MINISTRY OF AGRICULTURE, FISHERIES AND FOOD **CSG 15**

Research and Development

Final Project Report

(Not to be used for LINK projects)

Two hard copies of this form should be returned to:
Research Policy and International Division, Final Reports Unit
MAFF, Area 6/01
1A Page Street, London SW1P 4PQ
An electronic version should be e-mailed to c.csgfinrep@csg.maff.gsi.gov.uk

Project title	Identification and evaluation of new or under-exploited sources of protein and energy, with particular emphasis on UK-grown plants and UK by-products.
MAFF project code	**LS0903**
Contractor organisation and location	Roslin Institute Roslin Midlothian EH25 9PS
Total MAFF project costs	£ 246863
Project start date	01/04/97
Project end date	31/03/00

Executive summary (maximum 2 sides A4)

The main objectives of this project were to identify plant and animal materials which have the potential for novel or increased use in poultry feeds. There is a particular need at present for a replacement for mammalian meat-and-bone meal. There is a longer-term need to replace fish-meal, the production of which may become ecologically unsustainable. The use of home-grown cereals, especially wheat and barley, is well-established but there is a need to examine new varieties, particularly varieties which have been bred for increased yield of protein or individual amino acids. The requirements for research are, therefore, to investigate plant or “bio-secure” animal sources of protein and energy, especially those which are or can be produced in the UK. The project reported on here was designed to examine some of the most likely candidate feedingstuffs and to evaluate them for use in the UK industry. The project was related to MAFF policy by the following aims: (1) To provide information on bio-secure sources of protein and other nutrients. In particular, to assess possible alternatives to meat-and-bone meal. (2) To maximise use of home-grown products and home-produced by-products to reduce dependence on imports and to increase market opportunities and diversification for UK arable farmers and renderers. (3) To maintain competitiveness of UK agriculture by providing information on ingredients and bird responses to nutrients. (4) To satisfy consumer preference for “healthy”, “natural” animal feedingstuffs. (5) To maintain an expertise and skills base for the UK agricultural industries. Feed evaluation and animal responses to nutrients are certain to remain a permanent requirement for the poultry and feedstuffs industry. (6) To implement technology transfer. (7) To provide postgraduate training opportunities for potential industry nutritionists. (8) There is a global dimension, in that there is a need to reduce competition between poultry and humans for high quality foodstuffs, such as maize and soya beans.

We believe that the research summarised here has made a useful contribution but we also consider that it is an area where continued effort is required to keep up with the production of new plant and animal varieties.

The survey evaluations confirmed that feather meal is a highly digestible source of amino acids, especially cystine, and that digestibility is greatly enhanced by the use of proteolytic enzymes during processing. It appeared that the positive synergism previously recorded between the digestibility of feather meal and blood meal may be specific to certain combinations of ingredients with feather meal. None of the plant materials tested gave a positive interaction.

In a free choice feeding experiment birds offered a diet with 200 g/kg of rapeseed meal ate similar amounts of that and the control diet. There was some aversion to a diet containing 200 g/kg of field peas but this may not be important when the bird is given pea meal in a complete diet. In such an experiment, in fact, the intake of a diet containing 100 g field peas/kg was greater than that of the control diet. In the present experiment, the diets were formulated to be similar in their contents of major nutrients but a variety of sensory and post-ingestional factors can influence choice.

Soyabean meal, field beans and several representative cultivars of field peas and lupins were assessed. Peas and lupins gave comparable true metabolisable energy (TME) values but with considerable variation among cultivars. Field beans gave a lower TME than the average of the other legumes. In the examples examineds, true amino acid digestibilities were quite high in all legumes. There was a clear tendency for TME to be lower for growing chickens than for adults. The addition of a proprietary feed enzyme mixture had no clear effect on TME or amino acid digestibilities but this needs more detailed investigation.

A high lysine barley cultivar had a lysine concentration about 25% higher than the other varieties tested. All three barley cultivars had similar TME values but true amino acid digestibility tended to be highest in the high-lysine variety. The digestibility of lysine was 79% in the high lysine variety, decreasing to 62% in the variety with lowest lysine content. The degree of difference in digestibility varied with individual amino acids. Linseed oil cake meal yielded rather low TME but amino acid digestibilities were comparable with those of more typical plant protein sources.

If maximal use is to be made of UK-grown plant protein sources, it is useful to know how much of these materials can be added to poultry diets while maintaining performance. Diets were therefore formulated to contain 100 g/kg or 200 g/kg of pea meal and solvent-extracted rapeseed meal and to be iso-energetic and iso-nitrogenous with a more conventional soya-wheat diet. Food intake was little affected by the inclusion of 100 g/kg of pea meal in the diet but 200 g/kg of peas caused a significant decrease at both stages of growth. Rapeseed produced a decrease in food intake at both concentrations and both stages of growth. Food conversion from d 0 to d 42 was little affected by the inclusion of either peas or rapeseed. Absolute breast muscle weight was significantly affected by diet but the fact that there was no significant difference in breast as a proportion of total body weight suggests that the effect on absolute weight was in direct proportion to the effect on total body weight. The fact that food conversion efficiency was not significantly affected by unusually high inclusions of field peas and rapeseed meal, even when there was reduced intake, was a positive finding. It was also encouraging that meat from birds grown on such diets was acceptable to human consumers (below).

