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

Research and Development

Final Project Report

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Project title	Desk study – Optimising the synergism between organic poultry production and whole farm rotations, including home grown protein sources
MAFF project code	**OF0163**
Contractor organisation and location	ADAS Consulting Ltd
Total MAFF project costs	£ 89,807
Project start date	01/01/99
Project end date	31/12/01

Executive summary (maximum 2 sides A4)

Background
Over the past fifty years most poultry in the UK have been managed in specialist indoor systems, and excluded as a significant enterprise from most other farm types. This meant that there was little information on how to integrate poultry into land-based systems such as organic production. Project OF0163 aimed to assess methods of integrating organic poultry into crop rotations, taking into account the need to meet the birds' nutritional and physiological requirements for health and performance, the recycling of nutrients between soil, plants and birds and practical limitations of the system.

Objectives
1. To review the scientific literature available on home grown protein sources so as to identify their maximum inclusion rates in organic poultry rations (laying hens and table chickens).
2. To measure nitrogen retention and to determine the nutrient content of manure from slow growing meat birds fed non limiting rations *versus* Label Rouge rations.
3. To measure nitrogen retention and to determine the nutrient content of manure in slow growing meat birds housed at a stable thermoneutral temperature *versus* a daily ambient temperature cycle during late autumn/winter months.
4. To review the scientific information available so as to determine the optimum position for poultry in whole farm rotations.
5. To provide examples of enterprise costings, including gross margins over variable costs, for mixed farms on a "with poultry" (laying hens and table chickens, separately) and "without poultry" basis.
6. To disseminate information on poultry management techniques as they apply to an organic system of egg production and table chicken production.

Methodology
The work was mostly desk based but there were some supplementary measurements made within two experiments in a DEFRA-funded project on extensive table chickens (OF0153). The first component of the work was to review the literature on the use of home grown protein sources in poultry feeds and to provide recommendations on their maximum inclusion rates in rations for organic chickens. In the second part of the work litter manures were sampled from several hybrids when they were either fed differing nutrient densities, or housed in differing thermal environments, and grown to 81 days of age. Sampling was done as add-on measurements to project OF0153, and measurements were made of litter dry matter, nitrogen (N), ammonium-N and uric acid-N contents. The availability of N in the manures was calculated as applied to crops. A second literature review addressed topics thought to be important to the success of integrating organic chickens into cropping (e.g. housing factors relevant to meeting the birds' physiological needs, husbandry, inputs and outputs of organic chicken enterprises, flock cycles, and pasture management and rotation). For a rotation including organic laying hens or table chickens, nutrient balances were calculated at both farmgate and soil surface levels. This allowed an assessment of nutrient recycling between the soil, plants and birds. The next element was to assess how well organic chickens fitted cropping in terms of flock cycle length, and sowing and harvesting of crops.

Finally calculations were made of farm gross margins including or not including organic chickens within the crop rotation. Laying hens and table chickens were considered separately, and calculations were made for bought-in feed *versus* home mixed feed.

At the end of the project two study days were held at ADAS Gleadthorpe to report outputs from the project.

Results
Home grown protein sources are less rich in protein, lysine and methionine than soya and they have antinutritive factors that limit their inclusion rate. This means that there is no one ideal home grown protein source for feeding to organic poultry. It is likely that a wider range of ingredients will need to be used in organic poultry feeds so as to meet the birds' nutrient requirements for health and performance, compared with non-organic feeds. One difficulty in doing this is that the cereal component occupies a lot of space within the ration, so other ingredients must be included on the basis of their nutrient density and this may increase the cost of the feed.

It is important that the essential amino acid content of organic feeds meets the birds' needs for health and performance. The latter does not necessarily mean optimal bird performance in terms of growth or egg mass output, but performance at a level that is financially and biologically sustainable. Furthermore, in meeting the required essential amino acid content, the crude protein content of the ration should not be increased. Feeding excess nitrogen increases manure moisture and nitrogen contents, and the potential risk of pollution.

It is desirable to balance the supply of essential amino acids in the feed, as the bird does not need equal intakes of each amino acid. It will be difficult to achieve this using organic feed ingredients. Fishmeal from sustainable sources is likely continue to be an important 'balancer' of nutrients in organic poultry feeds.

The manurial N value should be determined before application to the land. This is because factors such as breed, feeding strategy, feed specification, feed ingredient base and seasonal temperature effects on feed intake, will also affect manurial N value. For this reason, MANNER was not updated so as to include data on organic poultry manures.

A typical six course rotation - two years of grass/clover ley, one year of potatoes, one year of wheat, one year of peas and one year of wheat, was used in the calculation of nutrient balances. Laying hens and table chickens were included separately in the grass/clover ley. The rotation was did not supply feed protein nor all of the cereal component of the feed, and potassium and phosphorus were near break-even. More complex rotations need to be tested for nutrient sustainability, and this could include the trading of nutrients at a local level, and a wider variety of home grown protein sources.

Farm gross margins of egg output sales over feed costs, calculated so as to take into account the loss of transitional derogations (pullet rearing and hen house stocking density) were negative at current egg prices for the rotation and conditions used. There were positive farm gross margins of live weight sales over feed costs for table chickens but this did not take into account increased chick prices, when transitional derogations on organic breeding and hatching are removed. The findings on gross margins may be different for other scenarios.

Implications of findings, future work and policy relevance

There are several implications of the findings of this work. Firstly, it is not likely that organic poultry production will be as nutrient efficient as intensive conventional production. This is because organic feeds are not ideal in terms of nutrient supply and the balance. Fishmeal is an important nutrient 'balancer' in organic poultry rations, and if this is to be disallowed in the future, then nutrient efficiency may be reduced.

Wider rotations will be needed so as to provide more of the birds' nutrients from home grown sources. There will be a time lag involved, as methods of growing crops in organic systems are needed. The recycling of nutrients between the soil, plants and crops when using more complex rotations needs to be calculated.

Organic feed is the biggest part of total variable costs. One means of reducing feed costs may be to use high protein forages for grazing, rather than poorly utilised and low nutrient value ryegrass swards. The forages may also provide shelter for the birds and this may encourage them to spend more time outdoors. Ryegrass swards are kept necessarily short so as to avoid crop impaction. The use of a wider range of forage types for grazing by organic poultry needs to be assessed.

Methods of reducing feed costs will be critical to the success of future systems of organic poultry production. This is because chick costs and pullet costs will increase when transitional derogations on organic breeder flocks, hatching and pullet rearing end. Breeders and pullets will need to be fed on more expensive organic rations, and feed intakes will be higher in an outdoor system than in current indoor systems.

Technical difficulties associated with organic pullet rearing as identified and reported in project OF0192 need to be addressed. Similarly, this needs to be done for organic breeder flocks and hatching. Little is known about the price elasticity of organic eggs, but if costs of production are not reasonably contained the market for organic eggs may decrease. A gap in technical knowledge, changing standards and market uncertainties may mean that some organic poultry producers change to non-organic production.

Lastly, as transitional derogations on organic pullet rearing and breeder flocks come to an end there will be a need to find a production outlet for male chicks of egg lines. It is not likely to be acceptable to kill the male chicks at day old, as is current practice in non-organic systems. One approach may be to use dual-purpose hybrids, with female chicks reared for organic egg production and the male chicks are reared for meat.

The project addressed DEFRA's policy of supporting the development of organic livestock production within the UK. The project has provided information to DEFRA and the organic sector of the farming industry about the key technical findings and problems associated with integrating organic poultry into crop rotations.

Scientific report (maximum 20 sides A4)

1.0. OBJECTIVES

The project objectives are given below.

1. To review the scientific literature on home grown protein sources so as to identify their maximum inclusion rates in organic poultry rations (laying hens and table chickens).
2. To measure nitrogen retention and to determine the nutrient content of manure at about 81 days of age from slow growing meat birds fed non limiting rations *versus* Label Rouge rations,.
3. To measure nitrogen retention and to determine the nutrient content of manure at about 81 days of age in slow growing meat birds housed at a stable thermoneutral temperature *versus* a daily ambient temperature cycle during late autumn/winter months,.
4. To review the scientific information so as to determine the optimum position for poultry in whole farm rotations.
5. To provide examples of enterprise costings, including gross margins over variable costs, for mixed farms on a “with poultry” (laying hens and table chickens, separately) and “without poultry” basis.
6. To disseminate information on poultry management techniques as they apply to an organic system of egg production and table chicken production.

2.0. METHODOLOGY

The work was primarily a desk study although there was a limited amount of experimental work. The latter was carried out at ADAS Gleadthorpe as an “add on” to DEFRA-funded experiments within project OF0153.

2.1. To review the scientific literature on home grown protein sources so as to identify their maximum inclusion rates in organic poultry rations (laying hens and table chickens).

Literature searches of the major international abstracting databases were done using key words related to feeding rapeseed, peas, beans, lupins, linseed, sunflower meal, tomato products, or naked oats to poultry. Databases searched included agriculture, biology, life sciences, food sciences, and medical sciences.

