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The chicken eggshell quality

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The chicken eggshell quality

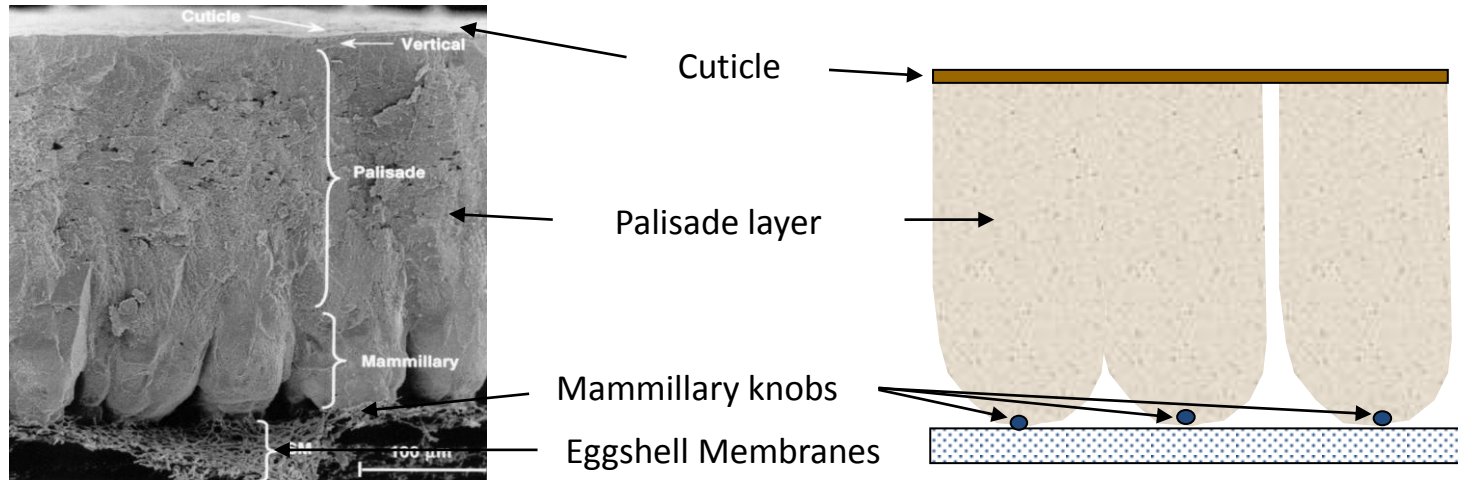
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The chicken eggshell formation

- ✓ 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 :

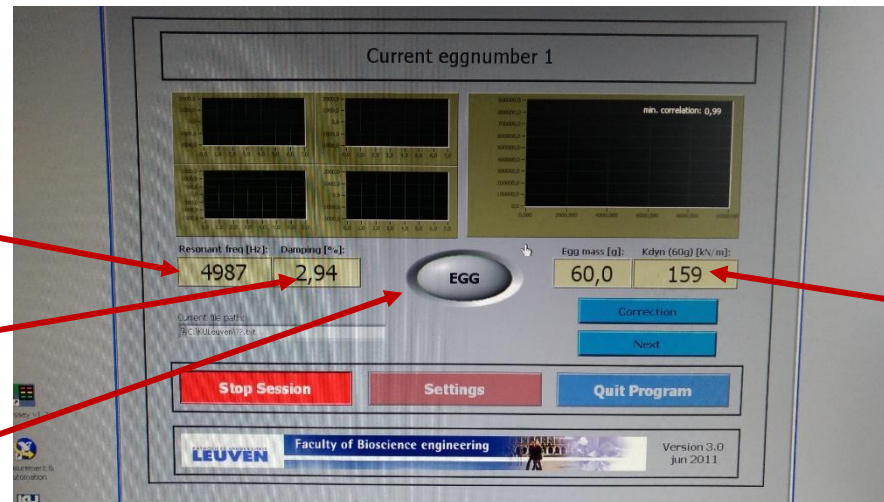
A piano hammer comes to hit the rotating egg on 4 different places
The acoustic vibration is registered by a microphone



