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 6.2
Report on Production and Egg quality

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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)	

Work package 6, Production and egg quality. Leader: ADAS (partner 3)

Work package 6 Final report productivity and egg quality

1. Introduction

1.1 Period of activity
From 1/1/2004 to 31/12/2005.

1.2 Work package objectives
The objectives of Work package 6 (WP6) were to collect, analyse and interpret productivity data and information from existing research projects, on conventional and furnished cages of different designs and also in non-cage systems, including studies using laying hens of a number of genotypes and at a range of stocking densities, over full laying cycles on research and commercial flock scales. It would bring together all of that material into a collective form, enabling comparisons between egg production systems in different Member States. It considered how the data contribute to our knowledge of welfare and discuss the suitability of various productivity variables as welfare indicators.

2. Methods

2.1 Database

A centralised, web based Excel database was developed in which all partners entered their data. This facilitated not only the collection of production data for WP6, but also data for the other WPs (WP3: health/exterior, WP4: behaviour, WP5: physiology) and ensured a uniform data format, which made comparisons between studies and meta-analyses of the available data possible. Information from WP2 describing different housing systems and housing categories used in laying hen production were incorporated into the database to be used as descriptors for the different studies. The main systems are conventional cages (CCs), furnished cages (FCs) and non-cage systems (NCs). Furnished cages were subdivided into small furnished cages (up to 15 hens/cage), medium furnished cages (15-30 hens/cage) and large furnished cages (> 30 hens/cage). Non-cage systems were subdivided into single tier non-cage systems and multi tier non-cage systems (for descriptions of the housing systems see the report from WP2). General information on the design of the studies was also collected.

Two main data entry rounds (one each year) were held to collect all the data from the eight different partners. The data entry process was managed by ADAS. The final database included eleven different topic worksheets (Data sources, General, Rearing housing, Laying housing, Management, Health/Exterior, Behaviour, Physiology, Production, Log, Acronyms), data from 230 different flocks and 459 lines of data. A data line comprised variables for a certain treatment, so data entered for a flock of birds could consist of several data lines covering the different treatment groups (e.g. different housing systems).

2.2 Production data collected for WP6

Different partners from the consortium (PV-Lelystad, DIAS, INRA, SLU, UNIVBRIS, UHOH and UNIZAR) contributed production data from their studies to WP6. Most of the data came from replicated scientific studies that have been subjected to statistical analysis and verification.

Status of data entry for WP6

- ADAS (partner 3) provided production data from two studies on laying hens in small group furnished cages. It was decided not to use data from a third flock because this study had to be aborted prematurely due to severe levels of feather pecking in intact beaked hens. In addition, data from a study on a commercial partner’s site with various models of small and medium group furnished cages was entered. In the second project year data from a study conducted on commercial farms covering different systems (conventional cages, single tiered non-cage systems and small, medium and large group furnished cages) was entered.

- PV-Lelystad (partner 2) provided production data from studies on different types of small, medium and large group furnished cages and from single and multi-tiered non-cage systems. The data was entered in the first project year, but expanded in the second project year.
- DIAS (partner 4) provided production data from single-tiered non-cage systems on commercial farms and data from conventional cages.
- INRA (partner 5) provided production data from studies on conventional cages and small and medium group furnished cages as well as multi-tiered non-cage systems.
- SLU (partner 6) provided production data from conventional and small group furnished cages as well as multi-tiered non-cage systems. In the second project year data from small group furnished cages and single- and multi tiered non-cage systems on commercial farms was entered.
- UNIVBRIS (partner 7) provided production data from studies on single-tier non-cage systems.
- UHOH (partner 8) provided production data from studies on furnished cages and from single- and multi tiered non-cage systems. In the second project year data from conventional and small, medium and large group furnished cages was entered.
- UNIZAR (partner 9) provided production data from studies on conventional cages and small group furnished cages.

3. Results for WP6

3.1. Production dataset

The data from the production worksheet in the LayWel database has been summarised in tables and graphs in the section below. Blank spaces in the tables denote that not enough data was available. Comments about the data are given below each table or graph. After discussion in the LayWel consortium it was decided not to perform statistical analysis on the data collected in the database as there might be too many unknown influences from variables due to the different studies (e.g. different locations and seasons). Therefore only descriptive statistics were used (means and SD). However, due to the amount of data in the LayWel database clear trends could be detected. In order to strengthen this, variables for which less than 8 data lines were available are not presented.

One of the conclusions from the EFSA report on Welfare aspects of various systems for keeping laying hens published in 2005 was that zoo-technical parameters are not reliable indicators of welfare, but may be used as the first indication of a possible welfare problem (EFSA, 2005). The parameters may be especially useful if sudden changes occur in the daily production. Several production indicators were mentioned and these included high or low feed and/or water intake, feed conversion ratio, misplaced eggs, low egg production (number and weight of eggs), poor egg shell quality and low body weight.