Published and on-going European organic research was taken into consideration and information arising in DEFRA-funded project OF0153 (Effect of breed suitability, system design and management on welfare and performance in traditional and organic poultry systems) was used wherever possible. While reviewing the literature an assessment was made of the extent to which published results from non-organic production systems may be applied to organic systems.

At the end of the review recommendations were made on maximum inclusion rates for the most useful raw ingredients in an organic ration. This was done separately for young (table chickens) and adult birds (laying hens).

The findings of the literature review were sent to DEFRA in August 1999 and they were presented to the steering group for DEFRA-funded project OF0153 on 19th September 2001 and to organic poultry producers at the DEFRA-funded study days held at Gleadthorpe on 11th and 12th December 2001.

2.2. To measure nitrogen retention and manure nutrient contents in slow growing meat birds fed non limiting rations *versus* Label Rouge rations at about 81 days of age

This was done as add-ons to a DEFRA-funded experiment in project OF0153. The main experiment aimed to characterise performance, mortality, and meat quality in several breeds, first crosses, and hybrids of chicken when fed a presumed non-limiting three-stage ration programme *versus* a Label Rouge three-stage ration programme. Some details of the main experiment are given below.

There were four breed types used: namely fast growing, medium to fast growing, slow growing and very slow growing. Fast growing breeds were UK broiler hybrids supplied by Ross Breeders Ltd, and they were Ross 308 birds, Ross 508 birds, and Ross YA x PM3 birds. Medium to fast growing breeds were commercial hybrids supplied as imports by Hubbard ISA, they were ISA 757 birds, ISA 957 birds, Redbro birds, and Master Gris birds. Slow growing breeds were imported commercial hybrids supplied by Hubbard ISA and they were ISA 457 birds, ISA 657 birds, and Gris Barre birds. In each case Hubbard ISA stock were sourced from France and imported as hatching eggs. The eggs were contract hatched by Maurice Millard Ltd. Very slow growing breeds were traditional UK breeds supplied by the Rare Breeds Survival Trust and they were Light Sussex, White Sussex, Ixworth and White Dorking. All birds were housed simultaneously at day old.

There were two feed treatments, namely a non-limiting three-stage ration programme (with respect to Ross 308 birds) and a Label Rouge three-stage ration programme. The non-limiting rations were purchased from BOCM PAULS Ltd. The crude protein contents of the starter, grower and finisher rations were 210 g/kg, 210 g/kg and 185 g/kg, respectively. The Label Rouge rations were home-mixed and of a mash consistency. The crude protein contents of the starter, grower and finisher rations were 182 g/kg, 161 g/kg and 159 g/kg, respectively. Birds received a starter allowance of 0.550 kg/bird for the presumed non-limiting ration and 0.635 kg/bird for the Label Rouge ration. The grower allowance was 1.250 kg/bird for the non-limiting ration and 1.630 kg/bird for the Label Rouge ration. This provided a common cumulative nitrogen intake of 18.5 g/bird at the changeover from starter to grower ration and a common cumulative nitrogen intake of 60.5 g/bird at the changeover from grower to finisher ration. Finisher rations were provided *ad libitum*.

Comparisons were not made between breed types. This was because gross differences in live weight gain and performance were expected, and by ignoring breed type comparisons, breed comparisons within a breed type were strengthened.

The experiment used a split plot design in which the first level was feed type and this was fully randomised within a room. The second level was breed treatment. All breed treatments were imposed on both feed types, except for the White Dorking which was imposed on the Label Rouge type diet only. This was due to poor fertility and hatchability which limitied the number of day old chicks available at housing. Breed treatments were fully randomised within feed type. Except for the White Dorking birds there were 140 chicks per treatment combination.

Feed usage and live weight were measured at ration changeover, and on days 56 and 81. Nitrogen intake, nitrogen gain, and nitrogen retention (as a percentage of the total nitrogen consumed) were determined for Ross 308 birds, ISA 657 birds, Gris Barre birds and Ixworth birds on each feed treatment.

For the same treatment combinations, composite litter samples were taken on day 80, and measurements made of litter dry matter, total nitrogen (N), ammonium-N, and uric acid-N contents.

Note: Ross 308 birds are not slow growing in terms of early live weight gain but some UK organic table chicken producers use them. Label Rouge rations were similar to organic rations for table chickens in terms of the nutrient content.

2.3. To measure nitrogen retention and manure nutrient contents at about 81 days of age in slow growing meat birds housed at a stable thermoneutral temperature *versus* a daily ambient temperature cycle during late autumn/winter months

This was done as add-ons to a DEFRA-funded experiment in project OF0153. The main experiment aimed to characterise performance, mortality, and meat quality in several breeds, first crosses, and hybrids of chicken when housed in either a stable thermoneutral environment or a diurnally fluctuating thermal environment during the post brooding period. Some details of the main experiment are given below.

There were two breed suppliers providing a total of five breeds. Moy Park Ltd, based in Northern Ireland, supplied Ross 308 chicks (commercial broiler) and SASSO S77N chicks. SASSO S77N chicks were 'slow growing', and were thought to have a growth profile that was suited to meeting typical market live weights of about 2.0 kg to 2.5 kg between days 70 and 81. Hubbard ISA sourced hatching eggs in France for the following breeds: ISA 957, Redbro, Master Gris and ISA 657 (Master Gris was substituted for Gris Barre because of difficulties in sourcing Gris Barre hatching eggs). The hatching eggs were imported into the UK and they were contract hatched by Maurice Millard Ltd. There were 560 chicks of each breed. All chicks were housed at day old in the climatic house at ADAS Gleadthorpe, and on the same day.

The two post brooding temperature regimes were: i) a stable thermoneutral environment (ambient temperature of 20°C at day 24,gradually reduced to 18°C by day 50, and then held constant until day 81), and; ii) a diurnally fluctuating temperature regime determined by outside temperature.

A stable thermoneutral environment was achieved using standard ventilation and thermostatic equipment provided for each of the eight rooms. Speed controls were fitted to the minimum ventilation fans in rooms used for the diurnally fluctuating temperature regime. This enabled fans to run continuously so as to bring cool outside air into the room but without causing draughts over the birds. The temperature within the room changed as outdoor temperature changed, but there was a temperature lift within the room of about 5°C.

UK stock was housed in separate rooms to imported stock. Thus, within UK stocked rooms a comparison of performance was made between a fast growing breed type and a slow growing breed type, whereas within rooms containing imported stock, comparisons were made of medium to fast growing breed types and slow growing breed types.

A split-plot design was used. The post brooding temperature regimes were the main room treatments and the sub-plot treatments were breed. There were two replicates of the post brooding temperature regimes and each breed was replicated twice within the room. The duration of the growing period was 81 days. Label Rouge rations were fed as detailed above.

Feed usage and live weight were measured at ration changeover and on days 56 and 81. Nitrogen intake, nitrogen gain, and nitrogen retention (as a percentage of the total nitrogen consumed) were determined for Ross 308 birds, SASSO S77N birds, and for Redbro birds and ISA 657 birds on each post brooding temperature regime.

For the same treatment combinations, composite litter samples were taken on day 80 and measurements were made of litter dry matter, total nitrogen, ammonia-N, and uric acid-N contents.

2.4. To review the scientific information so as to determine the optimum position for poultry in whole farm rotations

This piece of work involved a review of published literature. In addition some new information on nutrient balances was produced.

There were three main elements to this work. The first of these was specific to poultry production. Information on poultry husbandry, and on inputs and outputs from the organic poultry enterprise was needed. Much of this information was obtained from organic poultry producers and from DEFRA-funded project OF0153. Published information was used when available, when thought to be relevant to organic farming systems.

The second key area was to calculate nutrient balances at farmgate and soil surface level for rotations including poultry. A nutrient balance is a nutrient accounting process which sums all of the inputs and outputs to and from a given system. It provides an indication of the likely long-term changes in soil nutrient status, and so it may be used to predict the effect of changes to farm systems and practices. Published rotations were used, but they were adapted so that poultry grazed grass/clover leys. Information used in the case studies is given below.

<u>2.4.1. Case studies</u>

Nutrient balances

The integration of poultry into an organic rotation is currently quite rare in the UK, and so a hypothetical rotation was proposed and nutrient balances calculated. The rotation consisted of two years of grass/clover ley, followed by one year each of potatoes, wheat, peas and wheat. Each phase of the hypothetical rotation occupied a 3 ha block and crop yields and nutrient contents were estimated from published organic sources. It was calculated that a realistic flock size would be 1 000 laying hens, or 2 500 table birds, occupying one hectare of the ley, with the remaining ley maintained by cutting and mulching.

