SSPE-CT-2004-502315

LAYWEL

Welfare implications of changes in production systems for laying hens

Specific Targeted Research Project (STReP)

Thematic Priority: Integrating and strengthening the ERA, Area 8.1.B.1.4, task 7

Deliverable 7.1
Overall strengths and weaknesses of each defined housing system for laying hens, and detailing the overall welfare impact of each housing system

Due date of deliverable: 23
Actual submission date: 24

Start date of project: 01/01/2004 Duration: 24 months

Organisation name of lead contractor for this deliverable: University of Bristol

Revision [final draft]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	x
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Contents

Outline

This chapter first considers the approaches to welfare assessment and integration, and then discusses the evidence available to the LayWel project for comparing welfare of laying hens in different systems. The methodology used for task 7.1 is then outlined before welfare indices are compared within and between systems. Results are summarised in a colour-coded table that estimates the risks to welfare within and between systems for a range of indices. The advantages and disadvantages of the three main categories of housing system are then discussed. We conclude with a list of recommendations that highlights areas for future research and development as well as some of the most important indicators of welfare that should be routinely and frequently monitored on farm.

Introduction

As outlined in WP1, animal welfare researchers tend to adopt one of two methodological approaches to welfare assessment. The '*welfare indicators*' approach takes measurements of basic health, behavioural, physiological or morphological responses and compares these between animals housed or treated differently (e.g. Broom and others, 1995; Appleby and others, 2002). The '*motivational priorities*' approach argues that animals are able to perform their own integration of inputs and make sensitive judgements about their own best interests. This has led to the development of techniques for assessing animal welfare using preference tests, measures of consumer demand and the self-selection of pharmacological agents.

Huge advances have been made in developing both methodologies to assess the welfare of the laying hen. Indeed, it could be argued that more is known about potential welfare indicators and motivational priorities in laying hens than in any other domesticated species. Despite this, problems in general methodology remain. The most important issue associated with the welfare indicators approach is the difficulty of interpretation if the indicators do not co-vary. For example, a higher incidence of bone fractures may be found in a system in which all the birds use the perches at night. Attempts to deal with this problem have focussed on methods of assigning relative weightings to different indicators, and then integrating the weighted parameters (Scott and others, 2003; Spoolder, 2003; and workpackages within current EU FP6 Welfare Quality programme).

Weighting of outcomes

There are numerous inter-related issues associated with weighting. For example:

i. *Individual versus group welfare*. How does one compare a situation in which a few birds suffer extremely poor welfare, whereas the majority have good welfare (such as a small outbreak of feather pecking or cannibalism) with one in which the majority appear to have satisfactory if not excellent welfare. Mathematically these might be equal, but in welfare terms the first example has extreme suffering of individuals, which might be completely unacceptable to some stakeholders. The second example exposes large numbers to sub-optimal conditions for a prolonged period.

ii. *Timescale*. The duration of sub-optimal conditions is important. Few would argue with the premise that greater suffering is associated with a bone break that occurs during the laying period than one that occurs just before slaughter. The outcome (pain experienced) may be the same, but the duration is different.

iii. *Magnitude*. Possibly more than any other issue, this requires an animal-based assessment to tell us how bad it is for them. A hen may suffer a traumatic, painful or frightening event that we might rate as poor welfare. However it could be well within her capacity to cope, particularly if it is a one-off event. On the other hand a single episode of cannibalistic bullying could result in a hen spending the rest of the laying period in a state of fear. In the event of not being able to rate the welfare consequences we should give birds the benefit of the doubt. From studies of stress we can be reasonably certain that prolonged sub-optimal conditions of magnitude do exhaust an animal's ability to cope and are definitely contrary for good welfare. How do we rate catastrophic events such as disease outbreaks or fires that may occur very infrequently yet affect virtually all birds?

iv. *Comparison of different outcomes*. This is the most challenging issue when considering weighting. Research on behavioural priorities is assisting with this to some extent, but bird preferences vary with time and between individuals. It therefore becomes extremely complex to attempt to rate and compare behavioural, physiological, production and other parameters.

Weightings are usually ascertained by surveying expert opinion using a variety of psychometric techniques (e.g. Main and others, 2003). The tautological problem is that the 'experts' themselves may have little objective basis on which to base their opinions. Thus, even if all experts agreed that the occurrence of physical injury should be weighted more strongly than stereotypic behaviour, they may be wrong. Problems with the motivational priorities approach lie in good experimental design and in knowing whether an animal has been offered a choice that it can perceive and understand. Continued work on perceptual and cognitive abilities of laying hens is needed to ensure that methods of assessing behavioural priorities are sound (Abeyesinghe and others, 2005). There is also a lack of integration between the two methodological approaches, which needs to be addressed to fine-tune the validation of different indicators. For example, the extent to which birds are attracted to, or avoid, environments associated with elevated corticosterone concentrations is not known. For other potential welfare indicators, choice, expressed as the self-selection of analgesic or anti-anxiolytic compounds could provide much needed validation. Thus, it is currently not known whether keel bone deformation, observed in some systems but not others, is detected by the bird or is painful, and hence it is unclear as to how much weight should be given to this indicator.

Where to draw the line

As with human welfare, this tends to be more of a cultural and political issue than a scientific one. The value judgements may be informed by science, but the dividing line between acceptable and unacceptable housing conditions will inevitably be different between different (groups of) people. As opinions of society change so too will the placement of the line.

In summary

Using a broad range of welfare indicators considered alongside available information on bird choice, should enable a realistic evaluation of the welfare of laying hens in different housing systems. However, it remains a challenge to weight different aspects of welfare, particularly across different categories. It may never be possible to provide an ideal system because increasing the opportunities for behavioural freedom (for example) may unavoidably increase the risk of transmission of certain diseases, or the risk of injury. This imperfect but realistic scenario suggests that the costs and benefits of each housing system need to be carefully assessed, using measures which are directly comparable between husbandry systems. The feasibility of improvements needs to be evaluated, and then a balanced conclusion may be drawn about which system(s) maximise overall welfare.

Information Available to WP7

The value of the final conclusions depends on the quality and quantity of the underpinning information and available evidence about laying hen welfare in different systems. The following questions need therefore to be considered:

- **Is the evidence comprehensive?**

  It is generally agreed that a range of different measures should be used to obtain an overview of bird welfare, and LayWel's Work Packages and database were structured accordingly. Housing systems that ignore any aspect will be criticised and efforts must be made to improve any area where standards fall short. Few studies have attempted to compare all aspects that relate to animal welfare and those that have are not recent (e.g. McLean and others, 1986) or attempt to draw conclusions from studies conducted in different ways (e.g. Appleby and Hughes, 1991). In the available LayWel database there are no single studies that include all (or even most) of the welfare indicators listed within WP1. We conclude that the evidence available to us is extensive but not comprehensive.

- **Is the evidence valid?**

  Considerable progress has been made in recent years in developing indices that relate to welfare. We consider most of the indicators evaluated in LayWel to be valid indicators of welfare, with certain caveats about some production indices (reviewed in WP6) and a need for further research on a minority of behavioural and physiological indicators. For example, it is not known whether some conditions are detected by hens or are perceived by them to be detrimental to their own welfare. There is also insufficient information about the effects of stress on immune function and organ weights in laying hens. In rats, chronic stress generally results in increased adrenal gland weight, and decreased spleen, thymus and bursa of Fabricius weight (e.g. Schao and others, 2003). Moreover, complex interactions between strain and gender also exist (e.g. Konkle and others, 2003). In chickens, most studies of stress and the immune system have been conducted on broiler strains, where differences in metabolic rate may influence physiological responses to stress (e.g. de Jong and others, 2002).

- **Is the evidence recent?**

In early discussions among partners it was agreed that only data from recent studies should be used. This was in part because the LayWel project is putting some emphasis on evaluating welfare in furnished (modified) cages. As this, and several other non cage systems are relatively new and continuing to evolve, more design and management modifications have occurred than in established housing systems. Performance and welfare of hens in furnished cages and other alternative systems may therefore have improved since earlier critiques, based on less refined designs. In addition, strains of laying hens are subject to continuous selection for improved productivity, with likely associated physiological and behavioural changes. We feel that current practices and more recent data are more relevant to inform stakeholders. Thus the overall assessment of the welfare of laying hens in different housing systems is based on the data obtained from experimental and commercial housing systems by the nine LayWel partners between 1998 and 2005, with most of the data from 2001 onwards. The housing systems are defined and described, with illustrations, in WP2.

- **Is the evidence of high quality?**

In assessing quality of evidence, it has been suggested that reviewers should attend to four key elements: study design, study quality, consistency and directness (the extent to which the subjects, interventions and outcome measures of the sample are similar to those of interest in the population) (GRADE, 2004). We have not undertaken a systematic grading procedure for each study contributing to LayWel (although this could be done with further resource). WP 7 has generally considered all evidence presented on equal terms and we have encountered no studies that are fatally flawed. There are, however, areas of unexplained inconsistency in results between different studies. Further work may reveal more clearly that there are different effects of housing system on different strains or in different countries, reducing inconsistencies.