It was therefore considered useful to collect these variables for WP6. After further discussions in the LayWel consortium during the initial phases of the project, data on the following 18 variables were collected on the production worksheet: body weight at the beginning, middle and end of lay (kg), feed intake (g hen day), feed conversion ratio (FCR), water intake (ml hen day), egg production (% hen day and % hen housed), average egg weight (g/day), egg mass output (g hen day and g hen housed), total egg mass output (kg/hen), first quality eggs, second quality eggs (all, cracked and dirty), eggs laid in nest box at peak lay (%), egg collection method (manual or automatic).

The aim of the LayWel project was to update knowledge on the welfare implications of the use of different categories of laying hen housing systems including both cage and non-cage systems. Special emphasis has been put on furnished cages, as required. To check whether this aim was achieved for the production data, the data input into the production sheet was checked. Figure 1 shows the total number of data lines entered in the production worksheet, separated for the three main systems.

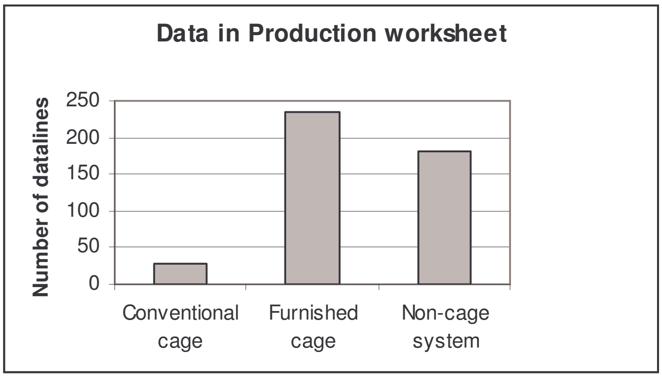

Figure 1. Number of data lines in the production worksheet of the database

The graph shows that furnished cages are well represented in the production dataset (53% of data lines). Non-cage systems and conventional cages account for 40% and 7% of the production dataset respectively.

3.2 Production related to main types of systems (CCs, FCs, NCs)

The EFSA report (2005) evaluated productivity between systems based mainly on recent scientific literature. The report states that: 'whilst production has been recorded in many studies within systems, not many studies have been conducted covering a wide range of systems' (EFSA, 2005). The report lists some recent trials and surveys from different European countries involving at least two systems providing productivity data. These were:

1. In Sweden, Tauson and Holm (2001) compared two parallel flocks in single level NC systems and FCs and found 3% lower egg mass and 4% higher feed conversion rate in the NC system.
2. In Germany, Leyendecker et al (2002) compared the performance of hens reared together, housed during the laying period in CCs, FCs and an aviary. Eggs collected were highest in the FCs and lowest in the aviary. Feed conversion ratio was better in cages than in the aviary.
3. In France, Michel and Huonnic (2003) compared CCs with aviaries. More eggs were collected from the caged hens than from those in the aviary, and the former had a superior feed conversion ratio.
4. In the UK, the National Farmers Union regularly conducts surveys among their members. In a recent survey of many producers with flocks housed from 17 to 72 weeks of age (NFU, 2003) they reported the highest eggs collected in CCs a mean of 307 eggs/hen (range 290-329) followed by single level NC systems, with a mean of 298 eggs/hen (range: 260-311). Mean feed intake was CCs 117: g/bird/day, alternative indoor: 124 g/bird/day and free range: 128 g/bird/day.
5. In Belgium, Zoons (2004, cited in EFSA, 2005) compared CCs, large group FCs and an aviary. The highest number of eggs was collected in FCs, followed by CCs, and the lowest was in the aviary.

The WP6 production data was summarised to see if the findings from these five studies could be substantiated with the large dataset of LayWel. Tables 1-3 and Figure 2 list some production parameters for the three main types of systems, conventional cages, furnished cages and non-cage systems.

Table 1. Feed and water intake

System	Feed intake (g hen day)		Water intake (ml hen day)	
	Mean	SD	Mean	SD
Conventional cage	114.97	5.445		
Furnished cage	113.82	7.507	184.17	10.053
Non-cage system	123.79	8.985	210.17	15.772

Feed intake in conventional cages and furnished cages is very similar. Feed intake is higher in non-cage systems than in conventional cages and furnished cages. This finding supports the NFU finding (NFU, 2003) and is commonly seen under practical conditions. The higher feed intake in hens from non-cage systems is due to a higher level of exercise and (for free range systems) exposure to a wider range of temperatures.

Although water intake will be routinely monitored on many commercial farms, few published data exist on water intake of hens in different housing systems. The data in Table 1 shows higher water intake in birds in non-cage systems. This is not surprising since water intake is closely associated with feed intake. A risk associated with higher water intake is that it may lead to an increase in excreta moisture. This in turn can lead to contamination of clean eggshells and an increase in the percentage of dirty eggs (Smith et al., 2000).

Table 2. Feed conversion and egg output

System	Feed conversion ratio		Total egg mass output (kg)	
	Mean	SD	Mean	SD
Conventional cage	2.14	0.139	21.37	1.379
Furnished cage	2.14	0.112	20.53	2.039
Non-cage system	2.48	0.217	19.39	2.256

Feed conversion in furnished cages is similar to that in conventional cages. Feed conversion in non-cage systems is higher (and thus less efficient) than in conventional and furnished cages. This supports the findings of Tauson and Holm (2001), Leyendecker et al. (2002) Michel and Huonnic (2003) and NFU (2003).

