DEPARTMENT for ENVIRONMENT, FOOD and RURAL AFFAIRS

Research and Development

Final Project Report

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Project title	Effect of breed suitability, system design and management on welfare and performance of traditional and organic table birds
DEFRA project code	**OF0153**
Contractor organisation and location	ADAS Consulting Ltd Meden Vale Mansfield Nottinghamshire NG20 9PF
Total DEFRA project costs	£ 288,231
Project start date	01/10/98
Project end date	31/03/02

Executive summary (maximum 2 sides A4)

Background

Over the past fifty years broiler production accounted for almost all of the meat chickens produced in the UK. As a result, only broiler hybrids were available for use by UK producers, and these were not thought to be suited for use in some extensive production systems. This meant that when consumer demand for extensively produced chicken meat increased in the late 1990s producers were unable to quickly identify and source the most suitable hybrids for UK conditions. Furthermore, systems of extensive production were still being developed, and little was known about design and management factors affecting range usage.

Project OF0153 aimed to characterise breed suitability for extensive production (free-range, traditional free-range and organic production) and to assess the contribution of management and system design on bird performance, range usage and animal welfare parametres.

Objectives

1. To characterise performance, behaviour and meat yields in several hybrids by permitting the genotypes to express themselves under non-limiting conditions, and when fed either presumed non-limiting rations or Label Rouge rations.
2. To establish the interactive effects of breed and post brooding temperature on performance, meat yields and the insulative value of feather cover.
3. To examine the effect of range design on performance, bird well-being and range usage when grown in winter months.
4. To examine the effects of brooding facility and range design on performance, bird well-being and range usage when grown in summer months.
5. To characterise bird movement within a standard controlled environment house and a free-range house.

6. To examine the interactive effects of brooding facility and feed and water provision on mortality and performance of free-range ISA 657 birds.
7. To examine the effects of early nutrient intake on mortality and performance of ISA 657 chicks brooded in free-range facilities.

Research findings

The work was done in three phases.

Phase 1 characterised, across a wide range of breeds, suitability for use in extensive production systems. This took into account of the effects of feed specification (Study 1), and diurnally fluctuating post brooding temperatures (Study 2), as would be experienced by outdoor chickens. Both studies were carried out in the climatic house at ADAS Gleadthorpe. The birds did not have access to pasture at any point in the 81-day growing period. Measurements of live weight, feed usage and FCE were made at key ages (56 and 81 days), and by measuring live weight at intervals throughout the growing period, it was possible to fit the Gompertz function. This allowed the prediction of age at growth inflexion, and an estimate of mature live weight. Behaviour, gait and the insulative value of the pelt were also studied.

The results indicate that across the range of breed-types available, domestically or through importation, it is possible to choose breeds on the basis of growth profile and desired market live weight at slaughter age, when feed is not restricted during the daytime. Breed differences were recorded in live weight, feed usage and FCE. UK broiler hybrids were the heaviest and had the best FCEs, whereas traditional UK breeds were the lightest and had the poorest FCEs. The implications of ration type on performance, chick mortality, and carcass characteristics were also quantified. UK broiler hybrids had the best breast meat yields when fed presumed non-limiting rations, but yield was significantly affected by low lysine and methionine intakes. Although other breeds had lower breast meat yields where lysine and methionine intakes were low, the percentage reduction in yield was less than that for broiler hybrids.

The traditional, lighter UK breeds were more active and showed more extreme escape responses when approached by a human than the heavier breeds. Some of the UK traditional breeds ground pecked in a stereotypic manner, and aggressive feather pecking occurred. Gait was similar in all breeds when live weight was accounted for in the analysis.

Phase 2 examined the effects of system design and management on range usage and bird performance. In Study 3, chicks were brooded in the climatic house and then transferred to range facilities for the post brooding period. They either had access to pasture only, or pasture plus artificial shelter. The work addressed both 56-day and 81-day production in a winter flock, using female Ross 308 birds and ISA 657 birds, respectively.

In Study 4, the effects of brooding facility and range design on range usage and performance were studied in ISA 657 birds grown to 81 days of age. Brooding was either in the climatic house or in the free-range facilities where chicks had visual and physical access to range from an early age. Environment enrichment was also used in the free-range facilities (straw bale and cabbage). Range design was either pasture only, or pasture plus artificial shelter and natural shelter (conifer wig-wam and straw bales). Range usage was measured using a system of transponders and receivers. Bird performance was measured at intervals throughout the growing period. Study 5 was an off-site study that examined bird movement in a commercial broiler house and a commercial free-range house. Automated analysis was by artificial intelligence software of video-images of birds moving in the house area.

Early access to pasture increased range usage, and natural shelter in the form of a conifer wig-wam was attractive to the birds and well used. Brooding in the low-tech free-range facilities was extremely labour intensive and sometimes resulted in higher mortality than when brooding was done in a controlled environment facility. Brooding mortality in the free-range facilities was due to difficulties in achieving an appropriate thermal environment at all times of the day and night.

Phase 3 comprised two studies. Study 6 examined the effects of brooder facility, and feed and water provision during early life on mortality and performance to 81 days of age. In a factorial design, chicks were brooded in the climatic house or free-range facilities, and allowed standard or generous feed and water provision. Study 7 examined the effects of early nutrient intake on mortality and performance and in this study chicks were brooded only in the free-range facilities.

Providing a generous number of feeder and drinker points within the free-range houses did not reduce brooding mortality. However, in this study mortality was high when chicks were brooded in the controlled environment facility. Chick quality was thought to be poor; it may even be possible that chicks from slow-growing hybrids need different hatching conditions than those needed by broiler hybrid chicks.

Early nutrient intake was found to affect growth performance to 42 days but not to 81 days of age, and mortality was low on all feed treatments. The work showed that brooding can be done successfully in low-tech houses during the most difficult time of year (late autumn / winter), but labour requirements increased significantly.

Implications of findings, future work and policy relevance

The research characterised the relative merits of varying breed, management and rearing options, for extrapolation to a range of extensive poultry production systems. Producers may choose from the wide range of hybrids available, those that best suit their production system, in terms of live weight at slaughter, meat conformation and behaviour.

Breast meat yield is thought to be important to UK consumers, and as the markets for extensively produced breast fillets and added value products develop it will be increasingly important. Trade-offs were identified between slowing live weight gain to market age, through nutritional means, and improving breast meat yield as a percentage of the eviscerated carcass. This points towards heavier live weights at slaughter, if breast muscle growth is not to be excessively restricted. A reduction in the minimum slaughter age for free-range table chickens from 56 days to 49 days could help increase breast meat yield, as a higher early live weight gain will co-incide with the critical period for breast muscle growth.

In organic production, the minimum growing period is 70 days provided that slow growing hybrids are used. To date there is no definition of ‘slow growing’ and several different hybrids are being used in organic table chicken production in the UK and EU. However in general, it is expected that ‘slow growing’ hybrids will have lower potential breast meat yields than broiler hybrids, so that lysine and methionine contents in feed will have less of an impact on breast meat yield than in broiler hybrids. It may be possible to optimise breast meat yield within an organic production system by using ration programmes where lysine and methionine supplies better meet the birds’ needs at critical phases of breast muscle growth. However, organic poultry production is still small scale, with limited supplies of more expensive feeds, which may rule out any sophisticated ration programming on a cost basis.

Ixworth birds showed potential in terms of breast meat yield when slaughtered at 84 days of age, despite a low slaughter weight. However, growing them to about 100 days of age and a typical slaughter live weight of 2.2 kg would have significant cost implications, as feed consumption would be higher and FCEs are poorer in older birds. Costs of production would be further exacerbated in an organic system of production.

Traditional free-range and organic table chicken meat will be more strongly flavoured and firmer than broiler meat. Flavour and texture may also be more variable than broiler meat. As traditional free-range and organic chicken meat is sold at a premium, efforts should be made to optimise eating qualities and to find a mechanism to allow consumers to purchase chicken meat according to their taste preferences. A research-based flavour scoring system applied at point of retail may be one method of achieving this.

Interesting breed differences were obtained in bird behaviour. Active and inquisitive breeds are needed for use in extensive production systems, as they are likely to be better foragers than more sedentary birds. However, their response to perceived danger may not always be an advantage. In outdoor systems chickens need to escape from predators. However, humans may also be perceived as predators - the more responsive the birds the more difficult it may be to manage them in the house. If the popholes are open then the birds may escape outdoors, but if the house is closed during feeding and welfare inspections, crowding and suffocation may result. For active breeds, house enrichment (using, for example, straw bales) may be even more important, providing shelter as well as the diversion of something to peck at.

Centralised brooding in larger automated houses is used by many organic table chicken producers, as this is thought to reduce brooding mortality. This approach is acceptable, provided that care is taken to minimise physiological stress and injury and trauma to the birds during handling and transport to range facilities. While brooding management was more difficult and labour intensive in small low-tech naturally ventilated houses, mortality post brooding was low, and predation was not a problem. Neither was there any evidence of parasitic disease. However, Paracox vaccination was used to control *Eimeria* infection, and the pasture was used only four times, with longer rest periods than strictly required by the organic Standards.

From the results of these studies, ryegrass based swards were not well utilised by birds. There is therefore a need to identify nutrient rich sward species for grazing by chickens. Digestibility and nutrient value of these species for poultry should be measured at a range of sward ages and sward heights through the growing season. Effects on meat flavour should also be monitored. As an added benefit, grazed forages may reduce the need for bought-in feeds, or for home-produced protein crops in an organic production system, and this would help in reducing variable costs.

The project provides information to DEFRA, poultry and organic farming sectors about key technical issues associated with table chicken and addresses DEFRA’s policy of supporting the development of extensive livestock production within the UK, and the protection of animal welfare.

For a fuller explanation of the different extensive poultry production systems, and their resource and management requirements see a separate DEFRA-funded review by Gordon (2000).

Scientific report (maximum 20 sides A4)

1. OBJECTIVES

The project objectives are given below. Objectives 1, 2 and 5 are unchanged; they are as given in the CGS7. Objectives 3, 4, 6 and 7 differ from those given in the CGS7; they are as agreed with the DEFRA project officer and as documented in the minutes of the steering group meetings for this project.

1. To characterise performance, behaviour and meat yields in several breeds and hybrids by permitting the genotypes to express themselves under non-limiting conditions and when fed either presumed non-limiting rations or Label Rouge rations.
2. To establish the interactive effects of breed and post brooding temperature on performance, meat yields and the insulative value of feather cover.
3. To examine the effect of range design on performance, bird well-being and range usage when grown in winter months.
4. To examine the effects of brooding facility and range design on performance, bird well-being and range usage when grown in summer months.
5. To characterise bird movement within a standard controlled environment house and a free-range house.
6. To examine the interactive effects of brooding facility and feed and water provision on mortality and performance of free-range ISA 657 birds.
7. To examine the effects of early nutrient intake on mortality and performance of ISA 657 chicks brooded in free-range facilities.

