



# Effect of layers housing system on the quality and microbiological safety of eggs

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Agriculture and Fisheries Policy Area



# Outline

- 1) Introduction
- 2) Eggshell contamination in pilot or experimental studies
- 3) Eggshell contamination in on farm comparisons
- 4) Eggshell dirt, shell quality and cracks in different housing systems
- 5) Egg content contamination in relation to housing systems
- 6) *Salmonella* contamination in relation to housing systems
- 7) Take home messages

# 1. Introduction



# Housing systems for laying hens

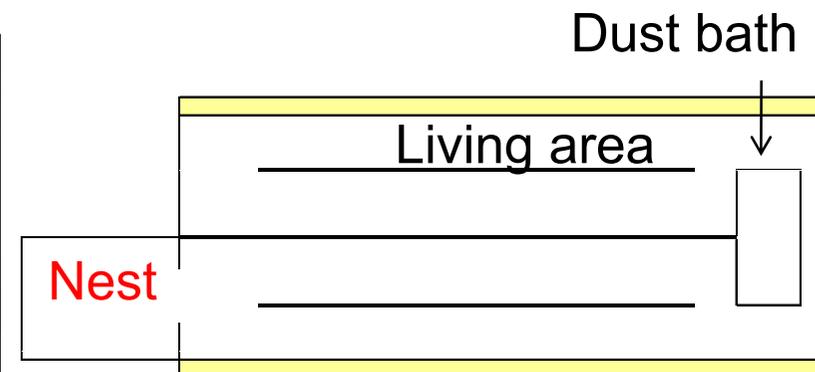
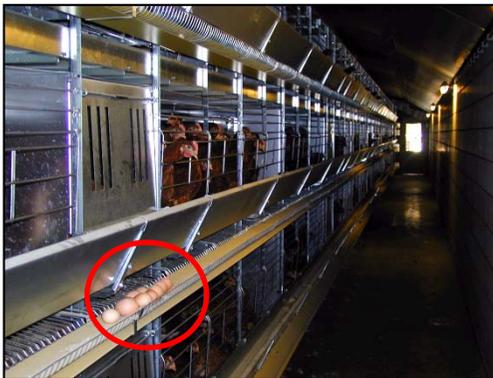
- Conventional cages

- 550 cm<sup>2</sup>/hen
- 5 to 6 or more hens/cage
- Banned from 2012
- EU directive 1999/74
- **Animal welfare**



- Furnished cages

- 750 cm<sup>2</sup>/hen, **nest** and living area with dust/litter bath and perches
- Larger groups 20-60 hens/cage



# Housing systems for laying hens

- Non-cage housing systems
  - 1111 cm<sup>2</sup>/hen, scratching area, **nests**, perches, ...
  - Possibly outdoor run – free range systems
  - Larger group size (5,000 – 30,000 hens)

Floor housing



Aviary



# Consequences of alternative housing on bacterial contamination and quality of table eggs?

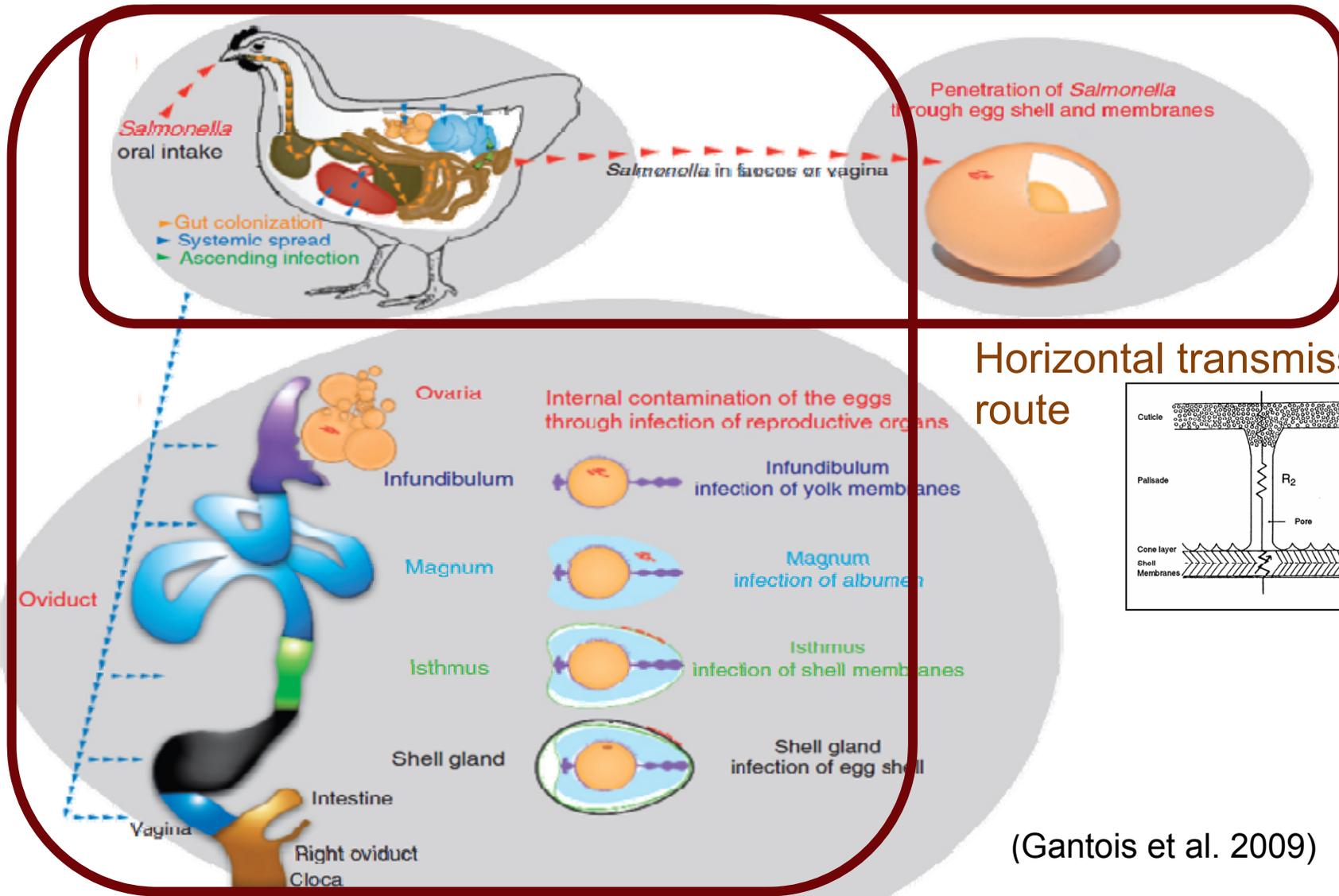
More dirty and cracked eggs?

Bacteriological eggshell contamination?

- Feces, more dust, other types of equipment (e.g. laying nests)

Egg content contamination?

# Contamination of the egg content



(Gantois et al. 2009)

Vertical transmission route

**Colonizing ability of *Salmonella* Enteritidis**

# Bacterial eggshell penetration (**horizontal route**)

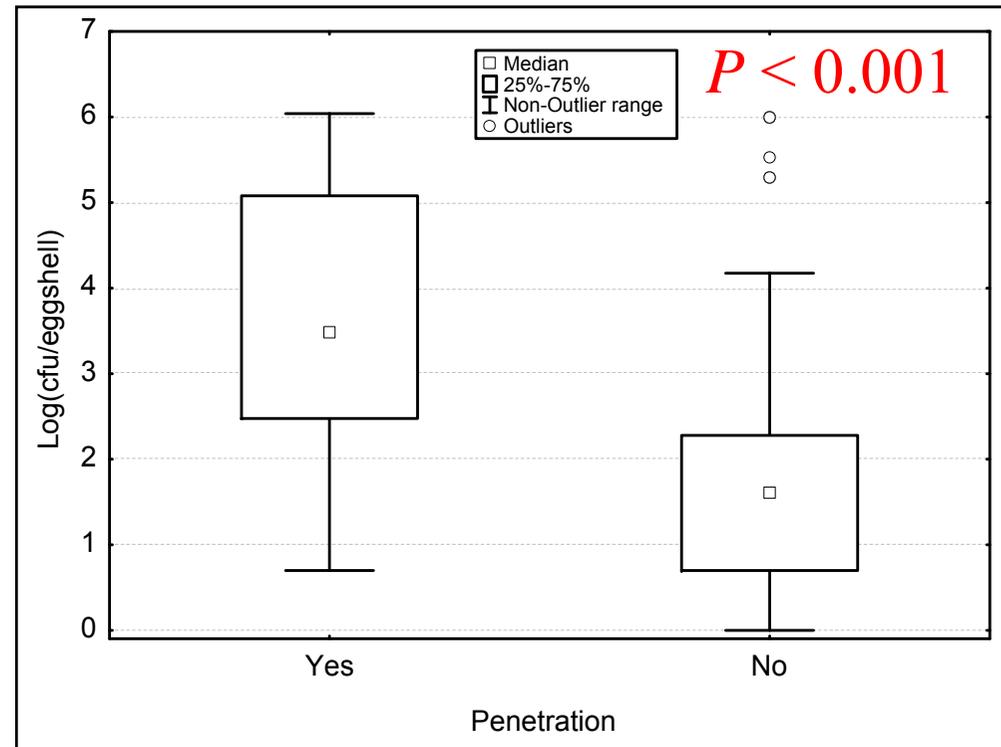
Higher bacterial eggshell load



Higher probability of eggshell penetration (**horizontal route**)