RF: Resonant frequency (Hz).

damping

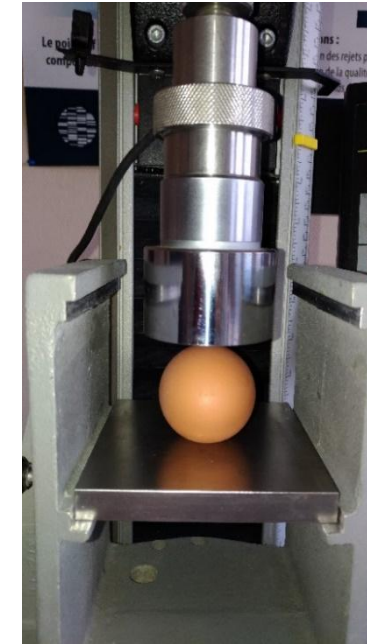
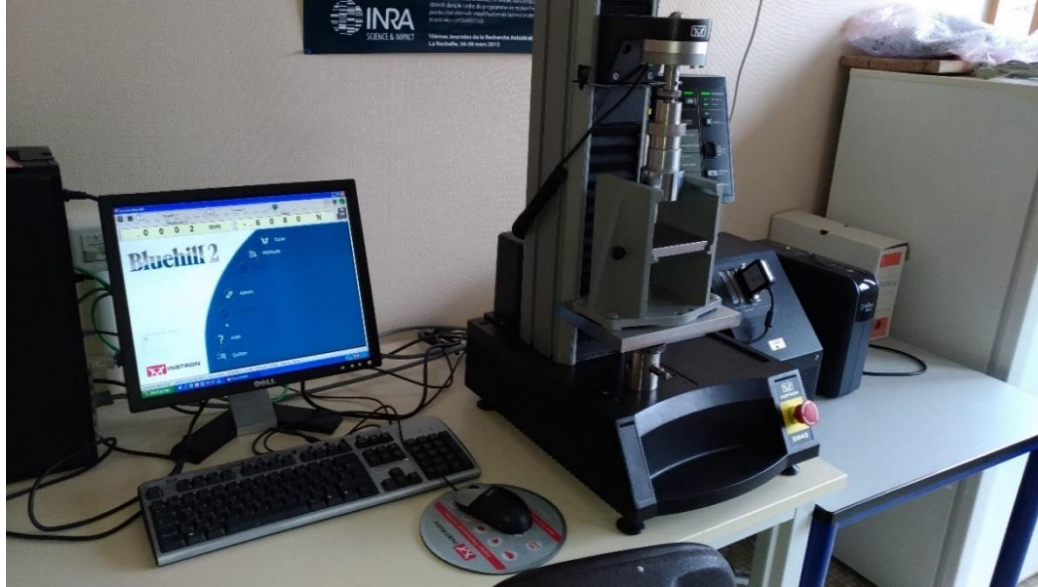
Broken egg (**1**) / Intact egg (**0**).



Dynamic stiffness
Kdyn (KN/m)

Eggshell biomechanical properties measurement

Instron mechanical data:



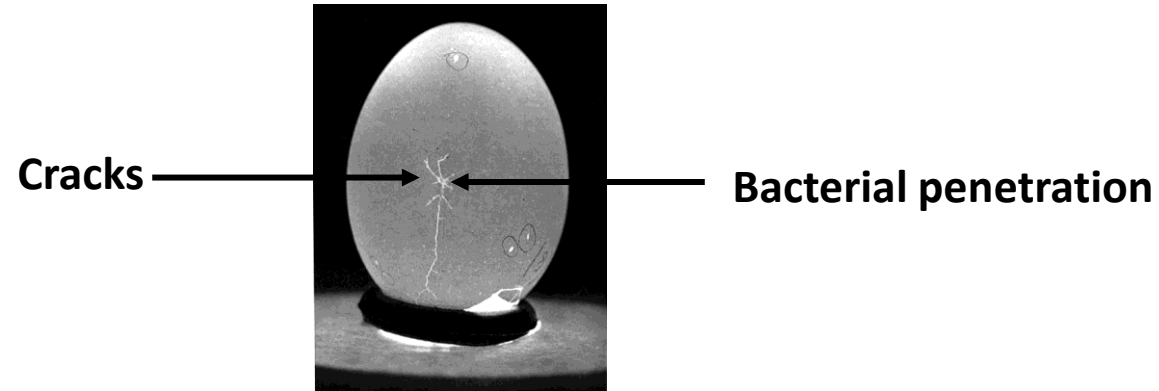
(**Sd**) (stiffness en N/mm) : Shell deformation under a specific load

