THE INFLUENCE OF HOUSING SYSTEMS FOR LAYING HENS ON THE MICROBIOLOGICAL EGG QUALITY

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Summary

With the introduction of alternative housing systems for laying hens in the EU, recently more research focused on the bacterial contamination of table eggs, e.g. eggshell and egg content contamination. Contamination of eggshells with aerobic bacteria is generally higher for nest eggs derived from non-cage systems compared to furnished cages or conventional cages. Studies indicate limited or no systematic differences in eggshell contamination with aerobic bacteria between eggs laid in the nest boxes of furnished cages and eggs laid in conventional cages. The major differences found in experimental studies between cage- and non-cage systems are less pronounced under commercial conditions. The effect of housing system on eggshell contamination with specific groups of bacteria is variable. Limited information is available on the influence of housing system on egg content contamination. Recent research does not indicate large differences in egg content contamination between eggs from cage- and non-cage systems (ignoring outside nest and floor eggs). The microflora of the eggshell is dominated by Gram-positive bacteria, whereas Gram-negative bacteria are best equipped to overcome the antimicrobial defences of the egg content. Much of the research on eggshell and egg content contamination focuses on *Salmonella,* since infection with *Salmonella* Enteritidis, resulting from the consumption of contaminated eggs or egg products, is still a major health problem. Observed *Salmonella* prevalence on the eggshell and in the egg content vary, depending on the fact whether investigations were based on randomly sampled table eggs or on eggs from naturally infected hens. Studies also show that it is highly unlikely that a move from conventional cages to alternative cage systems and non-cage housing systems will result in an increase in *Salmonella* infection and shedding, rather the opposite is expected.

I. INTRODUCTION

The shell can become contaminated when passing through the vent, but many researchers suggest that the main bacterial contamination occurs within a short period after laying due to contact with dirty surfaces (Quarles *et al.*, 1970; Gentry and Quarles, 1972). Messens *et al.* (2005) and De Reu *et al.* (2006a; 2006b, 2006d) reported that increasing numbers of micro-organisms on the eggshell consequently increase the risk of microbial eggshell penetration and egg content contamination. Beside this horizontal route of bacterial infection of eggs, egg contamination also occurs through the vertical or transovarian route. In the transovarian route (vertical transmission), the yolk membrane (very infrequently the yolk itself), the albumen

and/or the shell membranes are directly contaminated as a result of bacterial infection of the reproductive organs.

II. GLOBAL BACTERIAL EGGSHELL AND EGG CONTAMINATION

a. Effect of the housing system

In early studies, bacterial eggshell contamination has been compared in litter and wire floor houses. Quarles *et al.* (1970) reported that litter floor houses had on average nine times more bacteria in the air, and 20 to 30 times more aerobic bacteria on the shell than wire floor houses. Harry (1963) reported that the shells of eggs from deep litter systems had 15 times more bacteria and a higher proportion of potential spoilage organisms than eggs from battery cage systems.

Conventional cage housing for laying hens will be prohibited from 2012 in the European Union, following EU-directive 1999/74. From 2012 onwards, only furnished cages and non-cage systems (aviaries and floor housing) will be allowed. This has driven the recent attention towards the effect of housing system on the bacterial eggshell contamination of table eggs.

b. Conventional and furnished cages

De Reu *et al*. (2005b) compared the bacterial eggshell contamination of eggs laid in conventional cages with eggs laid in the nest boxes of furnished cages. No systematic difference in shell contamination with total counts of aerobic bacteria was found between these systems (ranging from 4.0 - 4.5 log CFU/eggshell). Also, for Gram-negative bacteria no difference was detected (both means ca. 3.0 log CFU/eggshell). The type of nest-floor material in the nest boxes of the furnished cages also did not systematically influence the bacterial eggshell contamination. Cepero *et al*. (2000; 2001) also found no differences in counts of aerobic mesophilic bacteria but reported a higher prevalence of coliforms on shells of eggs laid in furnished cages. Mallet *et al*. (2006) studied the hygienic aspects of eggs laid at different locations in furnished cages. A significant difference in total count of aerobic bacteria was observed on the eggshell of eggs collected from furnished cages (4.83 log CFU/eggshell) compared to conventional cages (4.56 log CFU/eggshell). This was mainly due to the eggs laid outside the nest in the litter area (4.96 log CFU/eggshell) or in the cage (4.94 log CFU/eggshell). The bacterial load on eggs laid in the nests was similar to those collected from the conventional cages. Similar conclusions were obtained for *Enterococcus.* Wall *et al*. (2008) also found a higher bacterial load on eggs from furnished cages compared to conventional cages. The bacterial counts were significantly ($P < 0.001$) higher in the furnished cages compared to the conventional cages as regards *Enterococcus* and total number of aerobic bacteria.