The highest total egg mass output was seen in conventional cages followed by furnished cages. The output for non-cage systems was lowest, this supports the findings of Tauson and Holm (2001) and the NFU (2003) and partly data from Zoons (2004, cited in EFSA, 2005).

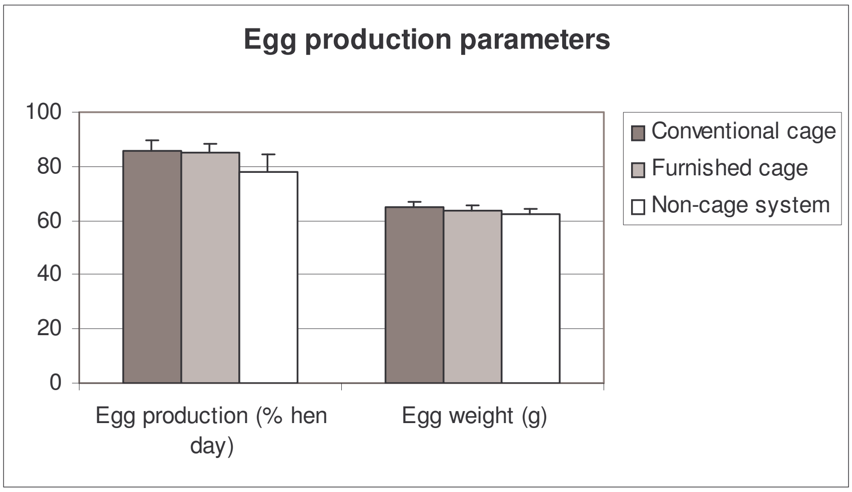

Figure 2. Egg production parameters

Figure 2 shows that egg production is similar in conventional and furnished cages and in both systems higher than in non-cage systems. This supports the findings of Michel and Huonnic (2003) and the NFU (2003) and partly supports the findings of Leyendecker et al. (2002) and Zoons (2004, cited in EFSA, 2005) in that the non-cage systems had the lowest egg production.

There were no major differences between the systems in egg weight.

Table 3. Egg quality parameters

System	First quality eggs (%)		All second quality eggs (%)	
	Mean	SD	Mean	SD
Conventional cage	93.29	6.953	6.50	8.434
Furnished cage	92.27	6.667	7.78	6.836

Non-cage system	91.50	7.925	7.81	7.964

Table 3 shows some egg quality parameters. There appears to be a trend that % first quality eggs is highest in the conventional cages, followed by furnished cages and non-cage systems. The opposite trend, although present, is less clear in % second quality eggs.

3.3 Production related to subtypes of main systems

Tables 4 and 5 provide data on a range of production parameters for the different types of the three main systems.

Table 4. Body weight, feed and water parameters

System	Bodyweight at middle of lay[a] (kg)		Feed intake (g)		Feed conversion ratio	
	Mean	SD	Mean	SD	Mean	SD
Conventional cage	2.01	0.128	114.97	5.445	2.14	0.139
Small furnished cage	1.84	0.181	114.15	8.230	2.13	0.117
Medium furnished cage						
Large furnished cage			112.03	2.728	2.19	0.085
Single tier non-cage systems	1.94	0.135	122.73	8.429	2.33	0.148
Multi tier non-cage systems	1.88	0.024	124.53	9.441	2.52	0.216

[a]*bodyweight was measured when the birds were between 37 and 55 weeks of age*

Bodyweight in the conventional cages is higher than in the other systems (for which data is available). This may be because of the more confined space birds in conventional cages are less active overall and in addition they have a less distinct day-night pattern in comparison with birds in cages with perches (furnished cages and non-cage systems). Therefore a number of birds will also be active at night and continue to feed. This could lead to a higher body weight.

Production data for medium sized furnished cages is scarce. This mirrors the trend that happened in the industry (and therefore in the research centres) where there was an initial use of small furnished cages (mainly data from Sweden, see Tauson, 2003) and after that mostly large furnished cages were used (mainly data from Germany and the UK).

Table 5. Egg production parameters

System	Egg production (% hen day)		Egg production (% hen housed)		Egg weight (g)	
	Mean	SD	Mean	SD	Mean	SD
Conventional cage	85.76	3.722	81.65	9.733	65.09	2.010
Small furnished cage	85.99	2.501	83.96	2.611	64.18	1.539
Medium furnished cage	85.45	3.714	81.63	6.619	62.84	1.889
Large furnished cage	82.78	3.174	81.18	3.217	62.17	1.632
Single tier non-cage systems	76.07	7.621	70.57	8.753	62.04	0.278
Multi tier non-cage systems	80.22	4.578	74.41	7.330	62.95	1.622

The main differences in egg production are between the cages on the one hand and the non-cage systems on the other hand. The multi-tier non-cage systems included in the database consisted of 2- and 3-tier systems, the egg production parameters between these did not differ greatly.

The trend in egg weights is that the heaviest are found in conventional cages and small furnished cages and lighter eggs are found in other systems.

