THE NUTRITIVE VALUE OF THE FIELD BEAN (*Vicia faba* L.) FOR POULTRY.

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To Judith

Summary

The content of proximate principles and amino acids in spring and winter field beans (*Vicia faba* L.) was estimated. The value of the field bean in diets for chicks, ducklings, poults and rearing pullets was established in large-scale experiments. The effect of autoclaving or additional methionine on growth and protein digestibility was established with chicks and colostomised hens, respectively. The field bean was assayed for its trypsin inhibitor activity (TIA) and an isolate high in TIA was obtained which was subsequently included in a chick diet.

Author's note

The studies on the field bean presented in this thesis have covered a number of aspects. To present the material in a co-ordinated form, and hence make it more lucid to the reader, the references to the literature on each aspect are given in the introduction to the appropriate section. Only the literature relevant to all aspects of the subject is presented in the introduction to the thesis.

Because much of the evidence presented in this study has been obtained in extensive field trials it was considered impracticable to include data from individual birds. Instead, this data will be lodged independently and may be obtained on application to

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1. INTRODUCTION

1.1 THE FIELD BEAN

The field bean (Vicia faba Linnaeus), known in the United Kingdom by the common names horse bean, field bean, broad bean, Windsor bean or fava bean, is a member of the family Leguminosae. The members of this family have the particular ability to participate in a symbiotic relationship with Rhizobium bacteria which can oxidise atmospheric nitrogen. This access to supplies of newly-fixed nitrogen is probably a major factor in the success of the Leguminosae and in their world-wide distribution.

Legumes were among the earliest crops cultivated by man. They have been used as human and animal food for about 8000 years (Aykroyd and Doughty, 1964). Archaeological evidence indicates that the field bean (Vicia faba L.) appeared in North Africa during the third to second millenium B.C. and later spread north over Europe, reaching Britain in the first millenium B.C. (Helbaeck, 1959).

Within the Leguminosae the section of agricultural importance is the Papilionoideae or 'pea family', which is classified into ten botanical sub-groups. Of these, six (Loteae, Galegeae, Podalyrieae, Genisteae, Sophoreae and Dalbergeae) are of little agricultural importance. The agricultural value of the four important groups is summarised in Table 1.1 .

All botanical varieties of field bean can be grown in Britain. Those suitable for spring sowing can be divided into three sub-groups on the basis of seed weight. The large-seeded forms (Vicia faba major) have a thousand-seed-weight greater than 840g and are usually used for human consumption. The medium-seeded horse bean forms

Table 1.1

Agricultural use of four groups of the Papilionoideae (Hutchinson, 1970)

Group	Forage	Pulses and Legumes
Vicieae	Twining or sprawling herbs. Annual tares and vetches.	Lens (lentil), Pisum (pea), Cicer (chick pea), Vicia faba (FIELD BEAN).
Hedysareae	Perennial herbs. Onobrychis (sainfoin).	Sprawling or bushy annual herbs. Arachis (groundnut).
Trifolieae	Upright perennial herbs. Trifolium (clover) Medicago (lucerne)	
Phaseoleae	World-wide	Twining or bushy annual herbs. Glycine (soyabean), Lablab, Phaseolus, Vigna (cowpea), Cajanus (pigeon pea).

(*Vicia faba equina*) and the small-seeded tick (or tic) bean forms (*Vicia faba minor*) are both used for animal feeding and have thousand-seed-weights of 560 to 840g and 280 to 560g, respectively. Those suitable for winter sowing are usually of the horse bean type. Some examples of the different types are given in Table 1.2 .

In this study two varieties, Throws M.S. and Minor, were used. The former is a synthetic variety composed of a small number of lines raised separately and combined before marketing to exploit the benefits of hybrid vigour. It is intended for winter sowing. The latter variety originated at the Belgian Plant Breeding Station, Gembloux and is intended for spring sowing.

Supplies of both varieties were obtained from the National Agricultural Advisory Service (now Agricultural Development and Advisory Service) Experimental Husbandry Farm at Boxworth.

Table 1.2

Examples of the three main varieties of *Vicia faba*

	Large seed (*V.faba major*)	Medium seed (*V.faba equina*)	Small seed (*V.faba minor*)
Winter sowing	Aquadulce	Throws M.S. Maris Beaver Daffa	Cote d'Or
Spring sowing	Longpod	Strubes Suffolk red	Maris Bead Minor Blue rock Franck's Ackerperle Herz Freya
Human food	Triple White (U.K.) Weir* (Holland)	Baladi (Sudan) Throws M.S. (U.K.)	Local types (India) Minor Maris Bead (U.K.)

* not now available commercially.

1.2 THE FIELD BEAN AS A CROP IN BRITAIN

The acreage of land under field beans has altered considerably in recent years. For several centuries the bean was an integral part of east coast arable rotations. As one of its common names indicates the bean was fed to horses. It was also included in rations for pigs and cattle, and in the latter case usually replaced equal amounts of oats and linseed cake (Orwin and Whetham, 1964).

When records of national crop acreages were first taken in the middle of the nineteenth century there were approximately half a million acres under beans in England and Wales. With the exception of war-time, however, this acreage declined steadily until 1964 when about 67 thousand acres were grown (M.A.F.F., 1970). In Scotland the bean acreage fell from 118 thousand acres in 1814 to 6 thousand in 1951 (Rodger, 1954).

This loss in importance of the bean crop was even more marked in the rest of north-west Europe (Greenwood, 1958) (Table 1.3). This decline can be attributed to a fall in the horse population, the high incidence of disease and crop failure associated in the past with the field bean and the relative ease with which imported proteins could be bought.

Since 1964 the acreage of beans in the United Kingdom has increased annually until in 1969 over 300 thousand acres were grown (M.A.F.F., 1970). Production of beans has risen even more rapidly due to improved yield per acre (N.E.D.O., 1968) (Table 1.4). Some of the increase in acreage is due to the value of the field bean as a break crop in intensive cereal farming systems. At

Table 1.3

Field beans in north-west Europe (1958)

Country	Acreage	Acres beans per 1000 acres arable
England + Wales	120,000	8.6
U.K.	123,000	6.8
Holland	3,500	1.4
W. Germany	45,000	2.1
Belgium	7,500	3.0
France	67,000	1.3

Table 1.4

Acreage and production of beans for stockfeed in the U.K.

('000 acres and '000 tons)

	1956/57 to 1958/59	1961/62 to 1963/64	1964/65 to 1966/67	1967/68
Acres	95	65	85	144
Production	81	67	96	170

the same time new varieties, weed-killers and insecticides were available to make husbandry easier. The crop was made more attractive economically by the introduction of a Government acreage subsidy for an experimental period beginning in 1968 and by the provision of merchant contracts. The crop also had the two advantages of using the same field and drying equipment as cereals and of requiring little labour.

Since British compounders were not very interested in small lots of beans, variable in moisture content due to ineffective drying, it was expected that initially the increase in acreage after 1964 would reduce the price of beans. However a strong demand for beans, particularly in Holland and Germany, and continental price levels in general combined to raise the price to a level uneconomic relative to other sources of starch and protein available in Britain (Smith, 1968). The markets supplied by the 1967 harvest are shown in Table 1.5 .

Following a disastrous harvest in 1968 (and the removal of the Government subsidy in 1971), the rise in bean acreage now falls far short of 1967 forecasts. Nevertheless a decline in the export potential to the Continent and the stable level of the pigeon trade outlet have combined to increase greatly the quantities of beans available to the U.K. compounding industry. These could be used to replace imported foodstuffs. In the year ending 31 December 1970 six hundred thousand tons of soybean meal and 386 thousand tons of fish meal were imported into the U.K. (Anon, 1971). Much of

Table 1.5

Disposal of the 1967 field bean harvest

	Tons
Export to Europe (mainly Holland and Germany)	80,000
Seed and pigeon trade	40,000
Animal feed	50,000
Total	170,000

this expenditure, particularly on soyabeans, is incurred outside the Sterling Area. It is estimated that by 1972/3 300 thousand tons of beans could be available to the compounding industry. This tonnage represents a potential import saving of £12½ millions per year. (N.E.C.O., 1968)

Much effort is being devoted to research in the use of the field bean in animal feeding and with the production of high-yielding hybrid seed (Bond, 1968) and the introduction of a scheme for certified seed production in 1969 (N.I.A.B., 1969) the field bean can play an important role in the United Kingdom in saving foreign exchange.

2. COMPOSITION OF THE BEAN

2.1 INTRODUCTION

It is essential to the formulation of nutritionally adequate diets that accurate analyses of constituent foodstuffs be available. A number of publications give the proportions of proximate principles and more detailed composition of samples of field beans such as their amino acid contents. These data are listed in Appendices 13.4 and 13.5 .

There is a considerable variation in the values given by these sources for any parameter. This variation can be attributed to variety, country of origin, sowing date, climate and analytical technique.

Early analyses of samples of the field bean reported in the literature do not give details of variety or source and it is likely that they do not relate to varieties currently grown in this country. More recent investigations examined the differences between varieties of beans suitable for spring or winter sowing in the U.K. Although all of the available evidence on nutrient composition is included in this section the most recent reports will most accurately reflect the composition of field beans in current supply.

The beans used in this study were samples of Minor (spring) and Throws M.S. (winter) beans. These varieties were chosen as they represented approximately 75 per cent of the acreage of spring and winter types, respectively, when this study began. Analyses of these two samples are reported where available.

2.2 Review of reports on the composition of the field bean

Proximate principles

Eden (1968), in a survey of 104 samples of spring and 28 of winter beans from crops grown in Cambridgeshire and the Isle of Ely in 1966 and 1967, concluded that the main variations existed in crude protein and crude fibre contents, and reported mean protein contents of 31.4 and 26.5 per cent and mean fibre contents of 8.0 and 9.0 per cent for spring and winter beans, respectively, on the dry matter basis. On the same basis Clarke (1970) quoted mean values of 34.1 and 26.7 per cent protein and 8.4 and 9.0 per cent fibre in samples of spring and winter beans.

These values for protein content, the mean of values from other published sources (Appendix 13.4) and those of the beans used in this study are set out in Table 2.1 . Spring beans have a mean protein content approximately 4% higher than winter beans according to all sources quoted in Table 2.1, although there is some overlap between different samples within the two types. The samples of Minor spring beans and Throws M.S. winter beans used in this study both had protein contents which were below average.

These protein levels demonstrate that the field bean has one of the highest protein contents available in a U.K. field crop.

Bond and Toynbee-Clarke (1968) have shown that the difference in protein content between spring and winter beans is of genetic origin. In two trials conducted by them both winter and spring varieties were planted in spring and harvested at the same time.

Table 2.1

Comparison on the dry matter basis of the protein contents of the field beans used in this study with mean values quoted by Eden (1968), Clarke (1970) and with those calculated from other sources.

	Crude Protein (%) (N x 6.25)	S.E.	Range
Spring-sown			
Eden (1968)	31.4	0.20	25.5 - 35.4
Clarke (1970)	34.1	-	27.9 - 36.6
All sources	30.5	1.43	27.7 - 34.1
Minor (from this study)	28.9	-	-
Winter-sown			
Eden (1968)	26.5	0.28	24.3 - 29.9
Clarke (1970)	26.7	-	24.1 - 28.6
All sources	27.0	1.17	26.0 - 28.7
Throws M.S. (from this study)	24.9	-	-

The difference in protein content between the two types was still maintained.

The crude fibre, ether extract, nitrogen-free extract and ash contents of spring and winter field beans, respectively, are set out in Tables 2.2 and 2.3 .

Spring and winter beans do not differ greatly in ash or in ether extract content and the reduced protein content of winter beans is compensated by increases in crude fibre and nitrogen-free extract. The crude fibre content of winter beans is approximately 1 per cent higher than that of spring beans and this was attributed to the thicker testa of the former by Clarke (1970).

Removal of the testa results in an increase in food value of the field bean. A crude fractionation can be achieved by passing beans through a hammer mill without a screen in place. The effect of fractionation on proximate analysis is shown in Table 2.4 which contains data from Clarke (1970) and also from this laboratory where fractionation was carried out by hand. In order to reproduce the type of material that might be produced by mechanical fractionation no attempt was made to remove any residual pieces of kernel (cotyledon) adhering to the pieces of hull (testa). Most of the protein found in the hull fraction probably results from this residue. Agreement between the two sources is very good and both authors indicate an increase of over 3.5 per cent in crude protein content and an increase of approximately 0.2 per cent in crude oil. This latter improvement and the reduction in crude

Table 2.2

Comparison on the dry-matter basis of the crude fibre, ether extract, nitrogen-free extract and ash contents of Minor spring beans used in this study with data from other sources.

	%	S.E.	Range
<u>Crude fibre</u>			
Eden (1968)	8.0	0.18	6.0 - 10.6
Clarke (1970)	8.4	-	6.2 - 11.0
Other	7.5	0.84	6.8 - 8.0
Minor	8.4	-	-
<u>Ether extract</u>			
Eden (1968)	1.5	-	1.2 - 2.0
Clarke (1970)	1.6	-	-
Other	1.40	0.19	1.03 - 1.67
Minor	1.45	-	-
<u>Nitrogen-free extract</u>			
Eden (1968)	55.2	-	49.9 - 59.4
Clarke (1970)	-	-	-
Other	57.2	-	55.2 - 58.4
Minor	59.8	-	-
<u>Ash</u>			
Eden (1968)	4.0	-	3.1 - 4.8
Clarke (1970)	-	-	-
Other	3.68	0.33	3.29 - 4.46
Minor	3.47	-	-

Table 2.3

Comparison on the dry-matter basis of crude fibre, ether extract, nitrogen-free extract and ash contents of Throws M.S. winter beans used in this study with data from other sources.

	%	S.E.	Range
Crude fibre			
Eden (1968)	9.0	0.24	7.5 - 10.6
Clarke (1970)	9.0	-	7.4 - 10.9
Other	-	-	-
Throws M.S.	9.2	-	-
Ether extract			
Eden (1968)	1.5	-	1.3 - 1.7
Clarke (1970)	1.6	-	-
Other	1.40	0.14	1.21 - 1.56
Throws M.S.	1.44	-	-
Nitrogen-free extract			
Eden (1968)	59.0	-	55.5 - 59.8
Clarke (1970)	-	-	-
Other	61.5	-	59.0 - 62.0
Throws M.S.	61.1	-	-
Ash			
Eden (1968)	4.0	-	3.4 - 4.4
Clarke (1970)	-	-	-
Other	3.74	0.27	3.39 - 4.00
Throws M.S.	3.42	-	-

Table 2.4

Analyses of fractionated winter beans (Throws M.S.).

(per cent of dry matter)

	Testa	Cotyledon	Whole bean (by calculation)
Clarke (1970)			
Crude oil	0.35	1.49	1.36
Crude protein	4.71	31.20	27.47
Crude fibre	54.10	1.65	9.14
Weight	14.3	85.7	100.0
Wilson (1971)			
Crude oil	0.24	1.49	1.29
Crude protein	9.20	31.70	28.10
Total ash	3.08	3.70	3.60
Calcium	0.28	0.06	0.10
Phosphorus	0.02	0.62	0.52
Weight	16.0	84.0	100.0

fibre content resulted in an increase in metabolisable energy (M.E.) content from 3029 kcal/kg in the whole bean to 3416 kcal/kg in the separated kernel (Clarke, 1970). These changes would be important in the preparation of pig and poultry diets and particularly in the formulation of diets for meat-type birds where energy requirements are such that use of high levels of beans requires a supplemental energy source such as maize oil.

Energy

The metabolisable energy (M.E.) content of field beans has been reported by few workers although its accurate determination is essential if the bean is to be valued correctly, since Carpenter and Johnson (1968) have estimated that a difference in M.E. value of 300 kcal/lb will affect the value of the bean in least-cost poultry diets by £3 per ton.

Bolton (1963) listed a value of 1896 kcal/kg whereas Bolton (1967) gave 3086 kcal/kg. Titus (1955) listed values of 1345 and 1411 kcal/kg for navy and pinto beans, respectively. Carpenter and Johnson (1968) determined the M.E. content of Minors (spring), Strube (spring) and Throws M.S. (winter) field beans using 3 to 5 week old chicks and obtained values of 2680, 2800 and 2520 kcal/kg, respectively. Waring (1969), using adult colostomised hens, obtained an M.E. value of 2960 kcal/kg for Garton's Tick bean. In subsequent work Waring and Shannon (1969) estimated the M.E. contents of Minor (spring) and Throws M.S. (winter) beans,respectively, to be 2470 and

2390 kcal/kg when corrected to 90 per cent dry matter. Clarke (1970) reported a value of 3029 kcal/kg for winter beans.

The values quoted by Titus (1955) refer to varieties of Phaseolus vulgaris known to contain digestive inhibitors and his values are low. More recent estimates refer to samples of field beans (Vicia faba) alone and more correctly reflect both the improvement that has taken place in this species in recent years and the current M.E. content of samples of this crop. For this reason the values estimated by Waring and Shannon (1969) for Minor and Throws M.S. have been used in diet formulation for this study.

Amino acids

In evaluating the field bean as a constituent in poultry diets it is important to estimate not only the protein content of the bean but also its amino acid pattern, for two reasons. Firstly the bean is a protein source and will need to make a substantial contribution to the amino acid requirements of the bird. Secondly poultry diets are tailored as closely as possible to the needs of the bird not only for economy but also because of the dangers of both over- and under-supply of amino acids.

The amino acid analyses of the field bean from the literature and those estimated by the author during this investigation are listed in Appendix 13.5 . The means of these analyses are given in Table 2.5 . Analytical techniques used to gather these data included microbiological assay as well as paper and column

Table 2.5

Amino acid contents of field beans (per cent)

(Mean of analyses in Appendix 13.5)

Amino acid	per cent	S.E.
Arginine	2.30	0.52
Glycine	1.10	0.11
Histidine	0.76	0.09
Leucine	1.98	0.36
Isoleucine	1.15	0.27
Lysine	1.67	0.24
Cystine	0.19	0.08
Methionine	0.14	0.05
Phenylalanine	1.17	0.18
Tyrosine	1.02	0.15
Threonine	1.04	0.13
Tryptophan	0.26	0.06
Valine	1.23	0.19
Alanine	1.15	0.12
Aspartic acid	2.79	0.29
Glutamic acid	4.78	0.57
Proline	1.21	0.16
Serine	1.29	0.15

chromatography and the analyses quoted cover a period of years and hence relate to different varieties. However, there is a constant amino acid pattern if not consistency in the estimates quoted for each amino acid. Apart from Jeroch and Hennig (1964), who quote a remarkable value of 0.76 per cent for the methionine content of one sample of beans, all authors report low levels of sulphur-containing amino acids. The mean level of methionine + cystine is 0.33 per cent of which cystine represents 0.19 per cent. The high standard errors associated with these values presumably reflect the difficulties involved in estimation of methionine and cystine without losses on hydrolysis. Thus not only is the field bean a very poor source of sulphur-containing amino acids but the actual content is difficult to estimate. This deficiency is particularly critical in the formulation of poultry diets since methionine and cystine are usually the first-limiting amino acids for poultry. To minimise the risk of methionine deficiency during diet formulation for this study the below-average methionine + cystine contents of 0.27 and 0.25 per cent were assumed for spring and winter beans, respectively. For contents of other amino acids except tryptophan the data of Waring and Shannon (1969) have been used. The tryptophan contents of the spring and winter beans used in this study were estimated to be 0.25 and 0.20 per cent respectively (McNab, 1970). The amino acid contents assumed in diet formulation during this study are contained in Table 2.6 .

Table 2.6

Amino acid contents of spring and winter beans used in diet formulation for this study (per cent).

Amino acid	Minor (spring)	Throws M.S. (winter)
Arginine	2.32	1.76
Glycine	1.15	1.00
Histidine	0.59	0.51
Leucine	1.99	1.66
Isoleucine	1.07	0.89
Lysine	1.62	1.41
Cystine	0.14	0.10
Methionine	0.13	0.15
Phenylalanine	1.16	0.92
Tyrosine	0.96	0.82
Threonine	1.02	0.87
Tryptophan	0.25	0.20
Valine	1.22	1.03

Fats

Although the fat content of field beans is low the fatty acid composition of the bean is of some interest in the formulation of poultry diets due to its high proportion of linoleic acid. Whitehead (1971) has estimated the fatty acid composition of the field beans used in this study and these estimates are compared in Table 2.7 with data published by Hilditch (1956) and Clarke (1970). In Table 2.8 the mean of the spring and winter bean data established by Whitehead (1971) is compared with data for other beans (Korytnyk and Metzler, 1963). The estimates of fatty acid composition of winter beans reported by Whitehead (1971) agree closely with those of Clarke (1970) who is probably also describing the variety Throws M.S. but differ from the patterns found earlier in Canadian and Indian samples of <u>Vicia faba</u> by Hilditch (1956). It is likely that the data of Clarke (1970) and Whitehead (1971) accurately describe the fatty acid pattern to be found in samples of field beans currently grown in the U.K. Because of the relatively high proportion of linoleic acid the use of field beans may be attractive in diets for laying birds because of the influence of linoleic acid on egg size. From the data presented in Tables 2.8 and 2.9 it can be seen that different species of bean vary greatly in their fatty acid composition but at least one other (Lima) has a proportion of linoleic acid similar to that in field beans and most have a slightly higher lipid content (Korytnyk and Metzler, 1963).

Table 2.7

Fatty acid composition of field beans

(per cent of total fatty acids)

	Author				
	Hilditch (1956)		Whitehead (1971)		Clarke (1970)
Fatty acid	Canada	India	Spring	Winter	Winter
Palmitic (C 16:0)	-	2.0	16.2	13.6	13.1
Stearic (C 18:0)	-	8.2	2.3	2.4	2.5
Oleic (C 18:1)	57.5	45.9	28.1	23.0	20.5
Linoleic (C 18:2)	35.0	30.0	50.0	56.8	54.8
Linolenic (C 18:3)	-	12.7	3.3	4.2	5.8
Other	-	1.2	0.1	-	3.5
Unspecified	7.5	-	-	-	-

Table 2.8

Comparison of fatty acid composition of beans used in this study (Whitehead, 1971) with that of other beans (Korytnyk and Metzler, 1963).

(per cent of total fatty acids)

	Whitehead (1971)	Korytnyk and Metzler (1963)				
		Lima	Blackeye	Pinto	Kidney	Californian
Palmitic	14.9	22.4	32.5	14.7	13.4	12.2
Stearic	2.4	3.3	4.6	1.0	0.74	0.61
Oleic	25.5	8.0	7.2	7.0	8.3	9.7
Linoleic	53.4	43.6	31.2	28.1	26.9	23.2
Linolenic	3.8	21.9	22.0	49.2	50.6	54.3
Other	0.0	1.2	2.5	0.0	0.1	0.0

Table 2.9

Lipid content of field beans and certain other beans (per cent).

Bean	Total lipid
Lima (1958 crop)	1.10*
Lima (1959 crop)	0.95*
Blackeye	1.50*
Pinto	1.85*
Kidney	1.90*
Californian small white	1.70*
Field bean	1.29**

* Korytnyk and Metzler (1963)

** Whitehead (1971)

Minerals and vitamins

Data on the mineral and vitamin contents of field beans are not widely reported. Values reported by Bolton (1967), Eden (1968), Aitken and Hankin (1970) and Clarke (1970) for the mineral and vitamin contents of field beans are contained in Tables 2.10 and 2.11 respectively. Field beans are low in manganese, sodium and chlorine. There is little difference obvious between spring and winter beans in mineral or vitamin contents on the limited evidence available.

Conclusions

Field beans represent a valuable source of home-grown protein although the balance of amino acids is such that methionine supplementation is generally required in poultry diets containing beans. The energy content of beans is higher than originally reported and although the fat content is not high the proportion of linoleic acid is attractive from the point of view of egg size.

Table 2.10

Mineral composition of field bean (dry matter basis)

	Eden (1968)		Clarke (1970)	Bolton (1967)
	Spring	Winter		
Calcium (%)	0.16	0.19	-	0.13
Phosphorus (%)	0.66	0.68	-	0.60
Chlorine (%)	Trace	Trace	-	0.03
Magnesium (%)	0.13	0.13	-	-
Potassium (%)	1.17	1.22	-	-
Sodium (%)	0.01	0.02	-	-
Manganese (ppm)	14	14	-	16
Iron (ppm)	-	-	64	-
Cobalt (ppm)	-	-	0.01	-
Zinc (ppm)	-	-	54	30

Table 2.11

Vitamin composition of field bean (dry matter basis)

	Bolton (1967)	Clarke (1970)	Aitken and Hankin (1970)
α-Tocopherol (mg/100g)	0.10	-	-
Choline (mg/g)	1.11	-	-
Riboflavine (ppm)	3.1	-	3.2
Nicotinic acid (ppm)	29.0	11.9	29.4
Pantothenic acid (ppm)	-	11.7	-
Thiamine (ppm)	-	15.0	3.7

GROWTH ON BEAN DIETS

3. BROILERS

Broiler experiments 2, 3 and 4 have been published.
The references are given below:-

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of broilers.
Br. Poult. Sci., 13: (In the press).

3.1 Introduction

Nikolaiczuk et al. (1948) and Brisson et al. (1950) observed that chicks fed from 1 to 6 weeks of age on a diet containing 35 per cent field bean meal and 18.5 to 19.0 per cent crude protein exhibited poor growth, poor feathering and poor feather pigmentation. Performance in all of these respects was improved by supplementation of the basal bean diet with other protein sources. Greatest benefit was provided by fish meal, fish solubles or a mixture of methionine and choline supplying 25 and 100 per cent, respectively, of the chick's requirement.

Bletner et al. (1963) obtained satisfactory growth with chicks fed diets which contained up to 60 per cent horse beans provided they were supplemented with 5 per cent fish meal and with fat, methionine and choline.

Blair and Bolton (1968) fed broilers from 4 to 9 weeks of age on pelleted diets containing 0, 10, 20 or 30 per cent Minor tic (spring) or Throws (winter) beans supplemented so that calculated lysine and methionine levels exceeded the requirements suggested by the Agricultural Research Council (1963). No significant effects of treatment on live-weight gain, food intake or food conversion ratio were observed. None of the diets contained supplemental fat or choline. Although the form of the diets used by Nikolaiczuk et al. (1948) and Brisson et al. (1950) is not given the diets used by Bletner et al. (1963) were all fed as mash. It is possible that some of the satisfactory performance reported by

Blair and Bolton (1968) may be attributed to pelleting of the experimental diets. Allred et al.(1957) obtained a highly significant response in growth to pelleting. The physical form of the diet did not completely explain the pelleting effect since regrinding to a particle size similar to that in mash did not reduce weight gain compared with pelleting.

Bolton (1960) found that pelleting with live steam at 60 lb/in^2 ($145^{\circ}C$) for 5 minutes did not alter chemical composition or digestibility of protein, oil or carbohydrate.

Carew and Nesheim (1962) showed that steam pelleting did not improve weight gain of chicks given diets containing soyabean meal. However, in a subsequent experiment when no other heat treatment had been applied to the soyabeans before pelleting, small increases in growth rate, feed conversion efficiency and fat absorbability were obtained when diets were pelleted and the pellets were reground before feeding.

Both Hussar and Robblee (1962) and Bayley et al. (1968) identified the important sources of variation in pelleting procedures: the choice of pelleting machine, the length of time over which the machine has been operating continuously before the sample is pelleted, the nature of the material pelleted and its previous heat treatment.

A field trial was designed in order to extend the observations of Blair and Bolton (1968) on the nutritive value for broilers of samples of field beans recently grown in the U.K. and also to evaluate the effects of dry pelleting a diet containing field beans. Waring and Shannon (1969) reported that the crude protein digestibility of field beans was 80 per cent while that of soyabeans was 90 per cent. In this trial the protein digestibility of field beans was assumed to be 80 per cent in two of the diets containing field beans and 100 per cent in the other two. This trial is described in sections 3.2 and 3.3 .

3.2 Broiler experiment 1.

Plan Treatments were allocated randomly to 30 pens located in two blocks of 15 pens on each side of a central aisle. The treatments were imposed in a 2 x 5 x 3 factorial design in which the factors were blocks, bean level and form of diet, respectively. Birds were allocated randomly to treatments so that there were approximately 32 birds per pen. The layout of treatments is contained in Appendix 13.6, Table 1 .

Management of birds 960 Ross II broiler chicks were wing-banded and weighed at one day of age. They were housed under infra-red brooding lamps on wood shavings. Air and brooder temperatures followed the recommendations of the breeder; about 27 and 34°C, respectively, at one day of age, reducing to 21°C for each after 3½ weeks. After 10 days the brooder surrounds were removed and thereafter the chicks were allowed 0.08 m^2 of floor space per bird. The birds were reweighed individually at 4 and 8 weeks of age.

Object The object of the experiment was to establish the nutritive value of field beans when present in broiler diets at levels up to 45 per cent.

Diets The compositions of the diets in parts by weight are set out in Table 3.1 . Calculated analyses are set out in Appendix 13.2, Tables 1-5 . Diets 1A to 1C contained a 50:50 mixture of spring and winter beans at 0, 30 and 45 per cent levels of inclusion, respectively. Diets 1D and 1E also contained the bean mixture at 30 and 45 per cent levels of inclusion but they contained higher levels of the other protein supplements to allow for an assumed 80 per cent digestibility of the bean protein. The beans were ground to pass a 3 mm screen and the other ingredients were ground in the normal manner. Pellets were 3 mm in diameter and were formed by a Templewood-Hawksley dry-pelleting machine.

Results The results of treatment on live-weight at 4 and 8 weeks of age are summarised in Tables 3.2 and 3.3 . The analyses of variance of between-pen differences is set out in Appendix 13.3 . Birds given diet 1A containing no field beans were significantly heavier ($P < 0.001$) at 4 weeks than those given diet 1D containing 30 per cent beans with an assumed protein digestibility of 80 per cent, and significantly lighter ($P < 0.001$) than birds on all other diets. Birds given pelleted diets were significantly heavier ($P < 0.01$) than those fed on mash or reground pellets.

Because of the anomalous nature of the data on live-weight at 4 weeks obtained from birds given diet 1D no other data from this experiment were analysed and a further trial was conducted.

Table 3.1

Broiler experiment 1 starter diets.

Composition (parts by weight)	1A	1B	1C	1D	1E
Bean meal	-	30.0	45.0	30.0**	45.0**
Maize	33.8	43.5	31.5	40.0	25.7
Wheat	29.5	-	-	-	-
Soyabean meal	6.0	-	-	-	-
Groundnut meal	22.0	16.5	11.0	19.8	16.9
Herring meal	5.0	5.0	5.0	5.3	5.0
Tallow (50:50 maize oil:beef dripping)	-	1.52	3.87	1.43	3.86
$CaCO_3$	0.69	0.50	0.47	0.47	0.45
$CaHPO_4$	2.35	2.35	2.35	2.35	2.35
Methionine	-	0.18	0.25	0.16	0.23
Salt	0.25	0.25	0.25	0.25	0.25
Supplement*	+	+	+	+	+
Crude protein (%) (N x 6.25)	22.0	22.0	22.0	23.3	23.9

* Standard P.R.C. vitamin/trace mineral mixture for broilers as detailed in Appendix 13.7 .

** Only 80% digestibility of bean protein assumed.

Table 3.2

Live-weight at 4 weeks (g) of broiler chicks given diets 1A to 1E of broiler experiment 1 in the form of mash, pellets or reground pellets.

	Diet					
	1A	1B	1C	1D	1E	Mean
Form of diet						
Mash	457.1	576.6	596.5	336.1	629.5	519.2
Pellets	524.3	706.1	710.8	381.7	677.8	600.1
Reground pellets	478.9	592.2	533.5	289.8	598.4	498.6
	486.8	625.0	613.6	335.9	635.2	

Table 3.3

8 week weights (g) of broilers given diets 1A to 1E of broiler experiment 1 up to 4 weeks and diet 1F from 4 to 8 weeks of age.

	Previous diet				
	1A	1B	1C	1D	1E
Form					
Mash	1904	2102	2015	1803	2051
Pellet	1966	2086	2131	1912	2061
Reground pellets	1900	2094	1955	1744	2082
	1923	2094	2034	1820	2065

3.3 Broiler experiment 2.

Object The object of the experiment was to investigate the effect of bean level on broiler performance using diets different in composition from those of broiler experiment 1.

Birds and management 960 Ross I male broiler chicks were used. Their management was as in broiler experiment 1 (pp 17,18).

Diets The compositions of the experimental diets 2A to 2F are set out in Table 3.4 and the calculated analyses are set out in Appendix 13.2, Tables 6-11 . Diets 2A to 2E were fed from 0 to 4 weeks and diet 2F, which was prepared as 5 mm diameter pellets, was given to all birds from 4 to 8 weeks of age. The diets were analysed for moisture, crude protein, ether extract and ash by conventional methods and available carbohydrate contents were determined by the method of Bolton (1960a). The results of the proximate analysis and of metabolisable energy (M.E.) values calculated from the equation derived by Bolton (1962) are contained in Table 3.5 . The diets 2A to 2C were analysed for their total amino acid content by the method of Waring and Bolton (1967) after hydrolysis by the method of Moore (1963). The results are given in Table 3.6 .

Table 3.4

Broiler experiment 2

Starter diets 2A to 2E and finisher diet 2F

Composition (parts by weight)	2A	2B	2C	2D	2E	2F
Maize	39.0	45.0	33.5	40.0	33.0	-
Wheat	28.0	-	-	-	-	40.0
Milo	-	-	-	-	-	26.0
Groundnut meal	5.0	5.0	5.0	5.0	5.0	-
Meat-and-bone meal	20.0	7.0	3.0	13.0	5.0	10.0
Soyabean meal	-	-	-	-	-	17.0
Bean meal	-	30.0	45.0	30.0*	45.0*	-
Herring meal	5.6	7.5	7.0	6.0	8.5	-
Maize oil	-	1.8	3.3	2.5	2.3	5.0
$CaCO_3$	-	0.30	1.0	-	0.5	-
$CaHPO_4$	-	0.05	1.0	-	0.5	1.5
Lysine	-	-	-	0.20	-	0.1
Methionine	0.05	0.20	0.25	0.20	0.20	0.05
Salt	0.25	0.25	0.25	0.25	0.25	0.25
Choline chloride** (g)	0.05	0.067	0.08	0.05	0.067	-
Zoamix** (g)	150	150	150	150	150	-
Supplement***	+	+	+	+	+	+

* 80% digestibility of field bean protein assumed.

** Amounts per 300 kg mix.

*** Standard P.R.C. vitamin/trace mineral supplement for broilers. (Appendix 13.7).

Table 3.5

Analyses of diets used in broiler experiment 2
(per cent, air-dry basis)

	Diet					
	2A	2B	2C	2D	2E	2F
Dry matter	88.32	86.62	86.42	87.20	86.88	88.25
Ether extract	4.24	4.61	5.57	5.81	4.95	5.22
Ash	8.67	6.20	5.87	7.77	5.85	8.67
Available carbohydrate	42.3	42.1	40.9	39.2	40.0	43.4
Crude protein (N x 6.25)	22.6	22.3	22.1	24.1	23.9	18.1
M.E. (kcal/kg)	3071	3082	3104	3124	3082	3032

Table 3.6

Amino acid compositions (per cent) of diets 2A to 2C used in broiler experiment 2.

	2A	2B	2C
Arginine	2.15	1.91	2.12
Histidine	0.43	0.41	0.53
Isoleucine	0.78	0.95	1.00
Leucine	2.00	1.93	1.77
Lysine	1.80	1.81	1.87
Cystine	0.26	0.31	0.29
Methionine	0.64	0.66	0.80
Phenylalanine	0.99	0.89	1.00
Tyrosine	0.83	0.79	0.94
Threonine	0.85	1.00	0.98
Valine	1.12	1.05	1.25

Results The main results of the experiment are set out in Tables 3.7 and 3.8 . Data were analysed by analysis of variance for between-pen differences. Analysis of variance tables are contained in Appendix 13.3 .