Higher egg content contamination



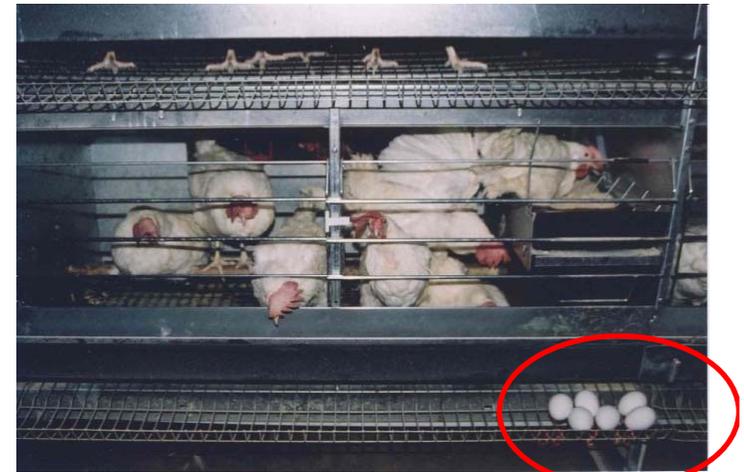
De Reu et al. 2006, Messens et al. 2005

## 2. Eggshell contamination in pilot or experimental studies

# Bacterial contamination of eggshells in furnished and conventional cages

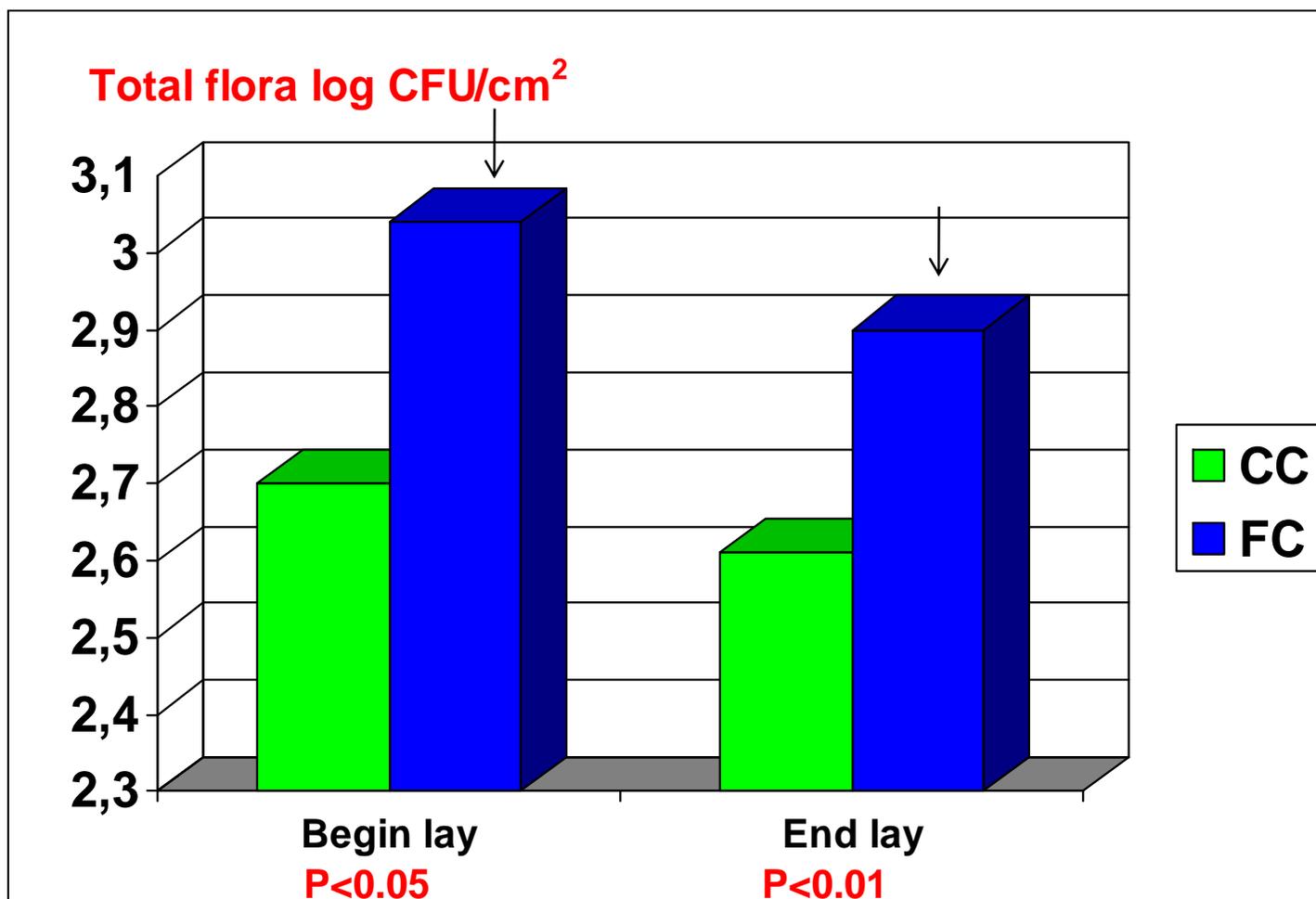
(Wall et al., 2008, J. Appl. Poult. Res., 47, p30-35)

- Conventional cages (CC)
- Furnished cages (FC)
- In FC nest eggs **AND** outside nest eggs (96% in nests)
- Bacterial eggshell contamination
  - Total bacterial flora (TF), Enterobacteriaceae and *Enterococcus*

