Farming Systems and egg production

Joël Gautron

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The chicken or the egg ?

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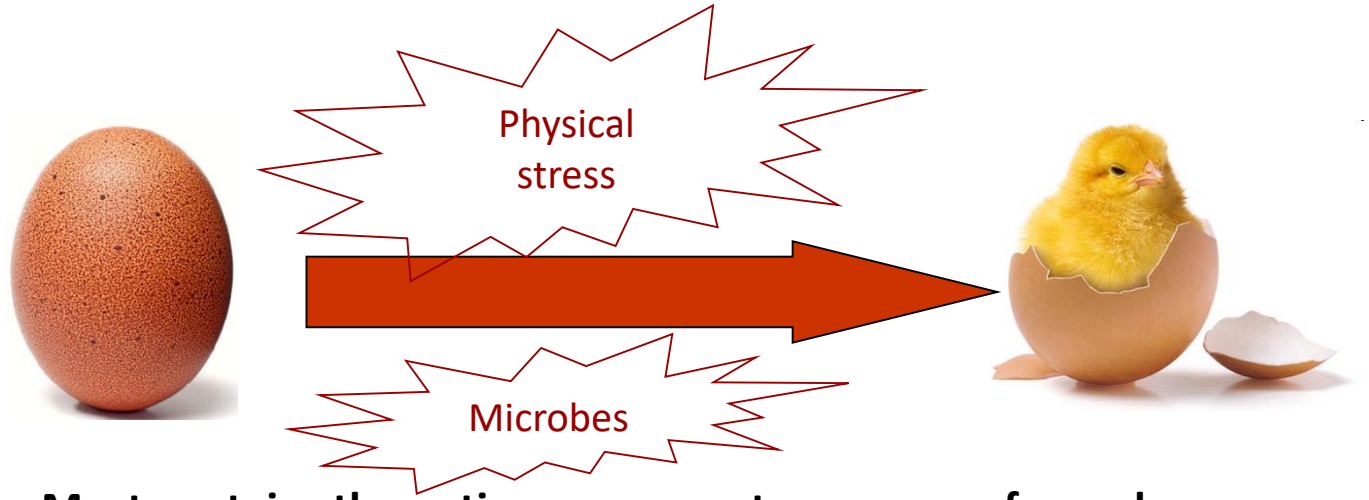
The chicken egg

The egg, a basic ingredient for food
Isolated chamber for embryo development

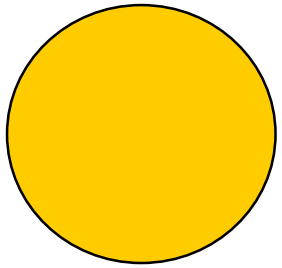


Must contains the entire components necessary for embryo

- Well-balanced nutritious ingredients
- Lot of compound (> 1000) with a broad range of biological activities
- Protective systems (natural defenses)

Physical defense (Mainly shell)
Chemical defense (Proteins with antimicrobial activities)

The egg composition is well adapted for embryo development

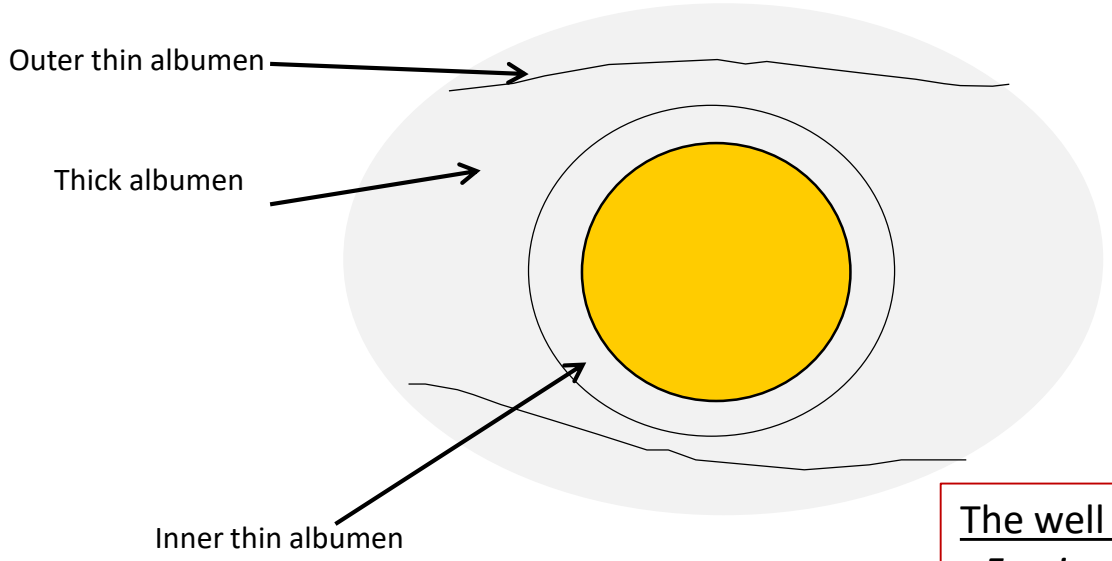


The well adpated composition of the yellow

- *Feminal gamete*
(Clear disk of 3.5 mm)
- *Nutritional reserves (lipids, proteins) and defenses (antibodies)*
- *Surrounded by a thin and translucent membrane*

The egg composition is well adapted for embryo development

The egg white, water rich (88%), proteins and glucides
- *Various textures of white*
- *Antimicrobial molecules*



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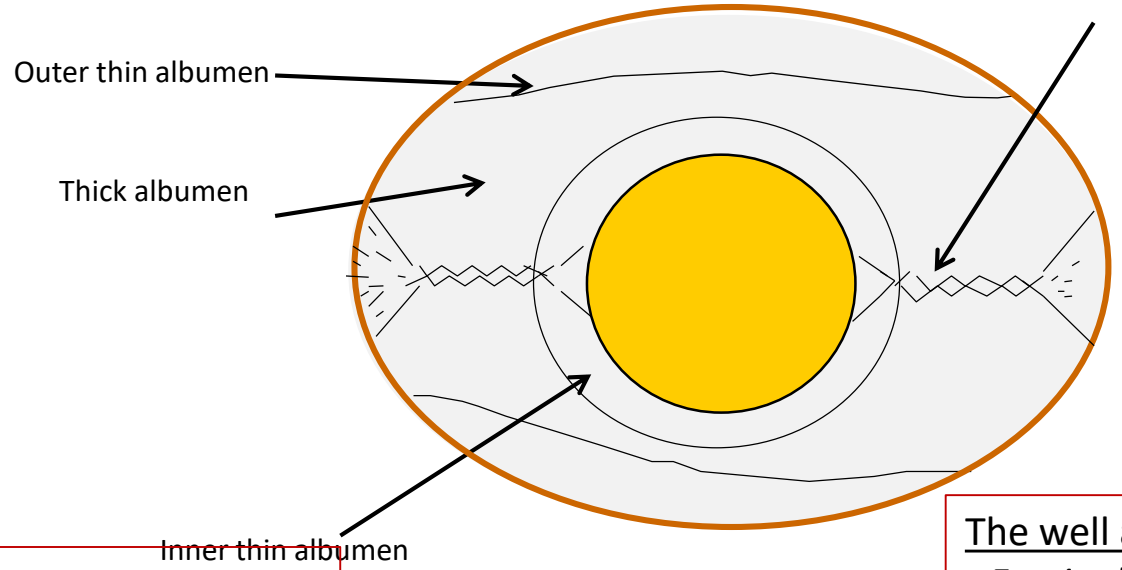
Chalazae to maintain the egg in suspension
Protection of the yolk from chocks



Mineral eggshell
- *Ensure the physical protecton*
- *Assure la protection thermique*
- *Assure les échanges gazeux*
- *Source de calcium pour l'embryon*