Laying hens
Current practice within the UK is for non-organic pullets to be transferred from the rearing site to the organic laying unit at 16 weeks of age. They are then reared according to organic Standards for six weeks, after which they achieve organic status. From week 22, hens are given access to pasture and eggs laid from then onwards may be sold as organic eggs. Between 16 weeks and 72 weeks of age an organic layer will consume about 50 kg feed. A ration based on wheat and peas would not meet the birds welfare requirements or support egg production, due to deficiencies in essential amino acids. A sufficient quantity of wheat was also unlikely to be provided by the rotation proposed. The ration formulation used was based on the use of other bought-in protein rich ingredients, and synthetic amino acids (as is current practice in the UK), and by using a typical nutrient specification greater confidence was given to egg mass output and manure nutrient content data.

Relatively low egg production and egg weight examples were chosen for the calculations (280 eggs per hen housed over a 52 week laying period and a mean egg weight of 59 g). The basis for assuming lower technical performance include; greater use of traditional breeds, feed amino acid imbalance and constraints on feed ingredients, and limitations on lighting regimes.

A laying hen will produce between 40 kg to 45 kg fresh droppings throughout the laying cycle, of which it is estimated that 60% will be produced within the house.

Table chickens
About 6.9 kg feed of feed will be eaten between day old and slaughter at between 73 and 81 days of age. For reasons given above for laying hens the feed was formulated to include soya and synthetic amino acids. Within one year, four flocks of 2 500 table birds (10 000 birds in total) could be accommodated on 1 ha of the grass/clover ley. They would require 69 t of feed (6.3 t starter, 16.3 t grower and 46.4 t finisher), consisting of about 48 t of wheat and 1.5 t of peas, with the remainder (19.5 t) bought-in from external sources. Again the hypothetical rotation would not be able to produce this quantity of wheat so a proportion would have to be bought-in.

Outputs from the system would include the 10 000 table birds, excess peas grown within the rotation, and manure estimated at about 3.4 kg per bird, with 60% deposited in the house.

Farmgate and soil surface nutrient budgets were calculated for hypothetical rotations. The farmgate balances included inputs of nutrients by purchased seeds, animals (table bird chicks only), feeds and bedding materials. These were compared with the output of nutrients in sold plant (potatoes/peas) and poultry (eggs/birds) products. The soil surface balances also included nutrient inputs as atmospheric deposition, nitrogen fixation and seeds, but feeds, purchased animals and bedding materials were excluded as these should be accounted for by including animal manures as an input. These inputs were compared with the output of nutrients in all harvested plant products, including those recycled on-farm, nitrate leaching losses and ammonia volatilisation losses following manure spreading.

The nutrient contents of poultry feeds, poultry products, manures and crops were derived from published literature.

The third key area of this piece of work was to assess how well organic poultry fit into the above rotation in terms of flock cycles and cropping, and this was done separately for laying hens and table chickens.

The findings of the literature review were presented to the steering group for DEFRA-funded project OF0153 on 19th September 2001 and to those attending DEFRA-funded study days held at Gleadthorpe on 11th and 12th December 2001. A copy of the literature review will be sent to DEFRA in February 2002.

2.5. Examples of enterprise costings, including gross margins over variable costs, for mixed farms on a "with poultry" (laying hens and table chickens, separately) and "without poultry" basis

The arable rotation used for this piece of work either included potatoes or it did not. The rotation was based on two years red clover based green manure, one year of winter wheat or potatoes, one year of winter oats, one year of field beans and one year of spring cereal. For each of these rotations, poultry were either included or not. A comparison was made of gross margins over variable costs. When poultry were included, calculations of gross margins over variable costs were made both for laying hens and for table chickens. A further comparison was made between the costs associated with on-farm mixing of feed and buying-in feed from a specialist compounder.

The following criteria were used in the calculations of gross margins over variable costs. The total farm area was 240 ha of utilisable land. The flock size was 4 800 for laying hens and 16 000 for table chickens, and there was one flock of laying hens per annum, or four flocks of table chickens per annum. For the laying hens one person was employed full-time, whereas for the table chickens one person was employed part-time. The cost of mobile housing and fencing was £3.44/hen/year (based on a house stocking density of 6 hens/m^2, as per Regulation EC1804/1999, and depreciation plus interest costs) and £0.52/chick/year (including depreciation plus interest costs).

For laying hens, an average feed intake of 49 kg/hen/year was used and the cost of feed was either £255/t when purchased or £214/t home mixed. For home mixing an extra 10% was allowed on top of feed intake so as to cover losses during mixing. A pullet price of £4.50/pullet was used and this was for birds reared in an organic production system. The egg price received was £1.09/dozen and an average of 280 eggs was produced/hen. Assumptions were made of the proportion of eggs in each size band.

A gross margin sensitivity analysis was done for feed costs (range from £235/t to £275/t) and for egg prices (range from £0.89/dozen to £1.29/dozen).

For table chickens, an average feed intake of 8 kg/bird was used, and the cost of feed was either £270/t when purchased or £244/t when home mixed. For home mixing, an extra 5% was allowed on top of feed intake to cover losses during mixing. A chick cost of £0.31/chick was used, although this may be up to £0.70/chick if using imported stock. The price received per kilogram of live weight was £2.10, based on an average live weight at slaughter of 2.1 kg/bird.

A gross margin sensitivity analysis was done for feed costs (range from £250/t to £290/t) and for price received per kilogram of live weight (range from £1.70/kg to £2.50/kg).

Mortality of 8% was allowed for both laying hens and table chickens.

For the arable crops, the following sales were assumed to be: i) potatoes £6 160/ha (based on 28.0 t potatoes/ha at £220/t); ii) winter oats £899/ha (based on 4.0 t oats/ha at £170/t plus an area aid payment of £219); iii) field beans £852/ha (based on 3.0 t beans/ha at £200/t plus an area aid payment of £252); iv) spring wheat £843 (3.2 t spring wheat/ha at £195/t plus an area aid payment of £219), and; v) spring barley £763/ha (3.2 t spring barley/ha at £170/t, plus an area aid payment of £219).

For further information, please refer to the full report for this component of the work.

2.6. To disseminate information on poultry management techniques as they apply to an organic system of egg production and table chicken production

Two study days were organised in December 2001 for representatives of industry, organic sector bodies, DEFRA and for independent organic consultants. The first of the study days was specific to organic table chicken production, and the second to organic egg production. Copies of the study day agendas and lists of attendees are available from the author of this report.

3.0. RESULTS

All milestones were met in full except for updating MANNER so as to include information organic poultry manure nutrient content. The basis for this is discussed below .

3.1. The use of homegrown protein sources in feeds for organic poultry

There is an increasing need to use home grown protein sources in organic poultry feeds in place of imported soya. This is because the use of home grown protein sources in feeds would improve the sustainability of the system at a more local level. There is also likely to be an adverse impact on environmental and socio-economic factors from importing soya, which is not in keeping with the ethos of organic farming.

In order to use home grown protein in organic feeds there is a need to establish whether or not they are suitable for feeding to poultry. This will depend on the type and levels of anti-nutritive factors contained in the ingredients, as toxic effects on the birds will limit ingredient inclusion rate. In addition, ingredients must also supply essential nutrients and energy, otherwise there may not be sufficient scope within the ration to use it effectively. A large proportion of an organic ration is made up by cereal, so that other ingredients must be of high energy value if adequate nutrient density is to be maintained.

A summary of home grown protein sources, and their potential use in organic poultry feeds is given below. This is focused on energy value, and concentrations of crude protein, lysine and methionine relative to soya (extruded full-fat). The range of antinutritive factors (ANFs) present in each of the ingredients is identified, and maximum inclusion rates recommended in a summary table. For more detailed information, including references used, please refer to the full review report.

It should be noted that the review did not consider the agronomic feasibility of growing various protein crops in an organic farming system.

3.1.1. Peas (*Pisum sativum*)

The majority of dry peas destined for use in animal feeding are round-seeded, free from tannins, and with low trypsin inhibitor activity (TIA). White flower coloured peas do not contain tannins, unlike coloured flowered varieties. Spring varieties sown between January and April are favoured because of their lower TIA and fibre contents compared with winter-sown varieties.

The dietary metabolisable energy value of peas (12.1 MJ/kg DM, as determined from meal diets fed to adult cockerels) is in-line with the energy value of poultry feeds. Therefore peas will not dilute feed energy value.

The metabolisable energy value of peas is lower in young chicks than in adult cockerels. Metabolisable energy is increased after pelleting (13.0 MJ/kg DM) due to an increase in the digestibility of starch, from approximately 75% to 90% in raw peas, to as high as 95% following heat treatment.

The crude protein content of peas (typically 241 g/kg $\pm$ 12 g/kg DM) varies according to genetic, cultural and environmental differences. The crude protein and lysine concentrations are less than those of soya, but higher than those found in cereals. Peas have low sulphur amino acid contents compared with soya. The digestibility of pea proteins is also improved by pelleting, but extrusion and fine grinding have very little effect.

3.1.2. Field beans (*Vicia faba*)

Field beans have a relatively high energy value, but crude protein, lysine, and sulphur amino acid contents are low relative to soya. Starch content is high, with a digestibility of approximately 85%. As for peas, heat treatment of the seed improves starch digestibility by approximately 10%, but there is a much smaller improvement (approximately 3%) in protein digestibility.

