
The Prevalence of Welfare Challenges Affecting Laying Hens in Different Housing Systems

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In previous Chapters we explored the time spent in negative affective states (operationally referred to as ‘pain’ - Box 1.1, Chapter 1 [1]) endured by an individual as a consequence of an injury, a disease or behavioral deprivation. To this end, we mapped each welfare challenge into four categories of pain intensity, and estimated the time in pain endured in each category using the analytical framework introduced in Chapter 1 [1]. Such an exercise enables comparing the burden of different welfare challenges using a universal, meaningful and non-abstract metric.

However, not all individuals will experience all harms. For example, while injuries like keel bone fractures are widespread among laying hens, events such as fatal cannibalistic attacks are experienced only by a few. Therefore, efforts to measure the load of negative experiences endured by populations must consider how prevalent each welfare challenge is, so that the pain it causes is determined for the average member of the population. In this way, comparisons of welfare can be done across production systems, countries, demographics and time periods.

To explore how the different welfare challenges discussed in this book affect commercial layer populations, in this chapter we review evidence on their prevalence for each of the indoor housing conditions described previously (conventional cages, furnished cages, single-tier aviaries and multi-tier aviaries; Chapter 2 [2]). We focus on the prevalence of challenges of physical nature (Chapters 3 [3], 4 [4], 5 [5] and 7 [6]), since the prevalence of challenges of psychological nature is addressed in Chapter 6 [7].

Because our interest is in the experience of layer populations in commercial conditions, we focus on data sources reporting prevalence data in commercial settings only. The search and organization of this information is revealing by itself, not only of the frequency with which different challenges affect populations, but also of the many existing data and research gaps in the literature. Identifying those gaps is not only helpful to guide future research efforts, but also to identify where claims and beliefs are unsustained by data.

General Methodology

For each of the welfare challenges investigated, we identified potentially eligible data sources by searching Web of Science and Google Scholar for relevant studies, from 2000 onwards, using the keywords (“laying hen” OR layer) AND (aviar* OR cage* OR housing OR barn) AND the name of the welfare challenge (OR synonyms). In addition, bibliographies of key articles and reviews were hand searched. For a data source to be considered, it had to report prevalence data for the challenges in question (or data enabling its calculation) disaggregated by housing systems and the corresponding age of the flock/birds. In an effort to include more studies for which critical information was missing, we contacted authors for clarification.

For each data source, we identified one or more cohorts of animals, where a cohort is defined as the largest group of animals from a housing system for which the necessary data meeting the inclusion criteria were available. For each cohort, the following variables were extracted: data source information, country, housing system, year(s) of data collection, population characteristics (breed, beak trim status), sample size (number of hens, flocks, farms), flock size, harm prevalence, variance in prevalence (if only summary measures of prevalence were provided) and age (in weeks) of the flock/hens. Where quantitative information was only available in charts, we used WebPlotDigitizer© version 4.2 for data extraction [8].

In those cases where data was available from multiple sources, a meta-analytical approach was used to determine the pooled prevalence. To this end, we conducted a typical meta-analysis of prevalence (expressed in proportion), having the total number of hens (N) used by each data source for determining the prevalence of a condition as its sample size, and variance calculated using the binomial equation $p(1-p)/N$ [9]. Prevalence was transformed using the double arcsine square root transformation to stabilize the variance across data sources [9]. Data was pooled using the inverse variance heterogeneity (IVhet) model, which avoids the problems of overdispersion and increased mean squared error seen with the random effects model [10].

To incorporate the uncertainty in the prevalence of the welfare challenges, prevalence estimates will be represented by range, corresponding to the interval where we expect the true population mean for the parameter to lie, after taking into account the evidence reviewed, and the natural variability in the expected prevalence.

Keel bone fractures

Keel bone fractures are among the most serious welfare problems affecting laying hens in the egg industry (thoroughly discussed in Chapter 3 [3]). Fractures are observed in all housing systems, although there is a widely held view that indoor cage-free systems are associated with the highest occurrence. In this section we review data on the prevalence of keel bone fracture in each of the housing systems investigated.

Keel damage can be caused by fractures and deviations. Fractures are characterized by sharp bends, shearing or fragmentation of the bone [11,12], whereas deviations are represented by the abnormal shaping (bending) of the bone in response to long-term (low energy) pressure. Because the extent to which deviations have a negative impact on hen welfare is not yet well established [13], our focus in Chapter 3 [3] and here is on keel fractures, excluding those studies for which the prevalence of

fractures and deviations is only reported aggregated. No attempt is made to distinguish between the prevalence of mild, moderate and severe fractures since data is rarely discerned by severity.

Table 8.1. Studies reporting the prevalence of commercial layers with keel bone fractures at the end of the laying cycle in conventional cages (CC, red), furnished cages (FC, orange), indoor multi-tier (MT, light blue) and single-tier aviaries (ST, dark blue) since the year 2000.

