DEPARTMENT for ENVIRONMENT, FOOD and RURAL AFFAIRS **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
DEFRA, Area 301
Cromwell House, Dean Stanley Street, London, SW1P 3JH.
An electronic version should be e-mailed to resreports@defra.gsi.gov.uk

---

Project title	Workshop and desk study to appraise technical difficulties associated with organic breeder flocks and organic hatching
DEFRA project code	**OF0336**
Contractor organisation and location	ADAS Consulting Ltd ADAS Gleadthorpe, Meden Vale, Mansfield, Nottinghamshire NG20 9PF
Total DEFRA project costs	£ 34397
Project start date	10/02/03
Project end date	10/11/03

Executive summary (maximum 2 sides A4)

BACKGROUND

To date, Regulation (EC) 1804/1999 and UKROFS Standards allow conventionally produced day old chicks up to three days of age to be brought into systems of organic table chicken production. Chicks must be reared according to the rules laid down in Regulation (EC) 1804/1999 and according to UKROFS Standards for at least 70 days before the birds may be sold as being organic. The derogation for organic breeder flocks was agreed for a transitional period expiring on 31st December 2003. An extension to the derogation is being discussed at EU level (Article 14 Committee) but, as an interim measure, a new end date has not yet been published in the Official Journal.

If chicks are to be produced from breeder flocks in accordance with Regulation (EC) 1804/1999 this may potentially create a number of scientific and technical problems. A series of workshops and a literature review were commissioned by Defra to provide possible solutions to these problems.

OBJECTIVES

1. To organise a workshop involving key representatives of Defra, Soil Association, the poultry industry (organic and conventional), feed trade and scientific community and poultry veterinary practitioners in order to identify the important technical problems and limiting factors, and to identify possible solutions.
2. To address some of the perceived technical and scientific problems by means of a review of the scientific literature.
3. To convene a second workshop to review progress and to discuss the findings of the literature review. The second workshop also considered future research needs and mechanisms for technology transfer.

RESULTS

The initial workshop identified factors likely to limit the success of organic breeder production, and therefore of organic table chicken production. The priority issues were: the energy balance of breeders on range; supplying protein and amino acids; the future needs for 100% organic feed ingredients, including difficulties in meeting energy and protein requirements from organic sources; assessing the impact of diet on manure nutrient content; and health and disease.

The main findings of the literature review are summarised as follows:

1. Energy balance Varying conditions of temperature and bird activity mean that it is difficult to recommend appropriate feeding regimes. Furthermore, the prediction equations commonly used for estimating the energy balance of laying females were developed for commercial layers, not for breeders, and they were generally validated at indoor temperatures. Nevertheless the equations were reviewed and estimates were made of the possible effects of temperature and feather cover on *ad libitum* feed intake. Values ranging from 155 g to 190 g/day per bird were tabulated. These may be indicative of seasonal variation, though the workshop expressed some doubts about the ability of the birds to consume the higher level of feed.

2. Supplying protein and amino acids This topic is brought into focus by the withdrawal of the use of synthetic amino acids. There is general agreement in the literature that moderate protein intakes (23 g to 25 g/day) are adequate for female birds. Intake levels of 700 mg/day for methionine and cystine, 765 mg/day for lysine and 190 mg/day for tryptophan are typically recommended in the literature, but the rates given are often inconsistent and dated.

3. The future need for 100% organic ingredients Supplies of protein and oil are of most concern. Organic protein is likely to be expensive, and there may be consumer resistance to increased prices for the final product.

4. Impact of diet on manure nutrient content Nitrogen (N) excretion rates were estimated using published values for the N costs of maintenance and egg production. Excretion rates ranging from 984g to 1095 g N/female per year were estimated, for feed protein contents ranging from 155 g to 170 g/kg.

5. Health and disease In order to avoid foot problems caused by wet litter, recommendations are for adequate ventilation, modest stocking density, and regular foot and site inspection. Rotation of the pasture is essential to reduce parasitic infection, though the precise length of resting periods required are not certain. Helminths are more common in outdoor birds, and it is advisable to take precautions such as rotating paddocks, keeping grass short, avoiding reused litter, housing multi-ages separately, and pasture harrowing. There may be breed differences in ascarid resistance, but paddock rotation is also important. Roundworms may be carried by game birds and turkeys. Coccidiosis is potentially a major problem for range systems, though breeders may also develop a partial immunity in later life. Mites are likely to be a problem.

The incidence of mycoplasma may be less in smaller outdoor flocks than in intensive flocks. Whilst there is no direct evidence of mycoplasmas being spread by wild birds, several species appear to be susceptible *to M. gallisepticum.* Game birds are also susceptible. Wild birds may carry fowl cholera, so there is a risk that they may infect outdoor breeder flocks. Monitoring for pullorum disease is essential, because it can be vertically passed to the chicks. Newcastle disease affects wild birds, water fowl and turkeys, so outdoor breeders are at risk if they are in contact. There may be a risk of aviadenovirus from contact with ducks.

Zoonotic issues identified include *Salmonella enteritidis, S. typhimurium* and *Campylobacter*. Later slaughter and outdoor systems enhance the risk. Feed, wild birds and rodents, and possibly ascarid eggs, are potential vectors. Control measures for *Salmonella* include vaccination and competitive exclusion by promoting the gut *Lactobacilli* concentration. Organic birds may be vulnerable to *Campylobacter* infection from wild birds and perhaps from ruminant farm livestock acting as carriers.

IMPLICATIONS OF FINDINGS, FUTURE WORK AND POLICY RELEVANCE

The project addressed Defra's policy of supporting the development of organic poultry production in the UK. The work identified specific difficulties associated with organic breeding and hatching. Although information collected through consultation and literature review, provide some insight into the technical issues, significant information gaps remain. Requirements for further research were considered by workshop participants, and their recommendations include;

1. Bioenergetics Research into the energy balance of female birds, in particular the effects of feather cover and locomotion, and the time spent outdoors, has a high priority. The provision of outdoor shelter is also worthy of calorimetric investigation.

2. Nutrition Choice feeding may offer an approach address the problems of energy and protein balance, as related to the thermal environment.

3. Monitoring disease status The effects of rearing according to the organic requirements requires monitoring both for bird welfare and public health.

4. Nutrient budgets The monitoring of inputs and outputs in order to calculate plant nutrient budgets is required both on an individual farm and local co-operative basis. This requires data on manure nutrient content.

5. Sex ratios Outdoor systems may require different male:female ratios.

6. Management of slow growing breeder hybrids This has not yet been assessed in UK outdoor systems. Factors to be investigated include target body weights and variations in body weight. Flock performances, labour costs, and optimal flock life are factors requiring further investigation before sound advice, including guideline costings, can be offered to producers.

Scientific report (maximum 20 sides A4)

BACKGROUND

The transitional derogation EC Regulation 2092, as amended by 1804/99, permits the sourcing of day old chicks from non-organic breeding flocks. However this derogation is scheduled to end on 31st December 2003. An extension to the derogation is being considered at EU level (Article 14 Committee) but a new end date has not yet been published in the Official Journal. It is expected that when a new derogation is published this will only be for the short term. It will then be mandatory to source day old chicks for organic table chicken production from organic breeding flocks. This raises a new set of technical and scientific issues for organic producers. A series of two workshops and a major review of the scientific literature were undertaken in order to address the relevant problems, with a view to providing some solutions for organic producers, and to identify future research needs.

OBJECTIVES

1. To organise a workshop involving key members of the organic poultry sector, Defra, and the appropriate support industries and academic disciplines, in order to identify key scientific and technical problems, and to identify possible solutions.
2. To address the key scientific and technical problems by means of a review of the scientific literature.
3. To convene a second workshop to discuss the findings of the literature review and to consider future research needs.

METHODOLOGY

The work comprised three separate, but related stages. The first workshop was held on 2nd June 2003 at ADAS Gleadthorpe, with the purpose of discussing the issues raised by future changes to the organic regulations. A list of attendees and a copy of the workshop agenda are given in Tables 1 and 2 respectively.

Table 1 Attendees of Workshop 1 held on 2nd June 2003

Name	Organisation
Dr Janet Bradbury	University of Liverpool
Dr David Charles	DC R&D Ltd
Mrs Sue Gordon	ADAS Gleadthorpe
Mr Andrew Gunther	Burcombe, Tiverton, Devon
Dr Malla Hovi	University of Reading
Mr Joe Lawson	Moy Park Ltd
Mr Mike Tyers	Deans Foods Ltd
Mr Andrew Walker	ADAS Gleadthorpe
Mr Steve Wilson	BOCM Pauls Ltd

Table 2 Agenda for Workshop 1

Item	Name
1. Chairman’s introduction	Mr Andrew Walker
2. Workshop objectives and project details	Mr Andrew Walker
3. Short presentations on:	
i. Earlier work and key definitions	Mrs Sue Gordon and Dr David Charles
ii. Mycoplasmas	Dr Janet Bradbury
iii Disease and epidemiology	Dr Malla Hovi
4. General discussion to include prioritisation of topics for literature review and agree date of final workshop	All

Two short presentations were made at the workshop focussing on diseases in outdoor poultry and breeder flocks. Speakers and attendees were invited to comment on the likely difficulties that might be experienced when attempting to manage breeder flocks in an organic production system. These ‘problems’ have been listed in Table 3, and provide the topic headings for the subsequent literature review.