In the medical literature, randomised experimental trials are generally graded higher than observational (epidemiological) studies. However, in the field of laying hen welfare, many experimental studies have reduced directness, in that they are conducted on experimental not commercial flocks. We consider the evidence from experimental and observational studies to carry equal weight. The major factor reducing evidence quality is the lack of replication in a number of experimental studies, sometimes with only one replicate per treatment. We regard this as a serious limitation and have omitted the data from non-replicated studies in considering best welfare practice (Table 7.8).

- **Is the evidence unconfounded?**

Several measures, such as mortality and overall plumage condition have been collected across all systems. But other information has been collected from different systems in different ways, and information on certain parameters relating to welfare is available for some systems only. For example, in most free range systems there were no data for mortality due to pecking/cannibalism nor were damage to feet, keel bones or skin recorded. These free range systems did record cases of bumble foot, but did not give feather scores subdivided into body areas. Data on behaviour were very scarce, with a few measures recorded for some small furnished cage and single-tier non-cage systems and for 1 trial in conventional cages. Perch use was the most recorded, but clearly does not apply to conventional cages and there were several other systems for which perching behaviour was not recorded in the LayWel database. Physiological measures of welfare were also not recorded in all systems. Some indicators simply cannot be applied evenly across systems, as illustrated by three examples.

Fearfulness: a number of potential measures of fearfulness in laying hens have been devised. These include the response of the bird to a novel object, or to a looming stimulus (Jones and others, 1981). However, the responses of birds to such stimuli are heavily constrained by the housing system they are in. A caged bird can investigate the object or move to the back of the cage but not further. A hen in an alternative system could fly many metres, wing flap or run away. In an alternative system measures such as 'flight distance' are used to assess flock behaviour but this measure cannot be applied to caged hens. Responses that are dictated by the system of interest can be used to compare birds within systems, but not to compare the welfare of birds in different systems.

Short-term Physiological Stress Response: corticosterone release in birds shows a strongly diurnal rhythm and is also affected by overall photoperiod (Westerhof and others, 1994; Sudhakumari and Halder, 2001). Lighting conditions vary between indoor and outdoor systems so differences in corticosterone measures may therefore reflect altered glucocorticoid baselines rather than hypothalamic-pituitary-adrenal (HPA) activation indicative of stress. Information about the extent to which background variables influence such welfare indicators is needed before they can be directly compared across systems.

Immune Function: there is abundant evidence linking elevated glucocorticoid concentrations with suppressed immune responses (Blecha, 2000). In poultry, prolonged activation of the HPA system is associated with decreased lymphocyte proliferation, so that an increase in the heterophil:lymphocyte (H:L) ratio is considered a good indicator of stress in birds (Gross and Siegel, 1983; Maxwell, 1993). This is particularly so if birds are housed under conditions where disease challenge is similar. However, if pathogen exposure rates vary greatly between systems, as is likely with these data, then leukocyte populations may alter dramatically, independently of HPA system activation, because heterophila and lymphopenia are a natural immunological defence mechanism against bacterial infection in hens (Maxwell and Robertson, 1998). Infection with parasites can actually impair pituitary and hypothalamic regulatory mechanisms (Elsasser and others, 2000) over the medium to long-term. Thus H:L ratios and other measures of immune function may give some valid information, which can be interpreted only in association with an evaluation of bird disease state and pathological analysis.

Confounding of genetic and rearing factors with system

The objective of LayWel is to draw conclusions regarding the welfare of birds in different laying housing systems. It is therefore important to consider whether the housing systems are systematically confounded by differences in bird genotype or rearing practice, as genetic and developmental differences will contribute to baseline differences in bird condition on entry to the housing system under investigation.

1. Bird Genotype

Commercial laying hen hybrids have principally been selected for productivity rather than for their adaptation to particular housing systems. Thus several hybrids are available in the EU and these can be found in all systems, although the distribution of strain across system varies. Table 7.1 shows that the distribution of strains across housing systems within the LayWel database was not uniform. Over 20% of multi-tier systems have, for example, used Hisex Brown birds, but this strain has rarely been studied in any other system. Thus genotype is a potentially confounding factor, as a welfare comparison of systems may to some degree incorporate an assessment of adaptivity of particular hybrids.

Table 7.1. The distribution of strains across housing systems
(relative % frequencies of strain within housing system in brackets).

Breed	Conventional cage	Small furnished cage	Medium furnished cage	Large furnished cage	Single tier	Multi tier
Isa brown	10 (52.6%)	13 (9.8%)	5 (10.2%)		14 (17.9%)	23 (22.7%)
Isa white		7 (5.3%)				1 < 1%
Lohmann Brown	4 (21.1%)	17 (12.8%)	12 (24.4%)	6 (14.3%)	9 (11.5%)	11 (10.9%)
LSL	3 (15.8%)	60 (45.4%)	23 (46.9%)	34 (80.9%)	8 (10.2%)	31 (30.7%)
Lohmann traditional			1 (2.0%)		8 (10.2%)	2 (2.0%)
Lohmann silver					6 (7.7%)	
Hyline brown	2 (10.5%)	13 (9.8%)	8 (16.3%)	2 (4.8%)	7 (8.9%)	
Hyline white		6 (4.5%)			4 (5.1%)	
Babcock		8 (6.1%)			2 (2.6%)	
Tetra					11 (14.1%)	
Bovans					1 (1.3%)	5 (4.9%)
Shaver 579		6 (4.5%)			6 (7.7%)	
Hellevad					2 (2.6%)	
Dekalb		1 < 1%				6 (5.9%)
Hisex Brown		1 < 1%				22 (21.8%)

2. *Baseline Differences Due to Rearing.*

A similarly complex picture involves the conditions under which the birds are reared from hatching to point of lay (Table 7.2). The complexity of the rearing environment can vary widely. The provision of resources such as perches, substrate, feeder and drinker type is not standardised, and flock size also varies. The rearing environment is known to affect the age at which birds come into lay, their production potential, health, physiology (Huber-Eicher, 1999) and foraging, feather pecking and dustbathing behaviour (Nicol and others, 2001), as well as cannibalism (Gunnarsson and others, 1999). The rearing environment can also affect bone strength and the number of broken bones sustained at depopulation (Gregory and others, 1991). As with genotype, there are currently no clear distinctions between rearing environments used for pullets according to subsequent laying systems, but pullets entering alternative systems are *more likely* to have been reared with additional furniture and on different lighting programmes.

Table 7.2. Rearing systems used prior to housing in the different laying systems (relative frequency of rearing system within housing system in brackets)

Rearing system	**Conventional cage**	**Small furnished cage**	**Medium furnished cage**	**Large furnished cage**	**Single tier**	**Multi tier**
Single tier	8 (47.0%)	35 (26.1%)	5 (16.1%)		75 (100%)	60 (61.9%)
Multi tier	2 (11.8%)	2 (1.5%)				34 (35.1%)
Cage	7 (41.2%)	97 (72.4%)	26 (83.9%)	32 (100%)		
Other						3 (3.1%)

It can be seen, for example, that no single or multi-tier systems have used birds reared in cages, but that studies of large group-size furnished cages have only used birds reared in cage. This reflects current belief that birds destined for non-cage systems are best reared in non-cage systems, although systematic evidence for this is not strong. Moreover, this presents a high degree of confounding in the current analysis of housing systems where only studies of conventional and small-group size furnished cages have experimentally examined the effects of rearing background.

3. *Beak trimming*

There was a difference between housing systems in the proportion of hens with intact or trimmed beaks. Table 7.3 shows that studies of furnished cages and multi-tier systems have been more likely to use non-beak trimmed birds. Given the known association between beak trimming and reduced mortality, the interpretation of housing effects on mortality must take this confound into account.

Table 7.3. Beak trimming practice in studies of different housing systems

Beak treatment	Conventional cage	Small furnished cage	Medium furnished cage	Large furnished cage	Single tier	Multi tier
none	10 (40.0%)	97 (68.8%)	19 (43.2%)	36 (87.8%)	40 (50.6%)	78 (75.0%)
Trimmed at 1-10 d	15 (60.0%)	44 (31.2%)	25 (56.8%)	5 (12.2%)	39 (49.4%)	26 (25.0%)

- **Is the evidence collected at the right level (i.e. system rather than flock)?**

  An important consideration when comparing the welfare of hens in current housing systems is that there may be no such thing as a 'typical' system. Continued innovation to improve bird welfare has led to a growing variety of large group systems. It is important to consider that the degree of variation in design and management practices *within* systems could exceed the differences that exist *between* systems (e.g. using the systems defined in WP2). Continuing rapid innovation by commercial producers such as the insertion of curtains and partitions in alternative systems, or the removal of partitions and addition of larger pecking and scratching areas within cages, blurs distinctions between systems. Variations within systems will themselves significantly affect bird health, production and welfare. Even when systems are nominally similar, the extent to which birds use the resources provided varies greatly. Thus, the percentage of the flock going outside varies widely within current UK free-range systems (Green and others, 2000).

