Innovation and advances in precision livestock farming

Ludovic Brossard

Innovation and Advances in Precision Livestock Farming

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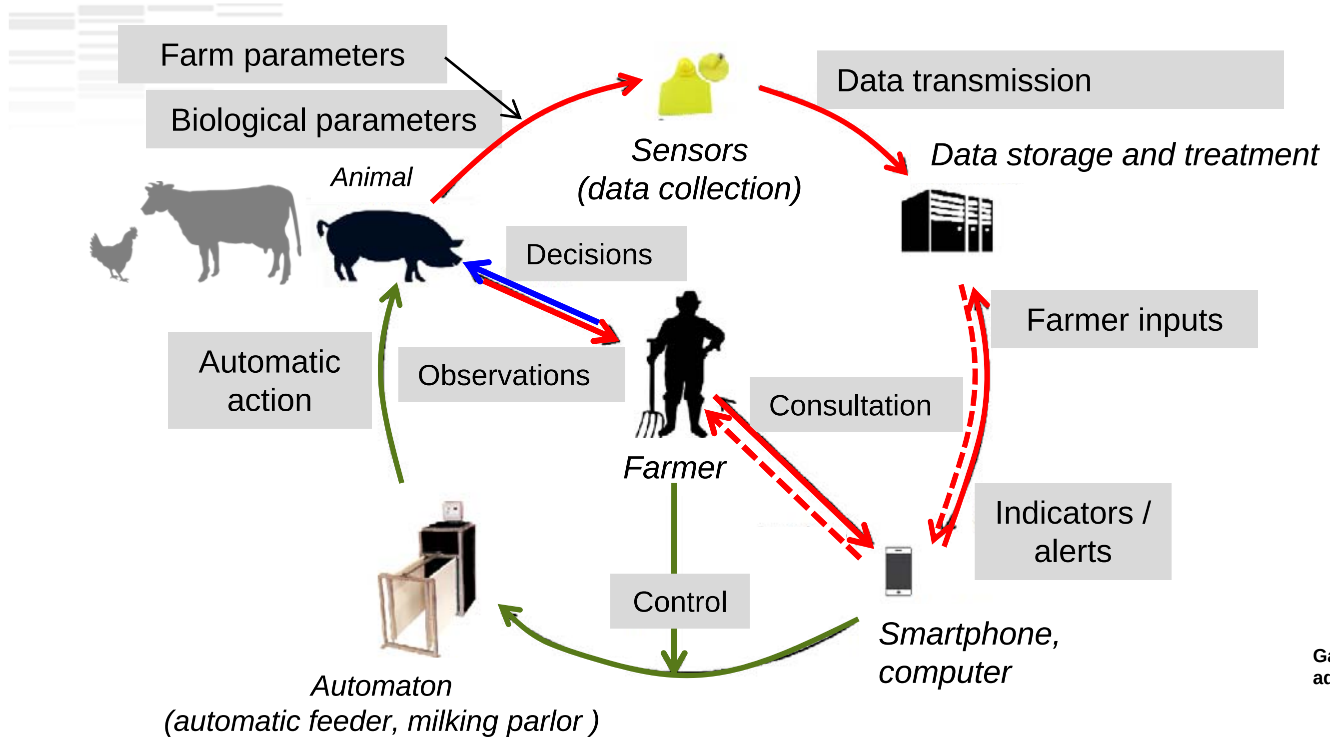
Content

- ✓ Principles and advances in PLF
- Feed efficiency and precision feeding
- Examples of consequences for feed /feed additives producers: Feed-a-Gene program
- Conclusion and perspectives

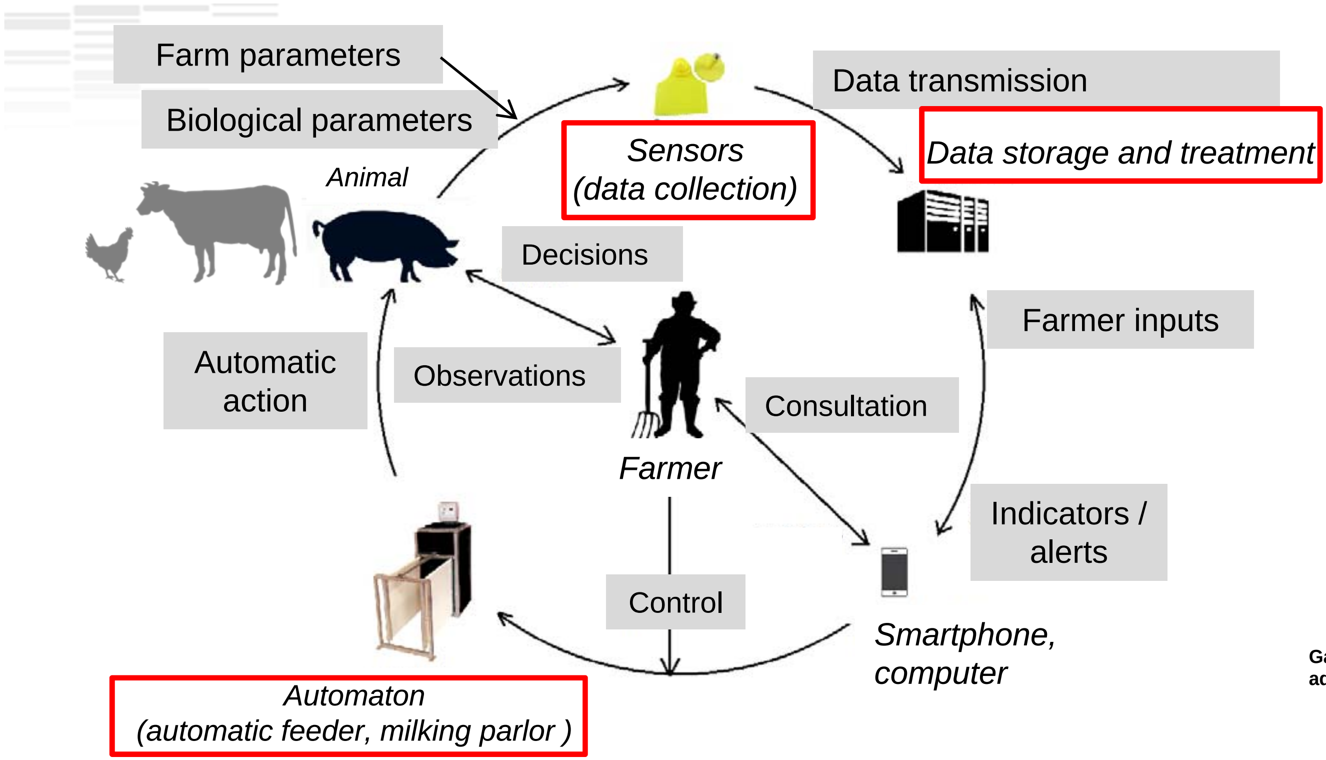
Principles of precision livestock farming



Gaillard et al., 2018,
adapted from C. Allain

➔Use of sensors and information and communication technologies to help farmer in piloting livestock farming system

Elements for precision livestock farming



Gaillard et al., 2018,
adapted from C. Allain

Sensors and automatons in cattle

Tools initially developed for herd piloting

Feeding & Reproduction

- Milking robots and automatic feeder: to reduce milking and feeding tasks
- Then reproduction monitoring : to secure mating and calving
- Housing piloting

Guatteo et Richard, 2017

Sensors and automatons in cattle

Tools now with others objectives as "health"

- ❖ Use of data initially dedicated to other objectives

  Activity : Heat detection → lameness detection
- ❖ Development of tools 100% dedicated for health