The low concentrations of methionine and linoleic acid in beans have limited their use in feeds for laying hens. A progressive reduction in egg size and an increase in mortality when feeding beans at concentrations of 100 g/kg and 200 g/kg in layers feeds were observed. In some experiments, rate of lay was also depressed. Supplementing feeds with methionine or linoleic acid did not prevent adverse effects of feeding beans on egg production.

Two anti-nutritionals present in field beans, vicine and covicine are associated with a low feed intake in laying hens, and a reduction in egg weight. Tannin levels in beans have often been seen as a constraint to the utilisation of beans as a home grown protein source. In poultry, tannins reduce protein digestibility, and to a lesser extent starch digestibility. White-flowered varieties are low in tannins, and more suitable for use in poultry nutrition.

3.1.3. Rapeseed (*Brassica napus, B. campestris*)

Rapeseed meal, in particular meal produced by expelling the oil, is rich in crude protein and lysine. It is not as rich as soya, but richer than peas or beans. Compared with soya, rapeseed meal is also higher in both methionine and cystine, which is potentially very useful as methionine is essential for health, growth and egg production, and must be provided in the feed.

Rapeseed has potential for use as a protein source, although there can be problems with egg and meat taint. The problem of taint is not consistent between hybrids, or between sources of rapeseed. Brown egg strains tend to be more susceptible to egg taint than white birds. The fishy taint is due to tri-methylamine (TMA) occuring in the egg yolk. TMA is formed in the bird’s gut as a breakdown product of the sinapine present within rapeseed meal. Similar problems of fishy flavours due to feeding rapeseed meal have also been found in chicken meat.

There have been substantial efforts made to breed varieties of rapeseed that are low in some ANFs. An example of this work is the “double low (00)” glucosinolate varieties. Glucosinolates are toxic to poultry even when fed at low concentrations, resulting in adverse effects on thyroid metabolism in young and adult birds. Prolonged feeding to adult birds may cause the liver to haemorrhage.

A range of other ANFs limit the use of rapeseed in feeds for poultry, namely phenolics, tannins and phytic acid. Whilst chemical extraction may reduce the ANF content in rapeseed by 90%, this would not be allowed in an organic system of production.

3.1.4. Lupins (*Lupinus* spp.)

Although the crude protein contents of both products are similar, sweet lupins (*L. angustifolius*) have lower energy, lysine, methionine and cystine contents compared to soya. It is the low essential amino acid content of lupins that limit their use in poultry feeds. In the late 1970s, sweet lupins were fed at concentrations of up to 150 g/kg to laying hens housed at ADAS Gleadthorpe. Both feed intake and egg output were reduced during early lay. Mortality also increased with lupin inclusion rate. Feeding extra methionine did not prevent these effects.

More recently, there have been several reviews of the potential of lupins as animal feedstuffs. These have raised possible problems due to ANFs e.g. oligosaccharides of the raffinose family, α-galactosides, pectins and alkaloids including lupanine, spartine, lupinine, and angustifoline. Whilst sweet varieties were reported to be very low in alkaloids, there is a risk of contamination by seeds of bitter varieties, which have been shown to depress growth rates in broilers.

In non-organic production, enyzmes have been developed to improve the feeding value of sweet lupins to poultry. A combination of enyzmes has been used; including a protease, carbohydrase and an α-galactosidase, which have sometimes improved live weight gain in broilers. However, enzymes would not be allowed in organic feeds. In some studies feeding lupins to broilers also increased the incidences of mortality and kidney problems.

Although some Spanish studies suggest that lupins can compete with soya as protein sources in poultry feeds, the weight of literature reviewed in this study recommends caution, pending more applied research under UK conditions, using varieties of *L. albus* that are likely to be available on the UK market.

3.1.5. Linseed (*Linus usitatissimum* L.)

The initial perception is that linseed will not be a valuable protein source for poultry, due to its low crude protein, lysine and methionine content compared with soya. Linseed also contains an array of ANFs including a vitamin B_6 antagonist (linamatine), phytic acid, a trypsin inhibitor and cyanogenic glucosides.

However, linseed is rich in α-linolenic acid which, when fed to chickens, can raise the α-linolenic acid content of eggs or meat . Products rich in α-linolenic acid are potentially useful, as consumption can lower the C18:2 to C18:3 (*n*-6:*n*-3) ratio in the human diet, leading to potential health benefits. Linseed is higher in α-linolenic acid than rapeseed or soya. Non-organic eggs having a high *n*-3 PUFA concentration (α-linolenic, DHA, DPA and EPA) are already available to the consumer. Potential consumer demand may be higher for an organically produced product. For chicken meat, too much enrichment with α-linolenic acid causes fishy odours, so caution will be needed. These fishy odours are due to rancidity, caused by fat oxidisation. Feed antioxidants that are active in the meat will be needed to retard fatty acid oxidation, but optimal concentrations are still to be identified.

3.1.6. Oilseed meal

Oilseed meals are by-products of the food oil industry, low in oil and high in protein content. However, the protein is unbalanced for animal nutrition due to its vegetable origin. Bio-availability and amino acid composition are also extremely variable.

3.1.7. Sunflower (*Helianthus annuus*)

Sunflower seed meal is a good source of protein. Although it is deficient in lysine it is very rich in sulphur amino acids. The inclusion rate of sunflower seed meal in non-organic broiler diets is less limited by ANFs (phytate, phenolic acids, chlorogenic acid and quinic acid) than by its moderate dietary energy value. However, the development of de-hulled sunflower seed meal has improved its nutritional value for poultry production.

3.1.8. Naked oats (*Avena* sp.)

The low metabolisable energy value of whole oats has meant that they have not been widely used in poultry feeds. Naked oats are lower in crude protein, lysine and methionine content than soya. However, the biological value of oat protein is high, and its amino acid composition is constant across a range of protein levels.

A large, naked (huskless) oat species (*A. nuda* L.) is available, with a grain similar in appearance to wheat. However with naked oats, there seems to be an inverse relationship between protein content and protein quality. As the protein content of the kernel increases this is associated with an elevation in prolamine content and a consequent decline in protein quality. Nevertheless, the prolamine content of naked oats is substantially less than that of other cereal grains, so that naked oats could have excellent potential for exploitation as a feed grain for poultry.

3.1.9. Other alternative vegetable protein sources

There has been limited work on the use of tomato residues as feed ingredients for poultry. Tomato residues have reasonable protein contents, but they are generally lacking in one or more essential amino acids. However, tomato products are a rich source of the carotenoid lycopene, and carotenoids in foods have been associated with enhancement of immune response. Dried tomato pomace is also a good source of Vitamin B_1 and a reasonable source of Vitamin B_2 and Vitamin A. It is likely that as organic tomato production and processing increases there will be a need to make better use of the by-products. The use of tomato by-products in organic poultry rations may provide a useful outlet for these waste products, without adversely affecting performance, egg colour, egg flavour, meat flavour and meat colour, and possibly enhancing immunocompetence.

Suggested maximum inclusion rates for some of the most useful ingredients are given in Table 1.

Table 1. Suggested maximum inclusion rates* for some ingredients (g/kg)

	Layers feed	Chick starter
Rapeseed	100	50
Peas	200	50
Beans	100	300

(* Important note: Maximum inclusion rates on an individual, not cumulative basis).

3.2. To measure nitrogen retention and manure nutrient contents at about 81 days of age in slow growing meat birds fed non limiting rations versus Label Rouge rations

The results on manure nutrient content (fresh weight basis) are reported here as these are of greater relevance to the current project. Nitrogen retention results will be reported in experimental reports for project OF0153, as they need to be discussed fully within the context of feed intake and growth rate.

Within the slow-growing breed type (Gris Barre and ISA 657 birds) breed and feed effects were found in some manure nutrient contents. The dry matter content of litter manure was higher for birds fed Label Rouge rations than for birds fed non-limiting rations. Label Rouge feed was lower in protein than non-limiting feed. Birds excrete excess protein and this is associated with wetter droppings. The effect of feed on litter dry matter content was greater in Gris Barre birds (p<0.05). Gris Barre birds ate more feed, and were heavier at 81 days of age than ISA 657 birds, and so the mass of droppings produced would have been greater for Gris Barre birds.

For the same treatments, there were effects of breed and feed on litter ammonium-N content (p<0.05). Litter ammonium-N contents were greater in birds fed non-limiting rations than in birds fed Label Rouge rations. However the feed had a greater effect on litter ammonimum–N contents from Gris Barre birds (e.g. 4 201 mg/kg ammonimum-N for birds fed Label Rouge feed, *versus* 8 920 mg/kg ammonimum-N for those fed non-limiting rations). By comparison, ammonimum-N contents were 3 450 mg/kg and 5 016 mg/kg for ISA 657 birds respectively.