Housing ▲	Source	Country	Feather	BY	M-Year	Flocks	Hens (n)	Prevalence (%)	Method
CC	Petrik et al 2015	Canada	Brown	Y	2012	9	300	 55	Palpation
CC	Sherwin et al 2010	United Kingdom	Mixed	Y		6	900	 18	Palpation
FC	Sherwin et al 2010	United Kingdom	Mixed	Y		6	900	 32	Palpation
FC	Rodenburg et al 2008	Belgium; Germany	Brown		2005	6	180	 62	Palpation
FC	Wilkins et al 2011	United Kingdom	Mixed		2008	9	900	 32	Palpation
FC	Wilkins et al 2011	United Kingdom	Mixed		2008	9	180	 36	Dissection
MT	Heerkens et al 2016	Belgium	Brown	Y	2012	47	2,350	 83	Palpation
MT	Rodenburg et al 2008	Netherlands; Belgium	Brown	Y	2005	3	90	 97	Palpation
MT	Stratmann 2016	Switzerland	White			1	160	 37	Palpation
MT	Stratmann 2015a	Switzerland	Mixed			4	400	 30	Palpation
MT	Stratmann 2015b	Switzerland	White			4	400	 41	Palpation
MT	Stratmann 2015b	Switzerland	White			4	400	 87	Dissection
ST	Petrik et al 2015	Canada	Brown	Y	2012	8	350	 40	Palpation
ST	Petrik et al 2013	Canada	Brown	Y	2012	1	100	 62	Dissection
ST	Petrik et al 2013	Canada	Brown	Y	2012	1	100	 57	Palpation
ST	Sherwin et al 2010	United Kingdom	Brown	Y	2006	7	1,050	 69	Palpation
ST	Rodenburg et al 2008	Netherlands; Belgium	Brown	Y	2005	4	120	 82	Palpation
ST	Wilkins et al 2011	United Kingdom	Mixed		2008	10	1,000	 53	Palpation
ST	Wilkins et al 2011	United Kingdom	Mixed		2008	10	200	 63	Dissection
ST	Wilkins et al 2004	United Kingdom	Unknown		2001	4	200	 62	Dissection
ST	Nicol 2006	United Kingdom	Unknown		2002	6	1,800	 55	Dissection

Although the study of keel bone fractures has attracted considerable attention over the last decades, few were the studies that measured the prevalence of the problem in commercial settings, with only two addressing the issue in conventional cage systems since the year 2000 (Table 8.1). Studies were concentrated in Europe, predominantly the United Kingdom and Switzerland. Outside Europe, we could only find data that met the inclusion criteria for Canada.

Figure 8.1 shows a forest plot with the proportion of laying hens with keel fractures at the end of the laying cycle, ordered by year of data collection within each system. The measures of prevalence reported range from approximately 20 to 60% in conventional cage systems, 30 to 70% in furnished cages and 30 to nearly 100% in cage-free aviaries. In all housing systems, however, the variability in the proportion of hens with fractures is very high, with a large overlap among systems. This observation speaks against the notion that the prevalence of fractures is inherently higher, or lower, in any particular system.

Although the pooled averages suggest that keel fracture prevalence is higher in non-cage systems (single- and multi-tier systems), the high heterogeneity in the reported values (with significant values of $I^2 > 95\%$) indicate that the pooled data is not representative of any particular system. Additionally, given the scarcity of data, it is not possible to investigate the influence of likely confounders, such as feather color and temporal trends, though visual inspection of Figure 8.1 shows that, within each system, the highest prevalence values are observed in earlier years. The possibility that, similarly to the observed decline in cumulative layer mortality in newly adopted systems [14], keel fracture prevalence reduces as producers acquire more experience with new systems cannot be ruled out, and should be explored further. Overall, these observations are broadly in line with a recently published review on the prevalence of keel fracture in laying hens, where the authors conclude that the link between housing system and keel bone fracture prevalence may not be supported [15].

Finally, it is important to bear in mind the limitations in the methods of assessment. Until 2015, the evaluation of keel fractures was mostly conducted by palpation of the keel bone in intact birds [16]. In this method, fractures are identified through the detection of calluses, lumps or dips along the bone. Although palpation is a highly useful technique to identify keel bone damage where other techniques (eg, dissection or radiography) are impractical, by relying on palpable indicators such as the presence of calluses, tissue swelling and angulation/dislocation of fragments, the method can miss fractures that are difficult to palpate (due to their size or location in the keel bone) and fractures that are healed or recent (calluses can take a long time to develop; Chapter 3 [3]). For example, a recent longitudinal study that used a more sensitive radiographic protocol [17] indicates that palpation could have underestimated the prevalence of fractures by 30 to 100%: in 24% of the fractures no callus (or swelling) was visible, and in those fractures that developed a callus (76%), only 49% had a callus at the time of detection. The extent to which palpation underestimates the prevalence of fractures compared to dissection is illustrated in several studies where both techniques were employed. When using dissection, the percentage of hens with fractures increased from 57% to 62% in the study of Petrik et al [18], from 53% to 63% (single-tier aviary) in the study of Wilkins et al [19] and from 41% to 86% in the study of Stratmann et al [20]. In fact, a recent study suggests that the degree to which fractures are underestimated might be higher in conventional cage systems. The authors observed that fractures in alternative systems are more often associated with substantial callus formation,

whereas fractures in caged birds were more discrete, resembling “greenstick” or stress fractures that are more difficult to identify [21].¹