These questions concerning the nature of the evidence have been considered in our evaluation of welfare.

Evaluation of welfare

Methods

The objective of WP7 is to assess the overall strengths and weaknesses of each defined housing system for laying hens, as well as the overall welfare impact of each housing system. In selecting the parameters to consider, the five freedoms provided a useful checklist to ensure that a range of measures was chosen. The five freedoms are popularly used as a baseline for animal welfare assessment and indicate that to experience good welfare an animal should be free from:

1) Injury, disease and pain
2) Fear and (dis)stress
3) physical discomfort
4) hunger and thirst (its diet should provide normal health and vigour)

and

5) should be free to express normal behaviour.

The LayWel partners spent some time carefully selecting the range of science-based outcomes used in the database. These therefore form the basis of our assessment in this WP7. However, as the database includes only welfare indicators, we have used the literature to incorporate supplementary information on bird choice where possible.

The two main methods we have used for integrating welfare are:

1. An analysis of the whole database
2. Welfare risk assessment

1. Database analysis

Data characterisation and selection

The first step was to characterise the data available in the LayWel database. The LayWel project was not intended to support many new research projects and this, together with the short timescale, has meant that the data available to evaluate have primarily been those from recent and ongoing studies. These studies were not designed to provide a comprehensive and balanced dataset. Nonetheless the database contains records from almost 1.2 million laying hens in seven different European countries.

Table 7.4 indicates that substantial data are available for three systems: small furnished cages (FC-small) with group sizes of up to 15 hens per cage; multi-tiered aviaries where nestboxes are separate from the tiers (MT-NN); and single tier non-cage systems (ST-NC). Data from 19 or more flocks are also available for conventional cage (CC) and a free range system (ST-NC+FR). Most of the non-cage system data came from commercial flocks. Whereas such data appear to be more relevant for the poultry industry, the lack of control of variables can affect the outcomes. For example, changes in diet may not be controlled and these have been shown to be one of the risk factors for outbreaks of feather pecking in epidemiological evaluation of commercial flocks (Green and others, 2000). For some of our data analysis, combinations of system types have been used, providing data from many flocks.

Table 7.4 Data available by housing system

System	No. of flocks	No. of replicates	No. of partners	Commercial flocks	Experimental or trial flocks
Conventional cage (CC)	19	32	6	5	14
FC-large	13	43	3	7	6
FC-medium	12	41	4	4	8
FC-small	71	143	6	50	21
MT-IN (Multi-tiered integrated nest)	4	8	2	0	4
MT-NC (Multi-tiered non cage)+CV+FR	7	7	1	7	0
MT-NN (Multi-tiered non-integrated nest)	74	83	3	65	9
MT-NN+CV+FR	6	6	1	6	0
ST-NC (single tier-non cage)	54	54	5	52	2
ST-NC+CV	11	11	2	11	0
ST-NC+CV+FR	7	7	1	7	0
ST-NC+FR	19	31	3	19	0

Note: FC denotes Furnished cage
CV denotes covered veranda ('Winter garden')
FR indicates unroofed outside area available for hens to range on

Overall analysis of database

As already indicated, the datasets were not designed to integrate for overall analysis. It is particularly important to appreciate that a line of data in the database may represent anything from the mean of a single replicate from a small experimental trial of relatively few hens up to the mean of six replicates of a large-scale commercial evaluation. It has not been feasible to weight the data accordingly because of differences in experimental designs. It is therefore important to be very cautious in drawing conclusions from comparisons of these data as a whole. Whilst in general there was agreement that overall statistical analysis was not appropriate, we have performed a limited amount of modelling, for mortality and plumage condition, for which there were the most data as they were recorded in almost all studies. The next most recorded variables were egg production and feed intake so a brief overview of these is included, although they are not key indicators of welfare.

Data were analysed using the GLM procedure in SPSS. A number of potentially important explanatory variables were confounded either partially (e.g. country with breed) or totally (e.g. hen colour with breed). Thus an iterative approach was taken involving addition and removal of explanatory variables until the best-fit model was obtained, assessed by the magnitude of the R-Squared value. Judgement was also required as to the number of levels at which to categorise explanatory variables. Housing system was categorised at 6 levels: conventional cages, single tier systems, multi-tier systems, furnished cages (small groups), furnished cages (medium groups) and furnished cages (large groups).

With a large and more balanced dataset it would be worth employing multi-level or hierarchical analysis techniques e.g. to examine the effects of breed within housing system within country. This was not possible with the data available.

2. Welfare risk assessment

The traffic light approach

The comparison of welfare across systems for The European Food Safety Authority took the approach of estimating the risk for welfare of important factors for each system (EFSA, 2005). In this LayWel study we have built on that by using a 'traffic light' approach to compare welfare outcomes and risks to good welfare across systems. This uses colour coding to indicate the probable risk for welfare based on data (principally from LayWel) that has been screened for quality, supported by background information from preference tests and expert opinion. This is a simplification of benchmarking as a means of assessing welfare (e.g. Huxley and others, 2004).

In essence our system uses **green** to denote the probability of good or satisfactory welfare or performance. In this report we shall use it to denote a low risk of poor welfare. Green coding may not always represent *optimal* welfare, but invariably the probability of at least good welfare, based on results available to date.

Orange denotes a medium risk of poor welfare. We also use it to indicate factors that are highly variable (within systems or between farms).

Red indicates a high risk of poor welfare. Often the housing system simply does not provide the facilities required - or the characteristics are such that there is very high risk of undesirable outcomes without extreme vigilance, as indicated by recent data from LayWel and other studies.

Please note that the ***risk*** *of poor welfare is being indicated. Thus in many cases it is possible for flocks within housing systems where an indicator is coloured red or orange to actually achieve good welfare. The system is not labelling systems as 'good' or 'bad' in terms of welfare.*

The colour coding enables a visual integration of relative welfare risk to the whole flock, but does not weight the different outcomes nor indicate the suffering of small numbers of individual hens. Duration, severity and proportion of flock affected are the main issues considered in colour coding. In the main, the welfare assessment is on a flock basis. The table of welfare risks and outcomes enables visual integration within and between systems.

Current best practice

For some key welfare indicators in each category of housing system we have also compiled a table of numerical data representing the best results, where available. These indicate what is currently achievable in terms of improved welfare with better design, maintenance, management, husbandry and genotypes in the various housing systems. These 'best figures' may coincide with industry best practice; particularly where data are available from commercial farms (several examples in the LayWel database). In order that the figures are representative, we have mainly selected data that have been published in peer-reviewed journals or those data from the LayWel database that represent relatively large and replicated studies. Alternatively we have given small ranges or limits indicating what has been achieved in well-designed but unpublished studies. Whereas the preferred format for such data is medians and ranges, means are more commonly reported and these have been used.

Following these summarising tables is a short list and discussion of some of the main welfare indicators based on the conclusions of the other WPs. We also discuss the strengths and weaknesses of each principal housing system.

Results

1. Database analysis

Co-variation in welfare indicators

Regardless of housing system it is possible from the available database to determine whether there are significant correlations between the different welfare indicators employed at the flock level. Production variables were not included in these analyses. Bivariate correlations were examined where a minimum of 12 flocks was available. To reduce errors associated with multiple unplanned comparisons only results where $p < 0.01$ are reported.

Only a handful of correlations were significant at chosen level. Bird mortality was negatively associated with the percentage of birds perching (Pearson –0.53, n = 114, $p < 0.001$) and positively associated with the proportion of birds with pecks to the comb (Pearson 0.26, n = 131, p = 0.003). Although the sample size was very small, there was also a strong negative correlation between heterophil:lymphocyte ratio and mortality (Pearson –0.69, n = 14, $p < 0.001$). The percentage of birds perching was negatively associated with water intake (Pearson, - 0.65, n = 24, $p < 0.001$).

It is difficult to draw too many conclusions about the general lack of correlations between indicators, as the number of flocks available with data on both indicators was too small to analyse in many cases. However, there were still hundreds of comparisons where correlations might have been detected and were not. As indicated in the introduction, one of the major challenges in drawing overall conclusions about bird welfare is a lack of association between the different indicators assessed. This appears to be a problem with the current LayWel database on European hen welfare.