  → pH and temperature measurement in rumen

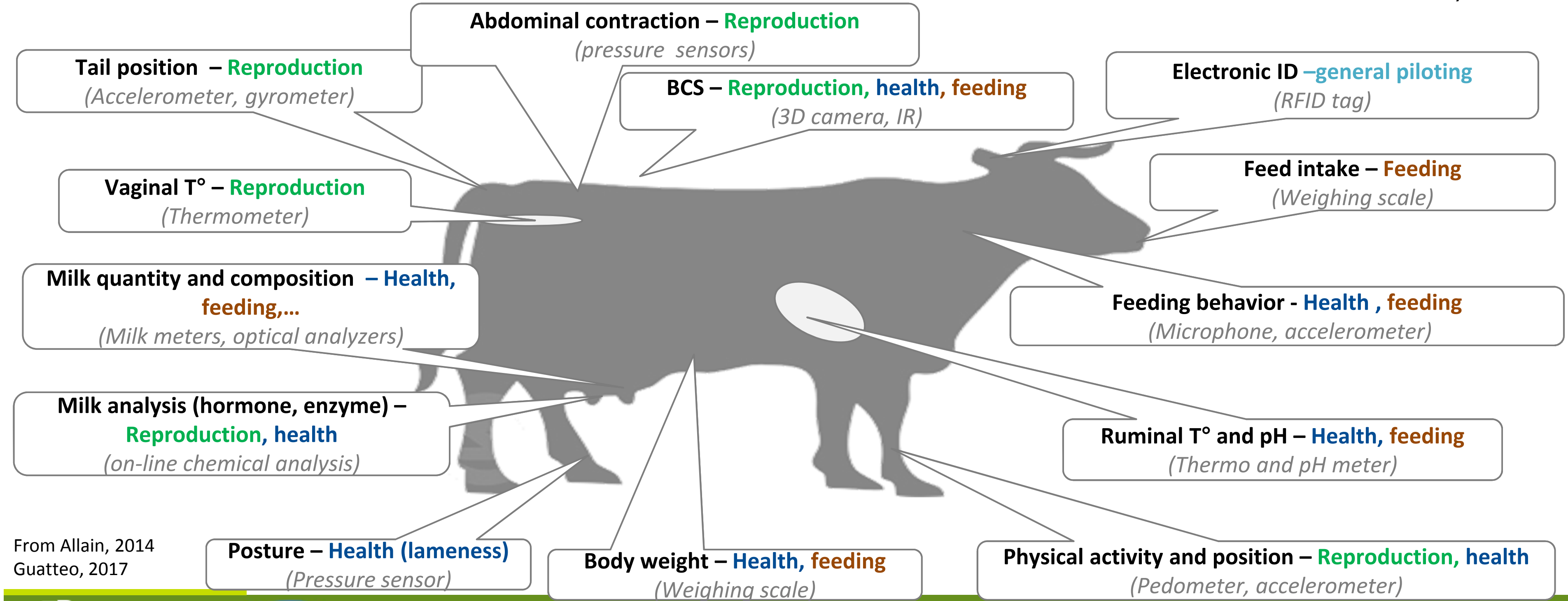
Guatteo et Richard, 2017

Sensors and automatons in cattle

Large panel of possibilities

Alone or in combination

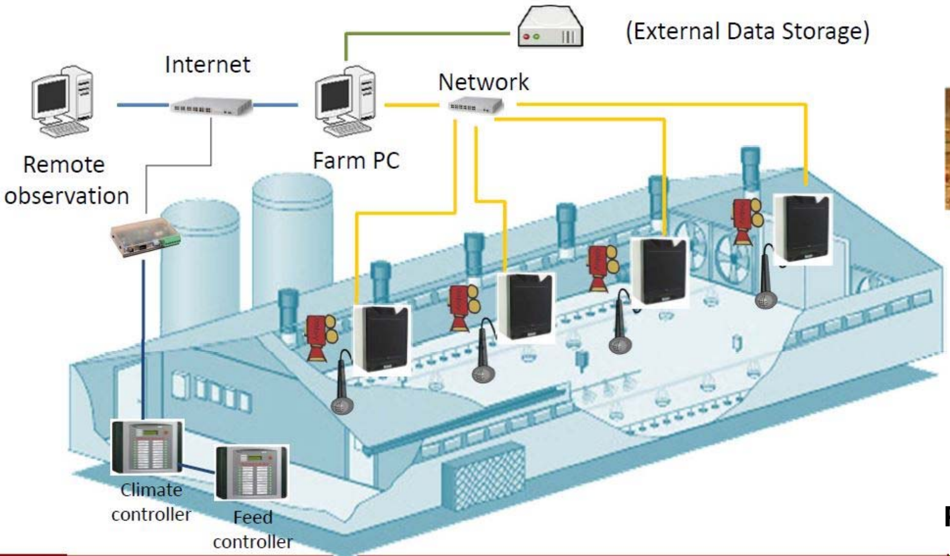
Guatteo et Richard, 2017



From Allain, 2014
Guatteo, 2017

Sensors and automatons in poultry

- Image monitoring (space occupation, behavior, welfare)
- Sound caption + weighing scales (growth)
- Feed intake
- Ambiance measurement (dust, ammonia)



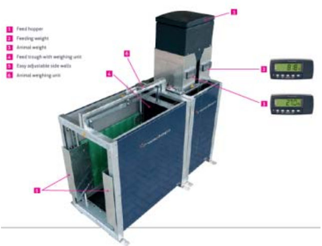
From Vramken, 2016, EU –PLF project

Sensors and automatons in pigs

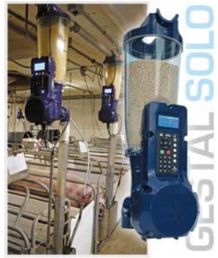
Feed intake

Growing pigs






Lactating sows

Gestating sows

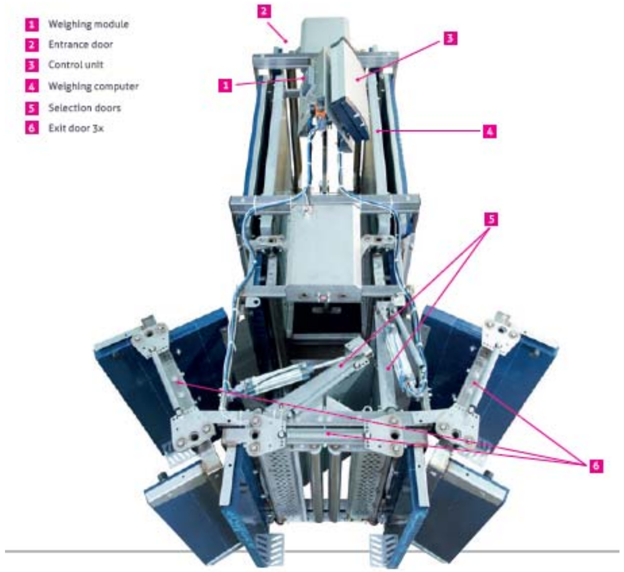






Sensors and automatons in pigs

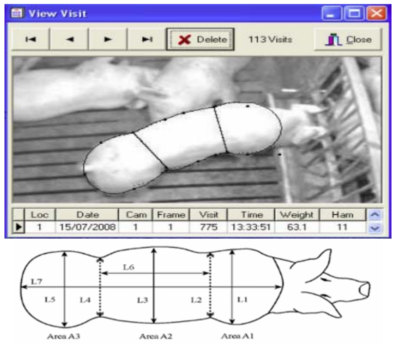
Weight



Other examples of real-time monitoring in pig

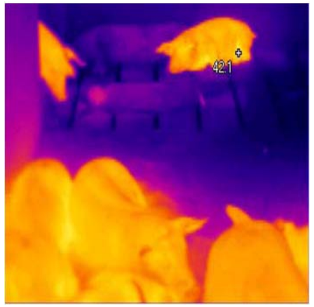
- **Weight: image**
- **Body composition: image, ultrasound, impedance**
- **Behavior: video, accelerometer**
- **Health: infrared image, sound, feeding and drinking behavior**

Weight



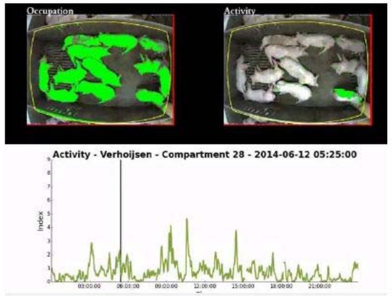
Drinking behavior

IR image



Composition

Behavior



Data management and treatment

- The increasing volume and diversity of data imply the development of adapted data chains for heterogeneous data (time, type, format): BIG DATA
  - Filtering, verification
  - Storage
  - Treatment
- Data usable for farmers but also other stakeholders (processors, feed industry, veterinarians, genetic companies, …) (cloud…)
- Already, advances but still progress to do in transforming data to information (from raw data, alone or combined, to usable data as growth curve, feed intake curve, alert information based on temperature or activity curve…)