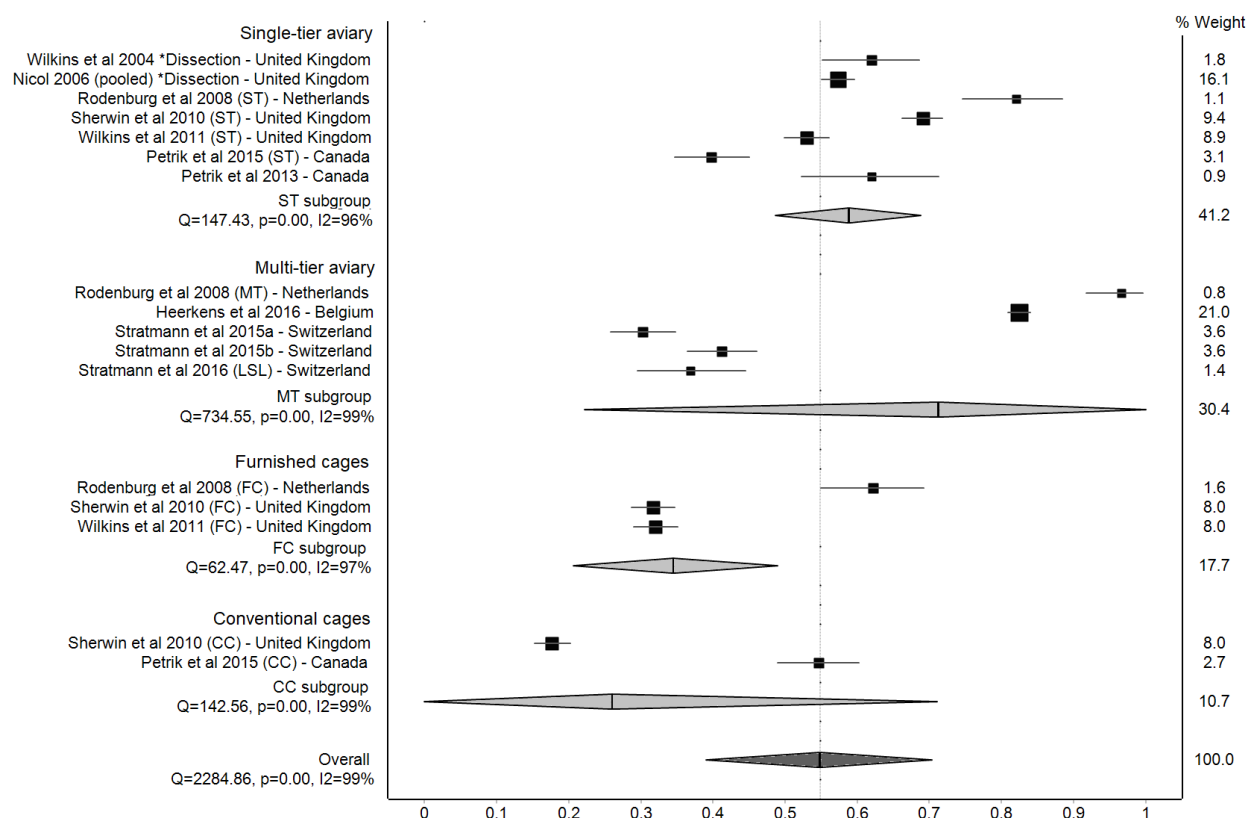


Figure 8.1. Prevalence of commercial layers with keel bone fractures at the end of the laying cycle (60-70 weeks) in conventional cages, furnished cages, indoor multi-tier and single-tier aviaries, ordered by the mid-year of data collection. Estimates exclude fractures endured during depopulation and transport.

Bone fractures endured during depopulation and transport

The poor skeletal health and brittle condition of the bones of commercial layers at the end of the laying cycle is typically associated with high rates of fractures during depopulation and transport. The problem seems to be particularly aggravated in laying hens kept in caged systems. It has long been recognised that caged layers have weaker bones than those raised in cage-free systems given

¹ Because the extent to which all greenstick fractures are painful (or as painful as more severe fractures) is not clear, and we conservatively want to avoid artificially inflating the negative welfare effects of conventional cages, we make no attempt to include these fractures in estimates of keel bone prevalence in caged systems in analyses focused on the comparison of housing systems (Chapter 9 [22]).

differences in their opportunities for physical exercise [23]. Indeed, bone breaking strength has been consistently found to be substantially higher (40-60%, depending on the bone) in hens kept in loose house systems compared to hens in conventional and furnished cages [24–26].

In line with these findings, the percentage of birds suffering broken bones during catching, handling and transportation (Chapter 7 [6]), where investigated, seems to be in the order of two to three times higher in cages than in non-cage systems. In the UK, 24% (13-41%) of spent hens from cages were found to have fresh fractures after depopulation, with this number rising to 31% following transport, with an average of 1.8 new fractures per injured bird [27]. In comparison, 10% hens from loose housing systems were fractured in this process, with an average of 1 fracture per injured bird [23]. In a more recent study, Sherwin and others [28] reported that keel bone fractures endured during depopulation, handling and transport were nearly five times more common in hens from conventional cages (24.6%) than in hens from furnished cages (3.6%) and single-tier aviaries (1.2%). In another study in the UK, the prevalence of new fractures was also significantly higher in cage systems (23%) than in furnished cages (13%) and single-tier aviaries (15%) [29]. These results are summarized in Table 8.2, along with an uncertainty range associated with each housing system. Unfortunately, there seems to be little data on the prevalence of fractures endured by hens in their last day of life in countries other than the United Kingdom. Further research should address this gap.

Table 8.2. Percentage of commercial layers sustaining new fractures following depopulation and transport, and number of fractures sustained (in brackets) in different housing systems.

	Conventional cages	Furnished cages	Cage-free aviaries
Gregory & Wilkins 1989	31% (1.8)		
Gregory et al 1990			10%
Sherwin et al 2010 *	24.6	3.6	1.2
Sandilands et al 2007	23	13	15
Uncertainty range (all fractures)	20-35%	4-15%	2-15%

*only fractures of the keel bone are reported

Injurious pecking: sizing the problem in different systems

In Chapter 4 [4], we explored the temporal evolution of the pain associated with the physical injuries resulting from injurious pecking, namely the pain associated with feather removal, skin and vent wounds and with fatal cannibalistic attacks. Here, we investigate the extent to which these consequences are present in commercial flocks kept in cage and cage-free systems by analysing the frequency of the following endpoints: forceful feather removal, severity and prevalence of skin and vent wounds, and prevalence of fatal cannibalistic attacks.

To this end, we conducted a review of the literature, focusing on the period from the year 2000 to 2020. To be considered for the quantitative (comparative) analysis, data sources had to report numerical data on one of the endpoints of interest disaggregated by the housing system (or proxies enabling their calculation). Thus, studies reporting only qualitative descriptors, such as ‘poor’ and ‘good’ plumage condition, were not considered. Additionally, we included information only for flocks aged between 50 and 70 weeks. Flocks with younger birds were not considered to limit the well-known confounding effect of age on the endpoints. The upper limit of 70 weeks was established to avoid confounding due to the practice of induced molting, still prevalent in many countries outside Europe. Additionally, results that aggregated hens with trimmed and intact beaks were excluded given the critical effect of beak trimming on the outcomes of injurious pecking. Because injurious pecking may not occur to the same extent in experimental settings as in commercial situations [30,31], only studies reporting data on commercial flocks were considered. Searches were conducted using Web of Science and Google Scholar, and bibliographies of key articles were hand searched.