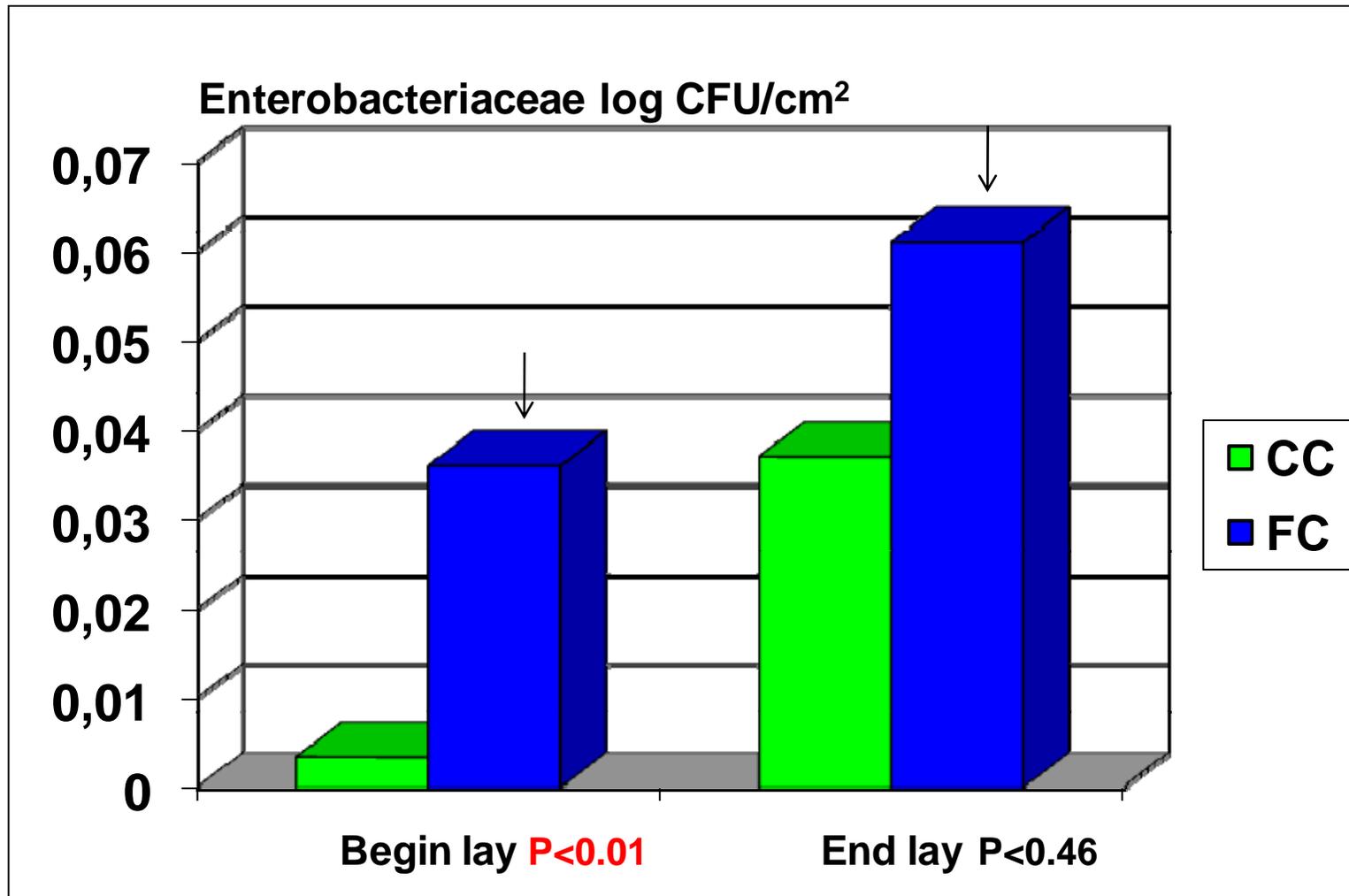


Also outside nest eggs      Nest eggs

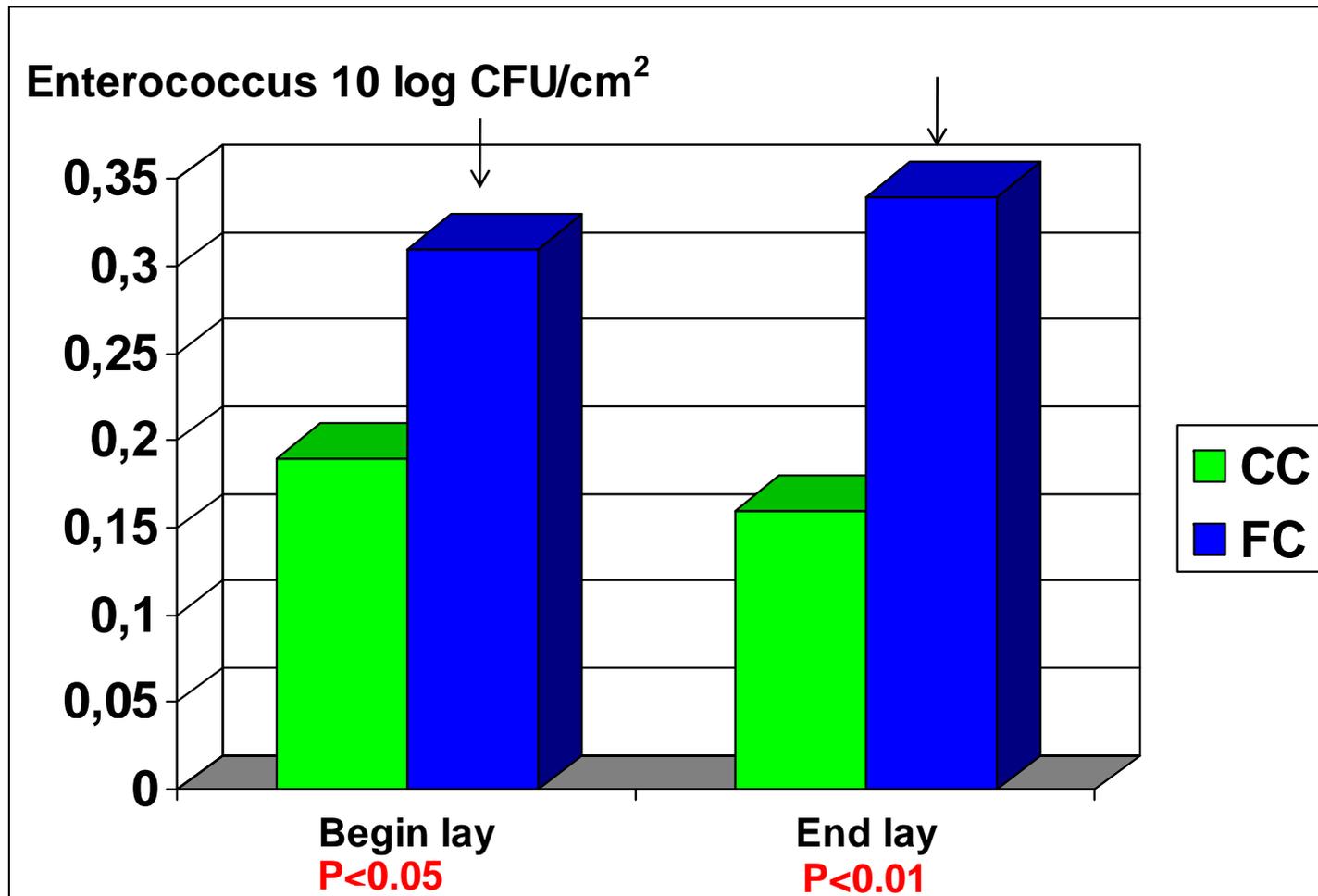
Load of **total flora** on eggs in **conventional cages** (CC) and **furnished cages** (FC) at begin (27-28w) and end of lay (62-63 w)



Load of **Enterobacteriaceae** on eggs in conventional cages (CC) and furnished cages (FC) at begin (27-28w) and end (62-63 w) of lay



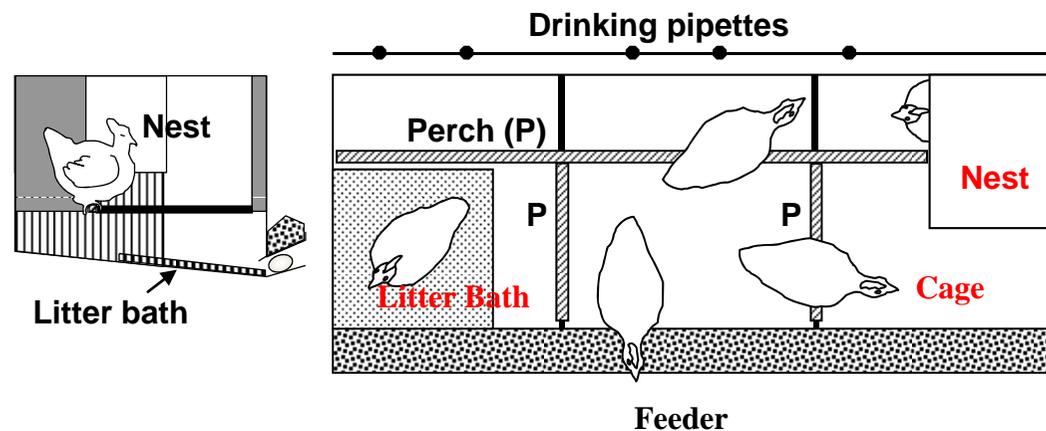
Load of *Enterococcus* on eggs in conventional cages (CC) and furnished cages (FC) at begin (27-28w) and end of lay (62-63 w)



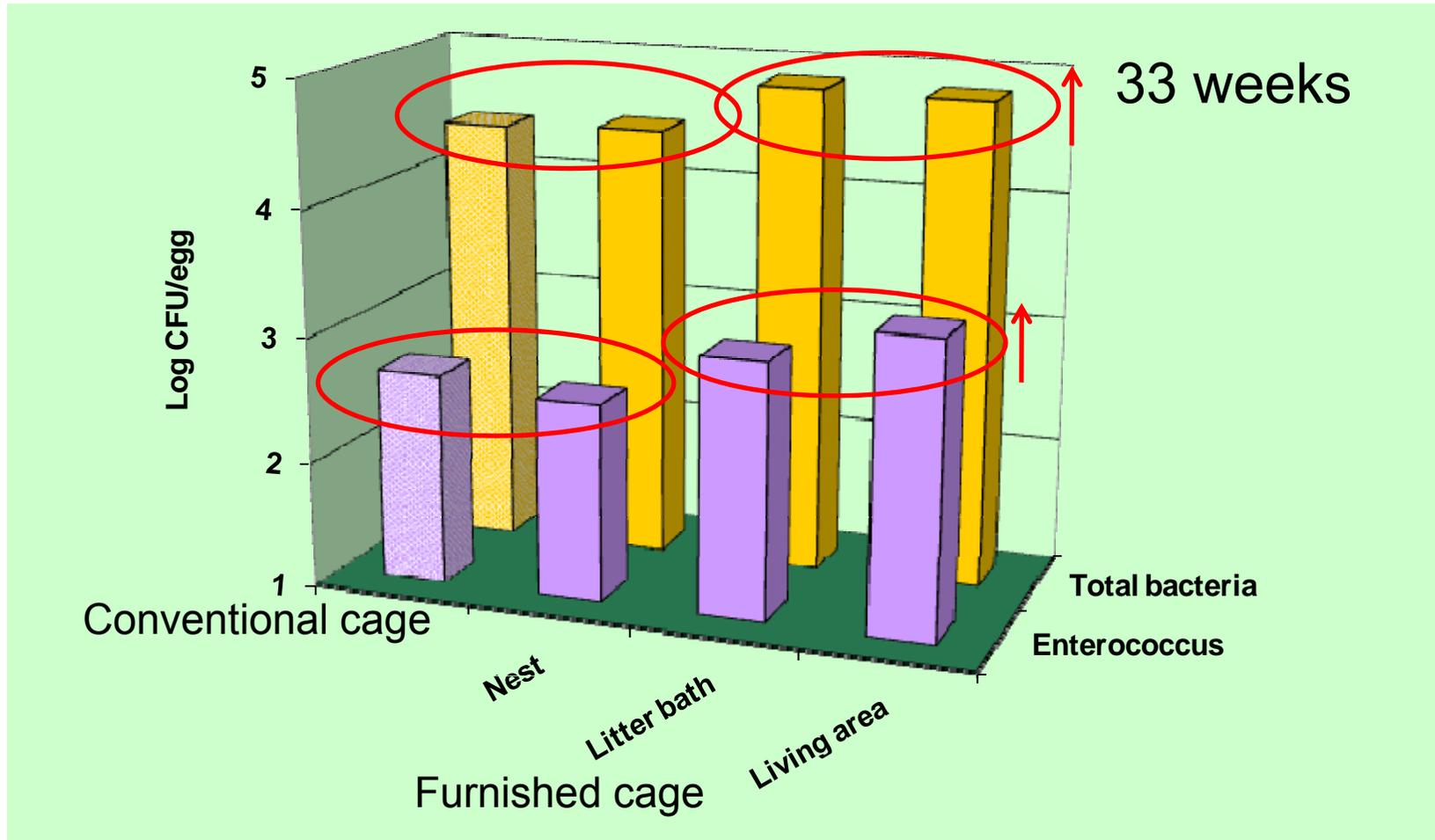
# Comparison of eggshell hygiene in two housing systems: standard and furnished cages