2. METHODOLOGY

There were three phases to the project. Phase 1 characterised breeds in terms of performance, behaviour and meat yields. This characterisation was used to assess their suitability for use in extensive table chicken production. The work was done in a controlled environment house so as to improve the accuracy of the findings, through the minimisation of background variation. Phase 2 examined the effects of range design and chick management on range usage and bird performance. In some treatments a controlled environment house was used to brood chicks but birds were given access to range for at least half of their life. Phase 3, examined the effects of feed and water provision and early nutrient supply on mortality during brooding. Brooding was mostly in naturally ventilated low-tech houses (free-range facilities) and birds had access to range for more than half of their life.

2.1. Phase 1 - Breed characterisation

There were two studies in this phase of the work.

2.1.1. Study 1 – Effect of breed and feed treatment on performance, behaviour and meat yields

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 (Ross 308, Ross 508, and Ross YA x PM3). Medium to fast growing breeds were commercial hybrids supplied as imports by Hubbard ISA (ISA 757 , ISA 957, Redbro, and Master Gris). Slow growing breeds were imported commercial hybrids supplied by Hubbard ISA (ISA 457, ISA 657, and Gris Barre). 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 (Light Sussex, White Sussex, Ixworth and White Dorking). All birds were housed simultaneously at day old.

There were two feed treatments, namely a presumed non-limiting three-stage ration programme (with respect to Ross 308 birds) and a Label Rouge three-stage ration programme[1]. The non-limiting rations were purchased from BOCM PAULS Ltd. The starter was in the form of crumbs and the grower and finisher rations were in the form of pellets. The crude protein contents of the starter, grower and finisher rations were 210 g/kg, 210 g/kg and 185 g/kg, respectively. Fishmeal was an ingredient in the starter, grower and finisher rations. The ME contents of the starter, grower and finisher rations were calculated to be 12.8 MJ/kg, 13.65 MJ/kg and 13.85 MJ/kg, respectively. The total cereal contents of the rations were 49.5%, 48.0% and 67.0% for the starter, grower and finisher, 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. Only vegetable protein sources were used in the Label Rouge rations, these being full fat soya and field peas. The ME contents of the starter, grower and finisher rations were calculated to be 12.3 MJ/kg, 12.5 MJ/kg and 12.5 MJ/kg, respectively. The total cereal contents of the rations were 65.5%, 75.0% and 76.0% for the starter, grower and finisher, respectively. Birds received a starter allowance of 0.550 kg/bird for the 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*. This provided a precise means of comparing the birds' protein conversion efficiency.

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 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.

Measurements were made of live weight at day old, at ration changeover (starter to grower and grower to finisher) and at 56 days and 81 days of age. Feed usage was measured between day old and the age at changeover from starter to grower ration, to confirm grower intake as given above, and to determine finisher intake. In addition, feed usage between 56 days and 81 days of age was measured.

Mortality was recorded daily throughout the 81-day growing period. Samples of birds dying between day old and seven days of age, between 35 days and 42 days of age and between 70 days and 77 days of age were sent to Sutton Bonington V.I.C. for *post mortem* analysis. Gait was assessed at 54 days and 81 days of age by researchers from Bristol University using the method reported by Kestin *et al.,* (1992). Statistical analysis of the gait data was done using correlation analysis, with live weight as a covariate.

At 21 days of age, the birds' behavioural response to an observer entering the pen was studied by researchers from Bristol University. The birds' initial reaction to the observer entering the pen was scored using the following system: 1) moving away calmly from the observer; 2) running away from the observer and group tightly; 3) running or flying away from the observer with some 'piling up' of birds, and; 4) extreme fear with flight and escape behaviour. The observer remained inside the pen with the birds for three minutes and during this period a note was made of how long it took birds to resume activities and to cease showing fear responses.

Scan sampling of behaviour at 42 days of age was done for one replicate of each breed x feed treatment combination. The number of birds within a pen undertaking specific activities (e.g. walking, sitting, preening, pecking, drinking, feeding) was estimated. Scan sampling at 12-minute intervals was done throughout the 16-hour photoperiod. Behaviour data was analysed using Mann-Whitney tests.

Provided that birds had achieved an as hatched market live weight at 56 days of age of at least 2.2 kg on both feed treatments, breeds were sampled and slaughtered at 59 days of age. The eviscerated carcass weight, and percentages of breast meat, dark meat and abdominal fat were determined. Breeds not sampled at 59 days of age were sampled at 84 days of age for meat yield information as detailed above.

Using the same sampling basis as given for meat yield work, breeds were sampled and sent to Lloyd Maunders Ltd for slaughtering, processing, cooking and tasting. The methodology was as for their retail taste assessments; the results were not suitable for formal statistical analysis.

[1]Label Rouge rations were similar in terms of nutrient content to organic rations for table chickens.

2.1.2. Study 2 – Effect of breed and post brooding temperature regime on performance, mortality and meat yields

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 70 days and 81 days of age. SASSO 77N chicks were used in the study because it was not possible for Rare Breeds Survival Trust to source sufficient numbers of hatching eggs from Ixworth stock. 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 imposed 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 within the room there was a temperature lift above outside temperature of about 5°C.

UK stock was housed in separate rooms to imported stock. 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 in Study 1.

Measurements were made of live weight at day old, at ration changeover (starter to grower and grower to finisher) and at 56 days and 81 days of age. Feed usage was measured between day old and the age at changeover from starter to grower ration, to confirm grower intake as detailed in Study 1, and to determine finisher intake. In addition, feed usage between 56 days and 81 days of age was measured.

Mortality was recorded daily throughout the 81-day growing period. Samples of birds dying between day old and seven days of age, between 35 days and 42 days of age and between 70 days and 77 days of age were sent to Sutton Bonington V.I.C. for *post mortem* analysis.

Birds were sampled from each treatment combination at 59 days of age and 82 days of age and they were slaughtered and the eviscerated carcass weight, and percentages of breast meat, dark meat and abdominal fat were determined. In addition, at both ages samples of birds from each treatment combination were sent to Lloyd Maunders Ltd for slaughtering, processing, cooking and tasting. The methodology was as for their retail taste assessments.

The insulative value of the feathers and pelt was determined for samples of males and females at 81 days of age for each treatment combination (breed x post brooding temperature regime). The method used was based on methodology reported by Wathes and Clark (1981). The pelt was 20 cm at its widest point tapering to a width of 10 cm over a length of 10 cm.

2.2. Phase 2 – Range usage

There were three studies in Phase 2. Of these Studies 3 and 4 were done at Gleadthorpe and Study 5 was done in commercial facilities owned by Premier Farming Ltd. Study 3 started in the winter of 2000 (end of January) and Study 4 started in the summer of the same year (early July).

2.2.1. Study 3 – Effect of outdoor artificial shelter on range usage and bird performance

There were two components of this study. One component was to address 56-day free-range production and the other to address 81-day traditional free-range and organic production. No comparisons were made of performance between birds grown to 56 days and birds grown to 81 days of age.

56-day production
For this experiment 672 day old, female Ross 308 chicks were used, brooded until 28 days of age in a controlled environment using one room of the climatic house. The room was fitted with four wood and wire pens each measuring 3 m x 5 m and housing 168 day old chicks. The stocking density at day old was 11.2 birds/m^2. At 29 days of age, the birds were moved in their brooding groups to the range facilities and each brooding group was randomly allocated to the two range treatments, these being pasture only and pasture plus artificial shelter.

Artificial shelter comprised a 1 m high strip of Galebreaker running centrally down a 25.5 m paddock. The length of the Galebreaker was 12.3 m and the start of the Galebreaker was 2.5 m from the pophole. In addition, there was overhead shelter comprised of galebreaker measuring 2 m long x 1 m wide and this was supported on wooden posts at a height of 1 m above the pasture. There were two replicates of each range treatment. The pasture allowance was 2m^2/bird.

Measurements were made of mortality, live weight at day old, 28 days and 56 days of age, feed usage between day old and 28 days of age, and between 29 days and 56 days of age, and range usage between 32 days and 56 days of age.

Range usage was measured by researchers from Leeds University using a system of transponders and receivers. In each paddock, a random sample of 50 birds were tagged with transponders. During the monitoring period there were eight receivers in each paddock. The locations of the receivers were standardised between paddocks, but the location was chosen to provide information on; 1) whether or not birds used the artificial shelter facilities, and; 2) whether birds not provided shelter ranged in a similar manner to birds provided with shelter.

Males were sampled at 59 days of age from each treatment and transported to Lloyd Maunders Ltd for slaughtering, processing, cooking and tasting according to methods used in their retail taste assessments.

81-day production
For the second experiment 672 as hatched day old ISA 657 chicks were used, brooded until 42 days of age in a controlled environment using one room of the climatic house. The room was fitted with four wood and wire pens each measuring 3 m x 5 m and housing 168 day old chicks. The stocking density at day old was 11.2 birds/m^2. At 43 days of age, the birds were moved in their brooding groups to the range facilities and each brooding group was randomly allocated to the two range treatments, these being pasture only and pasture plus artificial shelter (as described above). The pasture allowance was 2m^2/bird.

Measurements were made of mortality, live weight at day old, 28 days, 42 days and 81 days of age, feed usage between day old and 28 days of age, between 29 days and 42 days of age, and between 43 days and 81 days of age, and range usage between 60 days and 81 days of age. Range usage was measured as described above for Ross 308 birds.

Males were sampled at 83 days of age from each treatment and transported to Lloyd Maunders Ltd for slaughtering, processing, cooking and tasting according to methods used in their retail taste assessments.

2.2.2. Study 4 - Effect of brooding treatment and range design on range usage and bird performance

Four treatments were imposed: 1) standard brooding and pasture only; 2) standard brooding and enriched pasture; 3) enriched brooding and pasture only, and; 4) enriched brooding and enriched pasture. Standard brooding comprised chicks brooded in a controlled environment until 42 days of age, after which they were moved in their brooding groups to the range facilities. Until 42 days of age the birds received only artificial light and the daily fluctuation in temperature was minimal. Enriched brooding condition comprised chicks brooded in small naturally ventilated houses where they received natural light from day old, they were able to see the pasture through open windows from 12 days of age and were allowed access to range from 21 days of age. Bedding was woodshavings as for standard brooding, but for enriched brooding a straw bale was also provided in the house from day old. Enriched pasture was pasture plus artificial shelter as described in Study 3, but in addition natural shelter was provided midway down each side of the paddock and this was in the form of a 2 m high conifer wig-wam on one side and straw bales on the other side. Each of the four treatments were replicated twice. As hatched ISA 657 chicks were used for the experiment, grown to 82 days of age. Group size, stocking density and pasture allowance were as described in Study 3.