Mortality

Using all the available data on mortality, a model was produced with an R-Squared value of 0.55 (adjusted value 0.51). Some variables did not explain significant amounts of variation in bird mortality (e.g. rearing system) but there were five variables that were significantly associated with bird mortality. These were:

- **beak trimming** - significantly higher mortality in groups of non-beak trimmed hens (F=21.5, d.f. 1, 331; p<0.0001)
- **season** (F=7.7, d.f. 4, 331; p<0.0001). Birds placed in laying accommodation in the winter months had lower mortality than birds placed in laying accommodation at other times of year.
- **an interaction between housing system and whether the study of that housing system was conducted on commercial farms, experimental units or in a large-scale semi-commercial test facility** (F=5.3, d.f. 11, 331; p<0.001). It is interesting and important that there was no significant main effect of housing system, only an interaction with whether the system was run under truly commercial conditions or within a scientific institute. This suggests that differing management practices had just as big an impact on bird mortality as the housing systems themselves. The nature of the interaction is important. Mortality in conventional cages, single-tier systems, and furnished cages with medium or large groups was much greater under experimental conditions than under commercial or test-scale conditions. Mortality in multi-tier systems was not greatly affected by whether the conditions were commercial or experimental. In small-group furnished cages, the lowest mortality was found under test-scale conditions, with little difference between commercial and experimental conditions.
- **feather colour** (F=5.0, d.f. 3; 331; p=0.002) – the analysis compared white, brown and hybrid birds, and studies that had housed a mixture of brown and white birds. Overall white-feathered genotypes appeared to show lower mortality than brown-feathered hens.
- **country** (F=4.2, d.f. 5, 331; p=0.001).

The significant effect of all these factors when included together in one model shows that they are all important. Thus, even though different countries studied different systems, genotypes and beak-trimming practices, residual differences between countries existed once these other explanatory variables had been included in the model. However, the degree of confounding within the data base makes interpretation of the results quite complex by simple examination of grouped means. It is well established both scientifically and from practical experience that beak trimming reduces mortality in general, which is why the practice came to be used. It might however be a peculiarity of the LayWel data that beak-trimmed white birds had an average 6% mortality, which was more than doubled in brown birds with intact beaks, as there was not an even distribution of the number of birds of each genotype across systems, nor of beak treatment. Other risk factors such as group size could be more relevant predictors of mortality, and this is indicated by significantly greater mortality with larger group size in furnished cages and in non-cage systems (see WP3). However, some recent evidence gathered since the LayWel data base was closed, from groups of 40 and 60 hens in large furnished cages in the UK suggests that such cages, if well designed and managed, can have good feathering and low mortality even with intact beaked hens (Elson, 2005, personal communication).

For the database as a whole, mortality attributed to feather pecking and/or cannibalism accounted for approximately one third of all mortality. This varied between housing systems. Although there was no significant effect of rearing system on overall mortality, a more informal examination of the subset of data relating to subsequent mortality attributed to feather pecking and/or cannibalism in laying housing systems shows a possible relationship with rearing system, as shown in table 7.5.

There were too few and highly variable data records to analyse these relationships formally but it would be informative if future studies could examine the consequences of rearing pullets in furnished cages if this was to be their housing system during lay. Indeed there is a pressing need both for new systematic experimental work on the design and influence of rearing systems on subsequent welfare of laying hens in all housing systems, and for all studies and commercial producers to record and monitor the impact of rearing systems.

Table 7.5 Effect of rearing system on mortality due to pecking or cannibalism in the main categories of housing system

Average percentage mortality due to pecking/ cannibalism +/- s.dev	**Housing system**		
Rearing system	**conventional cage**	**furnished cage**	**Non cage**
single floor	23.6 +/- 23.3	15.1 +/- 17.1	6.1 +/- 7.2
multi tier			3.8 +/- 3.5
cages	0.9 +/- 0.9	11.9 +/- 12.0	
single floor and multi tier			1.8 +/- 2.2
cages and single tier			6.0 +/- 6.2

Plumage condition

The majority of studies included in the database had assessed plumage scores on scales that could be and were converted to a 100 point scale, where 100 represents full feather cover. Using these data, feather cover on average was similarly poor in the three main categories of housing system, with mean overall plumage scores of 45 (see Figure 7.1). There was considerable variation between as well as within housing systems (see also WP3).

However, a significant minority of studies had not assessed plumage scores but had, rather, assessed the percentage of birds within a flock with poor feather cover. In order to include *all* studies with information on plumage together in one analysis, the following steps were taken:

The plumage scores on the 0 – 100 scale were relatively normally distributed. The mean and standard deviation of plumage scores were calculated as 40.6 sd 23.2. The flocks were re-classified into four categories: good (scores > 1sd above the mean),

above average (scores 0-1sd above the mean), below average (scores 0-1sd below the mean) and poor (scores > 1sd below the mean).
The data on proportion of birds in a flock with poor plumage were not normally distributed. The median and inter-quartile range were therefore used to re-classify flocks into good (< 7.5% with poor plumage), above average (7.5-15.5% with poor plumage), below average (15.5.-35.5% with poor plumage) and poor (> 35.5% with poor plumage).

Although this is a rough and ready method of re-classification it does permit inclusion of data from ALL flocks within the database into the same analysis of factors associated with poor plumage. A model was produced with an R-Squared value of 0.46 (adjusted value 0.38). Some variables did not explain significant amounts of variation in bird mortality. There was no main effect of housing system and, surprisingly, no effect of beak treatment, once other explanatory variables had been entered. However, there were five explanatory variables that were significantly associated with plumage category. These were:

- **rearing system** (F=10.2, d.f. 3; 207, p<0.0001) Birds reared in floor systems tended to have better plumage than birds reared in cages.
- **country** (F=7.2, d.f. 6, 207, p<0.0001)
- **feather colour** - white birds tended to have better feather cover (F=6.5, d.f. 4, 207; p<0.0001)
- **season** (F=4.5, d.f. 4, 207; p=0.002) Birds placed in laying accommodation in spring or summer months tended to have better plumage than birds placed in autumn or winter
- **Interaction between housing category and whether the study of that housing system was conducted on commercial farms or experimental units** (F = 3.4; d.f. 5, 207; p = 0.005). In general, commercial conditions in conventional cages and small-group furnished cages resulted in better plumage than experimental conditions, but the converse was the case for single-tier, multi-tier and large group furnished cage systems.

The lack of an effect of beak treatment on plumage compared to its important effect on mortality, suggests that beak trimming may have a stronger influence on reducing severe injurious pecking resulting in cannibalism than it does on the type of gentle feather pecking that may reduce plumage condition.

The very strong significant effect of rearing system on plumage condition is interesting. It suggests again that there is a need for more information on the factors in rearing that affect subsequent welfare.

Production

Recorded egg production was higher in cage than non-cage systems on average and this could reflect misplaced eggs in non-cage systems or indeed be a biological reality related to greater temperature fluctuations and exercise levels. See WP 6 for more details.

Feed intake

Unsurprisingly, feed consumption was higher in non-cage systems in which the hens exercise more and may have access to range and be exposed to greater variation in ambient temperature. The feed conversion rate (FCR) was correspondingly poorer than cage systems. See WP 6 for more details. This is of course not a concern for the welfare of the hens.

Relationships between these variables

Considering the four variables outlined above, there was little difference between average values for the three main system categories (i.e. conventional cages, furnished cages and non-cage systems).

Figure 7.1 shows that in non cage systems overall, there was a tendency for productivity to be lower, for feather cover to be improved and for mortality to be higher compared with cage systems. However it is necessary to examine the systems in more detail because of variability and because of the limitations of the database already discussed.

More relevant for many stakeholders is a comparison of the three systems with substantial data obtained from commercial farms, which are small furnished cages (FC-small) with group sizes of up to 15 hens per cage; multi-tiered aviaries where nestboxes are separate from the tiers (MT-NN); and single tier non-cage systems (ST-NC) (see Table 7.4). So, considering just these three systems, Figure 7.2 indicates that productivity was on average better in single tier non-cage systems, due in part to lower mortality. There was high variation in plumage scores within systems. On average feather cover was poor in multi-tier aviaries with non-integrated nestboxes, yet single tier non-cage systems showed the greatest variation from flocks with full feather cover and undamaged plumage (score 100) to those almost denuded with mean overall scores of 13. Table 7.6 shows the proportion of these flocks that were beak-trimmed, where this information was recorded.

Note that the differences shown in figures 7.1 and 7.2 may not be statistically significant – they merely indicate the arithmetical means from the LayWel database and not even the mean of all individual birds that were scored. However the means shown in Figure 7.2 are for the three systems that had the most data – over 50 studies per system in 3 or more countries and mainly of commercial flocks - and are likely to be much more representative of these three particular systems. (All the data entered in the database are included for these three housing systems in Figure 7.2).