(Mallet et al., 2006, Br. Poultr. Sc, 47, p30-35)

- Conv. cages (CC) compared with furnished cages (FC)
- Same building, same conditions separated by a wall
- Eggshell contamination was compared:
  - Total bacterial flora and *Enterococcus*
  - In FC eggs sampled at different places = nest, living area (cage), litter bath



# Eggshell contamination at different locations in the cage



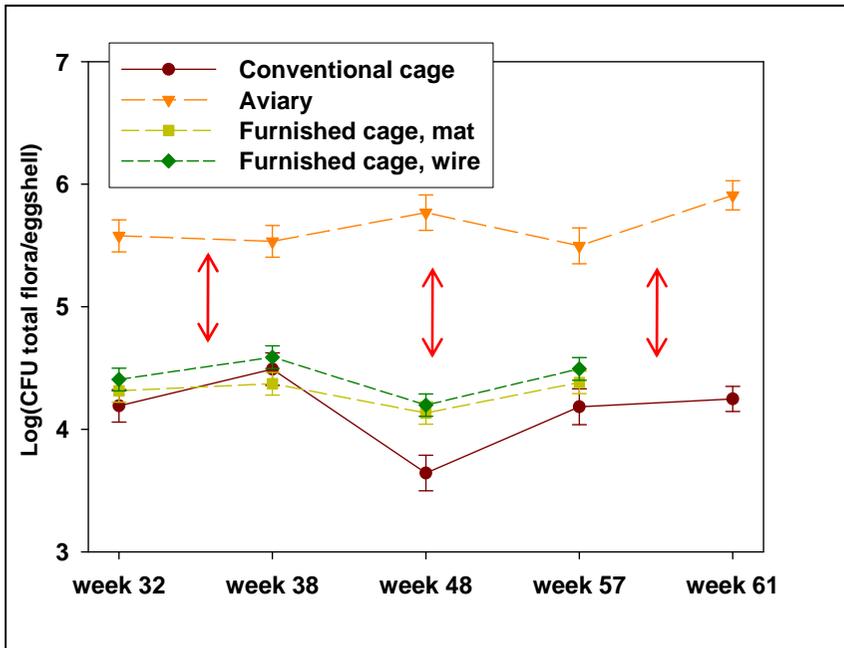
Reason more eggshell contamination in furnished cages:

⇒ More bacteria on the eggs laid **outside** nest of FC

# Bacterial eggshell contamination in conventional cages, furnished cages and aviary housing systems for laying hens

(De Reu et al., 2005, Br. Poult. Sci., 46, p149-155)

- Conventional cages (CC), furnished cages (FC), aviary or non-cage housing (A or NC)
- All systems in same experimental unit
- Sampling during entire laying period
- Sampling **eggs laid at nest-boxes** (FC and A or NC)
- Total bacterial flora (TF) and Gramnegative (G-) bacteria

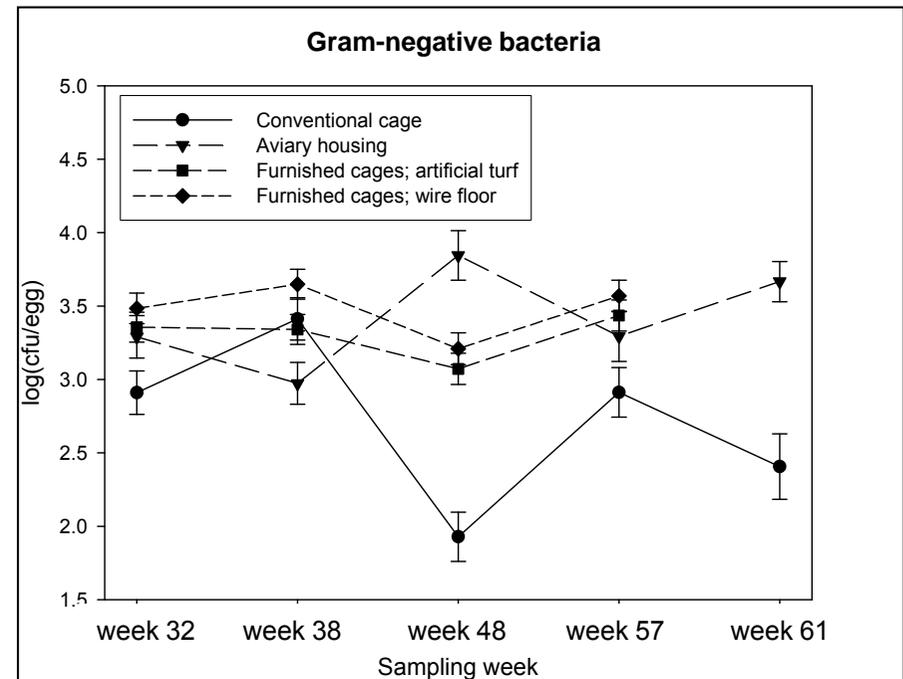


### Total flora on the eggshell:

- Shell contamination TF aviary (NC) > 1 log higher
  - Confirmed by Protais et al. 2003
- No systematic ≠ between CC and FC (TF)
  - Different from Wall et al. 2008
  - Confirmed Mallet et al. 2006 (nest eggs)

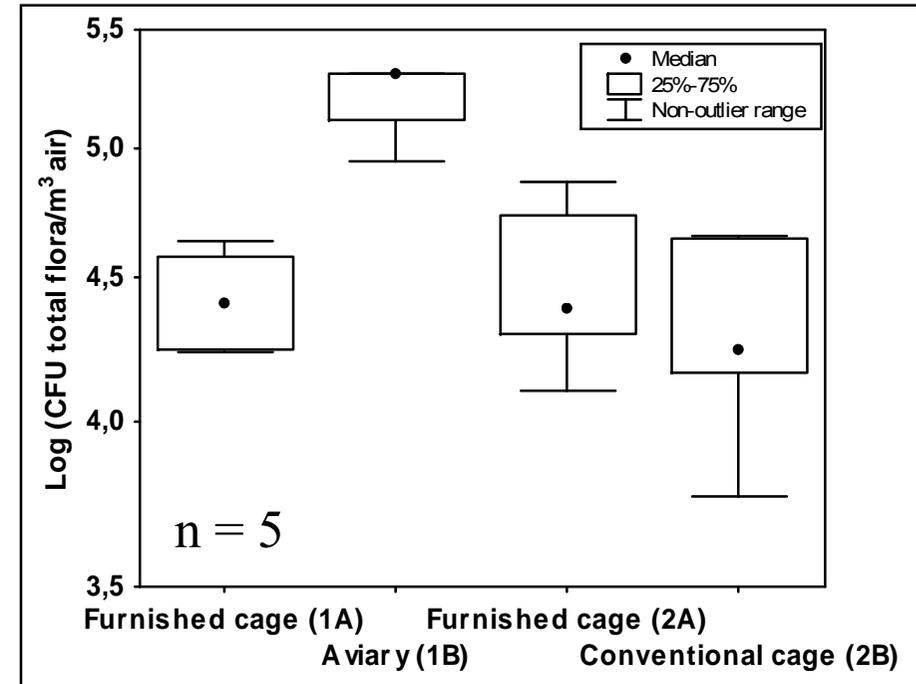
### Gramnegative bacteria on the eggshell:

- No systematic ≠ G- between 3 housing systems



# Correlation air and eggshell contamination

- Higher air contamination with total flora in NC
- **Significant** correlation between quantity TF air and TF eggshell
- $r^2 = 0.66$ ,  $P < 0.001$



Confirmed by Protais et al. 2003

Housing system	Eggshell TF contamination (log cfu/egg)	Air contamination TF (log cfu/m <sup>3</sup> )
Conventional cage	4.16 ± 0.26	4.2
Aviary	5.25 ± 0.30	6.6