Table 3 Perceived technical and scientific difficulties associated with organic breeders

Main problem	Impacting on
1. Energy balance	Feeding regime, shelter provision
2. Supply of protein and amino acids	Feed ingredient availability
3. Future need for 100% organic ingredients	Ingredient choice and availabilty
4. Feeding for optimal production, health and welfare	Health and performance of breeders and progeny
5. Effect of diet on manure nutrient content	Environmental pollution and cropping
6. Effects of environment on sexual maturity in males and females	Application of lighting programmes
7. Practical measures for reducing disease risk	Husbandry, biosecurity and vaccination policy
8. System design as it affects behaviour, health and welfare	System and paddock design
9. Constraints of organic standards on hatchery practice	Hatchery design and practice

Literature searches of the major international abstracting databases were carried out focussing on the technical problems specified in Table 3. The databases used covered agriculture, biology, life sciences, food sciences and medical sciences. Published and on-going European organic research was taken into consideration, including information arising from Defra-funded projects OF0153, OF0163, OF0192 and OF0327. 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. The findings of the review were written as a discussion paper, circulated to the workshop participants.

A follow-up workshop was held on 2nd October 2003 at ADAS Gleadthorpe to discuss the findings of the literature review, and to identify research priorities. A list of attendees, including a representative from the abattoir sector, and an agenda for the workshop are given in Tables 4 and 5 respectively.

Table 4 Attendees of the second workshop

Name	Organisation
Mr Andrew Walker	ADAS
Mrs Sue Gordon	ADAS
Mr Steve Wilson	BOCM Pauls
Dr David Charles	DC R&D
Dr Janet Bradbury	University of Liverpool
Dr Malla Hovi	University of Reading
Mr Mike Tyers	Deans Foods Ltd
Mrs Claire Knott	Crowshall Veterinary Services
Mr Jake Hancock	Soil Association
Mr Bill Yeats	Lloyd Maunders Ltd
Ms Julie Page	PD Hook Ltd

Table 5 Agenda for the second workshop

Item	Name
Welcome address, apologies and matters arising from the minutes of Workshop 1	Mr Andrew Walker
Presentation of findings from literature review plus discussion	Mrs Sue Gordon and Dr Malla Hovi
Future research priorities, research strategies and industry involvement	All
Any other business	

RESULTS

All project milestones and objectives were delivered in full and in accordance with the agreed timescale.

The main results of the work were presented through the literature review, which was circulated after the second workshop.

1. Background

Breeder flocks are the parents of commercial broiler chickens and table chickens. Based on a Soil Association estimate of UK organic table chicken production for this year of 3.5 million birds (Hancock, 2003 *personal communication*) some 28,000 to 35,000 organic breeders are required, depending on performance. Breeder flocks are usually housed indoors for reasons of biosecurity and environment control. It is in this respect that an organic breeder production system will differ. Organic breeder flocks will have to be allowed outdoors to graze. This will give rise to many scientific and technical challenges.

2. Technical difficulties related to practical organic breeder production

The main issues identified were associated with energy balance and the responses of the females to the thermal environment and shelter; ingredient sourcing, in particular the provision of proteins, amino acids and oils; the minimisation of the disease problems; and public health risks associated with outdoor production.

2.1 Energy balance of adult females

2.1.1 *Intake capacity*

The genetic potential for fast growth means that broiler breeder females fed *ad libitum* have a large intake capacity. They become obese on broiler diets. Appetite in poultry declines with increasing temperature, but even in indoor production the appetite of broiler breeder females is excessive and controlled feeding is used. In organic production there is therefore the dual difficulty of requiring *ad libitum* feeding while yet exposing the birds to lower temperatures than experienced indoors. Obesity is a serious risk, likely to cause both mating and welfare problems. This adds to the likelihood that organic table chicken producers will have to use hybrids other than broiler hybrids.

The use of 'slow growing' hybrids or traditional breeds could reduce obesity problems in the breeder flock. Defra-funded project OF0153 found that imported 'slow growing' hybrids are suitable for use in production systems requiring growing periods of about 70 days (e.g. organic). The work was summarised and published by Gordon and Charles (2002).

Because organic breeders will be subject to changes in their thermal environment, and because it is critical to avoid an over or under consumption of feed energy, the issue of energy balance is important. In practice, under conditions of varying temperature and bird activity, it will be difficult to operate appropriate feeding regimes. Individual bird variation further complicates practical feeding. For non-organic broiler breeders, the target maximum coefficient of variation for within flock variation in live weight is 8% (Ross Breeders, 1998).

The energy balance of the females must rank high on the list of factors to consider in an investigation of limits to the performance of organic breeders. Meanwhile the recommendations of the breeding companies for the energy balance of their birds should be carefully followed.

2.1.2 *Energy allowances and the effect of temperature*

Metabolisable energy (ME) intake is partitioned three ways. It supplies the energy content of egg output, that of body weight gain and that of heat loss. Of these, by far the largest component is heat loss. Emmans (1974) quantified the partition of ME intake for laying hens and expressed it in the relationship given below.

$M = bWk + 2E + 5\Delta W$, where;
M = ME intake (kcals/ bird day);
W = live weight (kg);

E = egg output (g/bird day);
ΔW = weight change (g/bird day);
k = a strain specific constant varying from 0.75 to 1.00; and
b = a constant depending on strain, temperature and feather quality.

Later, Emmans and Charles (1977) published values for the constants in the following version of the equation.
$M = W(a + bT)f + 2E + 5\Delta W$

Where a and b had values of 170, 155 and 140 and -2.2, -2.1 and -2.0 respectively for white, tinted and brown egg laying stocks. f was a multiplier for the effect of feathering on heat loss, and therefore on the maintenance requirement term $W(a + bT)$. Note that at the time of this work the kilocalorie (kcal) was the usual unit of feed energy. To convert from kcal to kJ multiply the feed energy value by 4.19.

On the subjective feather loss score, 1 indicated perfect feathering and 5 indicated complete feather loss. In practice, the score often changes from approximately score 2 to score 3 during lay for hens.

Since the amount of the available energy lost as heat is dependent on temperature and feather score, it is likely to be higher in winter than in summer and higher on range than indoors. Environmental temperature is likely to affect the amount of feed energy which should be offered to the birds and the published feeding recommendations of authorities such as Leeson and Summers (1997) incorporate this concept. They estimated, for example, that maintenance might take 140 g of peak feed requirement/day per bird at 18^{o}C, but only 125 g of peak feed requirement/day at 24^{o}C. Corresponding values for total feed were 180 g and 165 g/day per bird, respectively.

The study group noted that in the outdoor environment the effects of temperature may be modifed by wind speed and, if the feather coat is penetrated, by rain. In terms of physics, Wathes and Clark (1981a and b) characterised the effects of wind speed and other variables on the insulative properties of chicken plumage.

The equation of Emmans and Charles (1977) has been used to make the following estimates of feed intakes which might occur on *ad libitum* feeding for a feed providing 11.55 MJ/kg ME, and assuming that breeders have the same values of a and b as brown commercial layers. However, note that there are no experimental grounds for this assumption, so that the values in Table 6 are comparisons of possible temperature effects: they are not recommendations. The estimates are for birds of 3.4 kg live weight at 30 weeks of age, gaining weight at 4 g/bird per day, at 83.6% rate of lay, and with an egg weight of 60 g/egg.

Table 6 Estimates of the effect of temperature on *ad libitum* feed intake (Source: ADAS)

Feather score	Temperature (^{o}C)	Feed intake (g/bird day)
2	15	179
2	20	167
2	25	155
3	15	190
3	20	177
3	25	163

The literature contains many other equations for estimating the voluntary ME intake of layers. The Emmans and Charles (1977) equation was chosen for the above study because it takes into account feathering. Feathering was of particular concern to the study group, because outdoor birds are likely to be exposed to low temperatures.

Note that the equation of Emmans and Charles (1977) was developed with birds kept at indoor temperatures and therefore the lowest temperature quoted is 15^{o}C. However, in another research project at Gleadthorpe, funded by Defra (OF0327), attempts are being made to develop a model of laying hen energy balance at lower temperatures, and to build in the responses to the HEN predictive model of Charles (1984) and Hill *et al.* (1988).

An interaction between temperature, feather score and ME allowance seems almost inevitable, but they have not been tested experimentally. The study group observed that there is therefore scope for calorimetric research on the energy balance of breeders.

Some degree of feed restriction is normally practiced in the non-organic sector, and this is supported by experimental data. For example, Robinson and Wilson (1996) found that *ad libitum* fed birds produced less eggs, had more multiple ovulations, more shell quality problems, and lower fertility and hatchability, than birds fed to industry target weights.