Figure 7.1 A comparison of mean (& st.dev.) egg production, feed intake, plumage (feather) score and laying hen mortality between all non-cage, conventional cage and furnished cage systems
[using all the data available from the LayWel database for all housing systems]

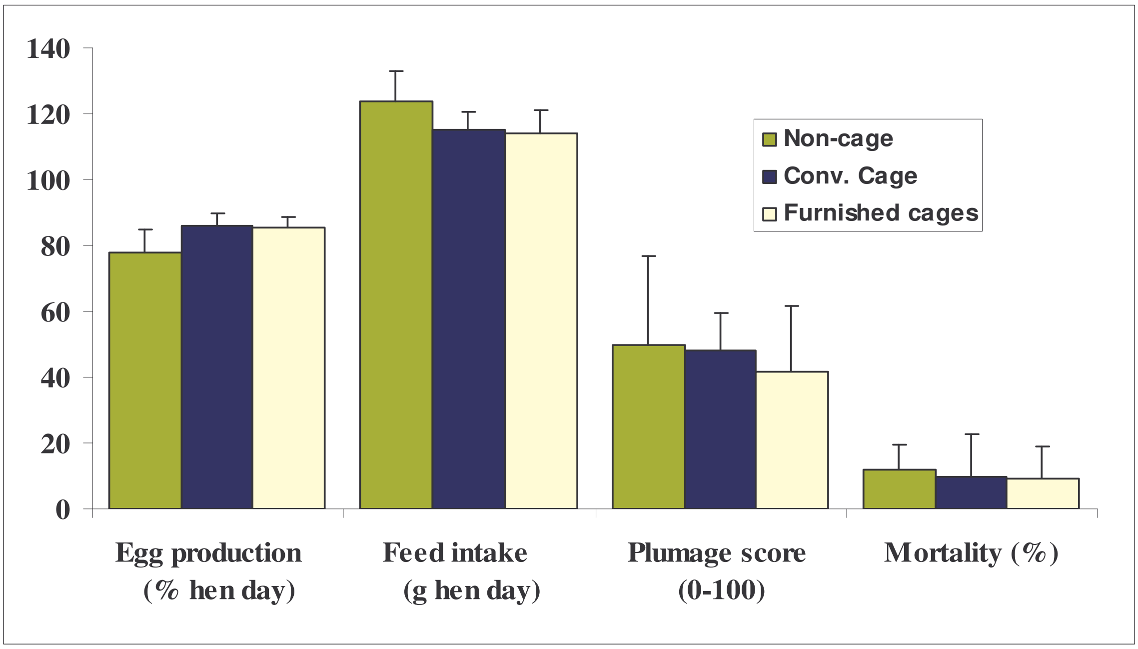

Figure 7.2 A comparison of mean (& st.dev.) egg production, feed intake, feather score and laying hen mortality between single tier non-cage (ST-NC), multi-tier (MT-NN) and small furnished cage (FC-small) systems *[data from the LayWel database for three housing systems each with over 50 studies in 3 or more countries]*

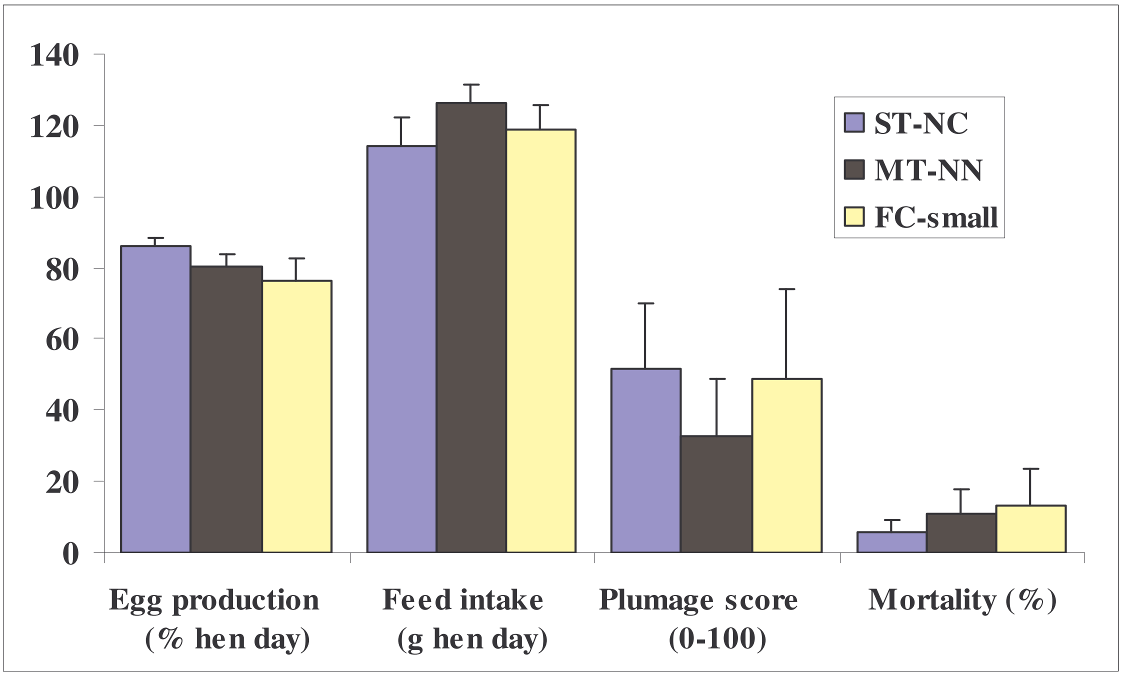

Table 7.6 Beak trimming practice in three systems

Beak treatment	**single tier non-cage**	**multi-tier** (MT-NN)	**FC-small** (<16 birds)
None	9 (30.0%)	77 (92.8%)	97 (69.3%)
Trimmed at 1-10 d	21 (70.0%)	6 (7.2%)	43 (30.7%)

2. Welfare risk assessment in different housing systems

The risks to welfare for the main systems of laying hen housing are colour coded according to the 'traffic light system' in Table 7.7. These risks have been assessed by using evidence-based expert opinion from the EFSA report and updated using evidence from our LayWel database. We have included some production parameters that were measured in LayWel studies, and which do not necessarily indicate welfare, but which may be associated with reduced welfare as indicated in WP6. Where there is insufficient evidence to make a risk assessment, cells have been left uncoloured.

*Please note that the **risk** of poor welfare is being indicated. Thus in some cases it is possible for flocks within housing systems where an indicator is coloured red or orange to actually achieve good welfare. The table is not labelling systems as 'good' or 'bad' in terms of welfare.*

Welfare in best current practice

Table 7.8 gives figures for some practical welfare indicators in different systems of laying hen housing, using data from replicated recent studies, principally from the LayWel database. Data from studies with fewer than two replicates were excluded, irrespective of the number of birds in the study. It is accepted that some of these figures may be rapidly superseded as system development, management and commercial practice change. For each parameter, the data given are the best values from commercial or experimental studies. Again there are still gaps to be filled in our knowledge of the welfare impact of different housing systems, particularly in terms of bird use of the facilities.

Table 7.7 Indicator / risk of poor welfare	Conventional cage	Furnished cage			Non-cage		Outdoor	Comments
		small	medium	large	single level	multi level		
Injury, disease and pain								
mortality (overall %)	yellow	yellow	yellow	yellow	red	red	red	
mortality due to feather-pecking /cannibalism in beak trimmed flocks	green	yellow	yellow	yellow	yellow	yellow	yellow	Genotype affects
mortality due to feather-pecking /cannibalism in non beak trimmed flocks	yellow	yellow	red	red	red	red	red	Genotype affects
mortality due to disease	green	yellow	yellow	yellow	yellow	yellow	yellow	
infectious disease and use of therapeutic drugs	green	green	green	green	yellow	yellow	yellow	Generally very low but more variable in non-cage systems, especially outdoor access
predation	green	green	green	green	green	green	yellow	low-variable in non-cage
internal parasites	green	green	green	green	red	red	red	
external parasites (red mite etc)	yellow	yellow	yellow	yellow	yellow	yellow	yellow	
use of prophylactic anthelmintics and coccidiostats	green	green	green	green	yellow	yellow	yellow	Variable - outdoor highest risk
osteoporosis/ low bone strength	red	yellow	yellow	yellow	green	green	green	
keel bone deformation	green	yellow	yellow	yellow	yellow	yellow	yellow	
bone breaks during lay	green	yellow	yellow	yellow	red	red	red	
bone breaks at depopulation	red	red	red	red	yellow	yellow	yellow	
bumble foot	green	yellow	yellow	yellow	red	red	red	Variable, usually low
beak trimming	yellow	yellow	red	red	red	red	red	Beak trimming more likely in larger groups
Hunger, thirst and productivity								
feed intake (g hen day)	green	green	green	green	green	green	green	Hens can usually eat to appetite
water intake	green	green	green	green	green	green	yellow	Water is generally freely available but outdoor hens may need to travel further and water could freeze in winter
FCR	yellow	yellow	yellow	yellow	yellow	yellow	yellow	high productivity may increase risk of osteoporosis and fractures
egg production (% hen day)	yellow	yellow	yellow	yellow	yellow	yellow	yellow	high productivity may increase risk of osteoporosis and fractures