Forceful Feather Removal

Direct observations of the number of feathers lost to injurious pecking are not available. Thus, the frequency with which hens housed in different housing systems endure the pain of feather removal could be estimated in two ways. A first logical approach would be to determine the number of feathers removed by flock mates as the product between (i) the number of severe feather pecks (SFP) received over the entire laying cycle and (ii) the ratio with which severe feather pecks result in the removal of feathers. Because it is impractical to record the feather pecking behavior of hens throughout the entire day, the most common approach to estimate SFP rates has been the observation of behavior in time windows of a few minutes to a couple of hours [28,32,33]. SFP rate must be then extrapolated to the entire laying cycle, taking into account its temporal variability along the day and the production weeks [34–38]. Unfortunately, neither are there estimates of SFP rates available for all housing contexts, nor data on the frequency with which severe feather pecks result in the removal of feathers.

Therefore, we follow previous authors in using the severity of plumage damage as an imperfect proxy measure of feather removal [36,39–42]. Plumage damage scores provided a numerical equivalent of a subjectively identified amount of feathers forcefully lost [43], as long as it reflects plumage damage in the body areas most frequently affected by severe feather pecking. For example, feather loss in the under-neck region and wings is often the result of abrasion against the housing structures and furnishings [40,44]. Conversely, abrasion rarely occurs in the back of the hen, thus feather loss in this area can be ascribed to SFP with more certainty. Therefore, we searched for studies reporting plumage damage scores based on those body areas that are often the target of SFP: the back, rump, vent, belly and upper neck areas.

Still, the analysis of plumage damage is not possible if scores are not standardized to a common scale. Several scoring systems have been used to assess the extent of plumage damage [40,45–47]. In general, different body parts are scored on a 3 to 5 points scale, from no damage to severe damage. However, existing methods differ in the number of body parts considered and the definitions of damage. For example, in the method of Tauson [45] the worst score indicates completely denuded areas, whereas in the Welfare Quality Protocol, the worst score is, instead, assigned to the presence of at least one featherless area of at least 5 cm in diameter [46]. Additionally, the way in which scores are integrated into a composite measure of plumage status for the flock differs greatly among studies. In

some cases, the scores of each body part are summed, yielding a total score per bird, which is then averaged across all birds in the flock. In others, body part scores are averaged or the worst score of any of the body parts is considered. The plumage status of the flock is then provided as an average for all body parts together, or as an average for each body part, or even as the percentage of animals with different scores. Thus, to be able to compare and integrate damage scores across studies, we standardized all results to a common scale ranging from 0% to 100%, where 0% represented perfect plumage cover and 100% represented the worst possible score (most feathers lost), as defined by each study. Of course, the definition of the worst score differed among studies, so the results must be interpreted considering this limitation.

Table 8.3. Standardized scores (0-100%) for feather loss (100% = worst possible score) in commercial layer flocks in four housing systems, ordered by the mid-year of data collection. The color scale from dark red to dark green corresponds to increasingly better plumage scores.

	Source	Body Parts	Country	Yr	CC	FC	MT	ST
1	Nicol et al 2006	Neck,back,tail,abdomen,breast	UK	2001				65
2	LaBrash 2003	All body parts	US	2002	58			
3	Rodenburg et al 2008	Neck, back,tail,breast,vent,wings	NL,BE	2005		47	38	58
4	Sherwin et al 2010	Neck,back,tail,vent,abdomen	UK	2006	62	70		79
5	Ferrante et al 2009	Neck,back,cloaca	IT	2007				22
6	Heerkens et al 2015	Neck,back,tail,vent	BE	2009		48		
7	Craig et al 2011	Neck, back, tail, vent, wings,keel	NZ	2009		29		
8	Sepeur et al 2015	All body parts	DE	2010				57
9	Blachford 2016-1	Neck, back, rump, belly, keel	US	2011	36	29	21	
10	Blachford 2016-2	Neck, back, rump, belly, keel	US	2012	21	29	14	
11	Petrik et al 2015	Neck,back,breast,vent	CA	2013	22			21

0 50 100

CC= Conventional cages; FC. = Furnished cages; MT = Multi-tier system; ST = Single-tier system

Only ten studies met the inclusion criteria; they are shown in Table 8.3, ordered by the mid-year of data collection. No differences in plumage damage between cage and cage-free systems were observed ($p < 0.05$ in all meta-regression models, controlling or not for years of data collection). For example, while one study [28] reported the best plumage score in conventional cages, such a finding

was not replicated in any other study. If anything, plumage damage was best at multi-tier aviaries (in line with the findings of a review from 2013, showing better feather scores in alternative systems [26]), but the number of studies (n=2) is extremely reduced to allow any conclusion. Interestingly, similarly to the pattern shown for cumulative hen mortality over the years [14], there was a gradual improvement of plumage condition over time (Figure 8.2), in line with the hypothesis that, as experience with each housing system evolves, producers become more capable at preventing and/or controlling injurious pecking. Still, further research is needed to confirm this pattern due the scarcity of data on plumage condition in commercial flocks kept indoors.