There was a trend for higher total available N as a percentage of total N (TAN% of total N) in litter manure from Gris Barre birds than in litter manure from ISA 657 Birds (p=0.08). For example, TAN% of total N was 31% for Gris Barre birds and 25% in ISA 657 birds. Feed treatment also affected the TAN% of total N in the litter manure (p<0.05). It was higher when feeding non-limiting rations than when feeding Label Rouge rations (36% for non-limiting feed *versus* 20% for Label Rouge feed). There were similar effects of feed treatment on litter uric acid-N content (p<0.05, 4 344 mg/kg for non-limiting feed *versus* 1 426 mg/kg for Label Rouge feed).

Within the fast growing breed type only Ross 308 birds (commercial broiler) were studied, but for both feed types. For this breed there was no effect of feed treatment on the litter dry matter content, TAN% of total N or ammonium-N content. There was a trend for uric acid-N content to be higher when feeding non-limiting rations compared with feeding Label Rouge rations (p=0.16, 8 032 mg/kg *versus* 1 983 mg/kg, respectively). Within the very slow growing breed type only Ixworth birds were studied, but again for both feed types. Non-limiting feeds increased the TAN% total N (p<0.05), uric acid-N (p=0.11) and ammonium-N (p=0.10) contents of the litter compared with Label Rouge feeds. For example, TAN% total N was 28% in litter manure from birds fed non-limiting rations, and 21% in litter from birds fed Label Rouge rations. There was no effect of feed treatment on litter dry matter content.

3.3. To measure nitrogen retention and manure nutrient contents at about 81 days of age, in slow growing meat birds housed at a stable thermoneutral temperature versus a daily ambient temperature cycle during late autumn/winter months

Please refer to experimental reports for project OF0153 for results on nitrogen retention.

There were no interactive effects of temperature and breed on litter manure dry matter, or N contents (total N, uric acid-N, ammonium-N or TAN% total N). Similarly there were no effects of temperature on these variables. Breed did not affect the litter manure contents of uric acid-N or total available N (%), but there were some effects of breed on the dry matter, total N and ammonium-N contents. These are detailed below.

The litter manure from SASSO S77N birds was drier (p=0.05) and contained less ammonium-N (p<0.01) than the manure from Ross 308 birds. For example, the dry matter content of litter from SASSO S77N birds was 698 mg/kg, compared with 571 mg/kg from Ross 308 birds. The ammonium-N content of the litter from SASSO S77N birds was 5 625 mg/kg, compared with 13 575 mg/kg in the litter from Ross 308 birds. In this group of birds the mean TAN% of total N was 31.8% across both breeds.

In the other group of birds (i.e. ISA Redbro birds *versus* ISA 657 birds) the only breed difference was in the litter ammonium-N content (p<0.05). The ammonium-N content of litter from ISA 657 birds was 5 160 mg/kg, compared with 8 430 mg/kg in litter from the Redbro birds. In this group of birds the mean TAN% of total N was 26.1%.

3.4. To review available scientific information so as to determine the optimum position for poultry in whole farm rotations

There has been little work done on integrating poultry into cropping systems. This is because non-organic poultry have been housed mostly in indoor systems over the past fifty years. Even in modern free-range systems of production the houses are usually fixed, so full integration into whole farm systems is not possible. At best, some of the feed is produced on farm and the manure is utilised for crop production. The objective of organic production is a system where nutrient recycling between the soil, plants and crops is fully planned and the birds are moved around the farm as the rotation proceeds. The potential benefits from this approach include improvements in crop yields, reduced poaching, better distribution of nutrients and reduced parasite load. These issues were discussed in the literature review, the results of which are summarised below.

To assess the efficiency of nutrient recycling between the soil, plants and birds nutrient balances are required. Inputs and outputs of the cropping system were calculated for poultry using information from DEFRA-funded project OF0153 and from industry data. Crop yield information and the nutrient contents of crops and poultry products were taken from published data. Examples of how poultry production mighty fit into arable rotations are given in the literature review, based on the hypothetical rotation used in the calculation of nutrient balances. The review paper also discussed poultry husbandry in some detail. In future, organic poultry production is likely to be more common on arable farms, rather than by the conversion of non-organic free-range sites. However, arable producers are less likely to be familiar with technical aspects of poultry production, such as the birds' thermal needs, how light patterns affect egg production, factors affecting range usage, or how to store eggs for best quality. Some of these are discussed below.

<u>3.4.1. Poultry Husbandry</u>

Housing

Housing offers shelter free from predation, and in which the thermal and lighting environment meets physiological needs. Well-designed and well-managed housing is essential to the success of the system, and this no less true for systems that allow outdoor access. Even when birds range well during the daytime they will return to the house at night. Ventilation systems should provide for an adequate air change rate so that the air quality does compromise bird health. If the house is poorly designed or poorly managed then the litter will deteriorate, leading to poor air quality, dirty birds, dirty eggs, and poor disease control.

In practice, the penetration of wind and rain through popholes makes litter management difficult, particularly when the popholes are large. Regulations on pophole size exist, but thought should be given to their layout. For example, by having sufficient popholes on both sides of the house it may be possible to keep popholes on the windward side closed. An external verandah may be useful as a buffer zone between the house and the outside weather. Furthermore, mud on the feet of birds may be left on the verandah rather than being bought into the house.

Regulations exist on stocking density within the house, and for laying hens, the minimum ratio of litter floor area to raised droppings pit, perch space and nest box provision. Thought should be given as to the best method of providing feed and water within the house. These provisions will be easier for static rather than mobile houses, as access roads are likely to be better and automation possible. Methods of egg collection and of the transport of eggs from the house to an egg store also need careful consideration. Cracked and dirty eggs are downgraded, as they constitute a health risk to humans.

For mobile housing there are additional constraints related to portability and ease of movement from one field to another. In small houses there will be less flexibility in choosing the layout of equipment, labour input per bird will be higher, and the management of house physical environment more difficult than in larger houses.

Careful thought is needed at the design and planning stage if chicks are to be brooded in mobile housing. Spot brooding is most likely to be used, but there should be sufficient space for the chicks to choose their thermal environment. It is essential that the gas supply does not run-out during brooding, otherwise the chicks will become chilled. In static houses, alarms are often used to warn of temperature fluctuation, but this may not be practical or effective in a mobile house. Draughts over the chicks must be avoided, so popholes must be airtight or a cardboard surround used. Cardboard surrounds are also useful for keeping chicks in the ‘brooding zone’ if temperatures are too low in some parts of the house.

Light patterns and photoperiodism

Lighting patterns affect bird growth and egg production, but in organic production only daylight is relevant. This is because it is not possible to exclude daylight, so that light intensity within the house is below the threshold for darkness. Thus, in summer months it will not be possible to apply shorter daylengths than natural daylight hours. In winter months, when daylight hours are short, artificial lighting may be used to supplement daylight up to 16 hours per day.

Daylight hours affect growth because, unless the dark period is very long, chickens do not eat during darkness. Therefore, with the exception of the summer months it will be possible for producers to slow growth by avoiding supplementing natural daylight beyond the time of dawn and dusk.

For organic laying hens, a 16 hour daylength will be used throughout the majority of the laying period. This is because of the effect of daylength on ovulation rate. A fall in daylight hours reduces ovulation and egg production. For this reason, artificial lighting will be essential in houses for laying hens, and time clocks will be needed to ensure consistency from day to day.

Light patterns during the laying phase should be linked with light patterns applied during rearing. This is so as to avoid precociousness, and the risk of prolapse, due to a sudden step-up in daylength when housing point-of-lay pullets, or a reduction in photo-stimulation due to a step-down in daylength at re-housing.

Under UK conditions, difficulties will arise at some times of the year in applying light patterns to organic pullets. During February it will not be possible to apply light patterns to chicks hatched in this month. A 16 hour daylength will be required from day old until depopulation at the end of lay, so there can be no control of age at first egg, egg numbers or egg weight. Limitations to applying light patterns in some other winter months are discussed in full in the literature review.

The effects of limited steps-up in daylength at point-of-lay on egg performance in modern hybrids or traditional hybrids are not known. This is an important knowledge gap. If this is not addressed before there is a requirement to rear pullets in an organic system, seasonal fluctuations may arise in rearing and egg production.

Parasites and diseases

It is generally thought that intensively housed birds are at greater risk of respiratory problems, while birds on range are at greater risk of enteric diseases. Infections can be wind-borne, or they can be introduced onto a site by visitors, rodents, wild birds, pets, insects, or equipment.

Outdoor feeding of poultry is sometimes used to encourage range usage, but is likely to attract wild birds onto the pasture. However, wild birds may carry infections such as *Salmonella* and alternative methods of encouraging range use are required.

In organic farming routine medication of poultry is prohibited. Particularly for *Salmonella,* alternative methods of reducing the risk of infection from organic eggs and chicken meat are needed. A process of competitive exclusion within the gut may be the answer, and there is some evidence that *Lactobacillus* rich feed ingredients may have a beneficial role.

