Farming systems and egg production: The chicken or the egg dilemma

Joël Gautron

Farming systems and egg production

The chicken or the egg ?

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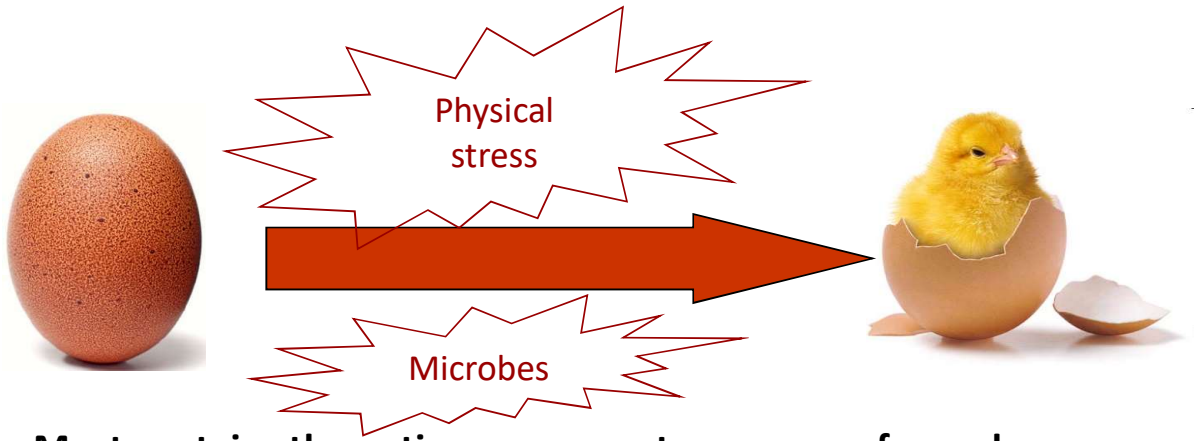
The chicken egg

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

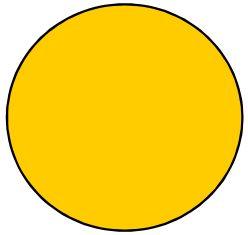


Must contains the entire components necessary for embryo

- 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

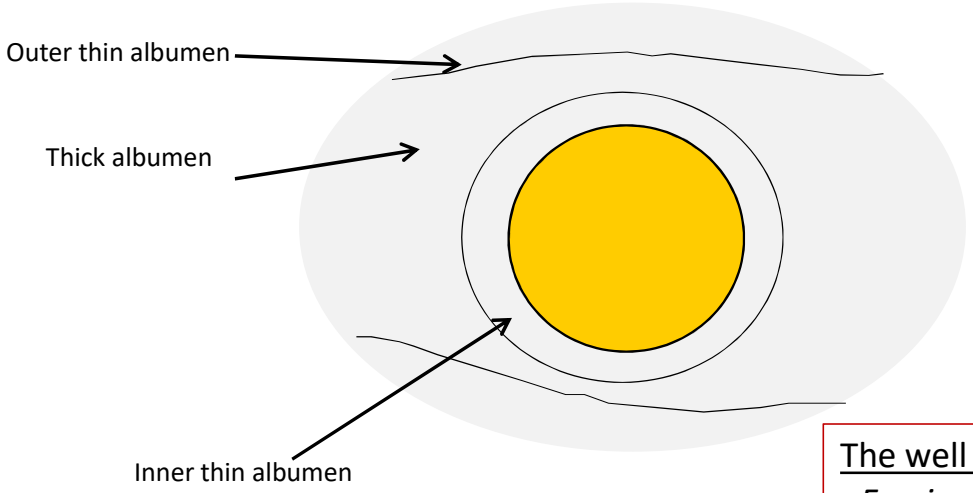


The well adpated composition of the yellow
- *Feminal gamete*
(Clear disk of 3.5 mm)
- *Nutritional reserves (lipids, proteins) and defenses (antibodies)*
- *Surrounded by a thin and translucent membrane*

The egg composition is well adapted for embryo development

The egg white, water rich (88%), proteins and glucides

- *Various textures of white*
- *Antimicrobial molecules*



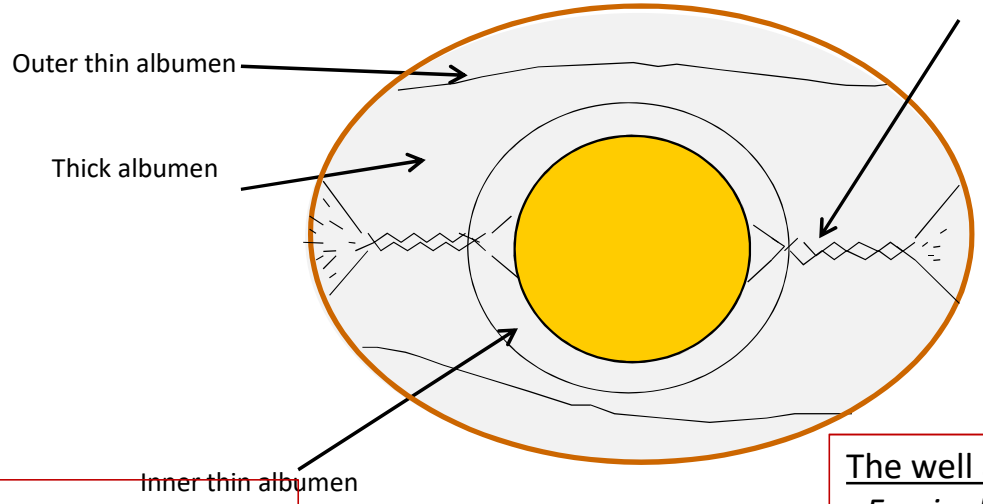
The well adpated compositrion of the yellow

- 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*

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

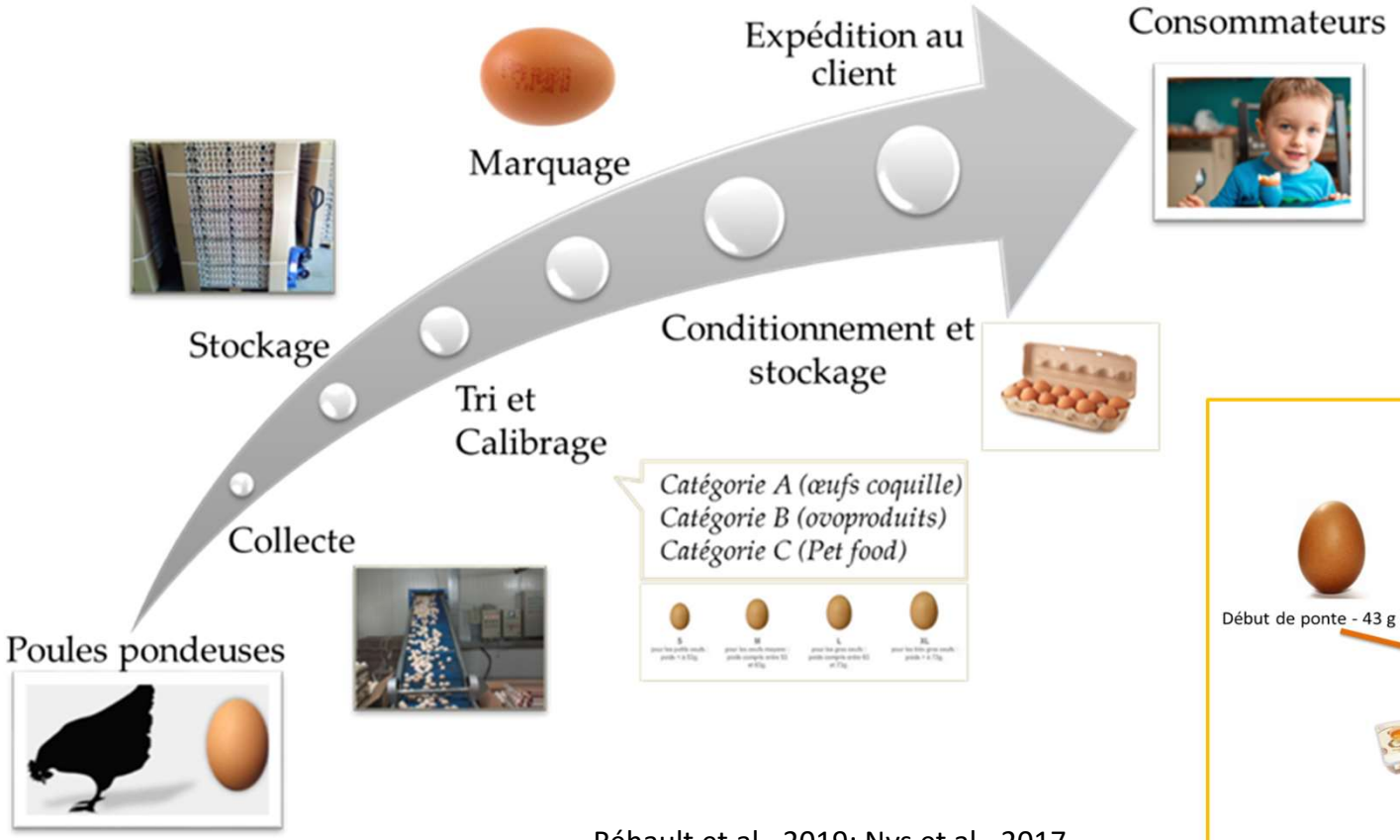


Mineral eggshell
- *Ensure the physical protecton*
- *Ensure a thermic protection*
- *Allow gaz exchanges*
- *Calcium source for embryo*