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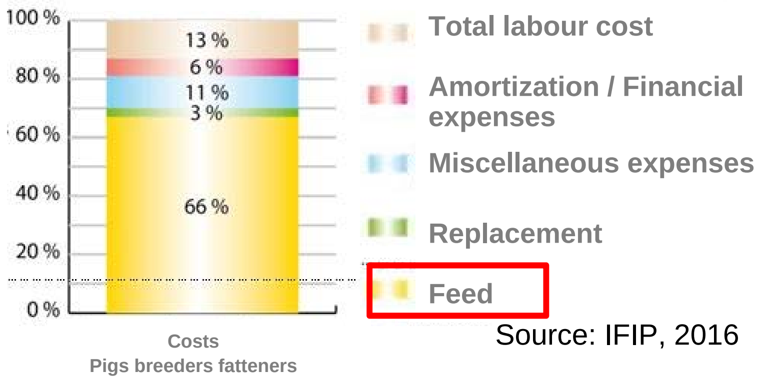
Nutrition - a major lever to improve the sustainability of animal production

- **Economy**
  - feed = about 2/3 of production cost
- **Environmental impact**
  - Reduction of resource use (feed)
  - Reduction of nutrient excretion (N, P...)
- **Quality of products**
  - Lean to fat ratio, Fat quality
  - Homogeneity of products



Source: IFIP, 2016

➔ **The improvement of feed efficiency is a major issue for sustainability of all production systems (conventional & alternative)**

Evaluation of efficiency of utilization of feed

- **Expressed as a ratio**
  - **Feed conversion ratio = Feed / Growth**

    => economic representation of a « cost of production »
  - ***Feed efficiency ratio = Growth / Feed***

    => representation of the efficiency of a biological process
- **Different units of expression**
  - **kg feed / kg gain => *most common !***
  - **MJ Energy / kg gain => *biological efficiency !***
  - **€ of feed / kg gain => *economic efficiency !***

Biological meaning of feed conversion ratio

$$\text{Observed FCR} = \frac{\text{Feed distribution}}{\text{Pig growth}}$$

$$\text{Observed FCR} = \frac{\text{Feed intake + spillage}}{\text{Pig growth}}$$

$$\text{"Real" FCR} = \frac{\text{Feed intake}}{\text{Growth}}$$

Biological meaning of feed conversion ratio

$$\text{FCR} = \frac{\text{Indigestible} + (\text{Maintenance} + \text{Growth})}{\text{lean} + \text{fat} + \text{bone} + \text{skin} + \text{organs...}}$$

$$\text{FCR} = \frac{\text{Indigestible} + (\text{Maintenance} + \text{Growth})}{(\text{protein} + \text{water}) + \text{lipids} + \text{minerals}}$$

=> means that FCR depends on :

- digestibility of feed and digestive efficiency of pigs
- composition of weight gain (lean/fat ratio)
- importance of maintenance versus growth (ADG)

Biological meaning of efficiency of nutrient utilization (amino acids, phosphorus)

$$\textbf{Lysine efficiency} = \frac{\textbf{lysine retained (in body protein)}}{\textbf{Indigestible + (maintenance + growth + oversupply)}}$$

$$\textbf{P efficiency} = \frac{\textbf{P retained (in bones and soft tissues)}}{\textbf{Indigestible + (maintenance + growth + oversupply)}}$$

=> means that efficiency of nutrient utilization depends on

- digestibility of the nutrient
- oversupply

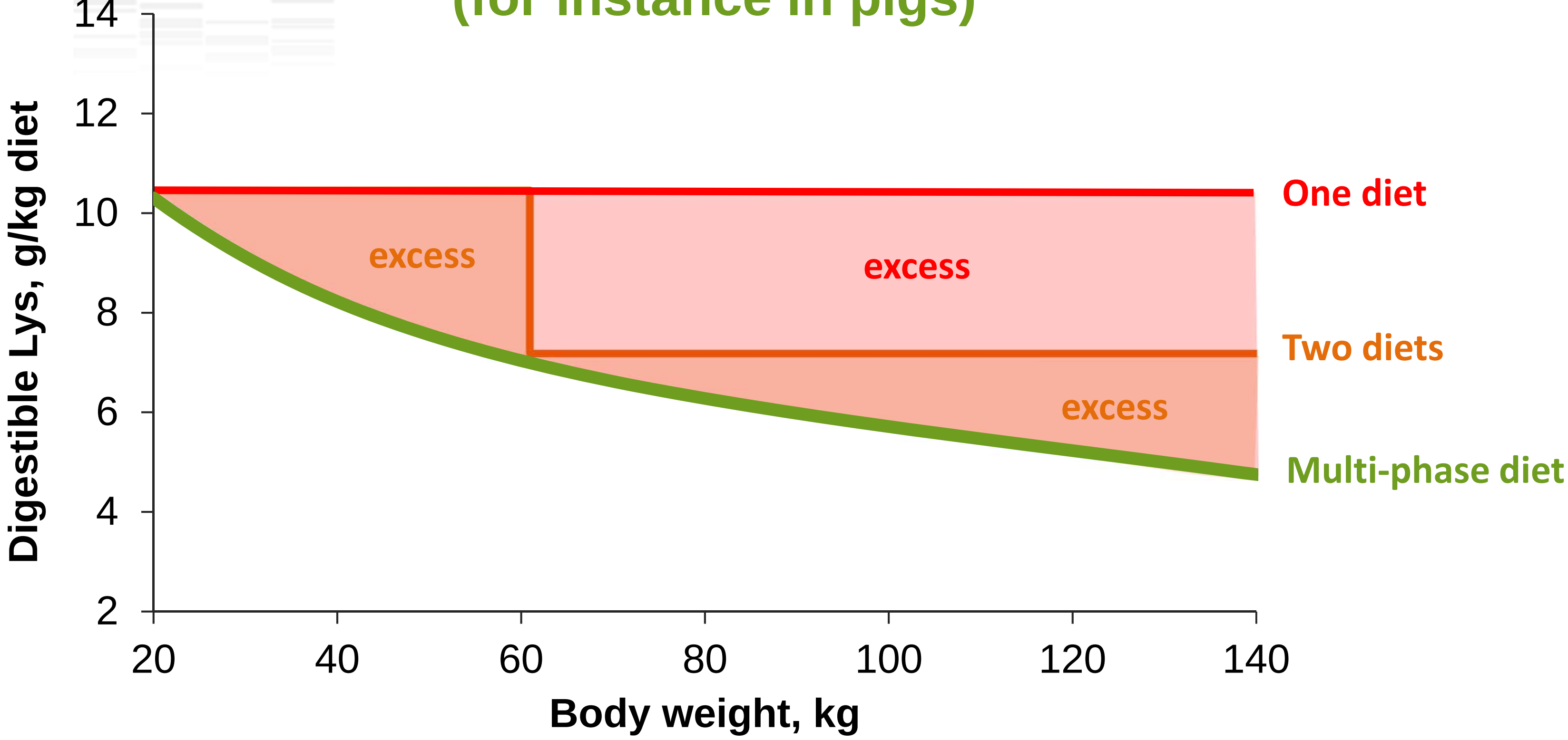
Strategies to improve feed and nutrient efficiency

- **Insure adequate, energy, amino acid and mineral supplies (for growth, health…)**
  - sufficient to maximize growth (↘ FCR)
  - not in excess to avoid the increase in excretion and in FCR
  - the optimal supply depends on pig genotype and sex, and age

