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## The chicken eggshell quality

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► **To cite this version:**

Joël Gautron. The chicken eggshell quality. Webinar on Egg quality, Feed channel - Adisseo, Apr 2018, Paris, France. hal-03625794

**HAL Id: hal-03625794**

**<https://hal.inrae.fr/hal-03625794>**

Submitted on 31 Mar 2022

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# The chicken eggshell quality

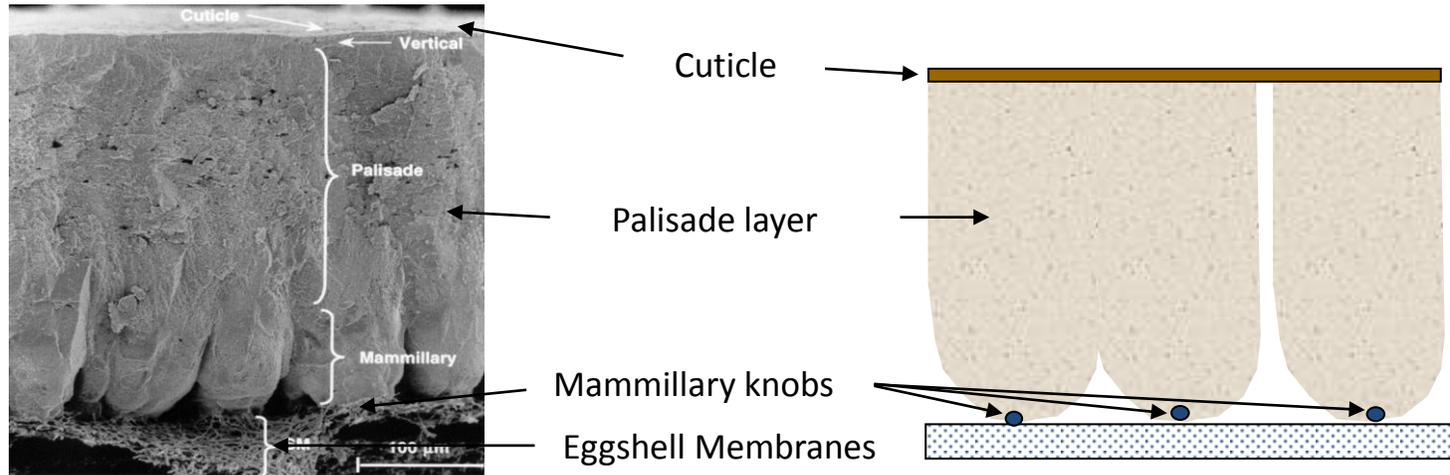
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# The chicken eggshell formation

- ✓ Eggshell biomineralization in uterus (fast process)
- ✓ 5-6 g of mineral (calcium carbonate) are deposited within a 20 h period



**95 % of calcium carbonate  
(calcite)**

Interaction

**3.5 % organic matrix  
(protéines, protéoglycanes)**

✓ Control of the mineralisation process

**Ultrastructure, Mechanical properties**

# Eggshell biomechanical properties measurement

## Acoustic egg tester :

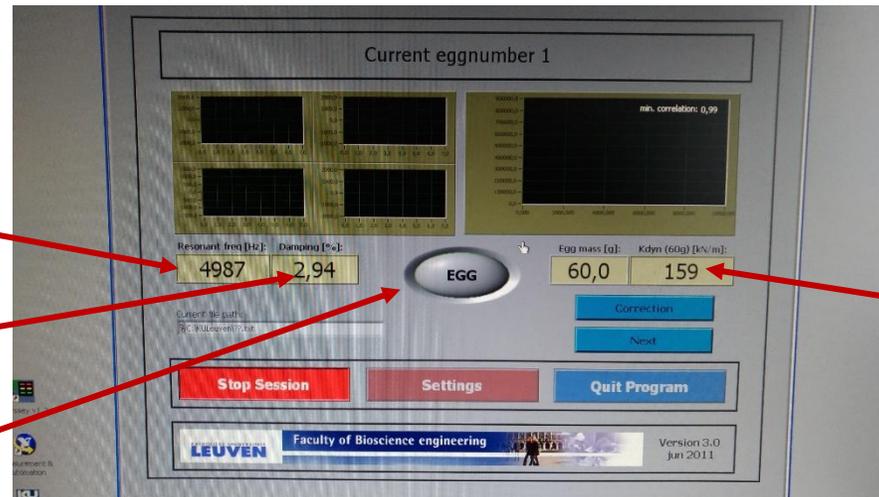
A piano hammer comes to hit the rotating egg on 4 different places  
The acoustic vibration is registered by a microphone



