The Old School, Brewhouse Hill, Wheathampstead,
Hertfordshire AL4 8AN, UK
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The welfare of laying hens in conventional cages and alternative systems: first steps towards a quantitative comparison

R Freire* and A Cowling

School of Animal and Veterinary Sciences, Charles Sturt University, Wagga Wagga, NSW 2650, Australia
* Contact for correspondence and requests for reprints: rfreire@csu.edu.au

Abstract

Research synthesis, using techniques such as meta-analysis to combine the results of a number of studies, is a particularly useful technique when there are multiple studies with conflicting results, or where there may be conflicting interests, and can serve to extract the maximum information from animal experiments. The effect of conventional cages and alternative housing systems on measures of production, behaviour, physical and physiological condition in laying hens is an important question that would benefit from research synthesis. We found that statistical constraints did not allow the usual methods of meta-analysis, so as a first step towards quantitative comparison, we used a simple vote-counting approach based on the treatment means. We counted the number of papers in which conventional cages or alternative systems had a higher weighted mean for various response variables. Egg production was higher in conventional cages than in alternative systems, though this effect was probably mostly confined to the comparison with multi-level indoor systems. Bones were stronger from hens kept in alternative systems than those kept in conventional cages. We confirmed previous reviews that birds show more comfort behaviour and possibly dustbathing (or vacuum dustbathing) behaviour in alternative systems, but aggressive pecking did not differ between systems. Perhaps surprisingly, mortality, feather pecking and body wounds were not found to differ between systems. The latter findings suggest that the chance of a mortality or cannibalism outbreak may be no greater in alternative systems than in cage systems, but it should be noted that our analysis did not consider the magnitude of the difference in mortality. In conclusion, the meta-comparison undertaken here supports some but contradicts other conclusions reached in qualitative reviews.

Keywords: *animal welfare, behaviour, cages, egg production, housing, laying hens*

Introduction

Concern for the welfare of laying hens in conventional (battery) cages has probably attracted more debate than any other intensive husbandry system. Conventional cages for laying hens have been criticised on the grounds that: i) in the absence of litter, hens are unable to express normal dustbathing and foraging behaviour; ii) in the absence of a nest, nesting motivation is frustrated; iii) restriction of movement within a cage causes frustration and prevents normal bone development; which (iv) is exacerbated by the absence of a perch for roosting (Baxter 1994). This concern for welfare has contributed to pressure on legislative systems in different regions of the world and has included banning conventional cages. However, conventional cages also have positive effects on welfare in that they provide a relatively hygienic environment, good environmental control and a small group size (Duncan 2001).

Welfare concerns the attempts of the animal to cope with its environment and generally focuses on the behaviour, physical condition and physiology of the animal (Broom 1986). One major difficulty in reaching a scientific consensus on the ability of conventional cages to ensure appropriate levels of hen welfare is in determining what welfare indicators are used and how they are interpreted. Researchers have previously considered that taking a wide and diverse range of variables is the best way of assessing welfare (eg Craig & Adams 1984), though more recently the limitations of this approach have been considered (eg Nicol *et al* 2011). The ability to perform specific behaviours, absence of unwanted behaviours, specific physiological responses and health measures, physical condition and injuries and production parameters have all been recorded and considered in assessing welfare of hens in cages in multiple experiments, and form the basis of many qualitative reviews (eg Appleby & Hughes 1991; Hester 2005; Rodenburg *et al* 2008; Lay *et al* 2011).

Qualitative review of the literature is a fundamental scientific activity which reduces large quantities of information into palatable pieces, is efficient in avoiding the need for a further study and can lead to the generalisation of scientific findings. Reviews on hen welfare in different housing systems have originated in various continents and by different authors and have generally required making value judgements based on the subjective evaluation and assessment of a range of welfare criteria. In these instances, the choice of welfare criteria reported and relative importance paid to each involves a certain degree of subjectivity from the authors. This degree of subjectivity has, in other disciplines, led to qualitative reviews being criticised as haphazard and biased, subject to the impressions and ideals of the reviewers (Murlow 1987). In addition, qualitative studies rarely address the appropriateness of statistical design of the studies or the statistical-analysis-associated inferences made from the studies.