Leeson and Summers (1997) suggested techniques such as lead feeding from egg production, and breeding companies have target weight for age profiles which are important to achieve. Overweight birds are not required, and while Summers and Robinson (1995) cautioned in a review the danger of excess follicle development if too much energy is fed, Pearson (1982) pointed out that too severe a restriction of energy intake led to depressed egg output. Pearson and Herron (1981) suggested that for broiler breeders a weight gain of about 1100 g/bird in 105 days was associated with optimal performance at the time. In their experiments in an environment where temperature fluctuated between 14°C and 23°C, weight gain and carcass fat increased and fertility decreased with increasing dietary energy intake. Maximum egg production occurred at an ME intake of 1.73 MJ/day.

Spratt *et al.* (1990a) determined the daily maintenance energy requirement of individually caged Hubbard hens maintained at 21°C as 292 kJ/kg (367 kJ/kg$^{0.75}$), which they noted was less per unit weight than that of commercial layers. It was associated with a requirement of 1.6 MJ/day of apparent ME (AME) to cover growth at a rate of 3 g live weight/day and egg production at 85%. Spratt *et al*. (1990b) estimated that the fasting metabolic rate was about 75% of the maintenance requirement. It seems possible that energy balance could be particularly important to certain vital functions including reproduction, since they found that the liver, gut and reproductive tract of broiler breeder hens accounted for 26% and 30% of energy expenditure in fed and fasted hens respectively, even though they only accounted for 6% and 4% of body weight. In the later work on Ross birds reported by Keaveney (1996), egg production was significantly reduced (by 6.4 hatching eggs/bird) when the dietary energy level was reduced from 11.2 MJ to 10.5 MJ/kg (intakes of 1.88 MJ *versus* 1.76 MJ/day).

2.1.3 *Energy requirements for locomotion*

The study group was concerned about the effects of locomotion on energy requirements, on the grounds that in outdoor production it seems probable that the birds will walk further than in indoor systems. Values for the energy costs of locomotion in poultry have not been published but the value 2 J/kg m has been estimated for ruminants and for wild animals walking on the flat (Hudson and White, 1984). If this applies to poultry, it is therefore about 7 J/m for a breeder weighing 3.5 kg.

2.2 Protein, fat, mineral and vitamin nutrition

While energy balance, including feathering and locomotion, was the prime nutritional limitation identified by the group there were other nutritional issues. The availability of suitable organic ingredients was a concern, as was the supply of protein and amino acids.

The availability of organic ingredients is likely to be limited at the time when 100% organic feed is required after the 24th August 2005. Perhaps of most concern to producers is the supply of protein and energy (oil). Although peas may be more widely used in poultry diets than at present, the quantity of organic peas grown in the UK is small (Taylor and Cormack, 2001 citing Soil Association, 2001). Organic protein is likely to be expensive, and because of there being a limited number of available ingredients, the amino acid balance will be less than optimal. Furthermore, it will not be possible to redress this using synthetic amino acids.

As the list of permitted ingredients is an inclusive list (Regulation EC1804/1999), this precludes the use of oils. Thus, the ability to alter the ME value of the diet is constrained to the use of permitted oilseed products.

2.2.1 *Protein and essential amino acid intake*

This issue has been brought into sharp focus recently by the debate about the permissibility of synthetic amino acids in organic poultry rations. An appraisal of issues of the supply of essential amino acids requires a discussion of amino acid metabolism, of protein quality, and of the rationale behind the calculation of requirements. A brief summary review of these matters was provided by Gordon and Charles (2002), and a wider review is currently being undertaken by Gordon (2003) in Defra-funded project OF0327.

There seems to be general agreement in the literature, and in the industry, that moderate protein intakes are adequate for breeders. Patel and McGinnis (1977) found that high protein concentrations decreased hatchability and increased the need for vitamin B_{12}. Pearson (1982), warned of such effects on the requirements for vitamin B_{12}, biotin and possibly other nutrients. Pearson and Herron (1982) found that high protein combined with low energy reduced hatchability. Summers (1995) offered tables of requirement and noted that 150 g/kg crude protein was sufficient and 130 g/kg often gave excellent results. Summers and Robinson (1995) suggested that protein concentrations as low as 8 g to 12 g/kg were sufficient for the males, but diets based on this were difficult to formulate. Lopez and Leeson (1995a) and Leeson and Summers (1997) reported work in which low protein diets supplemented with methionine and lysine were associated with a lower peak but better persistence of lay. Fertility was better, and this was thought to be because the low protein birds gained less weight. Lopez and Leeson (1995b) found that the low protein treatments were associated with lower egg weight and chick weight, but this had no effect by 48 days of age.

A general conclusion of Leeson and Summers (1997) was that "...most breeder flocks will be over-fed, rather than under-fed crude protein," and that it was difficult to justify feeding much more than 23 g to 25 g protein per day per bird. Harms and Russell (1995a) found that with additional methionine and lysine supplementation, low protein intakes supported adequate levels of performance. They considered the lysine requirement to be higher than that recommended by the National Research Council (NRC) but the protein requirement to be lower. Keaveney (1996) warned of the use of high protein diets at low energy intakes - 16.7 g/day of crude protein was too low, but she found that hatching egg output was not significantly affected over the range 21.7 g to 31.7 g/day. The data could also be interpreted as suggesting a curvilinear response, with a tentative maximum reached at about 23 g to 25 g/day in agreement with Leeson and Summers (1997). Larbier and Leclercq (1994) raised the question of whether or not there was a need to adjust protein intake for early or late maturity.

Despite the general agreement on protein intake the literature on amino acid requirement is surprisingly and alarmingly inconsistent for such a fundamental and routinely important constituent. Harms and Russell (1995a) pointed out the wide range of estimates of requirement for lysine, and, in a separate paper, for methionine (Harms and Russell, 1995b). The values given by Leeson and Summers (1997) were 952 mg to 990 mg/bird per day for lysine, and 490 mg to 512 mg/bird per day for methionine. The NRC (1994) publication suggested 19.5 g of protein per breeder hen per day, 700 mg methionine and cystine, 765 mg of lysine and 190 mg of tryptophan per day. For the cockerels, the recommendations were 12.0 g per bird per day of protein and 490 mg/d of methionine plus cystine (NRC, 1994).

2.2.2. *Fatty acids*

Since the chicken embryo derives more than 90% of its total energy requirements from fatty acid oxidation, lipid metabolism is important to its development (Romanoff, 1967, quoted by Noble *et al*., 1986).

Pearson (1982) explained in a review that yolk lipid is the main energy source for the developing embryo. The review pointed out that dietary fats did not affect total yolk lipid but did affect its fatty acid composition. Linoleic and arachidonic acids in the feed were essential to produce viable chicks. The response curve of hatchability to dietary linoleic acid indicated a requirement of about 1% in the feed. A review by Wilson (1997) commented that dietary palmitic acid increases yolk oleic acid and spares linoleic acid for embryonic growth. It also affects transport across the yolk sac membrane and facilitates yolk mobilisation.

Noble *et al*. (1986) found that the higher embryo mortality associated with younger breeders was associated with differences in yolk lipid accumulation and mobilisation. In eggs from younger parent flocks more triglycerides are found in the yolk at day 15, but less phospholipids and free cholesterol, than in eggs from older birds. Tullet (1995), in a review, explained that embryos from young parent birds have a reduced rate of lipid mobilisation from yolk contents. It was suggested that this might be because eggs from young breeders have shells of low conductance, which would limit the general metabolism of the embryo. He went on to suggest that whether this low conductance is a critical factor could be investigated by incubating eggs in supplemental oxygen.

2.2.3 *Vitamins and minerals*

The literature on vitamins and minerals in the diet of breeders is vast. Fortunately there have been several good reviews, including the extensive review of 132 references by Wilson (1997). Clearly the embryo is completely dependent upon the supply of vitamins stored in the egg. The review by Pearson (1982) described a relationship between parental dietary intake and the production of viable offspring. Relationships have been demonstrated between dietary intake, vitamin content of the egg and hatchability for riboflavin, vitamins A, D, E, K, pantothenic acid, nicotinic acid, pyridoxine and folic acid. Later, Whitehead *et al*., (1985) showed that biotin intake was related to yolk and chick plasma biotin content. Carrier proteins were shown to be involved for thiamin, riboflavin, biotin and vitamin B_{12} (reviewed by Pearson, 1982). The carrier proteins have finite saturation levels (e.g. Muniyappa and Adiga, 1979).

Pearson (1982) also listed deficiencies of the minerals Ca, P, Mg, Mn, Zn, Fe, Cu, Mo, I and Se as resulting in failure of hatchability or embryo abnormalities. Richards (1997) explained that the essential minerals act as catalytic or structural co-factors in enzymes and proteins. According to Leeson and Summers (1997) the first limiting vitamin is often likely to be riboflavin.

The dependence of the embryo on parental supply means that the vitamin and mineral contents of the breeder diet are important issues and Leeson and Summers (1997) pointed out that marginal inclusion rates could easily result in the loss of between two and five chicks per breeder. But this does not mean that the breeder diet should contain excessive concentrations for three reasons. Firstly, as pointed out by Leeson and Summers (1997) some of these nutrients are expensive. Secondly, some of them are harmful in excess or exhibit adverse interactions with other vitamins and minerals. These include the vitamins A, B_{12} and D (Wilson, 1997) and the minerals Se, Mg, Mo, and Na (Pearson, 1982) and I, P and Ca (Wilson, 1997). Thirdly, there is presumably little point in supplying more than the carrier proteins can carry. It seems that industry inclusion rates in the USA are often substantially higher than NRC (1994) recommendations, according to Leeson and Summers (1997), quoting a BASF survey of industry practice (Technical Bulletin #KC9305).

