERIMENT 1

Meat-and-bone Meal	Blood Meal (%)	Soft Tissues and Bone Meal (%)	Bone Meal (%)	Crude Protein (%)	Ash (%)	Ca (%)	P (%)
1 ..	12	77	11	54·7	24·7	8·47	4·01
2 ..	8	81	11	54·5	25·2	8·71	4·13
3 ..	4	85	11	54·2	25·8	8·96	4·24
4 ..	0	89	11	53·9	26·3	9·20	4·36

TABLE 4

COMPOSITION OF RATIONS IN EXPERIMENT 1

Ingredient	Meat-and-bone Meal 1	Meat-and-bone Meal 2	Meat-and-bone Meal 3	Meat-and-bone Meal 4
	Ration 1	Ration 2	Ration 3	Ration 4
Basal mixture (%)	82·00	82·00	82·00	82·00
Meat-and-bone meal (%) ..	17·00	17·05	17·10	17·15
Tricalcium phosphate (%) ..	0·37	0·24	0·15	0·00
Salt premix* (%)	0·50	0·50	0·50	0·50
Starch (%)	0·13	0·21	0·25	0·35

* Salt premix consisted of sodium chloride to which was added Nutrigain (Nicholas Pty. Ltd.), which contributed 5,600 I.U. vitamin A, 1,125 I.U. vitamin D3, 2·5 mg riboflavin, 3·0 mg Ca-pantothenate, 1·0 mg vitamin K-bisulphite and 75 p.p.m. Mn as $MnSO_4$ per lb feed.

The cockerels were reared from hatching to seven days of age in battery brooders on a ration consisting of 97·5 parts basal mixture, 2 parts limestone and 0·5 parts salt premix. They were then randomized into 12 groups each of 50 chickens, and three replicate groups were randomly allocated to each ration. Initial weights ranged from 40 to 60 g. At 28 days of age the number of cockerels in each group was reduced to 30. These were transferred from battery brooders to follow-on cages, where they were reared for a further 25 days. Chickens were individually weighed at 7-day intervals and group feed consumption was recorded at each weighing period.

(b) Results

(i) *Mortality*.—Mortality was insignificant, being two cockerels out of a total of 600. Post-mortem examinations indicated visceral gout and nephritis in one chicken, and nephritis in the other.

(ii) *Sexing Errors*.—Examination of the chickens at the end of the experiment showed that the sexing error in chickens reared for the total period was 5·8 per cent.

(iii) *Body-weight and Food Conversion Ratio*.—Weights at 28 days were not analysed in detail; the 12 subgroup means were used to estimate variability, means and standard errors. As sex was known for all chickens retained to the end of the experiment, covariance analysis was used to adjust mean weights to an all-cockerel basis for this period. Final weights rather than gains were analysed, as stratification on initial weights appears to have been successful in removing variability due to differences in 7-day weights. Assuming that the food consumption of pullets is lower than that of cockerels in the same proportion as their weight, no adjustments were necessary to calculate food conversion ratio (FCR = grams food per gram liveweight gain). Results are given in Table 5.

TABLE 5

WEIGHT OF CHICKENS AND FOOD CONVERSION RATIO IN EXPERIMENT 1

Ration		Weight at 28 days (g)	Weight at 53 days (g)	FCR at 53 days
1	.. ..	187·0 ± 1·3	640·0 ± 10·3	2·80 ± 0·03
2	.. ..	186·1 ± 1·3	627·1 ± 9·4	2·94 ± 0·03
3	.. ..	182·0 ± 1·3	623·4 ± 9·0	2·91 ± 0·03
4	.. ..	180·5 ± 1·3	616·8 ± 10·3	2·97 ± 0·03

There were no significant differences among the treatment means in 28-day weight, 53-day weight or FCR, but in each case there was a significant tendency (5 per cent. probability level) for weight to increase and FCR to fall as the percentage blood meal was increased.

Pullets were 139 ± 23 g lighter than cockerels (overall average 626·8 g) at the end of the experiment, i.e. their weight was 78 per cent. of the male weight.