Period 1. 0 to 4 weeks

Liveweight Birds offered the control diet 2A weighed significantly less ($P < 0.001$) than those fed on diets containing beans. No significant effect on live-weight due to bean level was noted. Birds fed on pellets were significantly heavier than those fed on mash ($P < 0.05$) and than those fed on ground pellets ($P < 0.001$). Birds fed on mash were significantly heavier than those fed on ground pellets ($P < 0.05$). There were no significant interactions.

Food consumption Birds fed on the control diet 2A ate significantly less food ($P < 0.001$) than those given diets containing beans. Birds given diet 2D ate significantly less ($P < 0.01$) than those on the other bean diets. Birds given pellets ate more ($P < 0.001$) than those given the other forms, but intakes of mash and reground pellets did not differ significantly. There was a significant interaction ($P < 0.05$) between the concentration of beans and the form of diet in that birds fed on control diet 2A ate more mash than ground pellets while those fed on the diets containing beans ate similar quantities of the three forms or ate more pelleted food.

Table 3.7

Growth from 0 to 4 weeks of age of broilers receiving mash, pelleted or pelleted-reground diets containing field beans at 0, 30, 45, 30 and 45 per cent rates of inclusion.

Diet

	2A	2B	2C	2D	2E		
Live-weights (g) at 4 weeks							
mash	540	679	701	693	702	663	
ground pellets	486	691	656	665	679	635	S.E. ± 12.5***
pellets	516	755	733	712	779	699	
mean	514	709	697	690	720		

S.E.± 16.3***

S.E. of difference between means in body of table ± 28.0

	2A	2B	2C	2D	2E		
Food eaten (g) per bird 0 to 4 weeks							
mash	920	1021	1102	1005	1094	1028	
ground pellets	848	1082	1059	1035	1096	1024	S.E. ± 14.6***
pellets	861	1185	1198	1053	1167	1093	
mean	876	1096	1120	1031	1119		

S.E.± 18.8***

S.E. of difference between means in body of table ± 32.6

	2A	2B	2C	2D	2E		
Food conversion ratio 0 to 4 weeks (food eaten, g/weight gain, g)							
mash	1.88	1.63	1.70	1.57	1.69	1.69	
ground pellets	1.96	1.69	1.76	1.69	1.75	1.77	S.E. ± 0.02*
pellets	1.86	1.69	1.76	1.60	1.61	1.70	
mean	1.90	1.67	1.74	1.62	1.68		

S.E.± 0.03***

S.E. of difference between means in body of table ± 0.053

	2A	2B	2C	2D	2E		
Percentage mortality 0 to 4 weeks							
mash	4.7	0.0	1.5	1.6	0.0	1.6	
ground pellets	3.1	0.0	0.0	1.6	1.6	1.3	S.E. ± 1.05 N.S.
pellets	1.6	1.6	1.6	0.0	0.0	0.9	
mean	3.1	0.5	1.0	1.0	0.5		

S.E.± 1.36 N.S.

S.E. of difference between means in body of table ± 2.36

***= significant at $P < 0.001$; *= $P < 0.05$; N.S.= not significant.

Food conversion ratio   Birds given the control diet (2A) had a significantly higher food conversion ratio ($P < 0.001$) than those fed on diets containing beans. Birds given diet 2E containing 45 per cent beans showed a significantly lower food conversion ratio ($P < 0.05$) than those given diet 2C which contained the same level of beans but in which the bean protein was assumed to be 100 per cent digestible. Food conversion ratio was significantly higher ($P < 0.05$) in birds fed on diets 2C and 2E containing 45 per cent of beans than in those given diets 2B and 2D containing 30 per cent of beans. Although food conversion ratio was higher ($P < 0.05$) when ground pellets were fed there was no significant difference between mash and pellets. There were no significant interactions.

Mortality   No significant effects on mortality of either bean level or form of diet were observed.

Period 2. 4 to 8 weeks

All birds were given diet 2F.

Liveweight   The live-weights of birds previously given control diet 2A were significantly lower ($P < 0.001$) than those previously given diets containing beans. Live-weights of birds previously given ground pellets were significantly lower than those of birds previously given mash or pellet diets. There was a significant interaction ($P < 0.05$) whereby live-weights of birds previously given diets 2A and 2E were depressed when these diets had been given as ground pellets.

Table 3.8

Growth from 4 to 8 weeks of age of broilers fed on a standard diet and previously given mash, pelleted or pelleted-reground diets containing field beans at 0, 30, 45, 30 and 45 per cent rates of inclusion.

Diet, given 0 to 4 weeks

Live-weights (g) at 8 weeks

	2A	2B	2C	2D	2E		
mash	1772	1965	2009	1994	2016	1951	
ground pellets	1618	2025	1950	1944	1883	1894	S.E. ± 24.8*
pellets	1988	2030	2033	1903	2114	1954	
mean	1693	2007	1997	1947	2004		

S.E. ± 21.1***

S.E. of difference between means in body of table ± 55.7

Food eaten (g) per bird 4 to 8 weeks

mash	3012	3218	3402	3340	3294	3253	
ground pellets	2930	3392	3316	3360	3247	3249	S.E. ± 66.2 N.S.
pellets	2916	3346	3439	3161	3517	3276	
mean	2953	3319	3386	3287	3353		

S.E. ± 85.4**

S.E. of difference between means in body of table ± 148.0

Food conversion ratio 4 to 8 weeks (food eaten, g/weight gain, g)

mash	2.44	2.50	2.60	2.57	2.51	2.53	
ground pellets	2.59	2.54	2.56	2.63	2.70	2.60	S.E. ± 0.03*
pellets	2.49	2.62	2.65	2.65	2.63	2.61	
mean	2.51	2.56	2.60	2.62	2.61		

S.E. ± 0.037*

S.E. of difference between means in body of table ± 0.064

Percentage mortality 4 to 8 weeks

mash	0.0	0.0	1.6	1.6	0.0	0.6	
ground pellets	1.6	0.0	0.0	0.0	0.0	0.3	S.E. ± 0.46 N.S.
pellets	0.0	0.0	0.0	0.0	0.0	0.0	
mean	0.5	0.0	0.5	0.5	0.0		

S.E. ± 0.60 N.S.

S.E. of difference between means in body of table ± 1.03

***= significant at $P < 0.001$; **= $P < 0.01$; *= $P < 0.05$;

N.S.= not significant.

Food consumption The only significant effect observed was that birds previously given control diet 2A ate significantly less than birds previously given other diets.

Food conversion ratio The food conversion ratios of birds previously given diets 2A or 2B were significantly lower ($P < 0.05$) than those of birds previously given the other diets. The food conversion ratios of birds previously given the mash diets were significantly lower than those of birds previously given diets in other forms. There were no significant interactions.

Mortality No significant effect due to previous nutrition was observed.

3.4 Discussion

In the first broiler experiment growth of the birds given diets 1A and 1D was unexpectedly low and did not allow explanation on the basis of dietary treatment. Reference to Appendix 13.2, Tables 1 and 4 gives no indication of any factor that may be limiting in the diets 1A and 1D as formulated. In broiler experiment 2 the same treatments were imposed but in this case the diets as a precaution did not contain groundnut meal at the same levels as in broiler experiment 1 but rather relied on meat-and-bone meal as the major source of protein to be replaced partly by beans. The most surprising result of experiment 2 was the significantly poorer growth of birds fed the control diet. Results of amino acid analyses (Table 3.6) do not suggest that there was any deficiency of an essential amino acid in this diet as the amino acid levels are fairly constant in the diets analysed. The main difference between the control and experimental diets was in the quantities of wheat and meat-and-bone meal used. One of these foods may therefore have been responsible for the poorer performance of the control birds. Meat-and-bone meal is a variable product and special care was taken to obtain a good sample for this experiment. It was analysed before use and found to have a crude protein content higher than that claimed by the suppliers. However, Waring (1969) obtained a value as low as 69 per cent for the protein digestibility coefficient of one sample of this material, and this may account for the poor performance of birds on diet 2A. It is desirable in a comparative feeding experiment that diets should be as similar as possible. However, when a protein source is investigated at levels up to 45 per cent of the diet similarity in ingredients between diets is not possible if they are to be isocaloric and isonitrogenous.

There were no significant differences in weight at 4 weeks of age among birds given diets 2B to 2E. The two diets (2B and 2C), where the digestibility of field bean protein was assumed to be 100 per cent, have thus been adequate since no response to the supplemental protein in diets 2D and 2E was obtained. Waring and Shannon (1969) used adult colostomised hens in their digestibility experiments and since it may be expected that young broiler chicks will be more sensitive to diet quality than adult birds, this result is at first surprising. This situation has arisen, however, because at a level of inclusion of 45 per cent of the diet the field bean is supplying only about half of the protein in a diet suitable for young broiler chicks and thus a difference in digestibility of 20 per cent in the bean protein (from 100 to 80 per cent) will affect total dietary digestible protein only by 10 per cent. It can be seen from Table 3.6 that diet 2C, which was formulated to contain 45 per cent field beans with an assumed digestibility of 100 per cent, exceeds the amino acid requirements for the chick published by the Agricultural Research Council (1963) by more than 10 per cent in all respects, except perhaps leucine. It is not therefore surprising that no response to supplementary protein (as contained in diet 2E) was obtained. To obtain a response it would be necessary for the total amino acid content of diet 2C to be tailored more closely to the needs of the bird.

In broiler experiment 2 birds given pellets grew better than those given mash. This result is well-founded (Davidson and Woodham, 1966). Growth of birds given ground pellets was poorer than that of birds given mash. Grinding the pellets resulted in a finer mash than that prepared for the mash treatments but intakes of mash and ground pellets were similar. The poorer performance on ground pellets cannot therefore be ascribed to reduced palatability. It is possible that in the pelleting process the protein is slightly damaged. It is well known that even mild heating of protein-carbohydrate mixtures can lead to reaction of the ϵ-amino group of lysine with carbonyl groups of reducing sugars, producing a bound form which is unavailable (Lea and Hannon, 1950). This damage may be overshadowed by advantages due to increased ease of ingestion when pellets are left intact but may become evident on regrinding. Whatever the cause, there is no evidence from this experiment to suggest that dry pelleting of diets containing field beans has any beneficial effect on the nutritive value of the bean. It has not been possible to examine the effects of steam pelleting in this context, but it is likely that less difficulty would be experienced in pelleting high bean diets with steam than was the case with the dry pelleting process used in this study. During the second part of broiler experiment 2 all birds were given the same diet from 4 to 8 weeks of age. The relative growth of birds during this period was similar to that observed from 0 to 4 weeks of age so that birds initially given the control diet weighed consistently less than the birds initially given the diets containing field beans.

Conclusion

Field beans may be included in pelleted diets for broilers at levels of up to about 25 per cent provided that methionine, choline and manganese are not deficient. At higher levels difficulties in pelleting without steam were encountered and there may be a reduction in food conversion efficiency as was reported by Blair, Wilson and Bolton (1970).

3.5 THE EFFECT OF FIELD BEANS ON CARCASE TASTE

Introduction

The usefulness of field beans (*Vicia faba* L.) as a major source of dietary protein has been examined (Blair and Bolton, 1968; Wilson, Blair and Bolton, 1969; Blair, Wilson and Bolton, 1970). It is important that all foodstuffs which may be used at high levels in diets for table poultry should be tested for their effect on carcase quality. Studies on the effect of field beans on the flavour of cooked broiler meat are presented in this section.

Broiler experiments 3 and 4.

Object Two experiments were conducted to examine the effects of field beans on carcase taste.

Birds and management Day-old Ross I male broiler chicks were housed on wood shavings under infra-red brooders. Air and brooder temperatures followed the recommendations of the breeder: about 27 and 34°C, respectively, at day-old gradually falling to 21°C for each at 3½ weeks of age. About 0.08 m^2 of floor space per bird was allowed and there were approximately 30 birds per treatment group.

Diets Two trials were carried out: in the first the birds were reared from 0 to 4 weeks of age on pelleted diets containing 0 or 45 per cent field beans, and from 4 to 9 weeks of age on diets devoid of beans; and in the second they were reared from 0 to 9 weeks of age on pelleted diets containing 0 or 45 per cent beans.

The treatments are set out in Table 3.9 and the compositions of the diets are contained in Table 3.10 . The birds in broiler experiment 3 were part of a larger experiment (broiler experiment 2) and the effect of dietary treatment on live-weight, food intake and food conversion efficiency is described in section 3.4 . The detailed effects of the dietary treatments used in broiler experiment 4 were described elsewhere (Blair, Wilson and Bolton, 1970).

Table 3.9

Dietary treatments during the 0 to 4 and 4 to 9 week periods.

Treatment group	0 to 4 weeks	4 to 9 weeks
3a	control diet A pelleted	finisher diet D pelleted
3b	diet B pelleted	finisher diet D pelleted
4a	control diet A pelleted	finisher diet D pelleted
4b	diet B pelleted	diet C pelleted

Table 3.10

Compositions of diets used in broiler experiments 3 and 4

Compositions (parts by weight)	A	B	C	D
Maize meal	40.0	34.0	-	25.5
Wheat meal	28.5	-	44.0	40.0
Meat-and-bone meal	20.0	3.0	10.0	10.0
Herring meal	5.0	7.0	-	-
Soyabean meal	-	-	-	17.0
Groundnut meal	6.0	5.0	-	-
Bean mixture*	-	45.0	45.0	-
Maize oil	-	3.3	-	5.0
$CaCO_3$	-	1.0	0.5	-
$CaHPO_4$	-	1.0	-	1.5
Salt (NaCl)	0.25	0.25	0.25	0.25
DL-methionine	0.05	0.25	0.30	0.05
Supplement**	+	+	+	+

* Contained ground spring and winter beans in the ratio 50:50.

** Standard vitamin/trace mineral broiler supplement containing a coccidiostat.

Processing of birds At 9 weeks of age 10 birds per treatment were killed. Each was dipped for 1 minute in hot water (54°C), wet-plucked and immediately eviscerated, chilled for 1 hour in ice-water, drained and sealed in a polythene bag. After storage overnight at -10°C the wrapped carcases were packed with solid CO_2 in an insulated container and despatched by rail to the Agricultural Research Council's Food Research Institute, Norwich.

On arrival the birds were still frozen and solid CO_2 was present in the containers. After thawing, the major and minor pectoral muscles were dissected. The muscle from each treatment was thoroughly mixed after mincing and placed in either 5oz (150g) cans for sensory assessment or screw-cap glass bottles (~ 12g) for gas chromatographic analysis. The sealed cans and bottles were stored at -60°C until required. The complete musculature of the leg was similarly treated after removal of fat and tendons.

Taste panel assessment 19 hours before cooking the cans were placed in melting ice at 1°C, then in running water at 15°C for 2 hours before each muscle was transferred to a glass beaker covered with aluminium foil and steamed for 35 minutes. The meat and liquor were thoroughly mixed and 10g dispensed into covered pots maintained throughout testing at 55°C.

Each treatment pair was presented as a triangular test on three separate occasions. Twelve experienced chicken testers were asked to identify the odd sample out of three on the basis of smell and taste. Half of the testers had the control birds, and the other half the experimental birds, as the odd sample in the triangle. Thus there were 36 tests per treatment pair. The results were analysed by the method of Steiner (1966), by which they are given a score equal to the sum of the number of correct decisions and one third of the number of 'no difference' decisions. If the score exceeds 18 there is a taste difference between the members of the treatment pair that is significant at the 5 per cent level.

Analysis of volatiles The volatiles from raw breast muscle were collected by the liquid oxygen entrainment procedure and were analysed by a model 801 gas chromatograph (Perkin-Elmer Ltd) as described by Grey and Lea (1969).

Results

Growth Average live-weights, food intakes and efficiencies of gain are set out in Table 3.11 .

In experiment 3 the birds given a diet containing 45 per cent beans to 4 weeks of age (group 3b) unexpectedly had greater live-weights, food intake and efficiency of gain than those given a control diet (3a). They were part of a larger trial (broiler experiment 2) and possible reasons for this difference are discussed elsewhere (section 3.4). In experiment 4 the birds fed on a diet containing 45 per cent beans (group 4b) were considerably heavier at 4 weeks than control birds (4a), but there was little difference in any respect at 9 weeks.

Table 3.11

Live-weights, food intake and efficiency of gain of birds fed on conventional diets and on diets containing field beans.

Treatment	Live-weight[1] (kg)		Food intake to 9 weeks[1] (kg/bird)	Efficiency of weight gain[1] (gain,g/intake,g)
	4 weeks	9 weeks		
3a	0.54	1.96	4.28	0.45
3b	0.71	2.21	4.51	0.48
4a	0.52	1.71	3.93	0.42
4b	0.65	1.70	3.87	0.43

[1] Mean values per pen of approximately 30 birds

Sensory assessment The decisions of the panel members are summarized in Table 3.12 .

Breast and leg samples from birds fed for 4 weeks on beans (group 3b) and breast samples from those fed for 9 weeks on beans (4b) were not significantly different in taste from their respective controls (3a and 4a). In the light of these findings it was considered unnecessary to taste leg samples from groups 4a and 4b.

Analysis of muscle volatiles The peaks obtained in this series of experiments have previously been tentatively identified by Grey and Lea (1969). One further peak, 2-propanol, was identified and confirmed by mass spectrometry. This had a retention index similar to ethanol on the Triton X 305 column and was therefore not previously resolved. However, Porapak Q separated the two peaks and it was found that 2-propanol contributed 2 per cent of the peak previously designated as ethanol. Dimethyl disulphide, previously identified by Grey and Shrimpton (1967), was found in trace amounts in all groups.

Mean total chromatogram areas and peak number are shown in Table 3.13 . Variation between control and experimental birds was small. The numbers of peaks obtained from groups 3a and 3b were similar. They were consistently greater than those from groups 4a and 4b. The contribution of the three major peaks to total chromatogram area is shown in Table 3.14 . This contribution was lowest in groups 4a and 4b. Acetone was the major component in all groups.

Ethanol is not invariably present in raw chicken muscle (Grey

Table 3.12

Results of sensory assessment of cooked chicken muscle.

Treatment	Taste panel		No. of subjects	Correct decisions	No difference	Correct decisions***	
	Breast	1	12	5	2	$5\frac{2}{3}$	
3a		2	12	3	4	$4\frac{1}{3}$	
		3	12	2	5	$3\frac{2}{3}$	
and						$13\frac{2}{3}$	N.S.
	Leg	1	12	4	5	$5\frac{2}{3}$	
3b		2	12	3	5	$4\frac{2}{3}$	
		3	12	3	4	$4\frac{1}{3}$	
						14	N.S.
4a	Breast	1	12	5	3	6	
and		2	12	4	1	$4\frac{1}{3}$	
4b		3	12	4	1	$4\frac{1}{3}$	
						$14\frac{2}{3}$	N.S.

*** after Steiner (1966)

Table 3.13

Chromatogram areas and number of peaks obtained from raw breast muscle

Treatment	Total area[1]	Area of minor peaks	Number of peaks
3a	259	18	34
3b	209	12	32
4a	168	28	26
4b	153	17	22

[1] Integrator units x 10^3/9g muscle

Table 3.14

Contribution of the three major peaks to total chromatogram area in raw breast muscle (per cent)

Treatment	Acetone	Methanol	Ethanol/2-propanol	Total
3a	78.2	6.1	8.6	92.9
3b	78.1	2.7	13.6	94.4
4a	59.9	10.2	13.1	83.2
4b	63.3	15.2	10.4	88.9

and Lea, 1969). In this series of experiments ethanol did not exceed 14 per cent of total chromatogram area. Previous ethanol values (~ 95 per cent of total peak area) resulted from atmospheric contamination after sterilisation of instruments by flaming in alcohol.

3.6 Discussion

In investigating a new source of protein for meat-type birds it is important to assess its effect on eating quality as well as on performance. For this reason a higher level of field beans than is commercially practicable was used in order to show up any adverse effects and changes in quality.

The experimental diets had little effect on the flavour of the cooked mince of breast or leg. Testers who correctly identified the odd sample in the three did so only with difficulty, thus emphasising the small degree of difference.

4. DUCKLINGS

4.1 Introduction

Hennig *et al*. (1961) fed Pekin ducklings from 1 week to 8 weeks of age on a control diet or a diet in which 17 per cent field beans replaced 5 per cent fish meal and 12 per cent cereals. Live-weight at 8 weeks, food intake and food conversion efficiency from 0 to 8 weeks of age were 2.206 kg, 7.310 kg and 0.302 kg gain/kg food intake for ducklings given the bean diet and 2.364 kg, 8.476 kg and 0.279 kg gain/kg food intake for those given the control diet.

Thus the birds given the diet containing field beans grew less quickly, but more efficiently, than those given the control diet. The live-weights achieved on both diets are poor and since it was not clear whether or not the two diets were similar in composition it was decided to investigate more fully the nutritive value of field beans in diets for young ducklings. In formulating the diets the recommendations of Scott *et al*. (1967) were followed in deciding energy, protein and amino acid contents.

4.2 Duckling experiment 5

Object The object of this experiment was the assessment of the value of field beans in diets for table ducklings and of the effect of the field bean on weight of carcase components.

Plan From 0 to 3 weeks of age 24 groups, each of about 16 male or female ducklings, were given a commercial duckling starter diet. From 3 to 8 weeks of age they were given diets containing 0, 15 or 30 per cent field beans. The treatments were imposed in a 2 x 4 factorial design with 3 groups per treatment. The factors were sex and diet, respectively. The layout of treatments is given in Appendix 13.6, Table 3 .

Birds and management 400 Pekin ducklings* were weighed individually at one day of age and allocated to 24 pens, each pen containing either males or females. The ducklings were floor-brooded. The pen floor was half wood shavings and half plastic-covered wire mesh and allowed approximately 0.23 m^2 of floor area per bird. Air temperature initially was 24°C falling by 1°C per week to 17°C at 8 weeks.

The ducklings were reweighed individually at 3 and 8 weeks of age. Food eaten per pen was recorded weekly.

* obtained from Hejgaards Anderugeri, Saxild Pr. Odder, Denmark.

Diets From 0 to 3 weeks of age all birds received a commercial control diet. From 3 to 8 weeks four dietary treatments were allocated randomly to pens. The calculated analyses of the four diets 5A to 5D, which contained a 50:50 mixture of spring and winter beans at levels of inclusion of 0, 15, 30 or 30 per cent, respectively, are contained in Appendix 13.2, Tables 12 - 15 . The compositions of diets 5A to 5D are given in Table 4.1 . Diets C and D were identical apart from supplements of 0.2 and 0.4 per cent DL-methionine to give calculated methionine + cystine contents of 0.67 and 0.87 per cent, respectively. The beans were ground to pass a 3 mm screen and all diets were prepared as 5 mm (diameter) pellets.

Techniques The diets were analysed for moisture, crude protein, ether extract and ash by conventional methods. Results of analyses are given in Table 4.2 .

Data for live-weight at 8 weeks, food intake and food conversion efficiency were analysed by analysis of variance with covariance on data obtained at 3 weeks. Analysis of variance tables are contained in Appendix 13.3 .

Results Results of treatment on live-weight at 8 weeks and food intake and food conversion efficiency from 0 to 8 weeks are contained in Table 4.3 .

Table 4.1

Compositions of diets used in duckling experiment 5

Compositions (parts by weight)	5A	5B	5C	5D
Maize meal	40.0	40.0	40.0	40.0
Soyabean meal	11.5	7.0	-	-
Wheat meal	33.15	20.65	12.45	12.25
Herring meal	4.0	4.0	4.0	4.0
Bean meal	-	15.0	30.0	30.0
Meat meal	7.0	7.0	7.0	7.0
$CaCO_3$	1.5	1.5	1.5	1.5
$CaHPO_4$	1.0	1.0	1.0	1.0
Salt (NaCl)	0.2	0.2	0.2	0.2
Maize oil	1.0	3.0	3.0	3.0
Lysine	0.2	0.2	0.2	0.2
Methionine	-	-	0.2	0.4
Supplement*	0.45	0.45	0.45	0.45

* Colborn 206 (Colborn Vitafeeds Ltd., Barton Mills, Canterbury, Kent).

Table 4.2

Analyses of diets 5A to 5D

(per cent, air-dry basis)

	5A	5B	5C	5D
Dry matter	90.2	90.3	90.7	90.6
Ash	6.5	6.9	6.9	6.9
Ether extract	4.7	7.2	7.4	7.6
Crude protein (N x 6.25)	18.7	19.6	19.0	19.0
Calculated M.E. (kcal/kg)	3053	3092	3019	3013

Table 4.3

Growth from 0 to 8 weeks of age of ducklings receiving diets containing field beans at 0, 15 and 30 per cent rates of inclusion.

	Diet number					
	5A	5B	5C	5D		
Live-weights (g) at 8 weeks						
Male	3061	3045	2946	3050	3026	
Female	2876	2700	2794	2625	2749	S.E. ± 43.6***
Mean	2968	2873	2870	2838		
		S.E. ± 61.7 N.S.				
Food eaten (g) per bird 0 to 8 weeks						
Male	8745	8690	8345	8779	8639	
Female	8686	8493	8402	8052	8408	S.E. ± 110.7 N.S.
Mean	8716	8591	8374	8416		
		S.E. ± 156.5 N.S.				
Food conversion efficiency 0 to 8 weeks (weight gain, g/food eaten, g)						
Male	0.35	0.35	0.35	0.34	0.35	
Female	0.33	0.31	0.33	0.32	0.32	S.E. ± 0.004***
Mean	0.34	0.33	0.34	0.33		
		S.E. ± 0.006 N.S.				

N.S. = not significant at $P < 0.05$; *** = $P < 0.001$.

Live-weight at 8 weeks Although the mean live-weight of ducklings given bean diets was numerically lower than that of birds given the control diet no significant difference in live-weight between treatments was noted. Male ducklings were significantly heavier ($P < 0.001$) than females at 8 weeks of age. There were no significant interactions.

Food intake from 0 to 8 weeks There was no significant effect of treatment on food intake to 8 weeks of age. Although male ducklings ate more than females the difference was not significant. There were no significant interactions.

Food conversion efficiency Male ducklings had significantly higher food conversion efficiency ($P < 0.001$) than females. There was no significant effect due to treatment on food conversion efficiency. There was an effect due to blocks whereby ducklings housed in block 1 were significantly poorer ($P < 0.01$) at converting food to live-weight gain than those in the other two blocks.

4.3 Analyses of duckling carcases At 8 weeks of age 6 male and 6 female ducklings were selected at random from birds on each of diets 5A to 5C. These 36 birds were killed by cervical dislocation and the carcases plucked and dressed.

Weights for dressed carcase, giblet and dressed carcase plus giblet were expressed as a percentage of dead weight and data were analysed by analysis of variance. Results are contained in Table 4.4 . Weights of skin, breast, skin plus breast, leg and total

Table 4.4

Giblet and dressed carcase weights of ducklings given diets containing 0, 15 and 30 per cent field beans

(per cent of carcase weights)

	Diet			
	5A	5B	5C	
Dressed carcase weight				
Male	59.50	59.43	59.96	59.64
Female	59.95	60.89	61.16	60.67
Mean	59.72	60.23	60.56	
Giblet weight				
Male	10.31	9.53	10.75	10.24
Female	9.12	9.08	8.80	9.00
Mean	9.72	9.29	9.78	
Dressed carcase + giblet weight				
Male	70.23	68.85	70.64	69.97
Female	68.89	70.12	69.74	69.58
Mean	69.56	69.55	70.19	

meat were expressed as a percentage of dressed carcase weight and data were analysed by analysis of variance. Results are contained in Tables 4.5 and 4.6 .

Results No significant effect due to treatment was observed on dressed carcase, giblet or dressed carcase plus giblet weights. Males had significantly heavier giblet weights than females ($P < 0.001$). There were no other significant sex or interaction effects.

In the component parts of the dressed carcase there were no significant effects due to sex or treatment on skin, breast and skin plus breast weights. Male ducklings had significantly heavier leg weights than females ($P < 0.01$) and a significantly greater weight of total meat ($P < 0.01$). There was a significant sex x diet interaction ($P < 0.01$) whereby males were heaviest and females lightest in weight of breast meat and total meat on the diet containing the highest level of beans (5C).

Table 4.5

Skin and breast meat of ducklings given diets containing 0, 15 or 30 per cent field beans

(per cent of dressed carcase weight)

	Diet				
	5A	5B	5C		
Skin					
Male	31.75	36.98	31.71	33.48	S.E. ± 1.15
Female	34.29	38.41	33.49	35.40	
Mean	33.02	37.69	32.60		
		S.E. ± 1.41			
Breast					
Male	14.39	12.46	15.57	14.14	S.E. ± 0.31
Female	14.66	14.16	13.14	13.99	
Mean	14.52	13.31	14.36		
		S.E. ± 0.37			
Skin + breast					
Male	46.14	49.43	47.29	47.62	S.E. ± 1.13
Female	48.94	52.58	46.63	49.38	
Mean	47.54	51.00	46.96		
		S.E. ± 1.39			

Table 4.6

Leg meat and total meat of ducklings given diets containing 0, 15 or 30 per cent field beans

(per cent of dressed carcase weight)

	Diet				
	5A	5B	5C		
Leg meat					
Male	13.40	11.71	12.79	12.63	S.E. ± 0.34
Female	11.56	11.00	10.30	10.95	
Mean	12.48	11.35	11.54		
		S.E. ± 0.41			
Total meat					
Male	35.44	32.15	38.40	35.33	S.E. ± 0.71
Female	32.41	32.38	29.51	31.43	
Mean	33.92	32.26	33.95		
		S.E. ± 0.87			

4.4 Discussion

The mean weight at 8 weeks of age of ducklings in experiment 5 was 2.89 kg which is considerably greater than that reported by Hennig (1961). The mean weights of ducklings given diets containing beans were lower in both studies than those of ducklings given control diets but this difference was not significant in experiment 5. Most of the difference in mean weight between ducklings on control and bean diets was due to the females, as the mean weight of male ducklings was much less variable with treatment (Table 4.3). The difference in weight between females given diets 5A and 5D just failed to reach significance at P=0.05. The poor weight of females on diet 5D is the result of a low food intake rather than a poor efficiency of food conversion to weight gain. During duckling experiment 5 water was provided by drinkers which were suspended overhead and operated by gravity. Some difficulty was experienced in maintaining the level of water in these drinkers, and it is possible that the reduction in food intake occurred as a result of occasional water deprivation. This would affect intakes of diets 5C and 5D more than that of the other diets since there were more 'fines' associated with the pellets of these diets. The sensitivity of ducklings to the form of the diet and their need for water are well documented. (Scott et al., 1967).

The density of stocking in experiment 5 was higher than intended and this may have affected food intake. Extra ducklings were obtained to allow for an anticipated mortality during the 0 to 3 week period. This mortality did not occur and this resulted in the stocking density being 0.23 m^2/bird instead of 0.35 m^2/bird as originally intended.

It is likely that with reduced numbers of birds per pen and with water supply in the form of a trough live-weight gain on all treatments might have been improved.

No effect of dietary treatment on the whole carcase or its components was observed. The experimental diets were formulated to isocaloric and isonitrogenous specifications and hence no effect on carcase composition would be expected. The close relationship between dietary energy/protein ratio and carcase composition is well-founded (Scott *et al*. 1967).

5. TURKEY POULTS

5.1 Introduction

In the absence of any information in the literature on the performance of turkeys fed on diets containing field beans turkey experiment 6 was conducted in which turkeys were fed beans during the 6- to 10- and 10- to 16- week periods.

5.2 Turkey poult experiment 6

Object The object of the experiment was to assess the nutritive value of field beans when included in diets for turkey poults at levels up to 30 per cent of the diet.

Plan From 0 to 6 weeks 20 and 28 groups, each of about 13 male or female turkey poults, respectively, were given a control diet. At 6 weeks of age they were reallocated so that pens each contained 10 males, 15 males or 15 females. From 6 to 10 weeks of age they were fed on one of four diets containing field beans at levels of 0, 15, 30 or 30 per cent; the last two diets differed in the level of methionine supplementation. From 10 to 16 weeks of age the poults were offered a control diet or a diet containing 20 per cent field beans.

The experiment was thus of a 3 x 4 x 2 factorial design where the factors were sex/stocking density, grower diet and finisher diet, respectively. The layout of treatments is shown in Appendix 13.6, Table 4 .

Table 5.1

Compositions of diet 6A, diets 6B to 6E fed from 6 to 10 weeks and diets 6F and 6G fed from 10 to 16 weeks.

(parts by weight)

Composition	6A	6B	6C	6D	6E	6F	6G
Wheat	-	30.5	29.8	27.5	27.2	-	-
Maize	35.5	20.0	9.0	-	-	37.0	25.0
Barley	-	-	-	-	-	19.8	20.2
Soyabean	56.0	30.0	30.0	24.0	24.0	33.0	24.0
Field bean	-	-	15.0	30.0	30.0	-	20.0
Herring meal	-	5.0	3.0	3.0	3.0	-	-
Whitefish meal	-	-	-	-	-	3.0	3.0
Meat-and-bone meal	-	5.0	2.0	2.0	2.0	-	-
$CaHPO_4$	4.5	3.0	4.0	3.5	3.5	2.85	2.85
$CaCO_3$	1.0	2.0	1.5	1.8	1.8	0.9	0.9
Methionine	0.3	0.2	0.4	1.0	1.3	0.2	0.25
Lysine	0.5	0.5	0.5	0.45	0.45	0.32	0.20
Salt	0.2	0.4	0.4	0.4	0.4	0.2	0.2
Colborn 204	0.45	0.36	0.36	0.36	0.36	-	-
Colborn 205	-	-	-	-	-	0.45	0.45
Corn oil	1.54	3.0	4.0	6.0	6.0	2.3	3.0

Birds and management   250 female and 400 male B.U.T. Triple 6 turkey poults were wing-banded and allocated to 48 pens according to a randomised plan. Each pen contained either males or females. Air and brooding temperatures followed the recommendations of the breeder. After reallocation of the poults at 6 weeks of age the stocking densities of 10 and 15 poults per pen allowed about 0.25 and 0.37 m^2 of floor space per bird, respectively. The poults were weighed individually at 6, 10 and 16 weeks of age. Food eaten per pen was recorded weekly.

Diets   The compositions of the diets 6A to 6G are set out in Table 5.1 . Calculated analyses are set out in Appendix 13.2, Tables 16-22 . Diet 6A was a convential starter diet based on maize and soyabean meal. Diets 6B to 6E were fed from 6 to 10 weeks. They were based on maize, wheat and soyabean meal and contained field beans at levels of 0, 15, 30 and 30 per cent, respectively. Diets 6D and 6E differed in having calculated methionine levels of 1.2 and 1.5 per cent, respectively. Diets 6F and 6G were based on maize, barley and soyabean meal and contained 0 and 20 per cent field beans, respectively.

The field beans were a 50:50 mixture of spring and winter varieties ground to pass a 3 mm screen.

Diets 6A to 6E were prepared as 3 mm diameter pellets and diets 6F and 6G as 5 mm diameter pellets. All pellets were prepared without the use of steam.

Techniques The diets were analysed for moisture, crude protein, ether extract and ash by convential methods. The results of analyses are set out in Table 5.2 .

Data for live-weight gain, food intake and food conversion efficiency were analysed by analysis of variance. Tables of analysis of variance are contained in Appendix 13.3 .

Results The results of the experiment are set out in Tables 5.3 and 5.4 .

Period 1 6 to 10 weeks

Data for live-weight, live-weight gain, food intake and efficiency of food conversion during the 6- to 10-week period are contained in Table 5.3 .