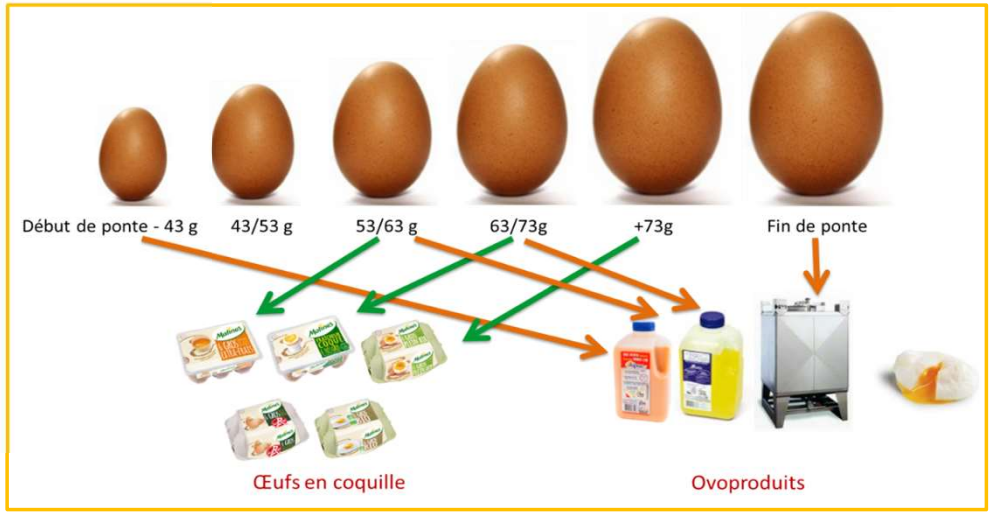
The well adpated compositrion of the yellow
- *Feminal gamete (Clear disk of 3.5 mm)*
- *Nutritional reserves (lipids, proteins) and defenses (antibodies)*
- *Surrounded by a thin and translucent membrane*