Whole breast fillets were removed for organoleptic testing. The purpose of the testing was to assess whether or not consumers could detect any flavour difference in the meat taken from the chickens fed on the non-control diets. Triangle Testing was conducted, according to British Standard 5929 (Part 3: 1984). Control *versus* peas 100 g/kg, Control *versus* peas 200 g/kg, Control *versus* rapeseed 100 g/kg and Control *versus* rapeseed 200 g/kg were tested. Only in the case of 200 g rapeseed/kg were consumers able significantly to distinguish between the controls and the test-fed chickens. Although the breast meat from birds given 200 g rapeseed/kg was identified as different, no strong aversion was expressed by the consumers. Further sensory analysis will be carried out to characterise the flavour difference in more detail.

Scientific report (maximum 20 sides A4)

Objective 1. To quantify the value of hydrolysed feather meal as a source of metabolisable energy and digestible amino acids for layer and broiler strains. This will include comparison of raw material samples from different sources and feather meal treated with proteolytic enzymes.

Objective 2. To assess interactions of feather meal utilisation with other protein sources, such as blood meal, poultry byproduct meal, fish meal and plant protein sources. (The ultimate aim is to produce a ”fish meal replacer” as well as a replacement for ruminant meat byproducts).

Objective 3. To assess the acceptability of the above materials to growing birds by means of choice-feeding experiments.

Objective 4. To quantify the value of legume seeds (especially lupins and peas) as sources of metabolisable energy and digestible amino acids; this will include comparison of samples of seeds from different sources. (The aim here is to offer alternatives to soya bean meal in feed formulation).

Objective 5. To assess the effect of proprietary enzyme preparations on the nutritional value of legume seeds.

Objective 6. To measure the performance of growing birds on a range of inclusions of the above protein sources and screen for differences in portion yield and organoleptic qualities.

Objective 7. To assess the value of high-protein, particularly high-lysine, barley cultivars (with and without treatment with proprietary enzymes).

Objective 8. To assess the value of linseed oil cake as a protein and energy source.

Objective 9. To examine the value of linseed oil as a source of energy and linolenic acid. This would include examination of the fatty acid profile of meat and eggs from birds fed on different fat/oil sources; the specific interest would be in n-3 polyunsaturated fatty acids.

***Objective 1.* To quantify the value of hydrolysed feather meal as a source of metabolisable energy and digestible amino acids.**

Feather meal is clearly an excellent source of the cystine used in feather protein synthesis by birds. It must be hydrolysed by heat treatment (e.g. 45 minutes at 122 C) and should, therefore, be a safe raw material for poultry diets. Feather meal, like the other raw materials assessed in this project, was evaluated in a bioassay using adult cockerels, developed at the Roslin Institute with previous MAFF funding. Most previous work using the true metabolisable energy (TME) bio-assay has been done with adult cockerels, although most commercial interest is in the formulation of diets for broilers. A bio-assay has therefore been developed for the determination of TME in growing broiler chickens. After an initial 48 h fast, the test raw material is fed in 4 aliquots over 48 h, with droppings being collected 48 h after the last feeding. This method (repeat feeding) allows a greater quantity of the test feedstuff to be given and approximates more closely to normal feeding. Table 2 includes ME values for feather meal samples from various sources, given different hydrolysis treatments. The largest differences were between feathers treted and non-treated with proteolytic enzymes. This was typified by samples Feather 28 and Feather 29, which were of the same origin but Feather 29 had been treated with a proteolytic enzyme as well as being given the customary heat treatment.

Table 1. *The protocol for true metabolisable energy and amino acid digestibility measurements with cockerels.*

Time (h)	Tube-fed birds	Fasted birds (for EEL)
0	Food withdrawn	Food withdrawn
24	50 ml glucose solution	50 ml glucose solution
48	50 g test material	50 g glucose (granulated)
72	50 ml water palpate crop	50 ml water
96	Droppings collection Period may be extended by 24 h	Droppings collection

Table 2. *Metabolisable energy values of test raw materials, some with and without enzyme addition or enzyme treatment during processing (feather meal). Results were obtained in both adult cockerels and growing broiler chickens.*