Live-weight at 10 weeks Male poults were significantly heavier ($P < 0.001$) than females at 10 weeks of age. Males housed at 10 birds per pen were significantly heavier ($P < 0.05$) than those housed at 15 per pen.

Poults given the control diet (6B) were significantly heavier ($P < 0.05$) than those given diet 6D which contained 30 per cent beans and significantly heavier ($P < 0.001$) than those offered the diet 6E which contained further supplemental methionine but was otherwise similar. Poults fed on diets 6C and 6D were significantly heavier than those fed on diet 6E ($P < 0.001$). No significant interactions were noted.

Table 5.2

Proximate analyses (per cent, air-dry basis)

Turkey experiment 6   grower diets, 6 to 10 weeks.

	6B	6C	6D	6E
Dry matter	89.62	89.18	88.88	89.04
Crude protein (N x 6.25)	26.6	26.8	27.0	26.8
Ether extract	6.48	6.78	7.97	7.52
Ash	9.36	8.68	8.35	8.64

Turkey experiment 6   finisher diets, 10 to 16 weeks.

	6F	6G
Dry matter	90.2	89.6
Crude protein (N x 6.25)	22.3	21.4
Ether extract	4.08	4.38
Ash	5.82	6.22

Table 5.3

Live-weight, live-weight gain, food intake and efficiency of food conversion of turkey poults given diets 6B to 6E during the 6- to 10- week period.

	Diet					
	6B	6C	6D	6E		
Live-weight (g)						
Female	3718	3743	3622	3450	3633	
Male (15/pen)	4657	4456	4488	4202	4451	S.E. ± 38.6***
Male (10/pen)	4796	4785	4553	4254	4597	
Mean	4390	4328	4221	3968		

S.E. ± 44.6***

S.E. of difference between means in body of table ± 77.2

	6B	6C	6D	6E		
Live-weight gain (g)						
Female	2129	2085	2009	1840	2016	
Male (15/pen)	2729	2607	2534	2259	2532	S.E. ± 26.0***
Male (10/pen)	2843	2784	2615	2351	2648	
Mean	2567	2492	2386	2150		

S.E. ± 30.0***

S.E. of difference between means in body of table ± 52.0

	6B	6C	6D	6E		
Food intake (kg/bird)						
Female	4.81	4.97	4.52	4.38	4.67	
Male (15/pen)	6.03	5.80	6.04	5.42	5.82	S.E. ± 0.08***
Male (10/pen)	6.03	6.44	5.81	5.62	5.98	
Mean	5.62	5.74	5.45	5.14		

S.E. ± 0.09*

S.E. of difference between means in body of table ± 0.16

	6B	6C	6D	6E		
Food conversion efficiency (gain, g/food intake, g)						
Female	0.44	0.42	0.44	0.42	0.43	
Male (15/pen)	0.45	0.45	0.42	0.42	0.44	S.E. ± 0.006N.S.
Male (10/pen)	0.47	0.43	0.45	0.42	0.44	
Mean	0.45	0.44	0.44	0.42		

S.E. ± 0.006*

S.E. of difference between means in body of table ± 0.011

*** = significant at $P < 0.001$; ** = $P < 0.01$; * = $P < 0.05$;
N.S. = not significant.

Food intake from 6 to 10 weeks Male poults ate significantly more than females ($P < 0.001$) in the 6- to 10- week period. There was no significant effect due to stocking density on food intake.

There was no significant difference between the intakes of birds given diets 6B and 6C. Poults given diet 6C ate significantly more than those given diets 6D ($P < 0.05$) and 6E ($P < 0.001$). Those given control diet 6B ate significantly more than those given diet 6E ($P < 0.001$) and those given diet 6D ate significantly more than those given diet 6E ($P < 0.01$). No significant interaction was observed.

Efficiency of food conversion No significant effect of sex or stocking density on efficiency of food conversion was observed. Birds given diet 6E had a significantly poorer efficiency of food conversion than those given diet 6B ($P < 0.01$) and than those given diets 6C and 6D ($P < 0.05$). Other differences were not significant.

Period 2 10 to 16 weeks

Data for live-weight, food intake and efficiency of food conversion during the 10- to 16- week period are contained in Table 5.4 .

Final live-weight Male poults were significantly heavier than females at 16 weeks of age ($P < 0.001$). Males housed at 10 birds per pen were significantly heavier than those housed at 15 birds per pen ($P < 0.001$).

Table 5.4

Live-weight, live-weight gain, food intake and efficiency of food conversion of turkey poults given diets 6F and 6G during the 10- to 16- week period

	Diet			
	6F	6G		
Live-weight (g)				
Female	6182	6289	6235	
Male (15/pen)	8118	8066	8092	S.E. ± 54.2***
Male (10/pen)	8536	8417	8476	
Mean	7612	7591		
	S.E. ± 44.2 N.S.			
S.E. of difference between means in body of table ± 76.6				
Live-weight gain (g)				
Female	2593	2612	2602	
Male (15/pen)	3699	3570	3635	S.E. ± 45.7***
Male (10/pen)	3902	3857	3879	
Mean	3398	3346		
	S.E. ± 37.3 N.S.			
S.E. of difference between means in body of table ± 64.6				
Food intake (kg/bird)				
Female	10.81	10.74	10.78	
Male (15/pen)	13.75	13.75	13.75	S.E. ± 0.20***
Male (10/pen)	14.56	14.43	14.50	
Mean	13.04	12.97		
	S.E. ± 0.16 N.S.			
S.E. of difference between means in body of table ± 0.28				
Food conversion efficiency (gain, g/food intake, g)				
Female	0.24	0.24	0.24	
Male (15/pen)	0.27	0.26	0.27	S.E. ± 0.005***
Male (10/pen)	0.27	0.27	0.27	
Mean	0.26	0.26		
	S.E. ± 0.004 N.S.			
S.E. of difference between means in body of table ± 0.007				

***= significant at $P<0.001$; **= $P<0.01$; *= $P<0.05$;

N.S.= not significant.

At 16 weeks of age there was no significant difference between birds given diets 6B, 6C and 6D in the 6- to 10- week period, but birds previously given diet 6E were significantly lighter than those given diet 6B ($P < 0.01$) and significantly lighter than those previously given diets 6C and 6D ($P < 0.05$).

There was no significant difference in live-weight at 16 weeks of age between poults given finisher diets 6F and 6G.

No significant interactions were observed.

Food intake Male poults ate significantly more than females ($P < 0.001$) and males housed at 10 birds per pen ate significantly more than those housed at 15 per pen ($P < 0.05$).

No significant effect of 6- to 10- week diet on food intake from 10 to 16 weeks was observed.

There was no significant difference in food intake between birds fed the two finisher diets 6F and 6G.

No significant interactions were observed.

Food conversion efficiency Females had significantly poorer food conversion efficiency than males housed at 15 per pen ($P < 0.01$) and males housed at 10 per pen ($P < 0.001$). No significant effect due to stocking density was observed.

Poults formerly fed on diet 6E had a significantly higher food conversion efficiency than those previously given diet 6B ($P < 0.05$).

There was no significant effect of finisher diet on food conversion efficiency and no significant interactions were observed.

5.3 Discussion

During the growing period from 6 to 10 weeks the mean liveweight and efficiency of food conversion of poults given a control diet and a diet containing 15 per cent field beans were not significantly different. However, performance in both of these respects was reduced significantly when the level of field beans was increased to 30 per cent in diet 6D. The reduced performance of poults given diet 6D can be attributed to a fall in food intake and this is probably associated with the increased difficulty of pelleting diets which contain beans at this level. To alleviate this problem the high-bean diets were formulated to contain a proportion of maize oil to act both as an energy source and as a binding agent. However, more 'fines' were still associated with diets 6D and 6E than with diets 6B and 6C. The use of a synthetic pellet binding agent in bean diets is discussed elsewhere (Rearing experiment 7, section 6.3). Its application there was not successful in improving the quality of pellets containing high levels of beans.

Growth, food intake and food conversion efficiency of poults which were fed on diet 6E were all poor. This diet was identical with 6D except for a further supplement of 0.3 per cent methionine + cystine to give a level in the diet of 1.96 per cent. This diet when pelleted was similar in texture to 6D and hence the reduced intake of diet 6E can not be accounted for by postulating reduced palatability. It is possible that the level of methionine in the diet was excessive for poults. Estimates of the requirement of the poult for methionine and cystine vary greatly and are often based on extrapolation from chick requirements. Waibel (1959) suggests a requirement of 0.98 per cent. In formulating the diets for this experiment the value of 0.98 per cent was taken as the requirement of the growing poult and was then raised by a safety margin to give an allowance of 1.20 per cent methionine + cystine in the diet. If these assumptions are valid then it seems unlikely that symptoms of toxicity would be introduced when the level of methionine + cystine was raised further to 1.96 per cent of the diet. However, the requirement of the growing poult may be much less than assumed and the degree of oversupply greater. In studies with the chick Griminger and Fisher (1968) fed a basal diet containing 0.73 per cent cystine + methionine plus graded levels of DL- methionine. Growth depression began when 1.0 per cent supplementary methionine had been added. Severe depression did not occur until 1.4 per cent had been added i.e. at a level of methionine + cystine three times that reported by the Agricultural Research Council (1963) as the chick's requirement.

What may be more important, however, than total dietary methionine and cystine contents in the production of growth depression is the proportion of the total sulphur amino acid content which is added in the form of supplementary amino acids. Approximately two-thirds of the total methionine + cystine content of diet 6E was added as a supplement of DL- methionine and thus a toxic level may have been reached at a lower dietary level of methionine + cystine than would normally have been the case.

An interesting aspect of the poor performance of birds given diet 6D and more particularly diet 6E during the 6- to 10- week period was the capacity for recovery shown by these birds during the 10- to 16- week period whereby poults previously given diet 6E had the highest food conversion efficiency during the later period and those previously fed diet 6D had caught up to a point where they were not significantly different from control birds in terms of weight at 16 weeks of age.

This capacity for compensatory growth by poults has been investigated recently (Auckland, Morris and Jennings, 1969; Auckland and Morris, 1971) and it could mean that diets containing levels of beans up to 30 per cent are practical during the growing period of the poult provided that gross amino acid imbalance is avoided and provided that the finisher diet is such that maximum recovery is possible.

Conclusions

Bean levels of 15 to 20 per cent in diets fed to poults during the 6- to 16- week period will produce growth and efficiency of food conversion similar to that on control diets. Some care is necessary in amino acid supplementation. Use of steam pelleting would be advisable to reduce 'fines' and maintain palatability.

The information regarding stocking density is important in showing that there may be dangers in comparing results gained in small experimental pens with data from extensive housing and then attributing differences to dietary treatment alone.

6. REARING PULLETS

6.1 Introduction

Sanz Arias (1964) fed 60 Leghorn hens on diets containing soyabean meal or field bean meal and found no significant difference between the two groups in egg number, egg mass, feed per dozen eggs and age at first egg. Jeroch and Hennig (1964) fed 4 groups of 35 hens on a control diet, a basal bean diet containing 19 per cent field beans or the same diet supplemented with 20 mg oxytetracycline/kg feed alone or with 10 g vitamin B_{12}/kg. Performance of hens on the supplemented bean diets was the same as that of birds on the control diet. More recently, performance as good as that of birds given a control diet has been reported for light and heavy strains of hens fed from 20 to 68 weeks of age on diets containing 5, 10 or 15 per cent field beans (Beecham Agricultural Products, 1970).

There is no information in the literature on the value of the field bean in diets for pullets during the 0- to 16- week rearing period and a trial has been conducted with two breeds of pullet to investigate the use of beans during this period. This trial is reported in section 6.2 .

Although the differences in proximate analyses between varieties of beans suitable for spring and winter sowing are well reported no information on the comparative feeding value of the two types was available. This aspect of the use of beans was also investigated in the rearing trial. As well as the nutritive value of beans the treatments during the 0- to 6- and 6- to 16- week periods examined the effect of different energy levels during these periods on subsequent laying performance. The effects due to energy are described elsewhere (Wilson and Blair, 1972) and only effects attributable to the use of beans are described here.

6.2 Rearing experiment 7

Object To investigate the effect of feeding rearing pullets on diets containing spring or winter beans during the 0- to 6- and 6- to 16- week periods.

Plan Treatments were allocated randomly within blocks of pens in a house with 2 blocks of 16 pens on each side of a central aisle. Allocation was according to a 2 x 2 x 2 x 2 x 2 factorial design where the factors were blocks, breed, type of field bean, early rearing energy level and late rearing energy level, respectively. Birds were allocated randomly to treatments so that each pen contained approximately 32 birds. The layout of treatments within the house is described in Appendix 13.6, Table 5 .

Management of birds 500 White Link and 500 Ranger II pullets were wing-banded and weighed at one day of age. They were housed on wood shavings under infra-red lamps in a closed environment house. Temperature and ventilation were maintained according to the instructions of the breeder. Food and water were available ad libitum and the birds were reweighed individually at 6, 12 and

16 weeks of age. The space allowance was 0.08 m^2 of floor per bird.

Diets The compositions of the diets in parts by weight are set out in Tables 6.1 and 6.2 . Diets 7A to 7D were fed from 0 to 6 weeks and diets 7E to 7H from 6 to 16 weeks of age, while diet 7J was fed during the subsequent laying period from 16 to 72 weeks. The diets were prepared as 3 mm (diameter) pellets. They were analysed for moisture, crude protein, ether extract and ash by conventional methods. The results of the proximate analyses are contained in Tables 6.1 and 6.2 . The detailed calculated composition of diets 7A to 7H is contained in Appendix 13.2, Tables 23 to 31 . The rearing diets were also analysed for their total amino acid content by the method of Waring and Bolton (1967) and the results are given in Table 6.3 .

Results Data were analysed by analysis of variance and the results are contained in Tables 6.4, 6.5 and 6.6 . Tables of analysis of variance are contained in Appendix 13.3 .

Period 1 0 to 6 weeks

Results are contained in Table 6.4 .

Live-weight at 6 weeks White Link chicks were significantly lighter than Ranger II chicks at 6 weeks of age ($P < 0.001$). There was no significant difference between birds given spring or winter bean diets. There was no significant interaction.

Table 6.1

Rearing experiment 7 - starter diets.

Compositions (parts by weight)	7A	7B	7C	7D
Barley	50.85	51.52	-	-
Maize	-	-	51.30	48.79
Wheatings	16.6	14.2	-	-
Spring beans	20.0	-	20.0	-
Winter beans	-	20.0	-	20.0
Groundnut meal	3.8	4.9	19.75	21.7
Herring meal	5.7	6.4	5.0	5.0
Tallow	-	-	0.85	1.43
$CaHPO_4$	2.35	2.35	2.35	2.35
$CaCO_3$	0.46	0.41	0.53	0.52
Methionine	0.06	0.04	0.04	0.03
Supplement*	+	+	+	+

* Standard P.R.C. vitamin/trace mineral mixture. (Appendix 13.7, Table 2).

Analyses

Dry matter	89.2	88.3	89.7	87.9
Crude protein (N x 6.25)	18.5	19.0	21.4	21.7
Ether extract	2.24	2.31	3.35	3.72
Ash	5.78	5.81	5.71	5.54

Table 6.2

Layers experiment 7 diets 6 to 16 weeks

Compositions (parts by weight)	7E	7F	7G	7H	7J
Maize	16.1	5.5	45.1	46.58	22.0
Barley	55.2	65.6	12.2	9.2	57.35
Spring beans	20.0	-	20.0	-	-
Winter beans	-	20.0	-	20.0	-
Herring meal	4.8	5.5	7.0	7.7	9.0
Groundnut meal	-	-	7.6	8.5	-
Grass meal	-	-	-	-	2.5
Tallow	-	-	5.0	5.0	-
$CaHPO_4$	2.35	2.35	2.35	2.35	1.47
Na_2HPO_4	0.30	-	-	-	-
$CaCO_3$	0.67	0.53	0.43	0.37	7.25
Lysine	0.10	0.12	-	-	-
Methionine	0.14	0.13	0.08	0.07	-
Choline tartrate	0.16	0.09	0.06	0.05	-
Salt	0.25	0.25	0.25	0.25	0.25
Supplement*	+	+	+	+	-
Supplement**	-	-	-	-	+

* Standard P.R.C. vitamin/trace mineral mixture (Appendix 13.7, Table 2).

** Standard P.R.C. vitamin/trace mineral mixture (Appendix 13.7, Table 3).

Analyses (per cent, air-dry basis)					
Dry matter	87.8	87.5	88.3	87.0	89.6
Crude protein (N x 6.25)	15.9	16.3	18.4	18.7	15.4
Ether extract	3.7	3.4	6.4	6.6	3.8
Ash	5.9	5.3	5.8	5.5	9.7

Table 6.3

Amino acid contents of diets 7A to 7H (per cent)

	7A	7B	7C	7D	7E	7F	7G	7H
Aspartic acid	2.11	2.70	2.88	2.68	1.31	1.55	1.70	1.89
Threonine	*	1.21	1.14	0.89	0.68	0.75	1.27	0.84
Serine	*	1.41	2.04	1.25	0.69	0.47	1.29	0.97
Glutamic acid	4.90	4.70	6.18	5.36	2.87	2.96	4.06	3.72
Glycine	1.23	1.07	1.23	1.31	0.63	0.69	1.08	1.03
Alanine	1.07	1.14	1.28	1.12	0.66	0.72	1.14	0.97
Valine	0.99	0.99	1.05	1.05	0.62	0.73	1.09	1.05
Cystine	0.03	0.11	0.13	0.15	0.09	0.08	0.08	*
Methionine	0.34	0.25	0.21	0.20	0.22	0.23	0.29	0.32
Isoleucine	1.04	0.75	0.77	0.83	0.44	0.51	0.87	0.72
Leucine	1.30	1.48	1.91	1.82	1.02	1.16	1.60	1.57
Tyrosine	0.72	0.70	0.95	0.79	0.40	0.30	0.70	0.70
Phenylalanine	0.75	0.94	1.09	1.07	0.57	0.65	0.87	0.82
Lysine	1.30	1.13	1.05	1.14	0.78	1.07	1.07	0.89
Histidine	0.45	0.45	0.39	0.48	0.32	0.28	0.47	0.41
Arginine	1.37	1.41	1.87	2.06	1.06	*	1.41	1.28

* Not determined.

Table 6.4

Live-weight, food intake and food conversion efficiency of two breeds of pullet given diets containing spring or winter beans from 0 to 6 weeks.

Live-weight at 6 weeks (g)

	Spring	Winter		
White Link	459.3	454.5	456.9	S.E. ± 4.15***
Ranger II	509.1	509.5	509.3	
Mean	484.2	482.0		
	S.E. ± 4.15 N.S.			

Food intake 0 to 6 weeks (kg per pen)

	Spring	Winter		
White Link	44.50	41.50	43.00	S.E. ± 1.067*
Ranger II	40.47	38.89	39.68	
Mean	42.49	40.19		
	S.E. ± 1.067 N.S.			

Food conversion efficiency (live-weight, g/food intake, g)

	Spring	Winter		
White Link	0.33	0.35	0.34	S.E. ± 0.010***
Ranger II	0.40	0.41	0.40	
Mean	0.36	0.38		
	S.E. ± 0.010 N.S.			

*** = significant at $P < 0.001$; * = $P < 0.05$; N.S. = not significant

Food intake White Link chicks ate significantly more than Ranger II chicks ($P < 0.05$). There was no significant main or interaction effect of bean type on food intake.

Food conversion efficiency Ranger II chicks achieved a significantly better food conversion efficiency than White Link chicks ($P < 0.001$). There were no other significant main or interaction effects.

Period 2 6 to 16 weeks

Results are contained in Table 6.5 .

Live-weight at 16 weeks White Link chicks were significantly lighter ($P < 0.001$) than Ranger II chicks. There was no significant main or interaction effect due to type of field bean.

Food intake Food intake of Ranger II pullets was significantly greater than that of White Link pullets ($P < 0.01$).

There was a significant interaction ($P < 0.05$) whereby intake was higher on a low-energy diet when that diet contained winter beans but higher on a high-energy diet when that diet contained spring beans.

Food conversion efficiency Food conversion efficiency of Ranger II pullets was significantly greater than that of White Link pullets ($P < 0.001$). There were no significant effects due to bean type.

Table 6.5

Live-weight, food intake and food conversion efficiency of two breeds of pullet given diets containing spring or winter beans from 6 to 16 weeks

Live-weight at 16 weeks (g)

	Spring	Winter		
White Link	1352.0	1346.2	1349.1	S.E. ± 8.87***
Ranger II	1737.8	1720.8	1729.3	
Mean	1544.9	1533.5		
	S.E. ± 8.87 N.S.			

Food intake 0 to 16 weeks (kg per pen)

	Spring	Winter		
White Link	169.9	169.5	169.7	S.E. ± 2.38**
Ranger II	184.6	179.6	182.1	
Mean	177.2	174.5		
	S.E. ± 2.38 N.S.			

Food conversion efficiency (live-weight, g/food intake, g)

	Spring	Winter		
White Link	0.25	0.25	0.25	S.E. ± 0.004***
Ranger II	0.30	0.30	0.30	
Mean	0.28	0.28		
	S.E. ± 0.004 N.S.			

*** = significant at $P<0.001$; ** = $P<0.01$; N.S. = not significant.

Period 3 16 to 72 weeks

All birds were given diet 7J.

Results are contained in Table 6.6 .

Egg number There were no significant effects of breed or bean type on egg number.

Food intake Food intake of Ranger II hens was significantly greater than that of White Links ($P < 0.01$). There were no other significant effects.

Food intake per 100 eggs Ranger II hens ate significantly more per 100 eggs laid than White Links ($P < 0.001$). There was a significant interaction whereby White Link hens ate more food per 100 eggs if reared on spring bean diets while Ranger II hens ate more per 100 eggs if reared on winter bean diets.

Days to first egg Ranger II hens were significantly younger at first egg than White Link hens ($P < 0.05$). There were no other significant effects.

6.3 Discussion

The only significant main effects observed in this experiment were due to differences in performance between the two strains of pullet. This indicates that when known differences in proximate analyses are taken into account in formulating diets containing either spring or winter beans no other differences between the two types remain to affect performance. The performance obtained

Table 6.6

Performance from 16 to 72 weeks of two breeds of pullets previously fed on diets containing spring or winter beans.

	Spring	Winter		
Egg number (per module of 12 birds)				
White Link	2500	2742	2621	S.E. ± 70.6 N.S.
Ranger II	2670	2605	2637	
Mean	2585	2674		
	S.E. ± 70.6 N.S.			
Food intake (kg per module of 12 birds)				
White Link	473.7	477.0	475.4	S.E. ± 11.1**
Ranger II	541.5	530.9	536.2	
Mean	507.6	503.9		
	S.E. ± 11.1 N.S.			
Food eaten per 100 eggs laid (kg)				
White Link	18.96	17.39	18.18	S.E. ± 0.25***
Ranger II	20.29	20.45	20.37	
Mean	19.62	18.92		
	S.E. ± 0.25 N.S.			
Days of age at first egg				
White Link	172.4	170.3	171.4	S.E. ± 1.18*
Ranger II	165.5	167.9	166.7	
Mean	169.0	169.1		
	S.E. ± 1.18 N.S.			

*** = significant at P∠0.001;** = P<0.01;* = P<0.05;
N.S. = not significant.

during the laying year indicates that hens can safely be reared on diets containing 20 per cent ground spring or winter beans. Mean annual production was 219 eggs on the hen-housed basis with a peak of 80 per cent and 35 weeks above 60 per cent production. This performance was achieved despite a dip of 20 per cent in production for three weeks just after the peak level was reached. This dip occurred during very hot weather and may have resulted from either heat stress or a temporary infection. It was intended to investigate the effect of feeding field beans to laying hens and laying diets were prepared which contained 15 and 30 per cent field beans. These diets were pelleted using dry-pelleting equipment. Since laying diets are low in energy and protein and high in calcium there is an absence of ingredients which will bind pellets. It proved impossible, using the dry-pelleting machinery available, to produce satisfactory pellets from laying diets containing these levels of beans. Incorporation of a synthetic binding agent (Wafolin*) was tried in the presence of a regulated amount of water, but this only reduced the keeping quality of the meal without improving the pellets. It seems unlikely that satisfactory pellets can be produced for laying stock from diets containing 15 per cent field beans without the use of steam. For home-mixing installations the alternative is to feed bean diets as a mash. In this case the beans should be coarse-ground.

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* Berk and Co., Ltd., Glasgow.

7. EFFECT OF AUTOCLAVING AND ADDITIONAL METHIONINE

The work reported in this section has been accepted for publication and will appear in British Poultry Science in 1972.

7.1 Introduction

Growth rates of birds given diets containing field beans (*Vicia faba* L.) were the same as those of birds on control diets (Blair and Bolton, 1968; Blair, Wilson and Bolton, 1970). However, efficiency of food conversion was reduced by the inclusion of high levels of beans in chick diets. Also, the true digestibility coefficient of field bean nitrogen obtained with the colostomised fowl was lower by approximately 10 per cent than that for heat-treated soyabean meal (Waring and Shannon, 1969). One hypothesis to explain these findings is that field beans contain an antinutritive factor analagous to the trypsin inhibitors found in many other legumes.

Nikolaiczuk, Brisson and Maw (1948) reported that although chicks fed for 6 weeks on autoclaved field beans were heavier than those given raw beans this difference was not significant. Borchers and Ackerson (1950) fed rats for 20 days on diets containing 65 per cent field beans and found that autoclaving significantly improved growth, but this improvement was not associated with a trypsin inhibitor. *In vitro* evidence for the presence of a trypsin inhibitor in contempory samples of field bean meal is described in section 8. Liener, Deuel and Fevold (1949), using rats, showed that supplementing a diet containing concentrates of soyabean trypsin inhibitor with methionine overcame a considerable proportion of the growth inhibition. The feeding of chicks on a diet containing raw soyabean meal caused enlargement of the pancreas (Chernwick, Lepkovsky and Chaikoff, 1948). The enlargement has been related to the presence of trypsin inhibitors (Haines and Lyman, 1961; Nesheim, Garlich and Hopkins, 1962).

7.2 Chick experiments 8, 9 and 10

Object The experiments reported in this chapter assess the value of autoclaving and methionine supplementation on the nutritive value of contempory samples of field bean meal.

Birds and management Day-old female Chunky P broiler chicks were housed in tier brooders and reared for two weeks on a chick mash of a standard composition (Appendix 13.7). They were then starved for 5 hours, weighed individually, wing-banded and allocated to three groups of similar mean weight, each of 14 chicks. Each group was fed *ad libitum* on one of the three experimental mash diets for a further two weeks. The birds were starved, weighed and killed by cervical dislocation. The pancreas from each was immediately excised, dissected free from fat and other material and weighed wet.

Diets The three experimental mash diets consisted of a conventional diet and diets containing 65 per cent raw or autoclaved field bean meal as the major source of protein. The compositions of the diets are given in Table 7.1 .

Table 7.1

Composition and protein content of the diets used in chick experiments 8 and 9.

Composition (parts by weight)	8A*	8B	8C	9A*	9B	9C
Field bean meal (FBM)		65.0	-		75.0	-
Autoclaved FBM		-	65.0		-	75.0
Maize meal		20.0	20.0		10.0	10.0
Herring meal		5.0	5.0		5.0	5.0
Maize oil		5.0	5.0		5.0	5.0
$CaCO_3$		2.0	2.0		2.0	2.0
$CaHPO_4$		1.25	1.25		1.25	1.25
Salt (NaCl)		0.25	0.25		0.25	0.25
Choline chloride**		550	550		550	550
Supplement***		+	+		+	+
Crude protein (per cent) (N x 6.25)	19.8	26.5	26.4	19.8	27.9	28.4

* Bolton, W. (1967). Poultry Nutrition, p.93. Bull. No. 174. Ministry of Agriculture, Fisheries and Food. London, H.M.S.O. P.R.C. chick mash used as control diet in both experiments.

** Expressed as mg/kg.

*** Appendix 13.7 .

The beans were Minor tick spring beans which were ground to pass a 3 mm screen. Those used in diet 1C were spread in metal trays to a depth of about 20 mm, covered with aluminium foil and autoclaved at 120°C for 20 minutes. The foil was removed and the material air-dried overnight.

Chick experiment 9

Birds and management 48 female Chunky P broiler chicks were weighed at one day of age, wing-banded, and allocated to 16 groups such that group 1 contained the three heaviest and group 16 the three lightest. The birds in each group were then distributed at random to the three treatments which were randomly assigned to three pens in a tier brooder. Food and water were provided *ad libitum*. After two weeks all birds were starved for 4 hours and weighed. Eight birds per treatment were chosen at random and the pancreas weighed as in chick experiment 8.

Diets The compositions of the diets are given in Table 7.1 . Diets 9B and 9C are similar to diets 8B and 8C except that the level of beans was increased to 75 per cent by replacing maize and the period of autoclaving was increased to 30 minutes.

Chick experiment 10

Birds and management 280 female Ross I broiler chicks were allocated to 14 treatments as in experiment 9, and those treatments were randomly assigned to 14 pens. There were thus 20 chicks per pen housed on wood shavings under infra-red brooding lamps. Food and water were provided *ad libitum*. After two weeks the birds were weighed and killed as in experiment 8.

Diets The compositions of the diets are given in Table 7.2 . The fourteen mash diets contained 75 per cent bean meal. Preparation of the diets was as in chick experiment 9. Diets 10A to 10C contained raw beans supplemented with 0, 0.3 and 0.6 per cent methionine. Diets 10D to 10F contained autoclaved beans similarly supplemented. The bean meal in diets 10G to 10J was autoclaved for periods of 15, 60 and 90 minutes, respectively, and that in diet 10K was suspended in ethanol at room temperature for 16 hours followed by extraction with boiling ethanol in a Soxhlet thimble for 8 hours to remove tannin (Anantharaman, 1969).

Techniques Analyses for crude protein were carried out by conventional methods. The results are included in Tables 7.1 and 7.2

Data for body weight, pancreas weight (chick experiment 8) and pancreas size were analysed by analysis of variance for groups of unequal replication (Steel and Torrie, 1960). Pancreas size was

Table 7.2

Composition and protein content of diets used in chick experiment 10.

Composition (parts by weight)	10A	10B	10C	10D	10E	10F	10G	10H	10J	10K
Field bean meal (FBM)	75.0	75.0	75.0	-	-	-	-	-	-	-
Autoclaved FBM	-	-	-	75.0	75.0	75.0	75.0	75.0	75.0	-
(Period of autoclaving, min)	-	-	-	(30)	(30)	(30)	(15)	(60)	(90)	-
Ethanol-extracted FBM	-	-	-	-	-	-	-	-	-	75.0
Maize meal	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Herring meal	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Maize oil	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
$CaCO_3$	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
$CaHPO_4$	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
DL-methionine	-	0.30	0.60	-	0.30	0.60	0.30	0.30	0.30	0.30
Choline chloride*	550	550	550	550	550	550	550	550	550	550
Supplement**	+	+	+	+	+	+	+	+	+	+
Crude protein (%) (N x 6.25)	24.5	25.0	25.4	23.9	24.3	25.1	24.5	23.5	24.0	27.6

* Expressed as mg/kg.

** Described in Appendix 13.7 .

obtained by expressing pancreas weight as a percentage of body weight.

Results The results of chick experiments 8, 9 and 10 are contained in Tables 7.3, 7.4 and 7.5, respectively.

Chick experiment 8

The results of the experiment are set out in Table 7.3 .

Final live-weights Birds given the standard mash diet (8A) were significantly lower in final weight ($P < 0.001$) than those given diets containing raw or autoclaved beans. Birds given autoclaved beans had a heavier mean weight than those given raw beans, but the difference was not significant.

Pancreas weight The pancreas weights of birds given a control diet were significantly lower than either those of birds given a raw bean diet ($P < 0.01$) or those of birds given an autoclaved bean diet ($P < 0.05$).

Pancreas size Although mean pancreas size of birds given a raw bean diet was greater than the means of birds on the other two diets none of the differences was significant.

Chick experiment 9

The results of the experiment are set out in Table 7.4 .

Live-weight gain The gains in live-weight of birds given the control diet (9A) were significantly greater ($P < 0.001$)

Table 7.3

Mean live-weight gain, pancreas weight and food conversion efficiency of chicks given diets containing raw or autoclaved field bean meal

	Chick experiment 8		
	8A	8B	8C
Initial weight (g)	145	145	144
Final weight (g)	424(14)	506(14)	531(14)
Weight gain (g)	280a	361b	387b
Pancreas weight (g)	1.20(5)a	1.57(9)b	1.43(9)b
Pancreas size (per cent)	0.27a	0.30a	0.27a
Food intake (g/bird)	584	613	571
Food conversion efficiency (weight gain, g/food intake, g)	0.48	0.59	0.68

Values with different postscripts are significantly different at $P = 0.05$.

Figures in brackets indicate number of observations in the mean.

Table 7.4

Mean live-weight gain, pancreas weight and food conversion efficiency of chicks given diets containing raw or autoclaved field bean meal

	Chick experiment 9		
	9A	9B	9C
Initial weight (g)	40	40	40
Final weight (g)	148(15)	110(15)	171(16)
Weight gain (g)	108d	70c	131e
Pancreas weight (g)	0.73(8)	1.10(8)	0.94(8)
Pancreas size (per cent)	0.51b	0.84c	0.57b
Food intake (g/bird)	233	197	273
Food conversion efficiency (weight gain, g/food intake, g)	0.46	0.36	0.48

Values with different postscripts are significantly different at $P = 0.05$.

Figures in brackets indicate number of observations in the mean.

than those of birds given the raw bean diet (9B) but significantly less ($P < 0.01$) than those given the autoclaved bean diet (9C).

Pancreas size The pancreas size of birds given the raw bean diet was significantly greater ($P < 0.05$) than that of birds given the other diets.

Chick experiment 10

The results of the experiment are set out in Table 7.5 .

Live-weight gain The mean live-weight gain of chicks given a raw bean diet without supplemental methionine was significantly lower ($P < 0.01$) than that of birds given the autoclaved bean diet with no supplemental methionine and significantly lower ($P < 0.001$) than all other treatments. The supplementation of both raw and autoclaved bean diets with 0.3 or 0.6 per cent methionine significantly improved live-weight gain ($P < 0.001$), but the level of supplementation had no significant effect. Birds given diets containing autoclaved beans supplemented with methionine had numerically greater weight gains than birds given the corresponding raw bean diets, but these differences were not significant. The live-weight gain of birds given ethanol-extracted beans was not significantly different from the raw bean diet (10B) containing the same level of methionine.

Pancreas size The pancreas size of birds on autoclaved bean diets was significantly lower ($P < 0.05$) than that of birds given the corresponding bean diet. The pancreas size of birds

TABLE 7.5

Mean live-weight gain, pancreas size and food conversion efficiency of chicks given diets containing 75 per cent raw, autoclaved or ethanol-extracted field beans supplemented with different levels of methionine (chick experiment 10)

	A	B	C	D	E	F	G	H	J	K
Initial weight (g)	43	43	42	42	43	42	42	42	42	42
Final weight (g)	125 (18)	197 (19)	188 (19)	149 (17)	210 (18)	191 (15)	205 (18)	208 (18)	208 (17)	193 (18)
Weight gain (g)	82a	154cdef	146c	107b	167f	149cd	163def	166ef	166ef	151cde
Pancreas weight (g)	0.66	0.98	0.98	0.67	0.86	0.86	0.96	0.84	0.71	0.91
Pancreas size (%)	0.53f	0.50ef	0.52f	0.45cd	0.41bc	0.45cd	0.47de	0.40b	0.34a	0.47de
Food intake (g/bird)	283	300	257	353	320	318	312	329	348	315
Conversion efficiency (gain, g/food intake, g)	0.29	0.51	0.57	0.30	0.52	0.47	0.52	0.51	0.48	0.48

Figures in brackets indicate number of observations in each mean

Values with different postscripts are significantly different at P = 0.05

given beans autoclaved for 15 minutes was not significantly different from that of birds given raw beans and the same level of methionine. Autoclaving the beans for 30 or 60 minutes significantly reduced pancreas size ($P < 0.05$), and autoclaving for 90 minutes caused a further significant reduction ($P < 0.05$). The pancreas size of birds given ethanol-extracted beans (10K) was significantly smaller ($P < 0.05$) than that of birds given a raw bean diet with the same level of methionine (10B) and significantly heavier than that of birds given an autoclaved bean diet with the same level of methionine.