Indicator / risk of poor welfare	Conventional cage	Furnished cage			Non-cage		Outdoor	Comments
		small	medium	large	single level	multi level		
Behaviour								
nest box eggs at peak lay (%)	RED	GREEN	GREEN	GREEN	GREEN	GREEN	ORANGE	Some birds may lay outside
hens on perch at night (%)	RED	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	Variable - can be 100%
use of dustbath	RED	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	Variable
foraging	RED	ORANGE	ORANGE	ORANGE	GREEN	GREEN	GREEN	
social	RED	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	Abnormal social behaviour in large group sizes or restricted space allowance
behavioural restriction	RED	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	GREEN	
injurious pecking	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	variable risk increases with intact beaks
Fear, stress & discomfort								
fearfulness	RED	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	'victims' no refuge in conventional cage
corticosterone (end of lay)								
H:L ratio (end of lay)								
crowding/suffocation	GREEN	GREEN	GREEN	ORANGE	RED	ORANGE	ORANGE	
feather pecking in beak trimmed flocks	GREEN	GREEN			ORANGE	ORANGE	ORANGE	
feather pecking in non-beak trimmed flocks	RED	RED			RED	RED	ORANGE	Highly variable in most systems, with influence of genotype
feather loss	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	
plumage soiling	GREEN	GREEN	GREEN	GREEN	ORANGE	ORANGE	ORANGE	
bumble foot	GREEN	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	variation within and between flocks
thermal discomfort	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	
dust	GREEN	ORANGE	ORANGE	ORANGE	RED	RED	ORANGE	
ammonia	GREEN	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	
dirty eggs (%)	GREEN	ORANGE	ORANGE	ORANGE	ORANGE	ORANGE	RED	

KEY

- 'RED' areas where risk of poor welfare is high
- 'ORANGE' areas where risk of poor welfare is variable
- 'GREEN' areas where the risk of poor welfare is low
- unknown risk to welfare (insufficient data)

Table 7.8 Best results achieved in recent measurements in terms of laying hen welfare. Note that each indicator is considered separately; thus it is unlikely that a given study rated the best in all indicators of welfare.

Indicator	Conventional cage	Furnished cage			Non-cage		Outdoor	Comments
		small	medium	large	single level	multi level		
Mortality (%)	<3.0	<3.0	<3.0	<3.0	<3.5%	<3.0	<4.0%	Although individual studies show lower mortality, these were not well-replicated
Mortality due to feather pecking and/or cannibalism	(0.0-1.0)	0.0	0.1		(0.0-0.3)	0.3		limited data therefore indicative ranges given for some housing systems
Red mite treatment	none	none	none	none	none	none	none	indicates insufficient infestation for treatment
Bumble foot score	100	100	100	100	100	96	100	100 indicates no sign of bumble foot lesions
Feather cover	65	83	46	52	44	68		100 is maximal feather cover, thus most systems poor welfare
Use of nest boxes	N/A	97.8	99.3	99.5	99.1	99.7		Nestbox eggs at peak lay (%)
Use of perches	N/A	91.0	65.1	76.6	50.1	88.3		100% is maximal use of perches
Foraging behaviour	N/A							
Dustbathing behaviour	N/A				0.3			instances/bird/hour
Air quality								

More studies needed - insufficient data available

Key welfare indicators

The studies and reviews of the other WPs have found the following list of welfare indicators to currently be the most practicable and relevant for measuring laying hen welfare. These indicators have been frequently measured in studies to date, although it is hoped that future studies will encompass a broader range of indicators. Where possible they are animal-based measures that reflect what is important to the laying hen. Most are robust in terms of reliability and feasibility for measuring in commercial units. By monitoring these indicators hen welfare may be improved if action is taken to improve the underlying problems (*some examples are given*). These key welfare indicators form the basis for the self-assessment of laying hen welfare on farm (the manual for task 7.2) and are used for table 7.8.

- Mortality (*in most cases death is the end point of a long period of suffering or sub-optimal welfare and other birds that have not died may be experiencing similar stress – if probable causes of death are established, suitable action may be taken to alleviate the stressful conditions*)
- Mortality due to feather pecking and/or cannibalism (*this abnormal behaviour can spread rapidly through a flock and mortality levels may become excessive without rapid action – in the short term, identifying and removing aggressive hens or dimming the lights may be effective. As part of a flock health plan and good management, choice of appropriate genotypes, diets and enriched environments with good foraging opportunities as well as rearing pullets in suitable conditions should be considered to prevent these problems).*
- Presence (and levels of) of Red mite infestation (*this is an increasingly common problem where affected birds may suffer discomfort, anaemia and weight loss over a prolonged period – thorough disinfection and fumigation of housing between flocks is essential but levels should be continually monitored using traps*)
- Presence (and levels of) of Bumble foot (*which indicate poor hygiene and/or improper perch design – action should be taken to clean perches and to keep hens' feet clean from dirt and faeces - for example by having a slatted or hardcore area around pop-holes or by adding fresh clean litter*)
- Use of nest boxes (*if use of nest boxes is not approaching 100% then design and layout should be altered – it may help to observe the birds – normal nesting is a behavioural priority essential for good laying hen welfare. Pullets should be introduced to nest boxes before point of lay*)
- Use of perches (*perching, particularly at night is normal hen behaviour – if most birds are not perching then perch space or design needs to be altered*)
- Presence of and use of substrate for foraging and dustbathing (*hens need to spend time foraging for normal behaviour and welfare – if a suitable substrate is not provided then problems such as feather pecking and cannibalism can result*)
- Feather cover (*poor feather cover indicates abrasion from fittings and fixtures in the house or more commonly feather pecking from other birds, which is painful and may be associated with fear. Poor feather cover*

increases heat loss and discomfort in cooler weather, as well as having economic consequences of increased feed consumption)

- Air quality (*if levels of dust and ammonia are sufficient to be noticeable and irritating to humans then they are likely to cause health problems for birds*)
- Water intake (*high levels of water intake may be associated with heat stress or with boredom in barren housing conditions*)
- Sudden changes in feed or water intake (*these may predict onset of infectious disease for example*)
- Sudden decreases in production (*may be associated with infectious disease for example*)
- Aspects of egg quality (*dirty eggs indicate poor hygiene, red spots may indicate presence of red mite, blood smears can be associated with vent or cloacal pecking damage, calcium spots may be associated with stress*)

3. Advantages and disadvantages of different housing systems for the welfare of laying hens

Disadvantages in all systems

There are some management practices or conditions that reduce welfare in all or most systems and they include the following:

Beak trimming

Beak trimming is still widely used in many EC countries (although prohibited in some) to reduce the risk of pecking injuries and mortality, and there is good evidence that this practice is painful, and depending on methodology, can be chronically painful over a prolonged time as well as being acutely painful (Hughes and Gentle 1995). The principal disadvantage is that all birds are treated to reduce the possible (not definite) risk to welfare of some of the flock. Victims of severe feather pecking and cannibalism may suffer more than if they were beak trimmed (although this has for obvious reasons not been scientifically examined), but the goal should be to design and manage systems (particularly rearing systems) and to select genotypes to minimise the risk of agonistic behaviour. Birds housed in larger groups are most likely to be beak trimmed, so the risk of mutilation is lower in small cages. A previous epidemiological study in the UK of brown feathered genotypes found risk factors associated with outbreaks of feather pecking included the use of bell drinkers, several changes in diet, absence of loose litter at the end of lay and a temperature in the laying house of below 20^{o}C (Green *and others*, 2000). These factors did not necessarily cause or promote feather pecking, and it is still not understood what triggers this behaviour in hens. More recent UK data on Shaver 579 Leghorn hens in commercial units found that the incidence of both gentle and severe feather pecking was reduced as group size increased (from 2450 to 4200 birds/flock) and where bell drinkers rather than nipple drinkers were provided (see 4.6 for details).

Skeletal weakness The high productivity of the modern laying hen causes osteoporosis that is compounded in conventional cages by disuse osteoporosis, but present to a sufficient degree in all systems to present a substantial risk of fractures during handling at the end of lay. Recent evidence suggests that a high proportion of birds sustain keel bone fractures in all systems (compounded in non-cage systems by risk of crashing) at some point during the laying period.

Bumble foot

This is a variable risk in all systems that provide perches (thus rare in conventional cages). Risk is reduced by good hygiene and keeping the feet of birds clean from mud and faeces, as well as by good perch design. Although generally of relatively low prevalence, welfare of affected birds in its acute stage is compromised by inflammation and severe swelling of the foot pad making normal walking and perching impossible.

Conventional cages

The evidence from this report has in the main substantiated previous scientific knowledge that the welfare of laying hens is severely compromised in conventional cages (for example, see review by Baxter, 1994).

***Disadvantages*:**

The main disadvantages are discomfort and abnormal behaviour which are inherent to the system. The design of the system does not allow birds sufficient space for exercise, thus restricting or preventing behaviours such as wing flapping and flying, and leading to disuse osteoporosis that renders birds susceptible to fractures on depopulation. Our current knowledge indicates that the most important deficiency from the birds' perspective is the lack of provision of a discrete, enclosed nesting area. Nesting is a behavioural priority for hens. Moreover perching, dustbathing and foraging are also very important parts of the normal behavioural repertoire that cannot be (fully) expressed in conventional cages. Birds will work to gain access to perches at night, so lack of prevision of perches denies normal roosting behaviour for a substantial proportion of the whole day. There is some evidence that hens in conventional cages have insufficient space to maintain a normal 'personal space' and to escape from bullying by companions. Physiological stress levels are also higher in birds subject to spatial restriction.