c. Cage- and non-cage systems

In further experimental studies, it was found that eggs from aviaries were contaminated with higher numbers of aerobic bacteria than eggs from cage systems (Protais *et al.*, 2003a; De Reu *et al.*, 2005b). The difference was more than 1 log unit (up to 5.1 – 6.0 log CFU/eggshell for eggs from aviaries), with much higher counts on those eggs laid on the floor of the aviaries (up to 7 log CFU/eggshell). For Gram-negative bacteria no systematic differences were found between cage and non-cage housing systems (De Reu *et al.*, 2005b).

d. Experimental studies compared to on farm studies

De Reu *et al.* (2005a; 2006c) evaluated whether the differences in initial eggshell contamination, found in the experimental housing systems, were also applicable to commercial conventional cage and non-cage housing systems. Two conventional cage systems, one organic aviary system and one floor housing system were included. On average, a higher ($P < 0.001$) initial eggshell contamination with total count of aerobic bacteria was found for eggs from non-cage systems compared to conventional cage systems; respectively 5.46 compared to 5.08 log CFU/eggshell. However, initial contamination with total count of Gram-negative bacteria on the eggshells was significantly lower ($P < 0.001$) in the non-cage systems; 3.31 compared to 3.85 log CFU/eggshell. This study showed that the major differences in eggshell contamination with total count of aerobic bacteria, found between conventional and non-cage systems in the experimental studies (>1 log) were less pronounced in the sampled commercial housing systems. The even lower initial contamination with Gram-negative bacteria in the commercial non-cage systems was remarkable.

e. On-farm studies

Six flocks of laying hens in furnished cages and seven flocks in non-cage systems (three aviaries and four floor systems) were compared in the international study of De Reu *et al.* (2009b). On average, eggshells from furnished cages were slightly, but significantly ($P < 0.001$), less contaminated with total count of aerobic bacteria compared to non-cage eggshells (4.75 versus 4.98 log CFU/eggshell). In the non-cage systems, no difference in average contamination between aviary and floor systems was found. Both within the groups of furnished cage- and non-cage systems, major differences between farms were obtained. Differences in farm management can possibly explain this. For Enterobacteriaceae no significant difference in average eggshell contamination was found between furnished and non-cage systems. Hunau-Salaun *et al.* (2009) also found a comparable higher eggshell contamination for eggs from non-cage systems (4,82 CFU/eggshell) compared to conventional cages (4,40 CFU/eggshell). On the other hand, no difference between furnished cages and non-cage systems was found.

F. Bacterial air contamination and its relationship with eggshell contamination

In some studies the total count of aerobic bacteria in the air of poultry houses was proven to be positively correlated with the initial bacterial eggshell contamination at the henhouse (Protais *et al.*, 2003a; De Reu *et al.*, 2005b). Averages of 4 log CFU/m^3 air for the conventional and furnished cages were found compared with a 100 times higher average (> 6 log CFU/m^3) for aviary housing systems.

G. Influence of housing system on quality of eggs and egg products

At this moment, it remains unknown whether the differences in bacterial counts on the shell of eggs produced in different housing systems have an impact on the quality of eggs and egg products. Harry (1963), De Reu *et al.* (2006b; 2006d) and many other researchers found a correlation between bacterial eggshell contamination and egg infection or egg content contamination. The higher prevalence of coliforms on the shells of eggs laid in furnished cages was not correlated with signs of coliform contamination in egg yolk or albumen

(Cepero *et al.*, 2000; Cepero *et al.*, 2001). In a preliminary study of De Reu *et al.* (2007a; 2008), egg content contamination of nest eggs was 1.9% (5/269 eggs) for furnished cages compared to 2.3% (10/432 eggs) for non-cage systems.