7.3 Discussion

Wilson, McNab and Bentley (1971) have obtained *in vitro* evidence for the presence of a trypsin inhibitor in the field bean (*Vicia faba* L.). Chemical detection of such an anti-nutritive factor, however, does not indicate its effect on the chick or give information on ways of improving the nutritive value of the bean.

In a preliminary trial (chick experiment 8) live-weight gain was improved and pancreas size was reduced by autoclaving the field beans. Although neither of these effects was significant they suggested that a trypsin inhibitor, or some other factor susceptible to autoclaving, was being destroyed by heat treatment. Since the bean diets in chick experiment 8 were not supplemented with methionine they were limiting in sulphur amino acid content and thus another explanation of the growth response could be that autoclaving increased the availability of field bean amino acids in general and methionine in particular. That these two explanations can be complementary is indicated by Kakade *et al*. (1969) who point out the high cystine content of some trypsin inhibitors and give evidence for its unavailability before autoclaving.

The content of field beans in chick experiment 9 in the experimental diets was increased to 75 per cent of the diet and the trial was carried out from 0 to 2 weeks of age when chicks may be more vulnerable to a deleterious component in the diet. The period of autoclaving was increased to 30 minutes. Weight gain of birds given a diet containing 75 per cent raw beans (9B) was now significantly lower, and pancreas size significantly higher, than that of birds given autoclaved.

Chick experiment 10 was carried out to clarify the effect of autoclaving when bean diets were adequate in methionine and cystine and to ascertain the optimum period of autoclaving. One diet (10K) contained beans which were ethanol-extracted. This was done to investigate the effect of removal of tannins by this procedure on the nutritive value of the bean as tannins are known to inhibit the action of trypsin.

Growth on the basal raw bean diets in chick experiments 10 (10A) and 9 (9B) was similar. The basal autoclaved bean diet (10D) produced significantly poorer growth than the methionine-supplemented raw bean diet (10B). Weight gain was significantly increased by supplementing the basal autoclaved diet with 0.3 per cent methionine (10E) but gain on this diet was not significantly greater than that on diet 10B. Thus there is no significant effect of autoclaving when methionine and cystine levels are adequate. Supplementation of both raw and autoclaved beans with 0.6 per cent methionine seemed to give poorer weight gain than supplementation with 0.3 per cent methionine. This effect was not significant, but some detrimental effect may have resulted from the higher level of methionine addition. A similar effect has been described (Griminger and Fisher, 1968). Pancreas sizes of birds given raw bean diets 10A, 10B and 10C, respectively, were significantly greater than those of birds on the corresponding autoclaved bean diets 10D, 10E and 10F. An increase in the period of autoclaving from

15 to 90 minutes had no effect on live-weight gain, but significantly reduced pancreas size. This reduction in pancreas size may indicate that the trypsin inhibitor in the bean is being destroyed but no growth response to the destruction of this factor is obtained because autoclaving simultaneously reduces the value of the bean protein.

No significant growth response to the ethanol extraction used in chick experiment 10 was obtained.

Conclusion

The greater part of the response that was observed after autoclaving beans in experiments 8 and 9 may be attributed to an increase in availability of amino acids in diets deficient in methionine and cystine. A small and non-significant response is obtained when methionine levels are adequate. This response is not likely to justify commercial heat treatment of the field bean. Results of supplementation with 0.6 per cent methionine have indicated that excess methionine may be detrimental to optimum performance. There is no evidence that the removal of tannins has improved the nutritive value of the bean.

8. FIELD BEAN TRYPSIN INHIBITOR

8.1 Introduction

Osborne and Mendel (1917) observed that soyabeans would support growth of rats when autoclaved. This observation has been extended to other experimental animals (Liener, 1958). Read and Hass (1938) reported that an aqueous extract of soyabean flour inhibited digestion of gelatin by trypsin. This extract was subsequently purified by Bowman (1944, 1946, 1948) and isolated in crystalline form by Kunitz (1946). It was realised that the presence in raw soyabeans of an inhibitor of digestive enzymes could explain the findings of Osborne and Mendel (1917) and thus prompted much more research in this field. The work was stimulated by the world-wide importance of legumes in human and animal nutrition and it has resulted in the classification of most legumes on the basis of their enzyme inhibitor contents and of the effect their heat treatment has on subsequent animal growth. The nutritional aspects of legume trypsin inhibitors have been reviewed by Liener (1962, 1969), Pustzai (1967) and Gontzea and Sutzescu (1968) and the chemical and physical properties of isolated trypsin inhibitor preparations were reviewed by Liener (1969).

Information on the presence of trypsin inhibitors in the field bean (<u>Vicia</u> <u>faba</u> L.) and on growth of animals fed on heat-treated field beans is slight and contradictory. Some confusion in these conclusions can be attributed to the fact that the Indian bean <u>Dolichos</u> <u>lablab</u> also has the common-name field bean and some research into the presence of anti-nutritive factors in this bean has been reported under that name (Sohonie and Ambe, 1955; Dhonde and Sohonie, 1960; Phadke and Sohonie, 1962). Subsequent reviews have not always distinguished between the field beans Vicia faba and Dolichos lablab. The term field bean used in this section will refer to Vicia faba unless otherwise stated.

Borchers and Ackerson (1947) examined 30 legumes and found chemical evidence of trypsin inhibitor activity in 17 of them. The inhibitor activities ranged from 6.2 for golden mung bean (Phaseolus aureus) to 44.1 inhibitor units/0.1 g of defatted meal for the garden kidney bean (Phaseolus vulgaris). Soyabean meal had an inhibitor activity of 35.0 units/0.1 g of defatted meal. No trypsin inhibitor activity was found in field bean meal.

In further work Borchers and Ackerson (1950) compared growth of rats on raw and autoclaved samples of 11 species of legume. Growth of rats given a diet containing field beans as sole source of protein was significantly increased from 1.58 to 2.12 g/day when the beans were autoclaved at 121°C for 30 minutes. However, this improvement was not associated by the authors with the destruction of a trypsin inhibitor since the field bean sample used gave a negative response to their trypsin inhibitor test.

Liener and Pallansch (1952) isolated a toxic protein from defatted soyabean flour. This protein was devoid of anti-trypsin activity but had a marked haemagglutinating activity on red blood cells. Liener (1953) fed this protein (given the temporary name 'soyin') to rats and concluded that half of the difference in weight gain between animals fed raw or autoclaved soyabean meal could be accounted for by the presence of soyin in raw soyabeans. The haemagglutinating activity of this protein in raw soyabean meal was destroyed by heat treatment of the meal at 121°C for 20 minutes (Liener and Hill, 1953). However, De Muelenaere (1965) has investigated the haemagglutinating activity of 16 legumes by the method of Liener (1955). Although haemagglutinating activity in the field bean was reduced by autoclaving at 121°C for 30 minutes from 90 to 11 units/g, the initial level was low compared with that of other legumes and no intraperitoneal toxicity was observed when male rats were injected with a crude isolate of the bean. Therefore it is unlikely that destruction of a haemagglutinin is the explanation for the growth response obtained after autoclaving field bean meal by Borchers and Ackerson (1950).

Learmouth (1958) found that the field bean contained a heat-labile trypsin inhibitor in the germ. More recently Anantharaman (1970) autoclaved field bean meal at 107°C for 30 minutes to inactivate trypsin inhibitor. Nitsan (1971) examined the effect on growth and internal organ size of feeding a heated sample of Ethiopian field beans to rats. Growth rate and food eaten per unit of weight gain were both <u>reduced</u> by autoclaving at 120°C for 20 minutes, while pancreas weight expressed as a percentage of bodyweight was unaffected by this treatment of the beans. Although no data on inhibitor activities are included in the paper Nitsan (1971) reports that trypsin and chymotrypsin inhibitors were present in the beans and were not destroyed by heat treatment. He concludes that the field bean inhibitors must be of a nature different from those of the soyabean as the former were heat-resistant and caused neither pancreatic hypertrophy nor an increase in enzymic activity in the pancreas and caecum. These findings could also be explained by insufficient heat treatment on the one hand and a low level of inhibitor activity in the raw bean on the other.

Because of the contradictory reports on the trypsin inhibitor content of field beans the beans used in this study were examined for chemical evidence of this anti-nutritive factor. This work is reported in section 8.2 .

Green (1953) reported that synthetic substrates have a greater affinity for trypsin and hence inhibition is of a more competitive nature than is the case when protein substrates are used, hence the chemical detection of trypsin inhibitor activity in extracts of a bean is not necessarily evidence of nutritionally significant trypsin inhibition in vivo.

To clarify the relationship between the presence of an inhibitor and a growth response to autoclaving an extract with high inhibitor activity was obtained from the bean. This isolate was subsequently fed to chicks. The chick experiment is reported in section 8.3 .

8.2 Chemical investigation of in vitro trypsin inhibitor activity in field bean extracts.

Trypsin inhibitor activity (TIA) was assayed in whole ground bean extracts. The extracts consisted of the filtrate obtained after continuous stirring for 30 minutes of 10 g of bean meal in 100 ml of 0.0025 N HCl. The method of extraction was that of Sambeth et al. (1967).

TIA was measured by the method of Erlanger et al. (1961) where the inhibition of trypsin hydrolysis of N-benzoyl-DL-arginine p-nitroanilide HCl (BAPA) in the presence of bean extracts is determined. This hydrolysis results in the release of p-nitroaniline which is yellow in colour. Digestion, and hence its inhibition, can be estimated spectrophotometrically.

Time of reaction and trypsin concentration To establish optimal reaction conditions tests were carried out using 0.0025 N HCl in place of bean extract. This will be referred to as a 'blank extract'. Reaction times of 20, 40 and 60 minutes and trypsin concentrations of 18, 36, 60, 80 and 100 mg/100 ml of 0.001 N HCl were tested. Colour production after 60 minutes reaction proved excessive and produced full-scale deflections on the recording instrument. This instrument was able to measure absorbance over the range 0 to 1. Absorbances obtained after reaction times of 20 and 40 minutes are shown in the Table 8.1 . For the assays reported in this section a reaction time of 20 minutes and trypsin

Table 8.1

Increase in absorbance (x 10^2) of assay mixtures containing trypsin solutions with concentrations of 0, 18, 36, 60, 80 and 100 mg trypsin/ 100 ml after digestion times of 20 and 40 minutes at 23°C.

	Concentration of trypsin solution (mg/100 ml)					
	0	18	36	60	80	100
Absorbance (x 10^2) after 20 minutes	6.2	10.4	13.4	21.4	26.6	30.0
Increase in absorbance		4.2	7.2	15.2	20.4	23.8
Absorbance (x 10^2) after 40 minutes	7.0	15.0	25.2	36.2	49.4	59.4
Increase in absorbance		8.0	18.2	31.2	42.4	52.4

solutions containing 0, 50 and 100 mg trypsin/100 ml of 0.001 N HCl were used.

Inhibition of trypsin digestion by field bean extracts Hydrolysis of BAPA by trypsin was carried out under identical conditions in the presence of both blank and bean extract solutions. The effects of these two extracts on the absorbance of the assay mixtures are shown in Table 8.2 . In the presence of the blank extract the absorbance values are similar to the data in Table 8.1 . However, in the case of assay mixtures containing bean extracts there is no increase in absorbance with increase in concentration of trypsin solution and hence trypsin inhibition is indicated. The blank value associated with bean extract is high and the effect of this on the validity of comparisons between different tables of absorbance results was tested by comparing hydrolyses of BAPA in the presence of blank extracts with and without the addition of 1 ml of p-nitroaniline solution in order to simulate an absorbance level similar to that of the assay mixture containing bean extract. Results of this test are reported in Table 8.3 . Increase in absorbance with increasing trypsin content was the same regardless of the absorbance of the 'background' colour. Thus despite the high background colour associated with field bean extract the data reported in Table 8.2 genuinely indicate the effect of blank and bean extracts on trypsin hydrolysis. Thus complete trypsin inhibition has occurred in the presence of the field bean extract.

Table 8.2

Absorbance (x 10^2) after digestion at 23.5°C for 20 minutes of assay mixtures containing blank or field bean extracts and trypsin solutions containing 0, 50 or 100 mg trypsin/100 ml.

	Concentration of trypsin solution (mg/100 ml)		
	0	50	100
Absorbance (x 10^2) of mixture with blank extract	6.4	19.6	30.6
Increase in absorbance		13.2	24.2
Absorbance (x 10^2) of mixture with bean extract	30.0	30.1	30.0
Increase in absorbance		0.1	0.0

Table 8.3

Absorbances (x 10^2) of blank assay mixtures with and without the addition of 0.002 moles of p-nitroaniline.

	Concentration of trypsin solution (mg/100 ml)		
	0	50	100
Absorbance (x 10^2) of blank assay mixture	3.0	9.2	14.7
Increase in absorbance		6.2	11.7
Absorbance (x 10^2) of blank assay mixture + p-nitroaniline	15.6	21.4	27.0
Increase in absorbance		5.8	11.4

Effect of heat treatment of the bean on the result of trypsin inhibitor assay Comparisons were made between blank hydrolyses and hydrolyses occurring in the presence of extracts of field bean meal autoclaved for 20 or 40 minutes at 110°C. The results of these comparisons are given in Table 8.4 . An extract of field beans which had been autoclaved for 20 minutes at 110°C inhibited the tryptic digestion of BAPA, but an extract of field beans autoclaved for a further 20 minutes exhibited no inhibition at all. Thus the material causing *in vitro* trypsin inhibition is heat-labile and is destroyed by heating at 110°C for more than 20 but less than 40 minutes.

Site of trypsin inhibition in the field bean The evidence so far obtained showed the presence of an inhibitor of trypsin in extracts made from the ground raw field bean. A sample of beans was separated into kernel and hull and extracts were made of the two fractions. The extract made from the hull was deep-coloured and could not be assayed. It was therefore decolourised by adding saturated barium hydroxide solution until the extract reached pH 7 and then centrifuging at 1500 x g for 10 minutes. The effects of this extract and that from the kernel on the absorbance of assay mixtures are shown in Table 8.5 . The extract from the kernel of the field bean totally inhibited the digestion of BAPA by trypsin while the hull extract caused partial inhibition. Thus the kernel seems to have greater TIA activity per unit weight than the hull.

Table 8.4

Absorbance (x 10^2) of assay mixtures containing blank extract or extract of field beans autoclaved for 20 or 40 minutes at 110°C

	Concentration of trypsin solution (mg/100 ml)		
	0	50	100
Absorbance (x 10^2) of blank mixture	6.8	17.0	28.4
Increase in absorbance		10.2	21.6
Absorbance (x 10^2) of mixture with 20 minutes autoclaved bean extract	13.0	12.7	13.1
Increase in absorbance		-0.3	0.1
Absorbance (x 10^2) of mixture with 40 minutes autoclaved bean extract	12.2	23.0	32.5
Increase in absorbance		10.8	20.3

Table 8.5

Absorbance (x 10^2) of assay mixtures containing blank extract or extract of field bean hull or kernel after digestion for 20 minutes at 22°C

	Concentration of trypsin solution (mg/100 ml)	
	0	100
Absorbance (x 10^2) of mixture with blank extract	12.0	20.0
Increase in absorbance		8.0
Absorbance (x 10^2) of mixture with kernel extract	14.0	13.8
Increase in absorbance		-0.2
Absorbance (x 10^2) of mixture with hull extract	25.4	31.2
Increase in absorbance		5.8

However, the presence of barium ions may have affected the viability of the enzyme and this possibility was examined by conducting an assay with blank extracts, one containing barium hydroxide in the same concentration as the previous comparison. The results are shown in Table 8.6 . There is no difference in absorbance between the control solutions and those containing saturated barium hydroxide. The presence of barium ions has therefore not affected trypsin activity.

<u>Extraction of trypsin inhibitor isolate from field beans</u> Isolation of the trypsin-inhibiting fraction from field beans was attempted using the method of Sohonie and Ambe (1955). The procedure is described in Appendix 13.1 . The isolate was prepared from batches of 600 g of defatted meal and, after freeze-drying the product, each batch yielded approximately 0.6 g of fine white powder. The material was very soluble in water and had a crude protein (N x 6.25) content of 6.62 per cent. An amino acid analysis of the isolate was carried out and the results are given in Table 8.7 . Since other trypsin inhibitors when purified have been proteins with nitrogen contents of 13 to 16.7 per cent (Liener, 1969) the low protein content of this isolate suggested that its purity was low; this was confirmed by an assay of its inhibitor activity. To obtain an improved yield and purer isolate extractions of defatted field bean meal were made by the method of Garlich and Nesheim (1966) which is detailed in Appendix 13.1 . 10 kg of defatted

Table 8.6

Absorbance (x 10^2) of assay mixtures containing blank extract with and without barium hydroxide solution.

	Concentration of trypsin solution (mg/100 ml)		
	0	50	100
Absorbance (x 10^2) of blank extract	4.0	15.0	25.8
Increase in absorbance		11.0	10.8
Absorbance (x 10^2) of blank extract with barium hydroxide	4.5	15.0	26.0
Increase in absorbance		11.0	11.0

Table 8.7

Amino acid contents (per cent) in a trypsin inhibitor extract of field beans

Amino acid	Per cent
Aspartic acid	0.55
Threonine	0.34
Serine	0.27
Glutamic acid	1.36
Glycine	0.40
Alanine	0.23
Valine	0.25
Cystine	-
Methionine	0.19
Isoleucine	0.18
Phenylalanine	-
Tyrosine	0.30
Histidine	0.37
Arginine	0.60
Lysine	0.47
Leucine	0.25

Chromatogram peaks from cystine and phenylalanine were poorly resolved and the content of these amino acids was not established.

bean meal was fractionated by this procedure in batches of 2 kg. The resulting bean protein solution was dialysed against water for 48 hours and yielded 52 g of bean proteins on freeze-drying. This is five times the yield of material that resulted from extraction by the method of Sohonie and Ambe (1955).

The TIA of this preparation was assayed. The test solution contained 0.5 g of isolate in 100 ml of 0.0025 N HCl. Since 10 kg yielded 52 g that is approximately ten times the strength of inhibitor solution that would be equivalent to the 10 g of bean meal from which the earlier bean extracts were prepared. The effect of two dilutions of this test solution on the absorbance of assay mixtures is shown in Table 8.8 . For comparative purposes extracts of raw and autoclaved field bean meal and raw soyabean meal were prepared and diluted until they all reduced absorbance of assay mixtures by amounts similar to that achieved by the isolate test solution. In this way an estimate of the strength of the several inhibitors could be obtained. This comparison is shown in Table 8.9 . It seems from the data in Table 8.8 that the isolate contains approximately half of the trypsin inhibitor activity of the raw field bean or, at least, half of that portion of the total TIA which is obtained in an aqueous extract of bean meal.

From data in the same table it seems that the soyabean has an inhibiting action on trypsin under these assay conditions which is five times that of raw field beans and ten times that of the isolate at a concentration equivalent to the starting weight of field bean meal.

Table 8.8

Absorbance (x 10^2) of assay mixtures containing blank extract or isolate test solution at two dilutions.

	Concentration of trypsin solution (mg/100 ml)		
	0	50	100
Absorbance (x 10^2) of assay mixture with blank extract	8.2	18.0	30.0
Increase in absorbance		9.8	21.8
Absorbance (x 10^2) of assay mixture + isolate test solution diluted 1:19 with water	9.4	10.3	11.2
Increase in absorbance		0.9	1.8
Absorbance (x 10^2) of assay mixture + isolate test solution diluted 1:49 with water	8.0	10.0	12.1
Increase in absorbance		2.0	4.1

Table 8.9

Absorbance (x 10^2) of assay mixtures containing isolate test solution or extracts of soyabean meal or raw or autoclaved field bean meal

	Concentration of trypsin solution (mg/100 ml)		
	0	50	100
Blank extract	8.3	15.8	22.4
Increase in absorbance		7.5	14.1
Raw field bean extract	14.5	16.8	19.2
Increase in absorbance		2.3	4.7
Autoclaved field bean extract	15.4	20.0	25.1
Increase in absorbance		4.6	9.7
Soyabean extract diluted 1:1	15.0	16.0	17.0
Increase in absorbance		1.0	2.0
Isolate solution x 2	9.2	11.2	13.8
Increase in absorbance		2.0	4.6
Isolate solution x 5	11.2	11.9	13.0
Increase in absorbance		0.7	1.8

8.3 Chick growth on a diet containing the bean protein isolate

Chick experiment 11.

36 Chunky P female chicks were wing-banded and housed in 3 pens in one tier of an electrically heated brooder at one day of age. They were fed on a standard chick mash (Bolton, 1967). At 5 days of age when effects due to the yolk-sac would be reduced the birds were weighed, divided into groups of 3 birds in order of descending weight, and one bird in each group was randomly allocated to each of the 3 dietary treatments. Food and water were provided *ad libitum* for 14 days. All birds were then starved for 3 hours, weighed individually and killed by cervical dislocation. Each pancreas was removed immediately, dissected free of fat and other tissue and weighed wet.

The compositions of the diets (11A to 11C), fed as mash, are given in Table 8.10 . The three diets were identical except that the bean meal in diets B and C was autoclaved and diet C was supplemented with 0.5 per cent inhibitor extract. The bean meal was made from Minor spring beans ground to pass a 3 mm screen. Beans in diets B and C were spread in metal trays to a depth of 20 mm, covered with aluminium foil and autoclaved at 121°C for 30 minutes. The meal was air-dried before use.

Results

Data for live-weight gain, food intake, food conversion efficiency and pancreas size are presented in Table 8.11 . Pancreas size

Table 8.10

Chick experiment 11. Compositions of diets 11A to 11C

Compositions (parts by weight)	11A	11B	11C
Field bean meal (FBM)	75	-	-
Autoclaved FBM	-	75	75
Maize meal	10	10	10
Herring meal	6	6	6
Ground limestone	2	2	2
Dicalcium phosphate	1.25	1.25	1.25
Salt	0.25	0.25	0.25
Maize oil	5	5	5
Choline chloride*	550	550	550
Supplement**	+	+	+
Inhibitor extract	-	-	0.5

* Expressed as mg/kg.

** Standard P.R.C. vitamin/mineral mix for broilers (Appendix 13.7).

Table 8.11

Mean live-weights, food intakes and pancreas weights of chicks given diets containing raw beans or autoclaved beans with and without bean extract.

	11A	11B	11C
Initial live-weight (g)	71.9	69.3	70.6
Final live-weight (g)	202.5	221.6	219.4
Weight gain (g)*	130.6 a	152.3 a	148.8 a
Food intake (g/bird)	372.5	384.9	400.7
Food conversion efficiency (weight gain, g/food eaten, g)	0.35	0.40	0.37
Pancreas weight* (g/100 g final live-weight)	0.48 a	0.35 b	0.39 c

* Values with different subscripts are significantly different at P = 0.05 .

was calculated by expressing pancreas weight as a per cent of body weight. Results for weight gain and pancreas size were analysed by analysis of variance for groups with unequal replication (Steel and Torrie, 1960).

Live-weight gain The weight gain of birds given the diet containing raw beans (11A) was significantly lower than that of birds given the two other diets ($P < 0.05$). There was no significant difference in weight gain between birds given the two autoclaved bean diets with and without bean protein isolate.

Pancreas size Pancreas size of birds given diet 11A containing raw bean meal was significantly heavier than that of birds given diets 11B and 11C containing autoclaved beans ($P < 0.001$). Pancreas size of birds given autoclaved beans was significantly increased by the addition of bean protein isolate (diet 11C) ($P < 0.05$).

Discussion

The presence of anti-nutritive factors in many legumes is well-documented (Liener, 1969). Evidence for the presence of anti-nutritive factors in the field bean is slight and contradictory, and does not relate to varieties of field bean currently available in this country. Blair, Wilson and Bolton (1970) observed that incorporation of 45 per cent field beans in chick diets caused a reduction in food conversion efficiency. Waring and Shannon (1969) estimated the digestibility coefficient of field bean protein using the adult colostomised fowl and found it to be approximately 10 per cent lower than the value for heat-treated soyabean meal. Wilson and McNab (1972) obtained a significant response in chick growth after autoclaving field bean meal at 121°C for 30 minutes. One explanation for all of these separate observations is the possible presence in the field bean of one or more anti-nutritive factors. The data presented in Tables 8.2 and 8.4 show chemical evidence of trypsin inhibition in extracts obtained from the samples of field bean used in this study. The proportion of the total anti-trypsin activity of the field bean contained in these extracts is not known. For this reason no attempt was made to quantify the changes in absorbance into trypsin inhibitor units. Instead comparison was always made in the presence of a control assay thus overcoming effects due to changes in temperature and age of trypsin solution.

Evidence in Table 8.5 on the site of the inhibitor is inconclusive despite the fact that data in Table 8.6 indicate that the barium ions have not affected the viability of trypsin during the assay. The high background colour in the hull extract was probably due to tannins. Since tannins act as inhibitors of trypsin (Anantharaman, 1970) removal of colour by barium hydroxide may have prejudiced this assay by also removing a possible source of trypsin inhibition. In these circumstances it is not possible to measure the inhibitor content of bean hulls by this colorimetric method. It seemed likely that, if trypsin inhibitors existed as a defensive mechanism to enable seeds to survive ingestion in a viable condition, the inhibiting activity would be concentrated in the hull. Anantharaman (1969) showed that groundnut skins had a high trypsin inhibiting activity and produced growth depression and pancreatic hypertrophy in chicks unless the skins were first extracted with ethanol. The inhibiting activity in groundnut skins was attributed to tannins which were readily extracted by ethanol. The effect of ethanol extraction of field beans was investigated in chick experiment 10 (section 7.2). Chick growth was unaffected by this treatment but pancreas size was significantly smaller than that of birds given diets containing raw beans and significantly larger than that of birds given autoclaved beans with the same levels of methionine. Thus tannins are responsible for part only of the pancreatic hypertrophy observed after feeding raw field beans, although it is possible that the extraction procedure used by Anantharaman (1969) may not have removed all of the tannins from the field bean and thus their role may have been underestimated. However, the important conclusion from Table 8.5 is that the kernel of the field bean exhibits trypsin-inhibiting activity. Thus de-hulling the field bean would not remove all of the trypsin inhibitor activity.

Chemical detection of trypsin inhibitor activity is not conclusive evidence of the nutritional importance of this activity. This is so, even when a growth response is obtained to autoclaving which is concurrent with a loss of inhibiting activity, because the bean may contain other heat-labile anti-nutritive factors which are not assayed but which may be responsible for the observed effects on growth and pancreas size.

To investigate the importance of the trypsin-inhibiting activity measured <u>in vitro</u> two methods of obtaining an inhibitor isolate were tried. The second method, of Garlich and Nesheim (1966), yielded a material with an activity which was half that expected from the <u>in vitro</u> estimations, when related to the starting weights of beans. Since the <u>in vitro</u> assays may underestimate the total activity in the bean the activity of the isolate was probably less than half that to be expected from the equivalent weight of beans. In the time available only sufficient material could be prepared to allow addition to an autoclaved bean diet at a level of 0.5 per cent, which is the same level as the yield of isolate. Ideally at least twice this amount should be added to duplicate the trypsin inhibiting activity of the raw bean, and hence its effect on growth and pancreatic hypertrophy.

Following addition of the isolate to a diet containing autoclaved field bean meal there was no response in growth but a significant increase in pancreas size. In view of the dilute nature of the isolate it is not surprising that no growth inhibition occurred. It seems likely that pancreatic hypertrophy is obtained with low levels of inhibitor activity and growth becomes depressed only as inhibitor concentration rises. A more marked response may have been observed had more isolate been added to the diet.

It is interesting to note that food conversion efficiency is lower on the diet containing isolate and this indicates the extent of the nutritional significance of the isolate. One effect attributed to trypsin inhibitors is that the hypertrophic pancreas produces excessive enzyme secretion much of which is subsequently excreted (Lyman, 1957; Bielorai and Bondi, 1963). Thus efficiency of nitrogen utilisation is effectively reduced by overcompensation on the part of the pancreas and food conversion efficiency falls. The enzyme secretion has a high cystine content and thus the beneficial effect of supplementary methionine in raw bean diets (section 7.2) can be attributed to its cystine-sparing action.

The isolate at the strength used had no effect on chick growth when included in an autoclaved bean diet. This means either: (a) that growth inhibition would occur if a purer isolate were used, or (b) that the growth depression on raw field bean diets observed by Wilson and McNab (1972) and reported in section 7.2 is caused by some factor which is not extracted by the method of Garlich and Nesheim (1966). Liener (1951) and Sohonie, Apte and Ambe (1958) demonstrated that crystalline trypsin inhibitor preparations from the soyabean and double bean (Faba vulgaris M.), respectively, did not significantly affect rat growth when added to diets containing autoclaved beans.

From this study five conclusions can be drawn.

(i) The field bean contains a material, extractable with very dilute HCl, which inhibits trypsin *in vitro*.

(ii) The inhibitor (assuming only one) is not confined to the hull of the bean and de-hulling the bean will not be effective in removing trypsin-inhibiting activity.

(iii) A trypsin inhibitor isolate of approximately 50 per cent purity can be obtained readily. The inhibitor has one fifth of the potency of an aqueous extract from the same weight of raw soyabean meal.

(iv) The field bean isolate increases pancreas size in chicks of 1 to 3 weeks of age. This hypertrophic response is due either to the trypsin inhibitor or to the impurities in the isolate, and it is probably responsible for the reduced food conversion efficiency of birds given the isolate.

(v) The isolate at the strength used had no effect on chick growth when included in an autoclaved bean diet.

9. DIGESTIBILITY OF FIELD BEAN PROTEIN

9.1 Introduction

The digestibility by the chick of the protein in raw soyabeans is less than 80 per cent of that in heated soyabeans (Evans et al., 1947). De Muelenaere (1964) working with rats, reported that the protein digestibility in raw and autoclaved soyabean meal was 83 and 90 per cent, respectively. Waring (1969) used adult colostomised hens and reported that the true digestibility coefficient of the crude protein in one sample of field bean meal was 83 per cent, although values derived from data for individual birds ranged from 80 to 87 per cent. Subsequently Waring and Shannon (1969) reported that the true digestibility coefficients of the crude protein in Minor and Throws M.S. field beans were 84.3 and 80.8 per cent, respectively, while that of the crude protein in processed soyabean meal was 90.5 per cent. One possible explanation for the disparity in crude protein digestibility between field bean meal and processed soyabean meal is that natural trypsin inhibitors are present in raw field and soya beans. Those in the soyabean would be destroyed by the normal heat treatment, but no such treatment was given to the field beans studied by Waring (1969) and Waring and Shannon (1969). The reduced digestibility of the field bean may be due therefore to its native trypsin inhibitor. Experiments on field bean trypsin inhibitors are described in section 8 . Another explanation is that the field bean diets fed in the above work were low in sulphur-containing amino acids since field beans were the sole source of protein and are very deficient in such amino acids and the imbalanced supply of amino acids restricted the digestibility of the whole protein to that of the first-limiting amino acid.

A trial to test the validities of these explanations is described in section 9.2 .

9.2 Hen experiment 12

Experimental Six adult laying hens were used in this experiment. They were 18 months of age and had been colostomised by the method of Fussell (1960). All birds were physiologically normal at the time of experiment as adjudged by egg production and consistency of faeces. The birds were housed in individual metabolism cages. 100 g of food per bird and unlimited water were supplied daily in individual hoppers. Food residues were included in the following day's ration and corrections were made for spillage. Faeces were collected in small polythene bags covering the artificial anus. Bags were changed twice daily and their contents subsequently stored at -20°C prior to analysis. Food and faeces were analysed for total nitrogen content.

Diets The compositions of the three test diets 12A to 12C are given in Table 9.1 . The field bean meal consisted of a 50:50 mixture of Minor and Throws M.S. beans ground to pass a 3 mm screen. The beans included in diet 12C were autoclaved at 121°C for 30 minutes. Diets 12A, 12B and 12C were fed consecutively to

Table 9.1

Composition of diets (parts by weight).

	12A	12B	12C
Field bean meal	50	50	-
Autoclaved bean meal	-	-	50
Maize oil	5	5	5
Starch	24	23.4	24
Sugar	10	10	10
Methionine	-	0.6	-
Mineral/vitamin mix*	11	11	11

* This mix contained the following for 120 kg of diet

Vitamins

Rovimix E_{25}	4.8 g	Aneurine HCl	600 mg
Rovimix A + D_3	7.2 g	Pyridoxine HCl	840 mg
Rovimix A	7.2 g	Biotin	12 mg
Menaphthone	120 mg	Folic acid	180 mg
Riboflavin	480 mg	Vitamin B_{12}	2.4 mg
Ca-pantothenate	2.4 g	Choline chloride	210 g
Nicotinic acid	3.6 g		

Minerals

$CaCO_3$	7.2 kg	$MnCO_3$	7.2 g
$CaHPO_4$	3.96 kg	$MgSO_4 . 7H_2O$	180 g
NaCl	480 g	$FeSO_4 . 7H_2O$	24 g
K_2HPO_4	720 g	$CuSO_4 . 5H_2O$	2.16 g
KIO_3	84 mg	ZnO	3.24 g

the 6 hens for balance periods of 4 days after acclimatisation periods of 7, 3 and 3 days, respectively.

Calculation of results The true digestibility coefficients of the crude protein in the three test diets were obtained by calculating the regression of nitrogen absorption on nitrogen intake using the six observations for each diet plus three observations obtained from birds fed on a diet low in nitrogen content to estimate metabolic faecal nitrogen (MFN) output. The resulting regression equations (equations 1 to 3) are contained in Tables 9.2 to 9.4, respectively. The digestibility coefficient of the dietary nitrogen was defined in each case as the slope of the regression line. The data from birds given the low nitrogen diet were those of Shannon (1971) and they are contained in Tables 9.2 to 9.4 .

Results Data for nitrogen intake, excretion and absorption from birds given diets 12A to 12C are contained in Tables 9.2 to 9.4, respectively. The true digestibility coefficients of the crude protein in diets 12A to 12C were 80.8 ± 2.0, 81.6 ± 2.5 and 82.0 ± 2.2 per cent, respectively.

The accuracy with which the digestibility of the protein in each diet was estimated would have been improved had more birds been available.

Table 9.2

Nitrogen intake, excretion and absorption by 6 colostomised hens given diet 12A.

Bird	Food intake (g)	Food N (%)	N intake (g)	Faecal output (g)	Faecal N (%)	N excreted (g)	N absorbed (g)
1	196	1.86	3.646	36.7	2.51	0.921	2.725
2	257	1.86	4.780	74.7	1.98	1.479	3.301
3	217	1.86	4.036	46.6	2.32	1.081	2.955
4	211	1.86	3.925	51.0	2.03	1.035	2.890
5	335	1.86	6.231	72.1	2.30	1.658	4.573
6	193	1.86	3.590	32.5	2.67	0.868	2.722
7*			0.115			0.426	-0.311
8*			0.104			0.360	-0.256
9*			0.093			0.471	-0.378

The calculated regression of nitrogen absorption (y) on nitrogen intake (x) is described by equation 1 .