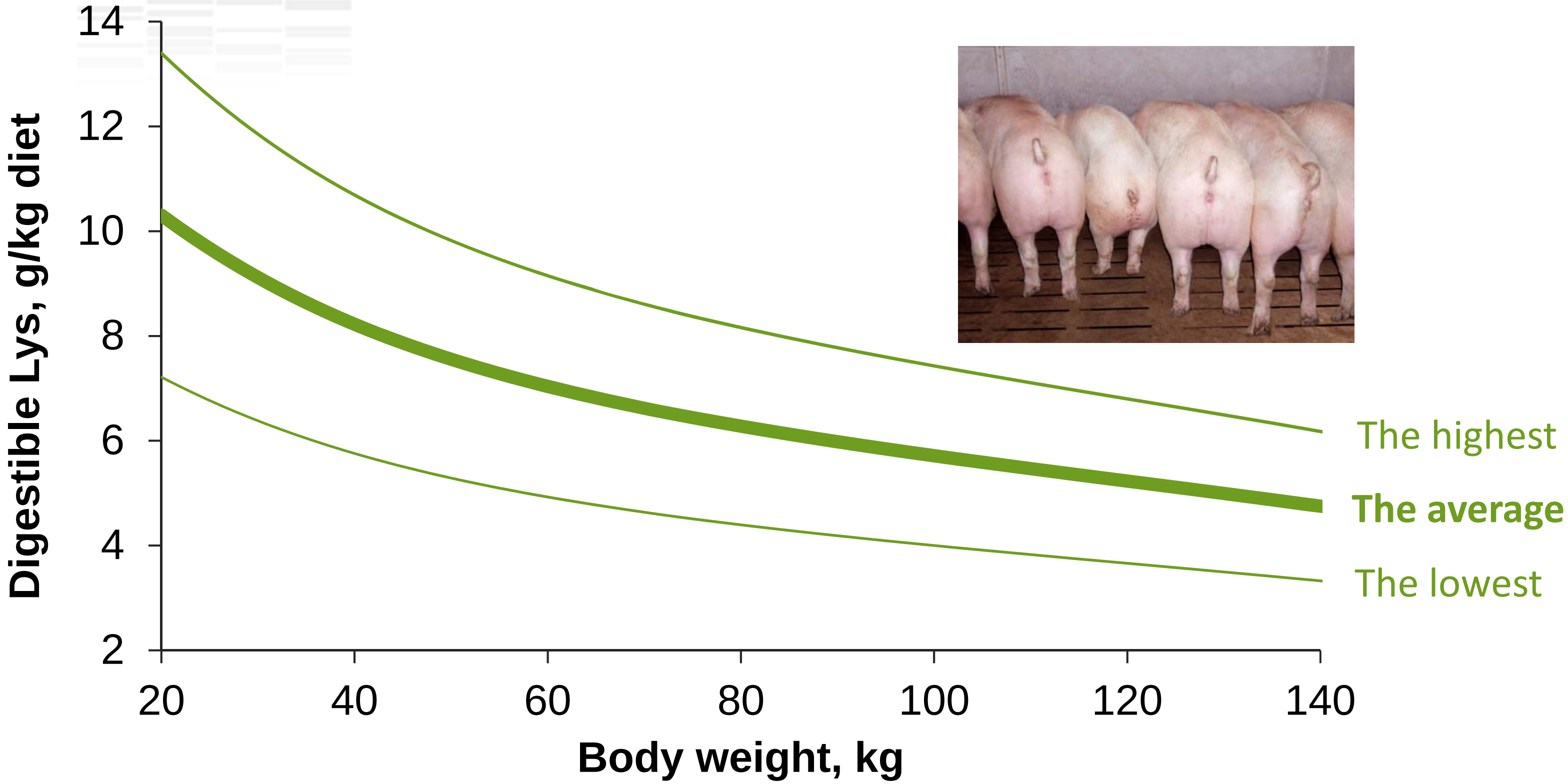
↳ **Difficult to implement in practice**
- variation of requirements over time
- variability between animals

⇒ **New opportunities offered by precision livestock farming**

Accounting for changes in nutrient requirements during growth (for instance in pigs)

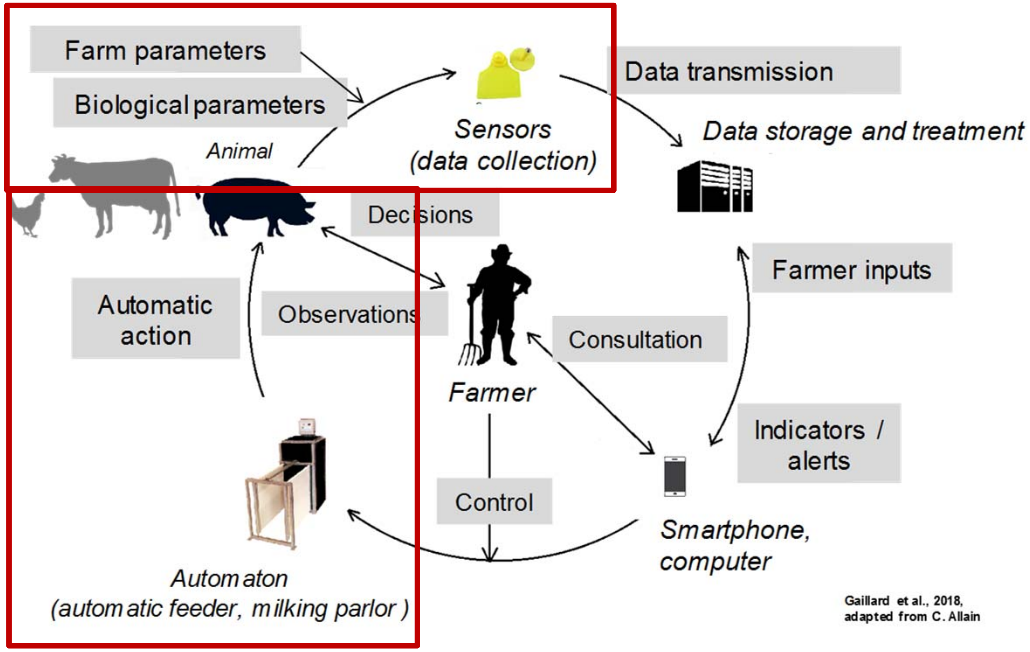


There is variation among pigs in nutrient requirements

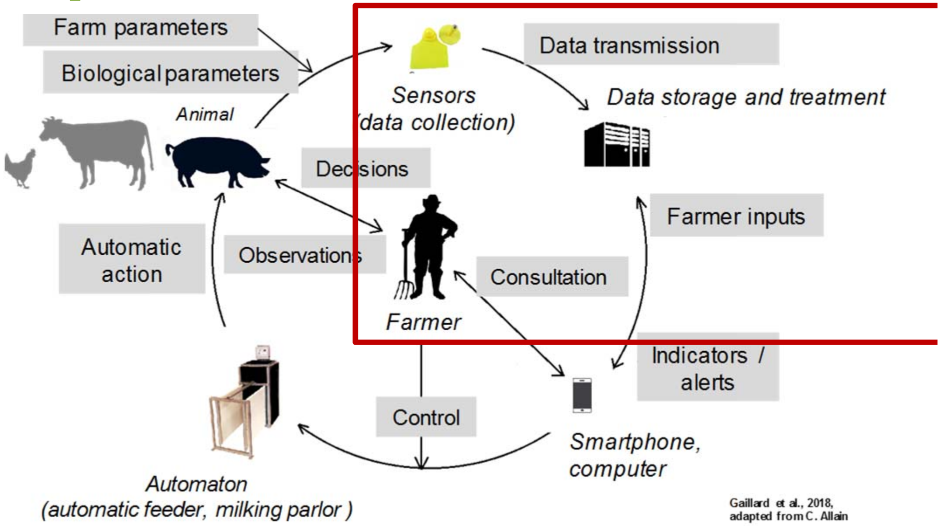


Principles of precision feeding

- **Improve the characterization of individual animals (or small groups)**
  - Feed intake, Growth potential
  - Body condition
  - Physical activity, health…
- **To better adapt supplies …**
  - Quantity / Quality
  - According to time
  - to groups or individuals
- **… and improve efficiency**
  - reduction of cost
  - reduction of excretion
  - control of quality