The well adpated compositrion of the yellow
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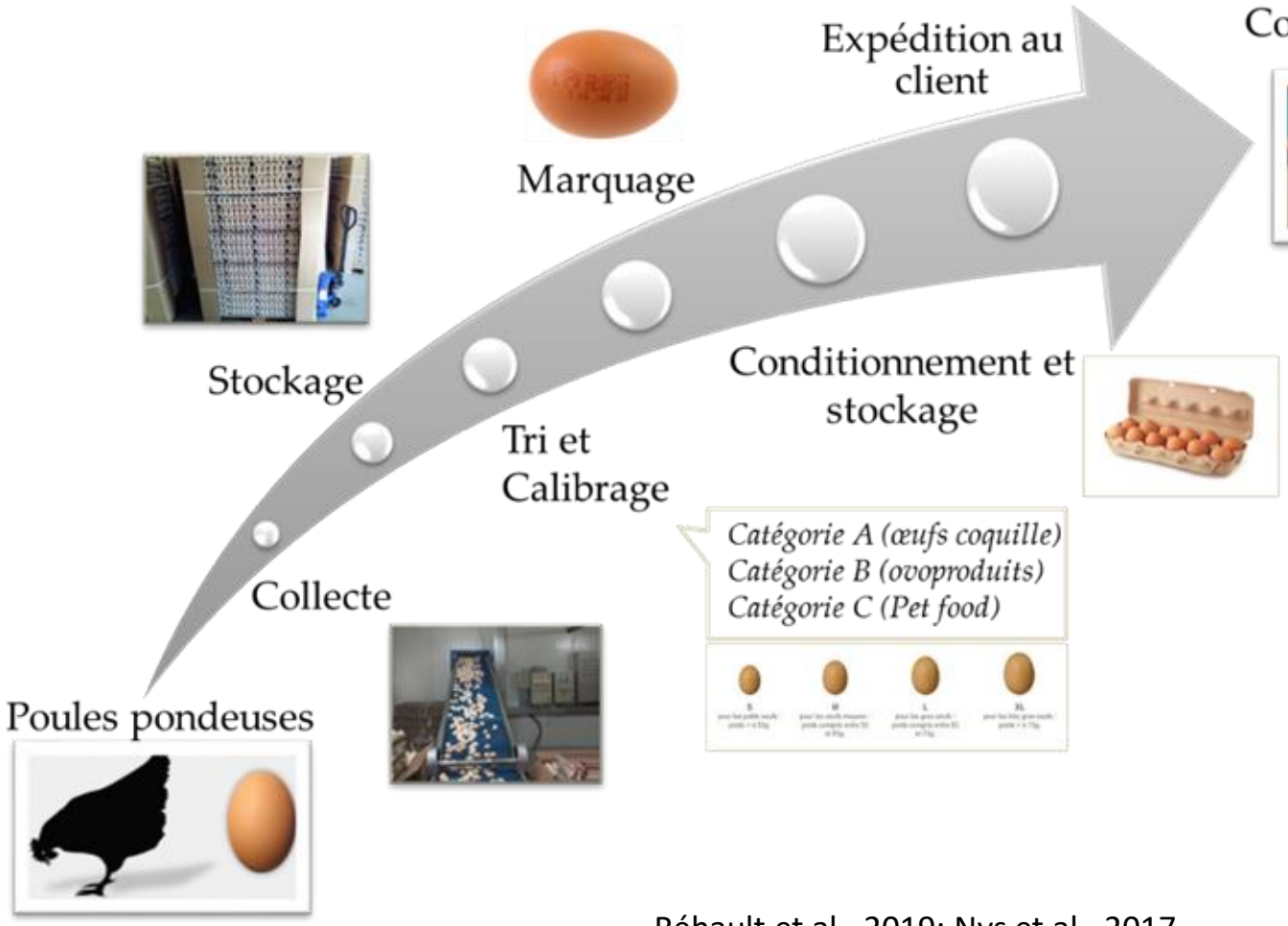
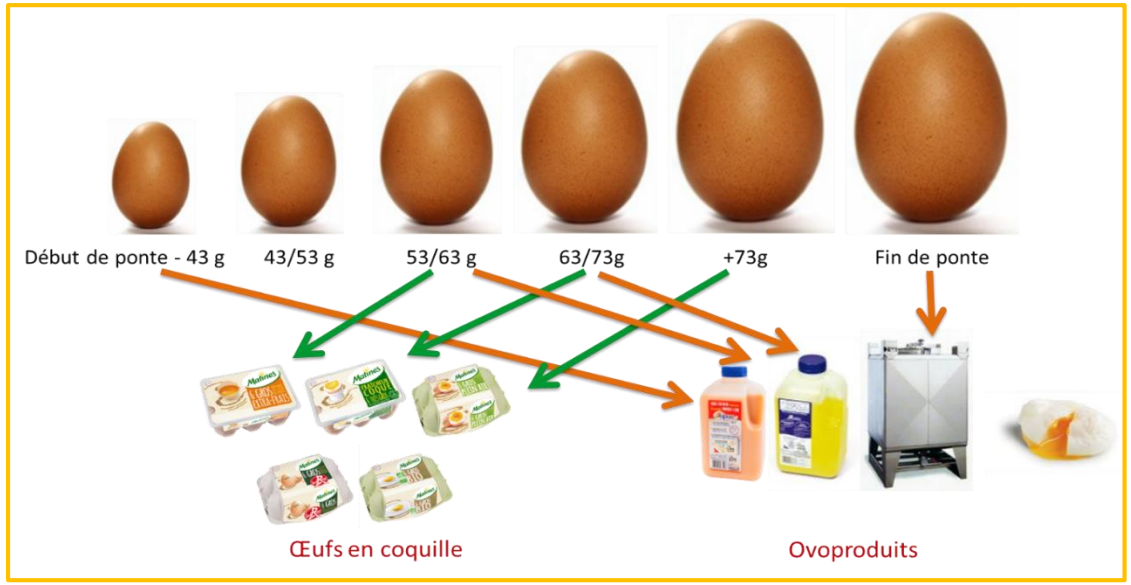
The egg as food product

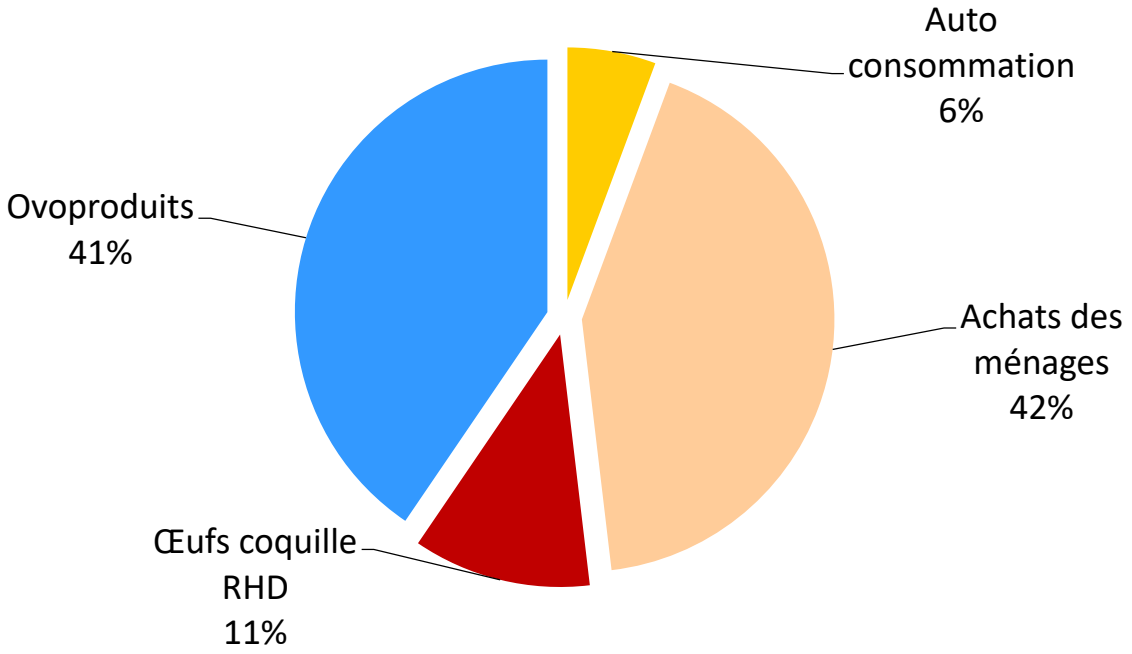
The egg's journey



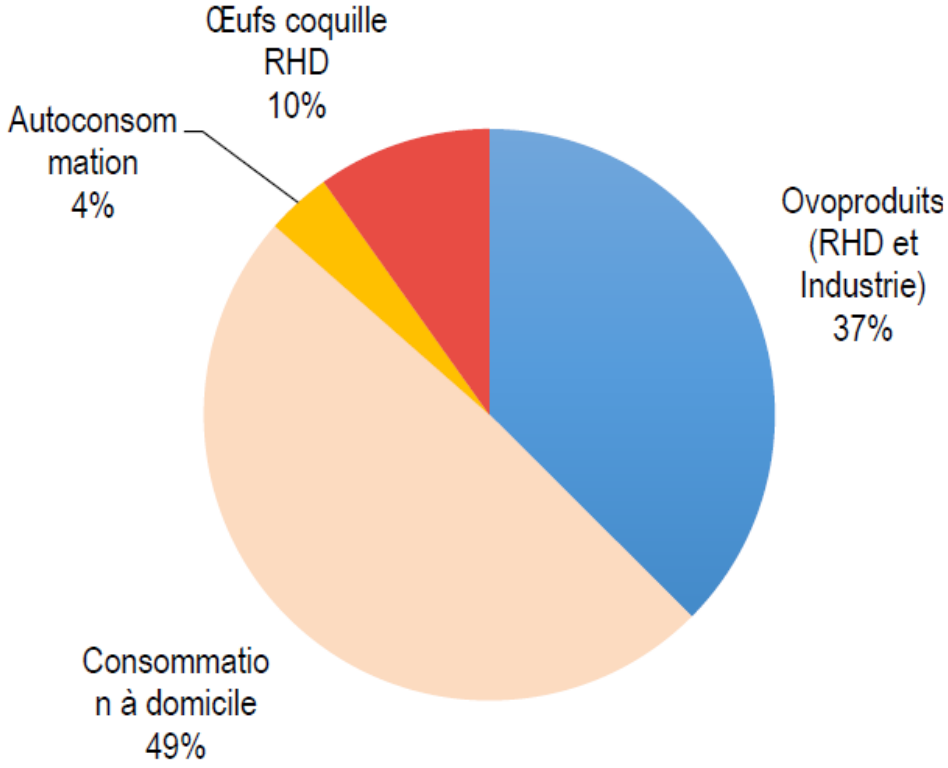
Réhault et al., 2019; Nys et al., 2017



Distribution of total French consumption



2013

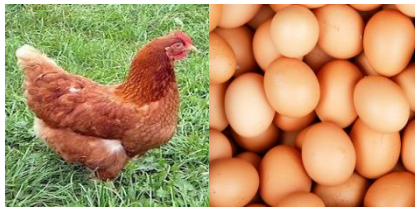


2017

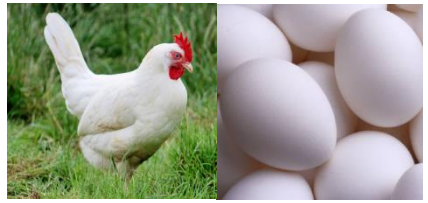
ITAVI d'après SSP, Kantar et Douanes

Shell and yolk colours

Shell colour is only dependent of genetic



Brown



Leghorn

Marans

Yolk colour depends of diet carotenoids

alfalfa

Corn

marigold

Paprika

No impact on flavours and taste (but important for consummers)