The egg as food product

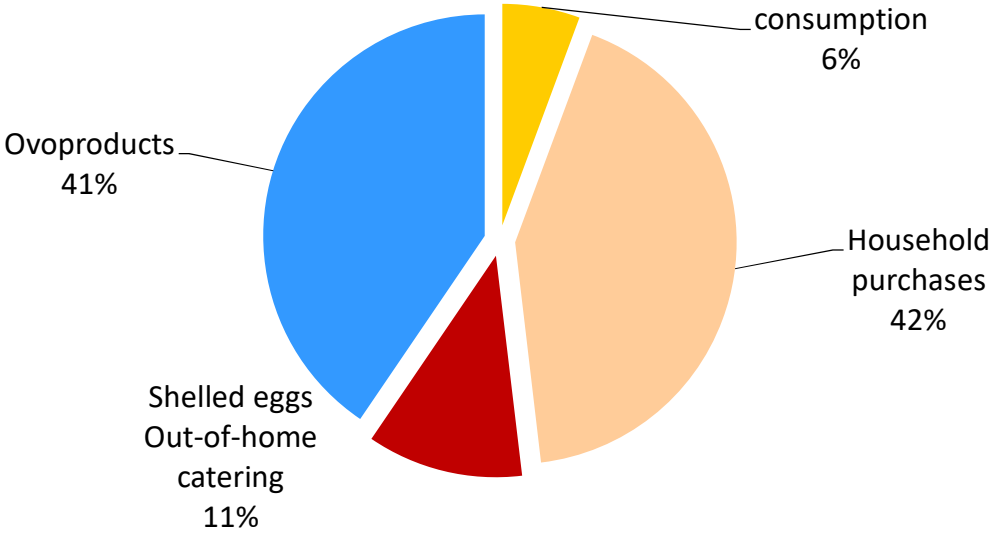
The egg's journey



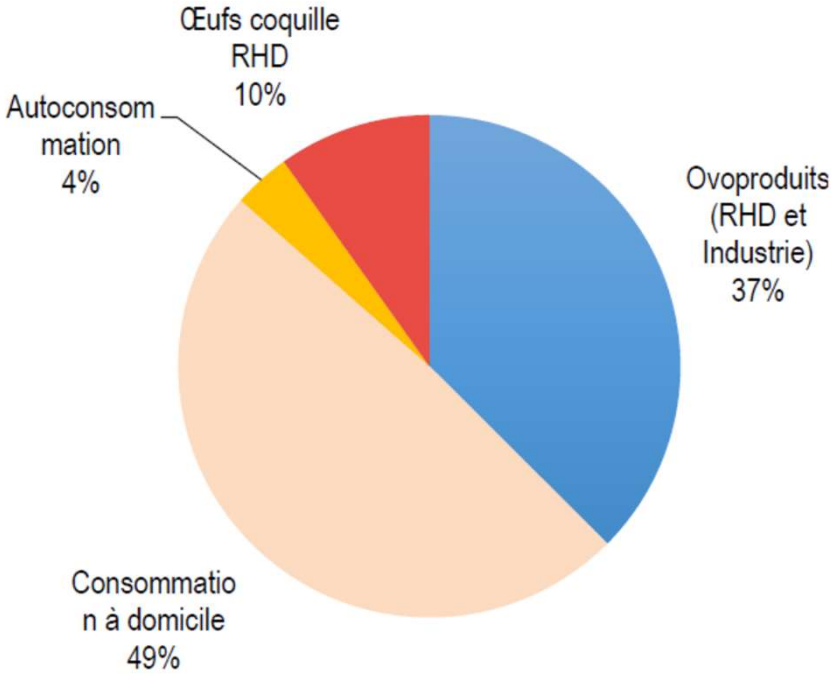
Réhault et al., 2019; Nys et al., 2017



Distribution of total French consumption



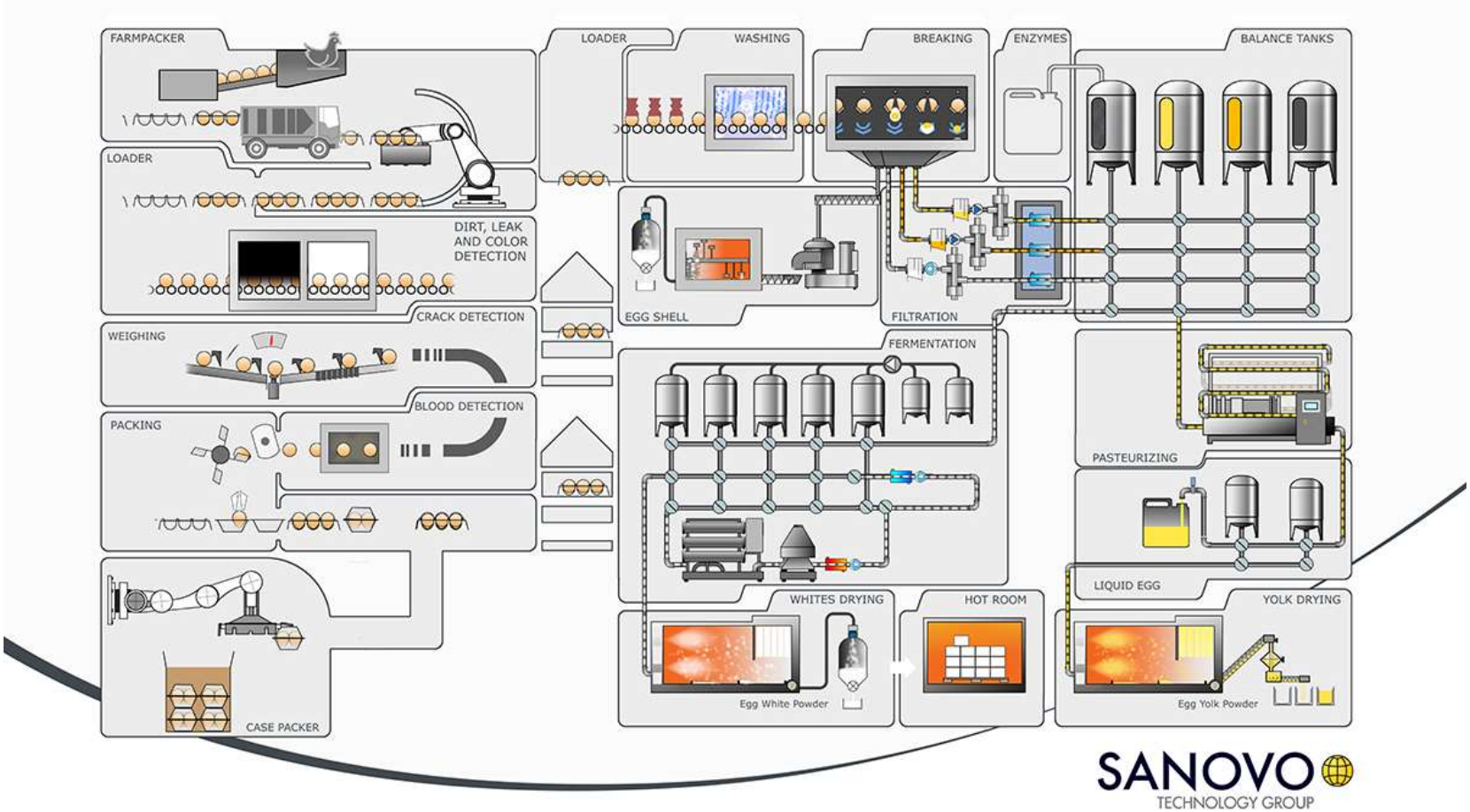
2013



2017

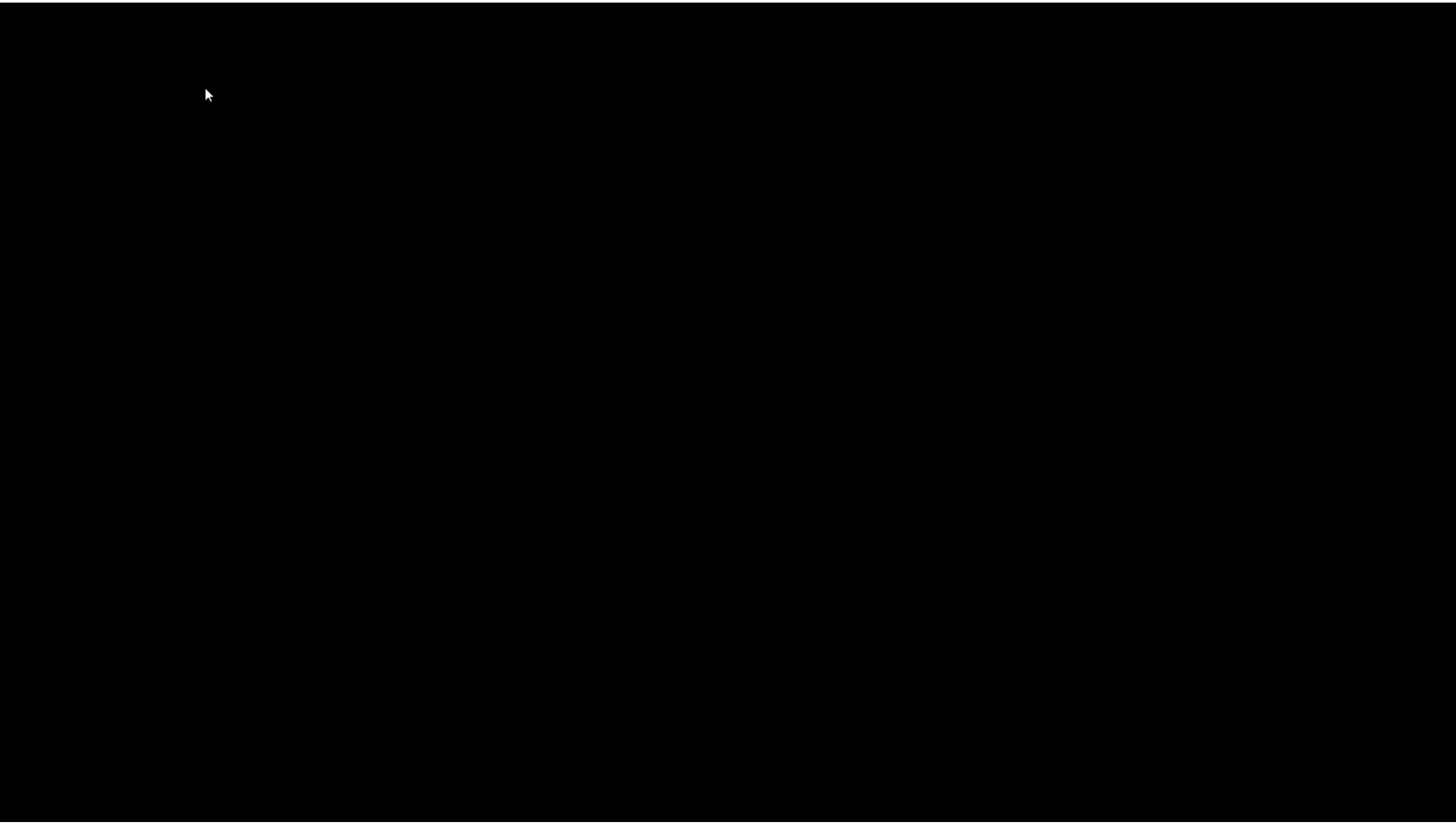
ITAVI d'après SSP, Kantar et Douanes

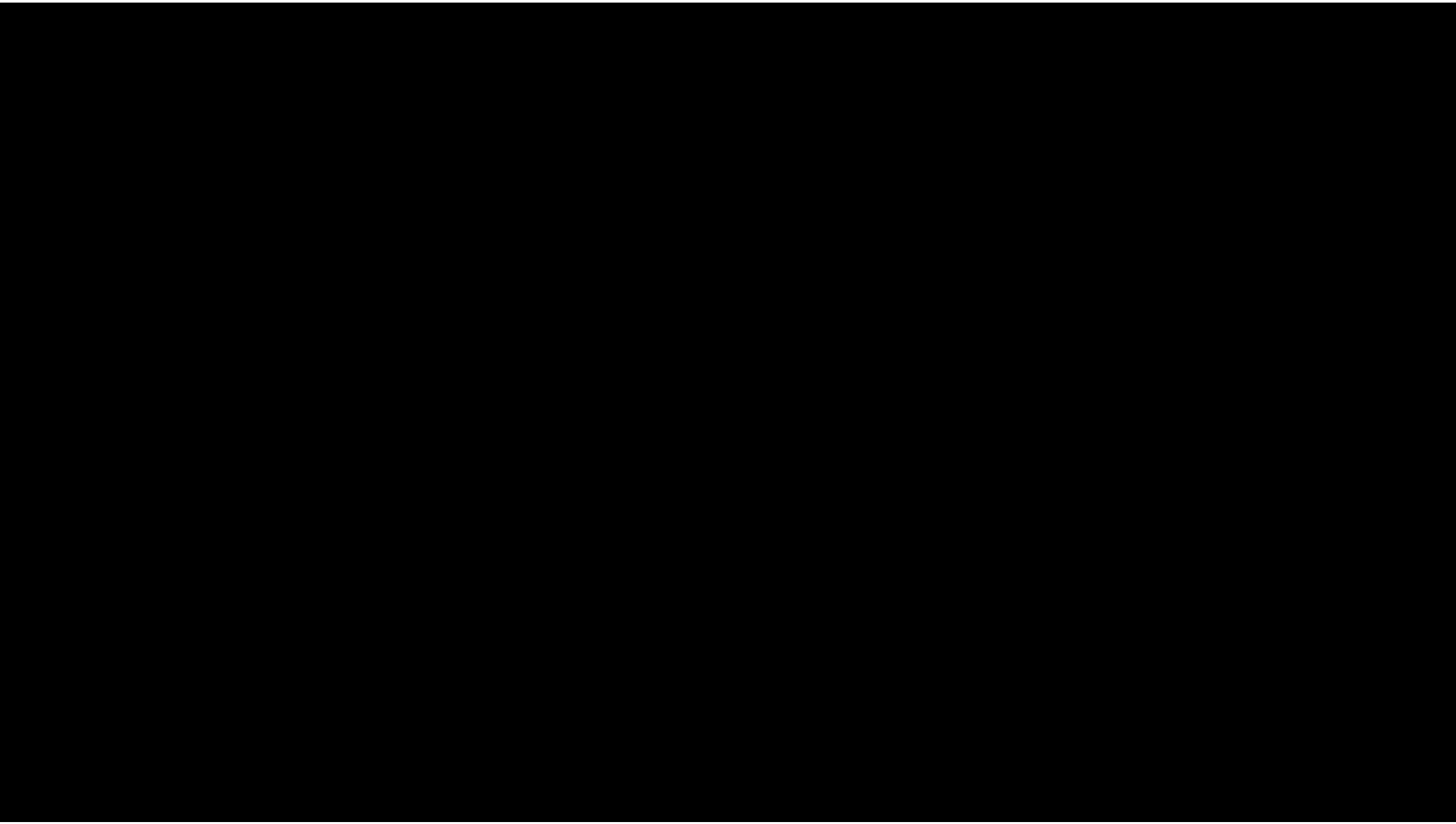
The ovoproducts



shell eggs marketing

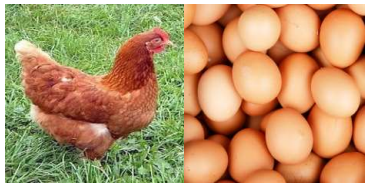
flow diagram for obtaining egg products



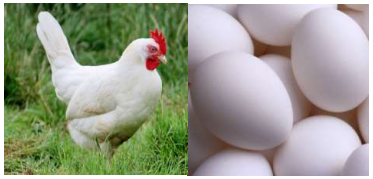


Shell and yolk colours

Shell colour is only dependent of genetic



Brown



Leghorn

Marans

Yolk colour depends of diet carotenoids

alfalfa

Corn

marigold

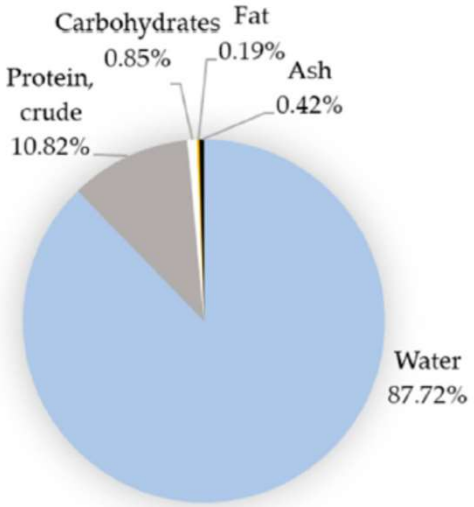
Paprika

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

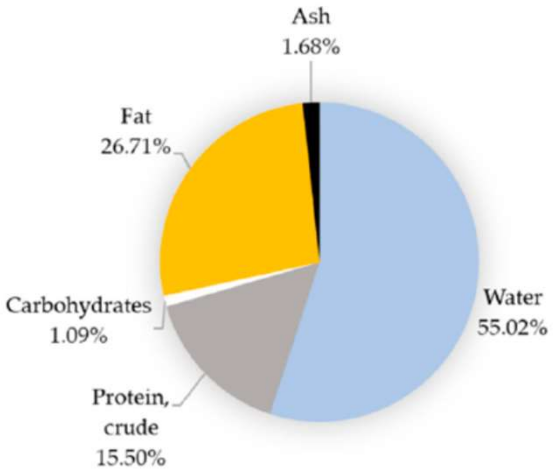
The egg composition is well adapted for human consumption

Egg as a food

- **Global composition of egg white and yolk**



White



Yolk

Réhault-Godbert et al., 2019

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

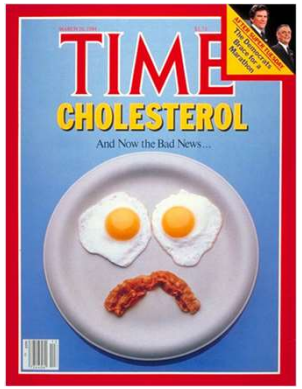
The egg composition is well adapted for human consumption

Egg as a food

• A bad reputation for table eggs

Why this bad reputation ?

- 1968, the american heart association mentioned that no more 3 eggs per a week must be ingested → suspected association between dietary and blood cholesterol
- 1984, March 26th, time magazine's front page is devastating to the egg's reputation



- Since 1995, the recommendations have changed following the results obtained in vitro and in vivo