The data on egg production in general suggest that egg production (and quality of eggs) is less optimal in non-cage systems, however these data should be interpreted with care as misplaced and broken eggs may distort the picture from non-cage systems. In these systems eggs laid outside the nest box will often not be collected (because they are broken and/or eaten), therefore egg production appears to be lower, first quality eggs can appear to be lower and the number of nest box eggs can appear to be higher. Caged and non-cage hens may lay the same number of eggs per hen and therefore biologically have equal performance but the appearance, and economic effect, would be one of superior productivity from the caged hens (EFSA, 2005). For an egg producer the number of collectable eggs is most important.

The production parameters overall, show that production is less efficient in non-cage systems (e.g. higher feed conversion ratios). The results highlight however, that the performance of birds in the different types of furnished cages is not worse than that of those in conventional cages.

3.4 Egg quality parameters related to subtypes of main systems

3.4.1 Cracked and dirty eggs

The number of eggs that are downgraded because they are of second quality (e.g. dirty or cracked) is an important economic factor for the egg industry. Besides the economic aspects, second quality eggs may pose a risk to food safety. Bacteria such as *Salmonella spp* may be present in large numbers in the layers' environment (Jones et al., 1995). Therefore, the use of dirty eggs, especially if soiled with faeces, and cracked eggs, either for processing purposes or for direct consumption, increases the risk of *Salmonella spp* penetration into the egg (EFSA, 2005).

There are differences in bacterial eggshell contamination between different housing systems. De Reu et al. (2005) found that the contamination with total aerobic flora was higher on eggs from a non-cage system (aviary) compared to conventional and furnished cages. This was influenced by higher bacterial air contamination due to higher dust levels in the non-cages system studied (aviary). There were no systematic differences between conventional and furnished cages.

Several aspects will influence the quality of eggs in different systems. Generally, the space per hen and group size are of relevance. For cages (both conventional and furnished cages) structural features such as wire thickness and quality, slope of the floor, presence of egg baffles and the space per bird (Brake and Peebles 1992; Alvey and Tucker, 1993; Carey et al., 1995), have been shown to be of influence.

Early designs of furnished cages showed features that were not always optimal to ensure egg quality. Even more recent designs of furnished cages have reported a higher number of cracked (e.g. Abrahamsson and Tauson, 1995; Alvey et al., 1996) or dirty eggs (e.g. Van Niekerk and Reuvekamp, 1997, 1999). Several improvements to furnished cage designs were studied and measures such as egg saver wires, long nest curtains and 100% nest lining with astroturf were effective in reducing the number of dirty and/or cracked eggs (Wall and Tauson, 2002). This shows that furnished cage designs can still be further improved (Appleby et al., 2002; Cooper and Albentosa, 2003; Tauson, 2003).

The hazards for food safety in relation to egg production systems have been reviewed thoroughly in Chapter 10 of the EFSA report (EFSA, 2005). Food safety falls outside the remit of the LayWel project. However, aspects of egg quality in relation to housing system have been analysed from the LayWel database and some egg quality parameters are summarised in Table 6.

Table 6. Egg quality parameters

System	Second quality eggs cracked (%)*		Second quality eggs dirty (%)	
	Mean	SD	Mean	SD
Conventional cage	2.60	1.035	4.87	2.128
Small furnished cage	1.96	2.059	4.69	4.544
Medium furnished cage	1.70	2.193	4.81	5.092
Large furnished cage	1.67	1.440	8.18	5.808
Single tier non-cage systems	1.07	0.848	8.43	8.213
Multi tier non-cage systems	3.16	1.821	7.74	4.784

*All assessed by candling

The data show a higher number of cracked eggs in conventional cages than in furnished cages. This may be because less cracked eggs occur when eggs are collected from nest boxes than from wire mesh cage floors. It has been argued that in modern conventional cages, the main cause of cracked eggs could be the high level of insults experienced during automatic collection (Overfield, 1995, cited in EFSA, 2005). Whether this could explain the high mean for the conventional cages from the LayWel dataset could not be assessed with certainty due to a lack of relevant information. The result could also have been influenced by the relatively low amount of data available for conventional cages. Therefore this mean should be interpreted with care. The number of cracked eggs was also higher in multiple tier non-cage systems. Levels for non-cage systems (including outdoor systems) can be very variable. In many cases, there may be a lower level of broken eggs in non-cage systems than in conventional cages as was shown for the single tier non-cage systems. It has also to be kept in mind, as mentioned in section 3.3, that misplaced and broken eggs can bias the comparison between egg output in conventional cages and non-cage systems.

The main conclusion from the data in the table is however, that the number of cracked eggs was low in the three types of furnished cages and did not differ greatly between the types of cages. This indicates that with the right design of furnished cage, cracked eggs should not be a problem.