Equation 1 $y = 0.8075\,x - 0.3549$ S.E. = ± 0.020

Nitrogen digestibility = 80.75 ± 2.0 per cent

Estimated MFN output = 0.3549 g/hen/4 days

= 0.0887 g/hen day

* birds 7, 8 and 9 received a diet low in nitrogen (Shannon, 1971)

Table 9.3

Nitrogen intake, excretion and absorption by 6 colostomised hens given diet 12B.

Bird	Food intake (g)	Food N (%)	N intake (g)	Faecal output (g)	Faecal N (%)	N excreted (g)	N absorbed (g)
1	238	1.914	4.555	47.8	1.832	0.876	3.679
2	378	1.914	7.234	87.1	1.728	1.505	5.729
3	285	1.914	5.455	70.3	1.802	1.267	3.653
4	343	1.914	6.565	80.9	1.671	1.352	4.894
5	341	1.914	6.527	83.0	1.943	1.613	4.914
6	357	1.914	6.833	80.5	1.726	1.389	5.107
7*			0.115			0.426	-0.311
8*			0.104			0.360	-0.256
9*			0.093			0.471	-0.378

The calculated regression of nitrogen absorption (y) on nitrogen intake (x) is described by equation 2 .

Equation 2 $y = 0.8155\,x - 0.3928$ S.E. = ± 0.025

Nitrogen digestibility = 81.55 ± 2.5 per cent

Estimated MFN output = 0.3928 g/hen/4 days

= 0.0982 g/hen day

* birds 7, 8 and 9 received a diet low in nitrogen (Shannon, 1971)

Table 9.4

Nitrogen intake, excretion and absorption by 6 colostomised hens given diet 12C.

Bird	Food intake (g)	Food N (%)	N intake (g)	Faecal output (g)	Faecal N (%)	N excreted (g)	N absorbed (g)
1	154	1.83	2.818	36.6	1.825	0.668	2.150
2	358	1.83	6.551	85.6	1.991	1.704	4.847
3	321	1.83	5.874	72.8	1.667	1.214	4.660
4	168	1.83	3.074	39.0	1.772	0.691	2.384
5	351	1.83	6.423	94.2	1.723	1.623	4.800
6	184	1.83	3.367	45.5	1.577	0.718	2.649
7*			0.115			0.426	-0.311
8*			0.104			0.360	-0.256
9*			0.093			0.471	-0.378

The calculated regression of nitrogen absorption (y) on nitrogen intake (x) is described by equation 3 .

Equation 3 $y = 0.8196\,x - 0.3052$ S.E. = ± 0.022

Nitrogen digestibility = 81.96 ± 2.2 per cent

Estimated MFN output = 0.3052 g/hen/4 days

= 0.0763 g/hen day

* birds 7, 8 and 9 received a diet low in nitrogen (Shannon, 1971)

9.3 Discussion

The calculated digestibility coefficients of field bean protein in the three diets show that neither autoclaving nor supplementation with methionine has increased the digestibility to a level comparable to that of soyabean meal as determined by Waring (1969) and Waring and Shannon (1969). The digestibility of the raw bean diet (12A) in this study is the same as the corresponding values in these previous reports.

There are several explanations for the failure of autoclaving or supplementary methionine to improve the crude protein digestibility in the field bean.

Autoclaving would improve digestibility only if the raw field bean contained a heat-labile factor which was detrimental to protein digestion. Chemical evidence of a heat-labile trypsin inhibitor in the raw field bean has been presented (section 8). Since these data indicate that an isolate of this inhibitor had one-fifth of the potency of a comparable soyabean extract its effect on protein digestion may be small. Furthermore, heat treatment may have a detrimental effect on the protein so that the net effect of autoclaving on digestibility would be the resultant of beneficial and deleterious components. In the case of the field bean, therefore, the detrimental effects of autoclaving may balance any improvement in digestibility.

The failure of methionine to increase the digestibility can be explained by one of two possibilities. Firstly digestibility may not be affected by the balance of amino acids available for digestion as the presence of endogenous nitrogen may mask the amino acid balance of the food. It is likely, however, that this masking would be maintained for a period of time measured in hours rather than days on a diet deficient in one amino acid. Thus Nasset (1964) suggested that amino acid balance in the gut was not likely to be maintained for greater than one day in these circumstances. The basal diet (12A) in this study had a calculated methionine + cystine level of approximately 0.13 per cent. While this is much below the requirement of the fowl for 0.55 per cent methionine + cystine reported by the Agricultural Research Council (1963) the period of adaptation and feeding of the basal diet may not have been sufficiently great to produce a deficiency status to which supplemental methionine could show a response. Furthermore, the requirement of 0.55 per cent is for hens in full egg production. The hens in this study, while maintaining egg production, did not have an egg production comparable to a commercial bird and hence their requirement for methionine + cystine may have been appreciably less than 0.55 per cent and the degree of deficiency consequently lower.

The other explanation for the failure to show an improvement in digestibility when bean protein was either autoclaved or supplemented with methionine is that the digestibility of the bean protein in the basal diet (12A) is not impaired in the first place. Rather, the method of calculation of the results in this and previous studies involving the field bean would influence the result of that calculation.

The determination of true digestibility requires a reliable estimate of MFN (Squance, 1966). In this study the MFN data used to calculate equations 1, 2 and 3 were determined with colostomised hens fed on a diet low in nitrogen and containing 5 per cent cellulose powder to provide a level of indigestible organic matter similar to that found in experimental diets. However, food intakes of hens given the low nitrogen diet were lower than those of birds given the experimental diets 12A to 12C. Thus MFN values used to calculate equations 1 to 3 may have been underestimated if MFN contains a component related to food intake, as suggested by Schneider (1934). More data on level of MFN excretion at different intakes of a low protein diet were obtained (Shannon and McNab, 1971). Using these augmented data regression of MFN output (y) (g/hen day) on DM intake (x) (g) gave a linear relationship expressed by equation 4 .

Equation 4. $y= 10.35 + 0.1072\ x$

The mean food intakes of hens given diets 12A, 12B and 12C were 235, 324 and 256 g, respectively. From equation 4 the calculated mean MFN outputs of the birds on these diets were therefore 0.089, 0.114 and 0.095 g/hen day. Equations 1, 2 and 3 were recalculated using the derived MFN value in place of those used previously. Thus each of the regression lines was now calculated with 7 observations. The resulting equations 5, 6 and 7 are contained in Table 9.5 . The true digestibility coefficient of bean protein is now estimated to be 78.5 per cent when raw, 82.1 per cent when

Table 9.5

Effect of using derived estimates of MFN output on the regression equations in Tables 9.2 to 9.4 .

$y = 0.8075\ x - 0.3549$ equation 1

becomes

$y = 0.7853\ x - 0.2310$ equation 5

S.E. ± 0.028

$y = 0.8155\ x - 0.3928$ equation 2

becomes

$y = 0.8214\ x - 0.4302$ equation 6

S.E. ± 0.042

$y = 0.8196\ x - 0.3052$ equation 3

becomes

$y = 0.7961\ x - 0.1809$ equation 7

S.E. ± 0.025

supplemented with methionine and 79.6 per cent when autoclaved; these values differ from those first calculated by up to 2 per cent. The value assumed for MFN output thus has a noticeable effect on calculated digestibility. This is so particularly when only one level of the test protein is fed and data on low intakes of nitrogen from the experimental diets are not available.

Although the revised MFN values of 0.094, 0.114 and 0.095 g/hen day may be an improvement, accurate assessment of field bean protein digestibility may still not have been attained for several reasons. Firstly, MFN output is influenced by the indigestible component of the diet (Meyer, 1956). In their comparison of field bean meal and soyabean meal Waring and Shannon (1969) used cellulose powder to equalise indigestible organic matter between diets. Thus the bean diets all had an indigestible organic matter content of approximately 6 per cent. However, the diet low in nitrogen contained only 5 per cent cellulose powder and thus may have underestimated the MFN output on diets containing 6 per cent indigestible organic matter. Furthermore the hull of the bean is present in ground bean meal as a component of considerable particle size. The hardness of this material is indicated by the high rate of wear found in milling equipment when beans are ground. It is thus likely to have an abrasive action on the gut wall which may not be duplicated by cellulose powder. Thus MFN output may be abnormally high on a diet which contains a large proportion of its fibre content in this form.

This possibility is supported by the finding of Waring (1969) that birds given a diet containing field bean meal had a calculated mean MFN output of 129 mg/hen day compared with 92 mg/hen day for hens given a similar diet with fishmeal as the sole source of protein. These values corresponded to 1.60 and 1.07 mg/bird/g dry matter intake. MFN output was thus approximately 50 per cent greater on a diet containing field beans than on a fishmeal diet with approximately a similar indigestible organic matter content when food intake was approximately 80 g/bird/day. Because of these findings the MFN values used in calculating equations 5, 6 and 7 were increased by 50 per cent to give values of 0.534, 0.684 and 0.570 g/bird/4 days, respectively. The effect of using the appropriate one of these values in calculating the digestibility of bean protein is shown in equations 8, 9 and 10 in Table 9.6 . The calculated true digestibility coefficients of the crude protein in raw field bean meal, autoclaved field bean meal and raw field bean meal supplemented with methionine are now estimated to be 81.6 ± 3.6, 85.3 ± 4.4 and 81.8 ± 3.7 per cent, respectively, when one of these revised MFN values is used in calculating each equation.

This is not to suggest that these values are correct. In the absence of more observations on the effect of field bean meal on MFN output great credence can not be attached to any current values for the crude protein digestibility of field bean meal. In these circumstances any differences between field bean meal and other protein sources in the slope of the regression line of nitrogen

Table 9.6

$y = 0.8075\,x - 0.3549$ equation 1
$y = 0.7853\,x - 0.2531$ equation 5

now become $y = 0.8164\,x - 0.3950$ equation 8
S.E. ± 0.036

$y = 0.8155\,x - 0.3928$ equation 2
$y = 0.8214\,x - 0.4302$ equation 6

now become $y = 0.8534\,x - 0.6326$ equation 9
S.E. ± 0.044

$y = 0.8196\,x - 0.3052$ equation 3
$y = 0.7961\,x - 0.1809$ equation 7

now become $y = 0.8182\,x - 0.2968$ equation 10
S.E. ± 0.037

absorption on nitrogen intake cannot properly be called differences in true digestibility of crude protein unless MFN is properly accounted for.

10. THE VALUE OF FIELD BEANS IN POULTRY DIETS

10. The value of the field bean in poultry diets

The field bean is of interest as an ingredient in poultry diets because it can be grown in Britain and it has a higher protein content than other field crops grown in the U.K. This protein has an amino acid pattern which is well-balanced for the fowl except in its low content of methionine and cystine. Use of worthwhile levels of field beans in poultry diets thus requires the addition of methionine and is governed by the cost of balancing the protein in this way. Due to new sources of supply and methods of production methionine has become less expensive and a continuation in this trend may make the field bean more economic.

The use of field beans in poultry diets is also governed by their energy level. The field bean appears in least-cost diet formulations designed for laying hens but not in formulations of chick or broiler diets where the energy level is over 1300 kcal/lb. Thus another factor limiting the use of beans is the cost of supplemental energy sources.

A third factor affecting the use of the bean is its cost. It was expected that the cost/ton of the field bean would fall with the increase in acreage after 1964. However, due to its export potential as a starch for compounders in Europe, the reverse was true and the cost of beans has remained uneconomic to most British poultry food compounders. Entry by Britain into the European Economic Community may alter considerably the relative prices of protein sources used currently in poultry diets.

Further work in plant breeding may improve the economic value of field beans by developing varieties higher in energy, protein or methionine. It is unlikely that all of these improvements can be combined in one variety.

Heat treatment of the field bean produces a small improvement in chick growth (section 7) but such treatment is unlikely ever to be economic while the field bean has a low oil content which does not merit extraction. A more likely method of improving the value of the bean is de-hulling. This can be achieved mechanically or by breeding as has been done already with some cereals. The cost of mechanical refinement on a large scale is difficult to estimate but the beneficial effect on the content of proximate principles in the field bean is shown in Table 2.4 .

Until the value is improved by one or more of the changes mentioned above the field bean will continue to be economic only as an ingredient in low energy poultry diets. At the present time it is most valuable in home-mixed mash diets for laying hens.

11. Conclusions

The field bean (Vicia faba L.) is a useful source of home-grown protein. It can be included in diets for all classes of poultry at levels of up to about 20 per cent. It is essential to ensure that methionine and energy levels are adequate in diets containing beans. No toxic effects result from use of field beans at dietary levels up to 45 per cent, but some reduction in efficiency of food conversion may be experienced and acceptability of such diets may be low if the beans are ground fine.

Extract of field bean protein exhibits trypsin inhibiting activity *in vitro* but this action is of little nutritional significance.

The value of the bean in poultry diets would be much improved by dehulling. The more extensive use of field beans in poultry diets in either whole or dehulled forms is dependent on economic rather than nutritional constraints.

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APPENDIX 13.1

Methods of analysis

Methods of chemical analysis.

Proximate analyses Estimation of moisture, crude protein, ether extract, ash and crude fibre were carried out by the conventional methods.

Amino acid analysis Determination of amino acid contents was carried out by the method of Waring and Bolton (1967) on hydrolysates of each sample prepared by the method of Moore (1963).

Available carbohydrate Determination of available carbohydrate contents in diets was by the method of Bolton (1960a).

Trypsin inhibitor activity The trypsin inhibitor activity of samples of field bean and soyabean meals was assayed by the method of Erlanger, Kokowsky and Cohen (1961) as modified by Sambeth, Nesheim and Serafin (1967). The sample was prepared by grinding it in a laboratory mill until the test material passed a 44 mesh sieve. 10g of the resulting powder was suspended in 100ml of 0.0025N HCl and stirred for 30 minutes. The suspension was centrifuged at 1500xg for 10 minutes. The supernatant was assayed in a reaction carried out in sample vials on an SP 40 AU automatic sample changer*. Absorbance was measured at 410 $m\mu$ by an SP 600 spectrophotometer* and read on an SP 22 recorder* operating in the logarithmic mode.

'Tris' and calcium chloride hexahydrate were 'Analar' grade.

N-benzoyl-DL-arginine-p-nitroanilide HCl and dimethyl sulphoxide were suitable for chromatography.

Trypsin was pancreatic in origin and had an activity greater than 0.54 Anson units/g.

All chemicals for these analyses were obtained from B.D.H., Poole.

Preparation of bean isolates   Extracts of the field bean with increased trypsin inhibitor activity were prepared by the method of Sohonie and Ambe (1955) and later by the method of Garlich and Nesheim (1966).

Statistical analyses

Experiments 1 and 2 were analysed by a computer programme designed by Dr R. Blair of the Poultry Research Centre to deal with factorial experiments.

Experiments 5, 6 and 7 were analysed by 'EDEX'. This is a programme for the analysis of experiments with a factorial structure which was developed by the Agricultural Research Council's Unit of Statistics, Edinburgh for running on an IBM 360/50 computer.

Other analyses were carried out manually on a Casio AL 200 electronic calculator using analysis of variance for groups with unequal replication (Steel and Torrie, 1960; p 112)

APPENDIX 13.2

Tables of composition of experimental diets

Introduction

The following tables of dietary composition were calculated and printed by computer, using a programme developed by the author. The source data consisted of analyses of foodstuffs stored on a magnetic disk. These data were compiled from analyses of foodstuffs carried out recently at the Poultry Research Centre where these analyses were available. Otherwise data were taken from Bolton (1967) or, finally, Scott, Nesheim and Young (1969). As a result the source data are made up from analyses which cover a period of years and several laboratories and may refer to different samples or species of foodstuff from those which were used in the feeding trials described in this study. The accuracy of the calculated analysis contained in each table is thus illusory and these tables are presented for guidance only.

Computer programme

The programme which is written in IBM 1130 Fortran IV is contained in the following three pages. Input is from 029-ISO cards.

Punching instructions for data

Card 1	-	Table number.
Card 2	-	Table name.
Cards 3 to 6	-	Four lines of notes may be included, otherwise blank cards.
Card 7	-	The number of ingredients (n).
Cards 8 to (7+n)	-	The code number of one of the ingredients in columns 1 and 2 and the percentage in columns 7 to 10 with the decimal point always in column 9.
Card 8+n	-	Use a 1 in column 1 to repeat. Any other character acts as terminator.

The programme arranges the ingredients in descending order of their percentage in the diet before printing.

```
PAGE   1    B WILSON

// JOB                                                   B WILSON                     PRC 009

LOG DRIVE   CART SPEC   CART AVAIL  PHY DRIVE
  0000        3307        3307        0000

V2 M07   ACTUAL 16K  CONFIG 16K

// FOR
*LIST SOURCE PROGRAM
*IOCS(DISK,CARD,1132 PRINTER)
*ONE WORD INTEGERS
      REAL NOTEA(20),NOTEB(20),NOTEC(20),NOTED(20)
      DIMENSION F(80),DRAY(80),G(80),ID(80),TABLE(20),TITLE(20),FOODA(4)
      DEFINE FILE 1(80,120,U,NREC1),4(50,8,U,NREC4)
    3 FORMAT(I2)
  125 FORMAT(' ','*  COMPOSITION OF DIET    *')
  358 FORMAT(' ','*',T5,'FOOD',T18,'PERCENT',T28,'*')
  599 FORMAT(1H+,T3,4A4)
  601 FORMAT(1H+,T10,'DIET SPECIFICATION',T45,'AMINO ACIDS (PERCENT)',
     1T80,'VITAMINS  ETC.')
  603 FORMAT(1H+,T3,'CRUDE PROTEIN (PERCENT)',T30,F8.3,T45,
     1'LYSINE',T60,F5.3,T72,'LINOLEIC (PERCENT)',T93,F8.3)
  609 FORMAT(1H+,T3,'MET.ENERGY KCAL/LB (A)',T30,F8.3,T45,'ARGININE',
     1T60,F5.3,T72,'      ZN   (PPM)',T93,F8.3)
  613 FORMAT(1H+,T15,'KCAL/KG (B)',T30,F8.3,T45,'GLYCINE',T60,F5.3,T72,
     1'  VIT A   (IU/G)',T93,F8.3)
  616 FORMAT(1H+,T45,'HISTIDINE',T60,F5.3,T72,'  VIT B2   (PPM)',T93,
     1F8.3)
  618 FORMAT(1H+,T3,'ENERGY/PROTEIN     (A)',T30,F8.3,T45,'LEUCINE',T60,
     1F5.3,T72,'  VIT B12 (PPTM)',T93,F8.3)
  621 FORMAT(1H+,T23,'(B)',T30,F8.3,T45,'ISOLEUCINE',T60,F5.3,T72,
     1'  VIT E    (PPM)',T93,F8.3)
  624 FORMAT(1H+,T45,'PHE+TYR',T60,F5.3)
  625 FORMAT(1H+,T3,'CALCIUM (PERCENT)',T30,F8.3,T45,'THREONINE',T60,
     1F5.3)
  628 FORMAT(1H+,T45,'TRYPTOPHAN',T60,F5.3)
  629 FORMAT(1H+,T3,'PHOSPHORUS (PERCENT)',T30,F8.3,T45,'VALINE',T60,
     1F5.3)
  632 FORMAT(1H+,T3,'CHOLINE (G/KG)',T30,F8.3)
  634 FORMAT(' ','*',T4,'TOTAL',T17,F8.3,T28,'*')
  635 FORMAT('****************************')
  637 FORMAT(' ','*',T28,'*')
  638 FORMAT(' ','*',T19,'-------',T28,'*')
  639 FORMAT(1H+,T3,'NITROGEN      (PERCENT)',T30,F8.3,T45,'METH+CYST',
     1T60,F5.3,T72,'      MN   (PPM)',T93,F8.3)
  662 FORMAT('********************************************************')
  663 FORMAT(1H+,T57,'************************************************')
  665 FORMAT(/////,40X,20A4)
  666 FORMAT(1H+,40X,20A4)
  667 FORMAT(1H+,35X,'NOTE')
  671 FORMAT(' ','*',T41,'*',T68,'*',T104,'*')
  672 FORMAT(20A4)
  690 FORMAT(1H1)
  720 FORMAT(I2,F10.3)
  670 CONTINUE
      SUM=0
      DO 356 IDO=1,80
      F(IDO)=0
      ID(IDO)=0
      DRAY(IDO)=0
  356 CONTINUE
```

```
      WRITE(3,690)
      READ(2,672)TABLE
      READ(2,672)TITLE
      READ(2,672)NOTEA
      READ(2,672)NOTEB
      READ(2,672)NOTEC
      READ(2,672)NOTED
      READ(2,3)N
      DO 722 IE=1,N
  722 READ(2,720)ID(IE),F(IE)
      WRITE(3,665)TABLE
      WRITE(3,635)
      WRITE(3,637)
      WRITE(3,125)
      WRITE(3,637)
      WRITE(3,635)
      WRITE(3,358)
      WRITE(3,637)
      DO 391 IG=1,N
      DECOR=F(1)
      KG=1
      DO 379 JG=2,N
      DICOR=DECOR-F(JG)
      IF(DICOR)378,379,379
  378 DECOR=F(JG)
      KG=JG
  379 CONTINUE
      IYY=ID(KG)
      NREC4=IYY
      FIND(4'NREC4)
      WRITE(3,637)
      READ(4'NREC4)FOODA
      WRITE(3,599)FOODA
      WRITE(3,360)DECOR
      IF(IG-2)5,6,5
    6 WRITE(3,666)TITLE
    5 IF(IG-4)20,21,20
   21 WRITE(3,667)
   20 IF(IG-5)22,23,22
   23 WRITE(3,666)NOTEA
   22 IF(IG-6)24,25,24
   25 WRITE(3,666)NOTEB
   24 IF(IG-7)26,27,26
   27 WRITE(3,666)NOTEC
   26 IF(IG-8)28,29,28
   29 WRITE(3,666)NOTED
   28 WRITE(3,637)
      SUM=SUM+DECOR
  360 FORMAT(1H+,T18,F7.3)
      DECOA=DECOR/100
      DO 600 IP=2,68,2
      NREC1=IP
      READ(1'NREC1)G
      DRAY(IP)=DRAY(IP)+(G(IYY)*DECOA)
  600 CONTINUE
      F(KG)=0
  391 CONTINUE
      WRITE(3,638)
      WRITE(3,634)SUM
      WRITE(3,662)
      WRITE(3,663)
```

```
      WRITE(3,671)
      WRITE(3,671)
      WRITE(3,601)
      WRITE(3,662)
      WRITE(3,663)
      WRITE(3,671)
      WRITE(3,671)
      WRITE(3,603)DRAY(4),DRAY(26),DRAY(50)
      WRITE(3,671)
      DRAY(3)=DRAY(4)/6.25
      WRITE(3,639)DRAY(3),DRAY(24),DRAY(52)
      WRITE(3,671)
      WRITE(3,609)DRAY(6),DRAY(28),DRAY(54)
      WRITE(3,671)
      DRAY(7)=DRAY(6)*2.2045
      WRITE(3,613)DRAY(7),DRAY(30),DRAY(58)
      WRITE(3,671)
      WRITE(3,616)DRAY(32),DRAY(60)
      WRITE(3,671)
      DRAY(33)=DRAY(6)/DRAY(4)
      WRITE(3,618)DRAY(33),DRAY(34),DRAY(62)
      WRITE(3,671)
      DRAY(35)=DRAY(6)*2.2045/DRAY(4)
      WRITE(3,621)DRAY(35),DRAY(36),DRAY(66)
      WRITE(3,671)
      WRITE(3,624)DRAY(38)
      WRITE(3,671)
      WRITE(3,625)DRAY(20),DRAY(40)
      WRITE(3,671)
      WRITE(3,628)DRAY(42)
      WRITE(3,671)
      WRITE(3,629)DRAY(22),DRAY(44)
      WRITE(3,671)
      WRITE(3,671)
      WRITE(3,632)DRAY(68)
      WRITE(3,671)
      WRITE(3,662)
      WRITE(3,663)
      READ(2,3)ITER
      IF(ITER)670,669,670
  669 CALL EXIT
      END

FEATURES SUPPORTED
 ONE WORD INTEGERS
 IOCS

CORE REQUIREMENTS FOR
 COMMON       0  VARIABLES     856  PROGRAM    1332

 END OF COMPILATION

// XEQ          1

*FILES(1,SGLPN),(4,FOODA)
```