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

Biomechanical parameters calculated

- Shell percentage %
- Shell index (g/100cm²)
- Shell thickness (mm) : $T = I/23.5$
- Elastic modulus which describes the material impact on shell rigidity
- Eggshell fracture toughness (Kc) en N/mm^{3/2}

Improve the eggshell quality



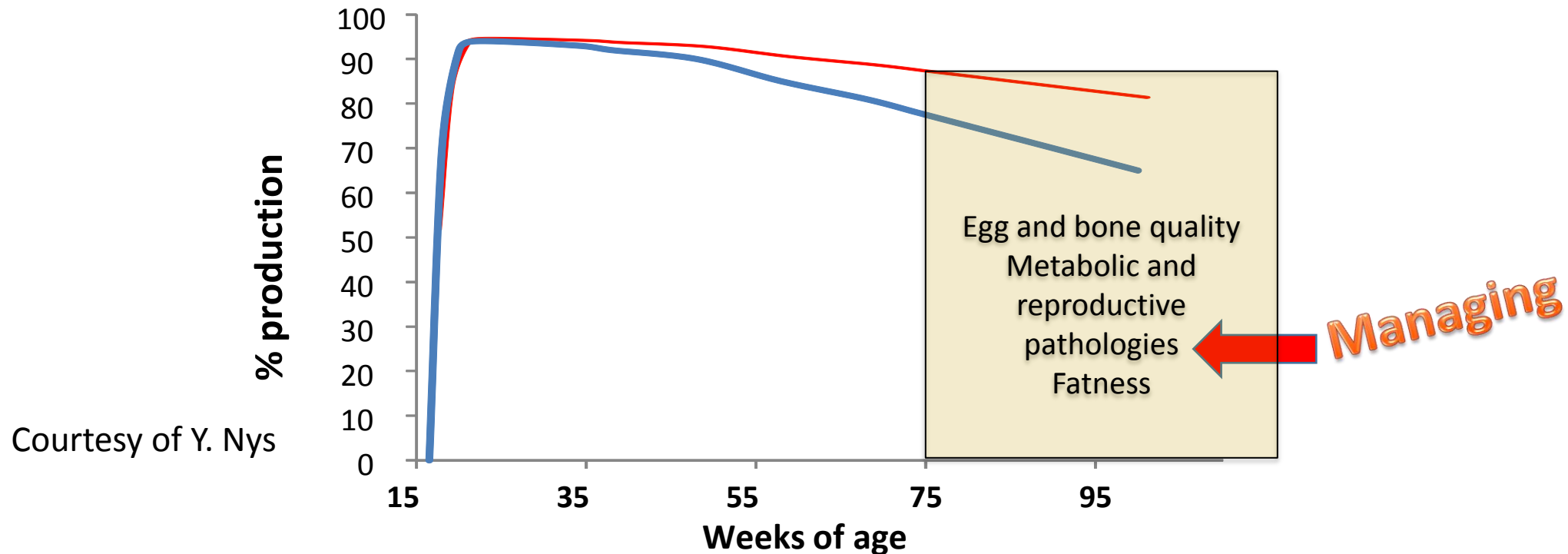
Shell quality Depends on Numerous factors