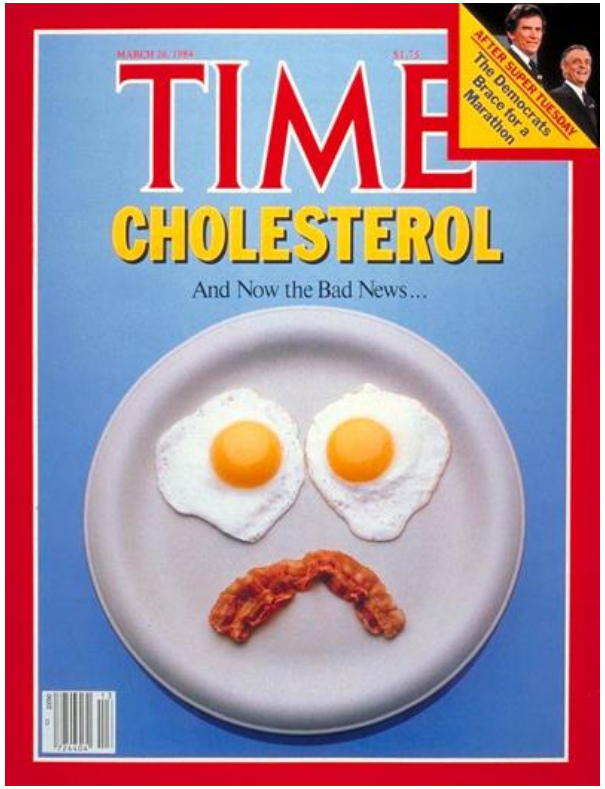
Egg as nutritional ingredient for humans

Nutritional characteristics for 2 eggs (100 g)

- **Calories : 155**
- **Total proteins: 12,3 g**
  High quality biological value (reference WHO 100/ Cow milk 86)
- **Total lipids: 11,9 g**
  - phospholipids rich: 31 % (soit 3,4 g)
  - majority of unsaturated fatty acids
  - cholesterol : 0,42 g (1,2 g / 100 g de jaune)
  - High digestibility value : 98% Triglycerids, 90% Phospholipids
- **Vitamins rich**:
  - A,D,E, B1, B6, B12, biotine (jaune), B2, folic acid, niacine (white)
- **Minerals**: phosphorus, iron and suffur

Egg as nutritional ingredient for humans

Egg and Cholesterol

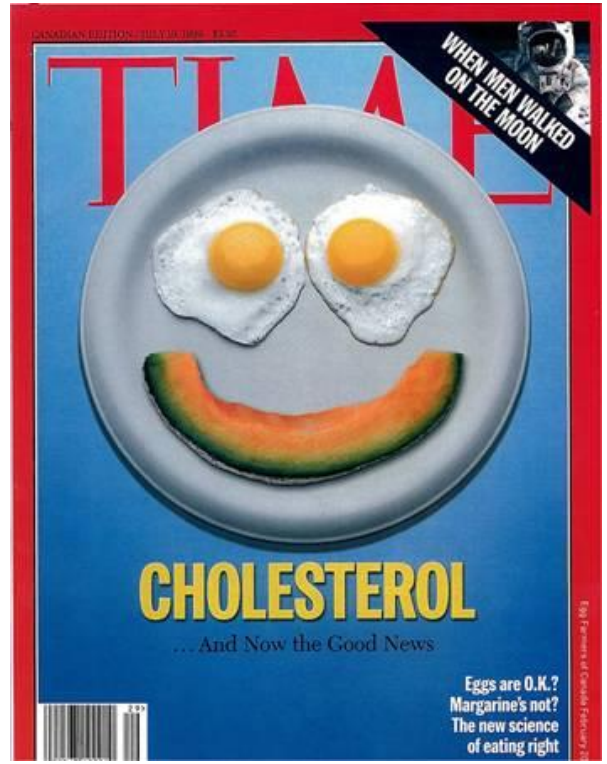


26 mars 1984

Can we eat eggs every day?

Yes, studies have shown that if cholesterol levels are normal, you can eat many eggs a day without affecting cholesterol levels.

If your cholesterol level is high, you should reduce your intake to 4 per week by cutting down on other sources of animal protein and fats.



19 juillet 1999

Egg as nutritional ingredient for humans

→ **Yellow to emulsify**

- An emulsion is an intimate mixture of two immiscible liquid substances
- The lecithin in the egg yolk is used as an emulsifier in the preparation of sauces in the kitchen.

→ **White is swelling**

- Beating the whites to snow means introducing air bubbles into a liquid mixture of water and protein to create a foam. This operation is called foaming.
- These properties vary during storage (gas exchanges between the inside and outside of the egg).

Egg as nutritional ingredient for humans

			
Biscuiterie/ pâtisserie/ viennoiserie	Colorant, liant, coagulant, moussant	Moussant, foisonnant, anti-cristallisant	Emulsifiant, colorant, Brillance (dorure)
Confiserie		Anti-cristallisant Foisonnant	Pouvoir aromatique
Glaces	Liant		Emulsifiant
Charcuterie (quenelle)	Liant, émulsifiant		
Pâtes alimentaire	Colorant, liant, pouvoir aromatique		
Mayonnaise/sauces chaudes		Agent de texture	Emulsifiant, agent de texture

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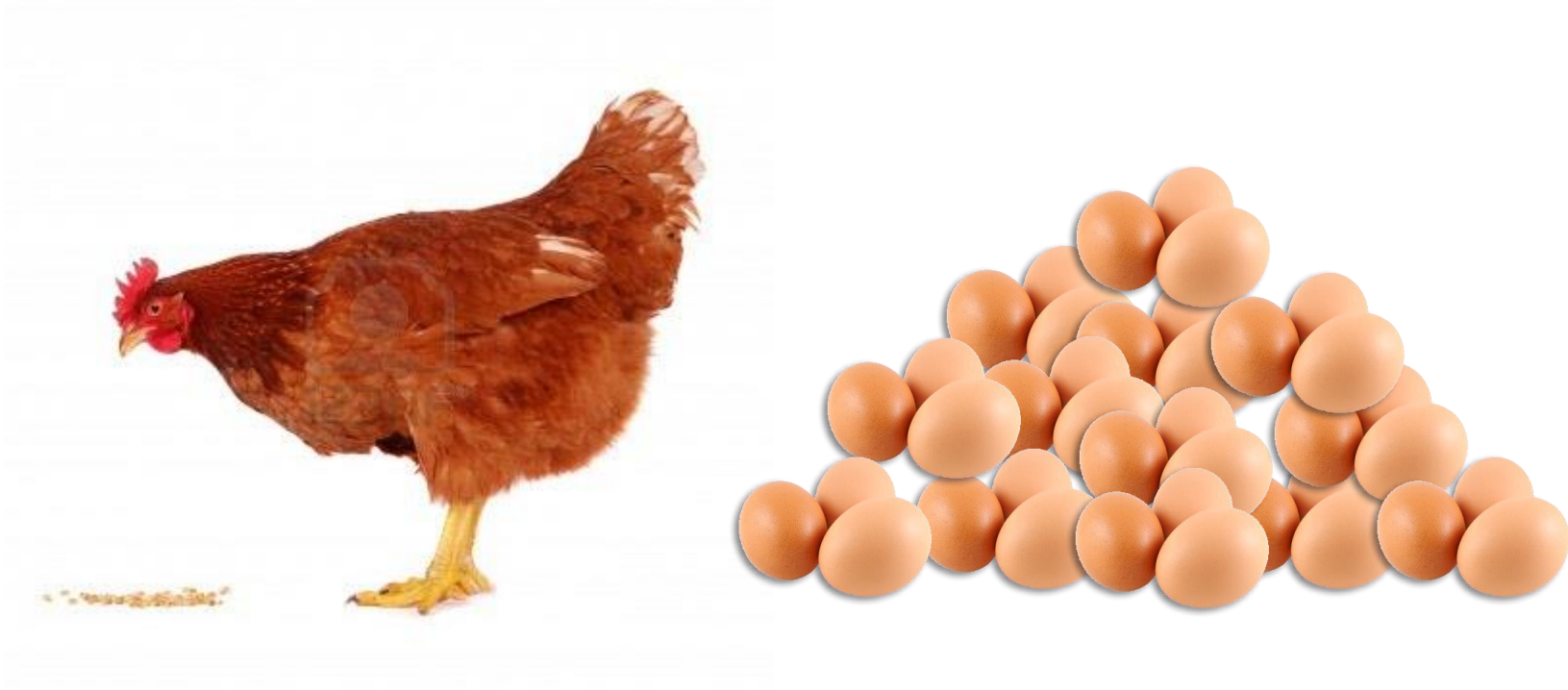
Egg production

Chicken eggs, products for human nutrition

Chickens cross selected for egg production



More than 300 eggs produced in one year of production, i.e. ten times the weight of the hen.

Transformation of plant matter into animal products = an enormous metabolic challenge!

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Hystory of egg production

- Before the war: Domesticated chickens => mostly self-consumption
- After the war: need to meet the demand (in quantity) and to control the sanitary conditions (in quality: zero risk) => confinement and breeding in cages.
- 80 90s => "productive egg".