Raw material	Bird type	Method	Treatment			
			no enzyme		with enzyme	
			mean	sd	mean	sd
Rapeseed meal	Adult	Tube-feeding	17.21	0.76		
	Chick	Tube-feeding	17.45	0.85		
Soyabean meal	Adult	Tube-feeding	11.16	0.41		
	Chick	Tube-feeding	9.40	0.43		
Field beans	Adult	Tube-feeding	10.67	0.61		
	Chick	Tube-feeding	11.42	0.91		
Linseed meal	Adult	Tube-feeding	9.98	0.88		
	Chick	Tube-feeding	8.89	0.87		
Fish meal	Adult	Tube-feeding	13.69	0.32		
	Chick	Tube-feeding	13.02	0.61		
Poultry meal	Adult	Tube-feeding	13.52	0.56		
	Chick	Tube-feeding	12.47	0.47		
Lupin A	Adult	Tube-feeding	11.74	0.64	11.45	0.57
	Chick	Tube-feeding	11.46	0.81	11.19	0.43
Lupin C	Adult	Tube-feeding	11.26	0.64	10.53	0.49
	Chick	Tube-feeding	10.47	1.27	10.75	0.65
Lupin D	Adult	Tube-feeding	9.58	0.35	10.40	0.87
	Chick	Tube-feeding	9.80	0.97	9.33	0.73
Pea Eifel	Adult	Tube-feeding	11.19	0.63	11.14	0.31
	Chick	Tube-feeding	10.48	0.57	9.97	0.55
Pea Elan	Adult	Tube-feeding	12.06	0.23	11.91	0.45
	Chick	Tube-feeding	11.06	0.61	10.17	0.68
Pea RO	Adult	Tube-feeding	10.79	0.49	11.01	0.37
	Chick	Tube-feeding	10.17	0.41	10.46	0.47
Barley High Lysine	Adult	Tube-feeding	12.47	0.33	12.54	0.22
	Chick	Tube-feeding	12.60	0.54	12.13	0.56
Barley MF	Adult	Tube-feeding	12.75	0.31	12.71	0.23
	Chick	Tube-feeding	13.39	0.68	12.78	0.35
Barley RO	Adult	Tube-feeding	13.01	0.20	12.45	0.28
	Chick	Tube-feeding	13.26	0.54	12.42	0.70
Feather 19	Chick	Repeat tube			12.20	1.16
Feather 21	Adult	Tube-feeding			12.14	0.41
	Chick	Repeat tube	11.02	0.33		
Feather 28	Adult	Tube-feeding	10.45	0.99		
	Chick	Repeat tube	9.60	1.10		
Feather 29	Adult	Tube-feeding			14.36	1.03
	Chick	Repeat tube			11.98unground	1.10
	Chick	Repeat tube			12.07ground	0.85
Feather 34	Adult	Tube-feeding			13.15	0.67
	Chick	Repeat tube			11.01	0.83
Feather 35	Adult	Tube-feeding			13.79	0.86
	Chick	Repeat tube			12.22	0.99
Feather 45	Adult	Tube-feeding			14.00	0.62
	Chick	Repeat tube			12.97	0.81
Feather 46	Adult	Tube-feeding			13.88	0.82
	Chick	Repeat tube			13.62	0.46
Feather 47	Adult	Tube-feeding			14.73	0.66
	Chick	Repeat tube			13.30	0.55
Feather 48	Adult	Tube-feeding			14.66	0.50
	Chick	Repeat tube			14.22	1.53
Feather F	Adult	Tube-feeding			13.96	0.60
	Chick	Repeat tube			12.38	0.75

Table 3. *Amino acid digestibilities. Examples from some of the key individual materials.*

Amino acid	**Digestibility %**					
	Lupin (A)	**Soya bean meal**	**Rapeseed meal**	**Bean meal**	**Linseed meal**	**Feather meal (F)**
Alanine	95.44	69.69	76.16	91.76	76.59	92.34
Arginine	98.78	99.70	108.44	95.96	92.59	91.84
Aspartic acid	94.29	92.17	73.28	87.96	77.96	76.74
Cystine	89.87	90.23	100.23	92.59	95.77	79.32
Glutamic acid	96.26	93.30	86.26	89.82	84.78	80.77
Histidine	92.14	89.99	76.69	89.71	67.37	71.66
i-Leucine	94.32	91.78	76.65	84.46	75.36	91.38
Leucine	95.21	98.28	81.67	86.94	72.99	90.43
Lysine	91.36	88.25	78.29	94.25	102.13	59.00
Methionine	88.80	98.91	108.27	101.96	95.41	103.88
Phenylalanine	99.67	92.31	83.08	86.40	81.19	97.13
Proline	95.70	88.19	72.75	89.08	65.19	86.04
Serine	95.47	89.36	69.35	86.10	68.84	88.46
Threonine	93.36	89.04	70.91	87.72	65.92	85.83
Tyrosine	100.76	92.51	77.83	84.96	68.87	88.32
Valine	91.43	88.16	69.98	83.37	66.97	87.49

Objective 2. **To assess interactions of feather meal utilisation with other protein sources.**

Feed evaluation and feed formulation are usually based on the assumption of linear additivity of ingredients and nutrients. Any occurrence of an interaction, whether positive or negative, must therefore be treated with interest. The experiments described here were designed to test whether interactions seen between feather meal and blood meal in metabolisability and amino acid digestibility (Table 4) were reproducible in blends with other substances (Tables 5 – 9). The TME values for the 2 pure materials in Table 4 were within the range of previously determined values. However, the 3 mixtures gave TME measurements consistently above the values which would be expected on the basis of linear additivity. The positive effect was significant in the 75% and 50% feather-meal mixtures, but the trend remained in the 25% mixture also. Amino acid digestibility measurements corroborated the TME effects, although they are not totally independent since they were determined simultaneously with the same birds. From the new results, it appears that this positive synergism may be specific to certain combinations of ingredients with feather meal. None of the plant materials tested gave a positive interaction (Tables 5-9).