- 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

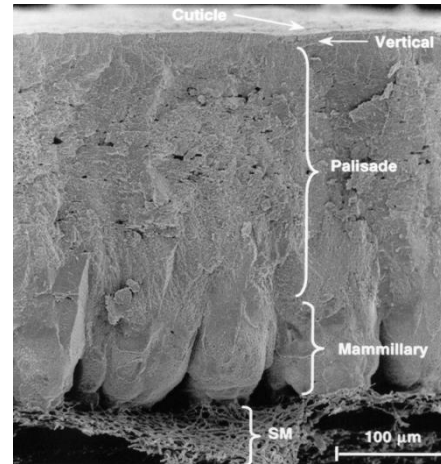
The current genetic strategy is to improve persistency in lay and to extend the laying cycle of existing flocks (+ 40 days between 2000 and 2011; financial and environmental interest!)



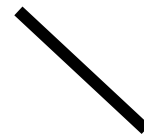
Weekly decreased in egg quality between 70 and 90 weeks of age estimated to be quite linear: - 0.4 haught unit, - 0,02% for egg shell, + 0,05 cm² egg surface (European data, 2015, practical conditions)

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)

Diminution of calcium intake affect shell quality

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

	Dietary calcium (%)		
	<2.5	3.5	>4
Shell thickness (μm)	348 ^a	374 ^b	378 ^b

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

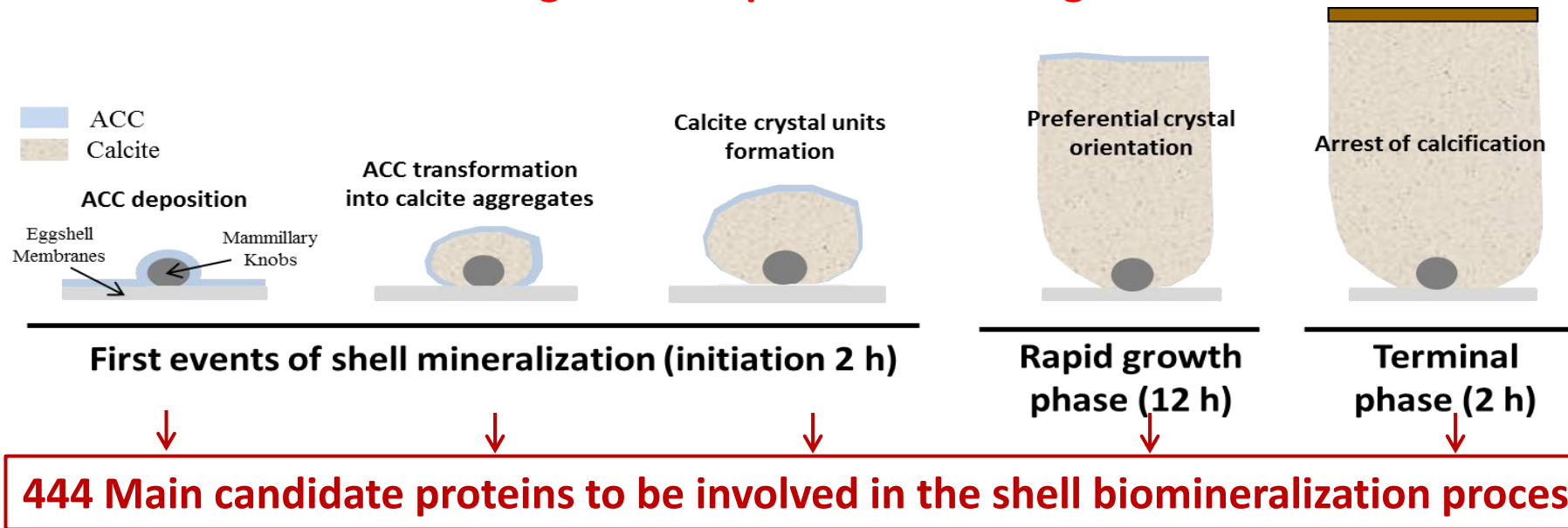
Trace elements (Mn) do not affect the shell amount, but improve eggshell breaking strength

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