IV. EXPERIMENT 2

(a) Experimental Design

Indications from Experiment 1 were that up to 12 per cent. blood meal could be incorporated with advantage in a meat-and-bone meal. This was therefore selected as a constant level in Experiment 2. Six meat-and-bone meals were prepared containing proportions of blood meal, soft tissues and bone meal, and bone meal as shown in Table 6. The calculated composition of these meat-and-bone meals is given on the basis of analyses from Table 2.

TABLE 6

COMPOSITION OF MEAT-AND-BONE MEALS IN EXPERIMENT 2

Meat-and-bone Meal	Blood Meal (%)	Soft Tissues and Bone Meal (%)	Bone Meal (%)	Crude Protein (%)	Ash (%)	Ca (%)	P (%)
1	12	85·375	2·625	57·1	22·7	7·48	3·62
2	12	77·000	11·000	54·7	24·7	8·47	4·01
3	12	68·625	19·375	52·3	26·7	9·46	4·40
4	12	60·250	27·750	49·9	28·7	10·45	4·80
5	12	51·875	36·125	47·5	30·7	11·44	5·19
6	12	43·500	44·500	45·1	32·7	12·43	5·58

The levels of components were selected to give one meat-and-bone meal comparable with one used in Experiment 1 (meat-and-bone meal 1, Experiment 1 equivalent to meat-and-bone meal 2, Experiment 2) and to give ash differences between successive samples in units of 2 per cent. This gave a protein, calcium and phosphorus difference in units of 2·4, 0·99 and 0·39 per cent. respectively between successive samples.

TABLE 7

COMPOSITION OF RATIONS IN EXPERIMENT 2

Ingredient	Meat-and-bone Meal 1	Meat-and-bone Meal 2	Meat-and-bone Meal 3	Meat-and-bone Meal 4	Meat-and-bone Meal 5	Meat-and-bone Meal 6
	Ration 1	Ration 2	Ration 3	Ration 4	Ration 5	Ration 6
Basal mixture (%) ..	77·50	77·50	77·50	77·50	77·50	77·50
Meat-and-bone meal (%)	17·36	18·12	18·96	19·87	20·88	22·00
Tricalcium phosphate (%)	3·74	3·12	2·45	1·71	0·90	0·00
Salt premix* (%)	0·50	0·50	0·50	0·50	0·50	0·50
Starch (%)	0·90	0·76	0·59	0·42	0·22	0·00

* As shown in Table 4.

Six experimental rations (Table 7) were then prepared, using each of these meat-and-bone meals and the basal mixture. All rations were equated for protein, calcium and phosphorus. A small amount of starch was required to balance the rations. The crude protein content of all rations was 19·0 per cent., of which 9·1 per cent. was contributed by the basal mixture and 9·9 per cent. by the animal proteins. The calcium content of all rations was 2·79 per cent. and

the phosphorus content 1·61 per cent., giving a Ca:P ratio of 1:0·58. These values were calculated from individual analyses of ration ingredients (Tables 1 and 2). The metabolizable and productive energy contents of these rations were calculated from published data (Anon. 1957; F. B. Morrison 1959). The metabolizable energy was 1273 kcal/lb and the productive energy 884 kcal/lb, giving kcal:protein ratios of 67:1 and 46·5:1 respectively.

Group numbers and the husbandry of chickens were comparable with Experiment 1, but with the increased number of treatments facilities permitted only two replicates on each ration. Initial weights at seven days of age ranged from 41 to 64 g.

(b) Results

(i) *Mortality.*—Mortality was low, being seven cockerels out of a total of 600. Two of these chickens had nephritis; gelatinous exudates were present in the abdomen and throughout the tissues of another chicken; no abnormalities were detected in the remainder.

(ii) *Sexing Errors.*—Total sexing error was determined on all chickens at 56 days of age, including those chickens removed from the experiment at 28 days. The error was 3·8 per cent.

(iii) *Body-weight and Food Conversion Ratio.*—All weights were adjusted by covariance analysis to an all-cockerel basis. There were significant differences in body-weight among the 12 pens, but the differences among treatments were not significantly greater than the differences between pens receiving the same treatment. Body-weights and FCR are given in Table 8.