Measurements were made of mortality, live weight at day old, 28 days, 42 days and 81 days of age, feed usage between day old and 28 days of age, between 29 days and 42 days of age, and between 43 days and 81 days of age, and range usage between 35 days and 81 days of age. Range usage was measured as described in Study 3.

Males were sampled at 82 days of age from each treatment, and were transported to Lloyd Maunders Ltd for carcass and organoleptic assessments as described above.

2.2.3. Study 5 – To characterise bird movement in a controlled environment house and a free-range house

Bird movement within a commercial broiler house and a commercial free-range house was studied by video-recording bird movement from a plan elevation and then analysing the tapes using artificial intelligence software developed by Leeds University.

2.3. Phase 3 – Effects of feed and water provision and early nutrient supply on mortality during brooding

Two studies were conducted in this phase. Study 6 was carried out in late spring / early summer, 2001 (May to August), and Study 7 was done during winter 2001/2002 (October to January).

2.3.1. Study 6 – The interactive effects of brooding facility and feed and water provision during brooding on mortality and performance

Brooding of ISA 657 chicks was carried out either in a controlled environment facility, or in the free-range facilities as described in Study 4. As an exception to this, chicks brooded in the controlled environment house were moved to the free-range facilities at 29 days of age, and chicks brooded in the free-range facilities had the windows open from 20 days of age. All birds were given access to range from 29 days of age.

There were two feed and water provision treatments - standard and generous. Standard feed provision was met by using four BEC tube feeders per pen or house providing a feeder to bird ratio of 1:42. One extra feeder was provided per pen or house for the generous feeder provision treatment (feeder to bird ratio of 1:33). Standard and generous water provision treatments were met by providing two or three Plasson bell drinkers per pen or house, providing drinker to bird ratios of 1:84 and 1:56, respectively. From 29 days of age, all birds had a standard feeder and drinker provision. Group size, stocking density and pasture allowance were as described in Study 3. A conifer wig-wam was provided in each of the paddocks. The wig-wam sited on the left-hand side of the paddock (as viewed from the pophole by the chickens when leaving the shed) at 29 days of age. It was moved in a clockwise direction around the perimeter of the paddock at about weekly intervals, so that by 81 days of age the wig-wam was on the right hand side of the paddock.

Measurements were made of mortality, live weight at day old, 28 days, 42 days and 81 days of age, feed usage between day old and 28 days of age, between 29 days and 42 days of age, and between 43 days and 81 days of age.

Males were sampled at 83 days of age from each treatment and they were transported to Lloyd Maunders Ltd for slaughtering, processing, cooking and tasting according to methods used in their retail taste assessments.

2.3.2. Study 7 – The effects of early nutrient intake on brooding mortality and performance

Four treatments were used: 1) Label Rouge feed from housing at day old and until 81 days of age; 2) conventional broiler starter feed from housing at day old and until three days of age inclusive, followed by Label Rouge feed until 81 days of age; 3) Oasis® (pellets having high moisture and crude protein contents) fed during transit only, and then Label Rouge feed from housing at day old and until 81 days of age, and; 4) Oasis® fed during transit and to three days of age inclusive, plus Label Rouge feed from day old and until 81 days of age. For treatments 1 and 2, neither Label Rouge feed nor conventional broiler starter feed was available during transit, respectively.

As hatched ISA 657 chicks were brooded in the free-range facilities as described in Study 4, except that the windows were not opened until 22 days of age and birds were given access to range from 27 days of age.

Measurements were made of mortality, live weight at day old, 28 days, 42 days and 81 days of age, feed usage between day old and 28 days of age, between 29 days and 42 days of age, and between 43 days and 81 days of age.

Males were sampled at 81 days of age from each treatment and they were transported to Lloyd Maunders Ltd for slaughtering and taste assessments.

Unless specified as otherwise analysis of variance tests were used throughout to test for the effects of treatment.

3.0. RESULTS

All milestones were met in full and on time.

The most important results are given below and in Section 4.0 the findings are discussed in the context of the different production systems in use within the UK. Mortality, parasite status and bird well-being are discussed in detail in the final report for DEFRA-funded project AW02021. Project AW02021 was an add-on project to OF0153, and it addressed bird health and well-being in extensive production systems.

3.1. Phase 1 – Breed characterisation

3.1.1. Study 1 – Effect of breed and feed treatment on performance, behaviour and meat yields

As-hatched live weight at 56 days of age ranged from 1.136 kg to 3.846 kgin birds fed presumed non-limiting rations and from 0.808 kg to 2.646 kg in birds fed Label Rouge rations. For both feed types, Light Sussex birds were the lightest and Ross 308 birds were the heaviest. At 81 days of age, as hatched live weight ranged from 1.911 kg to 5.178 kg in birds fed non-limiting rations and from 1.501 kg to 4.399 kg in birds fed Label Rouge rations (Figure 1). Again, Light Sussex birds were the lightest on both feed types and Ross 308 birds were the heaviest on both feed types.

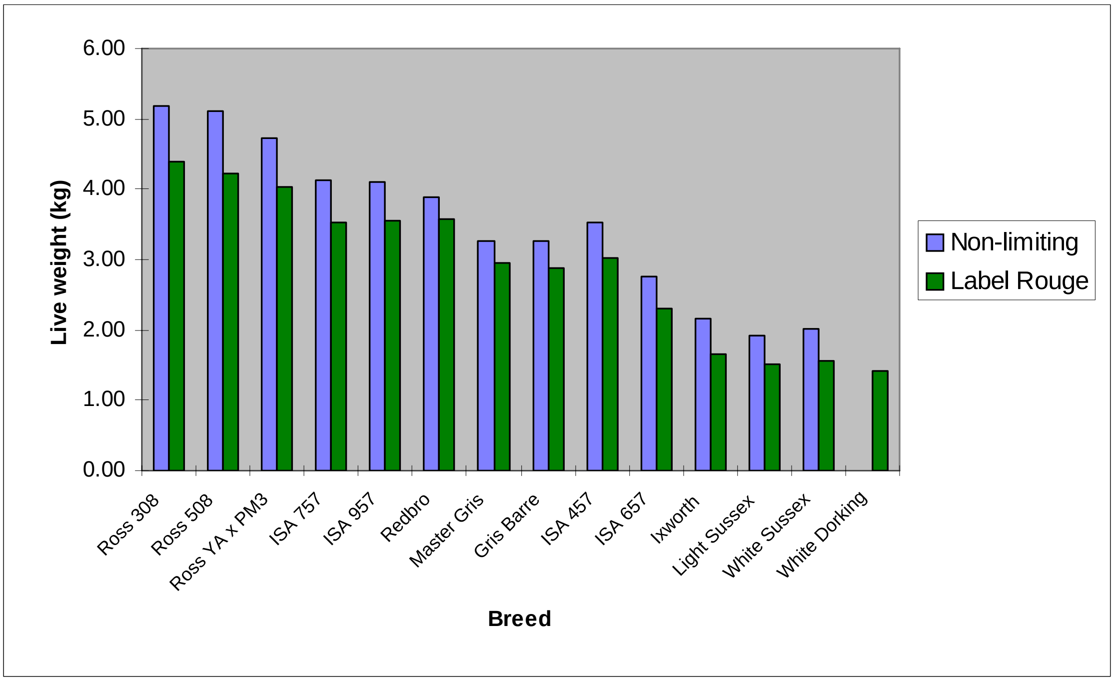

Figure 1. As hatched live weight at 81 days of age (kg/bird)

A target market as-hatched live weight of 2.15 kg for birds fed Label Rouge rations was achieved by Ross 308, Ross 508, Ross YA x PM3, ISA 757, ISA 957 and Redbro birds at 56 days of age and by Master Gris, Gris Barre, ISA 457 and ISA 657 birds at 81 days of age. The rare breeds had a very slow growth profile when fed Label Rouge rations and this meant that the target market live weight of 2.15 kg was not achieved at the end of the 81-day growing period. However, the growth profiles of these breeds when fed Label Rouge rations indicates that they have the potential to achieve a market live weight of 2.150 kg, but at an estimated age of between 96 and 105 days (estimated using the Gompertz function, see Gordon 2000). An example, is given in Figure 2 and this is for Ixworth birds.

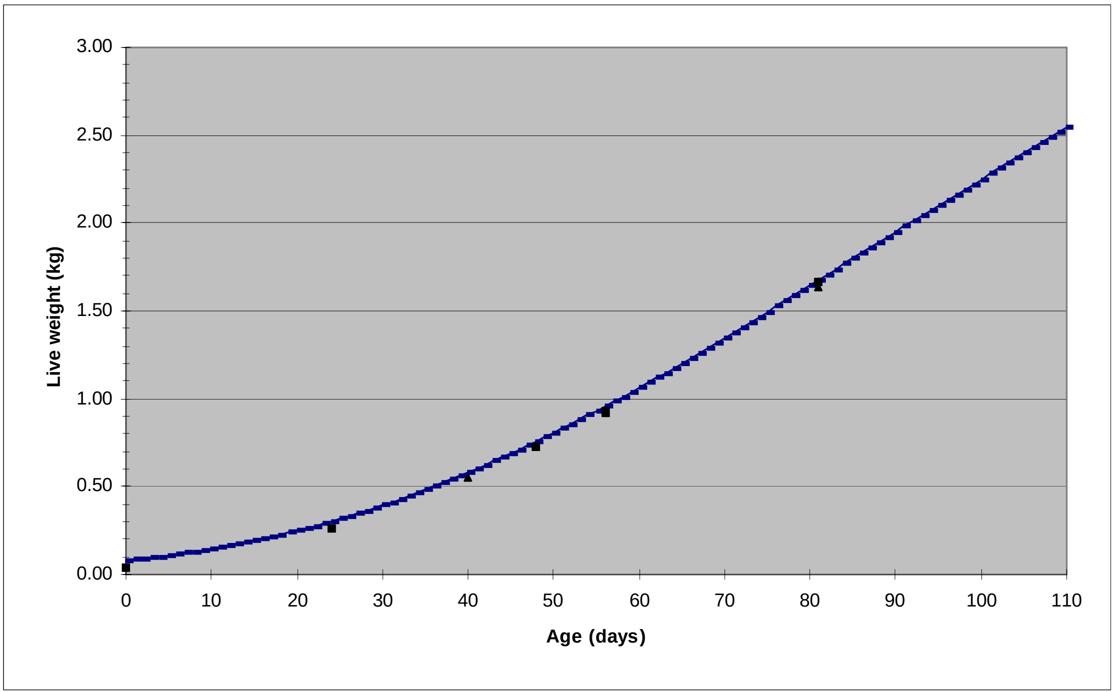

Figure 2. Gompertz prediction of live weight against age of Ixworth birds fed Label Rouge rations
Where: Live weight (kg/bird) = -0.0394 + 5.053 exp(-exp(-0.0165(t-86.57)))

Feed usage, live weight, FCE, breast meat yield and mortality results for the four breed-types are reported in sections 3.1.1.1 to 3.1.1.4. below, respectively. By categorising breeds into breed-types, and analysing for breed differences in performance within a breed-type it was possible to identify the better breeds; according to production system requirements (i.e. a minimum slaughter age of 56 days for current systems of free-range production, 81 days for traditional free range production, and between 73 days and 81 days for organic production). Results on gait and behaviour are reported across all breed treatments in section 3.1.1.5 and a summary of eating quality assessments is given in section 3.1.1.6.