III. EGGSHELL DIRT AND CRACKS IN DIFFERENT HOUSING SYSTEMS

a. Eggshell dirt

Beside bacterial eggshell contamination the occurrence of eggshell dirt may also be considered as a hygiene parameter. Additionally some types of eggshell dirt may give nutrients to bacteria present on the shell. In table 1 the occurrence of dirty eggs in different housing systems, found by different research groups, is summarized.

Table 1: Occurrence of dirty eggs (in % of eggs) in different housing systems

Study	Type of study	CC (%)	FC (%)	Non-cage (%)	P
Tauson et al. 1999	Pilot	6.5	n.a.	5.7	
Mallet et al. 2006	Pilot	4.9 (4.9-4.9)	5.0 (3.0-7.1)	n.a.	< 0.001
De Reu et al. 2009b*	Comm.	n.a.	22	24	> 0.05
De Reu et al. 2009a	Comm. (shop)	17.2	n.a.	4.4	n.d.

CC = conventional cage, FC = furnished cage, Comm = commercial housing
*= only nest eggs; n.a. = not analyzed; n.d. not determined

Both in the commercial studies of De Reu et al. (2009a, 2009b) as in the pilot study of Tauson et al. (1999) it was found that the frequency of dirty eggs in nests of non-cage systems was not higher than in cage systems. On the other hand the study of Mallet et al. (2006) showed that furnished cages can contain more dirty eggs compared to conventional cages. Two types of conventional cages and two types of furnished cages were compared. The study showed that a less optimal cage design of the furnished cages increased the number of outside nest eggs which contained more eggshell dirt compared to the nest eggs. As a result a significant difference was found in occurrence of dirty eggs between both types of furnished cage designs; 3.0 and 7.1% respectively (Table 1). Comparing both conventional cage designs with both furnished cage designs, on average both types of housing systems contained a comparable amount of dirty eggs (4.9% compared to 5.0%). To conclude the available research results indicate that nest eggs of non-cage systems are in normal circumstances not more susceptible for dirtiness compared to cage eggs.

An important aspect is also that 85 up to 98% of the floor eggs of non-cage systems have dirty eggshells (Abrahamsson and Tauson, 1998, De Reu et al. 2006a). This stresses the fact that floor eggs are unfit as table eggs.

b. Eggshell cracks

As eggshell cracks give the opportunity for bacteria to penetrate the eggshell and hence contaminate the egg content, the occurrence of cracks in eggs is also an important factor in comparing housing systems. In table 2 the results of different research groups studying the influence of housing systems on eggshell cracks are summarized.

Table 2: Occurrence of cracked eggs (in % of eggs) in different housing systems

Study	Type of study	CC (%)	FC (%)	Non-cage (%)	P
Tauson et al. 1999	Pilot	5.0	n.a.	4.6	
Guesdon et al. 2006	Pilot	8.1 - 12.2	15.4 - 19.6	n.a.	< 0.001
De Reu et al. 2009b	Comm.	n.a.	7.8%*	4.1	< 0.05
Hidalgo et al. 2008	Comm. (shop)	14	n.a.	8.7	> 0.05
De Reu et al. 2009a	Comm. (shop)	7.8	n.a.	5.6	n.d.

CC = conventional cage, FC = furnished cage, Comm = commercial housing
*= only nest eggs; n.a. = not analyzed; n.d. not determined

The study of Guesdon et al. (2006) as well as the study of De Reu et al. (2009b) showed that furnished cages are most susceptible for cracks. Guesdon et al. (2006) found in pilot studies 15.4 to 19.6% of broken (visual observation) and hair-cracked (candling) eggs in furnished cages compared to only 8.1 to 12.2% in standard cages. This was mainly due to hair-cracked eggs at the narrow nests of the furnished cages without egg saver and a relatively low frequency of manual egg collection. The study of De Reu et al. (2009b) documented variations of cracked eggs from 0 up to 24% for the individual farms. A high percentage (24%) of cracks was found in a furnished cage flock and was probably caused by a bad adjustment of the egg saver and the accumulation of eggs next to the nest box on a short part of the egg belt. In the study of Tauson et al. (1999) cracks varied from 2.2% to 7.7%, with no significant difference between the housing systems (conventional and floor housing systems) and an almost comparable mean % of cracked cage eggs (5.0% compared to 4.6%). In a market study on the quality characteristics of eggs from different housing systems, Hidalgo et al. (2008) found no significant difference ($P > 0.05$) in appearance of cracked eggs between cage (14%), free range (10%), barn (11%) and organic (5%) eggs. The comparison at the shop level of De Reu et al. (2009a) also showed that non-cage eggs do not contain more cracks compared to cage eggs (5.6 versus 7.8%). Of course eggs in those latter studies were already candled and sorted at the packaging station. In summary the different research results indicate that nest eggs of non-cage systems are in normal circumstances not more susceptible for cracks compared to cage eggs. In addition, results indicate that a good egg collection of the eggs from furnished cages is important to reduce cracks.