TABLE 8

WEIGHT OF COCKERELS AND FOOD CONVERSION RATIO IN EXPERIMENT 2

Ration			Weight at 28 days (g)	Weight at 53 days (g)	FCR at 53 days
1	..	..	190·8 ± 5·1	637·7 ± 8·7	2·97 ± 0·04
2	..	..	200·6 ± 5·1	641·0 ± 8·6	3·08 ± 0·04
3	..	..	204·3 ± 5·1	642·0 ± 8·6	3·04 ± 0·04
4	..	..	196·0 ± 5·1	615·9 ± 8·6	3·14 ± 0·04
5	..	..	197·5 ± 5·1	610·1 ± 8·6	3·18 ± 0·04
6	..	..	202·1 ± 5·1	625·8 ± 8·7	3·15 ± 0·04

There was a significant tendency (5 per cent. probability level) for weight to decline with increasing percentage bone meal in the ration. In particular, Ration 5 was significantly inferior to Rations 3, 2, and 1. There were significant differences (5 per cent. probability level) in FCR in the following treatments: 5>2,3,1; 6,4>3,1 and 2>1.

Pullets were 23±7 g lighter than cockerels (average 198·5 g) at 28 days of age, i.e. their weight was 88 per cent. of the male weight. Pullets were 131±33 g lighter than cockerels (average 628·7 g) at the end of the experiment, i.e. their weight was 79 per cent. of the male weight.

V. DISCUSSION

The evaluation of meat-and-bone meals in our experiments was based on their relative growth-promoting effects rather than on their ability to replace tissues in adult animals. The practical importance of testing meat-and-bone meals on growing chickens is based on an estimated current use of one-sixth of the total distribution of meat-and-bone meals for this class of livestock in Queensland (private communication, Division of Marketing, Department of Primary Industries, Queensland).

Factors affecting the value of any specific protein in a diet are the composition of this protein, the extent to which all food components including the protein can be digested and the contribution of amino acids from other proteins in the diet. Palatability may also be a factor. Thus the level of the test protein and the composition of the diet will influence the results obtained. Since the objective in our experiments was an evaluation of meat-and-bone meals in rations for growing chickens, experimental rations were based as far as possible on rations used in practice at that time. Using excessively high levels of meat-and-bone meal in experimental rations, or alternatively testing in diets which are grossly limiting in protein, such as the G.P.V. test, may offer certain advantages, but on the other hand the ranking of products in this manner may apply only to the particular test conditions.

Rations used in Experiments 1 and 2 were equated for total crude protein, calcium and phosphorus. The difference between rations in the amount of starch required for balancing was small; rations could be considered as isocaloric in any one experiment. Differences between rations were therefore due only to differences in the composition of the meat-and-bone meals under test.

Experiment 1 indicated that there was a significant tendency for weight to increase and FCR to fall as the percentage blood meal in meat-and-bone meals increased from 0 to 12. The amount of feed consumed by the chickens was comparable for all rations. The average digestibility in the chicken of the crude protein of blood meal is comparable with that of the protein of meat-and-bone meal (Titus 1961). The beneficial effect of blood meal in this experiment must therefore have been a function of its amino acid composition in relation to the amino acid requirement of growing chickens and the amino acid contribution from other proteins in the diet.

Lysine is often the factor limiting the protein quality of mixed diets, particularly where cereals supply a large proportion of the protein. Of the animal products, blood meal has the highest value of 'available lysine' (Carpenter 1960). Almquist (1957) has stated that a comparison of the chick requirements with the known supply of amino acids in feedstuff proteins shows that only arginine, lysine, methionine, cystine and tryptophan need particular attention in practical rations for the chicken. Calculation of the percentage of these amino acids for the rations used in Experiment 1 from published tables (Lyman, Kiuken, and Hale 1956; Anon. 1957), and comparison of the levels found to requirements for starting chicks (National Research Council 1954),

indicate that the rations were low in methionine, cystine, arginine and lysine. The only appreciable effect of increasing the concentrations of blood meal in the meat-and-bone meals in respect of the amino acid concentration of the rations was to increase the lysine content from a calculated 0·80 per cent. in Ration 4 to 0·88 per cent. in Ration 1. This would approximate the National Research Council requirement of 0·90 per cent.