Eggs and chicken strains

Table eggs

A basic ingredient for human consumption

Hatching eggs

Close and self sufficient chamber to allow the development of the chicken
(Bredders for layers and meat production)

Layer strains

(more than 300 eggs per year)
Non marketable for meat

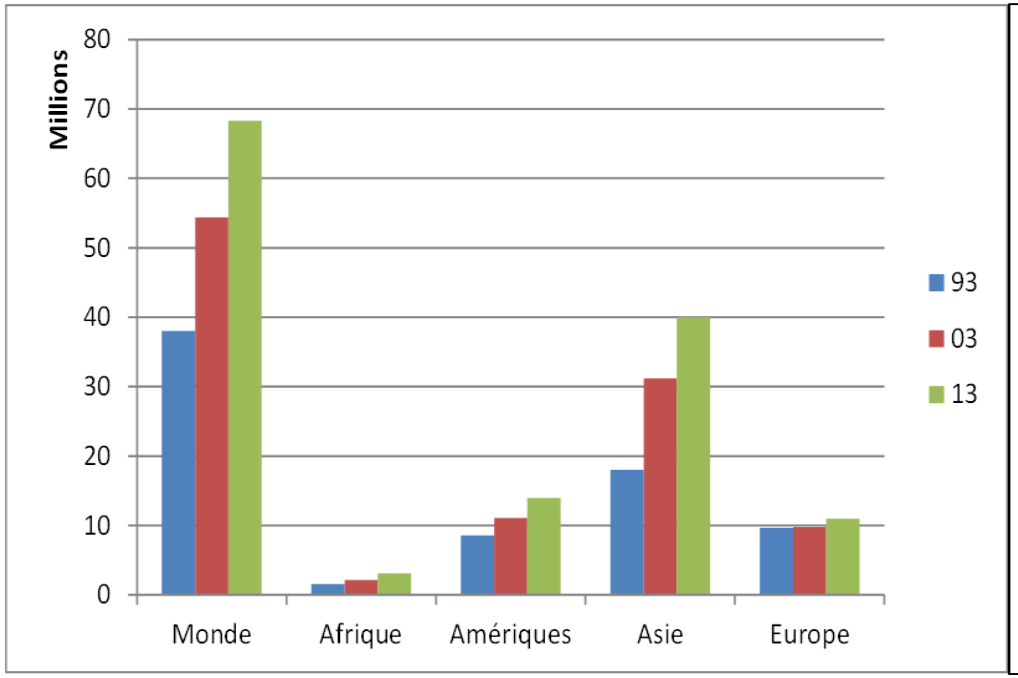
Meat strains

(150 eggs per years)
Non marketable for eggs

Eggs and chicken strains

Table eggs

A basic ingredient for human consumption



Production Monde 2013

- + 2% /an de 2003-13 (+ 4% /an de 93-03)

1. Chine 24.7MT
2. UE-28 6.2 MT
3. USA 5.6 MT
4. Inde 3.8 MT
5. Japon 2.5 MT
6. Mexique 2.2 MT

Echanges mondiaux

- environ 2.4 M teoc en 2011

(4% de la production mondiale)

- En valeur (2013)

1. USA 314 M€
2. UE (vers Pays-Tiers) 248 M€
3. Chine 135 M€

Itavi d'après FAO, Commission et FranceAgriMer

Hystory of egg production

- Before the war: Domesticated chickens => mostly self-consumption
- After the war: need to meet the demand (in quantity) and to control the sanitary conditions (in quality: zero risk) => confinement and breeding in cages.
- 80 90s => "productive egg".
- Since the end of the 90s: new consumer demands: strong awareness of citizens on agricultural production systems in general and animal production in particular, including poultry and eggs diversification of farming methods
- The current European production models are the result of this social demand Welfare Directive for laying hens (1999/74/EC).
- This regulation is also the result of scientific research to satisfy the 5 freedoms of animal welfare: no hunger, no thirst, free of movement, no fear/distress, while allowing the expression of natural behaviour.

Eggs and layers

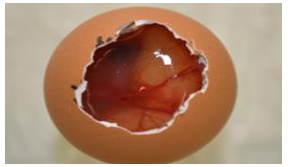
Health, economic and ethical issues

Table eggs

14,7 billions eggs per year in France

A basic ingredient for human consumption

- ✓ Risks of toxi-infections for the consumer (Salmonellosis)
- ✓ Economic losses (about 8%): downgraded eggs linked to degraded egg qualities (dirty, cracked or broken shells, poor internal qualities leading to problems of white/yolk separation)



Hatchery eggs

1,1 billion eggs per year in France

Close and self sufficient chamber to allow the development of the chicken

- ✓ 10% clear eggs (absence of fertilization, embryonic mortality)
- ✓ Elimination of male chicks from the laying strain (early in ovo sexing)

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Egg production system in Europe

Welfare Directive for laying hens (1999/74/EC)

Rules for rearing of hens

Enriched cages **Alternative systems**

- **The animals must be inspected at least once a day.**
- **The presence of perches is mandatory. If no minimum height is specified, hens must be able to put their fingers underneath.**
- **The presence of a nest is required. The nest is a separate space whose floor is not made of wire mesh. This nest can be provided for one or more hens.**
- **The nest is not considered a usable surface.**
- **The light program must follow a 24-hour rhythm. An uninterrupted period of darkness of an indicative duration of approximately 8 hours must be practiced in order to allow the animals to rest and to avoid eye problems. Light intensity must be sufficient to allow the animals to see and be seen, especially by the breeder during daily inspection.**

Egg production system in Europe

Welfare Directive for laying hens (1999/74/EC)

Rules for rearing of hens

Enriched cages

Alternative systems

Barn or aviary systems
Indoor or Outdoor

Code 3: Cage fitted with new standards
Code 2: Raised on the ground or in an aviary without outside access
Code 1: Aviary or ground + outdoor access
Code 0: Aviary or ground + outdoor access + Organic production

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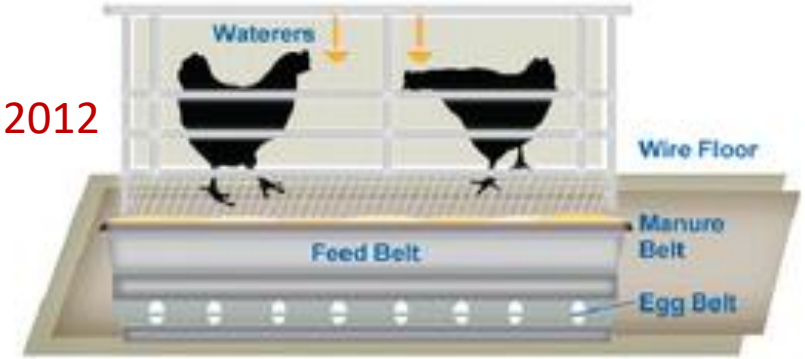
Code 3: Enriched cages

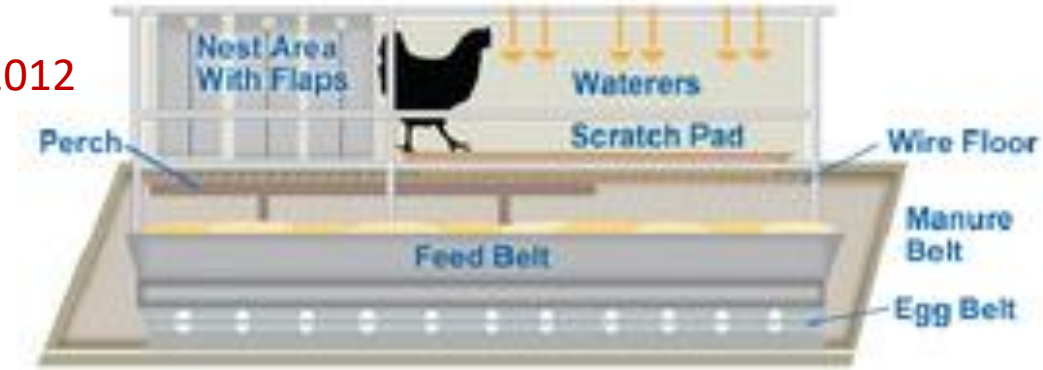
All European production of code 3 eggs has been in cages since 2012: laying hen welfare directive (1999/74/EC).

- **Cages with an area of at least 2000cm².**
- **Height of the cage increased**
- **Installation of perches (15cm /chicken)**
- **Installation of separate nests**
- **Scraping and pecking area**
- **12 cm feeder/hen**
- **100,000 hens in two buildings**

before 2012



since 2012



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Code 3: Enriched cages

Diet: 100% vegetable, minerals and vitamins

Cereals (such as wheat, corn...), protein crops (soybeans, field peas, lupin), vegetable oils, vitamins, food supplements (amino acids or synthetic coloring), source of calcium (3.5% instead of 1% in broilers)

Code 2: Barn or aviary without outdoor access

- 30,000 hens in a building
- Maximum density in the building 9 hens per m2
- Food 100% vegetable, minerals and vitamins (idem code 1)

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Code 1: Aviary or ground + outdoor access

30,000 hens max. per farm.

Maximum density in the building 9 hens per m2

With access to an outdoor course (4m2 per hen, 12 ha of course for 30 000 hens)

Food (100% vegetable, minerals and vitamins)

Code 1: Label Rouge specificities

Label Rouge specifications:

- Two buildings of 6000 hens maximum
- Access to an outdoor course (5m2 per hen, 6 ha for 12 000 hens)
- Food (100% vegetable, minerals and vitamins, 50% minimum of cereals, no additives)