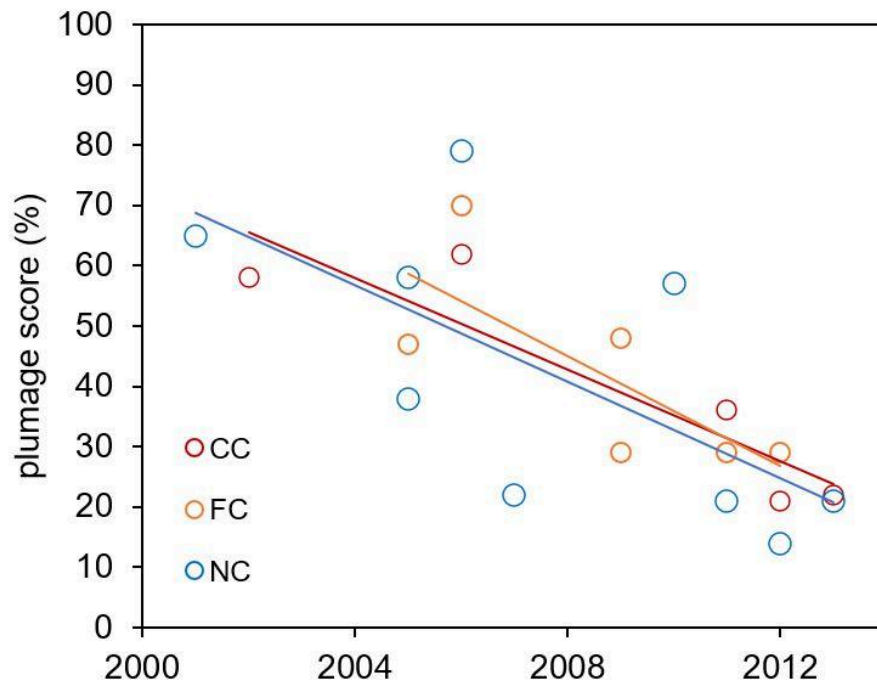


Figure 8.2. Standardized scores (0-100%) for feather loss (100% = worst possible score) in commercial layer flocks as a function of year of data collection. CC: conventional cages; FC: furnished cages; NC: single- and multi-tier aviaries.

To convert plumage damage scores into the number of feathers lost forcefully, we first sought to establish the number of feathers in those body areas vulnerable to severe feather pecking. The only data on the distribution of feathers per body part we could find was a study on the mean plumage weight in different body areas as a proportion of the mean weight of the total plumage [48]. In this study, the authors plucked 10 perfectly feathered individuals, and estimated that the capital, dorsal and abdominal regions of the fowl (the most affected by injurious pecking) represent 9.9%, 16.5% and 6.7% (total = 33.1%) of the total plumage weight, respectively. Considering that variability across breeds and individuals is likely present, we hypothesize that about 25 - 35% of the total feathers of a laying hen could in theory be forcefully removed. If laying hens have approximately 7,000-9,000 thousand feathers [49], this represents approximately 1,750 - 3,150 feathers. Thus a plumage damage score of, for example, 50% at the flock level would represent an 'average' loss of approximately 875 to 1,575

feathers plucked from each bird (though not necessarily distributed homogeneously across birds). This is, of course, a first and very broad tentative approximation of the number of painful feather removal events endured by an individual. For example, plucked feathers may regrow and be plucked out again repeatedly. Additionally, feathers may be lost due to dietary deficiencies instead of plucking. Unfortunately, existing data does not enable us to be more precise ².

The burden of pain caused by feather removal is then calculated as the product between the time spent in each of the categories of pain intensity per episode of feather removal (Pain-Track 4.1 in Chapter 4 [4]) and the estimated number of feathers removed (occurrences). Because complete recovery from the pain caused by feather removal is rapid (Pain-Track 4.1 in Chapter 4 [4]), and severe feather pecks do not happen in successive bouts [50], feather removal episodes are assumed to be independent (note that the distribution of feather loss across birds within a flock is not relevant in this case: the estimated burden of pain is assumed to be the same whether one bird has 50 feathers removed, or two birds have each 25 feathers removed).

Skin and Vent Wounds

Similar to plumage damage, various scoring systems have been used to assess the severity of skin wounds in laying hens, using a 3 to 5 points scale. In some cases, wounds are scored from no damage to severe damage based on comparisons with photographic scales [28,45]. In others, assessment is based on thresholds related to the number and size of wounds (e.g. the worst score corresponds to the presence of large wounds >2.2 cm in diameter) [51]. To be able to compare the data reported by different studies, we used the same procedure as that used for the analysis of plumage damage, and standardized all results to a common scale ranging from 0% (no wounds) to 100% (worst possible wound score). Ideally, this scale should reflect the prevalence and severity of wounds in the flock, summarized as a score for the average flock member.

Unfortunately, data on the prevalence and severity of skin wounds in commercial conditions is extremely scarce. Most studies conducted so far are experimental, or focused exclusively on organic or free-range layers, or older than two decades. This finding is in line with remarks by other authors that data on the incidence of injurious pecking and cannibalism in commercial cage systems is extremely scarce [31]. As far as we are aware, there have been only five published studies reporting such data since the year 2000, as shown in Table 8.4.

² As a thought exercise, we explored the number of pecks that might be required to remove a feather. To this end, we took as a basis estimates of ~0.5 to 4 severe feather pecks (SFPs) per bird per hour observed in non-cage flocks [37], and multiplied it by a daily time budget of 6 to 10 hours dedicated to foraging to determine the approximate minimum and maximum number of SFPs received by the average flock member per day (3-40 SFPs). Next, we multiplied it by 300 days (43 laying weeks) to determine such an average for a laying cycle where hens are depopulated at 60 weeks, yielding a range of 900-12,000 SFPs received by the average flock member. Considering that plumage damage scores at this age may vary from 20-50%, this translates into 350 to 1800 feathers lost by the average bird. Hence, the average number of SFPs needed to remove one feather goes is likely to lie between 2 (1,800/2) and 34 (12,000/350).

Table 8.4. Standardized scores (0-100%) for skin wound severity (100% = worst possible score) in commercial flocks kept in four housing systems, ordered by mid-year of data collection. The color scale from dark red to dark green corresponds to increasingly better (less severe) wound scores.