Table 4. *Measurements of TME and TME_N of feather meal, blood meal and their blends in groups of 8 cockerels. $TME_{N\ expected}$ was calculated on the basis of linear additivity of the 2 pure raw materials. SED is the standard error of a difference between means and LSD is the least significant difference (P<0.05)*

	Feather meal	**75FM: 25BM**	**50FM: 50BM**	**25FM: 75BM**	**Blood meal**	SED 34 df	LSD $p<0.05$
TME	14.6_a*	15.3_a	15.4_a	14.5_a	13.4_b	0.45	0.91
TME_N	13.4_{ab}	13.9_a	13.7_a	13.0_b	12.1_c	0.35	0.70
$TME_{N\ expected}$	13.4	13.1	12.8	12.5	12.1		

* Measurements in the same row not sharing a common subscript are significantly different at the 0.05 level

Table 5. *Metabolisable energy values of blended raw materials. Results were obtained in both adult cockerels and growing broiler chickens.*

Raw material mixture	**Bird type**	**Method**	**TME MJ/kg**	
			mean	sd
Rapeseed meal 25% + Feather 75%	Adult	Tube-feeding	13.66	0.59
Rapeseed meal 25% + Feather 75%	Chick	Tube-feeding	13.47	0.61
Rapeseed meal 50% + Feather 50%	Adult	Tube-feeding	15.07	0.53
Rapeseed meal 50% + Feather 50%	Chick	Tube-feeding	16.05	1.19
Rapeseed meal 75% + Feather 25%	Adult	Tube-feeding	15.80	0.25
Rapeseed meal 75% + Feather 25%	Chick	Tube-feeding	17.37	0.83
Soyabean meal 25% + Feather 75%	Adult	Tube-feeding	12.36	0.36
Soyabean meal 25% + Feather 75%	Chick	Tube-feeding	11.87	0.95
Soyabean meal 50% + Feather 50%	Adult	Tube-feeding	11.61	0.45
Soyabean meal 50% + Feather 50%	Chick	Tube-feeding	11.51	0.77
Soyabean meal 75% + Feather 25%	Adult	Tube-feeding	11.29	0.20
Soyabean meal 75% + Feather 25%	Chick	Tube-feeding		
Fieldbean meal 25% + Feather 75%	Adult	Tube-feeding	12.38	0.49
Fieldbean meal 25% + Feather 75%	Chick	Tube-feeding	11.17	0.77
Fieldbean meal 50% + Feather 50%	Adult	Tube-feeding	12.27	0.12
Fieldbean meal 50% + Feather 50%	Chick	Tube-feeding	11.18	0.71
Fieldbean meal 75% + Feather 25%	Adult	Tube-feeding	11.26	0.26
Fieldbean meal 75% + Feather 25%	Chick	Tube-feeding	11.63	1.05
Fish meal 25% + Feather 75%	Adult	Tube-feeding	13.25	0.58
Fish meal 25% + Feather 75%	Chick	Tube-feeding	12.22	0.63
Fish meal 50% + Feather 50%	Adult	Tube-feeding	13.36	0.50
Fish meal 50% + Feather 50%	Chick	Tube-feeding	12.03	0.54
Fish meal 75% + Feather 25%	Adult	Tube-feeding	13.44	0.34
Fish meal 75% + Feather 25%	Chick	Tube-feeding	11.99	0.57
Poultry meal 25% + Feather 75%	Adult	Tube-feeding	12.74	0.37
Poultry meal 25% + Feather 75%	Chick	Tube-feeding	12.35	0.74
Poultry meal 50% + Feather 50%	Adult	Tube-feeding	13.02	1.14
Poultry meal 50% + Feather 50%	Chick	Tube-feeding	12.17	0.33
Poultry meal 75% + Feather 25%	Adult	Tube-feeding	13.29	0.74
Poultry meal 75% + Feather 25%	Chick	Tube-feeding	12.46	0.95

Table 6. *Feather meal, soya bean meal and their blends. Measurements of TME and TME_N in groups of 8* ***broiler chicks****. $TME_{N\ expected}$ was calculated on the basis of linear additivity of the 2 pure raw materials).*

	Feather meal	75FM: 25SBM	50FM: 50SBM	25FM: 75SBM	Soya bean meal
$TME_{N\ observed}$	12.38	12.36	11.51	11.26	9.40
$TME_{N\ expected}$	12.38	11.65	10.90	10.15	9.40
SD of $TME_{N\ observed}$	0.75	0.95	0.77	0.79	0.43
95% conf. limit of TME_N	0.63	0.79	0.64	0.66	0.36
Significance of Obs – exp diff.	-	NS	NS	<0.05 (+)	-