Code 0: Organic eggs

Maximum 12 000 hens, buildings of 3000 hens maximum

Maximum density in the building 6 hens per m2

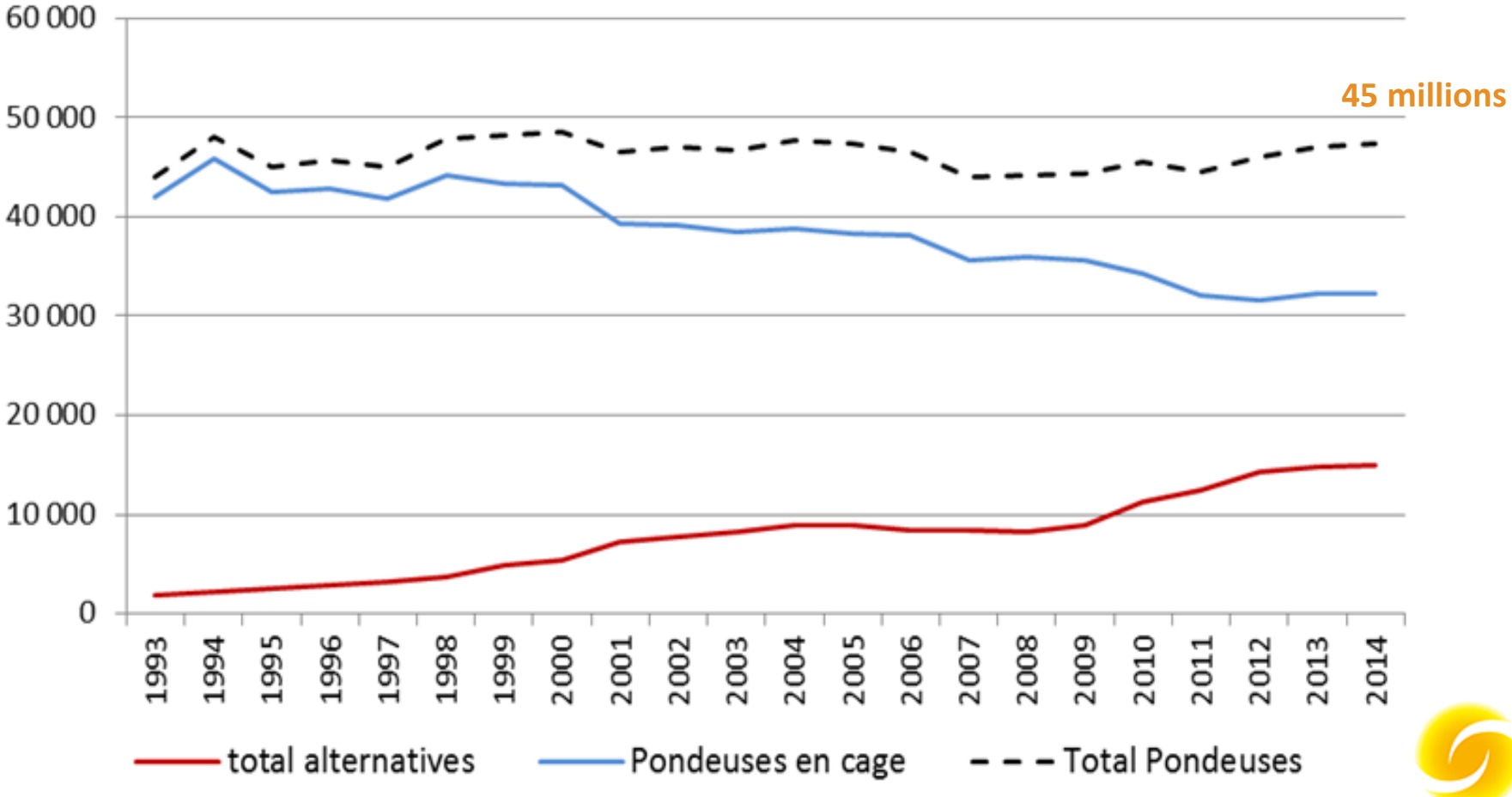
Access to an outside run (4 m2 per hen, max 4,8 ha)

Food: 100% vegetable, minerals and vitamins, <u>without synthetic additives 95% minimum of raw materials from AB</u>

Mainly prevention, stimulation of natural defenses. Lists of authorized veterinary drugs if needed

Evolution of egg production system in France

Number of hens in France (Thousands)



45 millions

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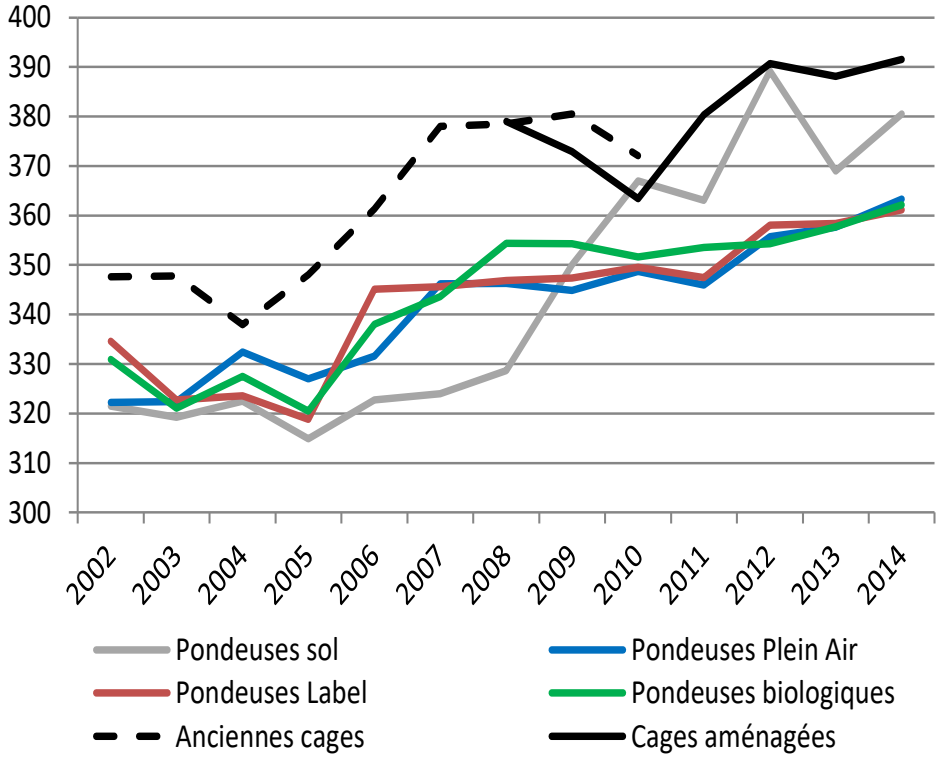
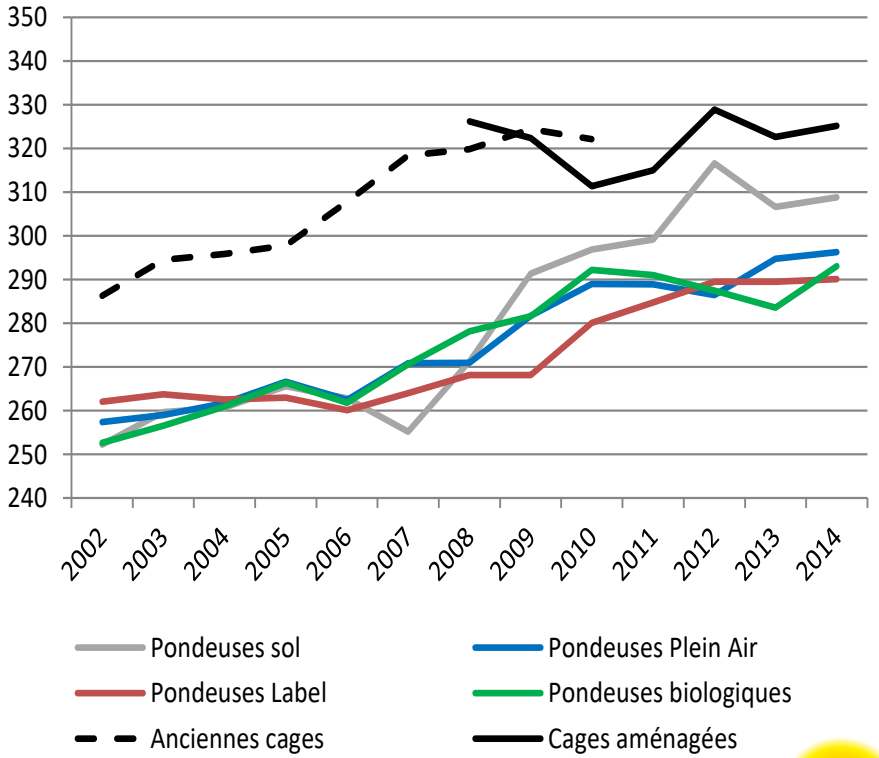
Characteristics of various systems

Durées de ponte (j)