A review of vitamin requirements by Whitehead and Portsmouth (1989) tabulated supplemental vitamin concentrations for broiler breeder diets based mainly on wheat or mainly on maize.

The supply of calcium and phosphorus to laying hens is a concern. The metabolism of these two minerals is both complex and important, but perhaps less likely to be quite so critical in breeders, as in commercial layers because of higher feed intakes and lower egg output. The separate feeding of a calcium source may be worth further attention, particularly since extensive methods of production, such as organic systems, lend themselves to it. Van Wambeke and de Groote (1986) found that partial replacement of limestone by oystershell improved rate of lay, and there was an interaction between calcium source and feeding time for shell quality. Reis *et al*., (1995) found benefits from providing a coarse limestone supplement to breeders.

The importance of vitamins suggests the need for great care in avoiding denaturation and the reduction of potency during the milling, production, distribution and storage of breeder feeds. McDonald *et al.* (1995) provides a reminder that many vitamins are destroyed by oxidation, a process which, is speeded up by the action of heat, light and certain metals such as iron.

2.3 Flock health

In the following sections an assumption has been made that organic breeders will have access to range, as suggested by the current organic livestock production standards (EU Regulation 1804/99). Issues highlighted may have a different significance in breeder production systems that allow outdoor access but not to pasture (e.g. verandah systems).

2.3.1 *Diseases and parasites mainly affected by husbandry and management*

This section covers poultry health issues that are mainly related to husbandry and management and includes conditions such as lameness, endemic viral and bacterial diseases and parasitic conditions. These conditions have been grouped together to highlight the fact that they all can be controlled satisfactorily by implementing existing husbandry knowledge of free-range systems.

2.3.1.1 Lameness/foot problems

Wet litter is a major cause of foot lesion and foot erosion-associated lameness in adult chickens kept in free-range and barn systems. Foot lesions and erosions predispose the birds to deeper infections of the footpad, leading to staphylococcus-associated bumble foot and foot abscesses (Richard, 1991).

There is no current data on the epidemiology of foot lesion-associated lameness in UK layer or breeder flocks. In Sweden, Gunnarson *et al.,* (1997) reported an incidence of bumble foot of more than 5% at 35 weeks in some layer flocks reared in aviary systems and suggested that white hybrids were most at risk from developing severe forms of foot lesion.

Tauson and Abrahamson (1994) concluded that the presence of perches reduced the incidence of foot lesions. Later work has shown that perch design is important (Tauson and Abrahamson, 1996). Wahlstrom (1999) found that hens fed diets containing a high proportion of oats and, as mash rather than as crumble, had a lower incidence of severe foot lesions than birds fed standard diets.

Low stocking densities, both outdoors and indoors, good husbandry practices, including regular foot health checks and wound care, careful site maintenance and selection and good housing hygiene are recommended good practice (Hovi *et al.*, 2000).

2.3.1.2 Aspergillosis/mycotoxicosis

Richard (1991) thoroughly reviewed the epidemiology and control of aspergillosis in poultry, suggesting that there is no evidence that the incidence of aspergillosis in free-range systems would be any different from that found in indoor, intensive systems, as the disease is mostly caused by contaminated feed. There is, however, an old reference from Guberlet (1923), who suggested that birds kept in free-range conditions were more resistant and appeared to escape disease on some farms, even when mycotoxin was detected.

Diagnostic precautions, both at feed mixer and at farm level, should be adequate measures to control the problem, when implemented conscientiously. This is particularly important as mycotoxins may accumulate in the chicken liver at subclinical toxic concentrations. The birds show little evidence of disease, but the mycotoxin concentrations may cause a human health risk due to the consumption of chicken liver products.

2.3.1.3 Internal parasites

Helminthiasis

Helminthiasis is more common in outdoor than indoor flocks. In recent years, there has been very little new work carried out in the UK on the control of poultry helminths, apart from work on anthelminthic use. A small survey of free-range layer flocks demonstrated a wide variety of helminth parasites in most of the flocks with no apparent adverse effect on production (Pennycott and Steele, 2001). In Denmark, an increase in parasitic infestation of poultry has been recognized in free-range and organic flocks, in particular with *Ascaridia galli*, *Heterakis gallinarum* and *Capillaria* species (Permin and Nansen, 1996).

Information on parasite survival in the pasture is now becoming dated and is based on empirical data that recommends two to three months' rotation of paddocks, but there is a poor understanding of rotation intervals in relation to the timing of return to the same ground. Reduction of stocking densities by encouraging birds to use the whole area allowed for raging could be expected to dilute the build-up of parasites.

In addition to the above measures, the standard poultry husbandry recommendations list the following precautions (Richard, 1991):

- keeping grass short will help parasite control as ultraviolet sunlight appears to kill worm larvae;
- avoiding re-use of litter prevents larval build-up;
- harrowing and removal of topsoil around housing/most used areas of paddocks;
- grouping of different age-groups separately, as some parasites proliferate in wet litter, and;
- siting paddocks in areas that are not at risk from poaching, dampness and water-logging.

Ascarids

Permin *et al.,* (1999) reported an infection rate of 63% in organic/free-range layers (42% of deep litter birds and 5% of battery caged ones) in Denmark. As ascaridiasis can have severe health effects, including increased mortality, there is an obvious need to monitor parasite loads in free-range systems. This is, however, complicated by the fact that high prevalences may not cause ill thrift in flocks where a natural balance has been achieved.

Most standard text books suggest that Ascarid eggs survive in outdoor conditions for more than 60 weeks. It has been suggested that birds having limited outdoor run access are at more risk than those in genuine free-ranging systems. In deep litter systems, worm problems may increase during the winter months, if the litter becomes too wet (Methling *et al.,* 1994).

As birds develop goblets cells in their duodenum (over three months of age) they acquire a level of resistance to ascarid-infection. Breed differences in resistance to ascaridiasis have been observed, suggesting that selection could be used as a control method (Permin and Ranvig, 2001). Permin *et al.,* (1998) also report that higher levels of dietary protein and the size of the initial infecting dose (Permin *et al.,* 1997) have an impact on pathogenecity.

Gapes and capillariasis

Roundworms that have a larval passage through the earthworm are particularly likely to cause problems in free-range systems, and there is a suggestion that their infectivity increases during the passage (Horton-Smith, 1953). Gapes (*Syngamus trachea*) and capillariasis (various *Capillaria* species) are the main types of roundworms within this category.

Game birds and turkeys have been identified as particular carriers of both gapes and capillariasis. Therefore mixing of game bird or turkey rearing with organic breeder enterprises is not advisable. A total of 53.6% of Danish organic and free-range flocks have been found to be infected with *Capillaria obsignata,* 31.9% with *Capillaria anatis* and 1.5% with *Capillaria caudinflata* (Permin *et al.,* 1999).

Apart from keeping game birds and turkeys separately from organic poultry breeder units, routine management measures for parasite control have been found to be effective in controlling roundworms: rotational pasture, non-permanent (preferably not earth-floor) housing, composting of poultry manure and separation of different age groups of birds (Richard, 1991).

Coccidiosis

While coccidiosis, a disease caused by protozoal parasites, tends to be associated with intensive rearing conditions and young stock, it is found in all management systems, including extensive outdoor systems. In Austria, problems have been reported in organic table chicken units (Zollitsch *et al.,* 1995). A French study found non-medicated organic birds to carry more coccidia than free-range medicated ones (Williams *et al.,* 1996). In the UK Lampkin (1997) reported a variety of mortality rates (2.5-30%), in the first two weeks in one organic table chicken flock.

As birds develop partial immunity to coccidial infection in later life, coccidiosis is unlikely to be a problem in a breeding unit, if reasonable standards of management (e.g. monitoring, pasture resting and composting), are maintained. Availability of an effective vaccine (Lunden and Thebo, 1999; Waldenstedt *et al.,* 1999) also helps to address problems that may arise despite appropriate husbandry measures.

2.3.1.4 External parasites

The free-living, blood-sucking mites, red mite (*Dermanyssus gallinae*) and fowl mite (*Liponyssus sylvarium*), with the former being the most common in the UK, are likely to be a greater problem for organic breeder flocks than internal parasites. Permin and Nansen (1996) suggested that the prevalence of mites in organic poultry systems is likely to be higher than in non organic systems, due to restrictions on acaricide use and due to the housing systems used.

There is a limited amount of data on the prevalence of mite in UK free-range or organic systems. Swarbrick (1986) reported on a red mite problem in a free-range flock in England, with high mortality, anaemia and egg drop syndrome. In Sweden, Hoglund *et al.* (1995) found that 33% of deep litter flocks and 67% of backyard flocks were infested with red mite, but only 4% of caged flocks were affected. In Switzerland, Mauerer *et al.*,

(1993) reported that 85% of deep-litter and outdoor systems were infected. They also found that neither flock size nor access to outdoors appeared to affect the likelihood of the flock becoming infected.