The biggest proportion of second quality eggs consists of the eggs classed as dirty. These data show the number of dirty eggs in conventional cages are comparable with those in furnished cages (except large furnished cages). This is in line with data from furnished cage models with improved design (Guesdon and Faure, 2004; Van Niekerk and Reuvekamp, 1997, 1999), although other results indicated that the percentage of dirty eggs was higher in furnished cages than in conventional cages (Appleby et al., 2002; Guesdon and Faure, 2004; Van Niekerk and Reuvekamp, 1997, 1999). Further investigation of the high mean number of dirty eggs in large furnished cages revealed that the data came from two studies using different designs of cages. These studies varied considerably, in the study where older and less advanced designs of furnished cages were used, the number of dirty eggs was higher (11.3%) than when more modern and well-designed furnished cages were used (3.3%). If furnished cages (of any group size) are poorly designed, there is a higher risk that eggs are laid away from the nest boxes and these are likely to end up being dirty because of soiled cage floors, especially near perches. In non-cage systems, if nest boxes are poorly designed or not easily accessible, the percentage floor eggs will increase leading to an increase in dirty eggs. Data on the number of dirty eggs from less well-designed cages were also included in the means for small and medium furnished cages (see the SD), but its influence on the mean was much smaller because more data from a wider range of studies (with improved designed furnished cages) were available.

These investigations show that it would be advantageous to extend the use of the LayWel database to collect more data on production in modern, well designed furnished cages, as they are constantly being improved and much of the more recent data (some of it already now available) could not be included in the database due the end point of the project. The LayWel dataset also shows that, as for cracked eggs, with the correct design of furnished cages, dirty eggs should not be a problem.

3.4.2 Nest box use

Besides structural features of cages, cage furnishings such as the nest box, dust bath and perches can be of relevance to egg quality in furnished cages. Competition of hens for nests may lead to an increase of eggs laid in the dust bath, if nests are not sufficiently attractive and/or the dust bath is not properly designed, positioned and managed (Guesdon and Faure, 2004). The EFSA report mentions several factors that may affect the production of downgraded eggs specific for furnished cages: use of nests (depending on their design, size and position in the cage), cleanliness of nest mats, dust bath design and management, position and design of the perches (EFSA, 2005). Even if one aspect (e.g. nest-box or perches) of an otherwise well-designed furnished cage is not functioning, egg quality can be affected. The above-mentioned factors are also in part relevant for non-cage systems. Regular laying in the same location is advantageous to egg producers as it reduces the cost of egg collection and the number of egg losses (Cooper and Albentosa, 2003). Use of nests is also affected by the genotype of chickens used (Abrahamsson et al., 1996).

In WP6 it was investigated which parameters in the LayWel database related to nesting could be analysed. This was mainly nest box use for egg laying and the effects of nest box design on nest box use and on first and second quality eggs. Table 7 shows the number of eggs laid in the nest box at peak lay. The same data are presented graphically in Figure 3.

Table 7. Eggs laid in the nest box at peak lay

System	Nest box eggs at peak lay (%)	
	Mean	SD
Small furnished cage	92.76	6.052
Medium furnished cage	94.80	7.278
Large furnished cage	95.43	4.313

Single tier non-cage systems	96.13	4.236
Multi tier non-cage systems	95.81	5.776

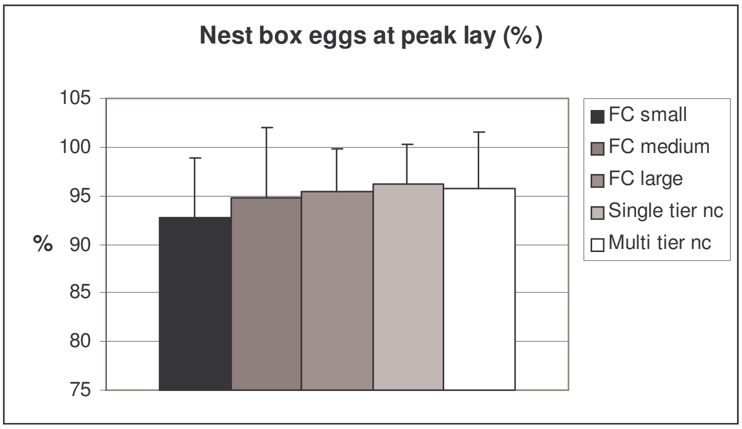

Figure 3. Eggs laid in the nest box at peak lay

The main conclusion from these data is that when hens are provided with a nest box they use it to a very high degree (overall mean for all systems was 95%). In some studies, nest box use was 100%. This is in line with other studies, reporting that 85-95% of eggs are laid in nest boxes (Abrahamsson and Tauson, 1997; Walker and Hughes, 1998; Van Niekerk and Reuvekamp, 1999).

Nest box use in the LayWel dataset was further investigated by sorting the data for the number of eggs laid in the nest box from high to low. Three classes were made: high, medium and low (each class contained1/3 of the available data). The data for the total number of second quality eggs was sorted alongside the data for nest box eggs to see whether there was any correlation between eggs laid in the nest box and second quality eggs. For each ranking class the mean was calculated and these are shown in Table 8.

Table 8. Ranking of eggs laid in the nest box

Rank class	Nest box eggs at peak lay (%)	All second quality eggs (%)
	Mean	Mean
High	99.1	9.2
Medium	96.6	9.6
Low	88.4	10.8

The data show that when nest box use is high, the percentage of eggs laid in the nest approaches 100%. It also shows that in the low class the percentage of eggs laid in the nest box eggs is still high at 88%. The table also shows that a high nest box use is associated with a lower number of second quality eggs.