DIET COMPOSITION TABLES

```
                                             ****   TABLE  1   ****
***************************
*                         *
*  COMPOSITION OF DIET    *
*                         *
***************************
*  FOOD          PERCENT  *
*                         *
*  MAIZE          33.800  *
*                         *
*  WHEAT          29.500  *          BROILER EXPERIMENT  1        CONTROL STARTER DIET  1A
*                         *
*GROUNDNUT        22.000  *
*                         *
*SOYA BEAN         6.000  *      NOTE
*                         *
*HERRING M.        5.000  *          VITAMIN/TRACE MINERAL CONTENTS DONT INCLUDE P.R.C. SUPPLEMENT
*                         *
*  CA.HPO4         2.350  *          ALL FOODSTUFFS ARE FEED GRADE
*                         *
*  CA.CO3          0.690  *
*                         *
*  SALT            0.250  *
*                         *
*                -------  *
* TOTAL           99.589  *
*****************************************************************************************************************
*                                     *                           *                                             *
*      DIET SPECIFICATION             *  AMINO ACIDS (PERCENT)    *         VITAMINS  ETC.                      *
*****************************************************************************************************************
*                                     *                           *                                             *
*CRUDE PROTFIN (PERCENT)     21.970   *  LYSINE          0.920    *  LINOLEIC (PERCENT)          1.388           *
*NITROGEN      (PERCFNT)      3.515   *  METH+CYST       0.775    *        MN   (PPM)          25.477           *
*MET.ENERGY KCAL/LB (A)    1337.979   *  ARGININE        1.774    *        ZN   (PPM)          43.138           *
*              KCAL/KG (B) 2949.575   *  GLYCINE         1.160    *    VIT A    (IU/G)          0.355           *
*                                     *  HISTIDINE       0.554    *    VIT B2    (PPM)          1.870           *
*ENERGY/PROTEIN       (A)    60.899   *  LEUCINE         1.668    *    VIT B12 (PPTM)         12.414           *
*                     (B)   134.252   *  ISOLEUCINE      0.824    *    VIT E     (PPM)          6.419           *
*                                     *  PHE+TYR         1.767    *                                             *
*CALCIUM (PFRCENT)            1.016   *  THREONINE       0.707    *                                             *
*                                     *  TRYPTOPHAN      0.182    *                                             *
*PHOSPHORUS (PFRCENT)         1.045   *  VALINE          1.054    *                                             *
*                                     *                           *                                             *
*CHOLINE (MG/KG)           1208.909   *                           *                                             *
*                                     *                           *                                             *
*****************************************************************************************************************
```

```
                                                      ****   TABLE  2   ****
****************************
*                          *
*  COMPOSITION OF DIET     *
*                          *
****************************
*  FOOD         PERCENT    *
*                          *
*  MAIZE         43.500    *
*                          *
*BFANS(S+W)      30.000    *             BROILER EXPERIMENT  1       STARTER DIET  1B
*                          *
*GROUNDNUT       16.500    *
*                          *
*HFRRING M.       5.000    *        NOTE
*                          *
*  CA.HPO4        2.350    *             VITAMIN/TRACE MINERAL CONTENTS DONT INCLUDE P.R.C. SUPPLEMENT
*                          *
* CORN OIL        1.520    *             BEAN MIXTURE IS EQUAL PARTS SPRING AND WINTER
*                          *
*  CA.CO3         0.500    *             CORN OIL MIXED WITH BEEF DRIPPING BEFORE USE
*                          *
*  SALT           0.250    *             ALL FOODSTUFFS ARE FEED GRADE
*                          *
*METHIONINE       0.180    *
*                ------    *
* TOTAL          99.799    *
*********************************************************************************************************
*                                       *                           *                                   *
*       DIET SPECIFICATION              *   AMINO ACIDS (PERCENT)   *          VITAMINS  ETC.           *
*********************************************************************************************************
*                                       *                           *                                   *
*CRUDE PROTEIN (PERCENT)      22.613    *   LYSINE          1.038   *  LINOLEIC (PERCENT)       2.190   *
*NITROGEN      (PERCENT)       3.618    *   METH+CYST       0.734   *        MN   (PPM)        15.672   *
*MET.ENERGY KCAL/LB (A)     1327.649    *   ARGININE        1.767   *        ZN   (PPM)        41.359   *
*           KCAL/KG (B)     2926.802    *   GLYCINE         1.110   *    VIT A   (IU/G)         0.267   *
*                                       *   HISTIDINE       0.514   *    VIT B2   (PPM)         2.221   *
*ENERGY/PROTEIN      (A)      58.711    *   LEUCINE         1.709   *    VIT B12 (PPTM)        12.103   *
*                    (B)     129.429    *   ISOLEUCINE      0.817   *    VIT E    (PPM)         3.707   *
*                                       *   PHE+TYR         1.677   *                                   *
*CALCIUM (PERCENT)             0.956    *   THREONINE       0.741   *                                   *
*                                       *   TRYPTOPHAN      0.174   *                                   *
*PHOSPHORUS (PERCENT)          1.045    *   VALINE          1.033   *                                   *
*                                       *                           *                                   *
*CHOLINF (MG/KG)            1112.899    *                           *                                   *
*                                       *                           *                                   *
*********************************************************************************************************
```

```
                                                    ****   TABLE  3   ****
***************************
*                         *
*  COMPOSITION OF DIET    *
*                         *
***************************
*  FOOD         PERCENT   *
*                         *
*BEANS(S+W)      45.000   *
*                         *
*  MAIZE         31.500   *            BROILER EXPERIMENT  1      STARTER DIET  1C
*                         *
*GROUNDNUT       11.000   *
*                         *
*HERRING M.       5.000   *        NOTE
*                         *
* CORN OIL        3.870   *            VITAMIN/TRACE MINERAL CONTENTS DONT INCLUDE P.R.C. SUPPLEMENT
*                         *
*  CA.HPO4        2.350   *            BEAN MIXTURE IS EQUAL PARTS SPRING AND WINTER
*                         *
*  CA.CO3         0.470   *            CORN OIL MIXED WITH BEEF DRIPPING BEFORE USE
*                         *
*METHIONINE       0.250   *            ALL FOODSTUFFS ARE FEED GRADE
*                         *
*  SALT           0.250   *
*                         *
*                ------   *
* TOTAL          99.689   *
*****************************************************************************************************
*                                    *                               *                              *
*      DIET SPECIFICATION            *  AMINO ACIDS (PERCENT)        *        VITAMINS  ETC.        *
*****************************************************************************************************
*                                    *                               *                              *
*CRUDE PROTEIN (PERCENT)     23.080  *  LYSINE             1.148     *  LINOLEIC (PERCENT)    3.104  *
*NITROGEN       (PERCENT)     3.692  *  METH+CYST          0.734     *       MN   (PPM)       14.252  *
*MET.ENERGY KCAL/LB (A)    1337.699  *  ARGININE           1.757     *       ZN   (PPM)       40.540  *
*              KCAL/KG (B) 2948.958  *  GLYCINE            1.085     *   VIT A    (IU/G)       0.190  *
*                                    *  HISTIDINE          0.504     *   VIT B2   (PPM)        2.433  *
*ENERGY/PROTEIN       (A)    57.957  *  LEUCINE            1.692     *   VIT B12 (PPTM)       12.073  *
*                     (B)   127.767  *  ISOLEUCINE         0.847     *   VIT E    (PPM)        5.492  *
*                                    *  PHE+TYR            1.701     *                              *
*CALCIUM (PERCENT)            0.963  *  THREONINE          0.782     *                              *
*                                    *  TRYPTOPHAN         0.181     *                              *
*PHOSPHORUS (PERCENT)         1.038  *  VALINE             1.046     *                              *
*                                    *                               *                              *
*CHOLINE (MG/KG)           1101.599  *                               *                              *
*                                    *                               *                              *
*****************************************************************************************************
```

```
                                                        ****   TABLE  4   ****
****************************
*                          *
*  COMPOSITION OF DIET     *
*                          *
****************************
*  FOOD          PERCENT   *
*                          *
*  MAIZE          40.000   *
*                          *
*BEANS(S+W)       30.000   *          BROILER EXPERIMENT  1        STARTER DIET  1D
*                          *
*GROUNDNUT        19.800   *
*                          *
*HERRING M.        5.300   *       NOTE
*                          *
*  CA.HPO4         2.350   *          VITAMIN/TRACE MINERAL CONTENTS DONT INCLUDE P.R.C. SUPPLEMENT
*                          *
* CORN OIL         1.430   *          BEAN MIXTURE IS EQUAL PARTS SPRING AND WINTER
*                          *
*  CA.CO3          0.470   *          CORN OIL MIXED WITH BEEF DRIPPING BEFORE USE
*                          *
*  SALT            0.250   *          ALL FOODSTUFFS ARE FEED GRADE
*                          *
*METHIONINF        0.160   *
*                          *
*                 ------   *
* TOTAL           99.759   *
**************************************************************************************************
*                                  *                            *                                *
*      DIET SPECIFICATION          *  AMINO ACIDS (PERCENT)     *          VITAMINS  ETC.        *
**************************************************************************************************
*                                  *                            *                                *
*CRUDF PROTEIN (PERCENT)    23.951 *  LYSINE            1.090   *  LINOLEIC (PERCENT)      2.134 *
*NITROGEN      (PERCENT)     3.832 *  METH+CYST         0.746   *        MN    (PPM)     17.225 *
*MFT.FNERGY KCAL/LB (A)   1316.589 *  ARGININE          1.912   *        ZN    (PPM)     43.311 *
*           KCAL/KG (B)   2902.421 *  GLYCINE           1.190   *    VIT A    (IU/G)      0.259 *
*                                  *  HISTIDINE         0.545   *    VIT B2   (PPM)       2.282 *
*ENERGY/PROTEIN      (A)    54.969 *  LEUCINE           1.782   *    VIT B12 (PPTM)      12.819 *
*                    (B)   121.181 *  ISOLEUCINE        0.863   *    VIT E    (PPM)       3.504 *
*                                  *  PHE+TYR           1.760   *                                *
*CALCIUM (PERCENT)           0.957 *  THREONINE         0.778   *                                *
*                                  *  TRYPTOPHAN        0.186   *                                *
*PHOSPHORUS (PERCENT)        1.083 *  VALINE            1.094   *                                *
*                                  *                            *                                *
*CHOLINE (MG/KG)          1165.239 *                            *                                *
*                                  *                            *                                *
**************************************************************************************************
```

```
                                                       ****   TABLE   5   ****
****************************
*                          *
*  COMPOSITION OF DIET     *
*                          *
****************************
*  FOOD         PERCENT    *
*                          *
*BEANS(S+W)      45.000    *
*                          *
*  MAIZE          25.700    *             BROILER EXPERIMENT  1        STARTER DIET  1E
*                          *
*GROUNDNUT       16.900    *
*                          *
*HERRING M.       5.000    *        NOTE
*                          *
* CORN OIL        3.860    *             VITAMIN/TRACE MINERAL CONTENTS DONT INCLUDE P.R.C. SUPPLEMENT
*                          *
*  CA.HPO4        2.350    *             BEAN MIXTURE IS EQUAL PARTS SPRING AND WINTER
*                          *
*  CA.CO3         0.450    *             CORN OIL MIXED WITH BEEF DRIPPING BEFORE USE
*                          *
*  SALT           0.250    *             ALL FOODSTUFFS ARE FEED GRADE
*                          *
*METHIONINE       0.230    *
*                          *
*                ------    *
* TOTAL          99.739    *
***********************************************************************************************************
*                                        *                           *                                    *
*       DIET SPECIFICATION               *   AMINO ACIDS (PERCENT)   *           VITAMINS  ETC.           *
***********************************************************************************************************
*                                        *                           *                                    *
*CRUDE PROTEIN (PERCENT)        25.191   *   LYSINE         1.218    *   LINOLEIC (PERCENT)       3.092   *
*NITROGEN      (PERCENT)         4.030   *   METH+CYST      0.761    *         MN   (PPM)        17.001   *
*MET.ENERGY KCAL/LB (A)       1322.879   *   ARGININE       1.999    *         ZN   (PPM)        43.532   *
*            KCAL/KG (B)      2916.287   *   GLYCINE        1.209    *     VIT A   (IU/G)        0.179   *
*                                        *   HISTIDINE      0.553    *     VIT B2   (PPM)        2.499   *
*ENERGY/PROTEIN      (A)        52.513   *   LEUCINE        1.801    *     VIT B12 (PPTM)       12.068   *
*                    (B)       115.765   *   ISOLEUCINE     0.916    *     VIT E    (PPM)        5.251   *
*                                        *   PHE+TYR        1.830    *                                    *
*CALCIUM (PERCENT)               0.962   *   THREONINE      0.837    *                                    *
*                                        *   TRYPTOPHAN     0.201    *                                    *
*PHOSPHORUS (PERCENT)            1.097   *   VALINE         1.138    *                                    *
*                                        *                           *                                    *
*CHOLINE (MG/KG)              1176.559   *                           *                                    *
*                                        *                           *                                    *
***********************************************************************************************************
```

```
                                                                      ****   TABLE  6   ****
*************************
*                       *
*  COMPOSITION OF DIET  *
*                       *
*************************
*  FOOD        PERCENT  *
*                       *
*  MAIZE        39.000  *
*                       *
*  WHEAT        28.000  *                  BROILER EXPERIMENT  2       STARTER DIET  2A
*                       *
*MEAT+BONE      20.000  *
*                       *
 HERRING M.      5.600            NOTE
*                       *
*GROUNDNUT       5.000  *                  VITAMIN/TRACE MINERAL CONTENTS DONT INCLUDE P.R.C. SUPPLEMENT
*                       *
*  SALT          0.250  *                  CHOLINE CHLORIDE IS 50 PERCENT,FEED GRADE
*                       *
*METHIONINE      0.050  *                  DIET CONTAINS COCCIDIOSTAT
*                       *
*CHOL.CHLOR      0.050  *                  ALL FOODSTUFFS ARE FEED GRADE
*                       *
*               ------  *
* TOTAL         97.949  *
**************************************************************************************************************
*                                    *                             *                                         *
*       DIET SPECIFICATION           *  AMINO ACIDS (PERCENT)      *            VITAMINS  ETC.               *
**************************************************************************************************************
*                                    *                             *                                         *
*CRUDE PROTEIN (PERCENT)     21.358  *  LYSINE           1.105     *  LINOLEIC (PERCENT)        1.198       *
*NITROGEN      (PERCENT)      3.417  *  METH+CYST        0.795     *        MN   (PPM)         15.680       *
*MET.ENERGY KCAL/LB (A)    1358.739  *  ARGININE         1.573     *        ZN   (PPM)         48.226       *
*             KCAL/KG (B)  2995.340  *  GLYCINE          2.056     *    VIT A    (IU/G)         0.321       *
*                                    *  HISTIDINE        0.493     *    VIT B2   (PPM)          2.410       *
*ENERGY/PROTEIN      (A)     63.617  *  LEUCINE          1.680     *    VIT B12 (PPTM)         22.630       *
*                    (B)    140.243  *  ISOLEUCINE       0.822     *    VIT E    (PPM)          6.375       *
*                                    *  PHE+TYR          1.643     *                                         *
*CALCIUM (PERCENT)            1.673  *  THREONINE        0.755     *                                         *
*                                    *  TRYPTOPHAN       0.158     *                                         *
*PHOSPHORUS (PERCENT)         1.245  *  VALINE           1.114     *                                         *
*                                    *                             *                                         *
*CHOLINE (MG/KG)           1393.699  *                             *                                         *
*                                    *                             *                                         *
**************************************************************************************************************
```

```
                                                    ****   TABLE  7   ****
****************************
*                          *
*  COMPOSITION OF DIET     *
*                          *
****************************
*  FOOD         PERCENT    *
*                          *
*  MAIZE         45.000    *
*                          *
*BEANS(S+W)      30.000    *          BROILER EXPERIMENT  2       STARTER DIET  2B
*                          *
*HERRING M.       7.500    *
*                          *
*MEAT+BONE        7.000    *      NOTE
*                          *
*GROUNDNUT        5.000    *          VITAMIN/TRACE MINERAL CONTENTS DONT INCLUDE P.R.C. SUPPLEMENT
*                          *
* CORN OIL        1.800    *          BEAN MIXTURE IS EQUAL PARTS SPRING AND WINTER
*                          *
*  CA.CO3         0.300    *          CHOLINE CHLORIDE IS 50 PERCENT,FEED GRADE
*                          *
*  SALT           0.250    *          DIET CONTAINS COCCIDIOSTAT
*                          *
*METHIONINE       0.200    *
*                          *
*CHOL.CHLOR       0.067    *
*                          *
*  CA.HPO4        0.050    *
*                          *
*               ------     *
* TOTAL          97.166    *
***********************************************************************************************
*                                        *                          *                         *
*       DIET SPECIFICATION               *  AMINO ACIDS (PERCENT)   *       VITAMINS  ETC.    *
***********************************************************************************************
*                                        *                          *                         *
*CRUDE PROTEIN (PERCENT)       22.320    *  LYSINE         1.193    * LINOLEIC (PERCENT)  2.170  *
*NITROGEN      (PERCENT)        3.571    *  METH+CYST      0.762    *       MN   (PPM)   10.304  *
*MET.ENERGY KCAL/LB (A)      1339.449    *  ARGININE       1.600    *       ZN   (PPM)   42.779  *
*             KCAL/KG (B)    2952.814    *  GLYCINE        1.410    *   VIT A    (IU/G)   0.240  *
*                                        *  HISTIDINE      0.489    *   VIT B2   (PPM)    2.580  *
*ENERGY/PROTEIN       (A)      60.008    *  LEUCINE        1.736    *   VIT B12 (PPTM)   21.174  *
*                     (B)     132.288    *  ISOLEUCINE     0.846    *   VIT E    (PPM)    4.170  *
*                                        *  PHE+TYR        1.655    *                         *
*CALCIUM (PERCENT)              0.924    *  THREONINE      0.785    *                         *
*                                        *  TRYPTOPHAN     0.164    *                         *
*PHOSPHORUS (PERCENT)           0.853    *  VALINE         1.074    *                         *
*                                        *                          *                         *
*CHOLINE (MG/KG)             1411.949    *                          *                         *
*                                        *                          *                         *
***********************************************************************************************
```

```
                                                        ****   TABLE  8   ****
****************************
*                          *
*  COMPOSITION OF DIET     *
*                          *
****************************
*  FOOD         PERCENT    *
*                          *
*BEANS(S+W)      45.000    *
*                          *
*  MAIZE         33.500    *              BROILER EXPERIMENT  2        STARTER DIET  2C
*                          *
*HERRING M.       7.000    *
*                          *
*GROUNDNUT        5.000    *         NOTE
*                          *
* CORN OIL        3.300    *              VITAMIN/TRACE MINERAL CONTENTS DONT INCLUDE P.R.C. SUPPLEMENT
*                          *
*MEAT+BONE        3.000    *              BEAN MIXTURE IS EQUAL PARTS SPRING AND WINTER
*                          *
*  CA.CO3         1.000    *              CHOLINE CHLORIDE IS 50 PERCENT,FEED GRADE
*                          *
*  CA.HPO4        1.000    *              DIET CONTAINS COCCIDIOSTAT
*                          *
*METHIONINE       0.250    *
*                          *
*  SALT           0.250    *
*                          *
*CHOL.CHLOR       0.080    *
*                          *
*                -------   *
* TOTAL          99.379    *
*****************************************************************************************************
*                                           *                              *                        *
*        DIET SPECIFICATION                 *  AMINO ACIDS (PERCENT)       *     VITAMINS  ETC.     *
*****************************************************************************************************
*                                           *                              *                        *
*CRUDE PROTEIN (PERCENT)         23.173     *  LYSINE            1.248     *  LINOLEIC (PERCENT)       2.746   *
*NITROGEN      (PERCENT)          3.707     *  METH+CYST         0.752     *      MN    (PPM)         11.562   *
*MET.ENERGY KCAL/LB (A)        1336.199     *  ARGININE          1.677     *      ZN    (PPM)         41.739   *
*              KCAL/KG (B)     2945.650     *  GLYCINE           1.225     *   VIT A    (IU/G)         0.182   *
*                                           *  HISTIDINE         0.497     *   VIT B2    (PPM)         2.662   *
*ENERGY/PROTEIN       (A)        57.660     *  LEUCINE           1.730     *   VIT B12 (PPTM)        18.191   *
*                     (B)       127.111     *  ISOLEUCINE        0.875     *   VIT E     (PPM)         5.179   *
*                                           *  PHE+TYR           1.710     *                        *
*CALCIUM (PERCENT)                1.135     *  THREONINE         0.815     *                        *
*                                           *  TRYPTOPHAN        0.177     *                        *
*PHOSPHORUS (PERCENT)             0.902     *  VALINE            1.082     *                        *
*                                           *                              *                        *
*CHOLINE (MG/KG)               1447.499     *                              *                        *
*                                           *                              *                        *
*****************************************************************************************************
```

```
                                                      ****   TABLE 9   ****
****************************
*                          *
*  COMPOSITION OF DIET     *
*                          *
****************************
*  FOOD          PERCENT   *
*                          *
*  MAIZE          40.000   *
*                          *
*BEANS(S+W)       30.000   *          BROILER EXPERIMENT  2      STARTER DIET  2D
*                          *
*MEAT+BONE        13.000   *
*                          *
*HERRING M.        6.000   *     NOTE
*                          *
*GROUNDNUT         5.000   *          VITAMIN/TRACE MINERAL CONTENTS DONT INCLUDE P.R.C. SUPPLEMENT
*                          *
* CORN OIL         2.500   *          BEAN MIXTURE IS EQUAL PARTS SPRING AND WINTER
*                          *
*  SALT            0.250   *          CHOLINE CHLORIDE IS 50 PERCENT.FEED GRADE
*                          *
*  LYSINE          0.200   *          DIET CONTAINS COCCIDIOSTAT
*                          *
*METHIONINE        0.200   *
*                          *
*CHOL.CHLOR        0.046   *
*                          *
*                 ------   *
* TOTAL           97.195   *
********************************************************************************************************
*                                      *                          *                                    *
*      DIET SPECIFICATION              *  AMINO ACIDS (PERCENT)   *          VITAMINS  ETC.            *
********************************************************************************************************
*                                      *                          *                                    *
*CRUDE PROTEIN (PERCENT)       23.817  *  LYSINE          1.472   *  LINOLEIC (PERCENT)        2.447   *
*NITROGEN      (PERCENT)        3.810  *  METH+CYST       0.775   *        MN   (PPM)        10.119   *
*MET.ENERGY KCAL/LB (A)      1340.999  *  ARGININE        1.744   *        ZN   (PPM)        45.684   *
*             KCAL/KG (B)    2956.232  *  GLYCINE         1.760   *    VIT A    (IU/G)        0.215   *
*                                      *  HISTIDINE       0.510   *    VIT B2   (PPM)         2.708   *
*ENERGY/PROTEIN      (A)       56.301  *  LEUCINE         1.806   *    VIT B12 (PPTM)        20.204   *
*                    (B)      124.117  *  ISOLEUCINE      0.892   *    VIT E    (PPM)         4.510   *
*                                      *  PHE+TYR         1.726   *                                    *
*CALCIUM (PERCENT)              1.201  *  THREONINE       0.836   *                                    *
*                                      *  TRYPTOPHAN      0.177   *                                    *
*PHOSPHORUS (PERCENT)           1.051  *  VALINE          1.146   *                                    *
*                                      *                          *                                    *
*CHOLINE (MG/KG)             1374.799  *                          *                                    *
*                                      *                          *                                    *
********************************************************************************************************
```

```
                                                         ****   TABLE 10   ****
**************************
*                        *
*  COMPOSITION OF DIET   *
*                        *
**************************
*  FOOD         PERCENT  *
*                        *
*BEANS(S+W)      45.000  *
*                        *
*  MAIZE         33.000  *              BROILER EXPERIMENT  2        STARTER DIET  2E
*                        *
*HERRING M.       8.500  *
*                        *
*GROUNDNUT        5.000  *          NOTE
*                        *
*MEAT+BONE        5.000  *              VITAMIN/TRACE MINERAL CONTENTS DONT INCLUDE P.R.C. SUPPLEMENT
*                        *
* CORN OIL        2.300  *              BEAN MIXTURE IS EQUAL PARTS SPRING AND WINTER
*                        *
*  CA.CO3         0.500  *              DIET CONTAINS COCCIDIOSTAT
*                        *
*  CA.HPO4        0.500  *              CHOLINE CHLORIDE IS 50 PERCENT,FEED GRADE
*                        *
*  SALT           0.250  *
*                        *
*METHIONINE       0.200  *
*                        *
*CHOL.CHLOR       0.067  *
*                        *
*                ------  *
* TOTAL         100.316  *
***************************************************************************************************
*                                     *                              *                            *
*      DIET SPECIFICATION             *   AMINO ACIDS (PERCENT)      *       VITAMINS  ETC.       *
***************************************************************************************************
*                                     *                              *                            *
*CRUDE PROTEIN (PERCENT)      24.925  *   LYSINE           1.374     *  LINOLEIC (PERCENT)  2.226 *
*NITROGEN      (PERCENT)       3.988  *   METH+CYST        0.757     *        MN   (PPM)   11.764 *
*MET.ENERGY KCAL/LB (A)     1334.799  *   ARGININE         1.805     *        ZN   (PPM)   45.275 *
*           KCAL/KG (B)     2942.564  *   GLYCINE          1.417     *    VIT A    (IU/G)   0.180 *
*                                     *   HISTIDINE        0.534     *    VIT B2    (PPM)   2.897 *
*ENERGY/PROTEIN       (A)     53.550  *   LEUCINE          1.860     *    VIT B12  (PPTM)  22.670 *
*                     (B)    118.052  *   ISOLEUCINE       0.951     *    VIT E     (PPM)   4.349 *
*                                     *   PHE+TYR          1.830     *                            *
*CALCIUM (PERCENT)             1.010  *   THREONINE        0.884     *                            *
*                                     *   TRYPTOPHAN       0.190     *                            *
*PHOSPHORUS (PERCENT)          0.930  *   VALINE           1.183     *                            *
*                                     *                              *                            *
*CHOLINE (MG/KG)            1499.849  *                              *                            *
*                                     *                              *                            *
***************************************************************************************************
```

```
                                                          ****   TABLE 11   ****
**************************
*                        *
*  COMPOSITION OF DIET   *
*                        *
**************************
*  FOOD         PERCENT  *
*                        *
*  WHEAT         40.000  *
*                        *
*   MILO         26.000  *         BROILER EXPERIMENT  2       FINISHER DIET  2F
*                        *
*SOYA BEAN       17.000  *
*                        *
*MEAT+BONE       10.000  *      NOTE
*                        *
* CORN OIL        5.000  *         VITAMIN/TRACE MINERAL CONTENTS DONT INCLUDE P.R.C. SUPPLEMENT
*                        *
*  CA.HPO4        1.500  *         BEAN MIXTURE IS EQUAL PARTS SPRING AND WINTER
*                        *
*  SALT           0.250  *         DIET CONTAINS COCCIDIOSTAT
*                        *
*  LYSINF         0.100  *         CHOLINE CHLORIDE IS 50 PERCENT,FEED GRADE
*                        *
*METHIONINE       0.050  *
*                        *
*                ------  *
* TOTAL          99.899  *
*******************************************************************************************
*                                  *                         *                            *
*      DIET SPECIFICATION          *  AMINO ACIDS (PERCENT)  *        VITAMINS  ETC.      *
*******************************************************************************************
*                                  *                         *                            *
*CRUDE PROTEIN (PERCENT)    19.098 *  LYSINE         1.060   *  LINOLEIC (PERCENT)   3.261 *
*NITROGFN      (PFRCENT)     3.055 *  METH+CYST      0.760   *        MN   (PPM)   21.964 *
*MFT.FNERGY KCAL/LB (A)   1444.999 *  ARGININE       1.335   *        ZN   (PPM)   43.954 *
*           KCAL/KG (B)   3185.500 *  GLYCINE        1.353   *    VIT A   (IU/G)    0.348 *
*                                  *  HISTIDINE      0.477   *    VIT B2  (PPM)     1.935 *
*FNERGY/PROTEIN     (A)     75.658 *  LEUCINE        1.547   *    VIT B12 (PPTM)    4.840 *
*                   (B)    166.788 *  ISOLEUCINE     0.801   *    VIT E   (PPM)    11.816 *
*                                  *  PHE+TYR        1.685   *                            *
*CALCIUM (PFRCENT)           1.173 *  THREONINE      0.724   *                            *
*                                  *  TRYPTOPHAN     0.195   *                            *
*PHOSPHORUS (PERCENT)        1.026 *  VALINE         0.984   *                            *
*                                  *                         *                            *
*CHOLINE (MG/KG)          1110.199 *                         *                            *
*                                  *                         *                            *
*******************************************************************************************
```

**** TABLE 12 ****

DUCKLING EXPERIMENT 5 - CONTROL DIET , 3 TO 8 WEEKS

COMPOSITION OF DIET

FOOD	PERCENT
MAIZE	40.000
WHEAT	33.150
SOYA BEAN	11.500
MEAT+BONE	7.000
HERRING M.	4.000
CA.CO3	1.500
CA.HPO4	1.000
CORN OIL	1.000
COLB. 206	0.450
SALT	0.200
LYSINE	0.200

TOTAL	100.000

NOTE

ALL FOODSTUFFS ARE FEED GRADE MEALS.

VITAMIN/TR.MINERAL CONTENTS DONT INCLUDE COLBORN 206 CONTRIBUTION

DIET PREPARED AS PELLETS

DIET SPECIFICATION		AMINO ACIDS (PERCENT)		VITAMINS ETC.	
CRUDE PROTEIN (PERCENT)	18.212	LYSINE	1.132	LINOLEIC (PERCENT)	1.681
NITROGEN (PERCENT)	2.913	METH+CYST	0.696	MN (PPM)	17.264
MET.ENERGY KCAL/LB (A)	1384.669	ARGININE	1.231	ZN (PPM)	37.910
KCAL/KG (B)	3052.502	GLYCINE	1.224	VIT A (IU/G)	0.337
		HISTIDINE	0.457	VIT B2 (PPM)	1.995
ENERGY/PROTEIN (A)	76.030	LEUCINE	1.498	VIT B12 (PPTM)	13.124
(B)	167.609	ISOLEUCINE	0.744	VIT E (PPM)	8.135
		PHE+TYR	1.591		
CALCIUM (PERCENT)	1.517	THREONINE	0.665		
		TRYPTOPHAN	0.151		
PHOSPHORUS (PERCENT)	0.873	VALINE	0.922		
CHOLINE (MG/KG)	1131.294				

```
                                                         ****   TABLE  13   ****
***************************
*                         *
*  COMPOSITION OF DIET    *
*                         *
***************************
*  FOOD          PERCENT  *
*                         *
*  MAIZE          40.000  *
*                         *
*  WHEAT          20.650  *          DUCKLING EXPERIMENT 5  -  LOW BEAN DIET , 3 TO 8 WEEKS
*                         *
*BEANS(S+W)       15.000  *
*                         *
*SOYA BEAN         7.000  *      NOTE
*                         *
*MEAT+BONE         7.000  *          VITAMIN/TR.MINERAL CONTENTS DONT INCLUDE COLBORN 206 CONTRIBUTION
*                         *
*HERRING M.        4.000  *          ALL FOODSTUFFS ARE FEED GRADE MEALS.
*                         *
* CORN OIL         3.000  *          BEAN MEAL IS EQUAL PARTS SPRING AND WINTER TYPES.
*                         *
*  CA.CO3          1.500  *          DIET PREPARED AS PELLETS
*                         *
*  CA.HPO4         1.000  *
*                         *
*COLB. 206         0.450  *
*                         *
*  SALT            0.200  *
*                         *
*  LYSINE          0.200  *
*                         *
*                 ------  *
* TOTAL          100.000  *
****************************************************************************************************
*                                      *                             *                             *
*      DIET SPECIFICATION              *  AMINO ACIDS (PERCENT)      *        VITAMINS  ETC.       *
****************************************************************************************************
*                                      *                             *                             *
*CRUDE PROTEIN (PERCENT)       18.809  *  LYSINE           1.183     *  LINOLEIC (PERCENT)   2.682  *
*NITROGEN      (PERCENT)        3.009  *  METH+CYST        0.596     *        MN   (PPM)    13.897  *
*MET.ENERGY KCAL/LB (A)      1402.719  *  ARGININE         1.294     *        ZN   (PPM)    37.817  *
*           KCAL/KG (B)      3092.293  *  GLYCINE          1.229     *   VIT A    (IU/G)     0.285  *
*                                      *  HISTIDINE        0.444     *   VIT B2   (PPM)      2.143  *
*ENERGY/PROTEIN      (A)       74.574  *  LEUCINE          1.512     *   VIT B12  (PPTM)    12.987  *
*                    (B)      164.400  *  ISOLEUCINE       0.744     *   VIT E    (PPM)      8.049  *
*                                      *  PHE+TYR          1.551     *                             *
*CALCIUM (PERCENT)              1.524  *  THREONINE        0.682     *                             *
*                                      *  TRYPTOPHAN       0.150     *                             *
*PHOSPHORUS (PERCENT)           0.893  *  VALINE           0.926     *                             *
*                                      *                             *                             *
*CHOLINE (MG/KG)             1078.744  *                             *                             *
*                                      *                             *                             *
****************************************************************************************************
```

```
                                                   ****   TABLE  14   ****
****************************
*                          *
*  COMPOSITION OF DIET     *
*                          *
****************************
*  FOOD          PERCENT   *
*                          *
*  MAIZE          40.000   *
*                          *
*BEANS(S+W)       30.000   *          DUCKLING EXPERIMENT 5  -  HIGH BEAN DIET . 3 TO 8 WEEKS
*                          *
*  WHEAT          12.450   *
*                          *
*MEAT+BONE         7.000   *       NOTE
*                          *
*HERRING M.        4.000   *          VITAMIN/TR.MINERAL CONTENTS DONT INCLUDE COLBORN 206 CONTRIBUTION
*                          *
* CORN OIL         3.000   *          ALL FOODSTUFFS ARE FEED GRADE MEALS.
*                          *
*  CA.CO3          1.500   *          BEAN MEAL IS EQUAL PARTS SPRING AND WINTER TYPES.
*                          *
*  CA.HPO4         1.000   *          DIET PREPARED AS PELLETS
*                          *
*COLB. 206         0.450   *
*                          *
*  SALT            0.200   *
*                          *
*  LYSINE          0.200   *
*                          *
*METHIONINE        0.200   *
*                          *
*                 ------   *
* TOTAL          100.000   *
***********************************************************************************************
*                                    *                             *                          *
*      DIET SPECIFICATION            *  AMINO ACIDS (PERCENT)      *      VITAMINS  ETC.      *
***********************************************************************************************
*                                    *                             *                          *
*CRUDE PROTEIN (PERCENT)     18.938  *  LYSINE          1.179      *  LINOLEIC (PERCENT)     2.655  *
*NITROGEN      (PERCENT)      3.030  *  METH+CYST       0.687      *        MN   (PPM)      11.337  *
*MET.ENERGY KCAL/LB (A)    1369.609  *  ARGININE        1.301      *        ZN   (PPM)      37.788  *
*          KCAL/KG (B)     3019.303  *  GLYCINE         1.204      *    VIT A   (IU/G)      0.249  *
*                                    *  HISTIDINE       0.414      *    VIT B2  (PPM)       2.237  *
*ENERGY/PROTEIN      (A)     72.320  *  LEUCINE         1.470      *    VIT B12 (PPTM)     12.896  *
*                    (B)    159.429  *  ISOLEUCINE      0.710      *    VIT E   (PPM)       6.831  *
*                                    *  PHE+TYR         1.454      *                          *
*CALCIUM (PERCENT)            1.525  *  THREONINE       0.669      *                          *
*                                    *  TRYPTOPHAN      0.141      *                          *
*PHOSPHORUS (PERCENT)         0.914  *  VALINE          0.899      *                          *
*                                    *                             *                          *
*CHOLINE (MG/KG)            986.584  *                             *                          *
*                                    *                             *                          *
***********************************************************************************************
```

```
                                                       ****   TABLE  15   ****
****************************
*                          *
*  COMPOSITION OF DIET     *
*                          *
****************************
*  FOOD          PERCENT   *
*                          *
*  MAIZE          40.000   *
*                          *
*BEANS(S+W)       30.000   *        DUCKLING EXPERIMENT 5  -  HIGH BEAN DIET + METHIONINE
*                          *
*  WHEAT          12.250   *
*                          *
*MEAT+BONE         7.000   *     NOTE
*                          *
*HERRING M.        4.000   *        VITAMIN/TR.MINERAL CONTENTS DONT INCLUDE COLBORN 206 CONTRIBUTION
*                          *
* CORN OIL         3.000   *        ALL FOODSTUFFS ARE FEED GRADE MEALS.
*                          *
*  CA.CO3          1.500   *        BEAN MEAL IS EQUAL PARTS SPRING AND WINTER TYPES.
*                          *
*  CA.HPO4         1.000   *        DIET PREPARED AS PELLETS
*                          *
*COLB. 206         0.450   *
*                          *
*METHIONINE        0.400   *
*                          *
*  SALT            0.200   *
*                          *
*  LYSINE          0.200   *
*                          *
*                 ------   *
* TOTAL          100.000   *
*****************************************************************************************************
*                                       *                            *                              *
*      DIET SPECIFICATION               *  AMINO ACIDS (PERCENT)     *        VITAMINS  ETC.        *
*****************************************************************************************************
*                                       *                            *                              *
*CRUDE PROTEIN (PERCENT)        19.112  *  LYSINE          1.179     *  LINOLEIC (PERCENT)    2.654  *
*NITROGEN      (PERCENT)         3.058  *  METH+CYST       0.882     *        MN    (PPM)   11.269  *
*MET.ENERGY KCAL/LB (A)       1366.849  *  ARGININE        1.300     *        ZN    (PPM)   37.724  *
*              KCAL/KG (B)    3013.218  *  GLYCINE         1.203     *    VIT A    (IU/G)    0.248  *
*                                       *  HISTIDINE       0.413     *    VIT B2    (PPM)    2.235  *
*ENERGY/PROTEIN       (A)       71.515  *  LEUCINE         1.468     *    VIT B12 (PPTM)    12.894  *
*                     (B)      157.654  *  ISOLEUCINE      0.709     *    VIT E     (PPM)    6.799  *
*                                       *  PHE+TYR         1.451     *                              *
*CALCIUM (PERCENT)               1.525  *  THREONINE       0.668     *                              *
*                                       *  TRYPTOPHAN      0.141     *                              *
*PHOSPHORUS (PERCENT)            0.913  *  VALINE          0.898     *                              *
*                                       *                            *                              *
*CHOLINE (MG/KG)               985.124  *                            *                              *
*                                       *                            *                              *
*****************************************************************************************************
```

```
                                                           ****   TABLE 16   ****
***************************
*                         *
*  COMPOSITION OF DIET    *
*                         *
***************************
*  FOOD          PERCENT  *
*                         *
*SOYA BEAN       56.000   *
*                         *
*  MAIZE         35.500   *             TURKEY EXPERIMENT 6 -  CONTROL DIET , 0 TO 6 WEEKS
*                         *
*  CA.HPO4        4.500   *
*                         *
* CORN OIL        1.540   *        NOTE
*                         *
*  CA.CO3         1.000   *             VITAMIN/TR.MINERAL CONTENTS DONT INCLUDE COLBORN 204 CONTRIBUTION
*                         *
*  LYSINE         0.500   *             ALL FOODSTUFFS ARE FEED GRADE MEALS.
*                         *
*COLB. 204        0.450   *             DIET PREPARED AS PELLETS
*                         *
*METHIONINE       0.300   *
*                         *
*  SALT           0.200   *
*                         *
*                ------   *
* TOTAL          99.989   *
*******************************************************************************************************
*                                      *                          *                                   *
*      DIET SPECIFICATION              *  AMINO ACIDS (PERCENT)   *           VITAMINS  ETC.          *
*******************************************************************************************************
*                                      *                          *                                   *
*CRUDE PROTEIN (PERCENT)       29.196  *  LYSINE          2.165   *   LINOLEIC (PERCENT)      1.881   *
*NITROGEN      (PERCENT)        4.671  *  METH+CYST       1.177   *         MN   (PPM)       16.792   *
*MET.ENERGY KCAL/LB (A)      1280.849  *  ARGININE        2.092   *         ZN   (PPM)       38.168   *
*           KCAL/KG (B)      2823.632  *  GLYCINE         1.323   *     VIT A    (IU/G)       0.199   *
*                                      *  HISTIDINE       0.760   *     VIT B2   (PPM)        2.630   *
*ENERGY/PROTEIN     (A)        43.869  *  LEUCINE         2.353   *     VIT B12 (PPTM)       0.070   *
*                   (B)        96.710  *  ISOLEUCINE      1.286   *     VIT E    (PPM)        3.253   *
*                                      *  PHE+TYR         2.679   *                                   *
*CALCIUM (PERCENT)              1.617  *  THREONINE       1.125   *                                   *
*                                      *  TRYPTOPHAN      0.303   *                                   *
*PHOSPHORUS (PERCENT)           1.246  *  VALINE          1.364   *                                   *
*                                      *                          *                                   *
*CHOLINE (MG/KG)             1810.499  *                          *                                   *
*                                      *                          *                                   *
*******************************************************************************************************
```

```
                                                      ****   TABLE  17   ****
****************************
*                          *
*  COMPOSITION OF DIET     *
*                          *
****************************
*  FOOD          PERCENT   *
*                          *
*  WHEAT          30.500   *
*                          *
*SOYA BEAN        30.000   *          TURKEY EXPERIMENT 6 -  CONTROL DIET , 6 TO 10 WEEKS
*                          *
*  MAIZE          20.000   *
*                          *
*HERRING M.        5.000   *       NOTE
*                          *
*MEAT+BONE         5.000   *          VITAMIN/TR.MINERAL CONTENTS DONT INCLUDE COLBORN 204 CONTRIBUTION
*                          *
*  CA.HPO4         3.000   *          ALL FOODSTUFFS ARE FEED GRADE MEALS.
*                          *
* CORN OIL         3.000   *          DIET PREPARED AS PELLETS
*                          *
*  CA.CO3          2.000   *
*                          *
*  LYSINE          0.500   *
*                          *
*  SALT            0.400   *
*                          *
*COLB. 204         0.360   *
*                          *
*METHIONINE        0.200   *
*                          *
*                 ------   *
* TOTAL           99.959   *
**************************************************************************************************
*                                      *                          *                              *
*      DIET SPECIFICATION              *  AMINO ACIDS (PERCENT)   *         VITAMINS  ETC.       *
**************************************************************************************************
*                                      *                          *                              *
*CRUDE PROTEIN (PERCENT)        24.664 *  LYSINE          1.876   *  LINOLEIC (PERCENT)    2.370  *
*NITROGEN      (PERCENT)         3.946 *  METH+CYST       1.043   *        MN   (PPM)     20.180  *
*MET.ENERGY KCAL/LB (A)       1342.899 *  ARGININE        1.708   *        ZN   (PPM)     41.024  *
*              KCAL/KG (B)    2960.420 *  GLYCINE         1.405   *    VIT A    (IU/G)     0.233  *
*                                      *  HISTIDINE       0.616   *    VIT B2   (PPM)      2.470  *
*ENERGY/PROTEIN      (A)        54.446 *  LEUCINE         1.901   *    VIT B12 (PPTM)     14.575  *
*                    (B)       120.027 *  ISOLEUCINE      1.053   *    VIT E    (PPM)      8.919  *
*                                      *  PHE+TYR         2.157   *                              *
*CALCIUM (PERCENT)               2.110 *  THREONINE       0.922   *                              *
*                                      *  TRYPTOPHAN      0.230   *                              *
*PHOSPHORUS (PERCENT)            1.202 *  VALINE          1.211   *                              *
*                                      *                          *                              *
*CHOLINE (MG/KG)              1509.149 *                          *                              *
*                                      *                          *                              *
**************************************************************************************************
```

```
                                                           ****   TABLE  18   ****
***************************
*                         *
*  COMPOSITION OF DIET    *
*                         *
***************************
*  FOOD        PERCENT    *
*                         *
*SOYA BEAN     30.000     *
*                         *
*  WHEAT       29.800     *             TURKEY EXPERIMENT 6 -  LOW BEAN DIET , 6 TO 10 WEEKS
*                         *
*BEANS(S+W)    15.000     *
*                         *
*  MAIZE        9.000     *        NOTE
*                         *
*  CA.HPO4      4.000     *             VITAMIN/TR.MINERAL CONTENTS DONT INCLUDE COLBORN 204 CONTRIBUTION
*                         *
* CORN OIL      4.000     *             ALL FOODSTUFFS ARE FEED GRADE MEALS.
*                         *
*HERRING M.    3.000     *             BEAN MEAL IS EQUAL PARTS SPRING AND WINTER TYPES.
*                         *
*MEAT+BONE     2.000     *             DIET PREPARED AS PELLETS
*                         *
*  CA.CO3       1.500     *
*                         *
*  LYSINE       0.500     *
*                         *
*METHIONINE    0.400     *
*                         *
*  SALT         0.400     *
*                         *
*COLB. 204     0.360     *
*                         *
*               ------    *
* TOTAL         99.959    *
********************************************************************************************************
*                                      *                          *                                    *
*       DIET SPECIFICATION             *   AMINO ACIDS (PERCENT)  *           VITAMINS  ETC.           *
********************************************************************************************************
*                                      *                          *                                    *
*CRUDE PROTEIN (PERCENT)       25.138  *   LYSINE          1.886  *   LINOLEIC (PERCENT)       2.695   *
*NITROGEN      (PERCENT)        4.022  *   METH+CYST       1.155  *         MN   (PPM)        21.116   *
*MET.ENERGY KCAL/LB (A)      1307.089  *   ARGININE        1.765  *         ZN   (PPM)        39.149   *
*           KCAL/KG (B)      2881.478  *   GLYCINE         1.236  *     VIT A   (IU/G)          0.176   *
*                                      *   HISTIDINE       0.612  *     VIT B2   (PPM)          2.467   *
*ENERGY/PROTEIN     (A)        51.996  *   LEUCINE         1.857  *     VIT B12 (PPTM)          8.425   *
*                   (B)       114.626  *   ISOLEUCINE      1.055  *     VIT E    (PPM)          9.297   *
*                                      *   PHE+TYR         2.173  *                                    *
*CALCIUM (PERCENT)              1.886  *   THREONINE       0.931  *                                    *
*                                      *   TRYPTOPHAN      0.240  *                                    *
*PHOSPHORUS (PERCENT)           1.271  *   VALINE          1.188  *                                    *
*                                      *                          *                                    *
*CHOLINE (MG/KG)             1456.039  *                          *                                    *
*                                      *                          *                                    *
********************************************************************************************************
```