Experiment 2 indicated that there was a significant tendency for weight to decrease and FCR to increase as the percentage bone meal in meat-and-bone meals was increased. In particular, products containing 26·7 per cent. ash or less were superior to products containing from 28·7 to 32·7 per cent. ash. The amount of feed consumed by the chickens was comparable for all treatments. As all rations in the experiment were balanced with regard to calcium and phosphorus content, the effect of bone meal must have been related to either its amino acid composition or its digestibility.

Assessing the amino acid content of rations as in Experiment 1 indicated that rations in Experiment 2 were also low in methionine, cystine, arginine and to a lesser extent in lysine. An increasing amount of bone meal was present in Rations 1–6. Although the protein in bone meals is low in lysine, methionine and tryptophan (Lyman, Kiuken, and Hale 1956), the concentration of amino acids was comparable in all rations. This resulted from the greater concentrations of meat-and-bone meal required in Rations 1–6 to achieve equal protein contribution.

Bone contains 15–25 per cent. protein, most of which is collagen (Eastoe and Eastoe 1954; Eastoe 1955). Eastoe and Long (1960) indicated that the protein of processed bones contained about 83 per cent. collagen and the protein of meat-and-bone meals contained 50–65 per cent. collagen. Whole muscle contains little collagen, but collagen must be expected to be present in all by-products containing meat, the amount increasing with the proportion of extraneous tissue. Little information exists regarding the digestibility of collagen, although Almquist (1957) gives it a relative nutritive value of 40 as protein for the chicken against 100 for muscle tissue protein. The effect of increasing levels of bone in meat-and-bone meals in this experiment could therefore have been due at least in part to the relative indigestibility of the collagen of bone protein.

The meat-and-bone meal common to both experiments was that used in Ration 1, Experiment 1, and Ration 2, Experiment 2. The major difference between these rations was the level of added minerals—0·37 per cent. tricalcium phosphate in Ration 1 compared with 3·12 per cent. in Ration 2. Chickens receiving these rations were comparable at the end of the experiment, but the FCR was better in Experiment 1 (2·80 ± 0·03, compared with 3·08 ± 0·04). The same strain of cockerels and the same ration ingredients were used in both experiments. Although the differences between groups could be due to the experiments not being conducted simultaneously, it would seem probable that the higher FCR in Experiment 2 could be due to the excessive mineral content in the diet. Sathe, Cumming, and McClymont (1964) and M. W. McDonald

(personal communication) have found that the performance of chickens on rations containing different meat-and-bone meals could be related to the minerals contributed by the rations.

A practical approach to any routine method of evaluation of meat-and-bone meals would be by the analysis of any simple chemical entity which can be correlated with a biological test. This was the basis of the "available lysine" procedure. In rations balanced for total crude protein only in which meat-and-bone meal and starch were the two variables, M. W. McDonald (personal communication) found a highly significant correlation between calcium, ash and bone contributed by the meat-and-bone meals and the weight gained by the chickens receiving these rations. Phosphorus contribution and weight gain were not correlated and there were no significant differences between meat meals in FCR. Depression in growth rate due to addition of calcium carbonate and calcium phosphate indicated that calcium excess was the main factor responsible for the effect. The data from Experiment 2 suggest that the growth of chickens in this experiment was related to the ash content of meat-and-bone meals. From the analyses of 48 meat-and-bone meals manufactured in Queensland, the following relationships are evident with regard to calcium, phosphorus and ash:

Ash (%)	< 20		20–25		25–30		30–35		35–40	
Ratios ..	$\frac{P}{Ca}$	$\frac{Ash}{Ca + P}$	$\frac{P}{Ca}$	$\frac{Ash}{Ca + P}$	$\frac{P}{Ca}$	$\frac{Ash}{Ca + P}$	$\frac{P}{Ca}$	$\frac{Ash}{Ca + P}$	$\frac{P}{Ca}$	$\frac{Ash}{Ca + P}$
Means ..	·519	2·516	·501	2·070	·480	1·959	·464	1·860	·450	1·863

It is apparent that there is a progressive decrease in P/Ca and Ash/Ca + P with increasing ash content. The explanation is that meat-and-bone meals of low ash content have proportionately greater amounts of soft tissues relatively higher in phosphorus. Thus either the ash, calcium or phosphorus level of meat-and-bone meals could be considered as providing some indication of quality particularly when interpreted in relation to crude protein and fat. Grau and Carroll (1958), in a review of chemical and biological methods of evaluating protein quality, concluded that no single figure can be devised to represent the value of a protein because proteins are not entities but a collection of various amino acids combined in various ways and present in various combinations. Naturally, any extreme processing procedure imposed on these products or the inclusion of considerable amounts of keratinaceous tissue would invalidate conclusions based solely on chemical analyses.

VI. ACKNOWLEDGMENTS

REFERENCES

ALMQUIST, H. J. (1957).—"Proteins and Amino Acids in Animal Nutrition." 4th Ed. (National Distillers and Chemical Corporation: Modesto, Calif.).

ANON. (1957).—"Feed Formulator." (Chas. Pfizer & Co. Inc.: New York).

ANON. (1957–1962a).—Principal factory products of Australia. *Commonw. Bur. Cens. Stat., Aust.*

ANON. (1957–1962b).—Secondary industries bulletin. *Commonw. Bur. Cens. Stat., Aust.*

ANON. (1958a).—Rep. Aust. Meat Bd 1957-58.

ANON. (1958b).—Rep. Dep. Agric. Qd 1957-58:92–6.

ANON. (1959).—Rep. Dep. Agric. Qd 1958-59:70.

ANON. (1960).—Rep. Dep. Agric. Qd 1959-60:84.

ANON. (1963).—Rep. Aust. Meat Bd 1962-63.

ANWAR, A. (1960).—A new method for calculating the gross value of proteins. *Poult. Sci.* 39:1406–8.

ANWAR, A. (1962).—Estimation of Gross Protein Value. 1. In proteins of animal origin. *Poult. Sci.* 41:937–8.

ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS (1955).—"Methods of Analysis of the Association of Official Agricultural Chemists." 8th Ed. (Association of Official Agricultural Chemists: Washington).

BOYNE, A. W., CARPENTER, K. J., and WOODHAM, A. A. (1961).—Progress report on an assessment of laboratory procedures suggested as indicators of protein quality in feeding stuffs. *J. Sci. Food Agric.* 12:832–48.

BRUNO, DOROTHY, and CARPENTER, K. J. (1957).—A modified procedure for the estimation of "available lysine" in food proteins. *Biochem. J.* 67:13P.

BUNYAN, J., and PRICE, S. A. (1960).—Studies on protein concentrates for animal feeding. *J. Sci. Food Agric.* 11:25–37.

BUTTERWORTH, M. H. (1962).—Evaluation of cereal protein quality for chicks by three different biological techniques. *J. Sci. Food Agric.* 13:6–15.

CARPENTER, K. J. (1958a).—Chemical methods of evaluating protein quality. *Proc. Nutr. Soc.* 17:91–100.

CARPENTER, K. J. (1958b).—Straight-acid procedure for determination of 'available lysine' in foods. Private Communication.

CARPENTER, K. J. (1960).—The estimation of the available lysine in animal-protein foods. *Biochem. J.* 77:604–10.

CARPENTER, K. J., and ELLINGER, GABRIELLE M. (1955a).—The estimation of 'available lysine' in protein concentrates. *Biochem. J.* 61:xi.

CARPENTER, K. J., and ELLINGER, GABRIELLE M. (1955b).—Protein quality and 'available lysine' in animal products. *Poult. Sci.* 34:1451–2.