Nbre œufs pondus/poule



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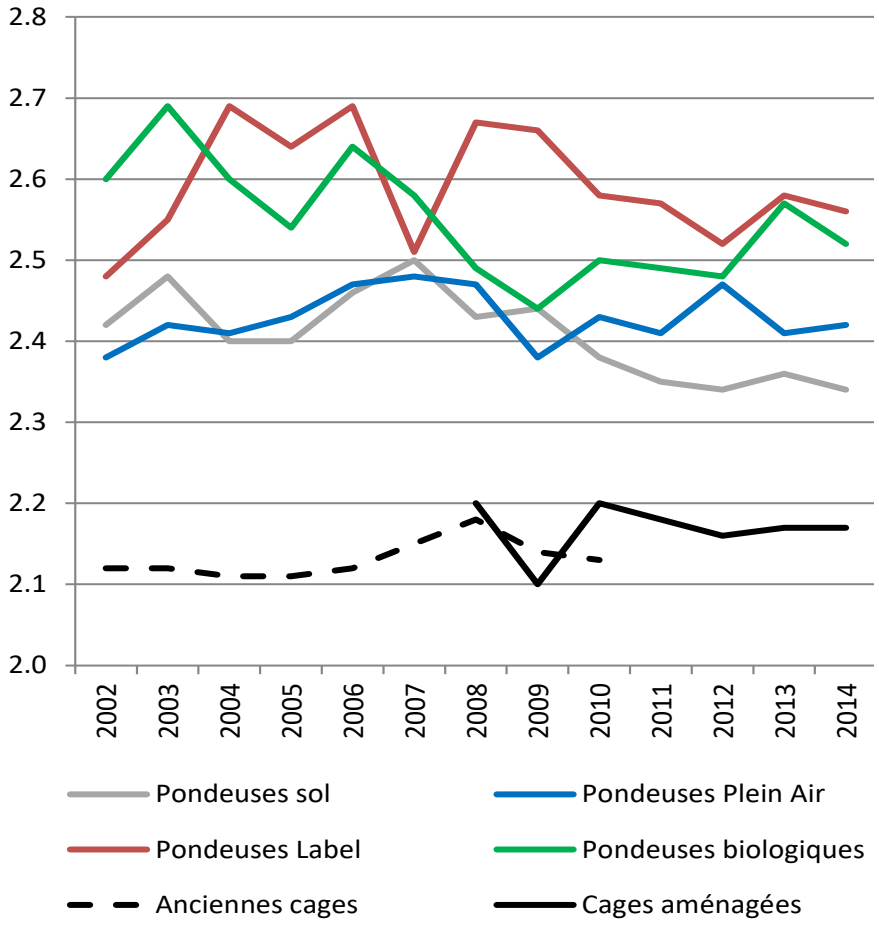
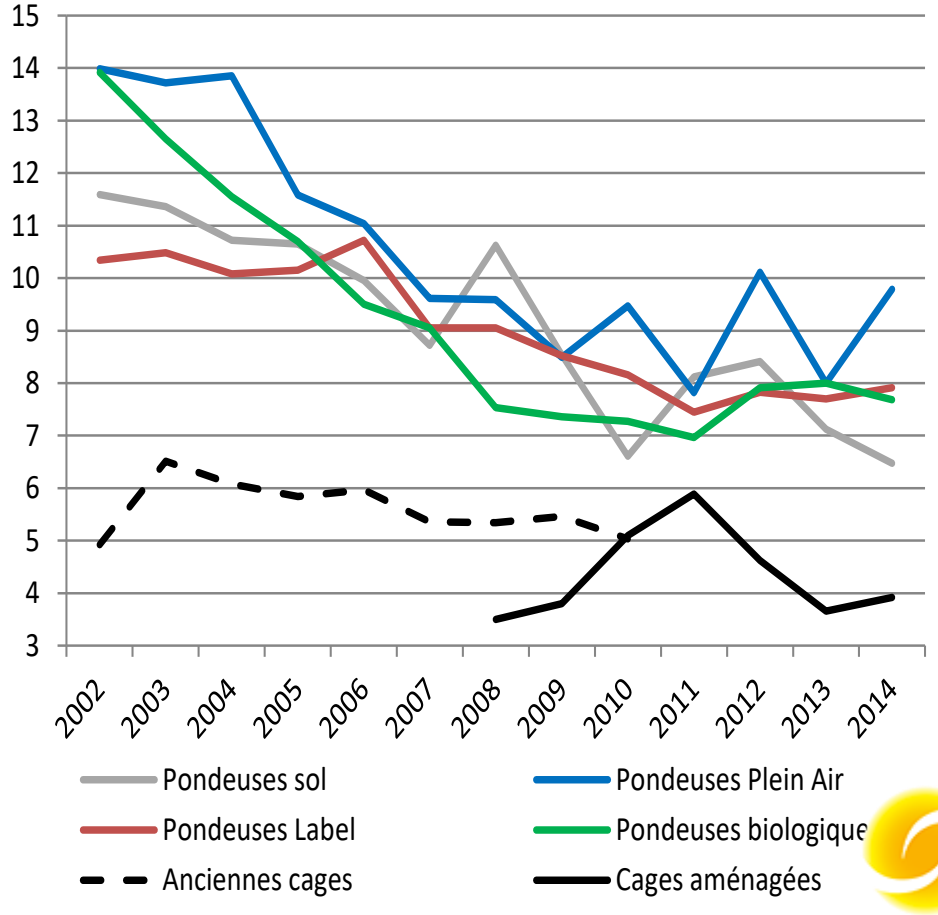
Characteristics of various systems

IC



Taux mortalité %



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Characteristics of various systems

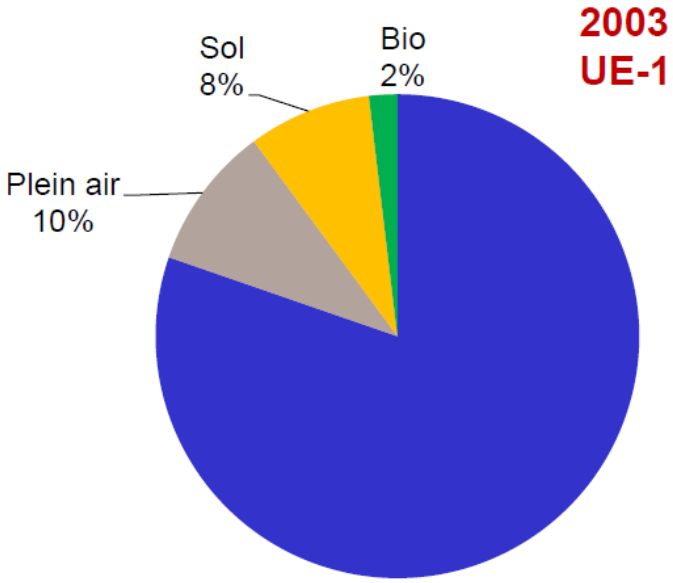
	Cage	Volière ou sol sans parcours	Volière ou sol + parcours	Label Rouge	Bio
Accès au parcours	NON	NON	OUI	OUI 5m²/poule	OUI 4 m²/poule
Densité en bâtiment (nb poules / m2 accessible aux poules)	13,3 (6 étages)	9,0 (2 étages)	9,0 (2 étages)	9,0	6,0
Mortalité (%)	3-4%	6-8%	6-8%	6-8%	8-10%
Taux de poussière dans le bâtiment (santé de l'éleveur et de la poule)	Faible	Fort	Fort	Moyen	Moyen
Utilisation vaccins et produits vétos	Similaire (que lorsque l'animal est malade)				
Impact environnemental (Bilan carbone)	Faible (IC=2.2)	Moyen (IC=2.4)	Moyen (IC=2.4)	Moyen (IC=2.6)	Moyen (IC=2.6)
Impact environnemental Utilisation de terres	Faible	Moyen	Moyen	Moyen	Fort

Characteristics of various systems

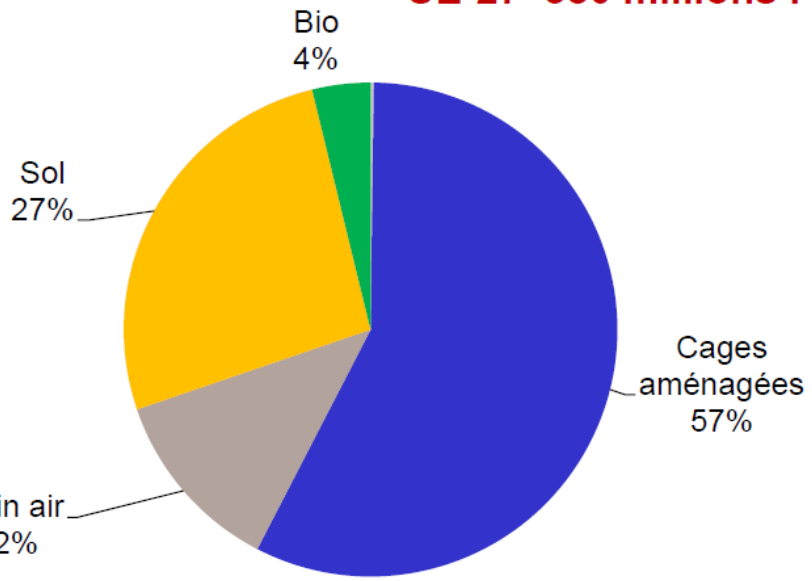
	Cage	Volière ou sol sans parcours	Volière ou sol + parcours	Label Rouge	Bio
Qualité organoleptique (goût) et nutritionnelle	Pas de différence				
Qualité sanitaire (salmonelle)	Pas de différence				
Coût de production sortie élevage (€ les 100 oeufs)	6,41	7.35	7,82	8,65	13,64
Cout de production base 100	100	115	122	135	213
Prix de vente consommateur (€ les 6) *Kantar 2014*	0,89	0,94	1,36	1,87	1,96
Prix de vente consommateur base 100	100	106	153	210	220

Evolution of egg production systems in UE

Evolution des systèmes de production dans l'UE

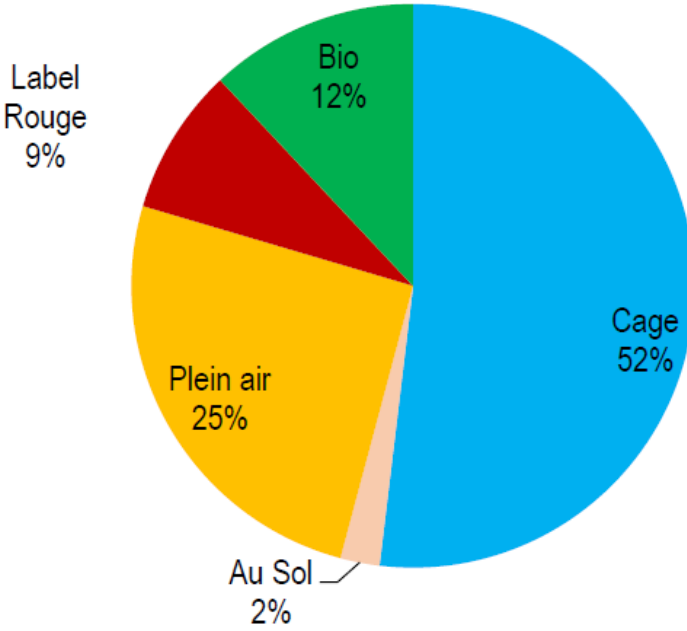


2003
UE-15 244 millions PP



2013
UE-27 380 millions PP

France 2017



Source Commission européenne


20
HEURES
2

Discussion

What is your favorite eggs and why ?

And Now ?
Egg in the next decade ?

The specialized chicken lines

Layer hens

(340 eggs per year)
Meat is not marketable

ZW female chicken

ZZ male chicken

Broiler Production

(<150 eggs per year)
Non marketable low quality eggs

6 billions of males are killed every year in the world

↓

Ethical and societal concern

Alternatives ?