Pasture management and the age at which birds have access to range will be important in the control of parasitic disease. Faecal worm counts should be monitored, and periodically birds should be sampled so as to establish the worm burden in the gut. This will be an important step in verifying whether or not pasture rotation is adequate for disease control. A veterinary health plan will be needed for the site, which should include strategies for parasitic disease control, and which may be further refined over time.

Mobile housing, rotated around the farm, perhaps offers the best opportunity for parasite control. However, the application of poultry manure on land that will be subsequently used by poultry may increase disease risks. Composting of poultry manure before application to land may be effective in killing some parasites, but this requires scientific evaluation.

Poultry are also susceptible to external parasites, including fleas and mites, and in particular red mite. The control of red mite is difficult, particularly in wooden fixtures prone to harbouring infestation. This aspect should be considered when buying or constructing houses for organic poultry, and in particular for laying hens, as wooden perches and nest boxes are often used.

Range usage

Outdoor temperatures in the UK are seldom within the optimum range for growth or egg production. Wind-speed and rain will also increase the environmental heat demand placed on birds. Provision of range shelter will benefit welfare and performance of the birds as well as encouraging greater utilisation of the range. DEFRA-funded studies at ADAS Gleadthorpe (Project OF0153) found that chickens ranged less in wet and windy weather, and stayed close to the house when shelter was absent from the paddock. Birds provided with early access to range also exhibited greater ranging activity than birds given access to pasture later in life. Provision of artificial windbreaks should prevent wind and rain penetrating through open popholes. Chickens choose to sit in shaded areas provided by tree canopies, and if these conditions can be provided the time spent outdoors may be greater than in an open field. For systems using mobile housing, where the houses are moved from one field to another it may be difficult to provide permanent natural shelters other than at the edge of the field. Temporary shelters such as conifer wigwams may be used, but these are time consuming to move around the pasture and farm. However an advantage of this type of shelter is that the birds follow it around the pasture, preventing poaching or a build up of parasites in any one area.

Pasture types and management

In organic systems of poultry production the pasture should contribute to the birds nutrient requirements. Poultry textbooks of the 1940s suggest that grazing good quality young grass provided a feed saving of up to 10%. In modern free-range systems however, the emphasis has been on hard wearing swards, rather than swards of high nutrient value. This has meant that swards have been mostly comprised of ryegrass.

If poultry graze high nutrient value swards, this could reduce reliance on expensive bought-in feeds and sustainability would be improved. Another benefit of moving away from ryegrass based swards is that some forage crops may provide aerial cover for chickens.

In modern free-range systems, pasture management has been kept simple. The grass is mowed short, and the clippings are collected so as to avoid crop impaction. Reseeding is done in poached areas to take advantage of spring and early summer growth. Pasture rest allows the sward to recover, or establish, and this is best done by paddock rotation. In mobile organic housing systems it is suggested that the houses are moved every seven days to prevent pasture damage close to the house. At the end of the stocking period, chain harrowing is recommended to distribute the droppings more evenly.

Egg storage
Eggs in the oviduct are at body temperature (41^{o}C), and they cool rapidly to ambient temperature after laying. Eggs should be stored at temperatures of between 12 °C and 15 °C. It is important to cool them as quickly as possible after laying, and to maintain these lower temperatures, in order to preserve internal quality and slow the growth of microorganisms. It is not always possible financially to justify refrigerated storage on-farm, so a number of practical designs for simple egg stores have been produced. It is also important that eggs are not stored next to chemicals, or products that will impart taint.

Food safety
Poultry manure is an integral part of nutrient cycling in organic systems. However due to concern over the safety of foods entering the human food chain, it is usually recommended that poultry manure should not be used on crops that will be eaten raw, such as salads and vegetables, as the risk of transfer of pathogens may be too great. Recommendations are available on manure stacking and storage to reduce the risk of bacterial contamination.

3.4.2 Organic poultry production – inputs and outputs

The main inputs into an organic egg production system are pullets and feed. At present, non-organic pullets of up to 18 weeks of age can be purchased, but they must be managed for a six-week period to organic Standards before the eggs may be sold as organic. Between 47 kg to 50 kg of feed will be consumed per annum. Significant outputs will include 260 eggs to 310 eggs, and 40 kg to 45 kg of fresh droppings per hen per year.

In organic table chicken production the main inputs are chicks and feed. At present non-organic chicks of up to three days of age can be brought into an organic production system. The chicks are then reared on according to organic Standards for 70 days, or for up to 78 days, depending on the age at sale. This is because the minimum slaughter age depends on the breed used, and will vary between 73 days and 81 days of age. Non-organic broilers eat about 5.9 kg of feed before they are slaughtered, at a live weight of between 2.0 kg and 2.5 kg. A similar range of live weights is required at slaughter for organic table chickens. However, the amount of feed eaten to achieve will vary, depending on breed, feeding strategy and weather conditions. In Project OF0153 a summer flock of free-range ISA 657 birds grown to 81 days of age ate about 6.7 kg of feed, whereas a winter flock ate about 7.6 kg. In both flocks feed was provided *ad libitum*, and target live weight at 81 days of age was about 2.3 kg.

In non-organic broilers grown to live weights of between 2.0 kg and 2.5 kg, about 3.5 kg of manure per bird is produced. In organic table chicken production, the weight of litter manure produced will vary and this will be due to factors that affect feed intake and litter moisture content. Examples of factors affecting litter manure output are: breed, feeding strategy and feed nutrient content, drinker type and the amount of water spillage, the extent of weather penetration through the popholes, management of the ventilation system, and pasture management and the amount of mud brought into the house by the birds. It may be necessary to add litter if the existing litter becomes damp and compacted so as to prevent hock burn damage and breast blisters. This will increase the amount of litter manure at the end of the growing period.

3.4.3 Poultry manurial values

The nitrogenous excretion from birds is mainly in the form of insoluble uric acid. Despite its relative insolubility, once uric acid is voided it is readily converted to ammonia (NH_3) by microbial activity. Currently, manure from organic laying hens is thought to be similar in composition to that of non-organic laying hens, as hybrid and feeds used are similar. However, this may not be the case for organic egg production systems of the future

In future, there will be a need for natural ingredients to supply all of the essential amino acids in the feed. If fishmeal, which is rich in essential amino acids, is prohibited, ingredients inferior in amino acid content will have to be used. Unfortunately, this may increase the overall crude protein content of the feed, leading to greater nitrogen excretion. The digestibility of plant proteins differs between sources, so that changes in ingredient base may further affect nitrogen excretion. Amino acid balances may be more difficult to optimise using only plant sources, and a miss-match between supply and the needs of the birds will also contribute to excess nitrogen excretion.

For organic table chickens, breed and feeding strategy will similarly affect manure nutrient content. Therefore, manure nutrient contents should be determined prior to land application, in order to optimise the utilisation of nutrients and avoid pollution.

3.4.4 Nutrient recycling and rotation viability

Through well planned rotations, organic cropping systems should make best use of recycled nutrients to complement natural processes such as nitrogen fixation, and minimise the need for imported nutrients.
The construction of nutrient balances for assessing the viability of organic poultry production systems demonstrated that a closed system, where all the inputs can be supplied on-farm, is currently not achievable, Some feeds have to be bought-in. Furthermore, a wide ingredient base will be needed to supply essential amino acids, which cannot be met by current crop rotations.

Some of the outputs of farmgate and soil surface nutrient balances for organic egg and chicken meat production, integrated within typical farm rotations, are given in Table 2.

Table 2. Farmgate and soil surface nutrient balances (kg/ha) for organic egg and chicken meat production

	Nutrient balance (kg/ha)		
	N	P	K
	FARMGATE NUTRIENT BALANCE		
Table birds: 6 course rotation (18 ha)	107	2.8	2.3
Laying hens: 6 course rotation (18 ha)	93	4.8	-17
	SOIL SURFACE NUTRIENT BALANCE		
Table birds: 6 course rotation (18 ha)	47	12	-0.2
Laying hens: 6 course rotation (18 ha)	29	5.3	-11

The farmgate nutrient budgets were very similar for nitrogen and phosphorus, regardless of the form of poultry production. On average, there was a surplus of 85 kg nitrogen/ha over all of the scenarios tested, with the surplus being slightly greater from table chicken production. This was mainly due to a higher nitrogen input in purchased feeds for table chickens. The phosphorus balance was near break-even for farmgate budgets, with a small average surplus of about 2 kg P/ha. This was greater for egg production due to a smaller amount of phosphorus sold in egg products, compared with whole birds. There tended to be a deficit of potassium in all scenarios, the largest deficit occuring in egg production which had lower potassium inputs from purchased feeds.

There was also a surplus of nitrogen in the soil surface balances but it was much lower than in the farmgate balances, probably because losses of nitrogen through leaching and volatilisation were included in the calculation. In contrast, the phosphorus surplus was greater in the soil surface balance, compared with the farmgate balance, because the output of phosphorus from harvested crops (soil surface balance) was much less than that sold from plant and animal products (farmgate balance). The potassium deficit was also greater in the soil surface balance compared with the farmgate balance for table chickens, but smaller in the case of egg production. This arose because of a greater output of potassium in harvested crops (soil surface) compared to sold plant and animal products (farmgate) for table chickens, but a higher input of potassium in manures (soil surface) compared to purchased feeds (farmgate) for the laying hens.