In contrast, quantitative reviews combine the results of a number of studies that address similar research hypotheses, minimising the above qualitative subjective review of various studies. The technique is particularly useful when there are multiple studies with conflicting results, or where there may be conflicting interests. Quantitative reviews have been considered more objective than qualitative reviews and better able to precisely identify effects in medicine (Mulrow 1994) and have begun to be applied to animal sciences (eg Phillips 2005). However, it is often recognised that a combination of qualitative and quantitative reviews are essential in ensuring that bias is limited and that reliability and accuracy of recommendations is maximised (Mulrow 1994). Our original aim was to synthesise the results of studies comparing differences in the effects of conventional cages and alternative systems on measures of production, behaviour and physical and physiological condition in laying hens by taking a meta-analysis approach. Initial screening of the material available showed that this was not possible. We therefore conducted a simple quantitative comparison of means as a first step towards a full meta-comparison.

Materials and methods

Selection of data set

Information regarding the effect of conventional cages on behaviour, physical condition, physiology and production was collected from studies published in peer-reviewed journals between 1974 and 2011. The Institute for Scientific Information (ISI) Web of Knowledge online database was used with a final viewing date of 20/3/2011. The search terms 'hen/hens' and 'cage/cages' and 'welfare/well-being' were used. Reference lists from all identified papers were then viewed to identify additional papers for consideration. Additionally, the reference list from the recent comprehensive review for the European Food Safety Authority (van Niekerk *et al* 2012) was also checked for additional papers that might have been missed in our initial literature search. Experiments to be used in the analysis had to compare hens in conventional cages (also called battery cages) and, in some alternative systems, including furnished cages, floor pens, aviaries, percheries and outdoor range systems. Hens had to be housed in these systems for more than two weeks to be included in the analysis.

Classification of variables

The number of variables reported and their definitions varied greatly and were selected by first removing all variables which were reported in less than five papers. Variables were grouped into three categories as follows and the most common unit of measurement is given:

- Production variables — egg production (laying % per hen per day), mortality (%) and bodyweight (kg);
- Physical and physiological variables — tibia and humerus breaking strength (N), feather score (rank: from 0, complete cover to 5, extensive damage), foot score (rank: 0, good condition to 4, very poor condition, or bumblefoot incidence), body wounds (rank: 0, no damage to 3, extensive damage), corticosterone (ng ml^{-1}) and immune response (log antibody titres); and
- Behavioural variables — comfort (%, including wing-flapping and leg-stretching), dustbathing (%, including vacuum dustbathing), activity (%, includes walking), feather pecking (number of pecks, excludes gentle pecks), aggressive pecking (number of pecks to the head or comb) and preening (%).

Classification of housing systems

Papers to be included had to have studied hens housed in groups (ie n > 1) in conventional wire cages. If papers tested more than one cage system, a weighted average was taken of all eligible cage systems. Cage systems with variations to the above conditions were excluded (eg plastic cages, cages with perches).

Alternative systems were classified into the following. Single-level indoor systems (SLIS) where the ground floor area was fully or partially covered with litter and birds had only one level at any one point (ie deep litter systems included). SLIS systems did not contain any furnishings (eg nest box, perch) unless stated in Table 1. In multi-level indoor systems (MLIS), birds can occupy at least two levels in at least some areas of the system, and usually comprised of a set of perches above a slatted or wire floor, with other parts of the floor covered with a loose substrate. MLIS systems provided nest boxes, and have also been called aviary or barn systems. Furnished cages (FC) contained a perch, dustbath and nest box unless stated, with birds predominantly on a wire floor (also called enriched and modified cages). An older term, get-away cage, was also included as a furnished cage if it provided the same furnishings as a furnished cage. Outdoor systems were a combination of SLIS or MLIS but provided birds with access to an outside uncovered area. A few systems did not fall into any of these classifications, and are described in Table 1.

Constraints on meta-analysis and statistical analysis undertaken

After the literature search, the next step in a meta-analysis was to address the suitability of the studies for statistical review. It is important in a meta-analysis for the experimental unit to be clearly defined with appropriate replica-

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Table 1 Summary of systems reported in the identified papers and variables included in analysis.