**RF:** Resonant frequency (Hz).

**damping**

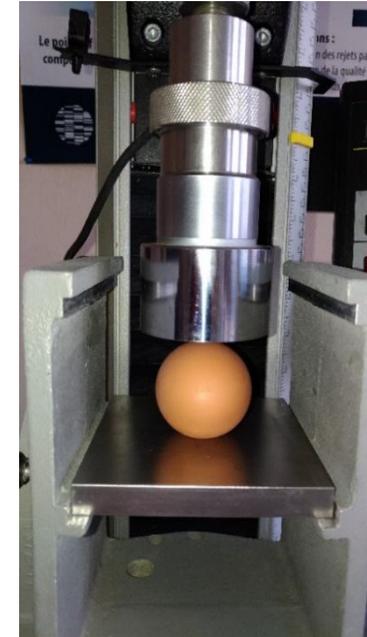
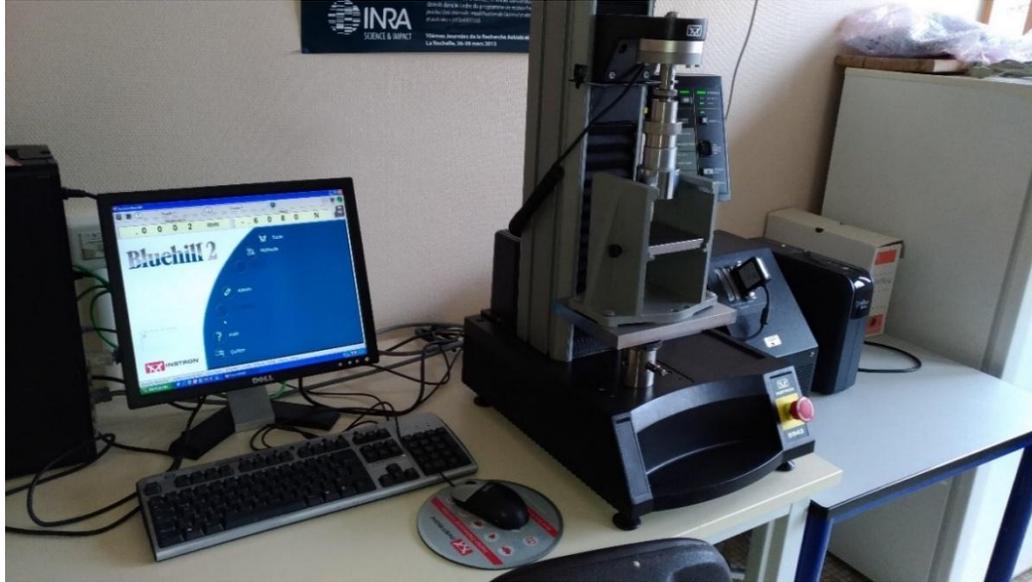
Broken egg (**1**) / Intact egg (**0**).



Dynamic stiffness  
**Kdyn** (KN/m)

# Eggshell biomechanical properties measurement

Instron mechanical data:



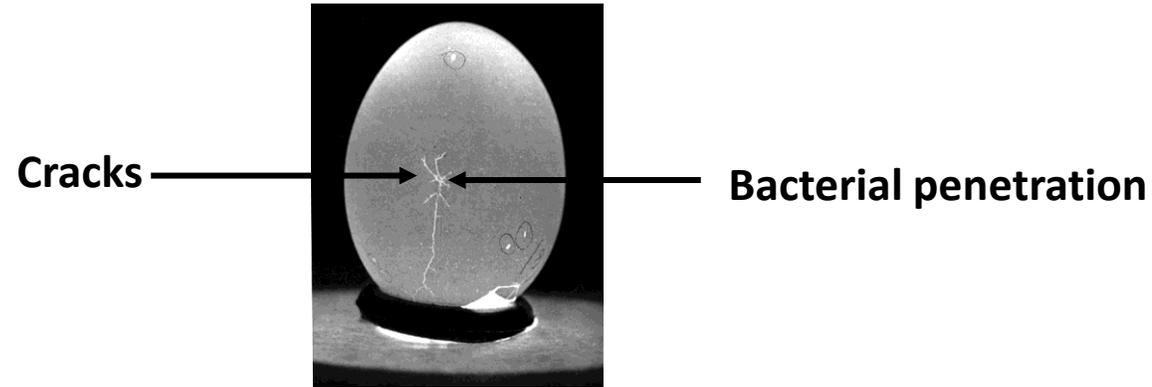
(**Sd**) (stiffness en N/mm) : Shell deformation under a specific load

(**F**) (Eggshell Breaking strength en N). A constant load is applied on egg equator until break