3.1.1.1. *'Fast growing' breed type - Ross 308, Ross 508 and Ross YA x PM3 birds*
Feed usage between day old and 56 days of age was greater when fed non-limiting rations than when fed Label Rouge rations and this resulted in heavier live weights at 56 days of age (feed usage 121 g/bird.day and 103 g/bird.day, respectively; as hatched live weight 3.644 kg and 2.517 kg, respectively; $p<0.05$). There was no effect of feed-type on feed usage between day old and 81 days of age but live weights at 81 days of age were heavier in birds fed non-limiting rations (as hatched live weight was 5.000 kg in birds fed non-limiting rations and 4.200 kg in birds fed Label Rouge rations; $p<0.05$).

Feed usage between day old and 56 days of age and between day old and 81 days of age was greatest in Ross 308 birds and lowest in Ross YA x PM3 birds, with Ross 508 birds having an intermediate feed intake (e.g. feed usage between day old and 56 days was 116g/bird.day, 105 g/bird.day and 114 g/bird.day, respectively; $p<0.01$). This resulted in Ross 308 birds having the heaviest live weights at 56 days and 81 days of age and Ross YA x PM3 birds having the lowest live weights (as hatched live weights at 56 days were 3.246 kg and 2.862 kg, respectively; as hatched live weights at 81 days were 4.789 kg and 4.374 kg, respectively; $p<0.01$).

Feed conversion efficiencies (FCE) between day old and 56 days of age and between day old and 81 days of age were better in birds fed non-limiting rations than in birds fed Label Rouge rations (FCEs between day old and 56 days were 0.531 and 0.428, respectively; FCEs between day old and 81 days were 0.436 and 0.372, respectively; $p<0.05$), but there were no breed differences in FCE.

There was a trend for an effect of feed-type on breast meat yield at 59 days of age (*p*=0.12). Breast meat yield tended to be higher in birds fed non-limiting rations than in birds fed Label Rouge rations (30.1% and 23.1% of evisecrated carcass weight, respectively).

There was no effect of feed-type on mortality between day old and 56 days of age but there was a trend for mortality over this period to be greater in Ross YA x PM3 birds than in Ross 308 birds and Ross 508 birds (mortalities were 10.7%, 3.6% and 3.2%, respectively; *p*=0.15). More of the Ross YA x PM3 chicks died during the first few days of housing than usual and this was due to the chicks being too hot during transit to Gleadthorpe. There was an interactive effect of feed-type and breed on mortality between day old and 81 days of age. Mortality was higher in birds fed non-limiting rations than in birds fed Label Rouge rations (*p*<0.05) and for all breeds, but more so for the heavier Ross 308 and Ross 508 birds than for the Ross YA x PM3 birds. Many more birds were culled due to leg abnormalities and poor gait when fed non-limiting rations, compared with birds fed Label Rouge rations. For information, mortality between day old and 81 days of age was 7.3% in Ross 308 birds fed Label Rouge rations.

3.1.1.2. *'Medium to fast growing breed type - Hubbard ISA 757, ISA 957, Redbro and Master Gris birds*
Feed usage between day old and 56 days of age was not affected by feed-type but there was an effect of feed-type on feed usage between day old and 81 days of age (*p*<0.05). Feed usage was greater in birds fed Label Rouge rations than in birds fed non-limiting rations (123 g/bird.day and 118 g/bird.day, respectively). There were breed differences in feed usage between day old and 56 days and between day old and 81 days of age (*p*<0.01 and *p*<0.001, respectively). Master Gris birds consumed less feed than ISA 757, ISA 957 and Redbro birds over both periods (83 g/bird.day, 95 g/bird.day, 100 g/bird.day and 96 g/bird.day, respectively). There was an interactive effect of feed-type and breed on live weight at 56 days and 81 days of age (*p*<0.05). Label Rouge rations reduced live weight compared with birds fed non-limiting rations but the effect was less pronounced in Master Gris birds (e.g. as hatched live weight at 56 days was 2.726 kg in ISA 757 fed non-limiting rations and 2.150 kg in I757 fed Label Rouge rations, whereas live weight at 56 days was 2.191 kg in Master Gris fed non-limiting rations and 1.893 kg in Master Gris fed Label Rouge rations).

FCEs between day old and 56 days, and between day old and 81 days of age, were better in birds fed non-limiting rations than in birds fed Label Rouge rations (FCEs between day old and 56 days were 0.483 and 0.397, respectively; FCEs between day old and 81 days were 0.397 and 0.333, respectively; *p*<0.01 and *p*<0.05, respectively). There was no effect of breed on FCE between day old and 56 days of age but there was an effect of breed on FCE between day old and 81 days of age, ISA 757 birds had the best FCE and Master Gris birds had the poorest FCE (FCEs were 0.383 and 0.345, respectively; *p*<0.01).

There was a trend for an interactive effect of feed-type and breed on breast meat yield at 59 days of age but only in the males (*p*=0.07). Breast meat yield was greater in males fed non-limiting rations compared with males fed Label Rouge rations, except for Redbro which had a similar breast meat yield irrespective of feed type (e.g. breast meat yield in ISA 757 males fed non-limiting rations was 25.7% of eviscerated carcass weight and 18.8% in ISA 757 males fed Label Rouge rations, whereas breast meat yield was 19.9% in Redbro males fed non-limiting rations and 19.2% in Redbro males fed Label Rouge rations).

Mortality between day old and 56 days and between day old and 81 days of age was not affected by feed-type or breed. Mean mortality between day old and 56 days of age was 5.6% and between day old and 81 days of age 9.7%.

3.1.1.3. *'Slow growing' - Hubbard ISA 457, ISA 657 and Gris Barre birds*
Feed usage between day old and 56 days and between day old and 81 days of age was not affected by feed-type but there was an effect of breed on feed usage. Feed usage over these periods was highest in ISA 457 birds and lowest in ISA 657 birds with the Gris Barre birds having an intermediate feed intake (e.g. feed usage between day old and day 81 was 110 g/bird.day in ISA 457 birds and 85 g/bird.day in ISA 657 birds; *p*<0.001).

Live weight at 56 days of age was heavier in birds fed non-limiting rations than in birds fed Label Rouge rations (as hatched live weights were 2.089 kg and 1.677 kg, respectively; $p<0.01$) and there was a trend for a similar effect of feed-type on live weight at 81 days of age (as hatched live weights were 3.193 kg and 2.746 kg, respectively; $p=0.09$). Differences in feed usage between breeds resulted in differences in live weight at 56 days and 81 days of age, ISA 457 and Gris Barre birds had eaten more feed and were heavier at 56 days and 81 days of age than ISA 657 birds (as hatched live weights at 56 days were 2.100 kg, 1.951 kg and 1.597 kg, respectively; as hatched live weights at 81 days were 3.288 kg, 3.078 kg and 2.542 kg, respectively; $p<0.001$).

There was an interactive effect of feed-type and breed on FCE between day old and 56 days of age ($p<0.01$). FCE was better in birds fed non-limiting rations than in birds fed Label Rouge rations irrespective of breed. ISA 657 birds had the best FCE between day old and 56 days when fed non-limiting rations but the poorest FCE when fed Label Rouge rations. There was an effect of feed-type on FCE between day old and 81 days of age but there was no effect of breed. FCE between day old and 81 days of age was better in birds fed non-limiting rations than in birds fed Label Rouge rations (0.385 and 0.330 respectively; $p<0.05$).

Breast meat yield at 84 days of age was greater in birds fed non-limiting rations than in birds fed Label Rouge rations (e.g. male breast meat yields were 25.4% and 24.4 % of eviscerated carcass weight, respectively; $p<0.05$) but there was no effect of breed on breast meat yield.

Mortality between day old and 56 days of age and between day old and 81 days of age was not affected by feed type or breed. Mean mortality between day old and 56 days of age was 2.0% and between day old and 81 days of age 3.6%.

3.1.1.4. *'Very slow growing' – Light Sussex, White Sussex and Ixworth*

There was a trend for a higher feed usage between day old and 56 days of age and between day old and 81 days of age in birds fed Label Rouge rations than in birds fed non-limiting rations (feed usage between day old and day 56 was 63 g/bird.day and 48 g/bird.day, respectively; feed usage between day old and day 81 was 78 g/bird.day and 65 g/bird.day, respectively; $p=0.12$ and $p=0.10$, respectively). It is thought that the high crude protein content of the non-limiting rations reduced feed intake because the dietary amino acid supply exceeded the birds' requirement for maintenance and growth.

Feed usage between day old and 56 days of age was not affected by breed but there was a trend for feed usage between day old and 81 days of age to be lower in Light Sussex birds than in White Sussex or Ixworth birds ($p=0.16$).

Live weights at 56 days and 81 days of age were greater in birds fed non-limiting rations than in birds fed Label Rouge rations (as hatched live weights at 56 days were 1.239 kg and 0.866 kg, respectively; as hatched live weights at 81 days were 2.035 kg and 1.568 kg, respectively; $p<0.05$). There were breed differences in live weight at 56 days and 81 days of age ($p<0.05$ and $p<0.01$). In terms of live weight, the heaviest birds were the Ixworths, with White Sussex birds being intermediate and Light Sussex being the lightest (as hatched live weights at 56 days of age were 1.132 kg, 0.972 kg and 1.054 kg, respectively; as hatched live weights at 81 days of age were 1.910 kg, 1.706 kg and 1.789 kg, respectively).