Table 7. *Feather meal, soya bean meal and their blends. Measurements of TME and TME_N in groups of 8* ***adult cockerels****. $TME_{N\ expected}$ was calculated on the basis of linear additivity of the 2 pure raw materials).*

	Feather meal	75FM: 25SBM	50FM: 50SBM	25FM: 75SBM	Soya bean meal
$TME_{N\ observed}$	13.96	12.36	11.51	11.29	11.16
$TME_{N\ expected}$	13.96	13.26	12.56	11.86	11.16
SD of $TME_{N\ observed}$	0.60	0.36	0.45	0.20	0.41
95% conf. limit of TME_N	0.50	0.30	0.38	0.17	0.34
Significance of Obs – exp diff.	-	<0.05 (-)	<0.05 (-)	<0.05 (-)	-

Table 8. *Feather meal, soya bean meal and their blends. Measurements of TME and TME_N in groups of 8* ***broiler chicks****. $TME_{N\ expected}$ was calculated on the basis of linear additivity of the 2 pure raw materials).*

	Feather meal	75FM: 25SBM	50FM: 50SBM	25FM: 75SBM	Soya bean meal
$TME_{N\ observed}$	12.38	12.36	11.51	11.26	9.40
$TME_{N\ expected}$	12.38	11.65	10.90	10.15	9.40
SD of $TME_{N\ observed}$	0.75	0.95	0.77	0.79	0.43
95% conf. limit of TME_N	0.63	0.79	0.64	0.66	0.36
Significance of Obs – exp diff.	-	NS	NS	<0.05 (+)	-

Table 9. *Feather meal, soya bean meal and their blends. Measurements of TME and TME_N in groups of 8* ***adult cockerels****. $TME_{N\ expected}$ was calculated on the basis of linear additivity of the 2 pure raw materials).*

	Feather meal	75FM: 25SBM	50FM: 50SBM	25FM: 75SBM	Soya bean meal
$TME_{N\ observed}$	13.96	12.36	11.51	11.29	11.16
$TME_{N\ expected}$	13.96	13.26	12.56	11.86	11.16
SD of $TME_{N\ observed}$	0.60	0.36	0.45	0.20	0.41
95% conf. limit of TME_N	0.50	0.30	0.38	0.17	0.34
Significance of Obs – exp diff.	-	<0.05 (-)	<0.05 (-)	<0.05 (-)	-

Objective 3. To assess the acceptability of UK-grown protein sources to growing birds by means of choice-feeding experiments.

If we are to make increasing use of UK plant protein sources, among which rapeseed meal and field peas are prime candidates, it is important to know their effects on diet palatability and intake. Free choice feeding is a method for assessing the preference of the animal itself. Diets were therefore formulated to contain 100 g/kg or 200 g/kg of pea meal and solvent-extracted rapeseed meal and to be iso-energetic and iso-nitrogenous with a more conventional soya-wheat (control) diet (Table 10). Titanium dioxide was added as an inert marker for digestibility and metabolisability measurements in related experiments. In all diets, lysine was fixed 11.00 g/kg, and other nutrients were formulated to be as similar as possible between diets and in excess of requirements. The diets were pelleted to prevent selection of individual ingredient particles by the birds. 20 male broiler chicks were reared to 14 d in heated brooders on a standard broiler-starter diet. At 14 d they were randomly allocated to individual cages fitted with two food troughs, one for each of the two diets. 10 birds were offered the choice between control and rapeseed and 10 the choice between control and field pea. The statistical significance of the choice was tested by one-sample t-test of the null hypothesis that the birds ate equal amounts of the test and control diets.

Table 10. *Raw material contents of diets*

Diet name	Control	Pea 200	Rape 200
Pea meal	0.0	**200.0**	0.0
Rapeseed meal	0.0	0.0	**200.0**
Wheat meal	623.0	448.0	506.0
Soya 480 g CP/kg	253.0	172.0	157.0
Maize gluten 600 g CP/kg	37.3	41.0	20.3
Soya oil	24.0	30.6	59.2
Fish meal	10.0	16.7	10.0
Methionine	1.70	3.14	2.00
Lysine hydrochloride	1.30	0.06	0.60
Dicalcium phosphate	14.5	13.8	11.3
Limestone flour	13.0	12.7	11.3
Vitamins and minerals	5.0	5.0	5.0
Choline chloride	0.30	0.30	0.30
Salt (sodium chloride)	2.90	2.70	3.00
Pellet binder	10.0	10.0	10.0
Titanium dioxide	4.0	4.0	4.0

From d 7 onwards, the degree of selection against the pea-containing diet approached statistical significance (Table 11). Between d 7 and d 14, birds ate about 1.8 times as much of the control as of the pea-containing diet. The failure of the control – field pea choice to reach statistical significance occurred because variance was increased by some birds making a clear but opposing choice in favour of the pea diet. The variability of birds in their diet selection is well known. Birds offered a rapeseed meal diet ate similar amounts of that and the control diet. The aversion to the pea-containing diet was numerically quite large, but may not be important when the bird is given pea meal in a complete diet. In the latter experiment, in fact, the intake of a diet containing 100 g field peas/kg was greater than that of the control diet. In the present experiment, the diets were formulated to be similar in their contents of major nutrients but a variety of sensory and post-ingestional factors can influence choice.