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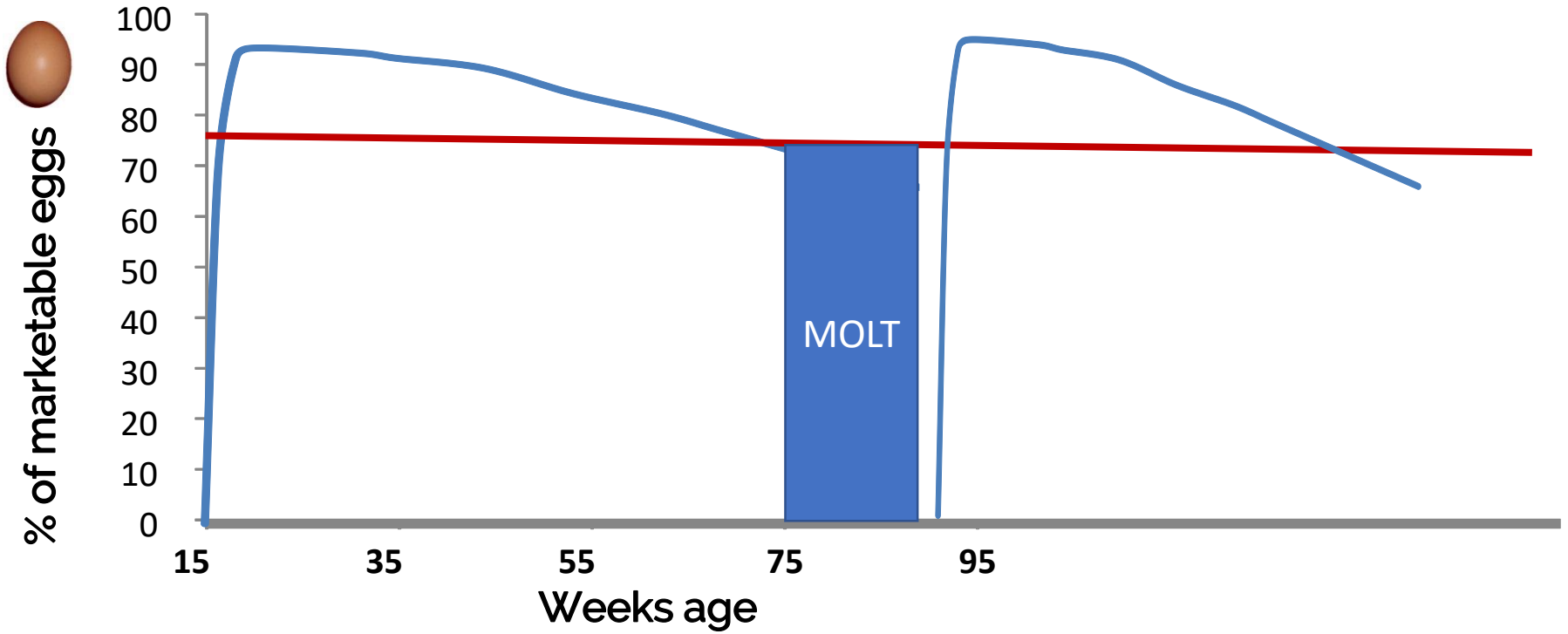
Reduce the number of layers

✓ Use of molt cycles



75 % of marketable eggs is the beneficial limit

Second and third laying cycles are possible after molting of the layer

→ Need to induce artificial molt with water and feeding privation not allowed in EU

Research is needed to induce moulting while respecting animal welfare

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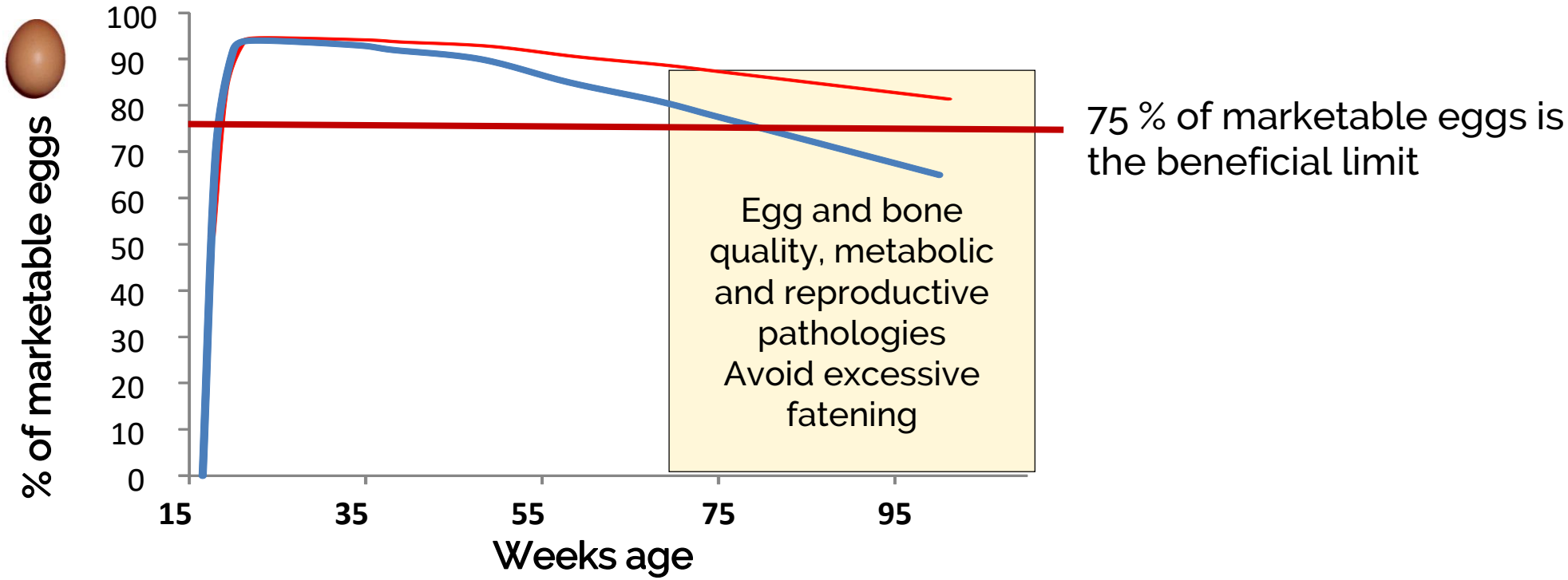
Increasing persistency of laying hens



Second and third laying cycles are possible after molting of the layer

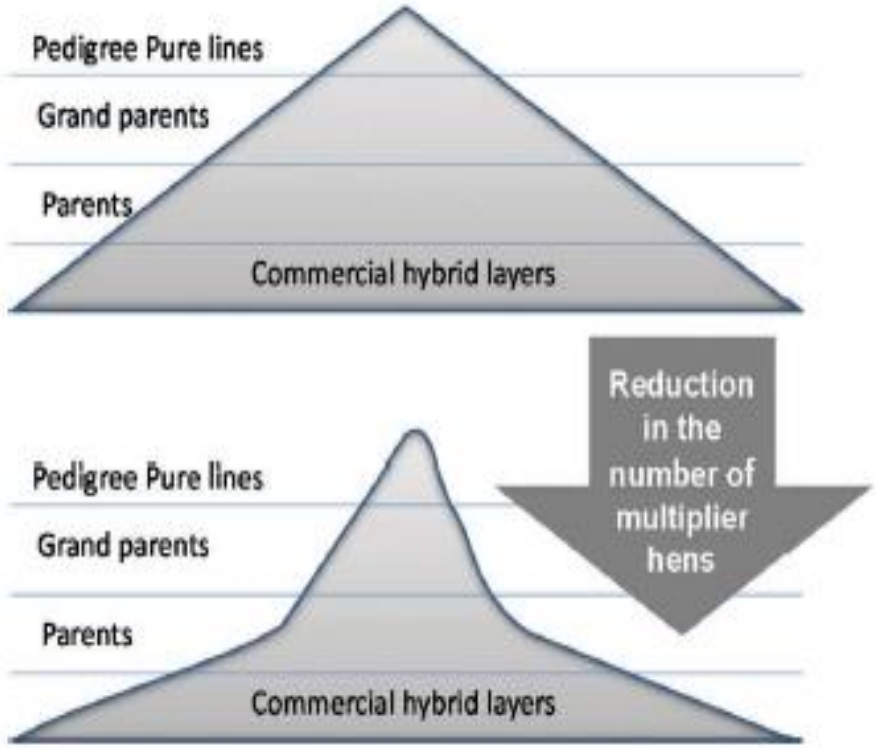
→ Need to induce artificial molt with water and feeding privation not allowed in EU

Increasing persistency of laying hens

Breeding companies claim that they will have developed the « long life » layer, which will be capable of producing 500 eggs in a production cycle lasting 100 weeks by 2020 (Van Sambeek, 2010)

Bain et al., 2016 estimated « than even 25 more eggs per hen could potentially reduce the UK flock, including breeding hens by 2,5 millions birds per annum. »

limited by the health charter in France…



Dual purpose chickens

Layers strain

(340 eggs per year)
Meat is not marketable

Broiler strains

(<150 eggs per year)
Non marketable low quality eggs

Crossbreed

Females are reared for egg production

↓

Low number of eggs
Quality ?

Unfavorable environmental impact

Males are reared for meat production

↓

Low meat yield
Different meat texture (consumer education)

Need to evaluate the productivity, the quality, the behaviour of animals in various housing systems and various environmental conditions, health and costs

IN OVO SEXING

Gender determination before the birth

- ✓ Must be fast (20 000 to 30 000 eggs per hour)
- ✓ Must be cheap
- ✓ Must be precise (98.5 %)
- ✓ Without detrimental consequences on the hatchability and the viability of the chicken
- ✓ Must be done before 9 days of embryonic development to avoid any nociception

→ A frantic race between states, scientists and industry to offer alternative solutions and hit the jackpot.