FCEs between day old and 56 days of age and between day old and 81 days of age were better in birds fed non-limiting rations than in birds fed Label Rouge rations (FCEs between day old and 56 days were 0.453 and 0.239, respectively; FCEs between day old and 81 days were 0.377 and 0.242, respectively). There were no breed differences in FCEs over these periods.

Breast meat yield at 84 days of age tended to be greater in males fed non-limiting rations than in males fed Label Rouge rations (22.8% and 21.3%, respectively; $p=0.09$), and there was a similar trend in the females but the level of significance was poorer ($p=0.19$). There were breed differences in breast meat yield at 84 days of age: Ixworth birds had higher breast meat yields than White or Light Sussex birds (males $p<0.01$, and females $p=0.09$). For example, breast meat yield was 24.7% of eviscerated carcass weightin male Ixworths and 24.2%

in female Ixworths, whereas yields were less than 22.5% for both male and female White and Light Sussex birds.

There was an interactive effect of feed-type and breed on mortality between day old and 56 days of age and between day old and 81 days of age ($p<0.01$ and $p<0.05$). Mortalities over these periods were higher in White Sussex birds fed non-limiting rations than in White Sussex birds fed Label Rouge rations, but there was no effect of feed-type on mortality in the other breeds (e.g. mortality between day old and 81 days of age was 14.5% in White Sussex birds fed non-limiting rations and 1.5% in White Sussex birds fed Label Rouge rations). Aggressive pecking and cannibalism in White Sussex birds fed non-limiting rations accounted for increased mortality. Chopped wheat straw was added to the wood shavings litter and this seemed to alleviate the behavioural problem.

3.1.1.5. Behaviour and gait

Several breeds responded calmly (initial response cateogory 1) to an observer entering the pen they were Ross 308, Ross 508, Gris Barre, ISA 457, ISA 957 and White Sussex birds. The next level of response, this being birds running away from the observer and group tightly (category 2) was displayed by Ross YA x PM3, ISA 757, ISA 657 and White Dorking birds. All of the other breeds were category 3, this being running or flying away from the observer with some piling-up, except for Light Sussex birds and these showed extreme fear with flight and escape behaviour (category 4). Only Ixworth and Light Sussex birds remained fearful for the full duration of exposure to a human.

Birds fed Label Rouge diets were more active, and in particular spent longer eating ($p<0.001$), standing ($p<0.01$) and walking ($p<0.05$) than birds fed non-limiting rations. Using the proportion of time spent lying as the main criterion, breeds were classifed as being active, moderate or inactive. All of the fast-growing breeds (Ross birds) were inactive, as were most of the fast-medium growing breeds (Hubbard ISA 757, ISA 957 and Redbro birds). Master Gris birds, these being the lightest in the latter breed-type, were classified as being moderately active. The slow growing breed-type (Hubbard ISA 457, Gris Barre and ISA 657 birds) were also moderately active. Only the very slow growing breed-types were classified as being active (White Sussex, Light Sussex, Ixworth and White Dorking birds). On average they spent almost twice as long walking or running around the pen as the inactive fast growing breed-types ($p<0.001$). Time spent feeding did not differ between breeds but time spent ground pecking did ($p<0.001$). The active very slow growing breeds spent an excessive amount of time ground pecking. Mean percentage time spent on the major activities by moderately active birds fed Label Rouge rations (Master Gris, Gris Barre, ISA 457 and ISA 657 birds) were: total lying 53%, standing idle 11%, sleeping 4%, lie preening 5%, eating 11%, standing ground pecking 5% and walking 5%.

There were significant effects of feed type and breed on gait at 54 days and 81 days of age ($p<0.001$). Gait was poorer in birds fed non-limiting rations than in birds fed Label Rouge rations and it was poorer in faster growing breeds compared with slower growing breeds. Gait deteriorated with age in all breeds. However, analysing the data with live weight as a covariable removed the effects of feed-type and breed. This suggests that at a given live weight all breeds had similar walking abilities.

3.1.1.6. Eating quality

Flavour, texture and succulence in birds killed at 56 days of age was average (score 3) or below average (score 2) but not poor (score 1, Figure 3). In birds fed non-limiting rations, Ross 308 and ISA 757 produced the best eating qualityscores but when fed Label Rouge rations eating qualities were similar across all breeds. Dark meat was as acceptable as breast meat in terms of eating qualities. This is important as dark meat is a larger proportion of total edible meat in extensive table chickens than in broilers.

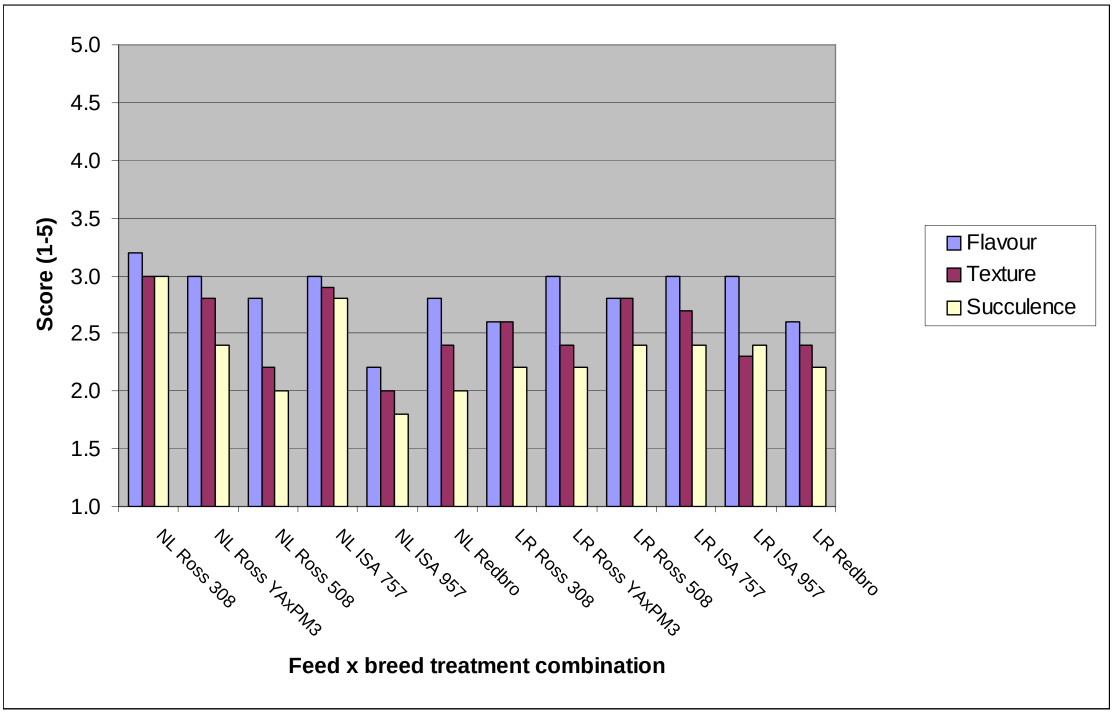

Figure 3. Flavour, texture and succulence scores of male breast meat at 56 days of age
Where: score 1= poor, 2= below average, 3= average, 4= above average, and 5= excellent

In birds killed at 81 days of age, flavour, texture and succulence tended to be marginally better for those fed Label Rouge rations (Figure 4). It is interesting to note that the very slow growing breeds had similar, if not slightly better, flavour scores than the ISA hybrids and yet the very slow growing breeds had not reached growth inflexion. Dark meat tended to score slightly less well on flavour and tenderness than white meat (approx -0.3 units in score), but succulence scores were similar for dark and white meat.

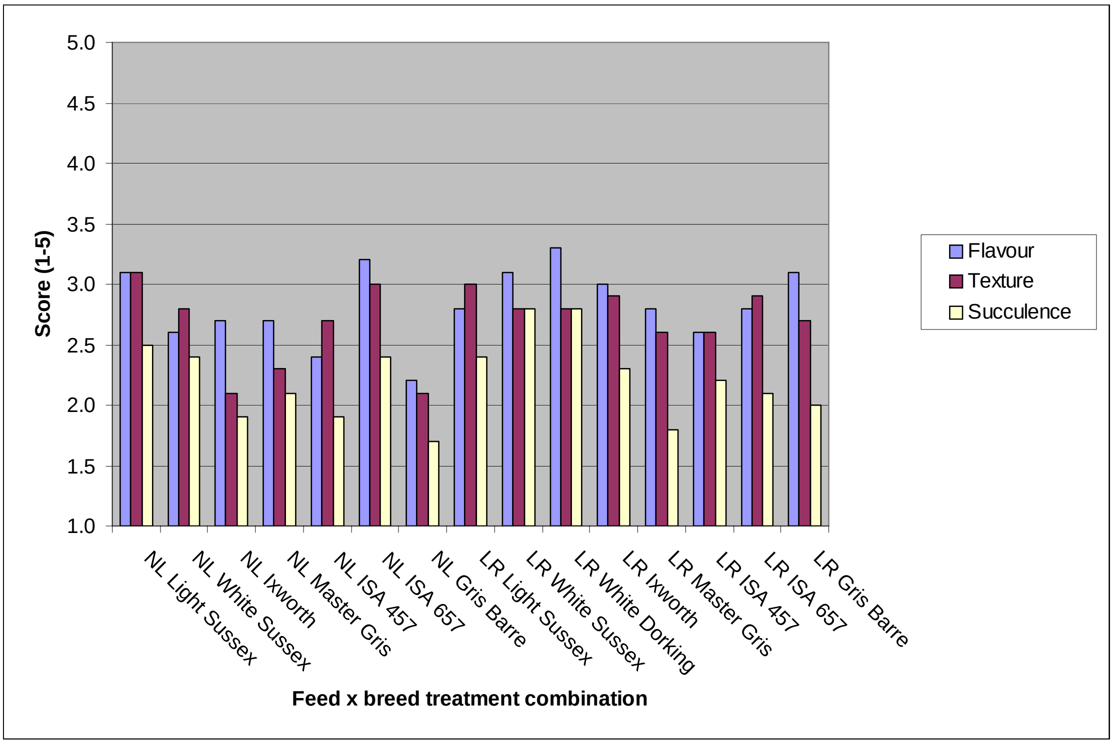

Figure 4. Flavour, texture and succulence scores of male breast meat at 81 days of age

3.1.2. Study 2 – Effect of breed and post brooding temperature regime on performance, mortality and meat yields

Mean as hatched live weight at 56 days of age ranged from 1.381 kg to 2.706 kg and from 2.268 kg and 4.501 kg at 81 days of the age. Throughout the 81-day growing period ISA 657 birds were the lightest and Ross 308 birds were the heaviest. The as hatched live weights of birds housed in a stable environment were similar at 56 days and 81 days on a breed basis, to those achieved in Study 1 for birds fed Label Rouge rations.