As wild and domesticated flying birds and turkeys are the usual hosts for the mite and new mite infections are usually brought into a flock/onto farm by bought-in pullets, a level of separation and monitoring should be implemented in organic breeder flocks. Continuous monitoring (especially during the winter months), periodic emptying and disinfection of the houses, separation of age groups and early intervention when problems are detected are appropriate husbandry measures.

2.3.2 *Infectious diseases, requiring good monitoring and biosecurity measures*

This section addresses infectious poultry diseases that can potentially be a problem in free-range systems due to lower biosecurity levels compared to intensive, indoor units.

Most of these diseases are rare or fairly well controlled in the UK at the moment, and only present a potential risk to outdoor breeder units. It is difficult to quantify the risk, in the absence of epidemiological data from free-range systems and limited availability of data on the ability of wildlife to spread these pathogens. Therefore, some monitoring of these diseases in organic breeder flocks would be desirable.

2.3.2.1 Mycoplasma

Mycoplasma gallisepticum and *M. synoviae* are prokaryotic pathogens that cause disease in chickens and turkeys. The disease has been considered a problem mainly in large intensive systems, where stress levels appear to make the bird more susceptible to infection and where infection pressure is higher (Jordan, 1985). Large layer flocks, with multi-age flocks are most at risk, and a high incidence of mycoplasmosis has been reported in the US (McBridie *et al.*, 1991).

Mycoplasma infection with both *M. gallisepticum* and *M. synoviae* in outdoor breeder flocks is seen as a major problem by the non-organic broiler industry which has established a voluntary *M. gallisepticum* eradication programme in parent flocks that provide day-old chicks for flocks outside internal, vertical production systems. Whilst there is no direct evidence of mycoplasmas being spread by wild birds, several species appear to be susceptible to *M. gallisepticum* and game birds are also susceptible.

The literature reports various interventions that can be implemented to control mycoplasmas. Eradication of infection is the most satisfactory approach to control, but maintenance of freedom in organic breeder flocks may be difficult, especially if wild birds do play a role in spread.

In the past, control measures have included treating the hatching eggs (dipping in antibiotics or heat treatment) and monitoring the progeny for infection. Flocks may be considered uninfected when monitored progeny from disease-free parent birds and hatching eggs are shown to be free from infection. This approach could be taken by organic breeding flocks, with monitoring to assess re-infection rates and clinical effects of potential infection. To control the disease in non-eradication situations, it has been suggested that breeding birds are maintained in separate flocks of no more than 200 to 300 birds, so that whole flock infection can be prevented, and so that only small flocks need to be destroyed in the advent of a detected infection. As with many other poultry diseases, mixing of multi-age groups should be avoided. Site rotation and hygiene may also assist in limiting transmission, as mycoplasmas are susceptible to disinfection and do not last for more than a few days outside the bird. If the above control measures appear inadequate in outdoor systems, vaccines are available to immunize birds.

2.3.2.2 Fowl cholera/*Pasteurella multocida*

Fowl cholera is an infectious and virulent disease that affects mainly layer and breeder flocks. The causative organism is *P. multocida*. All bird species are susceptible, and adult poultry are more susceptible than younger birds. While there are no data on the presence of fowl cholera in UK organic poultry flocks (i.e. no notifications of outbreaks have been made; VIDA data), *P. multocida*-infection has been reported in organic and backyard poultry in Denmark (Permin and Nansen, 1996; Christensen *et al.*, 1998). The characteristics of consecutive outbreaks of fowl cholera in wild and domestic birds were similar, and it is suggested that wild birds act as a source of infection to domestic, free-range poultry (Christensen *et al*, 1998).

Stress, resulting from various factors like poor ventilation, over-crowding and spread via contaminated drinking water have been identified as factors in the severity and speed of spread of fowl cholera. Therefore, following good basic husbandry is recommended. Monitoring of a breeding flock's disease status is also important to prevent the establishment of chronic infection that can cause low mortality and reduced egg production, which may otherwise go undetected. As destruction of the infected flock is again the best control measure, birds in a breeding flock should be kept in small separate units to avoid spread and the need to destroy the whole flock.

2.3.2.3 Fowl typhoid and pullorum disease

While zoonotic salmonella infections are dealt with in the next section, a brief overview of salmonellas pathogenic to poultry is given below.

Fowl typhoid is caused by *Salmonella gallinarum* and is associated with adult birds and poorly managed outdoor flocks. A particular association with ascaridiasis has also been suggested (Thamsborg, 1999). However, fowl typhoid is not common in the UK. If outbreaks occur, they are usually seen in the summer and spread rapidly throughout the flock, leaving some of the recovering birds as carriers. Good hygiene management, good control of ascarids, small and separate groups that can be isolated and destroyed in the face of an outbreak are recommended as control measures.

Pullorum disease is caused by *Salmonella pullorum* and it causes disease problems mainly in young birds. However, it is significant, at breeding level as the breeders can pass the infection vertically to the chicks. Pullorum disease has been eradicated from the UK poultry flock and very little is known about its potential risk factors in outdoor breeding systems. Monitoring of *S. pullorum* in free-range breeder units is vital.

2.3.2.4 Newcastle disease

Newcastle disease is a highly infectious viral disease that affects a wide variety of both domestic and wild birds. In the UK, outbreaks occur sporadically (Alexander *et al*, 1998; Alexander *et al*, 1985; Alexander and Gough, 1986). Birds kept outdoors are likely to be at a greater risk than birds kept in high-biosecurity indoor units. Recent UK outbreaks have been associated with waterfowl, migratory birds and pigeon contamination of feed stores (Alexander *et a*l, 1998, Alexander *et al*, 1999; Alexander *et al*, 1984 and Alexander *et al*, 1985).

Newcastle disease is a notifiable disease in the UK and The Diseases of Poultry Order 1994 (SI 1994/3141) sets out procedures to be followed regarding movement of birds, disinfection of premises and vaccination to ensure continued protection. Whilst vaccination alone cannot guarantee full protection, the combination of immunization and good husbandry and hygiene measures is likely to result in good protection levels. Suitable husbandry measures include:
- good ventilation and low stocking densities;
- good carcase disposal and composting of manure and
- separation of breeders from any contact with waterfowl and turkeys.

2.3.2.5 Aviadenovirus/Egg Drop Syndrome (EDS)

EDS, caused by the aviadenovirus has been virtually eradicated from the primary breeder flocks but may be a risk for organic systems due to the potential exposure to wild birds, ducks and geese, which carry the virus. EDS has been reported in organic flocks in Denmark (Permin and Nansen, 1996). In New Zealand, Christensen and Stanislawek (1994) found high levels of antibodies to EDS in a free-range flock having contact with ducks.

In outdoor breeder units, the control of EDS should be based on:

- accredited, disease free parent birds;
- good husbandry and hygiene management;
- spatial and hygiene separation from ducks and geese; and
- continuous monitoring.

2.3.3 *Public health issues*

This section addresses two public health concerns associated with poultry breeding systems: host adapted salmonellas and campylobacteriosis.

Salmonella enteritidis, *S. typhimurium* and *Campylobacter* are human pathogens that are carried by healthy birds in their intestine, which then contaminate the carcass during the slaughter process. The majority of human food poisoning incidents due to these pathogens are associated with poultry products. Their significance in breeding flocks is due to the vertical transmission of *Salmonella* species from the parents to the chicks. Vertical transmission of *Campylobacter* species has not been established, but recent work has shown that very young chicks are colonized by *Campylobacter* before the pathogen is detected in their environment (see below for references). This suggests that either the chicks are colonized by *Campylobacter* species at the hatchery or the colonization is derived vertically from the parent flock. The findings suggest that the control of both *Salmonella* and *Campylobacter* could be attempted at parent flock/hatchery level. However, the carrier status of poultry in terms of *Campylobacter* and *Salmonella* species is dependent on several issues, including age at slaughter, stocking density and vertical transmission. It appears that the organic system, with later slaughter age and access to outdoors, carries both risks and advantages in terms of carrier status.

2.3.3.1 *Salmonella enteritidis* and *S. typhimurium*

In poultry *Salmonella enteritidis* and *S. typhimurium* are host-adapted pathogens that rarely cause disease in the bird. When, in very rare cases, host-adapted salmonellas cause disease in poultry, it is virtually always seen in intensively reared broiler chicks of less than four weeks of age. Mortality rates in these outbreaks can reach 100%. Chicks exposed to *S. enteritidis* shortly after hatching can, however, remain infected, asymptomatic carriers of the infection and can produce contaminated eggs or spread the infection to other susceptible, previously unexposed hens, either in layer or breeder units (Gast and Holt, 1998). As a consequence, these *Salmonella* species have, great public health significance, causing a large number of food poisoning incidences in humans.

In addition to the vertical transmission of *Salmonella* through the ovaries of layer and breeder birds, poultry are exposed to a wide range of *Salmonella* serotypes from various sources including feed, rodents, wild birds and other vectors (Borland, 1975). Therefore the difficulty of maintaining high biosecurity in free-range units may expose organic breeder flocks to higher *Salmonella* risk than non-organic systems, although Swedish research has shown that good control in outdoor flocks is feasible (Berg and Odén, 1998).