- **Dietary cholesterol is not associated with blood cholesterol, but with dietary intake of saturated fatty acids** (Myristic acid (14:0) and palmitic acid (16:0))

Réhault-Godbert et al2019; Nys et al., 2018; Griffin 2011, Miranda et al., 2015: Hayes et al., =1992; Pronczuk et al., 1994

The egg composition is well adapted for human consumption

Egg as a food

- **Nutritional characteristics of eggs**

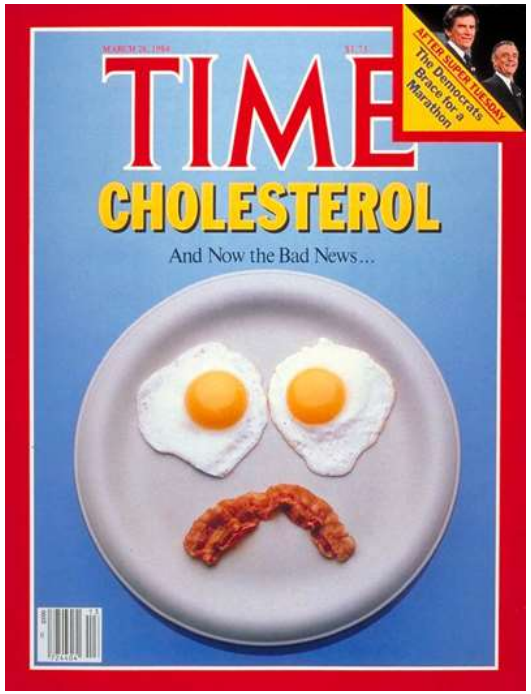
- **Dietary intake of linoleic acid (C18:2 n-6) lowers blood cholesterol and alpha-linoleic acid (C18:3 n-3) reduces the risk of cardiovascular disease**
- In eggs, **saturated fatty acids** including **myristic acid** (14:0) are low and **unsaturated fatty acids including linoleic acid** are high (1.38 g/100g).

Name	Average Content (g/100g)
FA saturated	2.64
FA 4:0	<0.05
FA 6:0	<0.05
FA 8:0	<0.05
FA 10:0	<0.05
FA 12:0	<0.05
FA 14:0	0.024
FA 16:0	1.96
FA 18:0	0.65
FA monounsaturated	3.66
FA 18:1 n-9 cis	3.51
FA polyunsaturated	1.65
FA 18:2 9c,12c (n-6)	1.38
FA 18:3 9c,12c,15c (n-3)	0.061
FA 20:4 5c,8c,11c,14c (n-6)	0.12
FA 20:5 5c,8c,11c,14c,17c (n-3) EPA	0
FA 22:6 4c,7c,10c,13c,16c,19c (n-3) DHA	0.09
Cholesterol	0.398

Réhault-Godbert et al2019; Nys et al., 2018; Griffin 2011, Miranda et al., 2015: Hayes et al., =1992; Pronczuk et al., 1994

Egg as nutritional ingredient for humans

Egg and Cholesterol

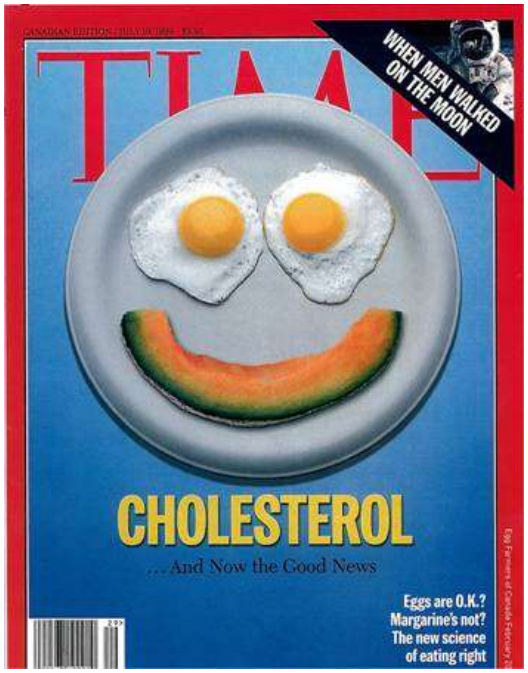


26 mars 1984

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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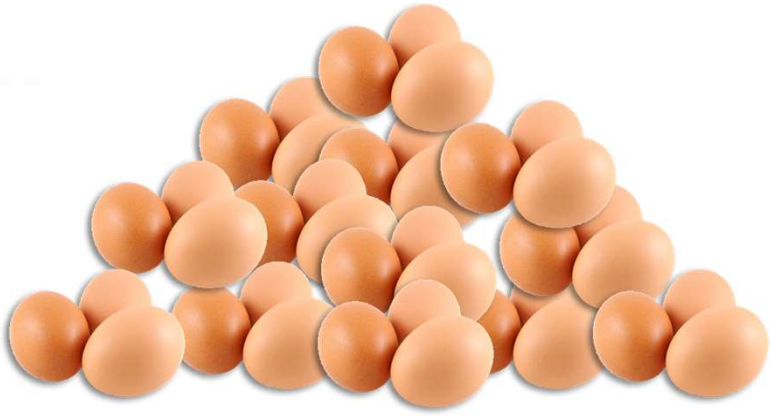
Egg production

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

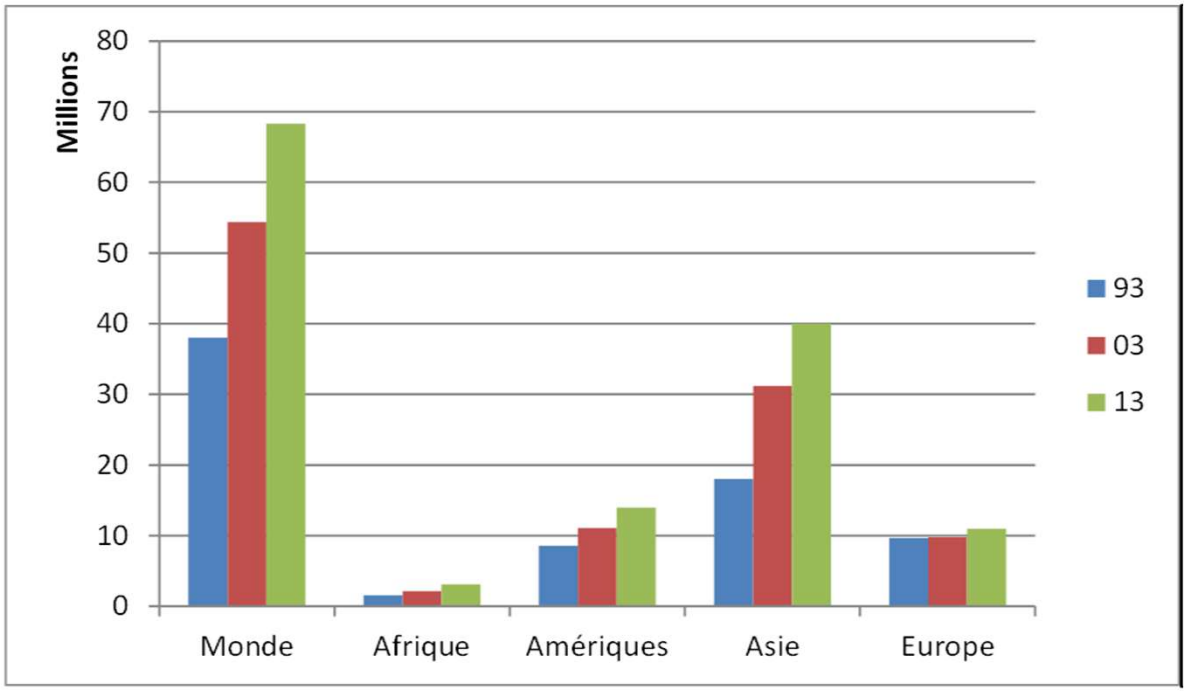
Meat strains
(150 eggs per years)
Non marketable for eggs