There was no effect of temperature on live weight at 56 days or 81 days of age, nor on feed usage between day old and 81 days of age, FCE between day old and 56 days of age, or FCE between day old and 81 days of age. There was an interactive effect of temperature and breed on feed usage between day old and 56 days of age; feed usage was higher in the diurnallly fluctuating temperature environment than in the stable thermal environment for Ross 308 birds, but not for SASSO S77N birds (108 g/bird.day versus 114 g/bird.day for Ross 308 birds and 69 g/bird.day and 68 g/bird.day for SASSO S77N birds, respectively; $p<0.05$). There were no effects of temperature on feed usage between day old and 56 days of age for the other breeds.

There were breed differences in live weight at 56 days and 81 days of age ($p<0.001$). As reported above breeds common to Study 1 and 2 performed similarly between studies when grown under similar conditions, thus live weight results are not repeated in this section. For reference, the as hatched live weight of SASSO S77N birds was 1.569 kg at 56 days of age and 2.495 kg at 81 days of age.

Heavier breeds ate more feed than the lighter breeds and they also had better FCEs throughout the 81-day growing period (e.g. between day old and 81 days of age $p<0.001$ and $p<0.01$, respectively). For SASSO S77N birds feed usage between day old and 81 days of age was 92 g/bird.day and the FCE was 0.401.

There was no effect of temperature or breed on the incidence of mortality between day old and 56 days of age or between day old and 81 days of age. The incidence of mortality between day old and 56 days of age was only 2.0% across all treatments, and 2.8% between day old and 81 days of age.

Male breast meat yield was lower in the diurnally fluctuating temperature environment than in the stable thermal environment (24.7% *versus* 25.8%, respectively $p<0.05$) but there was no effect of temperature regime on female breast meat yield. Breast meat yields were between 1% and 2% higher in ISA 957 birds than in other breeds ($p<0.05$).

There were no effects of temperature or breed on the insulative value of either the pelt with or without feathers or on the feathers alone. Pelt and feather thickness were similar across all treatments. Skin thickness was greater in Ross 308 birds than in SASSO S77N birds ($p<0.05$) but not when live weight was used as a covariate. There were several differences between means due to sex, but the only ones that remained when live weight was used as a covariate were tog value of the pelt with feathers (3.28 for females *versus* 2.55 for males, $p<0.05$) and the calculated tog value of feathers only (2.82 for females *versus* 2.03 for males, $p<0.05$).

3.2. Phase 2 – Range usage

3.2.1. Study 3 – Effect of outdoor artificial shelter on range usage and bird performance

56-day production
There were no effects of range treatments on feed usage, live weight or feed conversion efficiency between day old and 56 days of age in female Ross 308 birds. Mean live weight at 56 days of age was 2.263 kg, a typical market live weight, and the mean feed conversion efficiency between day old and 56 days of age was 0.420. Mortality in female Ross 308 birds was not affected by range treatment and the mean incidence of mortality between day old and 56 days of age was very low at only 1.0%. Most of the deaths occurred during the early brooding period and yolk sac infection was identified as the primary cause of death.

For female Ross 308 birds monitoring of range usage identified the following relationships; a positive linear relationship between maximum ambient temperature and the number of detections on range, and; a negative linear relationship between daily run of wind and number of detections on range. There were considerably fewer detections on range when it was raining. Multiple regression analysis produced the following equation relating the number of detections on range to weather conditions (Table 1).

Number of detections for female Ross 308 birds = 2.40*minimum ambient temperature (°C) + 20.5*maximum ambient temperature (°C) - 0.441*windrun (km) + 4.0*rainfall (mm) - 85
where: r^2= 0.44, p<0.05

Table 1. Daily weather conditions experienced by as-hatched Ross 308 birds

	Min. ambient temperature (°C)	Max. ambient temperature (°C)	Rainfall (mm.day^{-1})	Windrun (km.day^{-1})
Minimum	- 6.4	8.2	0.6	6
Maximum	11.6	15.7	5.2	369

Between 28/2/00 and 24/3/00

There was no relationship between the number of days spent in the range facilities and the number of detections on range. The greatest number of detections was at the receiver located close to the pophole and the peak detection rate was at 09.00 h (Figure 5). In general, Ross 308 birds did not range far from the house.

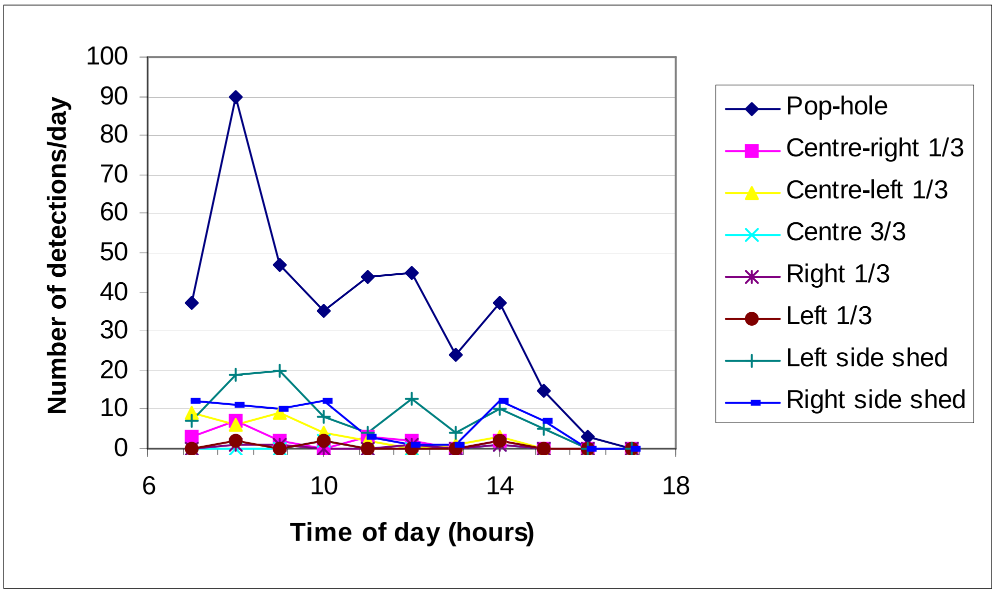

Figure 5. Mean number of detections for Ross 308 birds provided with artificial shelter on range

81-day production

There was a trend for feed usage between day old and 81 days of age to be higher in as hatched ISA 657 birds provided with pasture only (96 g/bird.day) than in birds provided with pasture plus artificial shelter (92 g/bird.day) but differences were not significant (p=0.22). This resulted in ISA 657 birds provided with pasture only being heavier at 81 days of age than in birds provided with pasture plus artificial shelter (2.332 kg and 2.279 kg, respectively, p<0.05). The effects of range treatment on live weight at 81 days of age may have been due to birds provided with shelter spending more time outdoors where feed was not available. There were no effects of range treatment on feed conversion efficiency or mortality between day old and 81 days of age (mean FCE was 0.292 and mortality 1.8%).

As for female Ross 308 birds, range usage in ISA 657 birds was similarly affected by weather conditions. Multiple regression analysis produced the following equation relating the number of detections on range to weather conditions (Table 2).

Number of detections for as hatched ISA 657 birds = 67.9 - 10.8*minimum ambient temperature (°C) + 4.63*maximum ambient temperature (°C) - 0.061*windrun (km) + 2.37*rainfall (mm)
where: $r^2 = 0.39$, $p<0.05$

Table 2. Daily weather conditions experienced by as-hatched ISA 657 birds

	Min. ambient temperature (°C)	Max. ambient temperature (°C)	Rainfall ($mm.day^{-1}$)	Windrun ($km.day^{-1}$)
Minimum	- 6.4	4.3	0.0	6
Maximum	7.9	15.7	31.4	404

Between 14/3/00 and 17/4/00

Artificial shelter on range tended to encourage ISA 657 birds to range further down the paddock than when provided with pasture only. However, even when provided with shelter the highest number of detections was at the receiver near to the pophole (Figure 6).

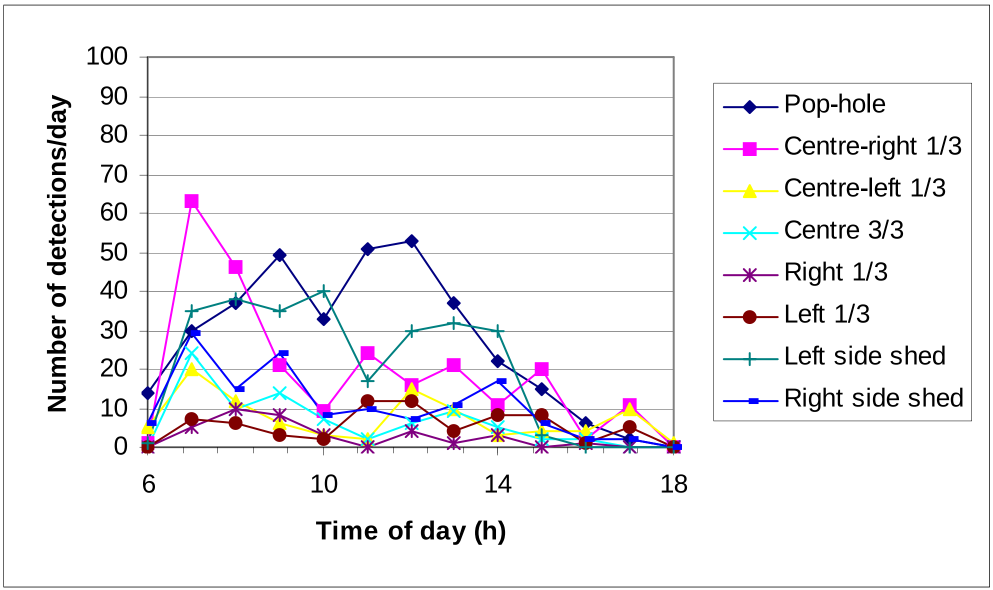

Figure 6. Mean number of detections for ISA 657 birds provided with artificial shelter on range

3.2.2. <u>Study 4 - Effect of brooding treatment and range design on range usage and bird performance</u>

There were no effects of brooding treatment and pasture design on feed usage or feed conversion efficiency between day old and 82 days of age, nor on live weight at 82 days of age (mean feed usage 82 g/bird.day, FCE 0.337 and as hatched live weight 2.497 kg, respectively). Mortality between day old and 28 days of age and between day old and 82 days of age was affected by brooding treatment and pasture design ($p<0.01$). The lowest incidences of mortality were in chicks brooded in a controlled environment (mean 0.8% between day old and 28 days of age and 0.9% between day old and 82 days of age). Enriched brooding increased mortality between day old and 28 days of age, and it was higher in birds provided with access to enriched pasture than in birds provided with access to pasture only (9.4% and 3.6%, respectively, $p<0.01$). Mortality post 28 days of age was very low on all treatments (mean 0.3%), thus it was the effects of treatment on brooding mortality that were apparent across the whole 81-day growing period.