Table 11. *Selection between a wheat-soya diet and nutritionally similar diets containing 200 g of field pea meal or solvent-extracted rapeseed meal per kg*

	Field pea choice		**Rapeseed choice**	
	Control	**Peas 200 g/kg**	**Control**	**Rape 200 g/kg**
Proportions of intake d 0 – d 7	0.57	0.43	0.52	0.48
Proportions of intake d 7 – d 14	0.64	0.36	0.49	0.51
Proportions of intake d 0 – d 14	0.61	0.39	0.50	0.50
Differences from equality in proportions of intake d 0 – d 7	-0.067 (*P*=0.486)		-0.023 (*P*=0.797)	
Differences from equality in proportions of intake d 7 – d 14	-0.141 (*P*=0.085)		0.013 (*P*=0.879)	
Differences from equality in proportions of intake d 0 – d 14	-0.111 (*P*=0.183)		-0.004 (*P*=0.962)	

***Objective 4.* To quantify the value of legume seeds as sources of metabolisable energy and digestible amino acids and *Objective 5.* To assess the effect of proprietary enzyme preparations on the nutritional value of legume seeds.**

Only a summary of results can be presented in this report. Soyabean meal, field beans and several representative cultivars of field peas and lupins were assessed. True metabolisable energy (TME) and amino acid digestibilities in both adults and broiler chickens are shown in Tables 2 and 3. Peas and lupins gave comparable TMEs but with considerable variation between cultivars. Field beans gave a lower TME than the average of the other legumes. In the examples shown, true amino acid digestibilities were quite high in all legumes. There was a clear tendency for TME to be lower for growing chickens than for adults. The addition of a proprietary feed enzyme mixture had no clear effect on TME or amino acid digestibilities but this needs more detailed investigation. Enzymes may also have beneficial effects over and above their effect on TME and digestibility.

***Objective 6.* To measure the performance of growing birds on a range of inclusions of the above protein sources and screen for differences in portion yield and organoleptic qualities.**

If maximal use is to be made of UK-grown plant protein sources, it is useful to know how much of these materials can be added to poultry diets while maintaining performance. Diets were therefore formulated to contain 100 g/kg or 200 g/kg of pea meal and solvent-extracted rapeseed meal and to be iso-energetic and iso-nitrogenous with a more conventional soya-wheat diet (Table 1). In all diets, lysine was fixed at 11.00 g/kg, and all other indispensible amino acids were present in excess of requirements. Titanium dioxide was added as an inert marker for digestibility and metabolisability measurements. Five replicate pens of 20 male Ross broilers were grown to 42 d on each diet. Body weights were recorded at 1, 21 and 42 d. Food intake was measured between d 1 and 21 and between d 21 and 42. All birds were killed at d 42 and breast muscle yield measured in two birds per pen. The results were subjected to analysis of variance.

Table 12. *Raw material contents and calculated analyses of diets*

Diet name	**Control**	**Pea 100**	**Pea 200**	**Rape 100**	**Rape 200**
Pea meal	0.0	**100.0**	**200.0**	0.0	0.0
Rapeseed meal	0.0	0.0	0.0	**100.0**	**200.0**
Wheat meal	623.0	555.5	448.0	564.5	506.0
Soya 480 g CP/kg	253.0	212.5	172.0	205.0	157.0
Maize gluten 600 g CP/kg	37.3	39.15	41.0	28.8	20.3
Soya oil	24.0	27.3	30.6	41.6	59.2
Fish meal	10.0	13.35	16.7	10.0	10.0
Methionine	1.70	2.42	3.14	1.85	2.00
Lysine hydrochloride	1.30	0.68	0.06	0.95	0.60
Dicalcium phosphate	14.5	14.15	13.8	12.9	11.3
Limestone flour	13.0	12.85	12.7	12.15	11.3
Vitamins and minerals	5.0	5.0	5.0	5.0	5.0
Choline chloride	0.30	0.30	0.30	0.30	0.30
Salt (sodium chloride)	2.90	2.80	2.70	2.95	3.00
Pellet binder	10.0	10.0	10.0	10.0	10.0
Titanium dioxide	4.0	4.0	4.0	4.0	4.0
TME_N MJ/kg	12.5	12.5	12.5	12.5	12.5
Crude protein g/kg	225.0	224.0	223.0	225.1	225.2
Lysine g/kg	11.00	11.01	11.02	11.03	11.05
Methionine+cystine g/kg	8.72	9.37	10.01	9.36	10.00
Threonine g/kg	7.69	7.75	7.81	7.96	8.23
Tryptophan g/kg	2.52	2.42	2.31	2.57	2.61

Food intake was little affected by the inclusion of 100 g/kg of pea meal in the diet but 200 g/kg of peas caused a significant decrease at both stages of growth. Rapeseed produced a decrease in food intake at both concentrations and both stages of growth. Weight gain was similarly affected, but effects on food conversion ratio were significant only between d 0 and d 21. Food conversion from d 0 to d 42 was little affected by the inclusion of either peas or rapeseed. Absolute breast muscle weight was significantly affected by diet but the fact that there was no significant difference in breast as a proportion of total body weight suggests that the effect on absolute weight was in direct proportion to the effect on total body weight.