The data in Tables 7 and 8 (and Figure 3) show that there were no big differences between the systems in nest box use. This indicates a strong preference of laying hens for an enclosed nest box space. Studies of hens' behavioural priorities have shown that hens place a high value on access to discrete, enclosed nest sites, overcoming high 'costs' (e.g. squeezing through narrow gaps or opening doors). The value they place on the use of nest boxes is comparable to feed (in food-deprived hens) (Cooper and Albentosa, 2003). Even in furnished cages, where there are more cage structures present that could provide some form of seclusion for egg laying (such as perches and the scratch area) the use of the nest box is very high.

Good use of nests is important to avoid an excess of downgraded eggs (Guesdon and Faure, 2004). Therefore the assumption that the more the hens use a nest box the more first quality eggs will be produced and consequently less second quality eggs can be expected was tested. Pearsons correlations were calculated for the variable % nest box eggs (at peak lay) with several other egg quality parameters (% first quality eggs, % second quality eggs cracked, % second quality eggs dirty and % all second quality eggs). The results showed that all the correlations were less than 0.2 and therefore no correlations were found. Although this may seem surprising at first sight, the explanation is that all the hens use the nest box to such a high extent (as shown above) that there is not a lot of variability in this factor and therefore the other factors are not affected.

We investigated in the LayWel database whether the amount of time the nest box was accessible to the hens (the nest box opening times) influenced the laying behaviour of the hens. Mainly two nest box opening times (at peak lay) were entered in the database: 15 and 24 hours, so the mean number of nest box eggs was calculated for those two opening times. Data were split for furnished cages and non-cage systems. The results are presented in Figure 4.

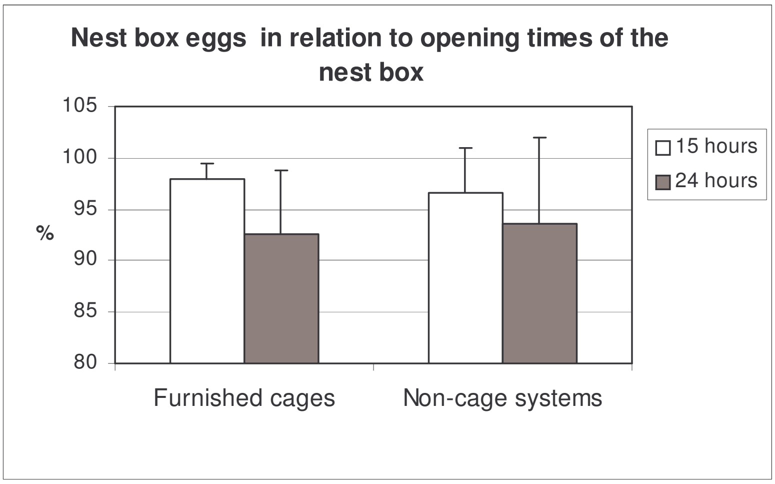

Figure 4. Nest box eggs at peak lay (%) in relation to opening times of nest box

The data for both furnished cages and non-cage systems show that with limited opening times of the nest box (15 hours) a higher number of eggs were laid in the nest box. With unlimited access to the nest box (24 hours) a lower number of eggs were laid in the nest box. This is an interesting finding, but further investigation of the LayWel data could not provide a conclusive explanation for the cause. Most likely, the design of a nest box influences its use by the hens. The nest boxes that were open for 15 hours were mainly large communal nests (for more than 10 hens), while 2/3 of the nest boxes that were open for 24 hours were small communal nests and the remaining 1/3 large communal nests. Whether this played a role in the hens' nesting choices needs to be investigated further and in more detail.

The closing and opening of the nest box might be relevant to the quality of eggs. If nest boxes are continuously open, as is the case in most current models of furnished cages, a certain percentage of hens may sleep inside them. This can be up to 10% of hens (Abrahamsson and Tauson, 1993; Appleby et al., 1993). When this happens there is a risk that soiling of the nest mat occurs, leading to less clean eggshells.

Another aspect of nest box design that might influence the use of nest boxes and therefore the quality of eggs is the type of floor used in the nest box. Some types of floor may be more attractive to hens e.g. Astroturf, than others, e.g. wire mesh (Abrahamsson et al., 1996). However, the type of nest floor material in the nest boxes of furnished cages did not systematically influence bacterial eggshell contamination (De Reu et al., 2005).

Information on the type of floor in the nest box was collected in the LayWel database and this was linked to the information on the number of eggs laid in the nest box at peak lay. Due to the number of data lines entered, the type of floor was split into two categories: Astroturf and 'other' including wire mesh, rubber prongs, plastic and coated wire mesh. The information was split for furnished cages and non-cage systems. The results are presented in Figure 5.