Eggs and chicken strains

Table eggs

A basic ingredient for human consumption

70 MT of eggs are produced each year in the word
> 1400 billion eggs per year



Itavi d'après FAO, Commission et Frai

2013 word production

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

1. China 24.7MT
2. UE-28 6.2 MT
3. USA 5.6 MT
4. India 3.8 MT
5. Japan 2.5 MT
6. Mexico 2.2 MT

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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".
- 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
>1400 Billions eggs in the world

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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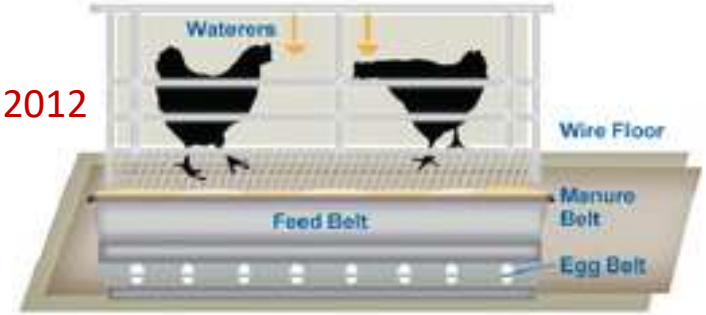
Code 3: Enriched cages

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)

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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

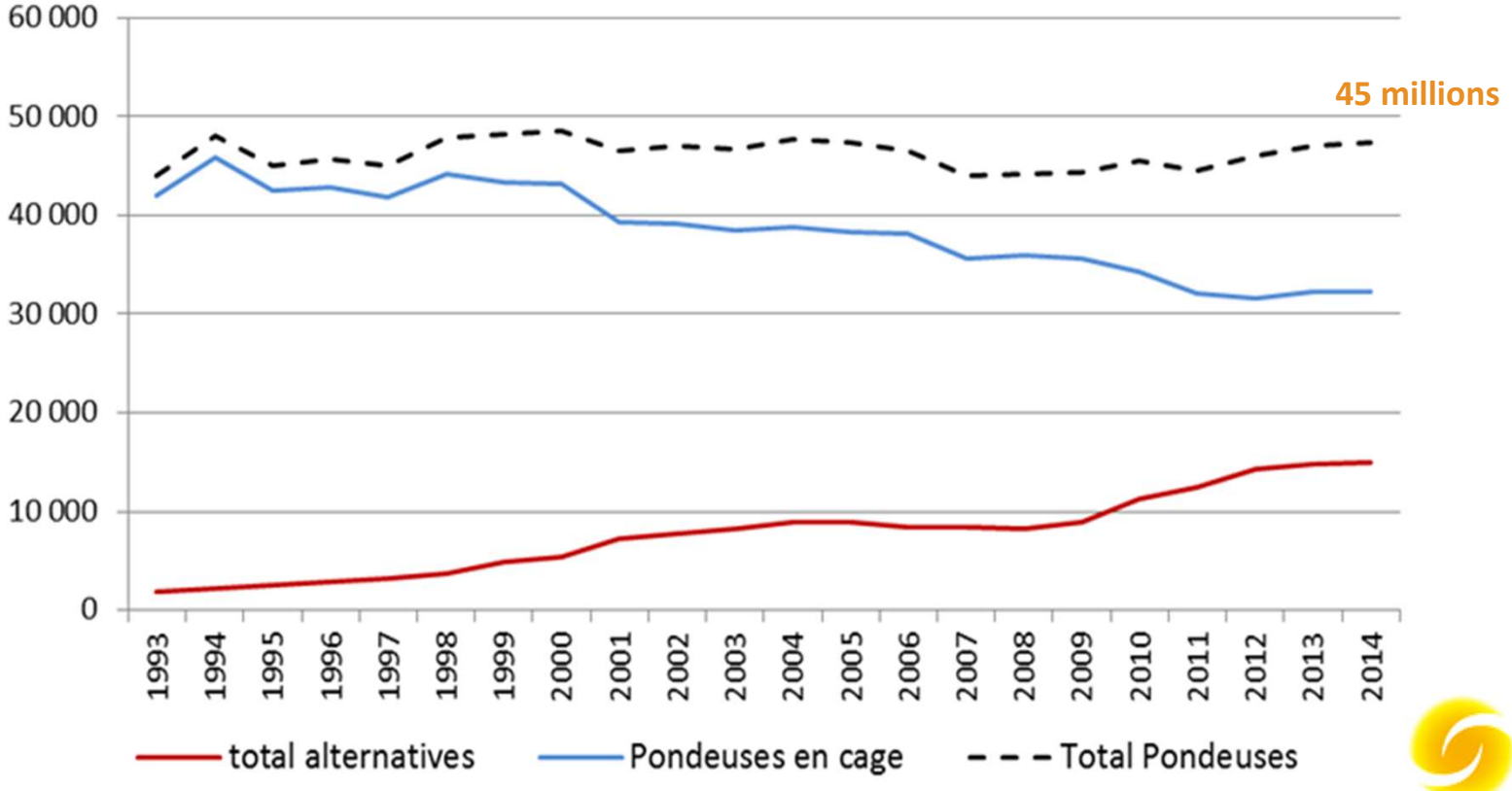
Access to an outside run (4 m2 per hen, max 4,8 ha)

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

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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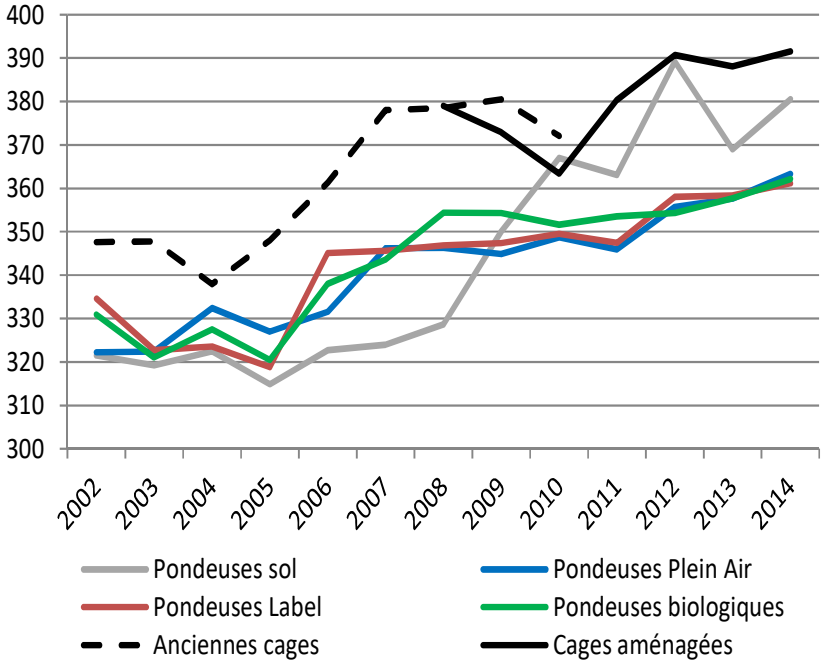
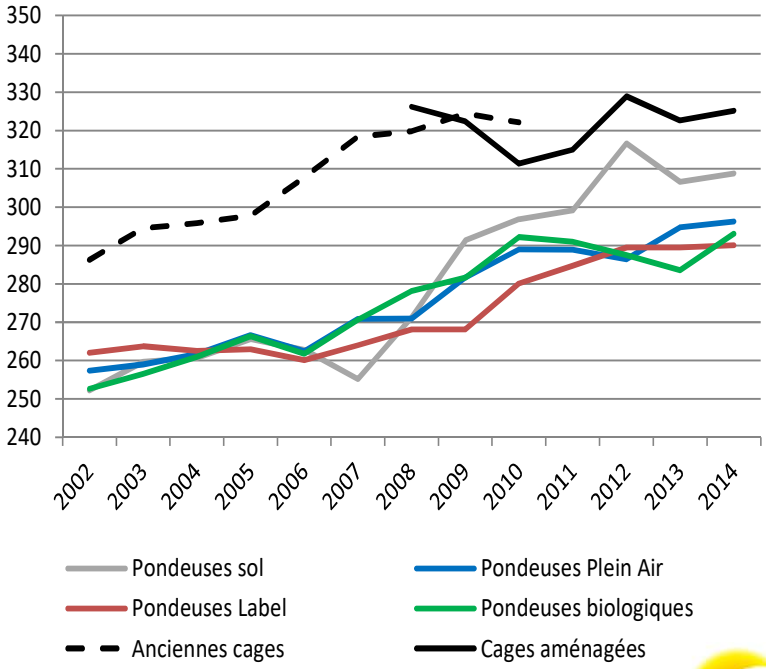
Characteristics of various systems