Apply up-to-date nutritional concepts and use simulation/prediction models



- **Protein-Amino acids**
  - Stand. ileal digestibility
  - « Ideal » protein
- **Energy**
  - Energy system (NE, ME)
- **Phosphorus**
  - Digestible phosphorus
- **Using nutritional simulation models** (e.g. InraPorc®) **to handle the information and take the decisions**
  - Determination of optimal nutrient supplies

Required elements for precision feeding

- **Tools for identification and measurement**
  - ex.: weighing scales, automatic feeders (control and measurement of feed intake)
- **Decision support tools**
  - ex.: mathematical models for real-time calculation of individual nutritional requirements taking into account behavior and housing conditions
- **Tools to control**
  - ex.: automatic feeders able to mix several feed to prepare individual ration to be fed; control of feed composition
- **An improved knowledge of feed** (nutritional composition, feed technology, additives…)

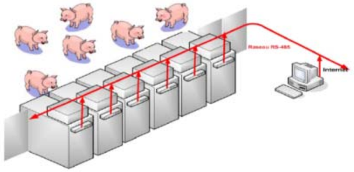
Precision feeding and feed characteristics

Importance of feed in such approach (Banhazi et al., 2012)

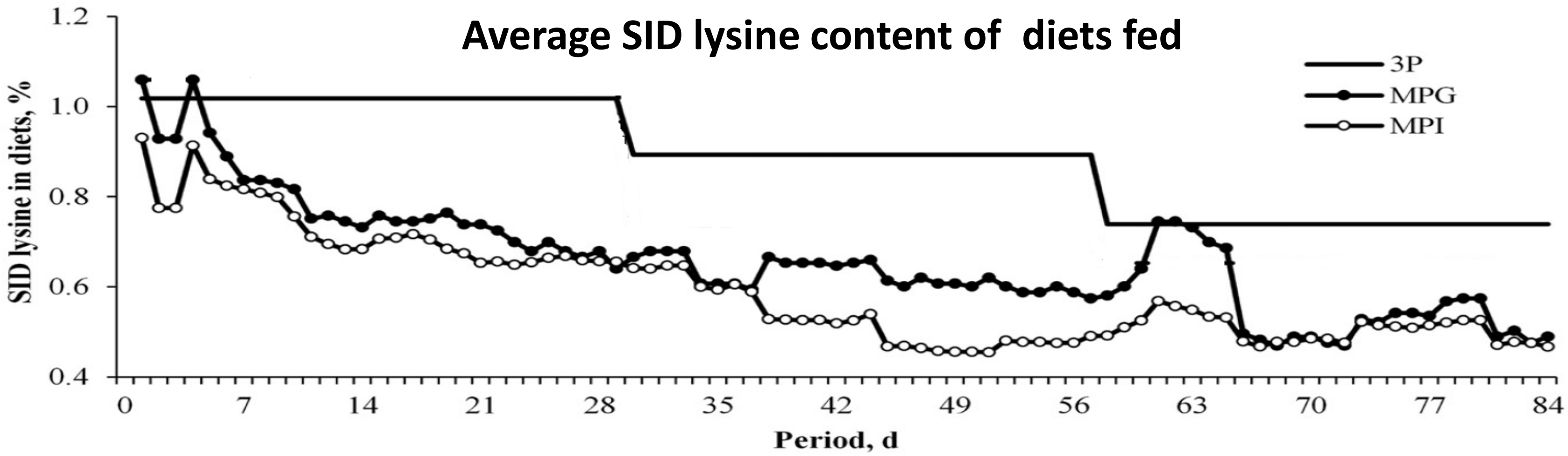
1. Use of a precise matrix for both nutrient requirement and nutrient content of the ingredients;
2. Proper use of modifiers such as enzymes, prebiotics, probiotics, antioxidants, mould inhibitors and other feed additives;
3. Exploiting genetic improvements in animals and feedstuffs;
4. Reduction of toxicants and antinutritive factors;
5. Use of improved feed and feedstuff processing techniques that will lead to better nutrient utilization

Some results in fattening pigs

Andretta *et al.* (2014)



Comparison of :	3-Phase group feeding	(3P)
	multiphase group feeding	(MPG)
	multiphase individual feeding	(MPI)



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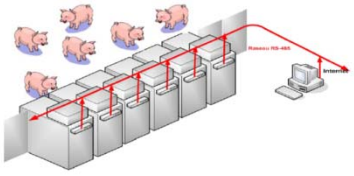
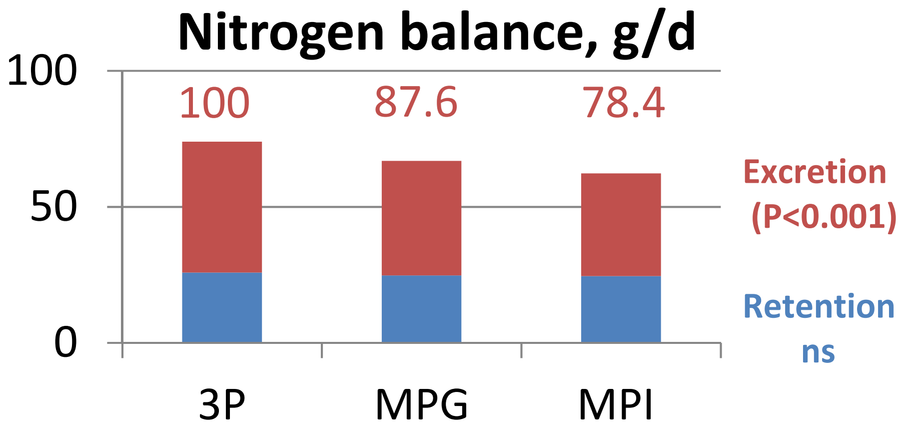
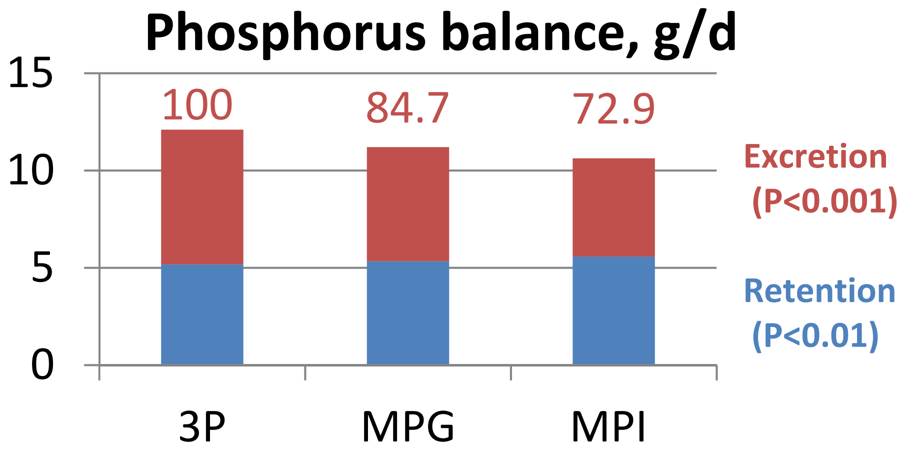


Comparison of :		
	3-Phase group feeding	(3P)
	multiphase group feeding	(MPG)
	multiphase individual feeding	(MPI)

No effect on ADG and FCR





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EU funded Research project

2015
2020

€10 M
Budget

Feed-a-Gene

Adapting the **feed**, the **animal** and the **feeding techniques** to improve the efficiency and sustainability of monogastric livestock production systems
(www.feed-a-gene.eu)

23
Partners
EU + China

15
Industry

8
Academic

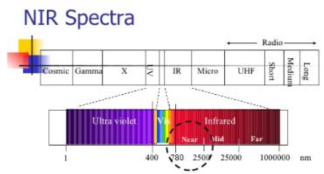
The Feed-a-Gene Project has received funding from the European Union's H2020 Programme under grant agreement no 633531.