	Paper	Cage systems		Alternative system			Birds		Variables included
		N	Area	Type	N	Area	Strain	BT	
1	Abrahamsson & Tauson (1995)	3	640	MLIS	175–231	565–935	LSL, LB, DK	N	EP, MO, BW, FE, FS, BS, WO
2	Abrahamsson *et al* (1996)	3	600	Furnished	5–15	600–750	Shaver, DK, LSL	N	MO, FE, FS, BS, WO
3	Appleby *et al* (2002)	4, 5	500–625	Furnished	5, 7, 8	625–1,000	ISA Brown	N	FS, FE, CB, AP, AC, DB
4	Ayorinde *et al* (1999)	2		SLIS			NAPRI	N	EP, MO
5	Bareham (1976)	6	600	Furnished	6	578	Shaver 288	N	EP, FE, FS, BW, PR, FP, CB, AP, DB, WO, AC
6	Black & Hughes (1974)	7	626	SLIS	8	2,862–4,895	Thorber, Shaver 288	N	CB, PR, DB
7	Craig *et al* (1986)	4, 6	310–929	SLIS	12	2,900	WL	Y	EP, MO, CO, FE
8	Fleming *et al* (1994)	5	450	MLIS	420–1,318	454–909		N	BS
9	Gibson *et al* (1986)	4	465	Outdoor	38		ISA Brown	N	CO
				SLIS	540, 660	2,500–3,000			
10	Guesdon & Faure (2004)	5, 6	635, 660	Furnished	7–15	826–1,134	ISA Brown	Y	MO
11	Guesdon *et al* (2004)	5, 6	635	Furnished	7–15	826–1,134	ISA Brown	Y	BS, CO
12	Hansen (1994)	3	720	MLIS	735–1,470	588	WL	N	CB, FP, AC
				Furnished	3–26	450			
13	Hetland *et al* (2004)	3	736	Furnished	8–16	750	LSL, Shaver 2000	N	EP, FE, WO
14	Jendral *et al* (2008)	3	450	Furnished	3–26	576–810	Shaver WL	Y	BS
15	Koelkebeck & Cain (1984)	2–6	390–1,160	SLIS (+NB)	51	940–3,730	WL	N	EP, MO, BW, CO, PR, AC
				Outdoor	50	7,430			
16	Koelkebeck *et al* (1987)	3, 4, 5	350–460	SLIS	35	940–3,730	WL	N	MO, EP, FE, CO, BW, PR, AC, FP, IR
17	Leyendecker *et al* (2005)	4	688	Furnished	10	609	Medium Hybrid	Y	EP, BS
				Outdoor	2,004–2,110	645–689			
18	McLean *et al* (1986)		550	MLIS	749	1,253	ISA Brown	N	EP, MO, BS, FE, AC, FP, AP
19	Mench *et al* (1986)	2	697, 1,394	SLIS	25	1,394	N-Line[2]	N	EP, BW, MO, CO, PR, FP, AP, AC, IR, WO
20	Newman & Leeson (1998)		733	MLIS		3,578	Medium Hybrid		BS
21	Norgaard-Nielsen (1990)	4	600	Furnished	75	1,000	WL	Y	EP, BW, BS, CB
				MLIS	75	1,428			
22	Pohle & Cheng (2009)	6	645	Furnished	10	610	Hyline WL	N	PR, AC
23	Roll *et al* (2008)	6	550	Furnished	10	750	ISA, Hyline Brown	N	EP, FE, PR, FP, AC, CO
24	Sherwin *et al* (2010)	Various		Furnished, MLIS, Outdoor	Various		Various	Y/N	MO, CO, FE, BW, FS, WO
25	Shimmura *et al* (2007)	2	450	Furnished	20	642	Boris Brown	Y	EP, DB, IR, CB, PR, AC, AP
26	Shimmura *et al* (2010)	2	450–600	Furnished	5–18	604–658	Medium Hybrid	Y	EP, MO, IR, CB, FP, FS, FE, BW, AC, DB, AP
				MLIS	18	7,200			
				Outdoor	18	250,000			
27	Singh *et al* (2009)	3	688	MLIS	21–24	6,115–6,990	LW, LB, HN	Y	EP, MO, BW
28	Tactacan *et al* (2009)	5	562	Furnished	24	642	SW	Y	EP, MO, CO, IR, BS, FE
29	Tanaka & Hurnik (1992)	3	730	MLIS	437	1,310	DK	Y/N[1]	EP, MO, CB
30	Tauson *et al* (1999)	3	640	MLIS	117–185	558–1,298	LSL, LB	N	EP, MO, BW, FE, FS, WO
31	Taylor & Hurnik (1994)	3	733	MLIS	437	1,310	DK	N	BW, FE, FS, BS
32	Taylor & Hurnik (1996)	3	733	MLIS	437	1,310	DK	Y/N[1]	EP, MO
33	Van Horne (1996)	47 flocks		MLIS	19 flocks		Range of strains		EP, MO
34	Vosláŕová *et al* (2006)			SLIS	36		ISA Brown	N	EP, MO
35	Yakubu *et al* (2007)	2	627	SLIS	50	880	Bovans Brown, LB		EP, MO, BW