	Source	Country	Yr	CC	FC	MT	ST
1	Rodenburg et al 2008	NL, BE	2005		7	17	7
2	Sherwin et al 2010	UK	2006	20	35		44
3	Craig et al 2011	NZ	2009		0		
4	Niekerk et al 2012	NL, SE	2009	3	2	10	6
5	Heerkens et al 2015	BE	2009		12		



0 50 100

No consistent patterns were obvious: while two studies [28,52] point to a higher wound severity in single-tier aviaries, another [33] indicates similar wound severity in single-tier aviaries and furnished cages. If anything, wound severity seems to be somewhat higher in multi-tier aviaries, although evidence in this regard comes from only two studies, both conducted more than a decade ago. Similarly, the range of years (2005-2009) for which data is available is too short to enable inferring potential trends over the years.

Therefore, we searched for studies reporting simply the prevalence of birds with skin wounds, as opposed to wound scores (which combine prevalence and severity). The very few reports that met the inclusion criteria indicate that the proportion of birds with skin wounds at the end of lay varied from about 1 to 9% in furnished cages [53–55], 5 to 30% in cage-free aviaries [51,53,56] and 10% in conventional cages [53].

For vent wounds, the proportion of hens affected seems to be somewhat lower. A comparison of conventional cages, furnished cages and single-tier aviaries conducted in the UK in 2006 found that respectively 6.2%, 1.6% and 10% of birds in these systems had been vent-pecked [28]. The observation of a lower prevalence of vent wounds is consistent with the finding for commercial free-range flocks in the UK in the late 90s, where approximately 56% of the flocks were affected by severe feather pecking, with an average within-flock prevalence of skin damage of 30% (thus average prevalence of skin damage of $56\% \times 30\% = 17\%$) [57], whereas 37% of the flocks were affected by vent pecking, with 3.5% of the hens with vent damage within each of the affected flocks (hence average prevalence of vent damage of $37\% \times 3.5\% = 1.3\%$) [38].

Overall, these results suggest that the proportion of hens with skin and vent wounds might be somewhat higher in cage-free systems. However, the extent to which these results are affected by differences in the level of experience with the systems is not clear. There is strong evidence to suggest that cumulative mortality in commercial systems gradually drops as experience with a system builds up [14]. It is possible that tissue pecking (a cause of mortality) is also reduced over time in cage-free

hens as management practices evolve and genetics are optimized to reduce the incidence of this behavior. For example, after conventional cages were banned in Sweden, the initial batches of layers raised in aviaries had severe problems with feather pecking and cannibalism, but these were reduced over time due to improved management and aviary design, change of hybrids and feed modifications [58]. Thus, it is possible that the somewhat higher frequency of wounds in non-cage systems is an artefact of the relatively greater recency of this system. This possibility is also suggested by the patterns shown in Figure 8.2, where plumage damage scores improve over time.

Unfortunately, recent surveys reporting both the between- and within-flock prevalence of skin and vent damage in commercially managed settings are not available. Naturally, even less data is available on the proportion of wounds that get infected - as far as we are aware, there has been no study conducted on the topic. Similarly, there seems to be no data on the cumulative number of skin and vent wounds suffered by laying hens over the entire laying cycle. Thus, to make a first attempt at estimating the burden of pain endured by laying hens as a result of skin wounds we provisionally consider the prevalence ranges reported in this section (5-15% in conventional cages, 1 to 10% in furnished cages and 5 to 30% in cage-free aviaries).

For vent wounds, the only study found was conducted in 2006, hence to the reported prevalence we add uncertainty intervals (3-8%, 1-4% and 5-15% in conventional cages, furnished cages and aviaries, respectively). Both in the case of skin and vent wounds, we assume a probability of infection (explored in Pain-Tracks 4.3, 4.5 and 4.6, Chapter 4 [4]) of 5-10%, and in all cases assume that a hen may experience from 1 to 3 wounds, on average, over the production cycle. Research in commercial settings is very much needed to investigate and correct these parameters.

Cannibalism as a cause of mortality

Systematic research on the causes of 'normal' hen mortality³ in commercial systems is extremely scant and, where available, based in one housing system only [60–62]. In the only study where normal mortality was compared across housing systems [63], the proportion of deaths due to cannibalism ranged from 0.2 to 7.6%. However, the housing systems analyzed had very large different degrees of maturity (management staff and stockmen had experience of over a decade with conventional cages, and no experience with cage-free aviaries and furnished cages), a major confounder of mortality [14].

Therefore, in an attempt to explore this question further, we analyzed the results of a large national survey conducted in the United States in 2013 [64], including over 300 farms and 1300 flocks, in which the percentage of flocks affected by cannibalism in conventional cages, furnished cages and cage-free aviaries was reported by farmers. Based on the farmers' answers, no major differences in the prevalence of cannibalism among housing systems were observed (Figure 8.3). Overall, most flocks (96% in conventional cages, 86% in furnished cages and 94% in the cage-free aviaries) experienced either no problems of cannibalism or only minor problems. As shown in Figure 8.3, moderate problems were higher in furnished cages, and <1% of cage-free flocks experienced severe outbreaks.

These findings are in line with the view that cannibalism can occur in all housing systems, but when outbreaks occur they can reach more severe levels in cage-free housing, where it is more difficult to control [42,65–68]. In larger flocks, peckers have more potential victims [66], and are harder to

³ As opposed to the analysis of convenience samples of hens submitted for necropsy due to abnormal levels of mortality (hence not representative of mortality in typical flocks) [59].

identify, hence cannot be easily removed. Also, cannibalistic pecking may spread through the flock by social transmission [69,70], making it more difficult to contain outbreaks when they first occur. Interestingly, it was in the furnished cages that cannibalism was more frequently seen as something more than a minor problem, affecting 14% of all flocks (Figure 8.3). In 2013, when the survey was conducted, less than 2 percent of the US flocks were kept in furnished cages, just recently implemented in some farms due to legislation promoting the phasing out of conventional cages in some states (eg, California). The observation of more frequent problems with cannibalism in these newly implemented cages is telling of the problems that may be experienced during the initial phases of transition to a new housing system. Most cage-free houses, in turn, were older than 10 years at the time of the survey (complementary information provided by the National Animal Health Monitoring System, USDA).