Objectives of the Feed-a-Gene project

- Feed:
  - Develop new local feed resources that are not/less in competition with food
  - Improve the nutritional value of feed resources
- Gene:
  - Use of novel traits indicative for feed efficiency and robustness that can be used as selection criteria
  - “Do better with feeds that may be worse”
- Traits, models, and feeding techniques:
  - Appreciate variation among animals
  - Develop precision feeding techniques
  - Evaluate the overall sustainability

Development of models to predict the nutritional value of feedstuffs and feed mixtures by NIRS in real-time

Feed-a-Gene

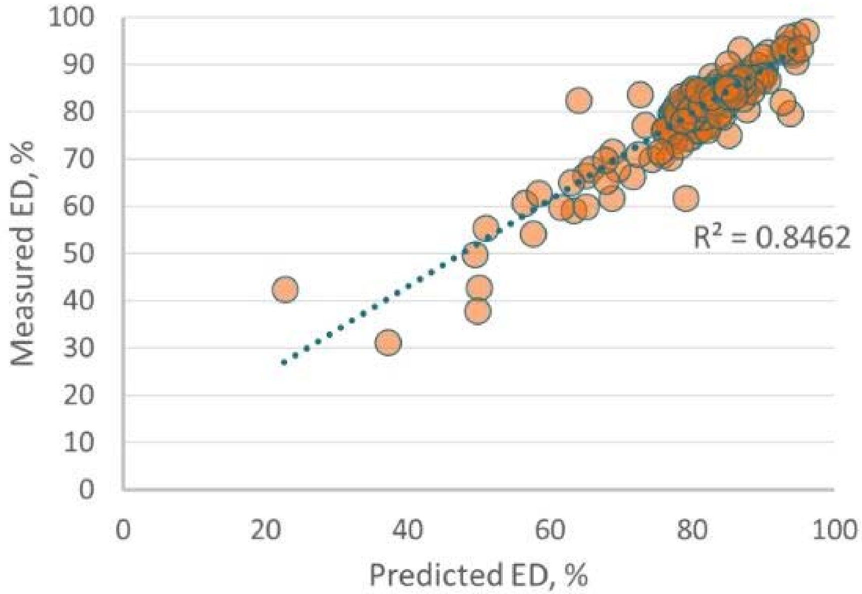


➢ Objectives

- To determine if it is possible to use NIRS to predict the nutritive value of animal feed
  - Chemical components
  - Digestible energy and macronutrients, and metabolizable energy in pigs

- For characterisation of chemical and nutritional properties of feed in real time

Energy digestibility of cereal grains in pigs: measured vs predicted by NIRS



(Noel et al., 2018, Aarhus University)

- **In general, NIR calibration models had good predictive ability and robustness, though they were not suitable to predict the mineral composition of cereals**

New animal traits for innovative feeding and breeding strategies

Feed-a-Gene

behavior and welfare

image analysis
serotonin, cortisol

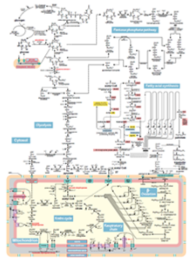
individual feed intake

feed intake patterns
feeding behavior

digestive efficiency

digestibility markers
gut health
microbiota

metabolic efficiency

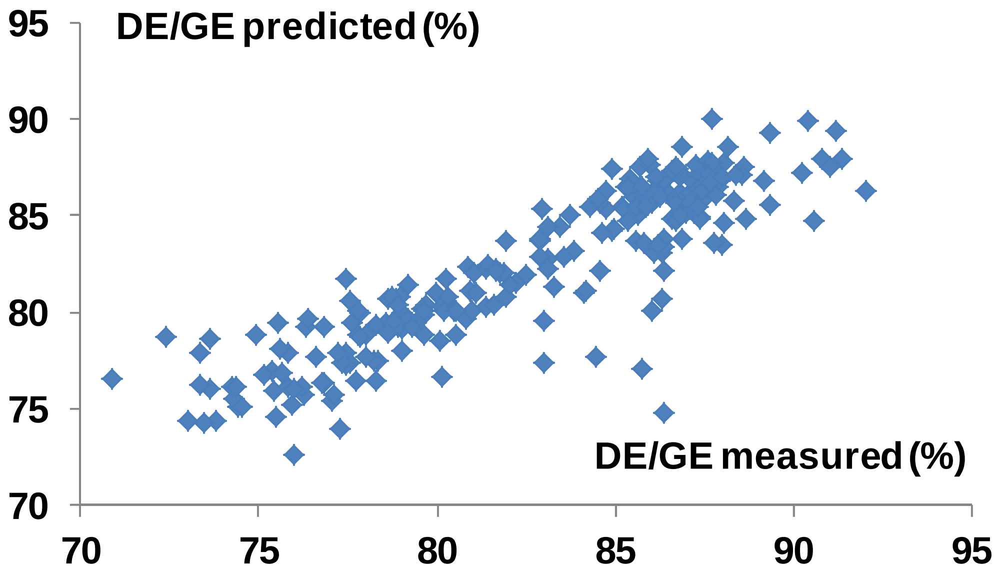


metabolomics

NIRS to analyze individual digestibility of feed

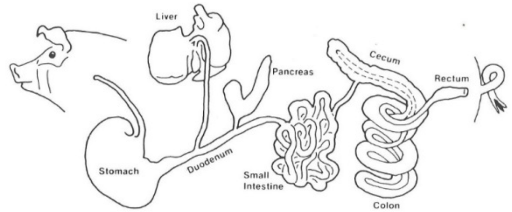
Feed-a-Gene

Calibration on 750 fecal samples
Validation (80 data): R^2=87%

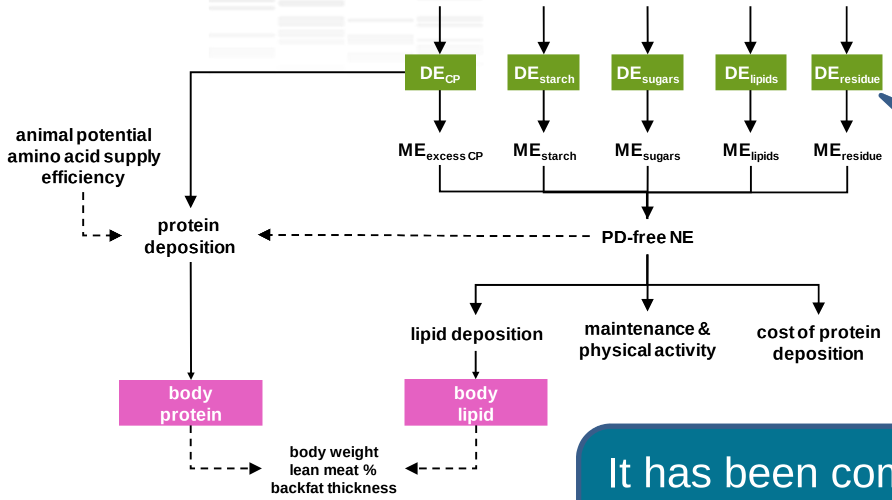


Labussière (2018)

Modeling biological functions



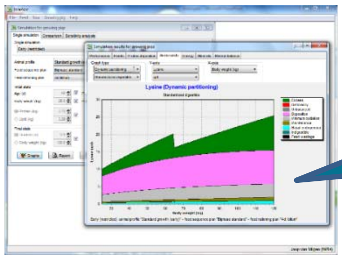
Feed-a-Gene



Nutritional growth models such as InraPorc use digestible nutrients as model inputs …

Can they help to better understand/predict feed use?