Egg-laying duration (d)



Numbers of eggs laid by hens



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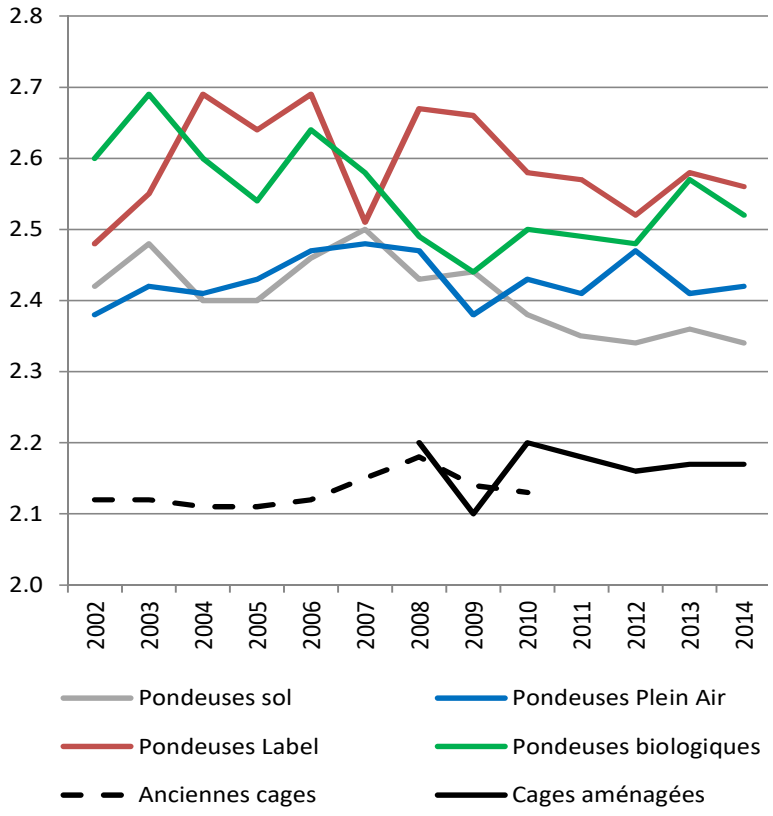
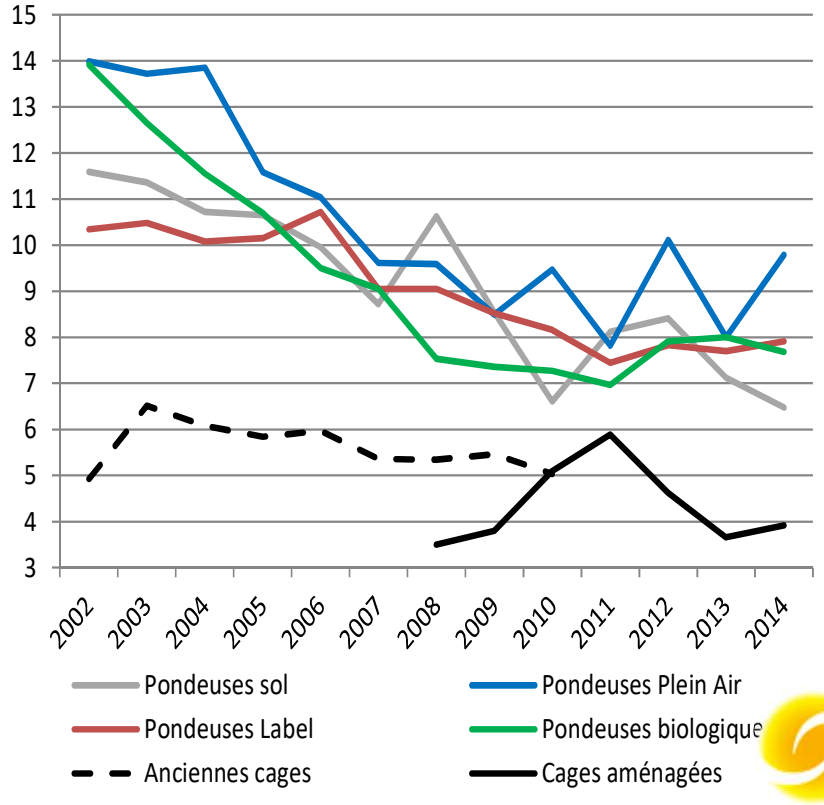
Characteristics of various systems

Feed conversion ratio



Mortality rate%



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Characteristics of various systems

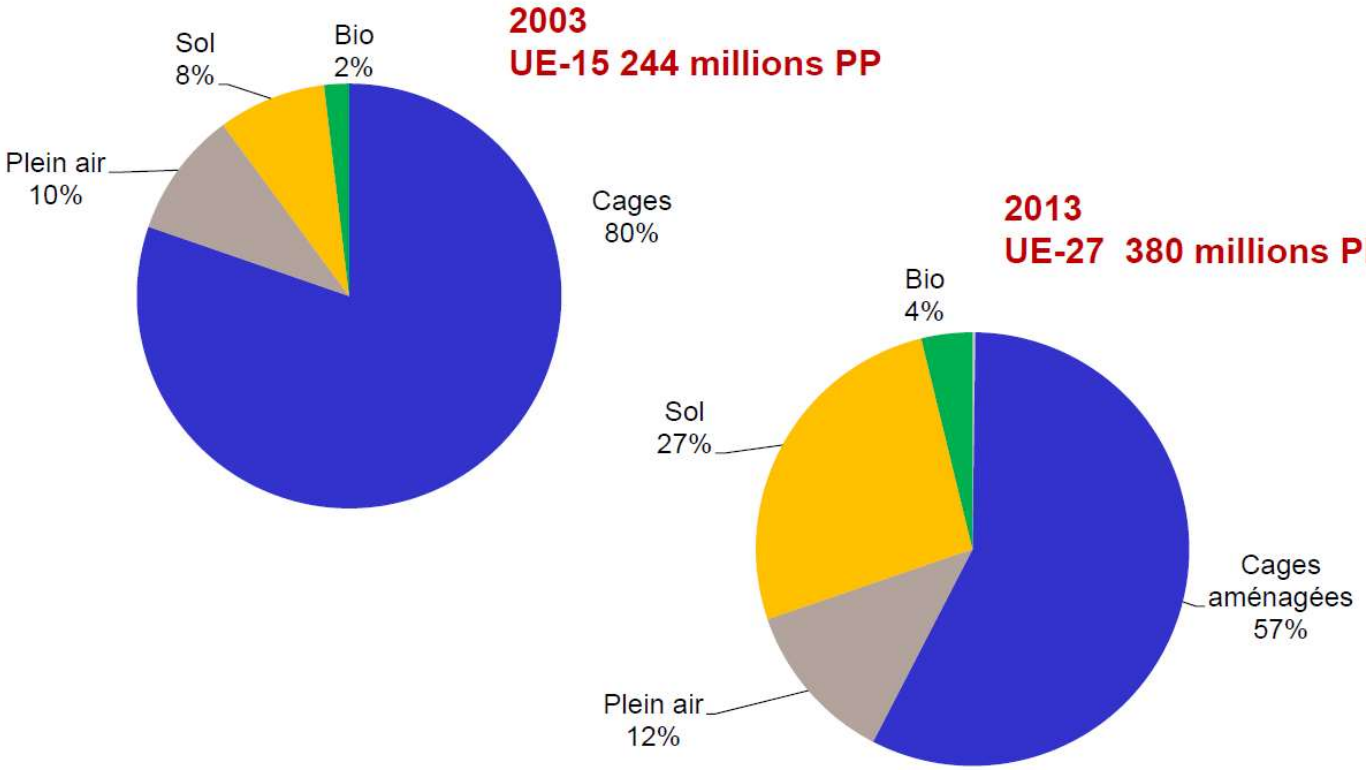
	Cage	Floor	Floor + outdoor access	Floor + outdoor access (Label Rouge)	Organic
Code on egg	3	2	1	1	0
Outdoor access (m^2/hen)	No	No	Yes (4)	Yes (5)	Yes (4)
Housing indoor density (nb hens/m^2)	13.3	9.0	9.0	9.0	6.0
Size of the flock	Usually 50 000 to 100 000	Usually 20 000	Usually 15 000	6 000 per building	3 000 per building
Mortality (%)	3-4%	6-8%	6-8%	6-8%	8-10%
Dust levels in the building	Weak	High	High	Moderate	Moderate
Feedstuffs	Céréals, proetaginous, Vegetal oils, vitamins and minerals				
Feed specificities	Synthetic amino acid, dyes and additives are allowed			Minimum 60% of cereals, No syhthetic dyes, limitation of additives	Organic plant-based Raw materials (65% cereals). No synthetic amino acids, dye and additives.
Feed conversion ratio	2.2	2.4	2.4	2.6	2.6