CARPENTER, K. J., ELLINGER, GABRIELLE M., and SHRIMPTON, D. H. (1955).—The evaluation of whaling by-products as feeding-stuffs. *J. Sci. Food Agric.* 6:296–304.

CARPENTER, K. J., ELLINGER, GABRIELLE M., MUNRO, MARGARET I., and ROLFE, E. J. (1957).—Fish products as protein supplements to cereals. *Brit. J. Nutr.* 11:162–73.

DUCKWORTH, J., WOODHAM, A. A., and McDONALD, T. (1961).—The assessment of nutritive value in protein concentrates by the gross protein value method. *J. Sci. Food Agric.* 12:407–17.

EASTOE, J. E. (1956).—The amino acid composition of mammalian collagen and gelatine. *Biochem. J.* 61:589–600.

EASTOE, J. E., and EASTOE, B. (1954).—The organic constituents of mammalian compact bone. *Biochem. J.* 57:453-9.

EASTOE, J. E., and LONG, JOAN E. (1960).—The amino acid composition of processed bones and meat. *J. Sci. Food Agric.* 11:87–92.

GRAU, C. R., and CARROLL, R. W. (1958).—Evaluation of protein quality. *In* "Processed Plant Protein Feedstuffs". (Academic Press: New York).

HARRIS, R. S., and BURESS, D. A. (1959).—Effect of level of protein feeding upon nutritional value of lysine-fortified bread flour. *J. Nutr.* 67:549–67.

HEIMAN, V., CARVER, J. S., and COOK, J. W. (1939).—A method for determining the gross value of protein concentrates. *Poult. Sci.* 18:464–74.

LYMAN, C. M., KUIKEN, K. A., and HALE, F. (1957).—Essential amino acid content of farm feeds. *J. Agric. Food Chem.* 4:1008–13.

MARKLEY, K. F., and HANN, R. M. (1925).—A comparative study of the Gunning-Arnold and Winkler boric acid modification of the Kjeldahl method for the determination of nitrogen. *J. Assoc. Off. Agric. Chem.* 8:455–67.

MCARDLE, A. A., JONES, M. D., and LOWE, A. G. (1960).—A griller trial using two grades of meatmeal. *J. Dep. Agric. S. Aust.* 63:502–4.

MCDONALD, M. W., and BEILHARZ, R. G. (1959).—The toxic factors in low quality meatmeals. Proc. Poult. Sci. Conv., Univ. of Sydney, 1959:51–6.

MORRISON, F. B. (1959).—"Feeds and Feeding." (Morrison Publishing Co.: Clinton, Iowa).

MORRISON, J. W. C. (1959).—The gross protein value of Australian meat meals. *J. Aust. Inst. Agric. Sci.* 25:63-4.

NATIONAL RESEARCH COUNCIL (1954).—Nutrient requirements for domestic animals. I. Nutrient requirements for poultry.

ROBERTSON, E. I., CARVER, J. S., and COOK, J. W. (1940).—Gross value of protein supplements for poultry. Bull. Wash. Agric. Exp. Sta., Pullman, No. 388.

SATHE, B. S., CUMMING, R. B., and MCCLYMONT, G. L. (1964).—Nutritional evaluation of meat meals for poultry. 1. Variation in quality and its association with chemical composition and ash and lipid factors. *Aust. J. Agric. Res.* 15:200–13.

SUMMERS, J. D., SLINGER, S. J., SIBBALD, I. R., and PEPPER, W. F. (1964).—Influence of protein and energy on growth and protein utilization in the growing chicken. *J. Nutr.* 82:463–8.

TITUS, H. W. (1961).—"The Scientific Feeding of Chickens." 4th Ed. (Interstate Press: Danville, Ill.).

UNDERWOOD, E. J., CONOCHIE, J., REED, F. M., and SMYTH, R. (1950).—The value of meatmeal and livermeal as sources of protein. *Aust. Vet. J.* 26:323–9.

WATERHOUSE, H. N., and SCOTT, H. M. (1962).—Supplemental value of fish meal protein in relation to other sources of protein in the test diet. *Poult. Sci.* 41:1936–9.