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                                                        ****   TABLE  19   ****
***************************
*                         *
*  COMPOSITION OF DIET    *
*                         *
***************************
*  FOOD          PERCENT  *
*                         *
*BEANS(S+W)       30.000  *
*                         *
*  WHEAT          27.500  *            TURKEY EXPERIMENT 6 -  HIGH BEAN DIET , 6 TO 10 WEEKS
*                         *
*SOYA BEAN        24.000  *
*                         *
* CORN OIL         6.000  *        NOTE
*                         *
*  CA.HPO4         3.500  *            VITAMIN/TR.MINERAL CONTENTS DONT INCLUDE COLBORN 204 CONTRIBUTION
*                         *
*HERRING M         3.000  *            ALL FOODSTUFFS ARE FEED GRADE MEALS.
*                         *
*MEAT+BONE         2.000  *            BEAN MEAL IS EQUAL PARTS SPRING AND WINTER TYPES.
*                         *
*  CA.CO3          1.800  *            DIET PREPARED AS PELLETS
*                         *
*METHIONINE        1.000  *
*                         *
*  LYSINE          0.450  *
*                         *
*  SALT            0.400  *
*                         *
*COLB. 204         0.360  *
*                         *
*                 ------  *
* TOTAL          100.009  *
*************************************************************************************************
*                                     *                        *                                *
*       DIET SPECIFICATION            *  AMINO ACIDS (PERCENT) *         VITAMINS  ETC.         *
*************************************************************************************************
*                                     *                        *                                *
*CRUDE PROTEIN (PERCENT)      25.876  *  LYSINE        1.857   *  LINOLEIC (PERCENT)     3.554   *
*NITROGEN      (PERCENT)       4.140  *  METH+CYST     1.655   *        MN   (PPM)     20.344   *
*MET.ENERGY KCAL/LB (A)     1311.699  *  ARGININE      1.802   *        ZN   (PPM)     39.309   *
*           KCAL/KG (B)     2891.640  *  GLYCINE       1.224   *     VIT A   (IU/G)     0.119   *
*                                     *  HISTIDINE     0.590   *     VIT B2  (PPM)      2.568   *
*ENERGY/PROTEIN     (A)       50.690  *  LEUCINE       1.801   *     VIT B12 (PPTM)     8.382   *
*                   (B)      111.747  *  ISOLEUCINE    1.039   *     VIT E   (PPM)     10.471   *
*                                     *  PHE+TYR       2.109   *                                *
*CALCIUM (PERCENT)             1.897  *  THREONINE     0.930   *                                *
*                                     *  TRYPTOPHAN    0.237   *                                *
*PHOSPHORUS (PERCENT)          1.210  *  VALINE        1.179   *                                *
*                                     *                        *                                *
*CHOLINE (MG/KG)            1379.549  *                        *                                *
*                                     *                        *                                *
*************************************************************************************************
```

```
                                                                    ****   TABLE  20   ****
***************************
*                         *
*  COMPOSITION OF DIET    *
*                         *
***************************
*  FOOD          PERCENT  *
*                         *
*BEANS(S+W)       30.000  *
*                         *
*  WHEAT          27.200  *          TURKEY EXPERIMENT 6 -  HIGH BEAN DIET + METHIONINE
*                         *
*SOYA BEAN        24.000  *
*                         *
* CORN OIL         6.000  *       NOTE
*                         *
*  CA.HPO4         3.500  *          VITAMIN/TR.MINERAL CONTENTS DONT INCLUDE COLBORN 204 CONTRIBUTION
*                         *
*HERRING M.        3.000  *          ALL FOODSTUFFS ARE FEED GRADE MEALS.
*                         *
*MEAT+BONE         2.000  *          BEAN MEAL IS EQUAL PARTS SPRING AND WINTER TYPES.
*                         *
*  CA.CO3          1.800  *          DIET PREPARED AS PELLETS
*                         *
*METHIONINE        1.300  *
*                         *
*  LYSINE          0.450  *
*                         *
*  SALT            0.400  *
*                         *
*COLB. 204         0.360  *
*                         *
*                 ------  *
* TOTAL          100.009  *
****************************************************************************************************
*                                        *                           *                             *
*       DIET SPECIFICATION               *  AMINO ACIDS (PERCENT)    *        VITAMINS  ETC.       *
****************************************************************************************************
*                                        *                           *                             *
*CRUDE PROTEIN (PERCENT)        26.138   *  LYSINE          1.856    *  LINOLEIC (PERCENT)    3.553 *
*NITROGEN      (PERCENT)         4.182   *  METH+CYST       1.947    *        MN    (PPM)    20.242 *
*MET.ENERGY KCAL/LB (A)       1307.559   *  ARGININE        1.800    *        ZN    (PPM)    39.213 *
*           KCAL/KG (B)       2882.514   *  GLYCINE         1.223    *    VIT A    (IU/G)     0.118 *
*                                        *  HISTIDINE       0.589    *    VIT B2    (PPM)     2.565 *
*ENERGY/PROTEIN     (A)         50.024   *  LEUCINE         1.799    *    VIT B12 (PPTM)     8.379 *
*                   (B)        110.278   *  ISOLEUCINE      1.038    *    VIT E     (PPM)    10.423 *
*                                        *  PHE+TYR         2.106    *                             *
*CALCIUM (PERCENT)               1.897   *  THREONINE       0.929    *                             *
*                                        *  TRYPTOPHAN      0.237    *                             *
*PHOSPHORUS (PERCENT)            1.209   *  VALINE          1.178    *                             *
*                                        *                           *                             *
*CHOLINE (MG/KG)              1377.359   *                           *                             *
*                                        *                           *                             *
****************************************************************************************************
```

```
                                                   ****   TABLE  21   ****
****************************
*                          *
*  COMPOSITION OF DIET     *
*                          *
****************************
*  FOOD         PERCENT    *
*                          *
*  MAIZE         37.000    *
*                          *
*SOYA BEAN       33.000    *      TURKEY EXPERIMENT 6 -  CONTROL DIET , 10 TO 16 WEEKS
*                          *
*  BARLEY        19.800    *
*                          *
*WH.FISH M.       3.000    *   NOTE
*                          *
*  CA.HPO4        2.850    *      VITAMIN/TR.MINERAL CONTENTS DONT INCLUDE COLBORN 204 CONTRIBUTION
*                          *
* CORN OIL        2.300    *      ALL FOODSTUFFS ARE FEED GRADE MEALS.
*                          *
*  CA.CO3         0.900    *      DIET PREPARED AS PELLETS
*                          *
*COLB. 205        0.450    *
*                          *
*  LYSINE         0.320    *
*                          *
*METHIONINE       0.200    *
*                          *
*  SALT           0.200    *
*                          *
*                ------    *
* TOTAL         100.019    *
******************************************************************************************************
*                                      *                            *                                *
*      DIET SPECIFICATION              *  AMINO ACIDS (PERCENT)     *        VITAMINS  ETC.          *
******************************************************************************************************
*                                      *                            *                                *
*CRUDE PROTEIN (PERCENT)       22.646  *  LYSINE          1.567     *  LINOLEIC (PERCENT)      2.350  *
*NITROGEN      (PERCENT)        3.623  *  METH+CYST       0.949     *        MN   (PPM)      13.563  *
*MET.ENERGY KCAL/LB (A)      1337.519  *  ARGININE        1.543     *        ZN   (PPM)      34.807  *
*             KCAL/KG (B)    2948.561  *  GLYCINE         1.077     *    VIT A    (IU/G)      0.336  *
*                                      *  HISTIDINE       0.589     *    VIT B2   (PPM)       2.182  *
*ENERGY/PROTEIN      (A)       59.060  *  LEUCINE         1.854     *    VIT B12  (PPTM)      3.727  *
*                    (B)      130.199  *  ISOLEUCINE      0.998     *    VIT E    (PPM)       5.433  *
*                                      *  PHE+TYR         2.062     *                                *
*CALCIUM (PERCENT)              1.347  *  THREONINE       0.873     *                                *
*                                      *  TRYPTOPHAN      0.236     *                                *
*PHOSPHORUS (PERCENT)           1.006  *  VALINE          1.073     *                                *
*                                      *                            *                                *
*CHOLINE (MG/KG)             1479.379  *                            *                                *
*                                      *                            *                                *
******************************************************************************************************
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                                                  ****   TABLE  22   ****
***************************
*                         *
*  COMPOSITION OF DIET    *
*                         *
***************************
*  FOOD         PERCENT   *
*                         *
*  MAIZE        25.000    *
*                         *
*SOYA BEAN      24.000    *          TURKEY EXPERIMENT 6 -  BEAN DIET  , 10 TO 16 WEEKS
*                         *
*  BARLEY       20.200    *
*                         *
*BEANS(S+W)     20.000    *       NOTE
*                         *
*WH.FISH M.      3.000    *          VITAMIN/TR.MINERAL CONTENTS DONT INCLUDE COLBORN 204 CONTRIBUTION
*                         *
* CORN OIL       3.000    *          ALL FOODSTUFFS ARE FEED GRADE MEALS.
*                         *
*  CA.HPO4       2.850    *          BEAN MEAL IS EQUAL PARTS SPRING AND WINTER TYPES.
*                         *
*  CA.CO3        0.900    *          DIET PREPARED AS PELLETS
*                         *
*COLB. 205       0.450    *
*                         *
*METHIONINE      0.250    *
*                         *
*  LYSINE        0.200    *
*                         *
*  SALT          0.200    *
*                         *
*               ------    *
* TOTAL         100.049   *
*******************************************************************************************
*                                  *                            *                         *
*      DIET SPECIFICATION          *  AMINO ACIDS (PERCENT)     *      VITAMINS  ETC.     *
*******************************************************************************************
*                                  *                            *                         *
*CRUDE PROTEIN (PERCENT)    22.765 *  LYSINE          1.461     * LINOLEIC (PERCENT)   2.490 *
*NITROGEN      (PERCENT)     3.642 *  METH+CYST       0.889     *       MN   (PPM)    13.370 *
*MET.ENERGY KCAL/LB (A)   1300.079 *  ARGININE        1.581     *       ZN   (PPM)    35.591 *
*           KCAL/KG (B)   2866.024 *  GLYCINE         1.059     *   VIT A   (IU/G)     0.275 *
*                                  *  HISTIDINE       0.558     *   VIT B2   (PPM)     2.315 *
*ENERGY/PROTEIN     (A)     57.108 *  LEUCINE         1.770     *   VIT B12 (PPTM)     3.716 *
*                   (B)    125.895 *  ISOLEUCINE      0.971     *   VIT E    (PPM)     5.731 *
*                                  *  PHE+TYR         1.974     *                         *
*CALCIUM (PERCENT)           1.353 *  THREONINE       0.867     *                         *
*                                  *  TRYPTOPHAN      0.230     *                         *
*PHOSPHORUS (PERCENT)        1.046 *  VALINE          1.059     *                         *
*                                  *                            *                         *
*CHOLINE (MG/KG)          1375.819 *                            *                         *
*                                  *                            *                         *
*******************************************************************************************
```

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                                                   ****   TABLE 23   ****
**************************
*                        *
*  COMPOSITION OF DIET   *
*                        *
**************************
*  FOOD        PERCENT   *
*                        *
*  BARLEY       50.850   *
*                        *
*SPR.BEANS      20.000   *         REARING EXPERIMENT 7  -  LOW ENERGY,SPRING BEAN STARTER DIET
*                        *
* WEATING       16.600   *
*                        *
*HERRING M.      5.700   *      NOTE
*                        *
*GROUNDNUT       3.800   *         P.R.C. MINERAL/VITAMIN SUPPLEMENT ADDED AT 0.18 PERCENT BUT ITS
*                        *
*  CA.HPO4       2.350   *         CONTRIBUTION IS NOT INCLUDED IN CALCULATED ANALYSIS.
*                        *
*  CA.CO3        0.460   *         ALL FOODSTUFFS ARE FEED GRADE MEALS
*                        *
*METHIONINE      0.060   *         DIET PREPARED AS PELLETS
*                        *
*               ------   *
* TOTAL         99.819   *
************************************************************************************************
*                                 *                            *                               *
*      DIET SPECIFICATION         *  AMINO ACIDS (PERCENT)     *          VITAMINS  ETC.       *
************************************************************************************************
*                                 *                            *                               *
*CRUDE PROTEIN (PERCENT)   19.056 *  LYSINE            0.951   *  LINOLEIC (PERCENT)   0.914   *
*NITROGEN      (PERCENT)    3.049 *  METH+CYST         0.637   *        MN    (PPM)   25.900   *
*MET.ENERGY KCAL/LB (A)  1162.549 *  ARGININE          1.315   *        ZN    (PPM)   50.123   *
*           KCAL/KG (B)  2562.840 *  GLYCINE           0.967   *   VIT A     (IU/G)   0.450   *
*                                 *  HISTIDINE         0.418   *   VIT B2     (PPM)   2.242   *
*ENERGY/PROTEIN      (A)   61.004 *  LEUCINE           1.347   *   VIT B12   (PPTM)  15.361   *
*                    (B)  134.485 *  ISOLEUCINE        0.800   *   VIT E      (PPM)   6.404   *
*                                 *  PHE+TYR           1.503   *                               *
*CALCIUM (PERCENT)          0.952 *  THREONINE         0.695   *                               *
*                                 *  TRYPTOPHAN        0.196   *                               *
*PHOSPHORUS (PERCENT)       1.047 *  VALINE            0.943   *                               *
*                                 *                            *                               *
*CHOLINE (MG/KG)         1270.134 *                            *                               *
*                                 *                            *                               *
************************************************************************************************
```

```
****************************                              ****   TABLE 24   ****
*                          *
*  COMPOSITION OF DIET     *
*                          *
****************************
*  FOOD          PERCENT   *
*                          *
*  BARLEY         51.520   *
*                          *
*WIN.BEANS        20.000   *          REARING EXPERIMENT 7  -  LOW ENERGY,WINTER BEAN STARTER DIET
*                          *
* WEATING         14.200   *
*                          *
*HERRING M.        6.400   *       NOTE
*                          *
*GROUNDNUT         4.900   *
*                          *          P.R.C. MINERAL/VITAMIN SUPPLEMENT ADDED AT 0.18 PERCENT BUT ITS
*  CA.HPO4         2.350   *
*                          *          CONTRIBUTION IS NOT INCLUDED IN CALCULATED ANALYSIS.
*  CA.CO3          0.410   *
*                          *          ALL FOODSTUFFS ARE FEED GRADE MEALS
*METHIONINE        0.040   *
*                          *          DIET PREPARED AS PELLETS
*                 ------   *
* TOTAL           99.819   *
***************************************************************************************************
*                                    *                                *                           *
*      DIET SPECIFICATION            *  AMINO ACIDS (PERCENT)         *       VITAMINS  ETC.      *
***************************************************************************************************
*                                    *                                *                           *
*CRUDE PROTEIN (PERCENT)      19.124 *  LYSINE            0.947       *  LINOLEIC (PERCENT)  0.897 *
*NITROGEN      (PERCENT)       3.059 *  METH+CYST         0.629       *       MN    (PPM)   24.613 *
*MET.ENERGY KCAL/LB (A)     1162.687 *  ARGININE          1.260       *       ZN    (PPM)   48.451 *
*           KCAL/KG (B)     2563.144 *  GLYCINE           0.967       *   VIT A    (IU/G)    0.446 *
*                                    *  HISTIDINE         0.415       *   VIT B2    (PPM)    2.285 *
*ENERGY/PROTEIN     (A)       60.795 *  LEUCINE           1.337       *   VIT B12 (PPTM)   17.065 *
*                   (B)      134.023 *  ISOLEUCINE        0.789       *   VIT E     (PPM)    5.999 *
*                                    *  PHE+TYR           1.474       *                           *
*CALCIUM (PERCENT)             0.957 *  THREONINE         0.683       *                           *
*                                    *  TRYPTOPHAN        0.189       *                           *
*PHOSPHORUS (PERCENT)          1.061 *  VALINE            0.929       *                           *
*                                    *                                *                           *
*CHOLINE (MG/KG)            1299.611 *                                *                           *
*                                    *                                *                           *
***************************************************************************************************
```

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                                                            ****   TABLE 25   ****
**************************
*                        *
*  COMPOSITION OF DIET   *
*                        *
**************************
*  FOOD       PERCENT    *
*                        *
*  MAIZE       51.300    *
*                        *
*SPR.BEANS     20.000    *       REARING EXPERIMENT 7  - HIGH ENERGY,SPRING BEAN STARTER DIET
*                        *
*GROUNDNUT     19.750    *
*                        *
*HFRRING M.     5.000    *     NOTE
*                        *
*  CA.HPO4      2.350    *       P.R.C. MINERAL/VITAMIN SUPPLEMENT ADDED AT 0.18 PERCENT BUT ITS
*                        *
*  TALLOW       0.850    *       CONTRIBUTION IS NOT INCLUDED IN CALCULATED ANALYSIS.
*                        *
*  CA.CO3       0.530    *       ALL FOODSTUFFS ARE FEED GRADE MEALS
*                        *
*METHIONINE     0.040    *       DIET PREPARED AS PELLETS
*                        *
*              ------    *
* TOTAL        99.819    *
**************************************************************************************************
*                                  *                                *                            *
*      DIET SPECIFICATION          *  AMINO ACIDS (PERCENT)         *        VITAMINS  ETC.      *
**************************************************************************************************
*                                  *                                *                            *
*CRUDE PROTEIN (PERCENT)   22.284  *  LYSINE           0.978        *  LINOLEIC (PERCENT)  1.613 *
*NITROGEN      (PERCENT)    3.565  *  METH+CYST        0.639        *        MN   (PPM)    16.391 *
*MET.ENERGY KCAL/LB (A)  1345.229  *  ARGININE         1.809        *        ZN   (PPM)    42.023 *
*           KCAL/KG (B)  2965.557  *  GLYCINE          1.134        *    VIT A   (IU/G)    0.315 *
*                                  *  HISTIDINE        0.524        *    VIT B2   (PPM)    2.068 *
*ENERGY/PROTEIN    (A)     60.366  *  LEUCINE          1.737        *    VIT B12 (PPTM)   12.122 *
*                  (B)    133.078  *  ISOLEUCINE       0.808        *    VIT E    (PPM)    2.577 *
*                                  *  PHE+TYR          1.683        *                            *
*CALCIUM (PERCENT)          0.952  *  THREONINE        0.726        *                            *
*                                  *  TRYPTOPHAN       0.172        *                            *
*PHOSPHORUS (PERCENT)       1.042  *  VALINE           1.039        *                            *
*                                  *                                *                            *
*CHOLINE (MG/KG)         1111.359  *                                *                            *
*                                                                                                *
**************************************************************************************************
```

```
                                                 ****   TABLE 26   ****
**************************
*                        *
*  COMPOSITION OF DIET   *
*                        *
**************************
*  FOOD         PERCENT  *
*                        *
*  MAIZE         48.790  *
*                        *
*GROUNDNUT       21.700  *            REARING EXPERIMENT 7  - HIGH ENERGY,WINTER BEAN STARTER DIET
*                        *
*WIN.BEANS       20.000  *
*                        *
*HERRING M.       5.000  *        NOTE
*                        *
*  CA.HPO4        2.350  *            P.R.C. MINERAL/VITAMIN SUPPLEMENT ADDED AT 0.18 PERCENT BUT ITS
*                        *
*  TALLOW         1.430  *            CONTRIBUTION IS NOT INCLUDED IN CALCULATED ANALYSIS.
*                        *
*  CA.CO3         0.520  *            ALL FOODSTUFFS ARE FEED GRADE MEALS
*                        *
*METHIONINE       0.030  *            DIET PREPARED AS PELLETS
*                        *
*                ------  *
* TOTAL          99.819  *
**********************************************************************************************************
*                                    *                             *                                     *
*      DIET SPECIFICATION            *  AMINO ACIDS (PERCENT)      *           VITAMINS  ETC.            *
**********************************************************************************************************
*                                    *                             *                                     *
*CRUDE PROTEIN (PERCENT)      22.384 *  LYSINE           0.959     *  LINOLEIC (PERCENT)        1.613     *
*NITROGEN      (PERCENT)       3.581 *  METH+CYST        0.636     *        MN   (PPM)         17.267     *
*MET.ENERGY KCAL/LB (A)     1343.268 *  ARGININE         1.775     *        ZN   (PPM)         41.926     *
*            KCAL/KG (B)    2961.234 *  GLYCINE          1.139     *    VIT A    (IU/G)         0.309     *
*                                    *  HISTIDINE        0.523     *    VIT B2   (PPM)          2.084     *
*ENERGY/PROTEIN      (A)      60.007 *  LEUCINE          1.709     *    VIT B12 (PPTM)         12.119     *
*                    (B)     132.287 *  ISOLEUCINE       0.791     *    VIT E    (PPM)          2.494     *
*                                    *  PHE+TYR          1.649     *                                     *
*CALCIUM (PERCENT)             0.956 *  THREONINE        0.709     *                                     *
*                                    *  TRYPTOPHAN       0.168     *                                     *
*PHOSPHORUS (PERCENT)          1.063 *  VALINE           1.020     *                                     *
*                                    *                             *                                     *
*CHOLINE (MG/KG)            1132.457 *                             *                                     *
*                                    *                             *                                     *
**********************************************************************************************************
```

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                                                                 ****   TABLE 27   ****
****************************
*                          *
*  COMPOSITION OF DIET     *
*                          *
****************************
*  FOOD         PERCENT    *
*                          *
*  BARLEY        55.200    *
*                          *
*SPR.BEANS       20.000    *          REARING EXPERIMENT 7  -  LOW ENERGY.SPRING BEAN GROWER DIET
*                          *
*  MAIZE         16.100    *
*                          *
*HERRING M.       4.800    *     NOTE
*                          *
*  CA.HPO4        2.400    *          P.R.C. MINERAL/VITAMIN SUPPLEMENT ADDED AT 0.18 PERCENT BUT ITS
*                          *
*  CA.CO3         0.670    *          CONTRIBUTION IS NOT INCLUDED IN CALCULATED ANALYSIS.
*                          *
*  SALT           0.250    *          ALL FOODSTUFFS ARE FEED GRADE MEALS
*                          *
*CHOL.CHLOR       0.160    *          DIET PREPARED AS PELLETS
*                          *
*METHIONINE       0.140    *
*                          *
*  LYSINE         0.100    *
*                          *
*                ------    *
*  TOTAL         99.819    *
**********************************************************************************************************
*                                        *                            *                                  *
*        DIET SPECIFICATION              *   AMINO ACIDS (PERCENT)    *          VITAMINS  ETC.          *
**********************************************************************************************************
*                                        *                            *                                  *
*CRUDE PROTEIN (PERCENT)        16.242   *   LYSINE          0.902    *  LINOLEIC (PERCENT)       0.906  *
*NITROGEN      (PERCENT)         2.598   *   METH+CYST       0.637    *        MN    (PPM)      11.341  *
*MET.ENERGY KCAL/LB (A)       1223.109   *   ARGININE        1.054    *        ZN    (PPM)      33.855  *
*              KCAL/KG (B)    2696.344   *   GLYCINE         0.780    *    VIT A     (IU/G)      0.466  *
*                                        *   HISTIDINE       0.345    *    VIT B2    (PPM)       1.946  *
*ENERGY/PROTEIN      (A)        75.302   *   LEUCINE         1.247    *    VIT B12 (PPTM)       13.373  *
*                    (B)       166.004   *   ISOLEUCINE      0.701    *    VIT E     (PPM)       3.891  *
*                                        *   PHE+TYR         1.340    *                                  *
*CALCIUM (PERCENT)               1.010   *   THREONINE       0.612    *                                  *
*                                        *   TRYPTOPHAN      0.159    *                                  *
*PHOSPHORUS (PERCENT)            0.905   *   VALINE          0.798    *                                  *
*                                        *                            *                                  *
*CHOLINE (MG/KG)              1726.539   *                            *                                  *
*                                        *                            *                                  *
**********************************************************************************************************
```

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                                                           ****   TABLE 28   ****
***************************
*                         *
*  COMPOSITION OF DIET    *
*                         *
***************************
*  FOOD          PERCENT  *
*                         *
*  BARLEY         65.600  *
*                         *
*WIN.BEANS        20.000  *             REARING EXPERIMENT 7  -  LOW ENERGY,WINTER BEAN GROWER DIET
*                         *
*HERRING M.        5.500  *
*                         *
*  MAIZE           5.250  *        NOTE
*                         *
*  CA.HPO4         2.350  *             P.R.C. MINERAL/VITAMIN SUPPLEMENT ADDED AT 0.18 PERCENT BUT ITS
*                         *
*  CA.CO3          0.530  *             CONTRIBUTION IS NOT INCLUDED IN CALCULATED ANALYSIS.
*                         *
*  SALT            0.250  *             ALL FOODSTUFFS ARE FEED GRADE MEALS
*                         *
*METHIONINE        0.130  *             DIET PREPARED AS PELLETS
*                         *
*  LYSINE          0.120  *
*                         *
*CHOL.CHLOR        0.090  *
*                         *
*                ------   *
*  TOTAL         99.819   *
********************************************************************************************************
*                                       *                          *                                   *
*       DIET SPECIFICATION              *  AMINO ACIDS (PERCENT)   *           VITAMINS  ETC.          *
********************************************************************************************************
*                                       *                          *                                   *
*CRUDE PROTEIN (PERCENT)       16.295   *  LYSINE          0.927   *   LINOLEIC (PERCENT)      0.761   *
*NITROGEN      (PERCENT)        2.607   *  METH+CYST       0.646   *         MN   (PPM)       12.166   *
*MET.ENERGY KCAL/LB (A)      1191.864   *  ARGININE        0.977   *         ZN   (PPM)       33.965   *
*            KCAL/KG (B)     2627.465   *  GLYCINE         0.781   *     VIT A  (IU/G)         0.485   *
*                                       *  HISTIDINE       0.335   *     VIT B2   (PPM)        2.025   *
*ENERGY/PROTEIN      (A)       73.141   *  LEUCINE         1.195   *     VIT B12 (PPTM)       15.375   *
*                    (B)      161.239   *  ISOLEUCINE      0.705   *     VIT E    (PPM)        4.019   *
*                                       *  PHE+TYR         1.312   *                                   *
*CALCIUM (PERCENT)              0.972   *  THREONINE       0.608   *                                   *
*                                       *  TRYPTOPHAN      0.162   *                                   *
*PHOSPHORUS (PERCENT)           0.923   *  VALINE          0.789   *                                   *
*                                       *                          *                                   *
*CHOLINE (MG/KG)             1540.209   *                          *                                   *
*                                       *                          *                                   *
********************************************************************************************************
```

```
                                                           ****   TABLE 29   ****
***************************
*                         *
*  COMPOSITION OF DIET    *
*                         *
***************************
*  FOOD         PERCENT   *
*                         *
*  MAIZE         45.100   *
*                         *
*SPR.BEANS       20.000   *             REARING EXPERIMENT 7  - HIGH ENERGY.SPRING BEAN GROWER DIET
*                         *
*  BARLEY        11.950   *
*                         *
*GROUNDNUT        7.600   *        NOTE
*                         *
*HERRING M.       7.000   *             P.R.C. MINERAL/VITAMIN SUPPLEMENT ADDED AT 0.18 PERCENT BUT ITS
*                         *
*  TALLOW         5.000   *             CONTRIBUTION IS NOT INCLUDED IN CALCULATED ANALYSIS.
*                         *
*  CA.HPO4        2.350   *             ALL FOODSTUFFS ARE FEED GRADE MEALS
*                         *
*  CA.CO3         0.430   *            . DIET PREPARED AS PELLETS
*                         *
*  SALT           0.250   *
*                         *
*METHIONINE       0.080   *
*                         *
*CHOL.CHLOR       0.060   *
*                         *
*                ------   *
* TOTAL          99.819   *
********************************************************************************************************
*                                      *                           *                                   *
*       DIET SPECIFICATION             *   AMINO ACIDS (PERCENT)   *           VITAMINS  ETC.          *
********************************************************************************************************
*                                      *                           *                                   *
*CRUDE PROTEIN (PERCENT)       18.847  *   LYSINE          0.929   *  LINOLEIC (PERCENT)       1.445   *
*NITROGEN      (PERCENT)         3 15  *   METH+CYST         61   *        MN  (PPM)         11 4 5   *
*MET.ENERGY KCAL/LB (A)      1411.729  *   ARGININE        1.366   *        ZN  (PPM)         37.029   *
*           KCAL/KG (B)      3112.156  *   GLYCINE         0.937   *    VIT A   (IU/G)         0.331   *
*                                      *   HISTIDINE       0.430   *    VIT B2  (PPM)          2.068   *
*ENERGY/PROTEIN     (A)        74.902  *   LEUCINE         1.515   *    VIT B12 (PPTM)        17.292   *
*                   (B)       165.122  *   ISOLEUCINE      0.732   *    VIT E   (PPM)          3.171   *
*                                      *   PHE+TYR         1.469   *                                   *
*CALCIUM (PERCENT)              0.954  *   THREONINE       0.660   *                                   *
*                                      *   TRYPTOPHAN      0.147   *                                   *
*PHOSPHORUS (PERCENT)           0.953  *   VALINE          0.911   *                                   *
*                                      *                           *                                   *
*CHOLINE (MG/KG)             1282.144  *                           *                                   *
*                                      *                           *                                   *
********************************************************************************************************
```

```
                                                    ****   TABLE 30   ****
***************************
*                         *
*  COMPOSITION OF DIET    *
*                         *
***************************
*  FOOD          PERCENT  *
*                         *
*  MAIZE          46.330  *
*                         *
*WIN.BEANS        20.000  *
*                         *
*  BARLEY          9.200  *
*                         *
*GROUNDNUT         8.500  *        NOTE
*                         *
*HERRING M.        7.700  *
*                         *
*  TALLOW          5.000  *
*                         *
*  CA.HPO4         2.350  *
*                         *
*  CA.CO3          0.370  *
*                         *
*  SALT            0.250  *
*                         *
*METHIONINE        0.070  *
*                         *
*CHOL.CHLOR        0.050  *
*                         *
*                 ------  *
* TOTAL           99.819  *
*****************************************************************************************************
*                                     *                          *                                  *
*      DIET SPECIFICATION             *  AMINO ACIDS (PERCENT)   *          VITAMINS  ETC.          *
*****************************************************************************************************
*                                     *                          *                                  *
*CRUDE PROTEIN (PERCENT)      18.958  *  LYSINE          0.928   *  LINOLEIC (PERCENT)     1.467     *
*NITROGEN      (PERCENT)       3.033  *  METH+CYST       0.619   *        MN    (PPM)     11.734     *
*MET.ENERGY KCAL/LB (A)     1410.992  *  ARGININE        1.311   *        ZN    (PPM)     37.090     *
*           KCAL/KG (B)     3110.532  *  GLYCINE         0.940   *    VIT A     (IU/G)     0.321     *
*                                     *  HISTIDINE       0.430   *    VIT B2    (PPM)      2.129     *
*ENERGY/PROTEIN      (A)      74.424  *  LEUCINE         1.505   *    VIT B12 (PPTM)      18.884     *
*                    (B)     164.068  *  ISOLEUCINE      0.716   *    VIT E     (PPM)      3.125     *
*                                     *  PHE+TYR         1.437   *                                  *
*CALCIUM (PERCENT)             0.955  *  THREONINE       0.646   *                                  *
*                                     *  TRYPTOPHAN      0.140   *                                  *
*PHOSPHORUS (PERCENT)          0.975  *  VALINE          0.898   *                                  *
*                                     *                          *                                  *
*CHOLINE (MG/KG)            1266.665  *                          *                                  *
*                                     *                          *                                  *
*****************************************************************************************************
```

REARING EXPERIMENT 7 - HIGH ENERGY,WINTER BEAN GROWER DIET

NOTE

P.R.C. MINERAL/VITAMIN SUPPLEMENT ADDED AT 0.18 PERCENT BUT ITS CONTRIBUTION IS NOT INCLUDED IN CALCULATED ANALYSIS.

ALL FOODSTUFFS ARE FEED GRADE MEALS

DIET PREPARED AS PELLETS