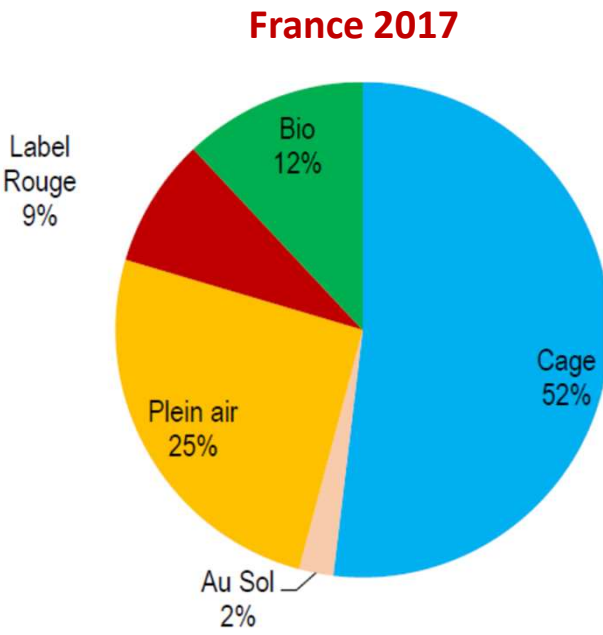
Characteristics of various systems

	Cage	Floor	Floor + outdoor access	Floor + outdoor access (Label Rouge)	Organic
Competition for the use of arable land	weak	weak	moderate	moderate	moderate
Organoletic and nutritional characteristics	No difference				
Sanitary quality	No or faint differences (related to density)				
Cost of production at the farm (€ for 100 eggs)	6,41	7.35	7,82	8,65	13,64
Cost of production % base	100	115	122	135	213
Consumer selling price (€ for 6 eggs)	0,89	0,94	1,36	1,87	1,96
Consummer selling price percentage base	100	106	153	210	220

Evolution of egg production systems in UE

Evolution of egg production systems in Europe





Source Commission européenne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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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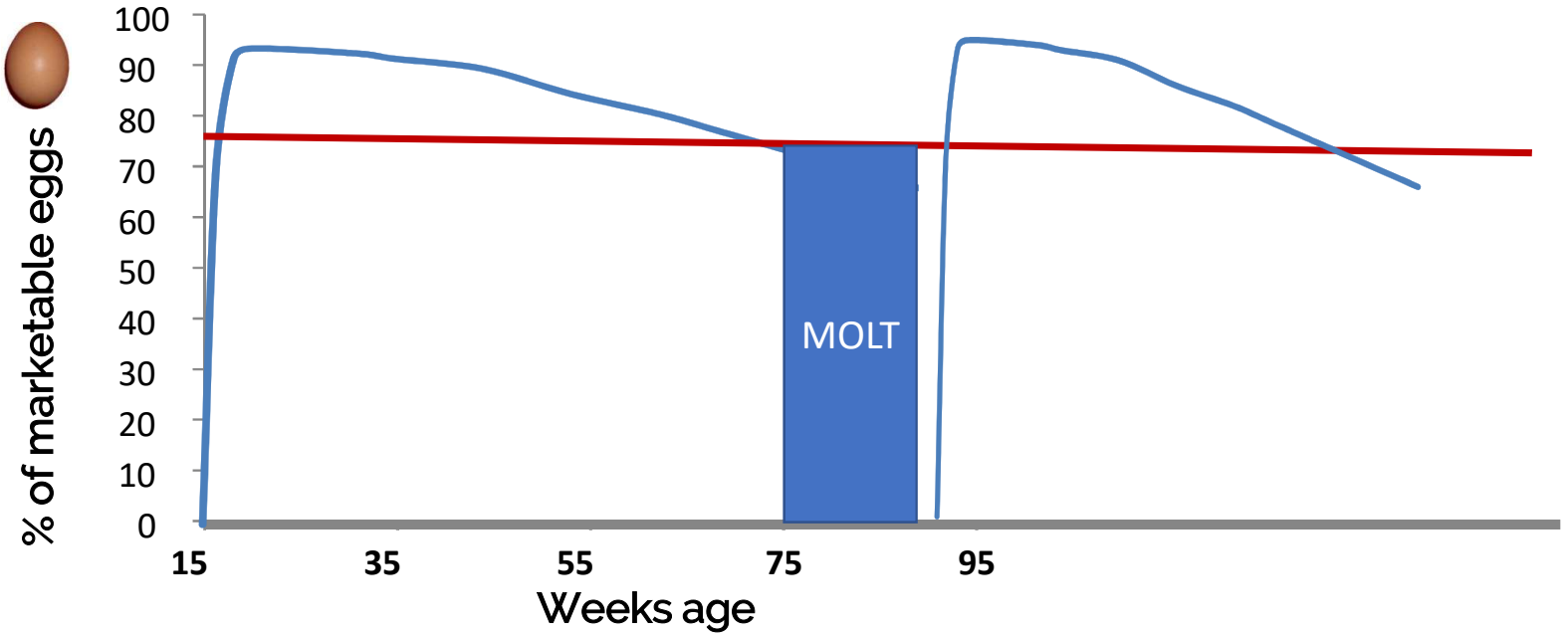
Reduce the number of layers

✓ 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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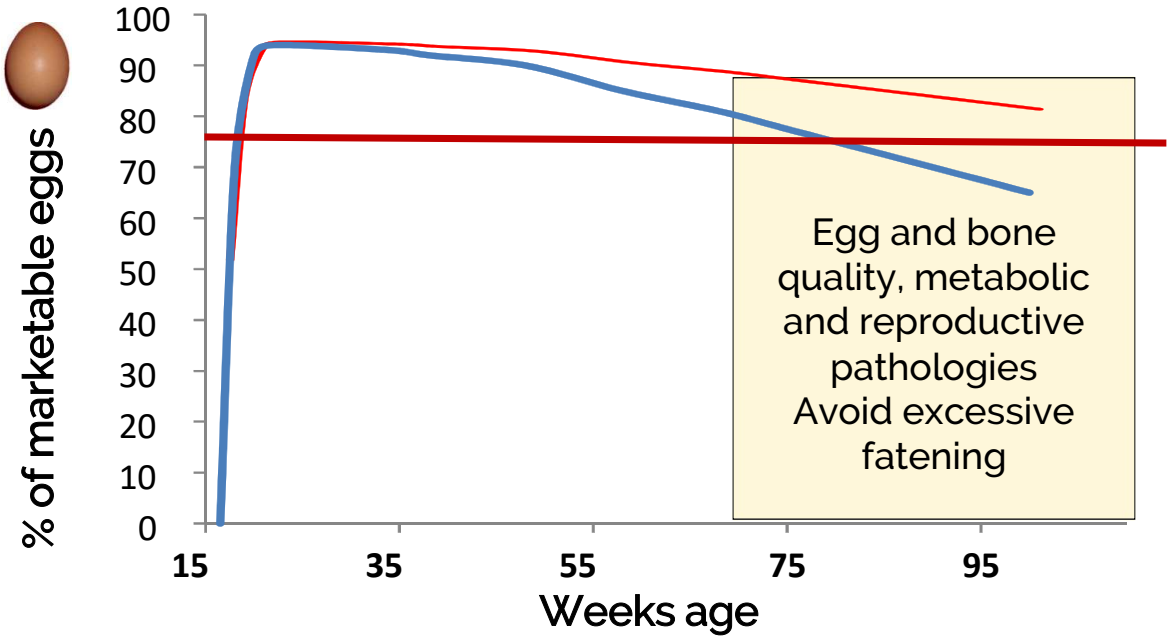
Increasing persistency of laying hens



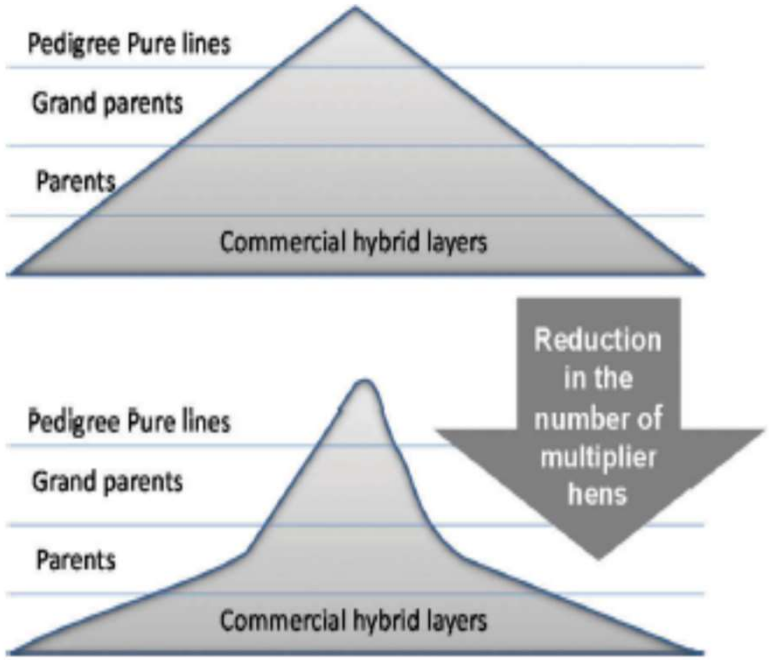
75 % of marketable eggs is the beneficial limit

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…



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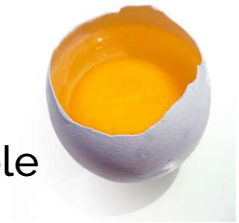
Dual purpose chickens

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

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In ovo sexing

Identify male eggs for removal before hatching

Postulate: male and female embryos "express" chromosomal, anatomical, physiological and molecular differences (direct indicators/markers) and some of these molecules may diffuse into the egg structures (indirect indicators/markers)

Step 1: Determine the sex of the embryo

Step 2: Search for dimorphic sex indicators / biomarkers (embryo / egg structures)

Step 3: Validate biomarkers on a large number of eggs from genetically different strains of laying hens

→ Towards a practical and marketable method

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Sexage *in ovo*

Identify male eggs for removal before hatching

→ Towards a practical and marketable method

- ✓ 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 XXX days of embryonic development to avoid any pain.