# Major conclusions pilot or experimental studies

- Bacterial eggshell contamination with TF:  
Nest eggs in aviary or NC systems 10 times higher compared to CC and FC
- Eggshell contamination of **nest eggs** in FC can be comparable to eggs from CC
- Eggs laid outside the nest of FC have more bacteria

# 3. Eggshell contamination in on farm comparisons

# Bacteriological contamination of eggs and eggshell quality in furnished cages and non-cage systems: an on farm comparison

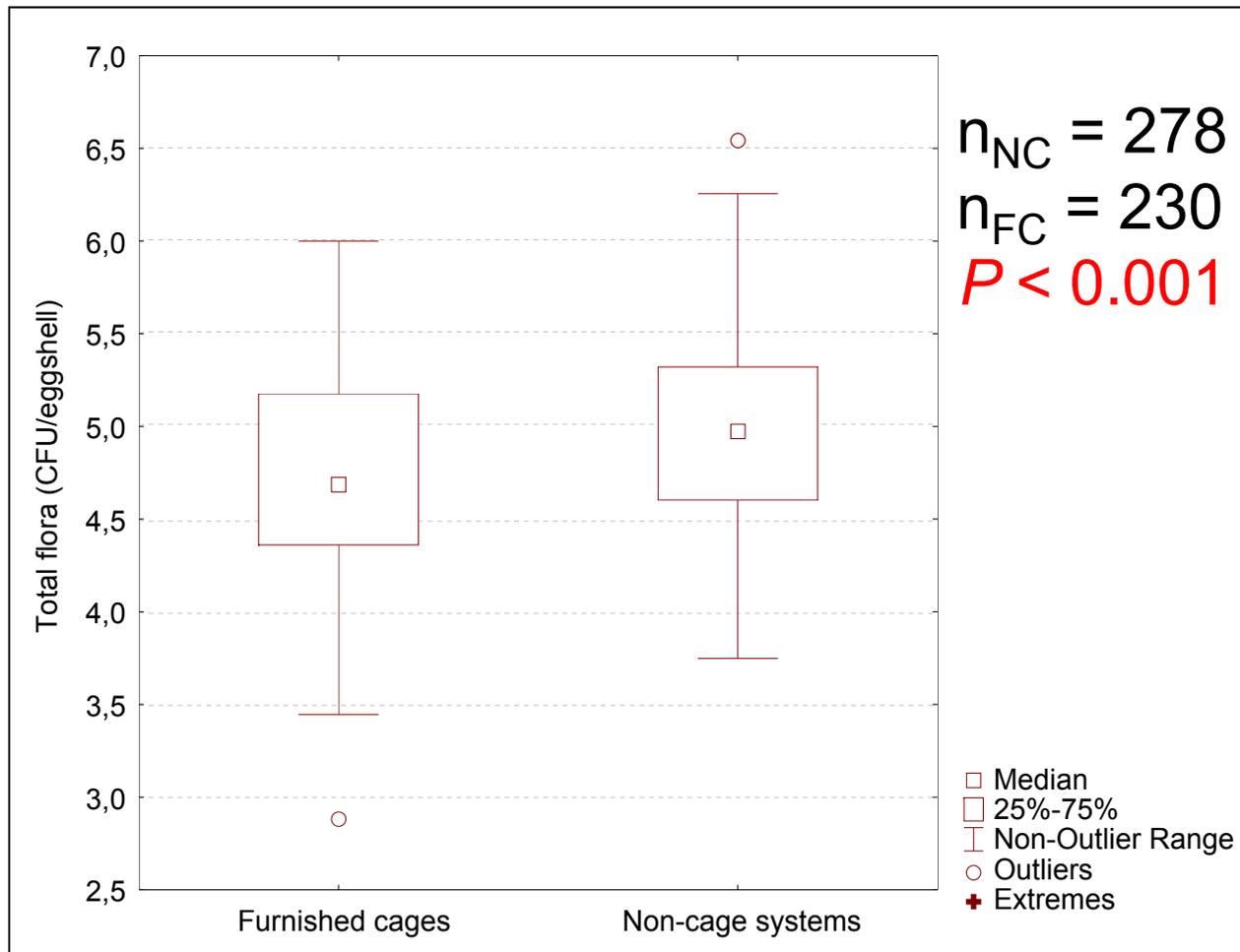
(De Reu et al., 2009, Poult. Sc.)

- 6 flocks furnished cages (FC)
- 7 flocks non-cage systems (NC)
- Sampling when birds were about 60 weeks
- Nest eggs
- Bacterial eggshell and air contamination