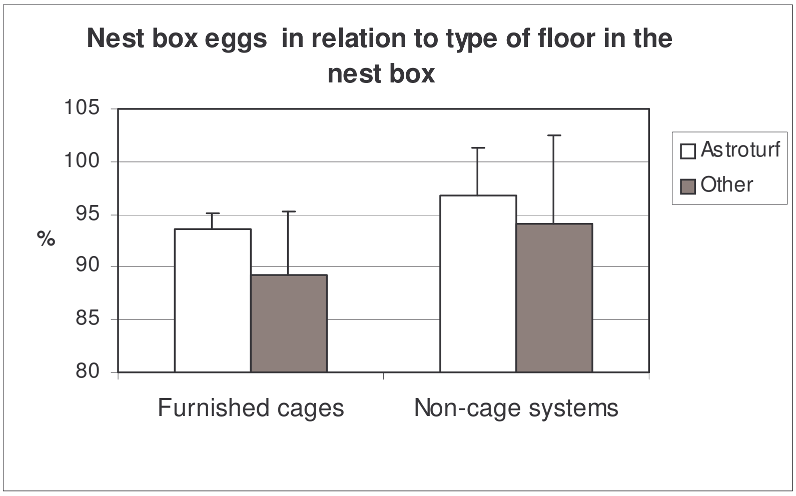

Figure 5. Nest box eggs at peak lay (%) in relation to type of floor in the nest box
Other = includes wire mesh, plastic, coated wire mesh

The results indicate that a higher number of eggs were laid in the nest box when this was lined with Astroturf than when lined with other material. This applied to both housing systems. Abrahamsson et al. (1996) also found that hens used artificial turf nests extensively for egg laying in comparison with wire mesh nests. 85% of the eggs were laid in the nests with artificial turf. The majority of furnished cages that are commercially available at present provide Astroturf in the nest boxes. If the floor of the nest box is interesting for a hen the dust bath becomes less attractive to lay eggs in and consequently the number of the eggs laid in the dust bath may be lower than 0.1% (Abrahamsson et al., 1996).

3.4.3 Dust bath use

Design and management of the dust bath (e.g. closing times and mechanism) is important as it can affect the number of eggs laid in the nests (Tauson, 2003; Guesdon and Faure, 2004). This will also assist in minimising the proportion of eggs laid in the dust bath. The time when the dust bath opens (after lights on) is also important to avoid or minimise the risk of eggs being laid in the dust bath. Tauson (1998) recommended restricting access to after 8-9 hours after lights on in a full light program, thus having the dust bath closed during the morning hours.

Information on the opening times of the dust bath in furnished cages was collected in the LayWel database and this was linked to information on the quality of eggs. Three categories of dust bath opening times were defined based on the data entered: 24, 8-9 and 2-6 hours. The percentage of second quality eggs (all, cracked and dirty) was calculated for these three categories. The results are presented in Table 9.

Table 9. Total time of access to the dust bath (at peak lay) in furnished cages (all types)

Access	All second quality eggs (%)		Second quality eggs cracked (%)		Second quality eggs dirty (%)	
	Mean	SD	Mean	SD	Mean	SD
24 hours	12.96	8.357	2.89	2.519	7.94	5.704
8-9 hours	12.91	8.428	3.10	2.179	7.50	6.757
2-6 hours			3.92	1.645	5.09	2.272

The data do not suggest a close relationship between the duration of opening times and the number of total second quality eggs or cracked eggs specifically. However with short dust-bath opening times (2-6 hours) the number of dirty second quality eggs was lower. This suggests that if dust baths remain open all day, eggs laid on the litter may rise as found by Appleby et al. (2002).

We investigated in the LayWel database whether the substrates used in the dust bath were linked to the quality of eggs. Two main categories of dust bath substrates were identified based on the data entered: sawdust and Astroturf (either in combination with feed or with sawdust). For other substrates not enough data was entered to calculate means. The percentage of second quality eggs (all and dirty) was calculated for these categories. The results are presented in Table 10.

Table 10. Substrates used for dustbathing in furnished cages (all types)

Substrates	All second quality eggs (%)		Second quality eggs dirty (%)	
	Mean	SD	Mean	SD
Sawdust	19.76	4.121	8.63	6.447
Astroturf and feed or sawdust	14.46	6.940	7.64	5.126

When sawdust was used as substrate in the dust bath a higher percentage of second quality eggs was observed. The second quality eggs category consisted mainly of dirty eggs. Data for cracked eggs did not differ (data not shown). Whether there is a causal link here is difficult to say without more information. It could be that with a more attractive dust bath for laying eggs, more eggs are laid in the dust bath leading to more second quality eggs (more soiling).

3.5 Free range systems

3.5.1 Effect of the range and/or veranda on production

Tables 11-13 provide data from non-cage systems only. The data were split into non-cage systems (both single and multi tier) with a free range and/or veranda and systems without. The main production parameters are presented.

Table 11. Body weight and feed intake

System	Bodyweight at middle of lay[a] (kg)		Feed intake (g)	
	Mean	SD	Mean	SD
Non-cage	1.83	0.073	121.53	6.459
Non-cage with free range and/or veranda	1.99	0.114	128.45	11.642

[a]bodyweight was measured when the birds were between 37 and 55 weeks of age

Feed intake is higher in systems with a range and/or veranda, mainly due to more exercise of the birds and exposure to a wider range of temperatures.

Table 12. Eggs produced

System	Egg production (% hen day)		Egg production (% hen housed)	
	Mean	SD	Mean	SD
Non-cage	78.70	5.497	73.03	7.984
Non-cage with free range and/or veranda	76.81	8.379	71.28	8.704

Egg production appears to be higher in non-cage systems without access to a free range or veranda.