```
                                                          ****    TABLE 31    ****
***************************
*                         *
*  COMPOSITION OF DIET    *
*                         *
***************************
*  FOOD         PERCENT   *
*                         *
*  BARLEY        57.350   *
*                         *
*  MAIZE         22.000   *             REARING EXPERIMENT 7  - CONTROL DIET , LAYING PERIOD
*                         *
*HERRING M.       9.000   *
*                         *
*  CA.CO3         7.250   *        NOTE
*                         *
*GRASS MEAL       2.500   *             P.R.C. MINERAL/VITAMIN SUPPLEMENT ADDED AT 0.18 PERCENT BUT ITS
*                         *
*  CA.HPO4        1.470   *             CONTRIBUTION IS NOT INCLUDED IN CALCULATED ANALYSIS.
*                         *
*  SALT           0.250   *             ALL FOODSTUFFS ARE FEED GRADE MEALS
*                         *
*                 ------  *
* TOTAL          99.819   *
********************************************************************************************************
*                                      *                           *                                   *
*       DIET SPECIFICATION             *   AMINO ACIDS (PERCENT)   *           VITAMINS  ETC.          *
********************************************************************************************************
*                                      *                           *                                   *
*CRUDE PROTEIN (PERCENT)       14.233  *   LYSINE          0.740   *   LINOLEIC (PERCENT)      0.976   *
*NITROGEN      (PERCENT)        2.277  *   METH+CYST       0.583   *         MN   (PPM)       11.065   *
*MET.ENERGY KCAL/LB (A)       1192.689  *   ARGININE        0.817   *         ZN   (PPM)       32.516   *
*           KCAL/KG (B)      2629.283  *   GLYCINE         0.745   *     VIT A   (IU/G)        8.698   *
*                                      *   HISTIDINE       0.319   *     VIT B2   (PPM)        2.185   *
*ENERGY/PROTEIN     (A)        83.792  *   LEUCINE         1.187   *     VIT B12 (PPTM)       23.536   *
*                   (B)       184.721  *   ISOLEUCINE      0.669   *     VIT E    (PPM)        8.037   *
*                                      *   PHE+TYR         1.209   *                                   *
*CALCIUM (PERCENT)              3.541  *   THREONINE       0.579   *                                   *
*                                      *   TRYPTOPHAN      0.139   *                                   *
*PHOSPHORUS (PERCENT)           0.745  *   VALINE          0.771   *                                   *
*                                      *                           *                                   *
*CHOLINE (MG/KG)             1155.234  *                           *                                   *
*                                      *                           *                                   *
********************************************************************************************************
```

APPENDIX 13.3

Tables of analysis of variance

The tables are set out in the order of the experiments to which they refer and in the order of the parameters measured within each experiment.

In the following tables

*** = significant at $P < 0.001$

** = significant at $P < 0.01$

* = significant at $P < 0.05$

N.S. = not significant

Broiler experiment 1

4 week weight

Source of variance	df	s.s.	m.s.	F
Beans	4	198622.05	49655.5	56.0 ***
Form of diet	2	28834.4	14417.2	16.3 ***
Error	8	7092.6	886.6	
Total	14	234549.05		

Broiler experiment 2

Live-weight at 4 weeks

Source of variance	df	s.s.	m.s.	F
Blocks	1	14.2541	14.2541	0.02 N.S.
Bean level (B)	4	176345.9397	44086.4849	58.82 ***
Form of diet (F)	2	20383.0864	10191.5432	13.60 ***
B x F	8	8330.7659	1041.3457	1.39 N.S.
Error	14	10493.3580	749.5256	
Total	29	215567.4041		

Broiler experiment 2

Food 0 to 4 weeks

Source of variance	df	s.s.	m.s.	F
Blocks	1	2132.33	2132.33	2.01 N.S.
Bean level (B)	4	253776.30	63444.08	59.71 ***
Form of diet (F)	2	29529.37	14764.68	13.90 ***
B x F	8	33155.66	4144.46	3.90 *
Error	14	14874.84	1062.49	
Total	29	333468.50		

Broiler experiment 2

Food conversion ratio 0 to 4 weeks

Source of variance	df	s.s.	m.s.	F
Blocks	1	0.0092	0.0092	3.29 N.S.
Bean level (B)	4	0.2817	0.0704	25.14 ***
Form of diet (F)	2	0.0349	0.0175	6.25 *
B x F	8	0.0218	0.0027	0.96 N.S.
Error	14	0.0395	0.0028	
Total	29	0.3871		

Broiler experiment 2

Per cent dead 0 to 4 weeks

Source of variance	df	s.s.	m.s.	F
Blocks	1	0.0003	0.0003	0.00 N.S.
Bean level (B)	4	28.0354	7.0089	1.26 N.S.
Form of diet (F)	2	1.8945	0.9473	0.17 N.S.
B x F	8	20.7963	2.5995	0.47 N.S.
Error	14	77.8333	5.5595	
Total	29	128.5598		

Broiler experiment 2

Live-weight at 8 weeks

Source of variance	df	s.s.	m.s.	F
Blocks	1	4921.9844	4921.9844	1.59 N.S.
Bean level (B)	4	434112.9992	108528.2498	34.99 ***
Form of diet (F)	2	29162.3819	14581.1910	4.70 *
B x F	8	67521.8430	8440.2304	2.72 N.S.
Error	14	43427.6122	3101.9723	
Total	29	579146.8207		

Broiler experiment 2

Food intake 4 to 8 weeks

Source of variance	df	s.s.	m.s.	F
Blocks	1	14407.51	14407.51	0.66 N.S.
Bean level (B)	4	737942.91	184485.73	8.43 **
Form of diet (F)	2	4080.49	2040.24	0.09 N.S.
B x F	8	186198.87	23274.86	1.06 N.S.
Error	14	306540.53	21895.75	
Total	29	1249170.31		

Broiler experiment 2

Food conversion ratio 4 to 8 weeks

Source of variance	df	s.s.	m.s.	F
Blocks	1	0.0031	0.0031	0.74 N.S.
Bean level (B)	4	0.0536	0.0134	3.22 *
Form of diet (F)	2	0.0439	0.0219	5.27 *
B x F	8	0.0436	0.0054	1.31 N.S.
Error	14	0.0583	0.0042	
Total	29	0.2025		

Broiler experiment 2

Per cent dead 4 to 8 weeks

source of variance	df	s.s.	m.s.	F
Blocks	1	0.3689	0.3689	0.35 N.S.
Bean level (B)	4	2.0392	0.5098	0.48 N.S.
Form of diet (F)	2	2.0168	1.0084	0.95 N.S.
B x F	8	8.1756	1.0220	0.96 N.S.
Error	14	14.9198	1.0657	
Total	29	27.5203		

Duckling experiment 5

8 week weight

Source of variance	df	s.s.	m.s.	F
Blocks	2	130838.25	65419.12	2.87 N.S.
Sex (S)	1	460097.04	460097.04	20.15 ***
Diet (D) 3 to 8 week	3	57293.79	19097.93	0.84 N.S.
S x D	3	76175.13	25391.71	1.11 N.S.
Error	14	319666.42	22833.32	
Total	23	1044070.63		

Duckling experiment 5

Food intake 3 to 8 weeks

Source of variance	df	s.s.	m.s.	F
Blocks	2	208665.33	104332.67	0.64 N.S.
Sex (S)	1	138472.04	138472.04	0.85 N.S.
Diet (D)	3	484904.79	161634.93	1.00 N.S.
S x D	3	435171.13	145057.04	0.89 N.S.
Error	14	2269578.67	162112.16	
Total	23	3536791.96		

Duckling experiment 5

Food conversion efficiency 3 to 8 weeks

Source of variance	df	s.s.	m.s.	F
Blocks	2	0.004281	0.002140	8.73 **
Sex (S)	1	0.007436	0.007436	30.35 ***
Diet (D)	3	0.001842	0.000614	2.51 N.S.
S x D	3	0.001367	0.000456	1.86 N.S.
Error	14	0.003430	0.000245	
Total	23	0.018356		

Duckling experiment 5

Dressed carcase weight

Source of variance	df	s.s.	m.s.	F
Sex (S)	1	9.1937	9.1937	2.15 N.S.
Diet (D)	2	4.2599	2.1300	0.50 N.S.
S x D	2	1.6121	0.8060	0.19 N.S.
Error	29	124.0580	4.2779	
Total	34	139.1237		

Duckling experiment 5

Giblet weight

Source of variance	df	s.s.	m.s.	F
Sex (S)	1	13.3574	13.3574	19.13 ***
Diet (D)	2	1.2746	0.6373	0.91 N.S.
S x D	2	3.2180	1.6090	2.30 N.S.
Error	29	20.2436	0.6981	
Total	34	38.0936		

Duckling experiment 5

Dressed carcase plus giblet weights

Source of variance	df	s.s.	m.s.	F
Sex (S)	1	1.3111	1.3111	0.34 N.S.
Diet (D)	2	3.1041	1.5521	0.40 N.S.
S x D	2	10.9859	5.4929	1.41 N.S.
Error	29	112.7379	3.8875	
Total	34	128.1390		

Duckling experiment 5

Carcase skin

Source of variance	df	s.s.	m.s.	F
Sex (S)	1	16.5313	16.5313	1.38 N.S.
Diet (D)	2	96.0389	48.0194	4.01 *
S x D	2	0.9592	0.4796	0.04 N.S.
Error	12	143.7402	11.9784	
Total	17	257.2696		

Duckling experiment 5

Weight of breast

Source of variance	df	s.s.	m.s.	F
Sex (S)	1	0.1058	0.1058	0.13 N.S.
Diet (D)	2	5.1909	2.5955	3.10 N.S.
S x D	2	13.2516	6.6258	7.91 **
Error	12	10.0509	0.8376	
Total	17	28.5992		

Duckling experiment 5

Weights of skin plus breast meat

Source of variance	df	s.s.	m.s.	F
Sex (S)	1	13.9921	13.9921	1.22 N.S.
Diet (D)	2	57.4710	28.7355	2.50 N.S.
S x D	2	13.2982	6.6491	0.58 N.S.
Error	12	138.0638	11.5053	
Total	17	222.8251		

Duckling experiment 5

Weight of leg meat

Source of variance	df	s.s.	m.s.	F
Sex (S)	1	12.6672	12.6672	12.35 **
Diet (D)	2	4.3607	2.1803	2.13 N.S.
S x D	2	2.4242	1.2121	1.18 N.S.
Error	12	12.3061	1.0255	
Total	17	31.7582		

Duckling experiment 5

Weight of total meat

Source of variance	df	s.s.	m.s.	F
Sex (S)	1	68.2112	68.2112	14.91 **
Diet (D)	2	11.2584	5.6292	1.23 N.S.
S x D	2	64.0382	32.0191	7.00 **
Error	12	54.8865	4.5739	
Total	17	198.3943		

Turkey poult experiment 6

10 week weight

Source of variance	df	s.s.	m.s.	F
Blocks	1	11316.02	11316.02	0.47 N.S.
Sex/stocking density (S)	2	8633082.79	4316541.40	180.99 ***
Diet (D)	3	1245676.23	415225.41	17.41 ***
S x D	6	168625.71	28104.28	1.18 N.S.
Error	35	834737.73	23849.65	
Total	47	10893438.48		

Turkey poult experiment 6

Food intake 6 to 10 weeks

Source of variance	df	s.s.	m.s.	F
Blocks	1	0.0176	0.0176	0.17 N.S.
Sex/stocking density (S)	2	16.3662	8.1831	80.31 ***
Diet (D)	3	2.4357	0.8119	7.97 **
S x D	6	0.9272	0.1545	1.52 N.S.
Error	35	3.5668	0.1019	
Total	47	23.3136		

Turkey poult experiment 6

Food conversion efficiency 6 to 10 weeks

Source of variance	df	s.s.	m.s.	F
Blocks	1	0.0008	0.0008	1.60 N.S.
Sex/stocking density (S)	2	0.0012	0.0006	1.20 N.S.
Diet (D)	3	0.0070	0.0023	4.60 *
S x D	6	0.0046	0.0008	1.60 N.S.
Error	35	0.0172	0.0005	
Total	47	0.0309		

Turkey experiment 6

16 week weight

Source of variance	df	s.s.	m.s.	F
Blocks	1	60990.02	60990.02	1.30 N.S.
Sex/stocking density (S)	2	45951795.04	22975897.52	489.72 ***
Diet (D) 6 to 10 weeks	3	465883.73	155294.58	3.31 *
Diet (T) 10 to 16 weeks	1	5355.19	5355.19	0.11 N.S.
S x D	6	450081.96	75013.66	1.60 N.S.
S x T	2	107825.38	53912.69	1.15 N.S.
D x T	3	110581.23	36860.41	0.79 N.S.
Error	29	1360563.44	46915.98	
Total	47	48513075.98		

Turkey experiment 6

Food intake 10 to 16 weeks

Source of variance	df	s.s.	m.s.	F
Blocks	1	0.1240	0.1240	0.20 N.S.
Sex/stocking density (S)	2	123.7751	61.8875	100.53 ***
Diet (D) 6 to 10 week	3	0.6147	0.2049	0.33 N.S.
Diet (T) 10 to 16 week	1	0.0547	0.0547	0.09 N.S.
S x D	6	4.3236	0.7206	1.17 N.S.
S x T	2	0.0288	0.0144	0.02 N.S.
D x T	3	2.0072	0.6691	1.09 N.S.
Error	29	17.8518	0.6156	
Total	47	148.7799		

Turkey experiment 6

Food conversion efficiency 10 to 16 weeks

Source of variance	df	s.s.	m.s.	F
Blocks	1	0.000002	0.000002	0.01 N.S.
Sex/stocking density (S)	2	0.006779	0.003390	9.77 ***
Diet (D) 6 to 10 weeks	3	0.002290	0.000763	2.20 N.S.
Diet (T) 10 to 16 weeks	1	0.000052	0.000052	0.15 N.S.
S x D	6	0.000504	0.000084	0.24 N.S.
S x T	2	0.000379	0.000190	0.55 N.S.
D x T	3	0.001740	0.000580	1.67 N.S.
Error	29	0.010052	0.000347	
Total	47	0.021798		

Rearing experiment 7

6 week weight

Source of variance	df	s.s.	m.s.	F
Breed (S)	1	21918.945	21918.945	80.18 ***
Bean type (B)	1	38.940	38.940	0.14 N.S.
Energy level (E) 0 to 6 weeks	1	13109.853	13109.853	47.96 ***
S x B	1	55.388	55.388	0.20 N.S.
S x E	1	105.488	105.488	0.39 N.S.
B x E	1	542.028	542.028	1.98 N.S.
Error	25	6834.428	273.377	
Total	31	42605.070		

Rearing experiment 7

Food intake 0 to 6 weeks

Source of variance	df	s.s.	m.s.	F
Breed (S)	1	87.9138	87.9138	4.82 *
Bean type (B)	1	42.0445	42.0445	2.31 N.S.
Energy level (E) 0 to 6 weeks	1	112.5750	112.5750	6.18 *
S x B	1	4.0186	4.0186	0.22 N.S.
S x E	1	14.6882	14.6882	0.81 N.S.
B x E	1	25.2761	25.2761	1.39 N.S.
Error	25	455.5745	18.2230	
Total	31	742.0907		

Rearing experiment 7

Food conversion efficiency 0 to 6 weeks

Source of variance	df	s.s.	m.s.	F
Breed (S)	1	1.12273	1.12273	21.25 ***
Bean type (B)	1	0.07120	0.07120	1.35 N.S.
Energy level (E) 0 to 6 weeks	1	0.00631	0.00631	0.12 N.S.
S x B	1	0.00045	0.00045	0.01 N.S.
S x E	1	0.06148	0.06148	1.16 N.S.
B x E	1	0.02344	0.02344	0.44 N.S.
Error	25	1.32075	0.05283	
Total	31	2.60636		

Rearing experiment 7

Live-weight at 16 weeks

Source of variance	df	s.s.	m.s.	F
Breed (S)	1	1156378.300	1156378.300	917.67 ***
Bean type (B)	1	1045.388	1045.388	0.83 N.S.
Energy level (E) 0 to 6 weeks	1	1443.188	1443.188	1.15 N.S.
Energy level (F) 6 to 16 weeks	1	146.633	146.633	0.12 N.S.
S x B	1	248.088	248.088	0.20 N.S.
S x E	1	1248.750	1248.750	0.99 N.S.
S x F	1	166.988	166.988	0.13 N.S.
B x E	1	2024.070	2024.070	1.61 N.S.
B x F	1	282.625	282.625	0.22 N.S.
E x F	1	2905.125	2905.125	2.31 N.S.
Error	21	26462.474	1260.118	
Total	31	1192351.630		

Rearing experiment 7

Food intake 0 to 16 weeks

Source of variance	df	s.s.	m.s.	F
Breed (S)	1	1241.265	1241.265	13.73 **
Bean type (B)	1	58.050	58.050	0.64 N.S.
Energy level (E) 0 to 6 weeks	1	253.688	253.688	2.81 N.S.
Energy level (F) 6 to 16 weeks	1	2644.463	2644.463	29.26 ***
S x B	1	42.550	42.550	0.47 N.S.
S x E	1	112.125	112.125	1.24 N.S.
S x F	1	20.963	20.963	0.23 N.S.
B x E	1	86.133	86.133	0.95 N.S.
B x F	1	461.320	461.320	5.10 *
E x F	1	82.240	82.240	0.91 N.S.
Error	21	1897.932	90.378	
Total	31	6900.730		

Rearing experiment 7

Food conversion efficiency 0 to 16 weeks

Source of variance	df	s.s.	m.s.	F
Breed (S)	1	0.60149	0.60149	86.17 ***
Bean type (B)	1	0.00301	0.00301	0.43 N.S.
Energy level (E) 0 to 6 weeks	1	0.03173	0.03173	4.55 *
Energy level (F) 6 to 16 weeks	1	0.20189	0.20189	28.92 ***
S x B	1	0.00136	0.00136	0.19 N.S.
S x E	1	0.01635	0.01635	2.34 N.S.
S x F	1	0.00370	0.00370	0.53 N.S.
B x E	1	0.01469	0.01469	2.10 N.S.
B x F	1	0.03262	0.03262	4.67 *
E x F	1	0.00122	0.00122	0.17 N.S.
Error	21	0.14658	0.00698	
Total	31	1.05464		

Rearing experiment 7

Egg number per module of 12 birds

Source of variance	df	s.s.	m.s.	F	
Breed (S)	1	1072.56	1072.56	0.027	N.S.
Bean type (B)	1	31417.56	31417.56	0.788	N.S.
Energy (E) 0 to 6 weeks	1	6045.06	6045.06	0.152	N.S.
Energy (F) 6 to 16 weeks	1	4064.06	4064.06	0.102	N.S.
S x B	1	94095.56	94095.56	2.359	N.S.
S x E	1	7876.56	7876.56	0.197	N.S.
S x F	1	77145.06	77145.06	1.934	N.S.
B x E	1	1040.06	1040.06	0.026	N.S.
B x F	1	3937.56	3937.56	0.099	N.S.
E x F	1	5148.06	5148.06	0.129	N.S.
S x E x F	1	31240.56	31240.56	0.783	N.S.
Error	4	159585.75	39896.44		
Total	15	422668.44			

Rearing experiment 7

Food intake per module 16 to 72 weeks

Source of variance	df	s.s.	m.s.	F
Breed (S)	1	14792.641	14792.641	14.93 *
Bean type (B)	1	53.656	53.656	0.054 N.S.
Energy (E) 0 to 6 weeks	1	1000.141	1000.141	1.009 N.S.
Energy (F) 6 to 16 weeks	1	2.481	2.481	0.003 N.S.
S x B	1	191.131	191.131	0.193 N.S.
S x E	1	184.281	184.281	0.186 N.S.
S x F	1	1859.766	1859.766	1.877 N.S.
B x E	1	77.001	77.001	0.078 N.S.
B x F	1	2.326	2.326	0.002 N.S.
E x F	1	454.756	454.756	0.459 N.S.
S x E x F	1	444.156	444.156	0.448 N.S.
Error	4	3964.073	991.018	
Total	15	23026.404		

Rearing experiment 7

Food intake per 100 eggs.

Source of variance	df	s.s.	m.s.	F	
Breed (S)	1	19.2721	19.2721	37.509	**
Bean type (B)	1	1.9740	1.9740	3.842	N.S.
Energy (E) 0 to 6 weeks	1	3.4410	3.4410	6.695	N.S.
Energy (F) 6 to 16 weeks	1	0.4160	0.4160	0.810	N.S.
S x B	1	3.0276	3.0276	5.893	N.S.
S x E	1	0.0036	0.0036	0.007	N.S.
S x F	1	0.0961	0.0961	0.187	N.S.
B x E	1	0.4556	0.4556	0.887	N.S.
B x F	1	0.1406	0.1406	0.274	N.S.
E x F	1	1.8360	1.8360	3.573	N.S.
S x E x F	1	0.2500	0.2500	0.487	N.S.
Error	4	2.0550	0.5138		
Total	15	32.9678			

Rearing experiment 7

Days of age at first egg.

Source of variance	df	s.s.	m.s.	F	
Breed (S)	1	172.980	172.980	7.75	*
Bean type (B)	1	0.080	0.080	0.00	N.S.
Energy (E) 0 to 6 weeks	1	0.500	0.500	0.02	N.S.
Energy (F) 6 to 16 weeks	1	17.701	17.701	0.79	N.S.
S x B	1	39.605	39.605	1.77	N.S.
S x E	1	1.125	1.125	0.05	N.S.
S x F	1	175.781	175.781	7.87	*
B x E	1	32.805	32.805	1.47	N.S.
B x F	1	26.281	26.281	1.18	N.S.
E x F	1	15.401	15.401	0.69	N.S.
Error	21	468.980	22.332		
Total	31	951.240			

Chick experiment 8

Final live-weight.

Source of variance	df	s.s.	m.s.	F
Among treatments	2	84444	42222	16.83 ***
Within treatments	39	97828	2508	
Total	41	182272		

Chick experiment 8

Pancreas weight

Source of variance	df	S.S.	m.s.	F
Among treatments	2	0.44	0.22	5.95 **
Within treatments	20	0.74	0.37	
Total	22	1.18		

Chick experiment 8

Pancreas size

Source of variance	df	s.s.	m.s.	F
Among treatments	2	0.002	0.001	0.5 N.S.
Within treatments	20	0.033	0.002	
Total	22	0.035		

Chick experiment 9

Weight gain

Source of variance	df	s.s.	m.s.	F
Among treatments	2	20910	10455	15.93 ***
Within treatments	43	28234	656	
Total	45	49144		

Chick experiment 9

Pancreas size

Source of variance	df	s.s.	m.s.	F
Among treatments	2	0.492	0.246	27.3 ***
Within treatments	21	0.197	0.009	
Total	23	0.689		

Chick experiment 10

Weight gain

Source of variance	df	s.s.	m.s.	F
Among treatments	9	125367	13929	23.4 ***
Within treatments	165	98300	596	
Total	174	223667		

Chick experiment 11

Bodyweight gain, 5 to 19 days of age.

Source of variance	df	s.s.	m.s.	F
Among treatments	2	3075	1538	4.43 *
Within treatments	26	9376	347	
Total	28	12451		

Chick experiment 11

Pancreas size

Source of variance	df	s.s.	m.s.	F
Among treatments	2	0.0785	0.0393	43.56 ***
Within treatments	26	0.0227	0.0009	
Total	28	0.1012		

APPENDIX 13.4

Proximate analyses of field beans

Proximate analyses of field beans from all available sources.

(per cent of dry matter)

References*	1	2	3	4	5	6
Variety	-	-	-	-	-	-
Type	'Cattle'	'Pigs'	-	-	-	-
Dry matter	86.0	86.8	90.3	85.0	88.3	-
Crude protein	29.7	31.8	26.7	29.8	32.2	27.6
Ether extract	1.74	1.15	1.22	1.06	1.47	-
Crude fibre	8.26	11.06	69.8	65.9	62.9	-
Nitrogen-free extractives	56.6	52.5				-
Ash	3.72	3.46	2.99	3.29	3.51	-

* Source of analyses.

1. Evans (1966).
2. Evans (1966).
3. Bolton (1959).
4. Bolton (1963).
5. Bolton (1967).
6. Mahon and Common (1950).

Proximate analyses of field beans from all available sources.

(per cent of dry matter)

References*	7	8	9	10	11
Variety	-	-	Minor	Throws	Strubes
Type	Spring	Winter	Spring	Winter	Spring
Dry matter	-	-	86.0	86.4	88.0
Crude protein	31.4	26.5	30.1	26.0	29.7
Ether extract	1.5	1.5	1.67	1.56	1.44
Crude fibre	8.0	9.0	6.78	6.56	6.78
Nitrogen-free extractives	55.2	59.0	58.0	62.0	58.4
Ash	4.0	4.0	3.44	3.89	3.67

* Sources of analyses

7. Eden (1968).
8. Eden (1968).
9. Carpenter and Johnson (1968).
10. Carpenter and Johnson (1968).
11. Carpenter and Johnson (1968).

Proximate analyses of field beans from all available sources.

(per cent of dry matter)

References*	12	13	14	15	16
Variety	-	-	Minor	Throws	-
Type	Large seed	Small seed	Spring	Winter	-
Dry matter	87.4	90.2	86.6	87.2	89.0
Crude protein	27.2	26.7	28.9	24.9	26.3
Ether extract	1.6	1.7	1.45	1.39	2.25
Crude fibre	9.2	9.2	65.22	68.83	8.76
Nitrogen-free extractives	55.6	58.3			67.64
Ash	3.8	4.0	4.46	4.90	3.82

* Sources of analyses

12. Brisson _et_ _al_. (1950).
13. Brisson _et_ _al_. (1950).
14. Waring and Shannon (1969).
15. Waring and Shannon (1969).
16. Aykroyd and Doughty (1964).

Proximate analyses of field beans from all available sources.

(per cent of dry matter)

References*	17	18	19	20	21
Variety	Local	Ackerperle	-	Maris Beaver	Throws
Type	-	Spring	-	Winter	Winter
Dry matter	86.7	87.4	89.5	89.9	89.8
Crude protein	28.2	26.2	26.8	27.8	28.1
Ether extract	1.48	1.63	1.03	1.36	1.21
Crude fibre	8.14	7.46	7.82	-	-
Nitrogen-free extractives	45.82	48.81	60.47	-	-
Ash	3.09	3.31	3.90	3.69	3.39

* Sources of analyses

17. Čižek and Rac (1964).
18. Čižek and Rac (1964).
19. Sanz Arias (1963).

20, 21. Analysed during this study.

Proximate analyses of field beans from all available sources.

(per cent of dry matter)

References*	22	23	24	25	26	27
Variety	Tarvin	Blue Rock	Ackerperle	Maris Bead	Strubes	Minor
Type	Spring	Spring	Spring	Spring	Spring	Spring
Dry matter	92.1	93.2	92.6	93.1	92.4	92.9
Crude protein	30.6	30.2	27.7	30.2	30.2	30.9
Ether extract	1.34	1.09	1.32	1.36	1.47	1.03
Crude fibre	-	-	-	-	-	-
Nitrogen-free extractives	-	-	-	-	-	-
Ash	3.58	3.29	3.63	3.73	3.57	3.47

* Sources of analyses

22 - 27 Analysed during this study.

APPENDIX 13.5

Amino acid analyses of field beans

Amino acid analyses of field beans from all available sources.
(per cent)

References*	1	2	3	4	5
Variety	-	-	-	-	Minor
Type	-	-	-	-	Spring
Arginine	1.68	1.74	1.64	1.83	2.32
Glycine	1.05	0.92	1.03	0.97	1.15
Histidine	0.83	0.72	0.80	0.81	0.59
Leucine	2.16	1.25	2.10	2.55	1.99
Isoleucine	1.57	1.28	1.53	1.46	1.07
Lysine	1.57	1.80	1.53	1.62	1.62
Cystine	0.31	0.28	0.30	-	0.14
Methionine	0.14	0.29	0.15	0.16	0.15
Phenylalanine	0.97	1.35	0.95	1.30	1.16
Tyrosine	0.91	0.78	0.85	1.06	0.96
Threonine	0.74	1.22	0.75	1.09	1.02
Tryptophan	0.26	0.36	0.25	0.26	-
Valine	1.45	1.38	1.42	1.36	1.22
Alanine	-	-	-	0.98	1.06
Aspartic acid	-	-	-	2.22	2.97
Glutamic acid	-	-	-	3.74	4.92
Proline	-	-	-	1.18	-
Serine	-	-	-	0.98	1.37

* Sources of analyses

1. Bolton (1959)
2. Bolton (1964, 1967)
3. Mahon and Common (1950)
4. Khan and Baker (1957)
5. Waring and Shannon (1969)

Amino acid analyses of field beans from all available sources
(per cent)

References*	6	7	8	9	10
Variety	Throws	-	-	76 x S45	Maris Beaver
Type	Winter	-	-	Spring	Winter
Arginine	1.76	1.86	-	2.87	2.54
Glycine	1.00	0.95	-	1.28	1.19
Histidine	0.51	0.80	-	0.82	0.77
Leucine	1.66	2.53	1.44	2.35	2.12
Isoleucine	0.89	1.58	1.04	1.22	1.14
Lysine	1.41	1.68	0.93	2.10	1.93
Cystine	0.10	-	0.10	0.37	0.29
Methionine	0.17	0.15	0.08	0.18	0.19
Phenylalanine	0.92	1.35	0.69	1.34	1.22
Tyrosine	0.82	1.11	0.45	1.10	0.98
Threonine	0.87	1.09	0.53	1.10	1.01
Tryptophan	-	0.24	0.16	-	-
Valine	1.03	1.35	0.82	1.34	1.27
Alanine	0.92	0.97	-	1.25	1.17
Aspartic acid	2.59	2.27	-	3.23	3.13
Glutamic acid	4.01	3.65	-	4.97	4.72
Proline	-	1.02	-	1.40	1.22
Serine	1.13	0.99	-	1.40	1.43

* Sources of analyses

6. Waring and Shannon (1968)
7. Khan and Baker (1957)
8. Aykroyd and Doughty (1964)
9. Bond (1970)
10. Bond (1970)

Amino acid analyses of field beans from all available sources
(per cent)

References*	11	12	13	14	15
Variety	Maris Beaver	Throws	Tarvin	Blue Rock	Ackerperle
Type	Winter	Winter	Spring	Spring	Spring
Arginine	2.17	2.53	2.89	2.93	1.36
Glycine	1.08	1.04	1.17	1.23	1.14
Histidine	0.66	0.76	0.75	0.77	0.72
Leucine	1.54	2.42	2.00	2.04	2.02
Isoleucine	0.63	1.38	1.08	1.12	1.00
Lysine	1.64	1.74	1.73	1.88	1.66
Cystine	0.15	0.13	0.15	0.14	0.21
Methionine	0.09	0.14	0.14	0.11	0.07
Phenylalanine	1.33	1.14	1.06	1.23	1.05
Tyrosine	1.19	1.20	0.97	1.18	0.92
Threonine	1.10	0.99	1.12	1.16	1.08
Tryptophan	-	-	-	-	-
Valine	0.93	1.14	1.19	1.26	1.16
Alanine	1.14	1.14	1.20	1.23	1.16
Aspartic acid	2.90	2.61	2.78	3.02	2.58
Glutamic acid	5.00	4.64	5.01	5.55	4.72
Proline	-	-	-	-	-
Serine	1.36	1.22	1.28	1.38	1.24

* Sources of analyses

Samples 11 to 15 were analysed during this study

Amino acid analyses of field beans from all available sources

(per cent)

References*	16	17	18	19
Variety	Maris Bead	Strubes	Minor	-
Type	Spring	Spring	Spring	-
Arginine	2.86	2.90	2.98	1.70
Glycine	1.20	1.14	1.23	-
Histidine	0.88	0.82	0.82	0.86
Leucine	1.98	1.90	1.99	2.64
Isoleucine	1.11	1.08	1.11	
Lysine	1.80	1.86	1.82	1.44
Cystine	0.14	0.13	0.15	-
Methionine	0.11	0.12	0.16	0.76
Phenylalanine	1.29	1.13	1.35	1.20
Tyrosine	1.25	1.10	0.82	-
Threonine	1.10	1.16	1.12	0.91
Tryptophan	-	-	-	0.26
Valine	1.23	1.30	1.27	1.59
Alanine	1.25	1.36	1.26	-
Aspartic acid	2.94	2.94	2.82	-
Glutamic acid	5.33	5.46	4.92	-
Proline	-	-	-	-
Serine	1.38	1.40	1.34	-

* Sources of analyses

16 - 18. Analysed during this study

19. Jeroch and Hennig (1964)

APPENDIX 13.6

Layout of treatments in experiments 1, 2, 5, 6 and 7.

Table 1.

Broiler experiment 1, treatment allocation to pens

Block 1		Block 2	
Pen	Treatment	Pen	Treatment
15	C - M	18	E - RP
14	D - RP	19	B - RP
13	C - RP	20	C - M
12	A - M	21	B - P
11	B - P	22	E - M
10	E - M	23	C - RP
9	E - RP	24	C - P
8	A - P	25	D - M
7	B - M	26	B - M
6	A - RP	27	A - P
5	D - M	28	D - RP
4	E - P	29	A - RP
3	D - P	30	D - P
2	B - RP	31	A - M
1	C - P	32	E - P

Diet A = 0% beans
Diet B = 30% beans
Diet C = 45% beans
Diet D = 30% beans*
Diet E = 45% beans*

M = Mash
P = Pellets
RP = Reground pellets

* Only 80% digestibility of field bean protein assumed.

Table 2

Broiler experiment 2, treatment allocation to pens.

Block 1		Block 2	
Pen	Treatment	Pen	Treatment
15	C - P	16	E - P
14	B - RP	17	A - M
13	D - P	18	D - P
12	E - P	19	A - RP
11	D - M	20	D - RP
10	A - RP	21	A - P
9	B - M	22	B - M
8	A - P	23	D - M
7	E - RP	24	C - P
6	E - M	25	C - RP
5	B - P	26	E - M
4	A - M	27	B - P
3	C - RP	28	C - M
2	D - RP	29	B - RP
1	C - M	30	E - RP

A - Diet with no beams

B - 30% beans

C - 45% beans

D - 30% beans*

E - 45% beans*

M - Mash

P - Pellet

RP - Reground pellets

* Only 80% digestibility of field bean protein assumed

Table 3

Duckling experiment 5, location of treatments, 3 to 8 weeks.

Block 3

Pen	Sex	Diet	Pen	Sex	Diet
12	M	A	13	F	A
11	F	C	14	F	D
10	M	D	15	M	B
9	F	B	16	M	C

Block 2

Pen	Sex	Diet	Pen	Sex	Diet
8	F	D	17	M	D
7	F	C	18	F	A
6	M	A	19	F	B
5	M	B	20	M	C

Block 1

Pen	Sex	Diet	Pen	Sex	Diet
4	M	C	21	F	C
3	F	B	22	M	B
2	F	D	23	M	D
1	M	A	24	F	A

Table 4

Turkey experiment 6, location of treatments

		Diet				Diet	
Pen	Sex	6 - 10 wk	10 - 16 wk	Pen	Sex	6 - 10 wk	10 - 16 wk
1	H	E	F	25	F	C	G
2	H	C	F	26	L	C	G
3	F	E	F	27	H	C	F
4	F	B	F	28	H	D	F
5	L	C	G	29	F	E	G
6	H	D	G	30	F	B	F
7	F	C	F	31	H	D	G
8	F	E	G	32	L	D	F
9	L	D	G	33	F	C	F
10	H	C	G	34	L	E	F
11	L	C	F	35	H	E	G
12	F	C	G	36	L	E	G
13	L	E	F	37	L	B	G
14	F	D	F	38	F	D	F
15	L	C	G	39	H	C	G
16	H	E	G	40	L	D	G
17	F	D	G	41	F	E	F
18	H	B	F	42	H	B	F
19	F	B	G	43	H	E	F
20	H	B	G	44	L	C	F
21	H	D	F	45	F	D	G
22	L	B	F	46	F	B	G
23	L	E	G	47	L	B	F
24	L	D	F	48	H	B	G
		Block 1				Block 2	

H = male poults, 15 per pen

L = male poults, 10 per pen

F = female poults, 15 per pen

Table 5.

Rearing experiment 7, location of treatments.

Pen	Breed	Energy level 0 to 6 wks	Energy level 6 to 16 wks	Beans	Diet 0 to 6 wks	Diet 6 to 16 wks
1	B1	2	4	S	C	G
2	B1	2	3	W	D	F
3	B2	1	4	S	A	G
4	B1	2	3	S	C	E
5	B2	1	4	W	B	H
6	B1	1	5	W	B	F
7	B2	1	4	W	B	H
8	B2	1	3	W	B	F
9	B2	1	3	S	A	E
10	B2	2	3	W	D	F
11	B2	2	4	S	C	G
12	B1	1	4	W	B	H
13	B2	1	3	S	A	E
14	B1	1	4	W	B	H
15	B1	1	4	S	A	G
16	B1	2	4	W	D	H
17	B1	2	3	W	D	F
18	B1	1	3	S	A	E
19	B1	1	3	W	B	F
20	B2	2	4	W	D	H
21	B2	2	3	S	C	E
22	B2	2	3	S	C	E
23	B2	1	3	W	B	F
24	B1	1	4	S	A	G
25	B2	2	4	W	D	H
26	B2	1	4	S	A	G
27	B1	2	4	W	D	H
28	B2	2	4	S	C	G
29	B1	1	3	S	A	E
30	B1	2	4	S	C	G
31	B2	2	3	W	D	F
32	B1	2	3	S	C	E

B1 = White Link

B2 = Ranger II

APPENDIX 13.7

P.R.C. chick mash

P.R.C. vitamin/mineral supplements

Table 1.

Composition of P.R.C. chick diet.
(parts by weight).

Barley meal	20.0
Maize meal	20.0
Wheat meal	22.5
Milo meal	7.5
Distilling solubles	1.25
Soyabean meal	15.0
DREG meal *	2.05
Whitefish meal	5.45
Meat-and-bone meal	2.95
Grass meal	1.25
Limestone flour	0.67
Dicalcium phosphate	0.63
Salt (NaCl)	0.22
Methionine	0.02
Vit/min/coccidiostat supplement	+

Calculated analysis (percent, air-dry basis).

Crude protein	19.6
Ether extract	3.0
Crude fibre	3.9
Calcium	1.23
Phosphorus	0.78
M.E. (kcal/lb)	1268

* spent yeast, cereal protein etc.

Table 2

Standard P.R.C. vitamin/trace mineral mixture for broilers
(g/1000 lb)

Rovimix A + D_3 (50/12.5)	14.5
Rovimix A 50	3.8
Rovimix E 25	46.0
Menaphthone	0.63
Riboflavin	1.88
Nicotinic acid	12.75
Calcium d-pantothenate	4.63
Cupric sulphate	6.25
Potassium iodate	0.33
Ferrous sulphate	102.5
Magnesium carbonate (light)	474.0
Manganous carbonate	95.0
Zinc oxide	28.75

Table 3.

Standard P.R.C. vitamin/trace mineral mixture for laying hens
(g/1000 lb)

Rovimix A + D_3 (50/12.5)	30.0
Rovimix A 50	25.0
Rovimix E 25	46.0
Menaphthone	0.63
Riboflavin	1.88
Nicotinic acid	12.75
Calcium d-pantothenate	4.63
Cupric sulphate	6.25
Potassium iodate	0.33
Ferrous sulphate	102.5
Magnesium carbonate (light)	474.0
Manganous carbonate	95.0
Zinc oxide	28.75