Total bacterial flora (TF), Enterobacteriaceae



# Average bacterial eggshell contamination TF FC versus NC



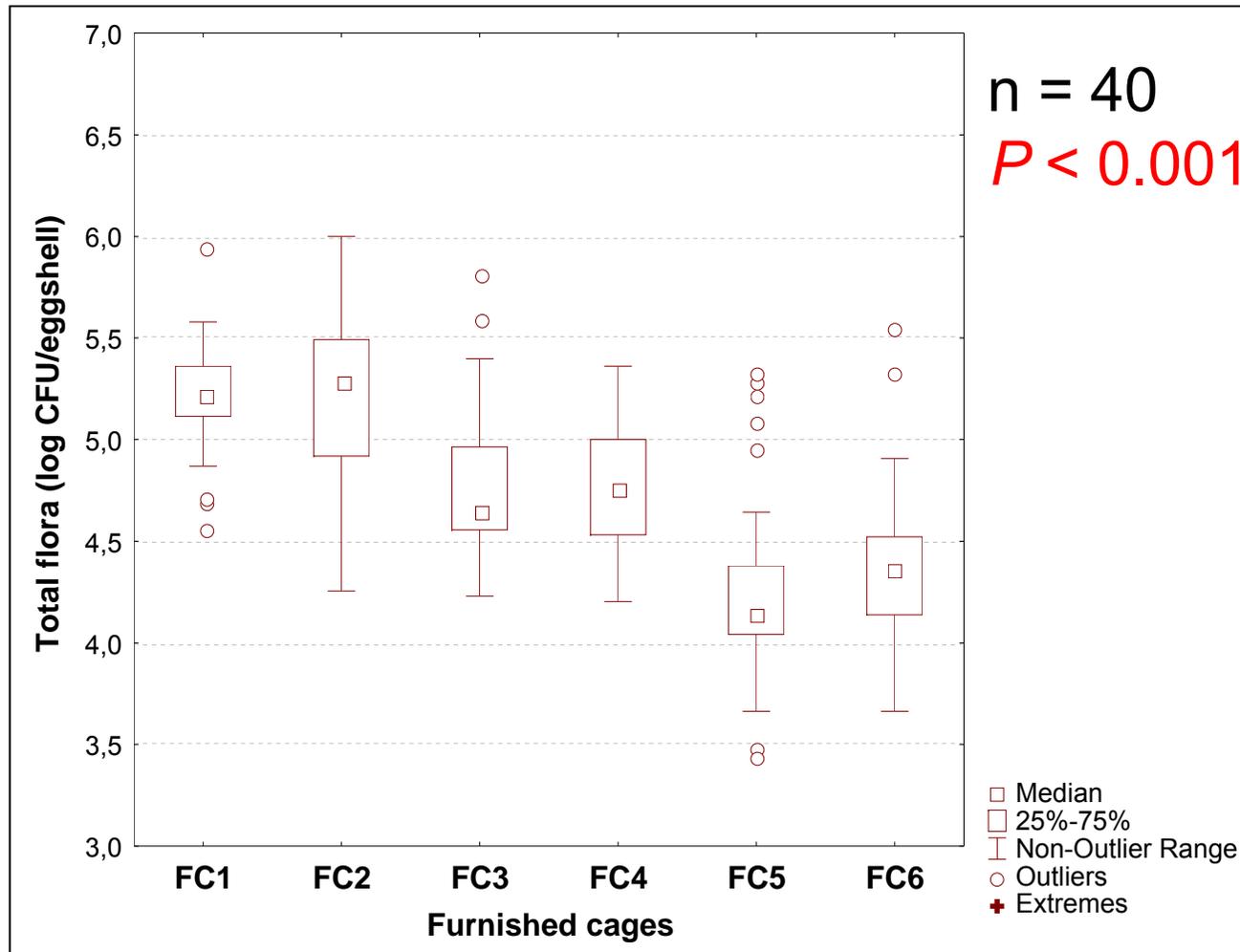
Range

4.75 versus 4.98 log  
56 000 versus 95 000  
cfu TF/eggshell

Bacteriological limited ≠

Smaller differences  
compared to pilot studies  
> 1 log

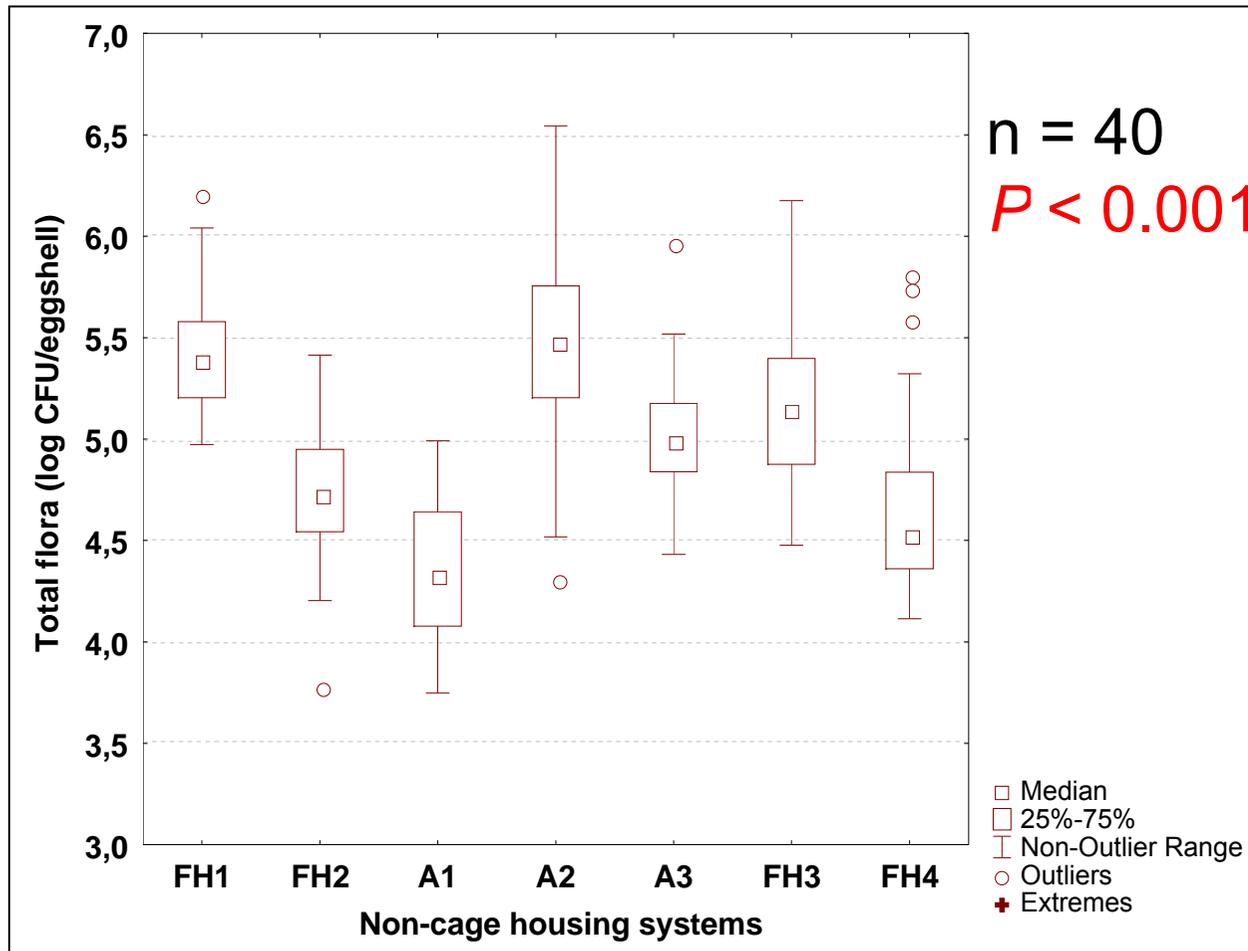
# Bacterial eggshell contamination TF in FC



Range:  
4.24 – 5.22 log  
17 000 – 170 000  
cfu TF/eggshell

Farm management  
+ construction!

# Bacterial eggshell contamination TF in non-cage systems



Range:  
4.35 – 5.51 log  
22 000 – 320 000  
cfu TF/eggshell

**Farm  
management +  
construction!**

FH = Floor housing  
A = Aviary

# Bacterial eggshell contamination with Enterobacteriaceae

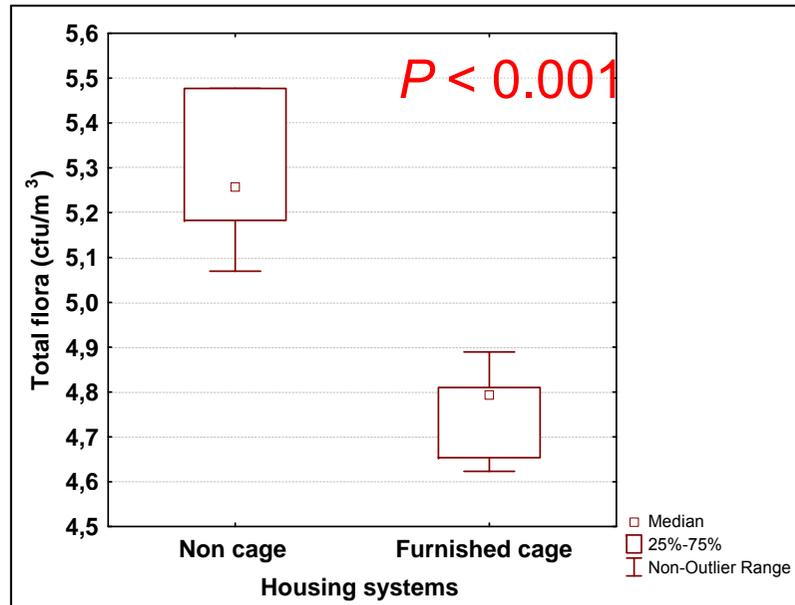
	n	≥ 10 cfu/eggshell
<b>Furnished cages</b>	<b>230</b>	<b>12%</b>
Floor housing	157	7%
Aviary	121	4%
<b>Non-cage</b>	<b>278</b>	<b>6%</b>

Furnished cages versus non-cage systems:  $P > 0.05$

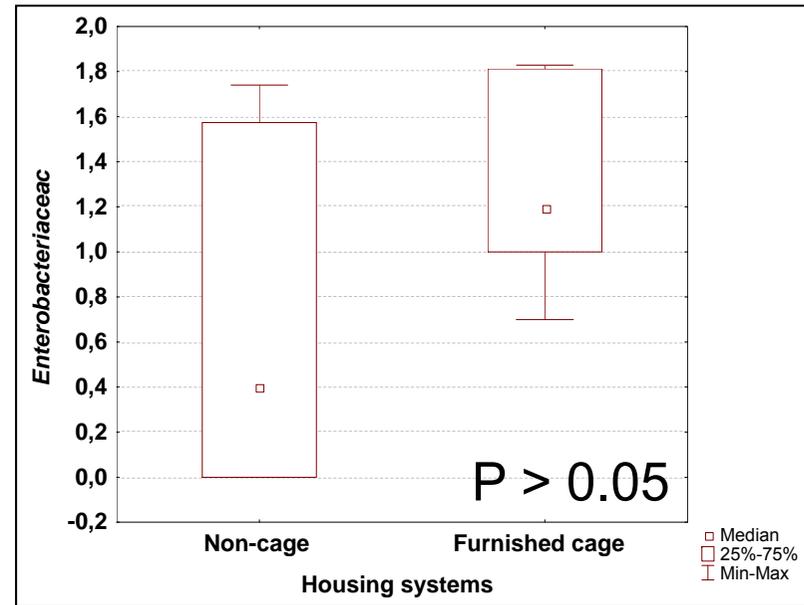
# Bacterial air contamination in hen houses

$$n_{NC} = 7, n_{FC} = 6$$

## Total aerobic flora



## Enterobacteriaceae



In NC = shell + air contamination with Enterobacteriaceae lower

Higher load of total flora (Gram+) shell/air in non-cage systems



Oppressing Gram- and Enterobacteriaceae shell/air in non-cage systems



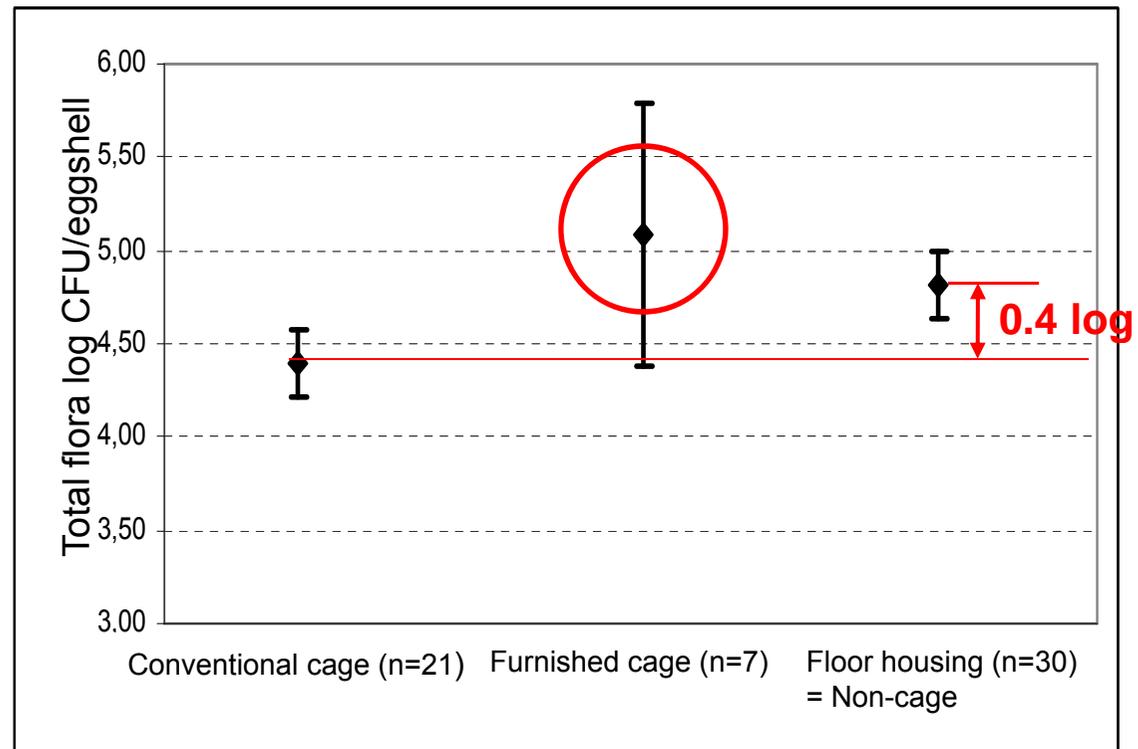
# Factors influencing bacterial eggshell contamination in conventional cages, furnished cages and non-cage systems