Table 13. *Food intake, weight gain, feed conversion ratio and breast muscle weight in broiler chickens fed on diets high in peas and rapeseed*

	Control	**Pea 100 g/kg**	**Pea 200 g/kg**	**Rape 100 g/kg**	**Rape 200 g/kg**	LSD	*P*
Food intake (g)							
d 0 – d 21	1135	1150	978	976	952	103.0	0.001
d 21 – d 42	3394	3405	3170	3120	3145	229.8	0.035
d 0 – d 42	4528	4556	4148	4096	4097	272.6	0.002
Weight gain (g)							
d 0 – d 21	769	780	653	645	596	32.1	<0.001
d 21 – d 42	1832	1808	1778	1683	1714	106.2	0.043
d 0 – d 42	2601	2588	2431	2328	2310	126.9	<0.001
FCE							
d 0 – d 21	0.68	0.68	0.67	0.66	0.63	0.039	0.003
d 21 – d 42	0.54	0.53	0.56	0.54	0.54	0.069	0.379
d 0 – d 42	0.57	0.57	0.58	0.57	0.56	0.044	0.292
Breast							
Weight (g)	475	447	431	420	395	43.07	0.009
Proportion	0.170	0.164	0.161	0.163	0.155	0.1020	0.190

The reduced intake on the 200 g/kg pea diet can be related to the 1.8-fold preference shown for the control diet over the 200 g/kg diet in a choice-feeding experiment. However, the reduced intake associated with rapeseed inclusion was not reflected in a clear preference in the choice experiment. The fact that food conversion efficiency was not significantly affected by unusually high inclusions of field peas and rapeseed meal, even when there was reduced intake, was a positive finding. It was also encouraging that meat from birds grown on such diets was acceptable to human consumers (below).

Sensory evaluation

With the increased drive towards the use of plant proteins, especially those which can be grown in the UK, it is important to assess the effects of these protein sources on product quality. Diets were therefore formulated to contain 100 g/kg or 200 g/kg of pea meal and solvent-extracted rapeseed meal and to be iso-energetic and iso-nitrogenous with a more conventional soya-wheat diet. Titanium dioxide was added as an inert marker for digestibility and metabolisability measurements (Table 14). In all diets, lysine was calculated to be first-limiting, at 11.00 g/kg, and other amino acids were present in excess of requirements. Five replicate pens of 20 male Ross broilers per diet were grown to 46 d.

Table 14. *Raw material contents of diets*

Diet name	Control	Pea 100	Pea 200	Rape 100	Rape 200
Pea meal	0.0	**100.0**	**200.0**	0.0	0.0
Rapeseed meal	0.0	0.0	0.0	**100.0**	**200.0**
Wheat meal	623.0	555.5	448.0	564.5	506.0
Soya 480 g CP/kg	253.0	212.5	172.0	205.0	157.0
Maize gluten 600 g CP/kg	37.3	39.15	41.0	28.8	20.3
Soya oil	24.0	27.3	30.6	41.6	59.2
Fish meal	10.0	13.35	16.7	10.0	10.0
Methionine	1.70	2.42	3.14	1.85	2.00
Lysine hydrochloride	1.30	0.68	0.06	0.95	0.60
Dicalcium phosphate	14.5	14.15	13.8	12.9	11.3
Limestone flour	13.0	12.85	12.7	12.15	11.3
Vitamins and minerals	5.0	5.0	5.0	5.0	5.0
Choline chloride	0.30	0.30	0.30	0.30	0.30
Salt (sodium chloride)	2.90	2.80	2.70	2.95	3.00
Pellet binder	10.0	10.0	10.0	10.0	10.0
Titanium dioxide	4.0	4.0	4.0	4.0	4.0

At 46 d, two birds of near-median weight were killed and whole breast fillets were removed for organoleptic testing. The purpose of the testing was to assess whether or not consumers could detect any flavour difference in the meat taken from the chickens fed on the non-control diets. The chicken breasts were kept frozen at -20 C until 24 h prior to cooking. Cooking times were established using chicken breasts trimmed to 200 g, cooked in lidded Pyrex dishes. Sample cooking times were based on the time taken for the core temperature of the breast to reach 80 C, to ensure fitness for consumption. All samples were cooked in the same oven on the same shelf to ensure inter-sample consistency. Each breast was cut into ten 10 g pieces for assessment. Samples were served to consumers in labelled polystyrene containers which were lidded. To determine whether or not consumers could detect any difference in flavour between the control sample and each of the test samples, Triangle Testing was conducted, according to British Standard 5929 (Part 3: 1984). Three samples were presented to the consumer; two of the samples were the same and different from the third. Consumers were asked to identify the “odd one out”. The triangles to be tested were as follows: (1) control + peas 100 g/kg; (2) control + peas 200 g/kg; (3) control + rapeseed meal 100 g/kg; (4) control + rapeseed meal 200 g/kg.