→ 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

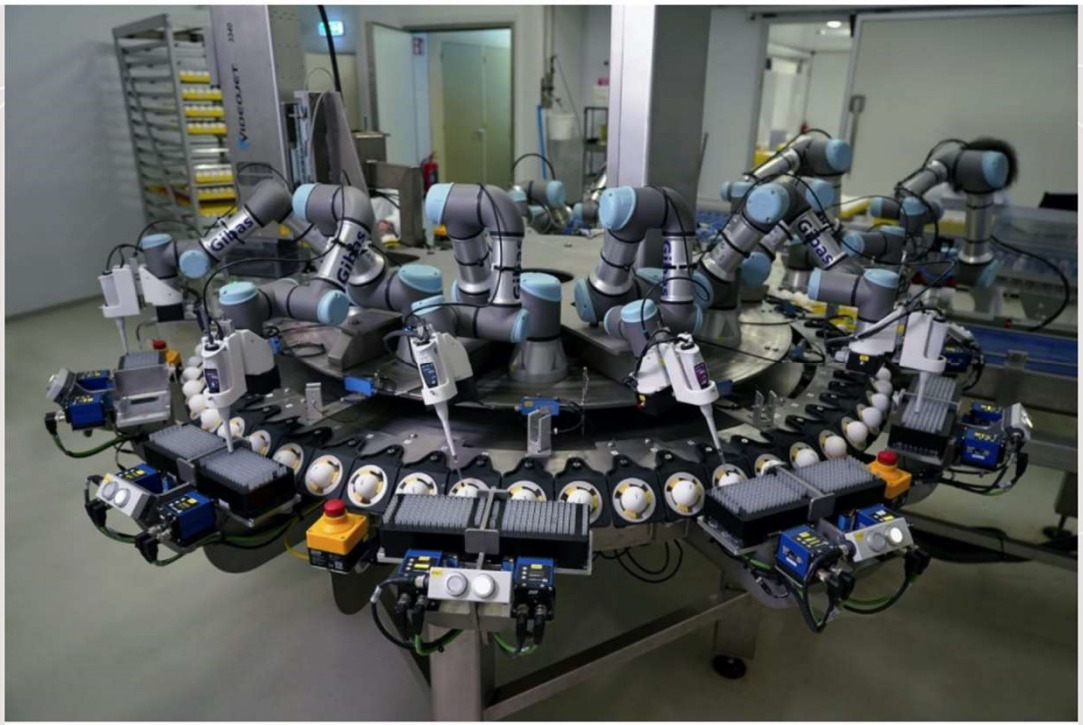
How to determine sex in ovo

Principle of the method	stade	Structure	Technique	invasiveness / precision / capacity	Marketing
Chromosomic	E9	Allantoïc liquid (200-300 µL)	PCR on cells suspended in allantoic fluid	Invasive, 97-99% 3000/h	**PLANTegg** (Allemagne) En cours (ALDI)
Molecular	E9	Allantoïc liquid	Determination of oestrone sulphate (hormone ♀)	Invasive, 98%, SELEGGT: 3600/h In Ovo: 1500/h	**SELEGGT** (Allemagne) **In ovo** (Pays-Bas): Machine= Ella
Physiological /phénotypical	E13	Whole egg/ luminous flash	hyper-spectral imaging / feather colour	Non invasive, 95%, 20 000 /h	**Agri Advanced Technologies** (Allemagne): Fermiers de Loué Machine: CHEGGY
Genome editing	E0	Whole egg/ Transilllumination	Imaging by fluorescence of a molecule produced by males after editing	Non invasive 100 %	**EggXYT** (Israël)

How to determine sex in ovo

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

THE SELEGGT PROCESS



The SELEGGT process is a way to prevent chick culling. The scientific approach of endocrinological (hormone-based) gender identification in the hatching egg has been automated in the SELEGGT process and is already in use today.

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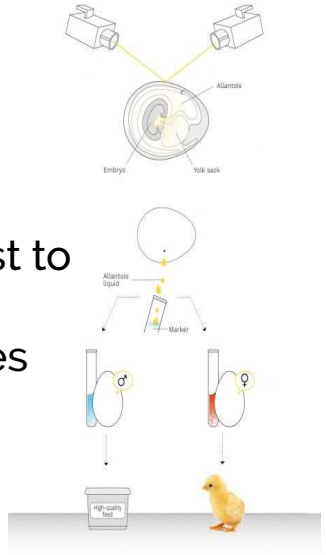

- ✓ Test performed at 9 days of incubation
- ✓ Small hole 12 mm in the shell
- ✓ Samples used a patented test to measure the level of Estrone sulfate only present in females

- ✓ 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 1 to 3000 eggs/hour

Comment determiner le sexe *in ovo*

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

- ✓ H NRM spectroscopy
- ✓ Fast 2 sec/oeuf
- ✓ Marketing
- ✓ Low throughput (1500 eggs/hours)

Comment determiner le sexe *in ovo*

Agri Advanced Technologies CHEGGY (https://www.agri-at.com/fr/produits/determination-du-sexe-in-ovo/cheggy/156-cheggy-downloads) (Allemagne)

- ✓ Hyperspectral technic (feather colour)
- ✓ 20 000 eggs/hour

Comment determiner le sexe *in ovo*

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 ???

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How to determine sex in ovo

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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 fully 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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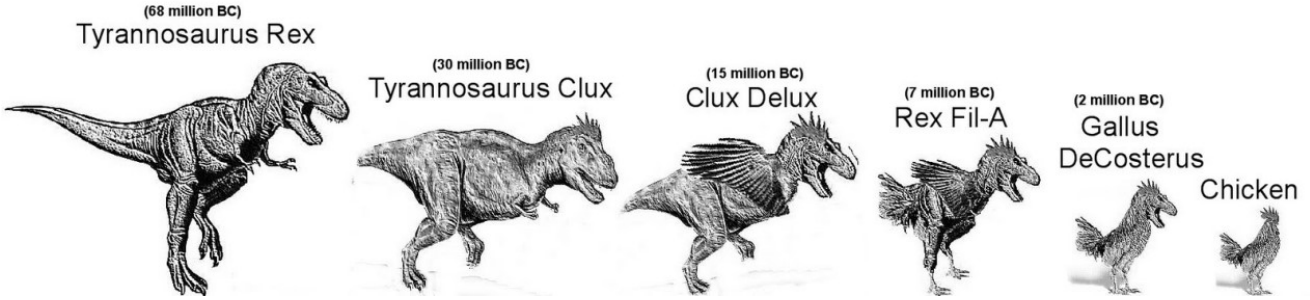
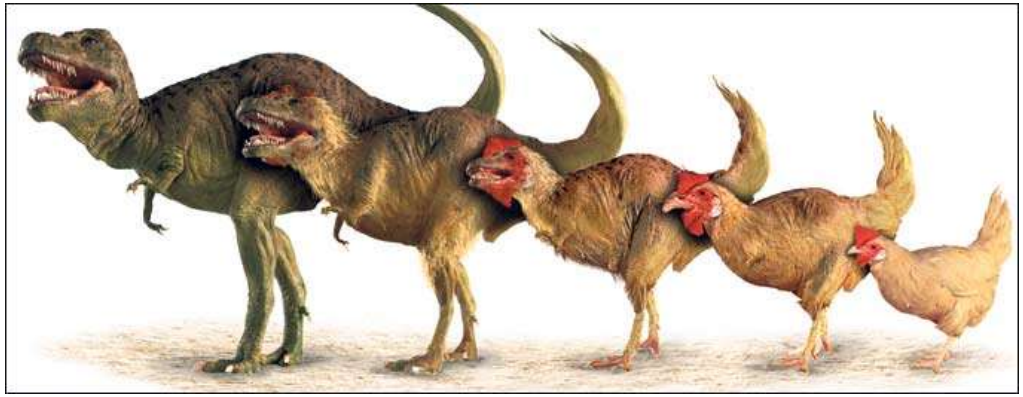
To conclude

The Chicken or the egg ?

This is the question that is poorly formulated

Birds are descendants of dinosaurs





The chicken or dinosaurs ?