(Huneau-Salaün et al., 2009)

## 58 commercial housings

Significant influence of eggshell TF contamination by:

- housing system
- hen age
- air dust concentration



Higher eggshell contamination for furnished cage eggs



Rather new systems: farmers have to learn how to manage them and the design has to be optimized to limit outside nest eggs

# Major conclusions on farm comparisons

- Average difference for TF on shell between cage (CC, FC) and non-cage (NC) systems are limited (0.2 and 0.4 log) compared to pilot studies ( $> 1$  log)
- Substantial differences within same housing system – **farm management and construction**
- NC systems lower load of Enterobacteriaceae and Gramnegative bacteria on shell and in air

## 4. Eggshell dirt, shell quality and cracks in different housing systems

# Occurrence of dirty eggs

Study	Conv. cage (%)	Furn. cage (%)	Non-cage (%)	P
<b>Pilot studies</b>				
Tauson et al. 1999	6.5	-	5.7*	≤0.01
Mallet et al. 2006	4.9-4.9	3-7.1	-	<0.001
Wall et al. 2007	6.4	7.1	-	n.s.
Wall et al. 2008	5.4	4.2	-	n.s.
Tactacan et al. 2009	4.2	12.1	-	≤0.001
<b>Pilot + commercial flock scale</b>				
LayWel	4.9	5.9	8.1**	-
<b>Commercial flock scale and on shop</b>				
De Reu et al. 2009a	-	22	24*	>0.05
De Reu et al. 2009b	17.2	-	4.4	-

\* = Only **nest eggs** (no floor eggs) \*\* = Including floor eggs n.s. = not significant

## Conclusions:

In FC → percentage of dirty eggs can be higher

Solution → cage design: limit outside nest eggs (Mallet et al., 2006)

Non-cage **nest** eggs seem to have not more dirty eggs than cage eggs



# Shell quality

CC = conv. cage; NC = non-cage

Study	Shell breaking strength (N)			Shell thickness (mm)		
	CC	NC	P	CC	NC	P
<b>Pilot studies</b>						
Van den Brand et al. 2004	-	-	-	0.321	0.321	n.s.
Wang et al. 2009	34.9	34.4	n.s.	0.33	0.33	n.s.
Petek et al. 2009	37.2	37.4	n.s.	0.336	0.343	≤0.05
Dukić-Stojčić et al. 2009	2.48 <sup>a</sup>	2.52 <sup>a</sup>	n.s.	0.374	0.371	n.s.
Englmaierová and Tůmová 2009	-	-	-	0.365	0.370	≤0.01
<b>Commercial flock scale (on farm)</b>						
Abrati 2006	37.8	35.1	≤0.05		0.456	≤0.05
		40.1	≤0.05	0.463	0.477	≤0.05

<sup>a</sup> = breaking stress (kg/cm<sup>2</sup>); in red: organic production

n.s. = not significant

## Conclusions:

Contrasting results for breaking strength and shell thickness of CC and NC eggs → differences in the amount of dietary Ca and available P?

# Occurrence of cracked eggs

Study	Conv. cage (%)	Furn. cage (%)	Non-cage (%)	P
<b>Pilot studies</b>				
Tauson et al. 1999	5.0 (4.3-5.6)	-	4.6 (2.2-7.0)*	≤0.01
Guesdon et al. 2006	10.2	<b>17.5</b>	-	≤0.001
Wall et al. 2007	2.2	3.3	-	≤0.001
Petek et al. 2009	1.5	-	2.4	≤0.001
Tactacan et al. 2009	0.7	0.6	-	n.s.
<b>Pilot + commercial flock scale</b>				
LayWel	2.6	1.8	2.2	-
<b>Commercial flock scale and on shop</b>				
Mertens et al. 2006	6.7	<b>10.7</b>	<b>2</b>	-
De Reu et al. 2009a	-	<b>7.8</b>	<b>4.1</b>	-

\* = Only nest eggs (no floor eggs)

n.s. = not significant

## Conclusions:

FC → are more susceptible to cracks

Solution → limitation of accumulation of eggs on **short and small** part of eggbelt + good adjustment of **egg saver**

Non-cage **nest** eggs seem to have not more cracks than cage eggs

# 5. Egg content contamination in relation to different housing systems

# Egg content contamination in relation to housing system

No indications for more egg content contamination for NC-eggs (**except floor eggs**) compared to cage eggs (CC and FC)

(Holt et al. 2011, De Reu et al. 2007 and 2008, Cepero et al. 2000 and 2001)

De Reu et al. 2007

	<b>Furnished cages</b>	<b>Non-cage</b>
# Flocks	4	6
Total	269 eggs	432 eggs
Contaminated eggs	5	10
% Contaminated eggs	1.9%	2.3%

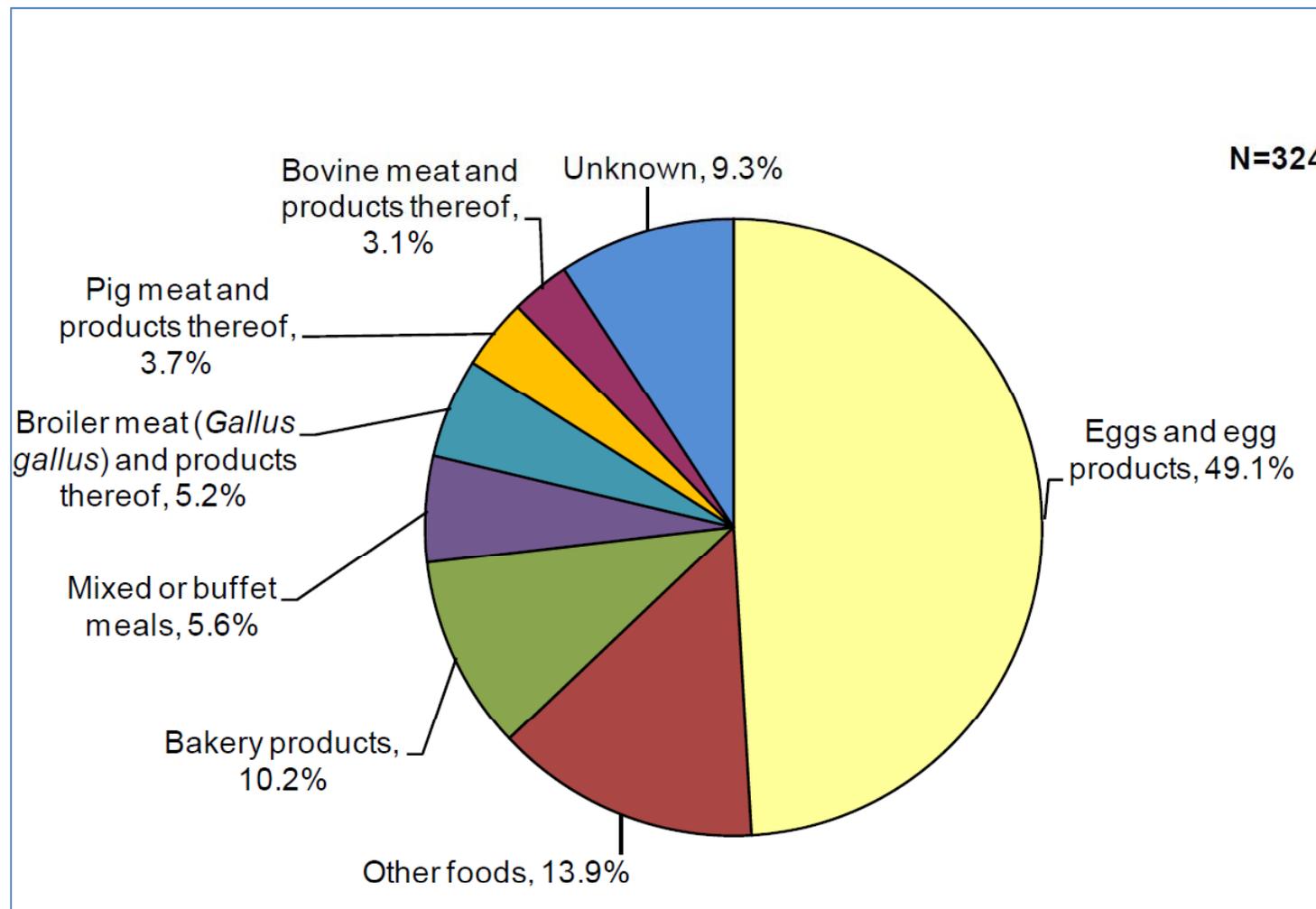
Dominating shell and content contaminant: *Staphylococcus* sp.