Mortality in chicks brooded in an enriched environment was due to yolk sac infection, nephritis and the failure to find feed and water. This reflected natural ventilation in the enriched brooding treatments, which made it difficult to achieve the correct thermal environment for chicks at all times of the day and night, and if the chicks were too hot or too cold they would not have moved around to feed and drink. Failure to feed and drink would have increased the incidence of "starveouts" and a low water intake would have increased the risk of kidney disease. Yolk sac infection was the only cause of mortality in chicks brooded in a controlled environment.

Birds brooded in the controlled environment house (standard brooding) ranged significantly less than birds brooded in the enriched environment of the free-range facilities (e.g. between 65 days and 74 days of age, $p<0.05$, Table 3). Conifer wig-wams provided in the enriched pastures were very attractive to the birds, especially when chicks were brooded in the free-range facilities with early access to pasture. In the latter treatment the highest number of detections was at the conifer wig-wam rather than at the pophole. There was very little use made of the artificial shelter, namely the windbreak or the overhead shelter.

Table 3. Total number of detections (mean of 4 or 2 pens) in 10-day periods according to treatment

Treatment		Age (days) 35 to 44	45 to 54	55 to 64	65 to 74
Brooding					
Enriched		586	251$^{\#}$	290	171*
Standard		1.5	61	110.5	72.5
Pasture					
Enriched		304¶	90	148	90
Standard		283¶	222	255	153
SD$^{=}$		182.0	59.4	37.2	76.1
Brooding * Pasture interaction					
Enriched	enriched	608	116	218	135
Enriched	standard	564	387	363	207
Standard	enriched	0¶	65	79	45
Standard	standard	3¶	58	142	100
SD		257.3	84.0	52.7	107.6

$^{\#}$ = p<0.1; * = p<0.05; ¶ not relevant as treatment not yet started; $^{=}$, SD applicable both to brooding and pasture comparisons

Transponder detections were qualified by visual observations. For example, Antenna 1 was close to the pophole exit from the shed and showed a predominance of detections in the groups that had access to pasture only (i.e. unenriched pasture), regardless of brooding treatment. By contrast, Antenna 6 was close to the wig-wam in treatments with enriched pasture, and to a perimeter fence in treatments with pasture only (at the same location in each paddock). There was a predominance of detections at this antenna in enriched pasture treatments, regardless of brooding treatment. The overall impression was one of birds with access to enriched pasture roaming more widely, while those with pasture only stayed closer to the shed.

Overall range usage tended to be better on warmer, non-windy, dry days and this confirms findings from the winter flock. A summary of the weather conditions experienced by the birds is given in Table 4.

Table 4. Daily weather conditions experienced by as-hatched ISA 657 birds

	Min.ambient temperature (°C)	Max.ambient temperature (°C)	Rainfall (mm)	Windrun (km)
Minimum	2.1	14.0	0.0	4
Maximum	15.4	27.0	22.8	399

Between 26/07/00 and 20/09/00

3.2.3. Study 5 – Characterisation of bird movement in a controlled environment house and a free-range house

Birds housed in free-range facilities and broiler facilities showed complex behavioural patterns. They walked around at a fast speed but this was followed by long periods of being inactive. There were differences in the speed of walking with age but a consistent reduction in speed with age was not found. Furthermore, on most of the days that walking was video-recorded broilers walked faster than free-range birds ($p<0.001$). Free-range birds tended to huddle in groups indoors whereas this was not seen in broilers. The huddling behaviour of free-range birds may have been due to a cooler house temperature than in the broiler house.

The direction of change of movement was less in broilers than in free-range birds ($p<0.001$), this may have been due to less ambling and more reward-based movement in broilers than in free-range birds. The direction of change of movement was influenced by age and it was highest when birds were young ($p<0.05$ to $p<0.001$ for differing age comparisons).

3.3. Phase 3 - Effects of feed and water provision and early nutrient supply on mortality during brooding

3.3.1. Study 6 – The interactive effects of brooding facility and feed and water provision during brooding on mortality and performance

There were no interactive effects of feed and water provision and brooding treatment, or effects of feed and water provision on mortality, feed usage, or feed conversion efficiency between day old and 28 days of age, nor on live weight at 28 days of age. The findings were similar for the period day old to 81 days of age. There was no effect of brooding environment on feed usage between day old and 28 days of age, but feed conversion efficiency to 28 days of age was best when brooded in the enriched environment (FCE 0.520 *versus* 0.459 respectively, $p<0.001$). Thus, live weight at 28 days of age was higher in chicks brooded in the enriched environment, than in the controlled environment (0.584 kg *versus* 0.516 kg/bird, respectively $p<0.01$).

There was a trend for feed usage between between day old and 81 days of age to be higher in chicks brooded in the enriched environment, than in the standard environment (e.g. feed usage between day old and 81 days of age was 90 g/bird.day *versus* 88 g/bird.day, $p=0.11$), but live weight at 81 days of age was similar between brooding treatments (mean as hatched live weight 2.496 kg/bird). Feed conversion efficiency between day old and 81 days of age was not affected by brooding treatment (mean FCE 0.337).

There were no effects of feed and water provision or brooding treatment on either brooding mortality or mortality between day old and 81 days of age. Mortality to 28 days of age was high on all treatments (mean 4.9%), and of this 1.5% occurred between day old and 7 days of age and 3.4% between 8 days and 28 days of age. By comparison, mortality between 29 days and 81 days of age was low (mean 0.5%).

Mortality to 28 days of age was due to yolk sac infection, nephrosis and starveouts. It is not clear why brooding mortality was high when using controlled environment facilities and standard brooding practice. Typically, mortality between day old and 28 days of age is less than 1% in the above facility at Gleadthorpe. Suggestions by the steering group for why mortality was high during brooding were: 1) transport conditions from the hatchery to Gleadthorpe were less than optimal; 2) a low protein feed during early life retards the development of vital organs, and; 3) 'slow-growing' hybrids may need different hatching conditions to conventional broiler hybrids.

By viewing the birds on many occasions throughout the study it was apparent that the birds were attracted to and sheltered underneath the conifer wig-wams irrespective of their position in the paddock.

3.3.2. Study 7 – The effects of early nutrient supply on brooding mortality and performance

There was a trend for chicks given Oasis® pellets during transit only to have a higher feed usage between day old and 28 days of age than for chicks receiving the other feed treatments (p=0.07). However, this did not result in chicks being fed Oasis® pellets during transit only being heavier at 28 days of age. They were of similar live weight as chicks receiving Label Rouge feed only, and as chicks receiving Oasis® pellets during transit and for the first three days of housing, plus Label Rouge feed from housing. Chicks fed a conventional starter crumb for the first three days of housing were heaviest at 28 days of age and they had the best FCE between day old and 28 days of age (p<0.01 and p<0.05, respectively). At 81 days of age, birds fed the conventional starter ration tended to be heaviest at 2.304 kg (p=0.06), but there were no effects of early nutrient supply on FCE between day old and 81 days of age (mean FCE was 0.307).

There were no effects of feed treatment during early life on mortality to 28 days of age or post 28 days of age. Mortality between day old and 28 days of age was low, the mean being 1.2% and it remained low throughout the 81-day growing period. Mean mortality between day old and 81 days of age was only 1.9%. The cause of mortality was yolk sac infection during early life and non-specific causes in older birds.

Although results are not presented, overall flavour and texture scores of ISA 657 birds tended to be better in later studies than in Study 1. The best flavour scores were from birds grown in Study 7, the mean score being 3.5. Acceptability of the meat may have increased due to repeated exposure.

4.0. DISCUSSION

The genotypes used in Phase 1 of the project had a wide range of growth profiles when grown under the same conditions. This means that there is more than adequate scope for UK producers to chose a genotype on the basis of its growth profile when feed is available *ad libitum* during the daytime.

A more difficult area for UK table chicken producers is genotype choice in terms of meat conformation. Breast meat yields of broiler hybrids fed Label Rouge rations were much lower than those of intensive broilers and this was due to the low lysine and methionine content of Label Rouge rations. By comparison, the percentage reduction in breast meat yield due to diet was less in the lighter hybrids than in broiler hybrids. However, the imported genotypes were long-legged compared with UK broiler hybrids and this gave them a markedly different dressed appearance than intensively produced broilers. This means that their success in the UK table chicken market will depend on consumer acceptance.

Poultry companies that have invested in extensive table chicken production will have the resources to develop hybrids that better meet UK consumer needs. These new hybrids would be available to small-scale organic chicken producers if they contract grow for the company. It would solve the problem of slaughtering and processing for small-scale organic producers, this being subject to organic Standards and onerous legislation.

It was interesting that Ixworth birds had a reasonable breast meat yield when slaughtered at 84 days of age (mean as hatched live weight 1.64 kg/bird). According to Gordon (2000) growth inflexion calculated using the Gompertz function did not occur until about 87 days of age in Ixworth birds. As breast meat yields are optimised post growth inflexion (see Gordon 2000 for a review), there is the possibility that breast meat yields may be higher when grown to market live weights of about 2.1 kg. If so, this would make Ixworth birds an attractive option for use in niche production systems provided that premiums cover the costs of the longer growing period and a poor FCE.

Meat flavour, texture and succulence were not optimised but this was not the aim of the project. Flavour and texture are related to physiological development and this was discussed in relation to extensive table chicken production in a review by Gordon (2000). Free-range birds are slaughtered close to growth inflexion and so flavour may not be optimised, by comparison traditional free-range birds are slaughtered sometime after growth inflexion and so flavour is likely to be more intense than broiler meat. The retail acceptance scores do not describe flavour intensity. Descriptions of meat flavour from birds slaughtered at 81 days of age were 'gamey', 'strong' or 'off'. From the review by Gordon (2000), age at slaughter influenced meat flavour the most and it is not clear whether or not breed differences occur. To test for the latter, Gordon (2000) suggested that sampling should be done on the basis of metabolic age and not live weight at slaughter as often used in published work. In this work, meat from the very slow growing breeds compared favourably with the meat of slow growing hybrids used in Label Rouge production even though the very slow growing breeds were under weight at slaughter. Growth inflexion had not been met and so flavour may have been less developed than if grown to about 100 days of age.