***Advantages*:**

The main advantages are relatively low risk of disease and parasitism associated with better hygiene than many other housing systems.
The small group size generally leads to a stable social hierarchy and lower risk of damaging feather pecking, cannibalism and smothering. The absence of litter in the system and the separation of birds from their faeces are usually associated with improved hygiene with cleaner eggs, low levels of parasitism (internal and external), bumble foot and reduced aerial pollution. Despite having fewer crevices for red mites to lodge in, outbreaks of infestation can occur, which is why the cell in Table 7.7 is coloured orange. Whilst mortality is on average lower than in other systems, outbreaks of cannibalism and disease are still possible, and these can create significant welfare problems. This was the case in one trial in our study, which increased overall average mortality for LayWel to higher levels than industry average, owing to the small dataset. There is negligible risk of predation, as the birds are completely enclosed in wire cages. Restriction of movement and lack of perches leads to a low risk of keel bone deformation and of fractures during production.

Furnished cages

Disadvantages**:**

The disadvantages of furnished cages do not appear to be inherent to the system but depend more on specific design, features, genotype and group size. Thus, risks of feather pecking and cannibalism leading to high mortality are increased in brown-feathered genotypes than in white hens and may increase with group size, especially in non beak trimmed birds, although recent UK data from cages of 40 and 60 hens suggest that mortality can be low (Elson, 2005, personal communication). Whilst the behavioural repertoire is significantly improved in comparison with conventional cages, aspects may not be considered to be normal. The low proportion of hens performing foraging behaviour and the absence of complete dustbaths in furnished cage systems indicate that the substrate areas in these systems do not fulfil the needs of the hens, confirming the results of earlier studies in furnished cage systems. Birds make use of the perches during the day for substantial (around 40-50%) amounts of time, and this is associated with keel bone damage (LayWel data; Vits and others, 2005). There are insufficient data to compare levels of keel bone deformity with those found in non-cage systems, nor is it established whether the condition has a detrimental effect on bird welfare. Hens kept in any of the four small furnished cage models compared did not differ in level of feather pecking or aggressive pecking. However the use of dustbaths varied between averages of 21 and 81% depending on cage model (see 4.6). Thus there clearly is a need for more research and development in design of furnished cages and implementation of current knowledge, reviewed by Tauson (2005).

Advantages**:**

Furnished cages retain many of the advantages of conventional cages without the drawback of severe behavioural restriction. The main advantages are better hygiene than most non-cage systems, so on average use of preventive drugs including coccidiostats is low, reflecting a low risk of infection with parasites or other infectious agents. Mortality is generally low, particularly in well-tested designs, and with experience of managing FC. High mortality can occur, particularly with some non-beak trimmed genotypes. Plumage is generally clean, but there is a variable risk of bumblefoot and red mite infestation. Although variable, up to 100% use of nestboxes in small furnished cages was recorded indicating that when well designed and managed, the systems meet the behavioural priority of hens for a discrete enclosed area for laying. Both bone strength and the behavioural repertoire are significantly improved in comparison with conventional cages.

Non-cage systems

***Disadvantages*:**

The main disadvantages are highly variable risks of feather pecking and cannibalism, leading in a few flocks to extremely high mortality and poor bird welfare. Mortality in well-replicated LayWel studies varied between a low 1.1% and a high 36.8% in single tier systems (ST-NC) with a similar range of between 2.2% and 35.3% in multi-tier systems (MT-NN). More research and refinement of system design and management is needed to prevent the high levels of mortality.

There is a high risk of hens sustaining fractures, with recent studies indicating about half the birds are affected (Wilkins and others, 2004; Nicol and others, 2006). The timing and causes of these fractures is poorly understood but is likely to include collision damage with perches, nestboxes and other structures.

There is a risk of subordinate birds having reduced access to feed, water (and range) due to bullying by dominant hens.

The risk of smothering is increased compared with small group (cage) systems.

The risk of internal parasites is relatively high in litter-based systems and very high in those with outdoor runs, but the use of anthelmintics and coccidiostats can limit the burden and thereby ensure good welfare for the birds, if their use is permitted.

There is a risk from predation that can be minimised with the use of electric fencing and shelter for example.

There is an increased risk of disease due to contact with droppings and in free-range systems due to contact with wild birds as well (e.g. this is thought to increase risk of contracting avian 'flu).

Aerial pollution tends to be high in litter-based systems and this can not only increase the load of infective agents but also depress the immune system. Good ventilation and reduced stocking rates can reduce the risk of problems.

House layout and equipment can often make inspection and catching of birds for treatment and at depopulation more difficult.

***Advantages*:**

The main advantages are a greater opportunity to express the full behavioural repertoire, especially foraging and particularly in free-range systems. Although variable, up to 100% use of nestboxes was recorded indicating that when well designed and managed, the systems meet the behavioural priority of hens for a discrete enclosed area for laying.

Hens have the freedom to exercise, including wing-flapping and flying and this increases bone strength.

Increased space availability can give submissive hens the opportunity to avoid aggressive birds.

Overall welfare impact

With the exception of conventional cages, we conclude that all systems have the potential to provide satisfactory welfare for laying hens. However this potential is not always realised in practice. Among the numerous explanations are management, climate, design, different responses by different genotypes and interacting effects. For example there was different use of nestboxes in furnished cages by different genotypes. The design of small furnished cages also had a significant impact on dustbath use.

All cage systems tend to provide a more hygienic environment with low risk of parasitic disease. There is possibly a high risk of poor welfare on a flock basis in all systems with larger group sizes (above approximately 10-15 birds) from damaging pecking and cannibalism. All laying hens also are at high risk from sustaining fractures both during the laying period and at depopulation. There is evidence that both these problems are associated with genetic selection for high productivity. Some existing genotypes (mainly white feathered) show a lower tendency for damaging pecking. Much greater emphasis should be placed on selecting genotypes with reduced damaging feather pecking tendencies for use in alternative housing systems for laying hens. Recent studies have shown that bone strength can be improved in laying hens by selection over only one or two generations without a great decrease in productivity (Fleming and others, 2005). For good laying hen welfare it is a priority that action be taken to reduce the current unacceptable level of fractures sustained during the laying period in all systems apart from conventional cages. This is likely to involve a combined approach of selective breeding, plus refinements to design and management including lighting.

Conventional cages do not allow hens to fulfil behaviour priorities, preferences and needs for nesting, perching, foraging and dustbathing in particular. The severe spatial restriction also leads to disuse osteoporosis. We believe these disadvantages outweigh the advantages of reduced parasitism, good hygiene and simpler management. The advantages can be matched by other systems that also enable a much fuller expression of normal behaviour. A reason for this decision is the fact that every individual hen is affected for the duration of the laying period by behavioural restriction. Most other advantages and disadvantages are much less certain and seldom affect all individuals to a similar degree.

References

Abeyesinghe, S.M., Nicol, C.J., Hartnell, S.J. and Wathes, C.M. (2005) Can domestic fowl show self-control? *Anim. Behav*. 70: 1-11

Appleby, M.C. and Hughes, B.O. (1991) Welfare of laying hens in cages and alternative systems - environmental, physical and behavioral aspects. *World's Poultry Science Journal* 47: 109-128.

Appleby, M.C., Walker, A.W., Nicol, C.J., Lindberg, A.C., Freire, R. and Elson, H.A. (2002). The development of furnished cages for laying hens. *Br. Poult. Sci*. 43: 489-500

Baxter, M.R. (1994) The welfare problems of laying hens in battery cages. *Veterinary Record*, 134 (24), 614-619.

Blecha, F. (2000) Immune system response to stress. *In*: The Biology of Animal Stress, eds G.P. Moberg and J.A. Mench, CABI Publishing pp. 111-122

Broom, D.M., Mendl, M.T., Zanella, A.J. (1995). A comparison of the welfare of sows in different housing conditions. *Anim. Sci* 61: 369-381

Elsasser, T.H., Klasing, K.C., Filipov, N. and Thompson, F. (2000) The metabolic consequences of stress: targets for stress and priorities of nutrient use. In: The Biology of Animal Stress, eds G.P. Moberg and J.A. Mench, CABI Publishing, pp 77 - 110

EFSA (2005) The welfare aspects of various systems of keeping laying hens. Annex to *The EFSA Journal*, 197, 1-23. EFSA-Q-2003-92

Fleming, R.H., McCormack, H.A., McTeir,. L. and Whitehead, C.C. (2005) Environmental and genetic effects on osteoclast recruitment in osteoporitic avian bone. Journal of bone and mineral research, 20 : 1307 abstr *and see also*: website <http://www2.defra.gov.uk/research/project_data/More.asp?I=AW1127&SCOPE=0&M=CFO&V=RI#Desc>).

GRADE, (2004) Grading quality of evidence and strength of recommendations. British Medical Journal, 328: 1490-1498

Gregory, N.G., Wilkins, L.J., Kestin, S.C., Belyavin, C.G. and Alvey, D.M. (1991) Effect of husbandry system on broken bones and bone strength in hens. *Veterinary Record* 128, 397-399.