An additional risk to free-range flocks has been suggested in relation to ascarid contamination of the environment, as ascarid eggs can act as vectors for *Salmonella* (Thamsborg, 1999). On the other hand, lower stocking rates and smaller flocks can provide a reduced risk of cross-infection. Uyttendaele *et al.* (1999) report significantly lower *Salmonella* contamination in free-range broilers, slaughtered at 12 weeks of age, than in intensively reared broilers, slaughtered at between six and eight weeks of age.

In breeder systems, *Salmonella* control is guided by the MAFF (1997) Code of Practice for the Prevention and Control of Salmonella in Breeding Flocks and Hatcheries, which refers to systems with high biosecurity status, and no access to range. Apart from high biosecurity, currently recognised control measures at breeding flock level include vaccination and competitive exclusion. It is suggested that the former can virtually eliminate vertical transmission risk (The Veterinary Formulary, 2000). Competitive exclusion treatment has been used, particularly in Scandinavia since 1980's and has been shown to have a preventing effect on *Salmonella* contamination (Snoeyenbos et al, 1978; Wierup *et al*, 1988 and Wierup *et al*, 1992). It has also been suggested that breed selection could be used to increase resistance to salmonella-colonisation (Beaumont *et al.*, 1999). Good salmonella control in a free-range breeder system should be based on an integrated approach, including:

- establishment of salmonella free flocks;
- good hygiene and rodent control;
- potential vaccination;
- potential competitive exclusion practices; and
- continuous monitoring.
-

2.3.3.2 *Campylobacter*

For the past 30 years *Campylobacter* has been identified as being a food-borne pathogen and it is a major cause of human enteritis. Like host-adapted *Salmonella*, *Campylobacter* does not cause disease in poultry. There are many species of campylobacteria but so far only *C. jejuni* and *C. coli* have been shown to be of public health significance. Unlike salmonellas, *Campylobacter* usually occurs sporadically rather than in outbreaks and its occurrence is, therefore, probably grossly under-reported. While *Campylobacte*r can colonise many domestic livestock species, poultry, and broilers in particular, appear to be the main source of human infection. It has been estimated that 60% of all broiler carcases originating from intensive production systems are contaminated with *Campylobacter* (Lake *et al.*, 2000).

In Denmark, more organic and free-range chickens were found to carry *Campylobacter* than non-organic, indoor-reared broilers (Heuer *et al.*, 2001), and in the UK unpublished data (from research presented at a Food Standards Agency meeting on 6th November by Tom Humphrey, Professor of Food Safety at Bristol University) suggests a similar trend. Organic breeder flocks may be more vulnerable to contamination with *Camplylobacter* than non-organic, indoor flocks, through contact with wild birds and their droppings. While it is known that ruminant livestock and wild birds carry large quantities of *Campylobacter* in their digestive system, the spread from other domestic stock or from wild birds to poultry is not well understood.

Until recently, it has been thought that young chicks are contaminated by their environment, even though the hatchery and housing facilities are disinfected after depopulating on an ‘all-in-all-out’ basis. Within house spread may be facilitated by contaminated drinking water and litter. However, recent work has indicated that *Campylobacter* is present in broiler chicks before it can be detected in the environment (Shreeve *et al.*, 2002), suggesting that vertical transmission could be a route of spread in poultry systems. Furthermore, *Campylobacter* has been isolated in the reproductive tract and the semen of breeders, and there is an association between the bacterial strains isolated from breeder flocks and their progeny (Buhr *et al.*, 2002; Cox *et al.*, 2002; Stern *et al.*, 2000; Jacobs-Reitsma, 1995). This supports the possibility of vertical transmission and suggests that breeder flocks should be considered as a potential source of *Campylobacter.*

Efforts to control *Campylobacter* have, to date, concentrated on hygiene measures applied in broiler units. These methods do not appear to have been effective in its control (Corry and Ataby, 2001). Although some biosecurity measures prevented the introduction of *Campylobacter* into a house, even the most stringent measures were unable to prevent its spread. Once infection entered a broiler house, all of the birds were quickly infected (Pattison, 2001). A Swedish report claims, however, that in some projects 60% of farms were able to consistently produce batches of broilers that were free from *Campylobacter* (Anon, 2000).
There are no effective vaccines available for the control of *Camplyobacter*. Furthermore, there are no data available to indicate the effectiveness of in-feed antibiotic administration in controlling *Campylobacter*.

In the absence of an epidemiological understanding of *Campylobacter* contamination and spread in chickens, it is difficult to make recommendations on the control of this pathogen in organic free-range breeders. Research into basic epidemiology and potential intervention strategies are both needed to establish the impact of outdoor units on *Campylobacter* control.

2.4 Production and husbandry systems

The effects of production and husbandry systems on performance are likely to be considerable. Unfortunately such topics tend to be less well scientifically understood than subjects such as nutrition, and there is much less documented material on breeders to review. However there are relevant scientific disciplines, notably behaviour, and over recent years there has been a great deal of work on systems for commercial eating egg production, much of which has been done for welfare reasons. Fortunately some good reviews are available and the following points, which may be relevant to the performance of broiler breeders, have been reviewed by Appleby *et al*. (1992). Nests, slats, litter and feeding space were considered in the full review.

2.4.1 *Housing system*

The advantages and disadvantages of static and mobile housing were discussed by the organic pullets group. After those deliberations the topic was then documented by Gordon and Charles (2002).

In addition the breeders study group considered verandahs to be worth further investigation. Surprisingly the authors of the traditional period, such as Robinson (1948), had little to say about the husbandry aspects of verandahs. However, like any housing system, verandahs could be analysed in terms of the environment for stock provided within them. The physical and engineering principles outlined by Charles *et al.,* (2002) suggest that the temperature in a verandah is likely to be only marginally higher than outdoors, reflecting high air change rates. The high air change rates should offer clean air quality, including low ammonia concentrations, but there is a risk of this being less true amongst dense clusters of roosting birds, entrapping pockets of stagnant air.

Although verandahs are open sided and low tech it might be worth considering insulation of the roof to provide protection from solar heat penetration in hot weather. Surprisingly even in open sided houses there may be some winter benefit from insulation, due to a reduction in back radiation of heat to the sky in clear cold weather. Insulation helps to prevent condensation, which can cause wet litter due to dripping and deterioration of the fabric of the building, but it is also expensive, particularly when adequately vapour proofed. Further information on the physical principles of insulation, including the effects of colour on radiative properties, can be found in Charles and Walker (2002).

2.4.2 *House temperature control and the* ventilation system

During the summer there are probably occasions when the birds are too hot. Samara *et al.* (1996) noticed in the literature that both high temperature and afternoon feeding delayed the time of oviposition. This led them to wonder whether delayed feeding could be used to ameliorate the effects of heat stress on shell quality. They found that it could not.

Housing associated with free-range organic production provides the birds with some protection from the extremes of the climate for some of the day. The need for adequate vapour checked insulation, to a U value of 0.35 W/m^2 or better, is generally accepted in the non-organic sector. Adequate standards of insulation conserve bird heat in cold weather conditions, and they reduce solar heat gain in hot sunny weather. Although in organic production systems the house popholes will be open during the daytime, adequate house insulation will enable a temperature lift to be achieved during the night-time when the popholes are closed.
The control of house temperature by the modulation of the ventilation rate is well understood in theory and is common practice within the non-organic poultry industry. Charles *et al*. (2002) documented the physical and engineering principles behind poultry house environmental control, and provided the following equation to estimate the minimum ventilation rate requirements of poultry.

Minimum ventilation rate = $b \times 10^{-4} m^3/s$ per $kg^{0.75}$
Where the value of *b* for broilers was given as between 1.9 and 2.0. Similar values will probably suffice for breeders. The equation yields values such as 0.05 m^3/s per 100 breeders of 3.5 kg each.

However, it is important to realise that it is frequently necessary to exceed the calculated minimum ventilation rate, even in very cold weather, in order to control the build up of ammonia in the house (Charles, 1992; Charles *et al*., 2002). This means that indoor temperature control is compromised in the interests of air quality.

The design of ventilation systems is considered in the review.

2.4.3. Lighting

There is no basis to suppose that the fundamental principles of photoperiodism for breeder females are any different from those understood for commercial layer females. These principles have been documented and reviewed in detail, for example by Morris (1968 and 1994), Lewis and Perry (1995), Lewis *et al*., (1997), and were recently summarised by Charles *et al.* (2002). A short day in rearing, followed by a step-up during lay is almost certain to be appropriate. Larbier and Leclercq (1994) recommended such a pattern for breeders. The breeding companies offer advice on lighting for their birds linked to recommended bodyweight profiles. Specific issues include the ideal age of beginning the step-up, and the rate of step-up.

Hocking (1996) emphasised the need for careful control of feed intake after photostimulation. Robinson (1997), reporting work at the University of Alberta, considered that the time between photostimulation and first egg was critical. He recommended that flock uniformity during lay could be improved by delaying photostimulation, without depressing egg or chick production. In the Alberta work, chick numbers per hen to 60 weeks of age were maximised with photostimulation at 140 days, using a single step-up in daylength. A gradual increase in feed allowance was better than a rapid increase.