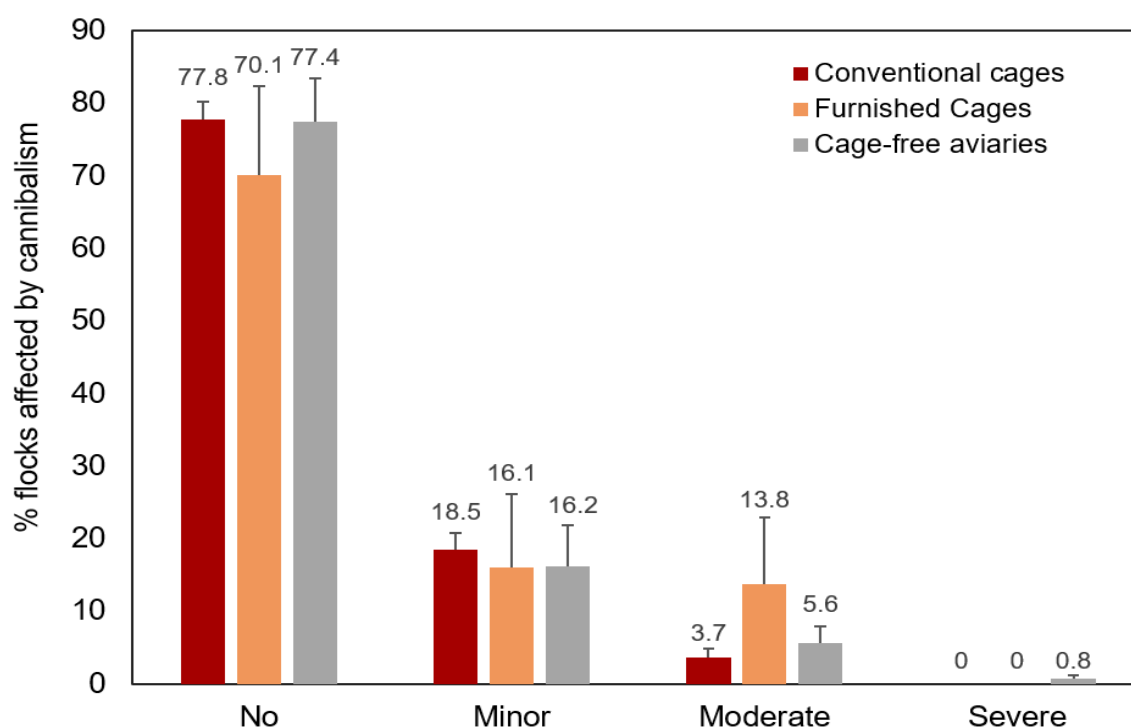


Figure 8.3. Mean percentage of flocks (SE) affected by cannibalism, according to the severity of the problem as reported by farmers in 19 states in the United States (2013). Data refers to the last flock in the farmers' hen houses. Source: USDA. Layers 2013 Part I: Reference of Health and Management Practices on Table-Egg Farms in the United States.

Based on the evidence presented, we tentatively estimate that the overall proportion of deaths due to cannibalism in commercial layer populations ranges from about 1 to 8% of all deaths [63]⁴. Assuming

⁴ This range is compatible with the findings of an old survey of commercial farms in the UK, which showed that approximately 1 in every three vent pecked birds died from the resulting injuries and blood loss [30]. Assuming that 2-7% of hens are survivors of vent-pecking attacks by the end of the laying cycle [20,30], this would translate into 1% to 3% of total deaths due to vent cannibalism.

mortality ranges from 3 to 8% [14], this corresponds to 0.03% to 0.6% of the flock dying from a cannibalistic attack.

The proportion of deaths due to cannibalism is likely lower in conventional cages than in furnished cages and cage-free aviaries when these systems are first introduced. However, differences are expected to reduce progressively as systems evolve. Severe outbreaks may still occur in cage-free aviaries given the inherently larger flock sizes, though these may be sporadic events in mature systems (as suggested by the <1% of the flocks affected by severe problems in the US survey). To quantify the burden of pain due to cannibalism we assume that cannibalism accounts for 0-2%, 1-3% of all deaths in conventional and furnished cages, respectively. In cage-free systems, we conservatively estimate a three-fold higher probability of deaths due to cannibalism (relative to furnished cages) prior to producers acquiring experience with the system (2-10%), progressively reducing with time. These estimates correspond to 0-0.16%, 0.03-0.24% and 0.15-0.8% of all birds in conventional cages, furnished cages and cage-free aviaries likely to die from a cannibalistic attack if cumulative mortality ranges from 3 to 8%. Of these deaths, 60-90% are estimated to result from fatal vent pecking events, and the remaining from fatal cannibalistic attacks. As stressed before, further research is critically needed for the investigation of these parameters.