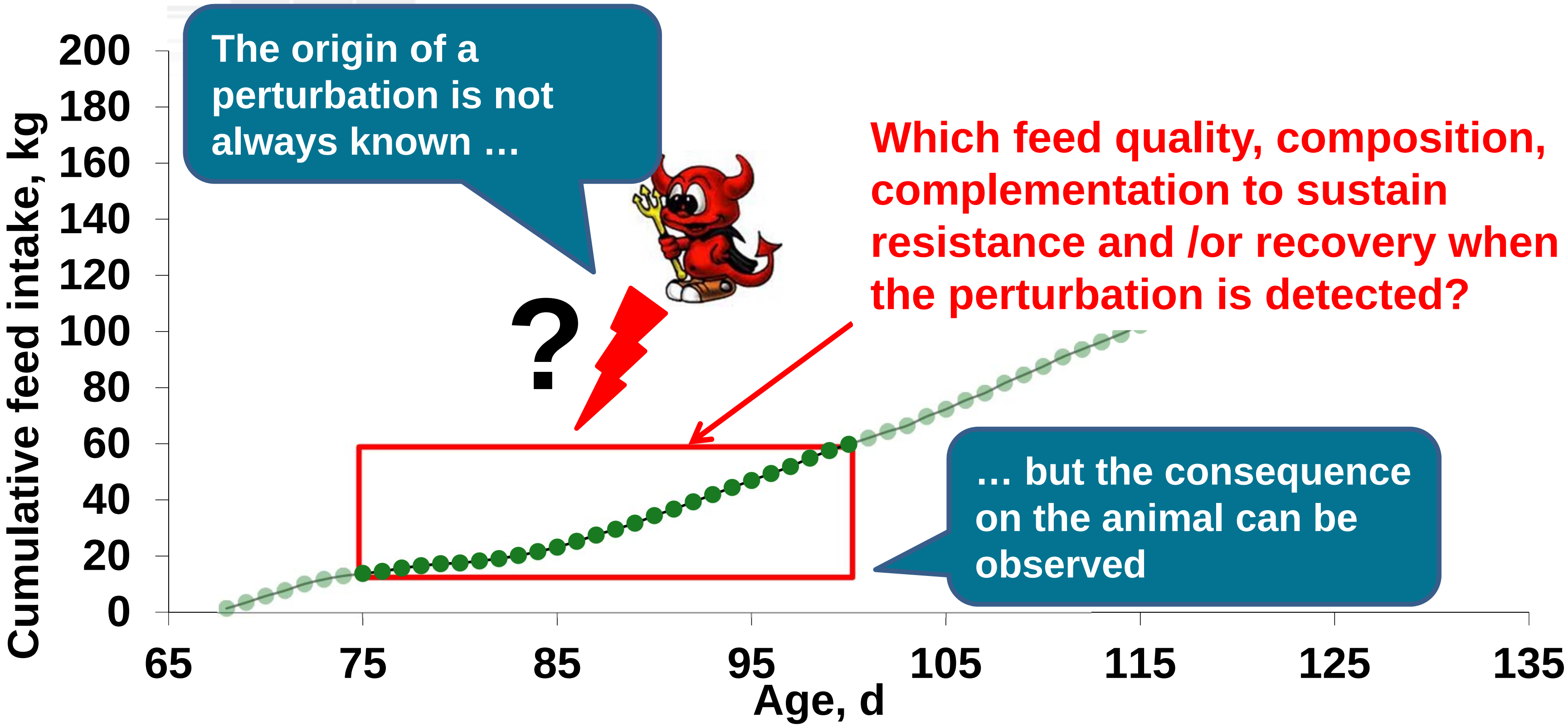
It has been combined with digestive models and extended to be generalized to pigs and poultry



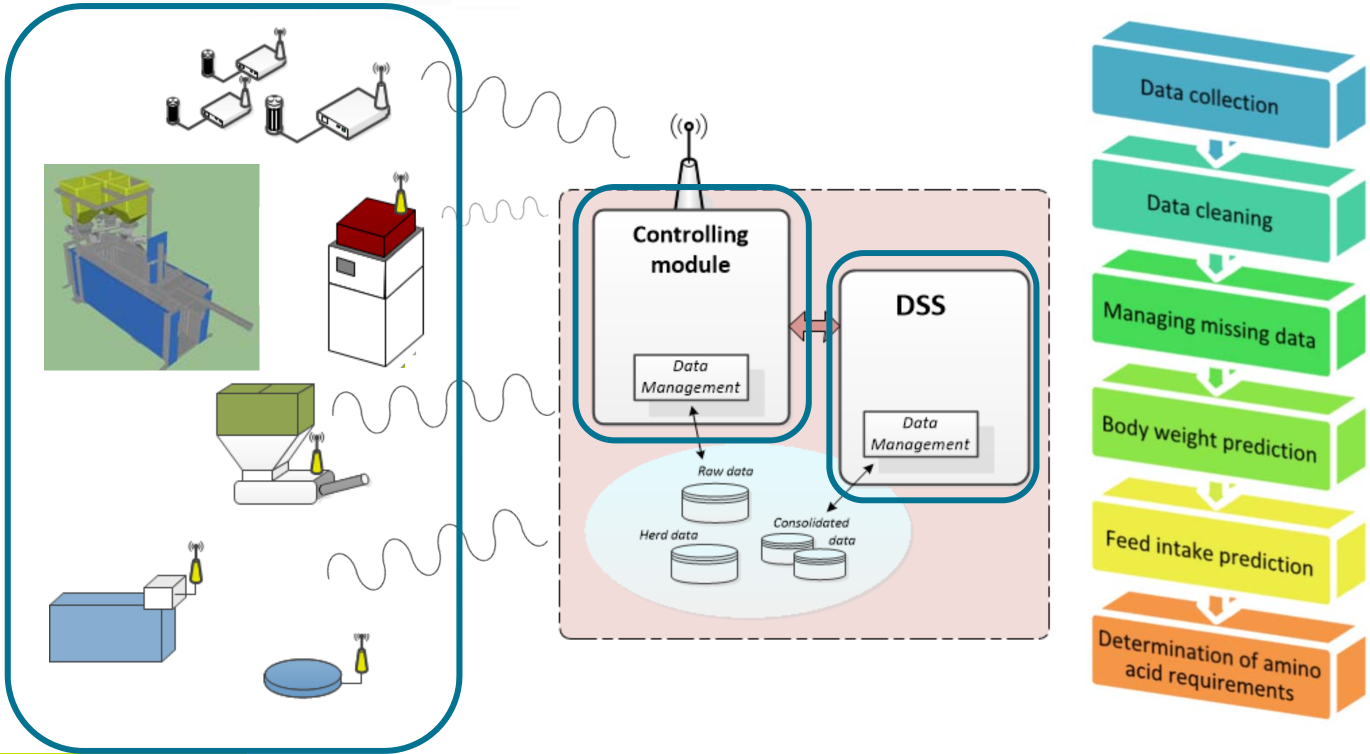
… to predict performance traits of a single animal in a "standard" environment

Modeling perturbations in feed intake patterns

Feed-a-Gene



Management systems for precision livestock feeding (pigs/sows/broilers)



Observation

Prediction

Control

System prototypes are now being tested

- **Growing pigs**
  - **Restricted feeding**

  - **Ad-libitum feeding**

- **Sows**
  - ***Gestation***

  - ***Lactation***

Example in lactating sows
A two-diet mix, for each sow, each day

Feed-a-Gene

Data

Sow
- Body Weight
- Backfat Thickness
- Parity

Litter
- Litter Size
- Average Daily Gain
- Duration of lactation

Sow
- Feed intake in previous days

Nutritional requirements factorial model, $g.d^{-1}$

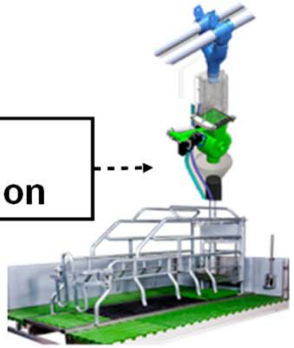
Feed intake predictive model, $kg.d^{-1}$