Each triangle was tested by 20 consumers. Control *versus* pea comparisons were by 20 consumers, aged between 20 and 49, but predominantly 20-29 (40%) and predominantly female (65%). Control *versus* rapeseed comparisons were by 20 consumers, aged between 20 and 49, but predominantly 20-29 (50%) and mostly female (90%). To avoid any bias, 10 of the consumers were given 2 control samples and one test sample, with a balanced presentation order (accounting for all possible permutations in the order in which the samples could be placed). The other 10 consumers were presented with two test samples and one control sample, again with a balanced sample presentation order. Testing took place in sensory evaluation booths. To avoid the consumers being influenced by any differences in colour all consumer testing was done under red lighting. Twenty consumers evaluated triangle 1 followed by triangle 2; a further 20 consumers evaluated triangles 3 and 4.
Control *versus* peas 100 g/kg. For any difference between the samples to be significant at $P<0.05$, 11 consumers needed to identify correctly the different sample in the triangle. Out of 20 consumers, only 6 were

able to identify the "odd one out" (*P*=0.703). We can conclude that consumers were unable significantly to distinguish any differences between the controls and the chickens fed on the diet containing 100 g peas/kg.

Control *versus* peas 200 g/kg. Out of 20 consumers, only 8 were able to identify the "odd one out" (*P*=0.339). We can conclude that consumers were unable significantly to distinguish any differences between the controls and the chickens fed on the diet containing 200 g peas/kg.

Control *versus* rapeseed 100 g/kg. Out of 20 consumers, 9 identified the "odd one out" (*P*=0.191). We can conclude that consumers were unable significantly to distinguish any differences between the controls and the chickens fed on the diet containing 100 g rapeseed/kg.

Control *versus* rapeseed 200 g/kg. Out of 20 consumers, 11 identified the "odd one out" (*P*=0.038). We can conclude that consumers were able significantly to distinguish between the controls and the chickens fed on the diet containing 200 g rapeseed/kg.

Although the breast meat from birds given 200 g rapeseed/kg was identified as different, no strong aversion was expressed by the consumers. Further sensory analysis will be carried out to characterise the flavour difference in more detail.

***Objective 7.* To assess the value of high-protein, particularly high-lysine, barley cultivars.**

The high lysine cultivar obtained had a lysine concentration about 25% higher than the other varieties tested (Table 2). All three barley cultivars had similar TME values. However, true amino acid digestibility tended to be highest in the high-lysine variety (Table 15). The digestibility of lysine was 79% in the high lysine variety, decreasing to 62% in the variety with lowest lysine content. The degree of difference in digestibility varied with individual amino acids. Table 15 gives only a subset of the results.

Table 15. *Barley amino acid digestibilities for cockerels*

Amino acid	Digestibility %		
	Barley High lysine 3.75 g/kg	Barley Control (MF) 2.79 g/kg	Barley Control (RO) 3.09 g/kg
Alanine	88.09	65.98	79.12
Arginine	90.27	70.59	70.16
Aspartic acid	81.49	59.45	70.18
Cystine	87.22	59.69	67.09
Glutamic acid	92.35	87.22	93.12
Histidine	84.29	71.10	83.80
i-Leucine	86.41	76.14	85.27
Leucine	88.07	79.12	87.24
Lysine	79.12	62.15	74.43
Methionine	90.22	58.20	71.08
Phenylalanine	89.13	82.76	89.64
Proline	93.11	84.89	93.01
Serine	86.49	63.02	90.57
Threonine	83.89	69.09	83.52
Tyrosine	91.21	78.70	90.28
Valine	83.91	71.04	79.52

Objectives 8 and 9. **To assess the value of linseed oil cake meal as a protein and energy source and linseed oil as a source of energy and linolenic acid.**

Values of energy metabolisability and amino acid digestibility for linseed oil cake meal are shown in Tables 2 and 3 above. TME is rather low, because of the high fibre and low oil content of the extracted product. Amino acid digestibilities, however, are comparable with those of more typical plant protein sources. There are cases in several of the materials tested where digestibility is over-estimated (>100%); this is likely to result from errors in the estimation of exogenous losses using fasted birds. There is still scope for technical development in this area, although comparative results within a single experiment are probably the best that can be achieved. Heavy but essential staff input on setting up new methods for amino acid analysis prevented the achievement of Objective 9. We have agreed with Dr Garwes that work in this area will be addressed as part of the current Project on Naked Oats for Laying Hens.

Please press enter