A painful disease: egg peritonitis

Egg peritonitis syndrome (EGPS) is a painful condition and an important cause of poor welfare in commercial laying hens (Chapter 5 [5]). It has been shown to be the main cause of mortality in commercial layers by various studies (Table 8.5). For example, in a flock of Babcock White Leghorns kept in single-tier aviaries in Canada, egg yolk peritonitis accounted for 22% of all deaths over a period of 33 weeks [70]. In another study conducted with 1,800,000 hens in conventional cages, and 118,000 hens in furnished cages, the proportion of deaths attributed to egg yolk peritonitis, salpingitis, internal layer and egg bound was respectively 26.6%, 4.7%, 1.4% and 0.7%, totalling 33% of mortality, by far the most prevalent cause of death [60]. Similarly, in the only study that compared the causes of normal layer mortality across housing systems using standardized diagnostic definitions, egg yolk peritonitis (defined by the authors as the congestion of visceral vessels with the presence of egg yolk within the coelomic cavity) was diagnosed as the cause of death in 25%, 19% and 12% of the daily mortalities in conventional cages, furnished cages and multi-tier aviaries, respectively, with salpingitis (oviduct greatly distended with a fetid yellow, easily crumbled exudate) responsible for an extra 2%, 1.6% and 3% of the deaths, and internal layer/egg bound for 0.5%, 0.3% and 1.2%, respectively [63]⁵. Thus, EGPS (which includes both conditions) accounted for 27.6%, 21% and 16.5% of the mortality in conventional cages, furnished cages and multi-tier aviaries, respectively. A higher prevalence in conventional cages is in line with observations of greater fat deposition in caged hens [72], a risk factor for EGPS.

In Table 8.5 we summarize these findings, and provide an estimate of the uncertainty range representing the proportion of deaths attributed to EGPS in each housing system. Uncertainty ranges are wider than observations to reflect the lack of knowledge about the epidemiology of EGPS in commercial conditions, as well as the possible variability across flocks. Considering that cumulative mortality should vary from approximately 2-6% at 60 weeks in all systems [14], or approximately 3-8%

⁵ Although the patterns reported for the two flocks studied are similar, we consider only flock 1, as the proportions associated with each cause of death add up to more than 100% for flock 2 [71].

at 70 weeks, of all the hens in a flock, the percentage dying from EGPS should vary from 0.3% to approximately 3.2%.

Table 8.5. Percentage of layer deaths attributed to egg peritonitis syndrome , proposed uncertainty range and estimates of the absolute prevalence of fatal victims in a flock, assuming a cumulative mortality of 3-8% at 70 weeks of age.

	Conventional cages	Furnished cages	Cage-free aviaries
Tablante et al 2000			
Fulton 2017	33%		
Fulton 2019	27.6%	21%	16.5%
Uncertainty range	20-40%	15-30%	10-30%
% of flock dying from egg peritonitis syndrome	0.6-3.2%	0.3-2.4%	0.3-2.4%

Studies on the prevalence of non-fatal cases of EGPS are even more scarce, with only one investigation published since 2000 [73]. The study, which involved the culling of a random sample of seemingly healthy hens from 15 Danish flocks at the end of the laying period reported that 4.13% of hens in furnished cages and 5.57% in single-tier aviaries had infections in the reproductive tract (salpingitis, peritonitis and oophoritis combined) or chronic lesions (e.g. scarification and/or serosal fibrosis on abdominal organs), the non-fatal chronic form of EGPS (Figure 5.2 in the Chapter 5 [5]). Since the range of prevalence (4.1-5.6%) derives from a single observation, we consider a wider interval (2-8%) to reflect our uncertainty about the prevalence of non-fatal cases of EGPS in commercial settings in general. Unfortunately, with one study it is not possible to determine whether the prevalence of the chronic form of EGPS differs across housing contexts. Although the three studies reported in Table 8.1 suggest a higher prevalence of EGPS in caged systems, the study of Wang and collaborators reports a lower prevalence in furnished cages. The extent to which this pattern can be generalized is not clear, hence no assumptions are made regarding differences among housing systems.

Research Gaps

- ❑ Published data on the prevalence of the injuries and diseases addressed in this chapter in commercial production is extremely scant. For example: (1) to our knowledge, only two studies reported the prevalence of fractures in conventional cages since the year 2000. In other housing systems, studies are concentrated in Europe (predominantly the UK and Switzerland); outside Europe, recent prevalence data in commercial settings is only available for Canada; (2) there is very little data on the prevalence of fractures endured by hens during depopulation and transport in countries other than the UK; (3) recent surveys reporting the prevalence of pecking injuries (skin and vent damage) in commercial settings are not available (most studies are focused exclusively on organic or free-range layers, or are older than two decades); (4) studies on the prevalence of egg peritonitis syndrome in seemingly healthy hens are scarce, with only one investigation published since 2000 [73]; (5) recent research on the causes of 'normal' hen mortality in commercial systems are scarce and, where available, focused in only one housing system [60–62].
- ❑ The lack of consistency in diagnostic methods of assessment of injuries and diseases (e.g. scoring systems of plumage damage, methods to detect the presence and severity of fractures) currently constrains the possibility of comparing findings in a global analysis.
- ❑ Quality of reporting is still poor and not standardized. Most studies presenting data on the prevalence of different harms do not report (or report incompletely) factors that are critical for their interpretation, such as (1) breed, (2) age of the flock, (3) beak trimming status, (4) stocking density, (5) flock size, (6) lighting conditions, (7) year of data collection (harm prevalence can change with time), (8) the degree of experience with the system (differences in the maturity of systems impede comparability [14]), (9) sample size, (10) variability measures and/or (11) results disaggregated by important variables. Importantly, recruitment criteria (e.g. for farms) are not commonly reported. To facilitate critical appraisal and adequate use of evidence, reporting guidelines in this area should be adopted.
- ❑ The understanding of the prevalence of different welfare harms to which animals are exposed will depend on the complementary collection of data at different stages of the production cycle. For example, data based on farm visits may underestimate the true prevalence of some welfare problems as farms allowing visits are less likely to include situations of abuse, neglect, and poor stockmanship (an effect we refer to as 'healthy-farm effect'), so should be complemented by surveys at the abattoir. Conversely, prevalence data obtained from the inspection of carcasses at the abattoir may underestimate the prevalence of other conditions, as animals affected by more severe disease may not make it to slaughter.

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