3.5.2 Effect of the range and/or veranda on egg safety

Table 13. Egg quality parameters

System	First quality eggs (%)		Nest box eggs at peak lay (%)		All second quality eggs (%)	
	Mean	SD	Mean	SD	Mean	SD
Non-cage	88.98	8.064	95.63	5.587	10.36	8.420
Non-cage with free range and/or veranda	97.68	1.993	97.27	4.390	2.32	1.993

No explanation could be found for the higher number of first quality eggs and low number of second quality eggs in systems with a free range and/or veranda. In other studies, a mean of 10-12% of broken and 5-15% of dirty eggs has been reported for free-range farms (Champagne, 1997; Champagne and Bernicott, 1999, cited in EFSA, 2005), which is much higher than the numbers reported here for free range. There may be a link with management. If this effect is real it is interesting and should be investigated further.

3.5.3 Effect of breeds in non-cage systems

To find out whether certain breeds perform better in non-cage systems than in cage systems several parameters were checked (only if enough data was available). Production parameters for breeds specifically developed for non-cage systems ('non-cage breeds') were compared with breeds that are generally more suitable for cages, but were housed in non-cage systems ('cage breeds'). The data is presented in Tables 14 and 15.

Table 14. Breeds in non-cage systems 1

Breeds	Feed conversion ratio		First quality eggs (%)	
	Mean	SD	Mean	SD
Non-cage breeds[a]	2.43	0.178	89.36	3.925
Cage breeds[b]	2.61	0.175	89.13	11.669

[a] *Non-cage breeds include Isa Brown, Hyline Brown and Lohmann Tradition*
[b] *Cage breeds include Lohmann Brown, Shaver 579, Hisex Brown*

Feed conversion is much better when breeds suitable for non-cage systems are used in non-cage systems. The percentage of first quality eggs is also higher, although the differences are not so big.

Table 15. Breeds in non-cage systems 2

Breeds	Egg production (% hen day)		Total egg mass output (kg)	
	Mean	SD	Mean	SD
Non-cage breeds[a]	77.71	5.758	17.51	0.903
Cage breeds[b]	74.76	4.484	17.75	1.979

[a] *Non-cage breeds include Isa Brown, Hyline Brown and Lohmann Tradition*
[b] *Cage breeds include Lohmann Brown, Shaver 579, Hisex Brown*

Egg production is improved when breeds suitable for non-cage systems are used in non-cage systems. However differences in total egg mass output between the breeds are not large. Overall, these data show the benefits of using a breed that is specifically developed for a type of housing system. The dataset also shows that this is not always done.

4. Discussion and conclusions

Production and egg quality

The production parameters overall, show that production is less efficient in non-cage systems (e.g. higher feed conversion ratios). The results indicate however, that the performance of birds in the different types of furnished cages is not worse than that of those in conventional cages. The egg quality parameters such as cracked and dirty eggs show that egg quality in furnished cages is dependent on cage design, but does not need to be a problem with the right cage design. The design of furnished cages has further improved recently and production parameters from these new models should be evaluated to get a more up-to-date picture of production in small, medium and large group furnished cages. This would require a short extension to the data population and use of the LayWel database, which would be well worthwhile.

Production, egg quality and welfare

High production is sometimes misused as an indicator of good welfare. As laying hens are bred for high production sub-optimal conditions will not easily affect their production level. On the other hand poor productivity or production drops can indicate impaired welfare. Production records are often analysed in respect of physical or economic return, which throw no light on bird welfare and productivity is generally measured on a flock basis but welfare concerns the individual (EFSA, 2005). Economic aspects of productivity should be considered separately from biological characteristics and only biological characteristics are relevant to welfare (Adams and Craig, 1985).

In the EFSA report (2005) welfare parameters relevant to production were discussed. The scientific panel assessed the welfare of laying hens in the different housing systems. The most relevant indicators from the report were included. Each risk to welfare was summarized on a six point scale describing its likely prevalence in a given housing system (risk: negligible, very low, low, moderate, high and very high). The only risk factor related to production parameters mentioned was the risk factor 'inability to perform nesting' It was classified for each system as follows: conventional cage: very high; furnished cages (small and large): low; non-cage system (single and multi tier): low. It was added that in the conventional cages inability to perform nesting had a high prevalence, and was therefore thought to pose a particularly severe threat to welfare.

The LayWel data on production parameters clearly illustrates the high use of the nest box for laying eggs by laying hens and therefore the high risk to welfare of hens in conventional cages when nesting is not possible. As discussed in section 4.4.2, the high use of nest boxes indicates that laying hens place a high value on a discrete nest space (reviewed by Cooper and Albentosa, 2003). Use of the nest box may therefore be used as an indicator of welfare. If the use of the nest box is low (e.g. due to poor design) or decreases over time, the needs of the hens are not met.

The conclusions of WP6 are that the main production parameters (feed and water parameters and egg production parameters) are not suitable as important indicators of welfare, but they should be monitored continuously and used as an indicator that welfare may be or become impaired. Nest box use can be used as an indicator of welfare as laying hens place a very high value on laying eggs in a secluded area.

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