BT: beak trimmed. Strains, LW: Lohman White; LB: Lohman Brown; LSL: Lohman Selected Leghorn; HN: H&N White; SW: Shaver White Leghorn; DK: Dekalb; WL: White Leghorn.
Housing; Systems (+NB, nest boxes). Variables considered, EP: egg production; MO: mortality; BW: bodyweight; BS: bone strength; CB: comfort behaviour; DB: dustbathing behaviour; AC: activity; IR: immune response; FP: feather pecking; AP: aggressive pecking; PR: preening; FE: feather score; FS: foot score; CO: corticosterone; WO: dorsal body wounds or cannibalistic pecks.
[1] MLIS, no; cages, yes. [2] N-Line: Marek's resistant strain developed by Cornell University. Blank: Not specified.

Table 2 The number of times that conventional cage systems and alternative systems had higher means (bold) and the paper number (in brackets) for production variables. Secondary analysis shows the comparison between CC and different alternative systems.

Analysis	Primary		Secondary		
Mean	**Cage higher**	**Alternative higher**	**Comparison**	**Cage higher**	**Alternative higher**
Egg production	**16** (1, 4, 13,15, 16, 17, 21, 22, 24, 25, 28, 29, 30, 32, 34, 35)	**6** (5, 7, 18, 19, 23, 33)	CC-SLIS	**4**	**2**
			CC-FC	**5**	**3**
			CC-OS	**1**	**1**
			CC-MLIS	**8**	**2**
Mortality	**8** (7, 10, 16, 18 19, 27, 32, 33)	**11** (1, 2, 4, 15, 24, 26, 28, 29, 30, 34, 35)	CC-SLIS	**2**	**4**
			CC-FC	**2**	**3**
			CC-OS	**1**	**2**
			CC-MLIS	**4**	**5**
Bodyweight	**9** (1, 15, 16, 19, 21, 24, 30, 31, 35)	**3** (5, 24, 27)	CC-SLIS	**3**	**0**
			CC-FC	**2**	**2**
			CC-OS	**2**	**1**
			CC-MLIS	**5**	**2**

CC: conventional cage; SLIS: single-level indoor system; FC: furnished cage; OS: outdoor system; MLIS: multi-level indoor system.

Table 3 The number of times that conventional cage systems and alternative systems had higher means (bold) and the paper number (in brackets) for behavioural variables. Secondary analysis shows the comparison between CC and different alternative systems.

Analysis	Primary		Secondary		
Mean	**Cage higher**	**Alternative higher**	**Comparison**	**Cage higher**	**Alternative higher**
Comfort	**0**	**9** (3, 5, 6, 12, 21, 22, 23, 26, 29)	CC-SLIS	**0**	**1**
			CC-FC	**0**	**7**
			CC-OS	**0**	**1**
			CC-MLIS	**0**	**4**
Dustbathe	**0**	**5** (3, 5, 6, 25, 26)	CC-SLIS	**0**	**1**
			CC-FC	**0**	**4**
			CC-OS	**1**	**0**
			CC-MLIS	**0**	**1**
Activity	**4** (3, 12, 22, 25)	**7** (5, 15, 16, 18, 19, 23, 26)	CC-SLIS	**0**	**2**
			CC-FC	**2**	**4**
			CC-OS	**0**	**2**
			CC-MLIS	**1**	**2**
Feather peck	**4** (12, 16, 18, 19)	**3** (5, 23, 26)	CC-SLIS	**1**	**0**
			CC-FC	**0**	**4**
			CC-OS	**1**	**0**
			CC-MLIS	**2**	**1**
Aggressive peck	**3** (5, 18, 19)	**3** (3, 25, 27)	CC-SLIS	**1**	**0**
			CC-FC	**1**	**3**
			CC-OS	**0**	**0**
			CC-MLIS	**1**	**1**
Preen	**5** (6, 15, 16, 19, 25)	**3** (5, 22, 23)	CC-SLIS	**3**	**0**
			CC-FC	**1**	**3**
			CC-OS	**1**	**0**
			CC-MLIS	**0**	**0**