## 6. *Salmonella* contamination in relation to different housing systems

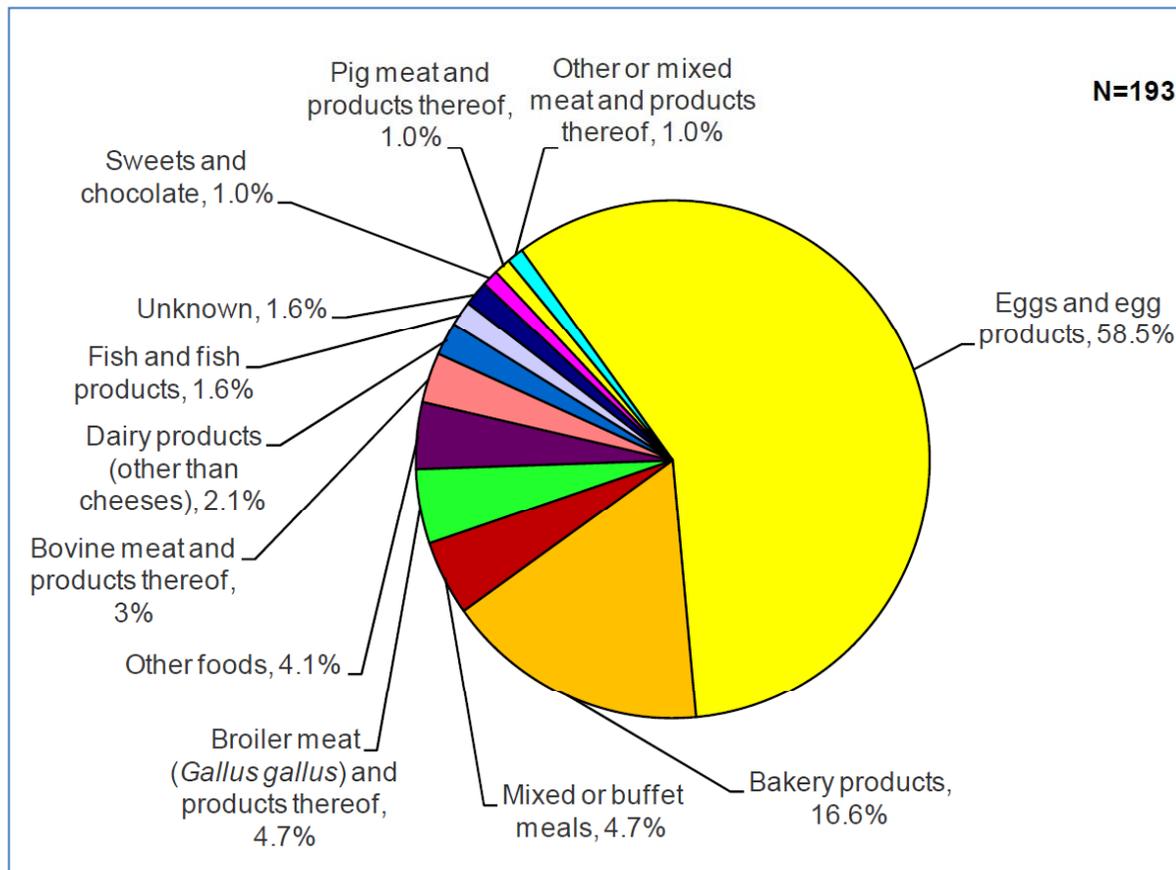
# Distribution of food vehicles in human *Salmonella* outbreaks

EU 2009 (EFSA 2010)



# Distribution of food vehicles in human SE outbreaks

SE = *Salmonella* Enteritidis



EU 2009 (EFSA 2010)

Egg and egg products: most important food vehicle (17%) for outbreaks

# Overview published observational studies effect housing on prevalence of SE infections

## ENVIRONMENTAL SAMPLING

Dewulf et al. 2009

Comparison	Nb of observations	Odds Ratio	95% conf. interval	Reference (+ comment)
Cage vs deep litter	1642	0.48	NA	Molenhorst et al. 2005 (serology)
Cage vs free range	34	0.61	0.15-2.34	Schaar et al. 1997
Cage vs aviary	8	1.28	0.51-3.21	Pieskus et al. 2008
Cage vs non-cage	30	2.11	0.28-15.77	Van Hoorebeke et al. 2009a
Cage vs non-cage	329	2.34	1.42-3.85	Methner et al. 2006
Cage vs non-cage	195	4.69	1.85-11.90	Van Hoorebeke et al. 2009b
Cage vs non-cage	3768	5.12	4.07-6.45	EFSA, 2007
Cage vs floor raised and free range	148	20.11 10.27	2.52-160.49 2.13-49.57	Namata et al. 2008 Dust samples Faeces samples
Cage vs on floor	519	35.1	12.2-101.1	Huneau-Salaün et al. 2009

# Factors influencing *Salmonella* contamination

Possibly not housing system CC per se but combination of factors related to CC system:

## 1) Herd and flock size

Independently of production type:

**Number of flocks**, number of **hens** per herd and flock → **risk factor**

(Heuvelink et al. 1999, Mollenhorst et al. 2005, EFSA 2007; Carriqua-Mas et al. 2008, Huneau-Salaün et al. 2009, Dewulf 2009)

# Factors influencing *Salmonella* contamination

## 2) Carry-over infections

- **Carry-over** for one to the next production round

(Davies and Breslin, 2003; Carrique-Mas et al. 2008; De Reu et al. 2006, Van Hoorebeke et al. 2009, Dewulf et al. 2009)

## 3) Age of building

- Cage systems are generally **older**
- Cage systems more **difficult to clean**

(Davies and Breslin, 2003; Carrique-Mas et al. 2008; De Reu et al. 2006, Van Hoorebeke et al. 2009, Dewulf et al. 2009)

## 4) Pests

- Cages **more attractive** environment **for pests** (birds are restrained in cages)

(Davies and Breslin, 2003; Carrique-Mas et al. 2008, 2009; Dewulf et al. 2009)

# *Salmonella* contamination in relation to different housing systems

## CONCLUSIONS

Highly unlikely that move from **cage** to **non-cage** will result in increase in *Salmonella* infection → **rather opposite**

Possibly not **housing system** per se but **combination of factors eventually related to housing system** are important

# 7. Take home messages

- 1) Comparison of housing systems must be based on **multiple commercial farms** (on farm comparison) – **farm. management + constr.**
- 2) In **furnished cages design** and management is very important
  - Limit outside nest eggs
    - Outside nest eggs: dirt ↑, bacterial load ↑
  - Limit accumulation of eggs on egg belt
    - Limit cracks
- 3) Non cage systems
  - Higher bacteriological air contamination with TF
  - High bacterial load of floor eggs (avoid as table eggs)
  - **Nest eggs** have an **acceptable** higher eggshell contamination with TF compared to cages
  - **Lower shell** and air **load** with **Gram- and Enterobacteriaceae**

## 7. Take home messages

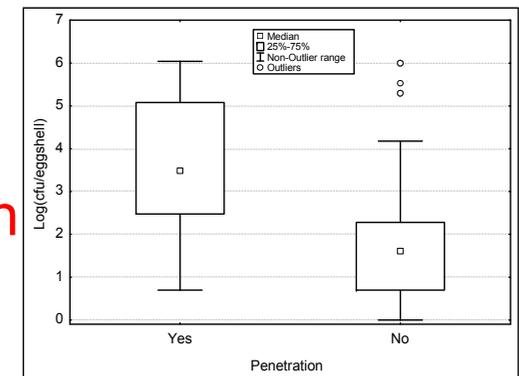
4) No real strong proves of higher **egg content** contamination in NC compared to FC and CC

- Exception floor eggs in NC (avoid)
- Nest eggs of NC:
  - Literature indicate comparable content contamination
  - Cracks not higher
  - Eggshell dirt not higher

5) Unlikely that move from **cage** to **non-cage** will result in increase in *Salmonella* infection

Still at tentative:

Higher eggshell contamination = higher possibility of shell penetration and **egg content contamination**





# Many thanks for your attention

Thanks to different research groups

Special thanks to  
Helena Wall, Serge Mallet, Adeline Huneau-Salaün, Jeroen Dewulf

## Thanks for the invitation



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