How to determine sex in ovo

- Destructives and non destructive methods

- Biological approaches
  - Hormonal detection
  - Metabolite marker detection

- Physicochemistry approaches
  - Dimorphic volatile odors between male and females

- Physical and optical approaches
  - FTIR spectroscopy
  - Raman spectroscopy
  - Magnetic resonance imaging
  - Hyperspectral analysis

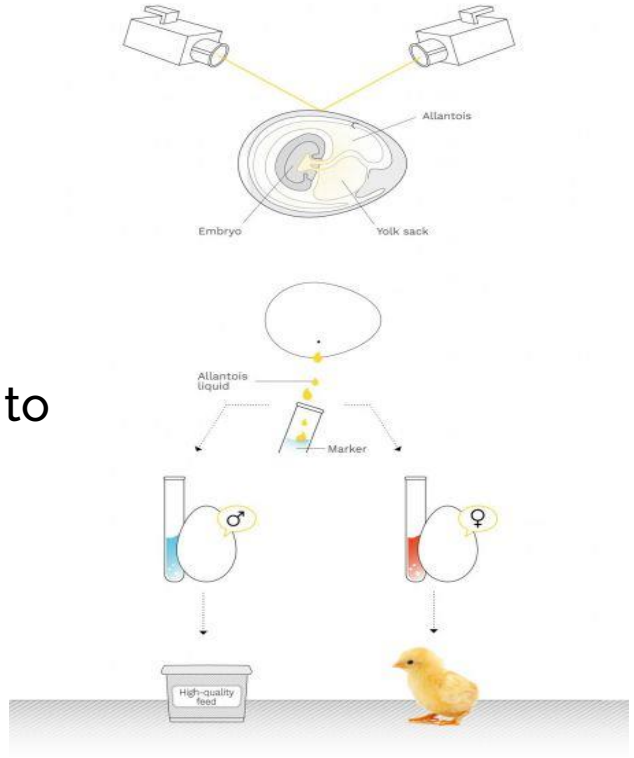
- Genetic engineering
  - Genome editing

In ovo sex determination

Hormonal testing

SELEGGT – Hormonal testing (http://www.seleggt.com/) (Allemagne)

- ✓ Test performed at 9 days of incubation
- ✓ Small hole 12 mm in the shell
- ✓ Samples used a patented test to measure the level of Estrone sulfate only present in females



- ✓ Accuracy 97-98%
- ✓ Prototype développed
- ✓ Almost 100 000 eggs already hatched
- ✓ Price 1-3 cents per egg, 7 Euros per pullet
- ✓ Low throughput of approximately 5,000 eggs

The only available commercial solution, but not enough fast for the entire egg market

In ovo sex determination

Hormonal testing

EMBREX – Hormonal testing (USA)

- ✓ Test performed at 17 days of incubation
- ✓ Samples used a patented test to measure the level of Estradiol 17B
- ✓ Accuracy 100% ?
- ✓ Prototype not developed
- ✓ Price unknown

Metabolite markers

In ovo – Biomarker detection (https://inovo.nl/solutions/in-ovo-egg-sexing/) (Netherlands)

- ✓ Use of H NRM spectroscopy
- ✓ Fast 2 sec/egg
- ✓ marketing planned in 2020

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In ovo sex determination

Physicochemical methods

Vital farms & Novotrans – odor detection (USA)

- ✓ Test performed at ?? days of incubation
- ✓ Vaccuum system to trap the odors
- ✓ Patented in USA 2019, June

- ✓ Accuracy ????
- ✓ Prototype ???
- ✓ Price ???
- ✓ throughput ???

Genetic engineering

EggXYt – Genetic alteration (https://www.eggxyt.com/) (Israël)

- ✓ Genome editing
- ✓ Feasable the day of lay
- ✓ Fluorescent detection through the shell

- ✓ Transgenic chickens
- ✓ Consumer acceptance ?
- ✓ Accuracy 100 %
- ✓ Price ???

In ovo sex determination

Physical methods

Spectroscopy – Analysis of fluorescence signals (tu-dresden.de) (Allemagne)

- ✓ Test performed at 3 days of incubation
- ✓ DNA quantity is different from male to female (2%)
- ✓ Blood vessels are illuminated and fluorescence is measured at 910 nm
- ✓ Accuracy 90 %
- ✓ No impact on hatchability
- ✓ Prototype ?

Hypereye – Hyperspectral imaging (Canada)

- ✓ Test performed at the day of lay
- ✓ Hyperspectral method
- ✓ Specific signature using mathematical algorithms
- ✓ Prototype was announced for 2018
- ✓ Throughput of 50 000 eggs per hours
- ✓ 1 to 5 canadian dollars cents per egg

In ovo sex determination

Physical methods

Spectroscopy – hyperspectral imaging- Evonta technology Dresden (Allemagne)

- ✓ Test performed at 14 days of incubation
- ✓ Difference in feather color
- ✓ Use of strain with different feathers depending on sex

- ✓ Accuracy 97 %
- ✓ Prototype ?
- ✓ Late determination 14 days
- ✓ Needs strains with feather differences

SOO –non invasive physical methods (France)

- ✓ Two complementary technics to predict the sex embryo. Raman hyperspectral and biocaptors

- ✓ Accuracy ??
- ✓ Prototype ?

How to determine sex in ovo

Project	Country	Method	Day of egg incubation	Accuracy %	Price Cents/egg	Number of egg / H	Marketing	Remarks
SELEGGT	Germany	Hormonal	9	97-98	1-3	5000	Yes	The only available commercial solution, but not enough fast for the entire egg market
EMBREX	USA	Hormonal	17	100 ?	???	???	No	No prototype, 17 days is too late
In ovo	Netherlands	Metabolite	9	??	???	???	Planned in 2020	2 Sec/egg
Vital farms	USA	Odor detection	???	???	???	???	???	
EggXYt	ISRAEL	Genome editing	0	100	???	A lot	Yes	Transgenic chickens, consumer acceptance
Dresden	Germany	Raman	3,5	90	???	???	Prototype	Accuracy to improve
Hypereye	Canada	Hyperspectral	0	99	1-5	30 000 50 000	????	Large number of eggs, No news since 2018
Evonta	Germany	Hyperspectral Feather color	14	97	???	???	???	Late determination, Needs strains with feather differences
SOO	France	Raman Biocaptors	???	???	???	???	???	
PPILLOW	France	Electromagnetic signature	???	???	???	???	No	

Many of them are still in development

Research and development must be continued (New methods, Big data, deep learning, artificial intelligence)

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Alternatives? Take-home messages

Few alternatives to the culling of male day-old chicks of layer lines:

- **Increasing of laying period and use of molt cycles to reduce the number of births chickens for renewal**
- **Developing dual purpose chickens, but not for a mass market**
- **Strengthening the development of *in ovo* sexing processes**

BUT

- **Today whathever method used, no fast and robust method is operational**
- **A race against time: There is an increased need for research and development before considering the industrial scale**
- **This change will be really challenging for producers with many technical and economical adaptations**

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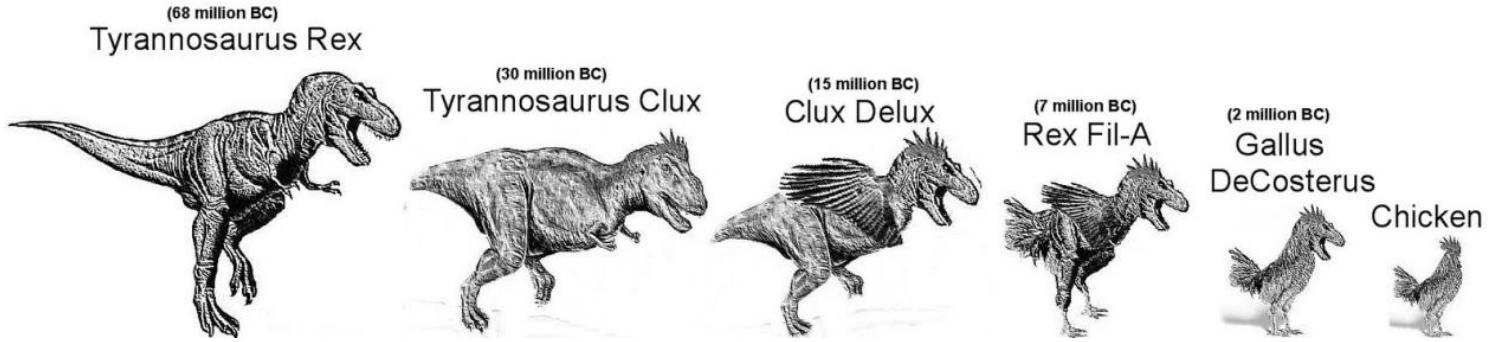
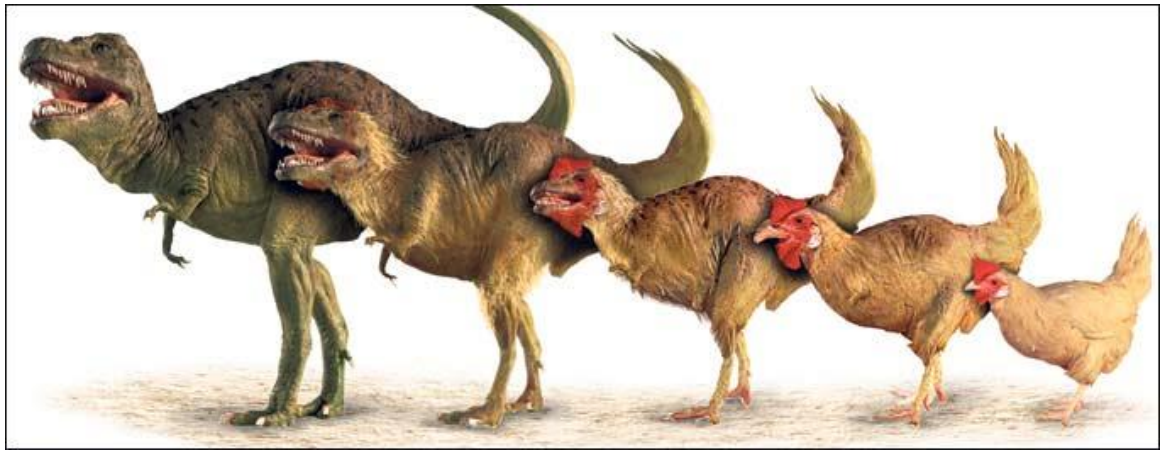
To conclude

The Chicken or the egg ?

This is the question that is poorly formulated

Birds are descendants of dinosaurs





The chicken or dinosaurs ?