Biomechanical parameters calculated

- Shell percentage %
- Shell index (g/100cm<sup>2</sup>)
- Shell thickness (mm) :  $T = I/23.5$
- Elastic modulus which describes the material impact on shell rigidity
- Eggshell fracture toughness (Kc) en N/mm<sup>3/2</sup>

# Improve the eggshell quality



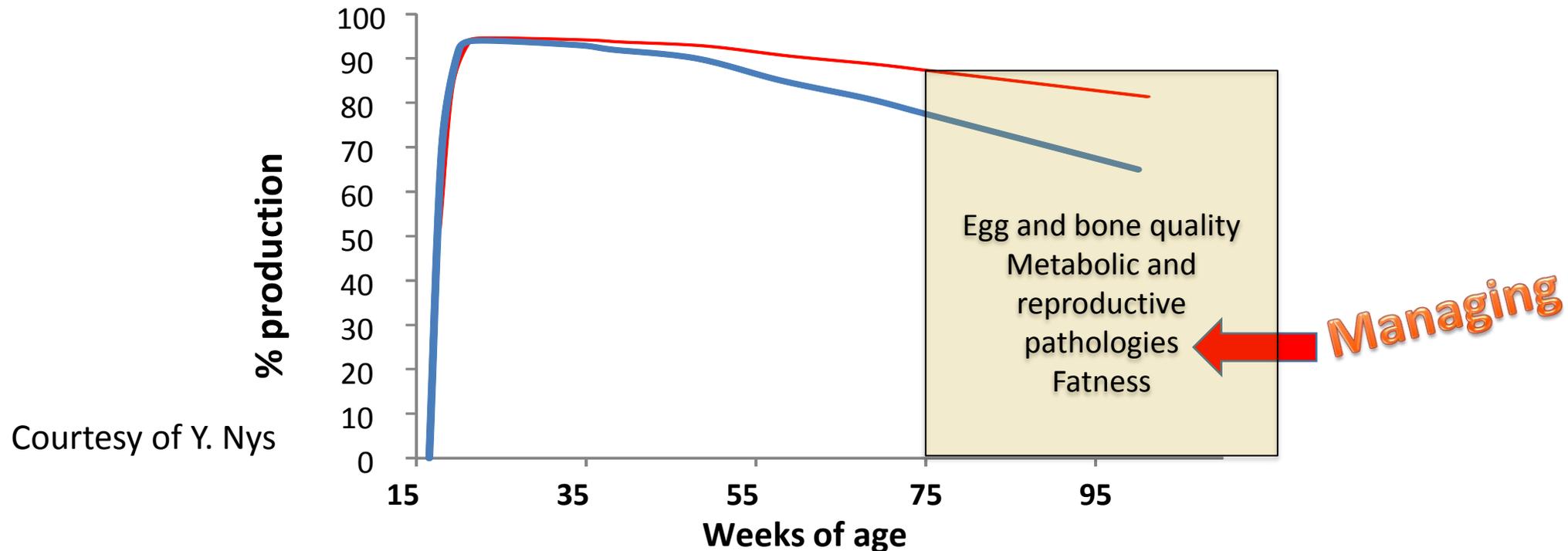
## Shell quality Depends on Numerous factors

- Genetic
- Hen physiology (age, mold)
- Environment of hens (lighting programs, temperature)
- Nutrition and management of hens
- “Insult”: rearing system, egg transport...
- egg sorting...

→ **Genetic, optimal nutrition limit but do not eliminate breakage**

# Extension of the Laying Period

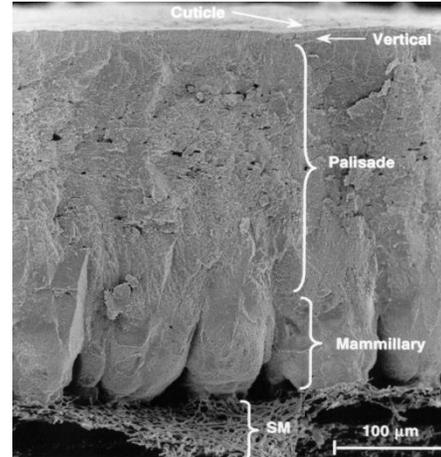
The current genetic strategy is to improve persistency in lay and to extend the laying cycle of existing flocks (+ 40 days between 2000 and 2011; financial and environmental interest!)