CC: conventional cage; SLIS: single-level indoor system; FC: furnished cage; OS: outdoor system; MLIS: multi-level indoor system.

tion and randomisation of the treatments to the units. Clearly, there are methodological constraints that make it virtually impossible for randomisation of the treatments to the units in poultry welfare research, ie in an experiment comparing cages with outdoor range systems, one unit of each would need to be randomly allocated to a position relative to the other. The grouping of conventional cages also presents a problem since, for the purposes of meta-analysis, the assemblage of cages makes the experimental unit. Chickens within the housing systems are sub-units and the assemblage of cages (sometimes referred to as blocks) provides a single measurement for each treatment.

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The standard meta-analysis procedure uses effect sizes extracted from the results in the relevant studies. The effect size is the difference between two treatment means divided by the standard error of that difference. A second, less-preferred method, vote counting, requires results from the relevant studies to be categorised into three classes: statistically significant positive results, statistically significant negative results and non-significant results. However, examination of the selected papers quickly revealed that it would not be possible to use either of these methods because: (i) as stated above, the statistical analysis in the majority of papers did not use the experimental unit necessary to allow meta-analysis; and (ii) in general, neither standard errors nor standard error of the difference were given. We therefore based our statistical method on the mean for each housing type as tabulated in each paper.

In order to numerically summarise these papers, we first counted the number of papers in which conventional cages or alternative systems had a higher mean for the various response variables (primary analysis). In each paper, weighted averages of the means for different variations of the same type of system were used so that each paper contributed only one count. For example, when there are two types of MLIS compared to conventional cages, the two MLIS results were averaged, weighted by the number of birds in each MLIS. Likewise, if the same variable was recorded multiple times, such as at different ages, a weighted average was taken to yield only one mean per housing system. It should be noted that the same count is given for large and small differences, and for studies with different statistical analyses. This approach was used to ensure accuracy since experimental design would have very little effect on the means. For a particular variable, if there was no difference between systems, half of the papers would have a higher count for conventional cages (and half for alternative systems).

Further (secondary) analysis was undertaken to examine differences between conventional cages and alternative systems that meet current standards. A vote-counting approach was again used, in which the number of comparisons in which conventional cages or alternative systems had higher means was scored. Conventional cage systems in which birds had less than 550 cm^2 per bird were excluded as this is the current local minimum requirement (Standing Committee of the Agriculture and Resource Management Council [SCARM] 2002) and compares well with current legislation around the world. Additionally, floor systems that provided less than 666 cm^2 per bird of useable area were also excluded, based on the current regulation of 30 kg m^{-2} for 2 kg birds (SCARM 2002). Our limit was therefore 15 birds m^{-2} which was similar to the minimum standard elsewhere in the world. In cases where there was more than one eligible conventional cage system, a weighted mean was obtained for the conventional cage system.

Results

Descriptive analysis

A total of 35 papers were identified which described experiments comparing differences in the effects of conventional cages and alternative systems on laying hen welfare and production variables. Conventional cage systems were reasonably homogonous with the number of birds varying between two and seven, and cage floor area per bird ranging from 310–1,160 cm^2 per bird. MLIS systems were compared in 14 papers, furnished cages in 15 papers, SLIS systems in eleven papers and outdoor systems in four papers, with some papers comparing more than one alternative system. Different breeds of chicken were used and measurements were made on birds of ages differing between ten and 100 weeks. Approximately half the papers beak trimmed birds, usually at less than ten days of age. The identified papers used a wide variety of measures of production, behaviour and physiological and physical variables. Table 1 provides a summary of the variables considered in each paper.

Production variables

Primary analysis indicated that egg production was greater in cages, particularly when cages were compared to MLIS systems (Table 2). Perhaps unexpectedly, housing system did not appear to have any effect on mortality (Table 2). Bodyweight did not appear to differ between housing systems (higher in CC in nine papers and higher in alternative systems in three papers; Table 2), though the secondary analysis indicates that caged hens were heavier than those housed in large-group systems (SLIS, MLIS and outdoor systems combined, ten versus three, respectively).