3.4.5 Integrating poultry into whole farm rotations

There is a need to examine how well poultry might fit into the above rotations in terms of pasture availability throughout a typical laying year, or over the minimum growing period for table chickens. Furthermore, this task must take into account the minimum pasture rest periods stipulated by UKROFS. The two year grass/clover ley is available for grazing by poultry for about 21 or 22 months, allowing for an establishment period. A flock of laying hens would occupy the ley for a little over a year (assuming that hens are depopulated at 72 weeks of age), meaning that slippage would occur as the rotation progresses. It would not be possible to complete two full flocks on the same ley, before the pasture had to be ploughed in to allow potatoes to be sown.

For table chickens, each successive flock grown to 81 days of age could be managed separately on 1 ha of the 3 ha ley, with a second flock on the first ha of the ley, following a 6 month rest of the pasture. This would spread the build up of manure and parasites more evenly over the land.

Illustrated examples of rotations including poultry were given in the literature review.

The integration of organic poultry into whole farm rotations will also be affected by factors such as the availability of labour and stockman skills, capital expenditure and investment in facilities, and disease status.

3.5 Examples of enterprise costings, including gross margins over variable costs, for mixed farms on a “with poultry” (laying hens and table chickens, separately) and “without poultry” basis

When considering the inclusion of a poultry enterprise significant capital will be required particularly for housing, but also to cover equipment costs, other machinery, and ‘working bird’ capital. For laying hens using purchased feed capital requirements were £137 792 (£155 292 with mill/mixed feed). For table birds using purchased feed £252 000 was required in capital (£277 000 for mill/mixed feed).

The viability of an organic poultry enterprise will depend in part on whether or not it generates more income than the enterprise it replaced. An egg gross margin of £32 182 (purchased feed) or £36 391 (mill/mix) was achieved when laying hens were included in the arable rotation (without potatoes). However, the extra costs incurred by the laying hen enterprise resulted in a reduction in the farm gross margin of £6 459 (purchased feed) or £2 250 (mill/mix). Similar losses were found when including laying hens in an arable rotation with potatoes. Therefore, future systems of organic egg production will incur high costs of production, and to remain viable this will need to be reflected in increased egg prices.

Better results were obtained for organic table chickens. Farm gross margins were increased by £10 438 (purchased feed) and by £17 478 (mill/mix) when including table chickens in an organic arable rotation without potatoes. Similar increases were found when including table chickens in an arable rotation with potatoes.

A sensitivity analysis was carried out as a part of this work. Both laying hen and table bird enterprises were very sensitive to small changes in sale price or feed costs/intakes. For example, a change of ± 5p/dozen in the price of eggs produced ± £5 599 on the farm gross margin, and a change of ± 10p/kg in the price of table chickens produced ± £13,440 on the farm gross margin.

The results were specific to the examples used; other rotations or management practices may produce better farm gross margins.

3.6. To disseminate information on poultry management techniques as they apply to an organic system of egg production and table chicken production

During the study days current technical and economic issues were identified, in addition to those likely to develop as Standards evolve in compliance with Regulation EC1804/1999.

Common to both laying hens and table chickens is the need to develop swards that are of high nutrient value, rather than the current ryegrass-based swards. Current pasture management was also thought to be basic. Participants suggested that research is needed to address these issues.

The role of methionine in egg production, health and aggressive feather pecking was discussed and acknowledged by the audience. For table chickens, the role of methionine in growth and breast meat yields was emphasised by presenting live weight and yield results from DEFRA-funded studies in project OF0153. It was agreed that methionine supply was a problem area, and that it was not restricted just to laying hens. As the market for organic convenience foods, and portions, increases there will be more pressure on producers to achieve high breast meat yields. The consensus was that research is needed to address the problem of methionine supply in organic poultry feeds.

Some organic ingredients are difficult to source, either in sufficient quantities, or within acceptable price constraints. For example, organic oils are used in food production for humans, and are not available for use in livestock feeds. This may mean that the feed oil content is lower than usual, which may impact on feed energy value, palatability, intake, performance and costs of production. There were also cost implications of not allowing organic and non-organic wheat in the same feed.

Predation by birds and animals was thought to be a high risk in systems rearing young birds outdoors. At present this problem is more relevant to table chickens, but in future if there is a requirement to rear pullets outdoors, the problem will increase.

Future requirements to rear pullets in an organic system, and for breeder flocks and hatching to be done according to organic Standards caused some concern. Producers thought that there was not sufficient knowledge to be able to address likely technical problems that may occur in these systems. Technical difficulties likely to occur in organic pullet rearing were identified in DEFRA-funded project OF0192 and these were reported to DEFRA. Producers of non-organic pullets attending the study day on organic laying hens were keen to point out that Standards for rearing table chickens may not be appropriate for pullets, and that Standards for pullets should be research based.

For organic table chickens, centralised brooding was thought to be the best option at present, but the possible detrimental effects of handling and moving birds at the end of brooding on welfare were considered. There has to date been no UK research on injuries and traumas in organic production systems. This may be an important area for research in the future, and in particular if "brooding and moving" is adopted in systems of organic pullet rearing.

Concerns were expressed about the changing Standards for organic egg production, and the impact of these on production costs. Much of this is apparent in the calculations of gross margins discussed above.

4.0. DISCUSSION

There are problems associated with formulating feeds for organic poultry. This is because of the need to provide all of the birds' nutrients for health, welfare, maintenance and performance using natural ingredients.

In contrast, synthetic amino acids have been widely used in non-organic poultry feeds for over forty years. There are several reasons for this. Firstly, poultry need to have some amino acids (essential amino acids) supplied in the feed. There are 11 essential amino acids for chickens, and of these lysine, methionine and cystine are the most important. Most vegetable protein sources have only low or moderate contents of essential amino acids and so vegetable-based feeds are not likely to meet the birds' requirements. Secondly, there is a need to supply essential amino acids in a balanced manner, as the bird does not need equal quantities of each specific amino acid. If the amino acid supply is not balanced within the feed then some amino acids will be poorly utilised, and this will lead to a higher excretion of nitrogen. An imbalance of amino acids in the feed may also cause nutrient deficiencies. Thirdly, it is easier to use synthetic amino acids to meet requirements at a lower overall crude protein content, than when relying on natural sources. In non-organic poultry production, synthetic amino acids have facilitated a reduction in manure nitrogen contents so as to reduce the risk of nitrogen pollution.

A great deal is known about amino acid requirements for maintenance, egg production and the growth in chickens. This has allowed optimisation techniques to be applied when formulating feeds. There is however, a desire for more 'natural' levels of bird performance in organic systems, and so feed optimisation may not be the goal. If this is the case, then organic systems will need to provide more of the feed on-farm and at reasonable cost. A high protein forage crop that the birds can graze for a large part of the year may be one solution.

A major problem for UK organic poultry producers is that feed is a very significant cost of production. Feed must be used efficiently by the birds, and the sale of produce must be sufficient to cover all of the costs. This emphasises the need for optimal bird performance.

Furthermore, the role of essential amino acid nutrition for health, immunocompetence, and normal behaviour must also be recognised. In organic rations the cereal component takes up a lot of space, so that other ingredients displacing cereals must also be sufficiently nutrient rich.

The findings of this project suggest that organic poultry feeds will have a wider ingredient base than in non-organic poultry feeds. In achieving this, some of the antinutritive factors may be diluted. Although mash is cheaper to produce, it is likely that organic poultry feeds will be fed in the form of crumbs or pellets. This is because heat treatment, which occurs during pelleting, is often associated with an improvement in feeding value.

The studies on the effects of breed and feed type have shown that there will be variability between litter manures in nitrogen content, and availability to crops. This means that the nutrient value of organic table chicken manures should be determined prior to land application, so as to optimise nutrient use and minimise the risk of nitrogen pollution. If there are changes in breed, feed specification, feed ingredient base or feeding strategy manure application may need to be re-evaluated. The nutrient content of litter manures should also be assessed taking into account seasonal effects, as there will be an effect of temperature on feed intake. If the feed energy to protein ratio remains constant across seasons, there may be a protein surplus in winter when intake is high and a deficiency in summer when intake is lower.

Including poultry in a typical organic cropping system was not entirely successful, in terms of the balance of nutrients recycling between the soil, plants, and birds. There was a surplus of nitrogen at farmgate and soil surface level, and this was largely because of the need to buy-in protein for feeding. There were deficits of phosphorus and potassium, and these varied depending on whether or not the calculation was done at farmgate or soil surface level.

In future systems, there will be a need for wider rotations so that poultry may be better integrated. Grass/clover leys are not well used by poultry in terms of nutrient supply and a high protein forage crop may be better used. This would reduce some of the pressure on protein supply and feed costs, and could improve the sustainability of the system. There is a need to optimise forage composition and land management for poultry, in terms of utilisation (e.g. time spent outdoors, nutrient supply, and intake), shelter from predators, and to minimise the risks of parasitic disease.