Optimal concentration calculation, $g.kg^{-1}$

A/B (%) determination

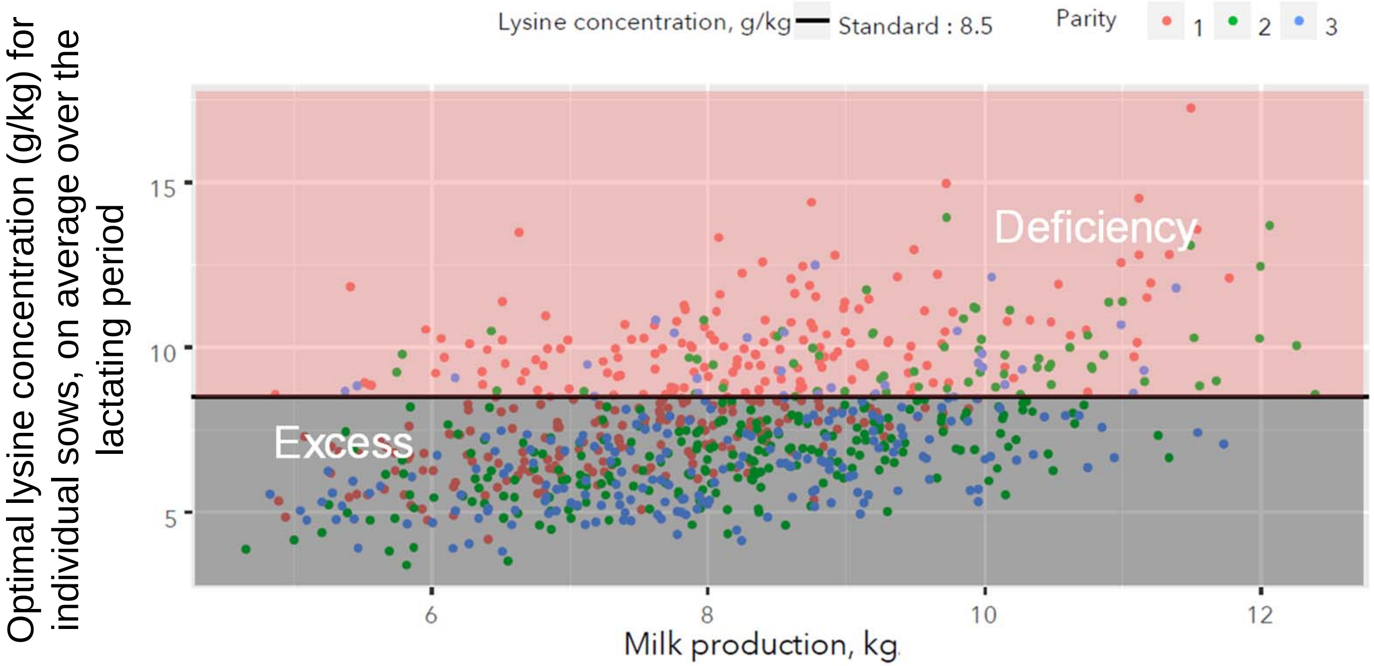
ME: 12.8 $MJ.kg^{-1}$
Lys_{DIS}: 11.5 $g.kg^{-1}$
P_{DIS}: 4.3 $g.kg^{-1}$

ME:12.8 $MJ.kg^{-1}$
Lys_{DIS}: 6.5 $g.kg^{-1}$
P_{DIS}: 2.3 $g.kg^{-1}$



Gauthier et al., 2018

Impact of two-diet mix strategy (simulation)

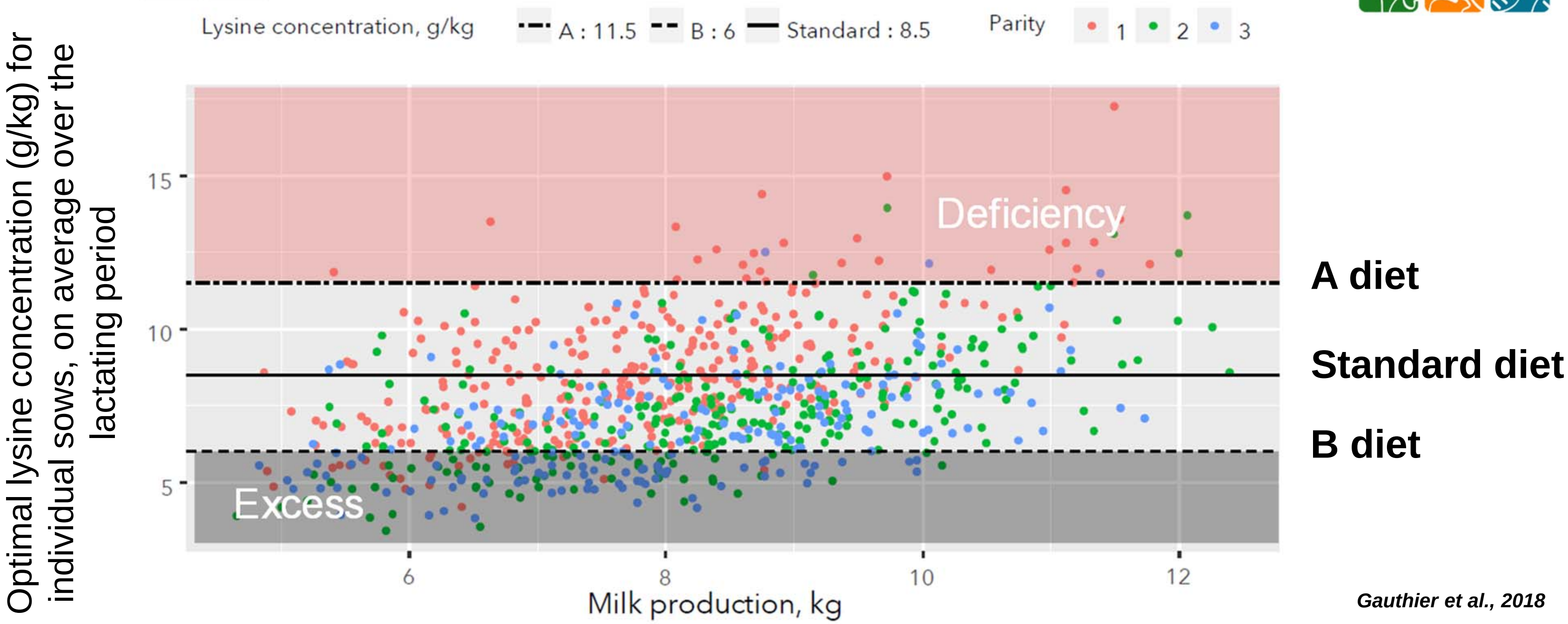


Standard diet

Gauthier et al., 2018

Impact of two-diet mix strategy (simulation)

Feed-a-Gene



Gauthier et al., 2018

➔ **A two-diet mix permits to better cover the individual requirements**

➔ **Lysine and P intake reduced by 8%, and imbalances by 52 to 70%**

Consequences on feed management (1)

- **With PLF and precision feeding techniques, possible to mix two or more diets ➔ change in formulation practices:**
  - **two “extreme” balanced diets (high/low nutrient content)**
  - **more than two diets (intermediate diets to reduce costs)**
    - **➔ A-B mix then B-C mix then C-D mix with nutrient content A>B>C>D**
  - **Two or more non balanced diets to further reduce costs and envt impact**

Letourneau Montminy et al., 2005; Joannopoulos et al., 2017

- **Management at farm level: possible to have “all-stages” strategy**

Consequences on feed management (2)

- **Better knowledge on animal status and feed /composition impact through real-time in situ data**
  - **Targeted actions on [digestibility, efficiency…] through additives depending on feed characteristics**
  - **Targeted actions through feed or water for health management or answer to housing conditions**
    - **ex.: amino-acids requirements (TRP…) ↗ with deteriorated health status ➔ adjustment through water or feed on supplies depending on health events**
    - **ex.: adjustment of energy density depending on climate**

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✓ Conclusion and perspectives

Precision livestock farming …

- Requires to transform data into information, which needs to be integrated
- Increases resource efficiency and reduces environmental impact
- Accounts for the needs of individuals

- New possibilities offered to feed and feed additives producers
  - formulation
  - use of new feedstuff
  - use of additives for more reactive and targeted actions
  - larger scale (several farms) management of feed provisional…

A future to write …

- PLF is still in its infancy
- Can change the design of animal production systems: evolution of these systems?

- **Large progress to come**
  - Technical and decision systems

- **Still to do before innovation acceptance**
  - return on investment to calculate
  - usefulness and ergonomic for farmers…

Thank you for your attention