Behaviour variables

Comfort behaviour, which included wing-flapping and leg-stretching, was higher in alternative systems than conventional cages, and was also higher in furnished cages than conventional cages (Table 3). There was some indication that there was more dustbathing behaviour in alternative systems than vacuum-dustbathing in cages. Curiously, activity levels did not differ between conventional cages and alternative systems (higher in four and seven papers, respectively; Table 3). No difference between systems was found in aggressive and feather pecking, or preening (Table 3).

Physical and physiological variables

Birds in furnished cages and MLISs had stronger bones than hens in conventional cages (Table 4). Feather condition was worse in cages than in alternative systems (eleven versus two, respectively) with secondary analysis suggesting that feather condition may be better in all types of alternative systems. Foot score and body wounds were not affected by housing system (Table 4). Housing system had no effect on corticosterone levels though there was some indication that immune response was higher in conventional cages than in alternative systems (Table 4).

Table 4 The number of times that conventional cages and alternative systems had higher means (bold) and the paper number (in brackets) for physical and physiological variables. Higher means for feather score, foot score and body wounds indicate more damage. Secondary analysis shows the comparison between CC and different alternative systems.

Analysis	Primary		Secondary		
Mean	Cage higher	Alternative higher	Comparison	Cage higher	Alternative higher
Breaking strength: Tibia	**0**	**12** (1, 2, 8, 14, 17, 18, 19, 20, 21, 26, 28, 31)	CC-SLIS	**0**	**0**
			CC-FC	**0**	**6**
			CC-OS	**0**	**0**
			CC-MLIS	**0**	**5**
Breaking strength: Humerus	**0**	**8** (2, 8, 11, 14, 17, 21, 26, 28)	CC-SLIS	**0**	**0**
			CC-FC	**0**	**6**
			CC-OS	**0**	**0**
			CC-MLIS	**0**	**4**
Feather score	**11** (3, 5, 7, 13, 18, 23, 24, 26, 28, 30, 31)	**2** (1, 2)	CC-SLIS	**1**	**0**
			CC-FC	**5**	**1**
			CC-OS	**2**	**0**
			CC-MLIS	**4**	**1**
Foot score	**5** (3, 5, 24, 30, 31)	**3** (1, 2, 26)	CC-SLIS	**0**	**0**
			CC-FC	**3**	**2**
			CC-OS	**0**	**2**
			CC-MLIS	**3**	**2**
Body wounds	**4** (5, 19, 23, 30)	**4** (1, 2, 13)	CC-SLIS	**1**	**0**
			CC-FC	**2**	**2**
			CC-OS	**0**	**1**
			CC-MLIS	**1**	**2**
Corticosterone	**3** (9, 11, 19)	**5** (7, 15, 16, 24, 28)	CC-SLIS	**1**	**2**
			CC-FC	**2**	**1**
			CC-OS	**0**	**2**
			CC-MLIS	**0**	**1**
Immune response	**5** (16, 19, 25, 26, 28)	0	CC-SLIS	**1**	**0**
			CC-FC	**3**	**0**
			CC-OS	**0**	**1**
			CC-MLIS	**1**	**0**

CC: conventional cage; SLIS: single-level indoor system; FC: furnished cage; OS: outdoor system; MLIS: multi-level indoor system.

Discussion

In summary, the simple comparison undertaken here provided a perspective and interpretation on published studies comparing conventional cages and alternative systems that differ in some areas from the conclusions of some qualitative reviews. It should be noted that we encountered constraints that did not allow us to undertake a standard meta-analysis as we originally intended. Instead, the approach that we undertook has limitations particularly since the same count is given for large and small differences in means. Egg production was higher and leg-bone strength lower in conventional cages than in alternative systems. We confirmed previous reviews that birds show more comfort behaviour in alternative systems (eg Appleby & Hughes 1991). Surprisingly, feather and aggressive pecking did not differ between systems as has been previously reported (eg Lay *et al* 2011). Mortality, which has been considered to be higher in alternative systems than in conventional cages (eg Appleby & Hughes 1991; Duncan 2001; Lay *et al* 2011) was not found to differ between systems. The absence of a difference in body wounds between systems supports the mortality meta-comparison results, indicating no difference between systems in injurious pecking. Corticosterone did not differ significantly between systems though birds in cages had a higher immune response.