Whereas commercial layers may be becoming more refractory to lighting, and therefore less demanding in their lighting requirements, there is no reason to suppose that breeders have done the same. Indeed the opposite is more likely, since selection may have favoured growth over reproduction. Summers and Robinson (1995) suggested that hybrid breeders were more dependent on light stimulation than Leghorns.

The earlier study group on organic pullets (see Defra project report OF0192) identified a potential difficulty with the application of photoperiodism due to the maximum of 16 hours light per day permitted by the organic certification bodies. However, the breeder study group considered that the problem may be less severe than anticipated by the pullet group, since the certification bodies were unlikely to insist on a maximum of 16 hours, provided that an adequate dark period is provided for rest.

2.4.4 Incubation and hatchery practice

Issues seen as influential included disinfection, the choice of multi stage or single, culling and the disposal of culls, and the welfare aspects of the disposal of spare male chicks including disposal by gassing. Clearly incubation procedures are relevant to the final yield of chicks per hen.

Incubation and embryology have huge scientific literatures of their own. Fortunately reviews have been published. Thus, for further information on incubation see a review of 162 references by Tullet (1995). He suggested that late deaths during incubation indicated problems with the incubator environment. He described diagnostic points for the appearance of egg contents due to 15 species of contaminating bacteria. For example *Pseudomonas fluorescens* may cause pinkish rots while *Acromonas* and *Proteus* may cause black rots. He advocated regular microbiological monitoring in order to have a check on hatchery disinfection practice. Incubator temperatures for small still air incubators were around 38.9 to 39.4^{o}C, and for larger multi-stage forced draught incubators 37.2 to 37.8^{o}C for most domestic poultry species. Best hatchabilities were obtained where eggs lost about 12% of their weight from the time of lay to embryo pipping. This led to a great deal of work on humidity requirement, but the recommendations were not straightforward because of variation in egg shell conductance. However graphs were provided for the effects of 3 wet bulb temperatures on the achievement of 12% weight loss (28.3, 28.9 and 29.4^{o}C). Note that the lack of rounded values appears to be because much of the original work was on round number temperatures in ^{o}F.

2.4.5 Rearing regimes and body weight at start of lay

Breeding companies offer target body weight profiles for their birds, and there can be little doubt that weight at the start of lay is an important criterion. For the reasons mentioned previously, overweight birds should be avoided. Body weight at point of lay is physiologically important, and so is flock uniformity during the prelay period (Hocking, 1993 and 1996). However, the birds need to enter lay with an adequate skeletal development (Classen and Stevens, 1995). Leeson and Summers (1997) observed that the slightly heavier flocks tended to be the best performers. Keaveney (1996), in a comparison of regimes, found the highest chick output in a treatment giving slightly heavier birds than the standard at the time. Fisher and Willemsen (1999) considered body weight to be a primary guide, and stressed the importance of uniformity.

The breeding companies and the practical nutrition guides, such as Leeson and Summers (1997), offer feeding schedules. Leeson and Summers (1997) suggested slowing early rearing growth by the use of a low protein starter. Their studies used concentrations in the starter as low as 130 g to 150 g/kg protein, but they suggested a compromise of between 150 g and 160 g/kg protein under ideal conditions, for easier formulation and care of amino acid balance, and for adequate feathering.

2.4.6 Management of males

There is general agreement in the literature that the nutritional needs of the cockerels are so different from those of the hens that separate feeding arrangements are necessary. The review by Summers and Robinson (1995), quoting Hocking (1990), commented that the influence of obesity on reproductive function in the male was of a physical or behavioural nature, rather than physiological. They advised that heavy males were more likely to get foot disorders and reported that separately fed males achieved more completed matings, with 4.2% higher fertility, due to lower body weight gains. They considered that diets as low as 80 g/kg to 120 g/kg protein were adequate for the males, but difficult to formulate. Larbier and Leclercq (1994) suggested that a maintenance diet containing about 110 g/kg to 120 g/kg protein was suitable, and high protein or high calcium concentrations were deleterious to fertility. Yet Hocking and Bernard (1997b) found no differences in early fertility between birds weighing 3.0 kg to 3.5 kg, nor between rates of gain of 1.0 kg and 1.5 kg to 60 weeks of age. They found no differences in fertility in birds fed diets containing either 120 g or 160 g/kg protein.

Larbier and Leclercq (1994) considered that males restricted during rearing were still capable of transfering rapid growth characteristics to their offspring. They recommended the same lighting programme as that used for the females.

In practice, organic breeder cockerels may have to be reared in a different house to the females. Ultimately however, it will depend on the size of the house, the suitability for partitioning for males and females, and on what equipment can be sensibly used within the available floor area. Due to the different size and shape of male birds. it will be important that the equipment provided within the shed does not cause damage to the birds or impede bird movement, either towards or away from the feeders, drinkers and popholes.

2.4.7 Flock age

Some important differences in the lipid metabolism of young birds were mentioned previously. In addition, Brake *et al*. (1997) suggested that since there are strain differences in albumen quality, in order to achieve good hatchability in younger flocks, the eggs must be stored longer for strains with better albumen quality. Tullet (1995) mentioned that the biotin concentration of eggs increased with flock age and only reaches the concentrations associated with adults after 10 to 12 eggs have been laid.

There is the possibility that some organic producers might consider prolonging the productive life of their breeder flocks beyond that typically used for broiler breeders. It is difficult to assess the implications of doing this. Tullet (1995) noted the decline in fertility and hatchability with age of parent flocks. He pointed out the difficulty of separating effects of age *per se* from effects of egg size and shell quality and porosity. He plotted flock age, as the independent variable, against hatchability of fertile eggs, embryo deaths and early mortality.

3. The impact of diet composition on manure nutrient content

For birds in production, nitrogen (N) excretion rates can be predicted by subtracting the N content of egg output from the N intake in feed. The latter is given by feed intake multiplied by feed N content. Smith *et al.* (2002) gave detailed examples of such calculations for several classes of pigs and poultry. They took the protein content of whole egg including the shell from Shrimpton (1987) and made the conventional assumption that N was given by protein/6.25 (e.g. McDonald *et al*., 1995, 2002). Based on these assumptions an *Excel* spreadsheet (*nexcret.xls*) was written to calculate N excretion rates, using balance sheet methods such as those tabulated by Charles (1996). The further assumption was made that even on the lowest dietary crude protein content tabulated in Table 7 the needs of the birds for the essential amino acids were fully satisfied. Thus, egg output was assumed to be unchanged over the range of crude protein contents tested, and surplus crude protein was excreted, presumably mainly as uric acid N. Table 7 shows some of the results.

Table 7 Effect of dietary crude protein content on N excretion (Source: ADAS)

Feed crude protein content (g/kg)	N excretion rate (g/female breeder per year)
155	984
160	1021
165	1058
170	1095

CONCLUSIONS AND RECOMMENDATIONS

The implications of this review are that there are some real technical difficulties associated with organic breeders. There has been a great deal of research addressing technical problems associated with non-organic broiler breeder production. Whilst a lot of this information is useful, and the basic biology of the bird does not differ between production systems, there are gaps in knowledge which, if not addressed through research will lead to practical difficulties.

There will be two fundamental differences between organic and non-organic breeders - the hybrids used and the birds' environment.

1. Breeds

Although organic table bird production does not strictly rule out the use of broiler hybrids, there are penalties associated with using this hybrid type. The growing period is longer than when using 'slow growing' hybrids. This makes it more difficult for producers to grow birds to the required market live weight at the prescriptive minimum slaughter age. Furthermore, there will be extra feed costs associated with doing this. There seems to be little doubt about the importance of body weight, particularly at point of lay. The recommendations of the breeding company on body weight profiles, and on feeding regimes, should be followed carefully.

The advent of organic breeder flocks will intensify the need to use 'slow growing' hybrids as obesity in the parent flocks may be less of an issue than for broiler hybrids. Obesity would undoubtedly be a problem in broiler breeder flocks if methods of feed control could not be used. Organic production is likely to rule out methods of feed control for this purpose. Obesity would reduce fertility and hatchability, as well as precipitating some welfare and health issues. Choice of dietary ME value and protein content are clearly important and the recommendations made by the breeding company should be followed.

2. Lighting regimes and photoperiodism

Non-organic broiler breeders are housed indoors for reasons of environment control, and biosecurity. However, the ethos of an organic production system is that birds should be allowed outdoor access to pasture for foraging and for manuring. Thus, light control for photostimulation will be more difficult as birds will experience natural daylight. There will be a need to take this into account when devising light programmes for application during rearing, and subsequently in lay.

3. Temperature and energy balance

The energy balance of breeder females is intrinsically difficult to manage. It seems sensible to recognise the difficulties, while taking great care with ventilation and with maintaining low ammonia concentrations. There is also a need to recognise and attempt to minimise heat stress problems in summer. Although broiler breeders are usually housed at moderately low temperatures, compared with broilers, the thermal environment of broiler breeders will be much more stable than for organic breeder flocks. The fluctuating thermal environment of an outdoor system will make it more difficult to feed energy according to the birds' needs. Feed energy requirements will vary from day to day, as outdoor temperatures fluctuate. Furthermore, daily fluctuations may be high as recently recorded in the UK reaching a peak of 38.1°C at Gravesend on 10th August 2003). An insufficient feed intake will reduce egg output, whereas a high intake will increase live weight and this will reduce egg output.