IV. EFFECT OF HOUSING SYSTEM ON THE *SALMONELLA* CONTAMINATION

a. *Salmonella* contamination of eggs

Much of the research on eggshell and egg content contamination focuses on *Salmonella,* since infection with *Salmonella* Enteritidis, resulting from the consumption of contaminated eggs or egg products, is still a major health problem. Several EU member states have reported data from investigations of table eggs, and the overall EU prevalence in 2006 was 0.8% (EFSA, 2007). More than 90% of all egg-isolates were strains of the serotype Enteritidis.

Little research is done on the influence of housing system on eggshell and egg content contamination with *Salmonella.* In a study of Humphrey *et al.* (1991), over 5700 eggs from 15 naturally infected flocks were examined, of which 32 or 0.6% were contaminated. The prevalence of egg content contamination of eggs from battery or free-range were comparable; 0.73 and 0.64% respectively. A study of the UK Food Standards Agency in 2003 also did not found significant differences in *Salmonella* spp. contamination on the shell due to the production system (Anon., 2004). On a total of 4753 retail samples of boxes with six eggs, the

eggshell of nine samples was contaminated. None of the 4753 pooled egg contents of retail samples were *Salmonella* positive. In a smaller study of De Reu et al. (2009a) 47 fresh egg samples from the Belgian market were sampled. Sixteen samples concerned cage-eggs, five floor housing eggs, 12 free range eggs, seven organic eggs, five samples from farm retail and two from private backyards. In none of the samples *Salmonella* was found.

b. Environmental *Salmonella* contamination

More research was focused on the influence of the housing system on environmental *Salmonella* contamination. The analysis of the existing data of an EU-wide baseline study on *Salmonella* in laying hens flocks performed in 2004-2005 (EFSA 2006) showed a significant difference in *Salmonella* prevalence according to housing type (Anon. 2008). In cage systems the highest *Salmonella* prevalence was found followed by a intermediate prevalence in barn systems and the lowest prevalence in the free range systems. More than 51% of all *Salmonella* isolates were serotyped as *Salmonella* Enteritidis. Recent data collected in the large-scale cross-sectional and longitudinal field study of the EU Safehouse project confirm those findings (Anon. 2008). An overview by Dewulf et al. (2009), on published observational studies evaluating the effect of housing system on the prevalence of *Salmonella* Enteritidis infections, also clearly indicates that a cage system has an increased risk for being *Salmonella* positive in comparison to non-cage housing systems. However, there is not necessarily a causal relationship between the housing type and the *Salmonella* infection. It is more likely that the housing system is a proxy of many other production characteristics such as magnitude of the flock or herd, age of the building, probability of previous *Salmonella* infection on the farm, … The authors summarized a number of important production characteristics that may be both related to the housing system and the probability of a *Salmonella* infection: herd and flock size, stocking density, stress, age of the building and carry-over infections, pests, vaccination, …

V. CONCLUSIONS

It is clear that eggshell contamination with aerobic bacteria is on average significantly higher for nest eggs from non-cage systems compared to nest eggs from furnished cages or eggs from conventional cages. The major differences found in experimental studies between cage and non-cage systems are less pronounced under commercial circumstances. The scarce information available on the influence of the housing systems on the egg content contamination indicates no major differences in egg content contamination between cage eggs and non-cage eggs (ignoring outside nest and floor eggs).

Studies also show that it is highly unlikely that a move from conventional cages to alternative cage systems and non-cage housing systems will result in an increase in *Salmonella* infection and shedding, rather the opposite is expected.

ACKNOWLEDGEMENT

The cited research of our group would not have been possible without the help of especially Ann Van de Walle. Sofie De Vlam, Elly Engels and Vera Van de Mergel are also gratefully acknowledged.

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