Beak trimming is usually undertaken to control mortality due to cannibalism in large-group systems, and is a routine management operation in many countries. Approximately half of the studies included in our comparison did not beak trim, therefore we expected large-group systems, in particular, to have higher mortality rates than conventional cage systems. In fact, this was found not to be the case; mortality did not differ between systems. The incidence of body wounds is often considered to be related to cannibalism, and hence can be related indirectly to mortality, yet this was also not affected by housing system. Additionally, feather pecking has previously been considered to be linked to cannibalism (eg Savory 1995), yet no effect of housing system was found on feather pecking. Mortality is often assumed to be greater in alternative systems yet the data presented here suggest that it is no higher in alternative systems than in cage systems. It is important to note that our

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analysis only considers in which system mortality was greater, and did not attempt to quantify the magnitude of the difference. Therefore, our analysis does not tell us about the variability in mortality rates in cage and alternative systems. Management has been found to be an important tool in controlling mortality and cannibalism in all systems (Aerni *et al* 2000; Green *et al* 2000), and it may be that the control of mortality and cannibalism should focus on management rather than the type of housing system.

It was clear that birds in furnished cages and MLIS had stronger tibia and humerus bones than those in conventional cages. Stronger bones are generally considered to have a positive effect in that they can be expected to reduce the incidence of bone breakages, particularly during depopulation (Knowles & Wilkins 1998). However, the addition of perches can also have negative effects in that accidents when moving between perches in large-group systems, or on and off them, may lead to hens breaking bones. Activity level has previously been considered to be an important factor determining bone strength (eg Jendral *et al* 2008) though activity levels were not found to differ between conventional cage and alternative systems in this study. It may nonetheless be that the type and intensity of activity is important, and this was not addressed in our study. A range of variables have previously been used to record foot condition, such as footpad dermatitis, bumblefoot and hyperkeratosis. Our meta-comparison included only general foot scores and bumblefoot, as the latter is considered the most serious, but it may be that including other factors would indicate a difference between systems. Hyperkeratosis, for example, has been found to be worse in cages than in non-cage systems (Abrahamsson & Tauson 1995).

The previously reported higher rate of dustbathing behaviour and comfort behaviour, such as wing flapping, body shaking and stretching in alternative systems, was supported by our analysis. Interestingly, there was more comfort behaviour in furnished cages than in conventional cages, even though there would not be a great difference in space per bird between these systems. Aggressive pecks (to the head and comb) were not found to differ significantly between conventional cage and alternative systems. This was not surprising — it has been known for some time that overt aggression can be low in large-group systems. It should be noted that these results represent what is observed at the flock level, and do not tell us what happens at the individual level. In large groups, a few birds can receive a large proportion of aggressive pecks, seemingly from any other bird (Duncan 1978). This 'victimisation' can lead to some birds being excluded from having full access to resources, such as litter and perches (Freire *et al* 2003).

Corticosterone sampling and interpretation of results can be challenging and it is likely that techniques have changed considerably in the time covered by the papers reviewed here. Although corticosterone was perhaps initially regarded as a good indicator of short-term stress, it quickly became evident that it is perhaps a better indicator of the presence of longer lasting stressors (Craig & Adams 1984). Lay *et al* (2011) recently reviewed changes in corticosterone and other physiological indicators of stress in a more recent collection of papers (since 1984). As in our study, Lay *et al* (2011) did not find a clear difference in physiological indicators of stress between housing systems, though they suggest that other factors and conditions are important.

There are practical difficulties associated with replicating large-group systems within a single study, and possibly this is the reason that van Horne (1996) and Sherwin *et al* (2010) looked at cross-farm studies. Quantitative comparisons such as the one reported here or the above cross-farm studies are particularly useful in dealing with the challenge of achieving sufficient replication of the treatments and sufficient randomisation in experimental design since different studies can constitute replicates of the experiment.

Animal welfare implications

A simple quantitative comparison of the published research comparing the welfare of hens in cages and alternative systems yielded a slightly different perspective to that gleaned from qualitative reviews. In particular, our comparison suggests that the chance of a mortality outbreak may be no greater in alternative systems than in conventional cage systems. Instead, the often-reported higher incidence of mortality and cannibalism in alternative systems may indicate the magnitude of the problem once outbreaks have occurred. We suggest that continued improvement in experimental design and statistics will allow quantitative reviews which use standard meta-analysis principles and have the potential to better support animal welfare decision-making.

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