If the house has been designed to provide an appreciable temperature lift, whilst still allowing for an appropriate rate of ventilation, then the indoor night temperature may reduce feed energy requirements. However, whether or not breeder hens respond to daily 'weighted' mean temperatures in terms of their energy requirements is not known.

As for free-range laying hens and free-range table chickens the contribution of pasture and macroinvertebrates to their energy and nutrient needs is not known. Neither is the effect of ranging outdoors on the birds' energy requirements. This encompasses heat loss through postural changes and energy expenditure in locomotion and other outdoor activities. Furthermore, the effects of wind chill, rain and solar gain on the chickens' energy balances have not been adequately quantified. It is conceivable that there might be differences in the insulative value of feathering between hybrids. Birds that have feathering extending down their legs might be better suited to outdoor production systems if they have a lower rate of heat loss during cold weather.

4. Feed presentation

One means of addressing the problem of feed energy supply might be to develop choice feeding systems for organic breeder flocks. If successful, this would allow the birds to adjust their feed energy intake according to their daily requirements. Such a system may have to be applied from a very young age, however, as chicks are better able to select energy and nutrients according to their maintenance and productive needs than when choice feeding is first introduced during lay (Forbes and Shariatmadari, 1994).

5. Ingredient sourcing

There is some concern that the introduction of 100% organic feed on the 25th August 2005 may cause difficulties in feeding organic poultry including breeders. In particular, organically grown energy rich (oilseeds and by-products) and protein rich ingredients may be difficult to source or so expensive as to preclude their use in organic poultry feeds. Feeds should contain sufficient linoleic and arachidonic acids, and perhaps also palmitic acid. The importance of linoleic acid to hatchability has been discussed, and although cereal and soya are relatively rich in linoleic acid, soya oil is often added to raise the dietary energy value and dietary linoleic acid content. It is imperative to the successful development of the embryo that the yolk is not nutrient deficient. Fatty acid profile is particularly important for young flocks of breeders.

There may be benefits from providing a separate calcium source. There is uncertainty, and therefore scope for error, in some fundamental recommendations, including factors as routine as the requirements for lysine and the sulphur amino acids. Great care should be taken to preserve vitamin potency during the production, distribution and storage of feeds.

Although breeder hens do not have high protein requirements, and their rate of lay is less than that of laying hens, it will be important to provide a balanced protein source. Feeding excess protein is likely to reduce performance and there will be implications in terms of the litter manure nutrient content, litter quality and house air quality and the risk of pollution.

6. Plant nutrient budgets

In an earlier Defra-funded project (project OF0163) farmgate and soil surface nutrient budgets were calculated. There is a need now to revisit these calculations, and to include breeder flocks within the scenario. To do this with any precision however, would require determinations of manure nitrogen contents for organic breeders. Performance data is also needed for this study, and this should be for suitable hybrids. It is envisaged that the nutrient budget calculations would be for a co-operative of producers, trading feed ingredients, bedding, manure and chicks between farms. This approach would enable a better recycling of nutrients between the soil, plants and birds than is likely to be possible on a single farm.

7. Health and disease

It is evident that free-range breeder systems present both advantages and risks in regard to infectious disease control and maintenance of high levels of food hygiene. Their contact with wild birds and vermin makes them susceptible to infection by important poultry disease agents or by important agents for public health.

Continuous monitoring, awareness of risks, implementation of known husbandry and control measures within the limitations of a free-range system, selection of production sites away from intensive poultry units and small flock sizes appear to be the way forward in ensuring that infectious disease are effectively controlled in free-range, organic breeder systems. Management and husbandry practices will impact on the prevalence of foot problems, aspergillosis, worm burdens and mites, however optimal management practices for the control of parasitic disease in poultry are not available

Very little is known of disease and health patterns in systems that:-

a) do not rely on high biosecurity and routine medicinal prophylaxis, and;
b) are based on access to range, organic ration formulation, small flock sizes and hands-on, intensive management input.

Research on disease and health patterns in these systems in non-experimental conditions is needed to establish how well a system that is potentially in balance with its environment can cope with the inevitable challenges from disease agents.

8. Public health issues

Further research is needed to establish how *Salmonella* and *Campylobacter* populations behave in the new ecological niche that is created by organic outdoor breeding systems. The research needs to address the whole production chain from breeder unit, through hatching and transport, to fattening and the post slaughter status of the product.

9. Costings

The cost of producing organic chicks has not been addressed, as it was not within the remit of the project. It is likely however, that organic production will significantly increase the cost of chick production. One reason for this is that there will be a need to set-up new units for organic breeder production, as it is very unlikely that it will be possible to convert any existing breeder facility into an organic breeder facility. Feed will be more expensive than that for non-organic breeders, and organic breeders will need more feed because of cold temperatures. Labour costs will be higher as the scale of production may reduce automation, and there maybe a need for greater feed management due to fluctuating temperatures.

10. Hatcheries
The physical environment needed for incubating and hatching chicks will not differ between organic and non-organic production systems. Differences will be between the permitted methods for cleaning and disinfection. Whatever agents are used for this it is imperative that the hatchery facilities are clean. Bacterial contamination of eggs will cause embryo mortality, dead-in-shells, and high chick mortality or morbidity.

11. Stockmanship
The levels of stockmanship skills needed for an organic breeder enterprise will be very high.

12. Local co-operation
The larger organic table bird producers, will, if they are to remain in organic production, set-up and manage their own organic breeder flocks. There may be specialist organic breeder farms, which are independent and aim to supply independent organic table chicken producers. This would be best operated at a local level if the trading of nutrients between farms were to be optimised. Until the market becomes stable however, there will be risks involved, both logistic and financial.

Perceived problems in organic breeder production systems identified at the start of the project, have mostly been confirmed, and in several cases solutions have not been gleaned from published work on non-organic intensive broiler breeder production systems. This is particularly true for disease issues and the industry regards this as a priority area for research. Whilst there are knowledge gaps on feeding organic breeders, some information from work on non-organic breeders has been transferrable to an organic production system, but there is still a lack of information relating to the birds' energy requirements in outdoor systems. The industry has expressed a willingness to be involved in research on these issues.

KNOWLEDGE GAPS/FUTURE RESEARCH REQUIREMENTS

There is a high priority need for more quantitative research information, including calorimetry studies, on the energy balance of the breeder females, in order to improve the likely reliability of such calculations. The work should include however, measurements of heat loss or heat gain by chickens in UK outdoor conditions. Furthermore, the energy cost of locomotion in chickens needs to be determined. To complement this work, there is a need to have a better understanding of how chickens spend their time outdoors, and to establish within flock variability in ranging activity. The provision of shelters outdoors and the benefits they provide in terms of microclimate and effects on rate of bird heat loss also needs to be considered.

Choice feeding of organic breeder flocks may be a means of providing appropriate feed energy and protein levels for maintenance and production needs. If successful it would enable the birds to regulate their intake accordingly in a fluctuating thermal environment. There may be a need to apply this feeding technique from day old as some evidence suggests that chicks are better able to make the appropriate selection.

There is a need to monitor the disease status of outdoor breeder flocks reared according to the ethos of organic livestock production. If disease problems arise, which are thought to be generalised and not site specific, then research will be needed to address this. Site specific problems should be investigated by the local veterinary surgeon.

There is a need to calculate nutrient budgets for the wider scenario of organic table chicken production including organic breeder flocks. This would be done on the basis of a local co-operative, which trades nutrients in plants, bedding, manure and chicks. To do this will require data on manure nutrient contents from organic breeder flocks and data on the inputs and outputs of organic breeder flocks (i.e. flock nutrient intake and egg output).

The optimal ratio of breeder males to breeder females may differ in an outdoor system and this needs to be examined. If the ratio is too high then the females will be injured, and if it is too low the output of fertile eggs will be reduced.

The management of 'slow growing' breeder hybrids in outdoor systems has not been assessed in the UK. The target within flock variation in body weight has not been established, and neither has the likely egg output, optimal flock life or labour requirement. This means that it is difficult to support producers in the development of organic breeder farms, and it is not possible to accurately calculate production costs.

There is a need for this information if organic breeder production is to be actively supported in the UK.

AKNOWLEDGEMENTS

The financial support of the (UK) Department for Environment, Food and Rural Affairs is gratefully acknowledged.

ADAS acknowledges the valuable contribution to this review of Dr Malla Hovi, Reading University, Andrew Gunther, Burcombe Farms and Dr David Charles, DC R&D.

IP TECHNOLOGY TRANSFER

To date technology transfer has been through the two workshops and the distribution of the review to participants. The format of the discussion paper will be modified so that it is suitable for publication.

REFERENCES

There is not sufficient space to include a reference list. A full reference list is available from the author and this may be requested by e-mail, using the following address: sue.gordon@adas.co.uk