Weekly decreased in egg quality between 70 and 90 weeks of age estimated to be quite linear: - 0.4 haught unit, - 0,02% for egg shell, + 0,05 cm<sup>2</sup> egg surface (European data, 2015, practical conditions)

# Improve the eggshell quality

Calcium Carbonate (calcite) 95 %



Organic matrix 3.5 %



Quantity

Remarkable mechanical properties



Control of calcification process

Mass or fabric

☞ Mass : nutrition, génétic, environemment, lightning programs

☞ fabric : genetic (eggshell matrix proteins), nutrition (trace elements)

# Improve the eggshell quality

## Nutrition (Nys et al)

Effect of dietary calcium levels on eggshell (Hartel, 1990)

Diminution of calcium intake affect shell quality

	Dietary calcium (%)		
	<2.5	3.5	>4
Shell thickness ( $\mu\text{m}$ )	348 <sup>a</sup>	374 <sup>b</sup>	378 <sup>b</sup>

Effect of Mn -Zn supplementation on eggshell quality (Mabe et al. 2003)

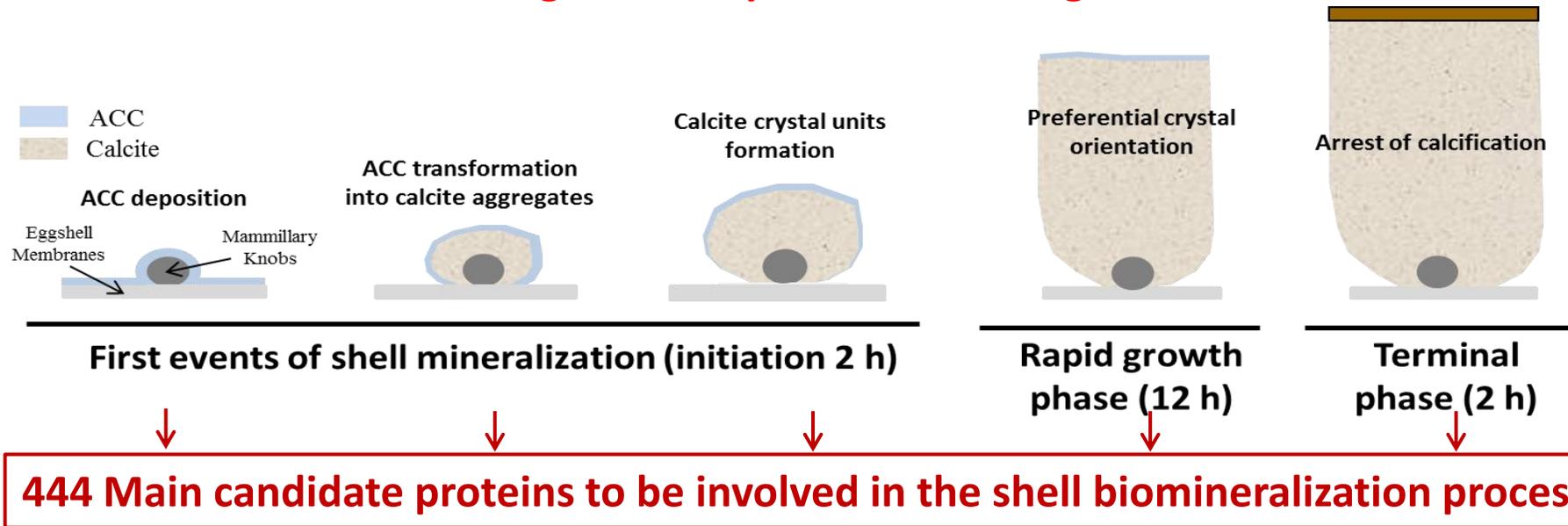
Trace elements (Mn) do not affect the shell amount, but improve eggshell breaking strength

Supplementation Mn-Zn	Eggshell %	Breaking strength (N)
0-0	9,7	29,5a
30-30	9,5	30,8ab
60-60	9,7	32,2b



# Improve the eggshell quality

## Identification of genes and proteins affecting shell texture



## Predicted functional activities of the identified matrix proteins ?

(Marie et al., 2014, 2015a,b)

Classification in 3 different groups according to their potential functions

Associated to mineralization process

Involved in the regulation of activity of proteins

Antimicrobial and other proteins



# Improve the eggshell quality

## Identification of genes and proteins affecting shell texture

Use as biological markers for genomic selection to reinforce eggshell breaking strength

- ✓ Associate transcripts with published and private SNPs, QTLs related to shell quality  
*(Collaboration with breeders and avian genetic teams)*

Use for precise phenotyping of the shell mechanical properties

- ✓ Molecular variants → Structure/function
- ✓ Study of protein interactions with mineral
- ✓ Structural *in situ* studies. Synchrotron, XRD, XANES, FTIRM, HRSEM to provide new insights into mechanisms, which control eggshell texture and its mechanical properties

*(Collaboration with synchrotron SOLEIL and University of Granada (Spain))*

**Selection of laying hens haplotypes for the continued improvement of eggshell solidity**  
**How genes are evolving according vit D metabolite nutritional status**