Genotype differences in behaviour were apparent and these will be important in an extensive production system. Birds should be active and inquisitive, as this is likely to make them better at ranging and foraging than sedate hybrids. Foraging is likely to be increasingly important in extensive production, and in particular in an organic production system. Ryegrass based swards are thought to be of low nutrient value for chickens and there is a need to look at alternative forages rich in protein. If the latter were to be used as vegetative pasture and it was eaten by chickens then this would be effective in reducing the amount of feed either bought-in to the system or produced on-farm. Feed costs are a very high proportion of variable costs of extensive production, and organic feed is very expensive (Turner, 2002). Alternative forages for grazing by chickens would be a means of reducing production costs.

Genotypes that display extreme fear reactions when approached by humans may not be suited for use in production systems using small mobile houses, unless sensitivity is reduced by habituation during early life. Stereotypic ground pecking in these genotypes was of concern as this may lead to aggressive pecking problems.

In Phase 2, brooding management and the provision of overhead natural shelter influenced range use. Early exposure to range increased range use. In commercial production chicks are brooded either in range facilities or in specialist brooding houses and the birds are then transferred to range facilities. However, 'brood and move' is specific to organic production as flock sizes are smaller than in non-organic free-range production and in organic production the free-range houses may be located in remote areas of a farm. This would make it more difficult to monitor house environment: hi-low temperature alarms are useless if they cannot be heard by the stockman at all times of the night and day. Investment in one centralised and static brooder facility will be more affordable and practicable than in several small mobile houses. The advantages and disadvantages of static and mobile housing for chickens were discussed in a review by Gordon *et al.,* (2002).

If a 'brood and move' approach is used then the brooding facilities should have a verandah so that chicks can experience outdoor conditions from an early age. The work at Gleadthorpe showed how labour intensive it was to brood in small very low-tech houses, and in some cases this increased mortality. Thus, provided that 'brood and move' is done well, taking into account the birds' physiological needs and that injury and trauma does not occur at transfer this may be an appropriate approach.

The conifer wig-wams were attractive to chickens and they encouraged the birds to range away from the house. This information is of use to producers using either static or mobile houses rotated around the farm. For static housing, conifer wig-wams rotated around the paddock may be a means of ensuring better land and manure use. In rotational systems, conifer wig-wams may be of similar use as producers will be limited in where they can plant trees and hedges. This is because trees and hedges will impact on cropping.

Natural shelter like the conifer wig-wams would provide ameliorated microclimates on range and when used by the birds this will reduce heat loss. It was noticed that the stocking density under the wig-wams was high and this would enhance the acceptability of the microclimate. Diurnally fluctuating cool temperatures did not increase the insulative value of the pelt, and since Study 2 other workers have reported that cold exposure in free-range systems does not increase feather insulative value (Ward *et al.,* 2001). Thus, shelter outdoors will be important in reducing heat loss in all but the summer months.

The conifer wig-wams provided overhead shelter from predators, and this is thought to result in their attractiveness to the birds. A full discussion of paddock enrichment and pasture management is given in a review by Gordon *et al.,* (2002).

5.0. CONCLUSIONS AND IMPLICATIONS OF FINDINGS

The main project conclusions are itemised below.

1. Breeds should be chosen according to their growth profile when daytime access to feed is not restricted.
2. A suitable basis for defining breed differences in growth potential may be mature live weight (fat free).
3. Active and inquisitive breeds should be chosen for use in extensive production systems as they are likely to be better rangers and foragers than the less active broiler hybrids.
4. Breeds that show extreme escape responses and ground peck in a stereotypic manner should be avoided as they will be more difficult to manage and there may be a risk of aggressive feather pecking.
5. Feather colour may affect the chickens' ability to hide from predators; white feathering may increase the risk of predation.
6. There are breed differences in breast meat yield, which is also affected by lysine and methionine intake.
7. There is the potential to optimise and promote the eating quality of extensively produced chicken meat.
8. Pasture use is encouraged by providing access to pasture in early life, but there are implications for the build-up of parasitic disease and methods of parasite control will be needed.
9. Conifer wig-wams are attractive to chickens, and encourage birds to range away from the house.
10. Chickens will follow a mobile conifer wig-wam around the paddock, and this practice can help to distribute droppings within the paddock.
11. 'Slow growing' hybrid chicks may not be available locally. Transporting small numbers of chicks is expensive, and conditions during transit will affect mortality rates.
12. Investment in free-range facilities and equipment will affect labour cost, ease of management and levels of performance achieved.

There has been discussion at EU level about reducing the minimum slaughter age for free-range table chickens from 56 days to 49 days of age. If this is allowed then female UK broiler hybrids will be well suited to this system in terms of their growth profile when fed cereal rich rations. The reduction in growing period may enable some improvement in breast meat yield as early live weight gain may be less restricted and this would benefit breast muscle growth. If a 56-day growing period is retained then it is thought that in time UK broiler hybrids will be less suited to free-range production because of genetic improvements in FCE and live weight gain. Producers would either have to accept a heavier bird at 56 days of age or feed would have to be restricted.

Traditional free-range and organic chicken meats will be more strongly flavoured and firmer than broiler meat. It will be important that consumers understand this and that eating qualities are consistently optimised. There may be greater variability in the eating quality of traditional free-range and organic chicken meat than of broiler meat. This is because producers are using a range of breed-types, and feed ingredients and feed specifications will vary between producers and flocks. Factors that affect muscle growth will affect meat texture and the age at growth inflexion, and the latter may influence flavour intensity. There may be sex differences in flavour intensity, especially if the slaughter age is delayed much beyond 81 days. Seasonal differences in the eating quality of extensively produced chickens has not been studied.

Gordon (2000) proposed that a research-based flavour intensity score for extensive chicken meat might be developed and applied at point of retail. This would help consumers to chose between products according to personal taste preferences.

There will soon be a need for organic breeder flocks and organic hatching as the derogation allowing the buying-in of conventional chicks up to three days of age ends on the 31 December 2003. This will increase the cost of organic table chicken production as chicks will be more expensive and there may be less breed choice. The quality of organic chicks is not known, but greater variability in chick quality is expected at least in the short-term and this will affect growth performance and possibly chick mortality. As organic feed accounts for almost all of the variable costs of production, a means of reducing feed costs will be important. At present the pasture is an under utilised nutrient source and efforts should be made to identify better forages for grazing by chickens. If the pasture contributed between 10% and 25% of the birds' nutrient intake then this would provide significant savings on feed costs.

There will be an increasing need for means of parasite control in organic poultry production. Even in systems that integrate chickens into the rotation strategies for control will be needed. Manure spreading on land that will later be occupied by chickens may be a means of introducing infection, as parasitic worm eggs and oocysts may survive in the soil for some considerable time. Composting of manure may reduce the risk of infection, but only if the heat generated through time is effective in killing parasitic eggs and oocysts.

6.0. POSSIBLE FUTURE WORK

Current systems of extensive table chicken production are too dependent on the use of bought-in feedstuffs. It is thought that in future systems of production the sward or forage crop will contribute to the birds' nutrient intake thereby reducing the need for compound feed. It will also provide shelter from overhead predators and a role in maintaining soil fertility. Invertebrates living on the soil surface or in the upper soil surface will also contribute to the birds' nutrient intake and this will reduce the need for feed protein.

Research to support the developments given above is needed and specific requirements are given below.

1. To optimise sward composition and pasture management for chickens.
2. To develop comprehensive strategies for reducing the parasite burden on land used by chickens.
3. To examine the effects of including chickens in rotations on biodiversity.
4. To develop methods of invertebrate enrichment so as to provide a high protein food source for chickens.

There are other research opportunities that are specific to organic table chicken production and these are given below. Research opportunities number 5 to 8 inclusive address current constraints of organic chicken production in the UK.

5. To appraise technical difficulties associated with organic breeder flocks and organic hatching and to address specific problems through research.
6. To examine the suitability of male dual-purpose hybrid chicks in organic table chicken production.
7. To appraise technical difficulties associated with feeding organic table chickens and organic breeder flocks.
8. To devise sustainable hypothetical organic rotations including table chickens.
9. To estimate the volume of waste products produced as a result of organic table chicken production and to assess how this may alter in the future. To suggest possible uses for waste products.
10. To assess whether or not the use of organic table chicken manures in some rotations prejudices food safety (mixed stocking systems).

7.0. IP AND KNOWLEDGE TRANSFER

Details of knowledge transfer activities to date are given below.

1. Information arising from the project was discussed at the twice yearly steering group meetings for this project. Attendees of the meetings were organic and non-organic free-range table chicken producers, feed manufacturers, breed suppliers, research collaborators and representatives of DEFRA.
2. A DEFRA-funded study day on organic table chicken production was held at Gleadthorpe in December 2001 and this was attended by organic and non-organic free-range table chicken producers, independent consultants and veterinary surgeons, feed producers and breeders. This was funded through DEFRA project OF0163.
3. Project findings were discussed with representatives of Freedom Foods, RSPCA at a meeting of the Broiler Working Group in January 2000, and during their visit to Gleadthorpe.
4. Project findings were presented at the DEFRA review of research on organic farming held at Warwick University in July 2001.
5. Through the following publications:
   Scientific journals
   KESTIN, S.C., GORDON, S. and SORENSEN, P. (2000). The relationship between lameness in broiler chickens and live weight, growth rate and age. *Veterinary Record* 148:195-197
   GORDON, S.H., CHARLES, D.R. and GREEN, G. (2001). Metabolic age: a basis for comparison of traditional breeds of meat chickens. *British Poultry Science* 42 (Supplement) S118-S119
   Conference proceedings
   GORDON, S.H., FORBES, J.M. and WALKER, A.W. (2002). Management factors affecting the use of pasture by table chickens in extensive production systems. Proceedings of the UK Organic Research 2002 Conference, Organic Centre Wales, Aberystwyth, 26th–28th March, pp269-272
   Popular press
   GORDON, S.H. and DRAKLEY, C. (2001). On the range at Gleadthorpe. Poultry Progress, October 2001
   In press
   GORDON, S.H. and CHARLES, D.R. (2002). Niche and organic chicken and egg production: its technology and scientific principles. Nottingham University Press, *in press*

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

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