Green, L.E., Lewis, K., Kimpton, A., and Nicol, C.J. (2000) Cross-sectional study of the prevalence of feather pecking in laying hens in alternative systems and its associations with management and disease. *Veterinary Record*, 147 (9), 233-238

Gross W.B., Siegel H.S. (1983) Evaluation of the heterophil lymphocyte ratio as a measure of stress in chickens. *Avian Dis*. 27 (4): 972-979

Gunnarsson, S., Keeling, L.J. and Svedberg, J. (1999) Effect of rearing factors on the prevalence of floor eggs, cloacal cannibalism and feather pecking in commercial flocks of loose housed laying hens. *British Poultry Science* 40, 12-18

Huber-Eicher, B. (1999) A survey of layer-type pullet rearing in Switzerland. *World's Poultry Science Journal* 55, 83-91

Hughes, B.O. and Gentle, M.J. (1995) Beak trimming of poultry - its implications for welfare. *Worlds Poultry Science Journal*, 51, 51-61.

Huxley, J.N., Burke, J., Roderick, S., Main, D.C.J. and Whay, H.R. (2004) Animal welfare assessment benchmarking as a tool for health and welfare planning in organic dairy herds. *Veterinary Record*, 155 (8): 237-239

Jones, R.B., Duncanm I.J.H. and Hughes, B.O. (1981) The assessment of fear in domestic hens exposed to a looming human stimulus. *Behavioural Processes*, 6: 121-133

Konkle, A.T.M., Baker, S.L., Kentner, A.C., Barbagallo, L.S.M., Merali, Z., Bielajew, C. (2003). Evaluation of the effects of chronic mild stressors on hedonic and physiological responses: sez and strain compared. *Brain Research*, 992: 227-238

Maxwell, M.H. (1993) Avian blood leukocyte responses to stress. *World's Poultry Science Journal* 49, 34-43.

Main, D.C.J., Kent, J.P., Wemelsfelder, F., Ofner, E. and Tuyttens, F.A.M. (2003) Applications for methods of on-farm welfare assessment. *Animal Welfare* 12: 523-526

Maxwell, M.H. & Robertson, G.W. (1998) The avian heterophil leucocyte: a review. *World's Poultry Science Journal*, 54: 155-178.

McLean, K.A., Baxter, M.R. and Michie, W. (1986) A comparison of the welfare of laying hens in battery cages and in a perchery. *Research and Development in Agriculture* 3, 93-98.

Nicol, C.J., Lindberg, A.C., Phillips, A.J., Pope, S.J., Wilkins, L.J. and Green, L.E. (2001) Influence of prior exposure to wood shavings on feather pecking, dustbathing and foraging in adult laying hens. *Applied Animal Behaviour Science* 73, 141-156

Nicol, C.J**.,** Brown, S.N., Glen, E., Pope, S.J., Short, F.J.,* Warriss, P.D., Zimmerman, P.H., and Wilkins, L.J. (2006) Effects of stocking density, flock size and management on the welfare of laying hens in single-tier aviaries. *British Poultry Science* (*in press*)

Schao, F., Lin, W.J., Wang, W.W., Washington, W.C. And Zheng, L. (2003) The effect of emotional stress on the primary humoral immunity of rats. *J. Psychopharmacology* **17**: 179-183.

Scott, E.M., Fitzpatrick, J.L., Nolan, A.M., Reid, J & Wiseman, M.L. (2003) Evaluation of welfare state based on interpretation of multiple indices. *Anim. Welf* 12: 457-468

Spoolder, H, De Rosa, G, Horning B, Waiblinger S, & Wemelsfelder, F. (2003) Integrating parameters to assess on-farm welfare. *Anim. Welf*. 12: 529-535

Sudhakumari, C.C. and Haldar, C. (2001) Effects of photoperiod alterations on adrenocortical, pineal and gonadal activity in nocturnal and diurnal birds. *Zoo. Sci*. 18: 71-79

Tauson, R. (2005) Management and housing systems for layers - effects on welfare and production. *World's Poultry Science Journal*, 61, 477-490.

Vits, A., Weitzenburger, D. Hamann, H and Distl, O. (2005) Production, egg quality, bone strength, claw length and keel bone deformities of laying hens housed in furnished cages with different group sizes. *Poultry Science,* 84, 1511-1519.

Westerhof, I, Mol, J.A., Vandembrom, W.E., Lumeji, J.T., Rijnberk, A. (1994). Diurnal rhythms of plasma corticosterone concentrations in racing pigeos (Columbia livia domestica) exposed to different light regimens, and the influence of frequent blood sampling. *Avian Diseases* 38: 428-434

Wilkins, L.J., Brown, S.N., Zimmerman, P.H., Leeb, T. and Nicol, C.J. (2004) Prevalence of keel and furculum damage in laying hens: validation of a palpation method. *Vet. Rec*. 155: 547-550.

Conclusions and recommendations

1. Database

A major achievement of the LayWel project has been the compilation of the database. Its structure and the collaborative discussions that led to this have been extremely valuable, and will undoubtedly influence and improve the design of future scientific studies of laying hen welfare. It has been extremely beneficial that LayWel partners representing seven countries, and with contacts in other EC countries, have worked together on designing and contributing data to the database. This will ensure a much more unified approach in the future and could lead to more collaborative projects.

The carefully structured layout of the database has enabled gaps in data availability to be clearly identified and has also indicated the type and format of data that future studies might collect. Additionally future methodology is likely to be more uniform.

In order to produce statistically valid models, more data are needed in most areas and thus the database ought to be expanded at least until sufficient data are entered to enable this. Data from in excess of 100 treatments (flocks) are generally required for modelling and this quantity could potentially be gathered within three years for many parameters.

We recommend that:

- *financial support is given to maintaining the database for at least 3 years so that future work may be included in it and so that modelling of the data is valid*
- *all scientists studying laying hen welfare consider expanding the number of indicators used in future work so that individual studies measure a greater range of indices (e.g. including physiology and behaviour)*
- *more data are collected for areas of limited data availability(as indicated in Tables 7.7 and 7.8)*

2. Integument scoring

A second major achievement of the project has been the development of feather scoring and integument (head and feet) scoring systems together with comprehensive sets of photographs. This has included developing methodology for transforming data from different scoring systems, which makes comparing different studies much easier.

We recommend:

- *the integument scoring systems are widely adopted, as they represent the consensus of the LayWel partners and an integration of several previous systems*
- *integument scoring is routinely and frequently carried out on all farms to assist in the detection of damaging pecking, which is currently a widespread welfare problem*

3. Behaviour

The most important enrichment for hens is the provision of a discrete, enclosed nest site. More scientific research is needed to determine whether perching is a behavioural priority and the extent to which hens value dustbathing and need a substrate, but there is strong evidence that both are behavioural needs. The presence of apparently purposeless behaviour or of high levels of aggression or redirected behaviours such as feather pecking and cannibalism are indicators that the housing system is not satisfactory for bird welfare.

Feather pecking is still a very predominant welfare problem in commercial flocks in non cage systems with a prevalence of between 40 and 80%. The prevalence of cannibalism is lower but with up to 20% of flocks were affected in one survey and up to 40% in another.

In furnished cages about 40 to 50% of the hens perched during the day and 80 to 90% during the night. The use of perches at night was higher in the smaller compared to medium or larger furnished cages, which could be due to design differences. The use of the dustbathing area was very different for the LayWel data from four models of furnished cages. Birds reared on floor had a slightly higher dustbathing activity than cage reared birds.

We recommend that:

- *more research is carried out to determine the influence of rearing system design on behaviour during lay and on the nature of and timing of provision of key resources such as foraging mediums, perches, nestboxes etc.*
- *all hens be provided with discrete, enclosed areas for egg laying*
- *perches are provided, and that more research and development is carried out to optimise their design and use by hens*
- *assessment of substrate quality in different laying hen housing systems should include recording of dustbathing behaviour activity and quality and foraging behaviour (see WP4 for methodology)*
- *more research is carried out to determine optimum substrates for foraging and for dustbathing (in particular environmentally-friendly alternatives to peat, which is a preferred choice for dustbathing)*
- *more research is carried out to determine optimum design of dustbathing areas in furnished cages*
- *suitable genotypes with minimal tendencies for aggressive pecking are selected for use in group housing systems*

4. Health

We recommend that:

- *both industry and research scientists direct maximum effort to establishing the causes of outbreaks of feather pecking and designing housing systems and management strategies to minimise this risk*
- *causes of the high levels of fractures during lay are determined together with strategies for reduction as a matter of priority*
- *hens are examined (and scored) for bumble foot regularly, but especially at 35-45 weeks of age*

Acknowledgement

This research project has been co-financed by the European Commission, within the 6th Framework Programme, contract No. SSPE-CT-2004-502315. The text represents the authors' views and does not necessarily represent a position of the Commission who will not be liable for the use made of such information