There may be an opportunity to form local co-operatives or farm linkages so that nutrients may be traded at a local level. An assessment of the effectiveness of nutrient recycling between the soil, plants, and crops would be valuable. The cost of nutrients relative to their biological value would also need to be examined.

Poultry are foragers and if they forage well they may affect the diversity and population sizes of invertebrate species in the soil surface layers. This may have a negative effect on crop pest control, if chickens eat and reduce the population size of useful invertebrates.

Husbandry needs and technical difficulties have been reported in the results of this project. It is expected that when derogations on pullet rearing, breeding and hatching end many more technical issues will arise. Gaps in the scientific literature mean that these problems will not be readily solved. The extra cost of production may trigger a move from organic to non-organic free-range poultry production. The results of farm gross margins including organic egg production show that current prices received by producers for organic eggs will not cover costs. This suggests that in the short-term there may be little expansion in the organic poultry sector, and in particular for organic eggs. The long-term viability of the market needs to be considered, and information on the price elasticity of demand for organic eggs is required.

5.0. CONCLUSIONS AND IMPLICATIONS OF FINDINGS

1. It is not possible to meet the birds' nutrient requirements using only home grown ingredients from a closed system. Some useful protein sources are not yet grown in organic systems, thus precluding their use in feeds for organic poultry. This means that there will be a need to bring feeds onto the farm from local sources or through imports. The social and environmental effects of this are not known.

2. There will be a need for fishmeal in some poultry rations. This will enable feeds to better meet birds' nutrient requirements. It is also likely to provide the best means for keeping feed crude protein contents moderate, and nitrogen manure contents within a 'normal' range.

3. Organic farming does not demand maximal livestock performance, however this is not synonymous with poor nutrient use. If the latter occurs this will increase production costs, reduce nutrient efficiency and in some cases it may increase pollution. The problem at present is that organic feed costs are very high, and there is a need to maximise nutrient utilisation through output, so that costs may be met. The organic regulation stipulates that feeds must be nutritionally adequate, but there is no guidance on what this means in the context of growth or egg output relative to the birds' genetic potential. References to 'slow growing' breeds in the Regulation are also a problem, because to date there is no agreed definition of 'slow growing'.

4. The recycling of nutrients between the soil, plants and poultry was not good when simply adding poultry to a typical organic rotation (grass/cover ley, grass/clover ley, potatoes, wheat, peas and wheat). The rotation was not balanced in terms of feed nitrogen, or in phosphorus and potassium for the crops. It is thought that rotations will have to be widened so as to produce a variety of feed ingredients. This will also need to take account of the effectiveness of recycling of nutrients between the soil, plants and poultry. Nutrients derived from pasture are thought to be low for poultry. There has been no recent work aimed at optimising the nutrient value derived from pasture. High protein forages may be of more value than grass/clover leys. Furthermore, some forages will provide cover for the birds and this may encourage ranging. Unless birds range well, forage intake will be low.

5. If a reasonable proportion of the birds' nutrient requirements for health and performance may be derived from the pasture or forage crop this would reduce the reliance on concentrate feed. This may have a positive impact on production costs and gross margins of product sales over feed costs.

6. Gross margins of egg output over feed costs, calculated so as to take into account the loss of all transitional derogations (pullet rearing and hen house stocking density), for specific rotations were negative at current egg prices. However, not all feeding options were considered (e.g. a bought-in protein concentrate, bought-in mineral mix and the feeding of home-grown cereal) and so there may be scope for improving farm gross margins when including poultry. For information, commercial producers have estimated a rise in production costs of 30p/dozen when derogations on organic egg production end. This means that either the price of organic eggs will have to increase substantially so as to cover increased costs, or methods of reducing production costs will be needed. There are many knowledge gaps associated with organic pullet rearing and with organic breeder flocks and hatching. Thus, it is not likely that producers will find methods for significant cost reductions in the short to medium term. If this is the case, organic egg producers may change to non-organic free-range egg production, and this will reduce the UK supply of organic eggs to consumers. Whether or not the supply of UK organic eggs then meets consumer demand will depend on the price elasticity of demand for organic eggs.

7. It is thought that parasitic disease will become more prevalent as more flocks are put through on the same land. This means that control strategies based on an understanding of the parasites' life cycles and host-environment interactions will be needed. The emphasis should be on pullets and laying hens as they may

have access to pasture for 56 to 66 weeks, and this would allow several generations of parasite life cycles to be completed. Findings for pullets and laying hens may then be applied to organic breeder flocks and organic table chickens.

6.0. POSSIBLE FUTURE WORK

Specific research opportunities have been identified and these are detailed below.

1. To devise hypothetical rotations including poultry that meet the following criteria: a) crop production is sufficient in terms of meeting the all of the birds cereal requirements and almost all of the birds protein requirements; b) recycling of nutrients between soil, plants and livestock is effective in maintaining soil fertility and avoiding pollution, and; c) sustainability is optimised.

2. To identify the contribution of alternative forages in providing home grown feed and vegetation cover to extensively reared poultry.

3. Organic poultry production will soon be extended so as to include pullet rearing. This means that there may be increasing pressure to find a use for male chicks of egg-lines, or there may be a greater emphasis on the use of dual-purpose traditional breeds. Most suitable breeds need to be identified, and their performance in organic systems assessed including ease of management and disposition towards feather pecking. The implications in terms of cost of production, loss of output and the potential to sustain market supplies using dual-purpose breeds would need to be considered.

4. There is a need to estimate the volume of waste products produced as a result of organic poultry production, and to assess how this may increase as the market sector increases. Possible uses for waste products need to be identified, and these should be sustainable.

5. The UK is not self-sufficient in organic poultry products, though it is closest to meeting consumer demands for organic eggs. Approximately 60% of consumer demand for organic chicken meat is met from imports. . The UK is also unable to meet all of its needs in terms of organic ingredients. The above practices will have an impact on socio-economic factors in the UK and on the environment, but to date this has not been assessed. There are important knowledge gaps which relate to the principles of organic farming as outlined by UKROFS. Research is needed to address this.

6. There are significant questions as to how the market will develop over the next few years. The cost elasticity of demand is a key issue. This is most relevant to the organic egg sector, because the ending of derogations will impact greatly on the cost of production. The organic egg market is a success story for the organic food sector, but this may change if the consumer is not prepared to meet the extra cost of production and demand falls.

   The effects of socio-demographic forces on the purchase of organic poultry products needs to be studied. Focus groups would be of use in trying to establish the cost elasticity of demand. Another important piece of market information is whether or not the demand is only for fresh organic chicken meat and eggs. This information could also be gained by holding focus groups. If there is gererally low acceptance of frozen organic poultry products, then the year round supply of fresh product will be important to the home market.

7. Chickens range poorly in open pastures: they make better use of shaded areas beneath tree canopies. Thus, range usage may be good in agro-forestry systems, or orchards. This is not surprising as modern hybrids of poultry are ancestors of the Red Jungle Fowl. A desk study is needed to assess the potential for combining organic poultry in agro-forestry systems and orchards. There are opportunities for case studies where producers in the UK are already doing this, but not in organic systems.

8. Comprehensive strategies for reducing the burden of endoparasites on land used by organic poultry are needed urgently if health and welfare problems are to be avoided. Economic pressures dictate that for fixed houses the resting period will not usually be greater than two months (UKROFS Standards). Capital investments made before the implementation of Regulation (EC) 1804/1999 and UKROFS Standards are

likely to have been on the basis of a two month resting period. A two month pasture rest period may enable vegetation to grow back, depending on the time of year, but it is not likely to reduce the endoparasite burden on the land. Oocysts and parasitic worms are able to persist in the soil for periods of greater than three months. Therefore this aspect of the Standards will not provide a means for the control of endoparasitic disease in poultry.

Information on endoparasites capable of infecting poultry in the UK, factors affecting the persistency of endoparasites in the soil, and factors affecting the severity of disease is needed so that comprehensive strategies for endoparasitic control may be proposed.

7.0. IP AND KNOWLEDGE TRANSFER

To date knowledge transfer has been through the two DEFRA-funded study days reported above, and through the steering group for DEFRA-funded project OF0153 (Effect of breed suitability, system design and management on welfare and performance in traditional and organic poultry meat systems).

The two literature reviews written for this project are to appear in a book published by Nottingham University Press. The title of the book is "*Niche and organic chicken production – its technology and scientific principles*", and it will be released in spring 2002. The reviews have been redrafted to form chapters of the book. Other chapters have been drafted using work done in two other DEFRA-funded projects (OF0153 and OF0192). This publisher is experienced at both targeted and general promotion of agricultural science books.

An extension leaflet has not yet been written, but one is planned and it will be drafted when information from complementary projects is fully available.

For further information on work covered in this project and for a list of references please contact the author of the report at sue.gordon@adas.co.uk