Towards the quantitative characterization of piglets robustness to weaning: A modelling approach

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Introduction

Weaning: a critical period

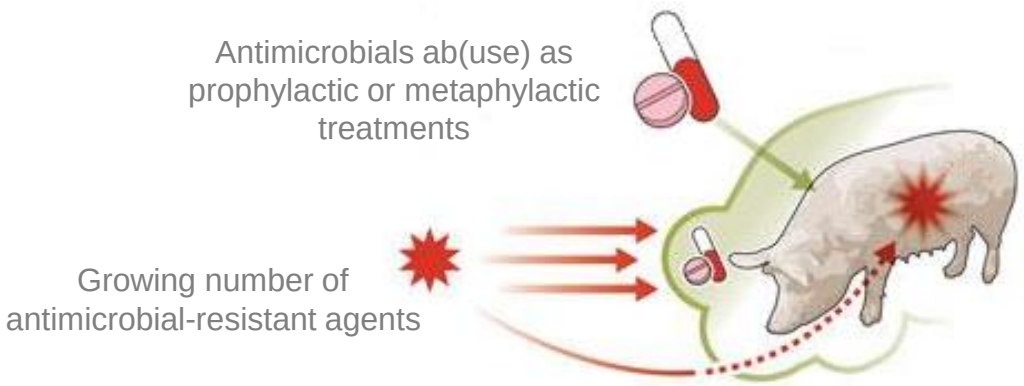
- Weaning is one of the most critical phases in modern swine breeding conditions[1]
- Practice at around 3-4 weeks of age. Natural weaning occurs around 17 weeks after birth[2]

[1] Lallès *et al*.: *Proc Nutr Soc.* 2007, 66:260-268.
[2] Jensen: *Appl Anim Behav Sci*. 1986, 16:131-142.

Introduction

Weaning: a critical period

- Weaning is a sudden, stressful, short, and complex event characterized by changes in diet, social, and environmental life conditions[3]
- Multiple stressors inducing: anorexia, intestinal inflammation, unbalanced gut microbiota…[4]



[3] Campbell *et al.*: *J Anim Sci Biotechnol.* 2013, 4:19.
[4] Pié *et al.*: *J Nutr*. 2014, 134:641-647.

Introduction

Weaning: assistance health and management

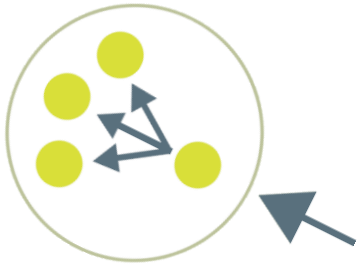
- Increasing interest of developing tools for assisting health and management decisions around weaning

- It is key to provide robustness indexes that inform on the animal resilience to weaning

Introduction

Robustness concept

- A new crucial goal in breeding strategies
- Definition: Capacity to maintain productivity in a wide range of environments without compromising reproduction, health, and wellbeing[5]



- Elements of robustness:
  - The potential to keep functioning (**resistance**) and take short periods to recover (**resilience**) under varying environmental conditions[6]
- **Multi-trait index**, according to their fitness value in a given environment and production system

[5] Friggens *et al.*: *Animal* 2017, 11:2237-2251.
[6] Star *et al.*: *J Agric Environ Ethics* 2008, 21:109-125.

Objective

our **aim**

Develop a modelling approach for facilitating the quantification of piglet resilience/robustness at weaning

our **material**

Using an experimental Large White population

our **strategy**

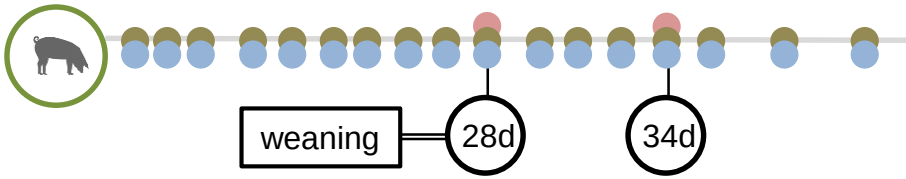
Construct a perturbed model in order to provide biological parameters that inform on the amplitude and length of the perturbation

Material & Methods

Experimental population

INRA's *Le Magneraud* experimental unit

- **325 Large White pigs**
  - Without antibiotic administration
  - Conventionally housed and fed during the post-weaning period
- **Recorded traits**
  - Body weight measurements
  - Diarrhoea score (0, 1, 2)
  - Health status measurements



Material & Methods

Mathematical model approach

Scilab[7]

Perturbed model
Gompertz-Makeham equation

Normalized Error function (i)

$$Error\ value\ = \left(\frac{W\ - Wd}{W_d}\right)^2 \qquad \text{(i)}$$

Where W_d represented the weight data (kg) and W the weight predicted by the model

Error weighted with respect to the size of the registers for each animal (ii)

$$J = \frac{sum\ (Error\ value)}{length\ (t)} \qquad \text{(ii)}$$

[7] https://www.scilab.org/.

Material & Methods

Mathematical model approach: A perturbed model

- Dynamic model based on the **Gompertz-Makeham law**[8] (iii, iv)
  - Describe live weight during the first 75 days after weaning
  - Animal response to the perturbation partitioned in two time windows:
    - perturbed / recovery window
    - Individual specific transition time between windows

Gompertz-Makeham law is an extension of the Gompertz model to consider the effect of a disturbing environment

[8] Golubev: *J Theor Biol.* 2009, 258:1-17.

Material & Methods

Mathematical model approach: A perturbed model

Dynamic of weight of piglets represented by two ordinary differential equations (iii, iv) based on **Gompertz-Makeham law**

$$dW/dt = W * (-C + \mu) \quad \text{(iii)}$$

$$d\mu/dt = -D * \mu \quad \text{(iv)}$$

Where *W* (kg) is the weight, *μ* (1/d) is the specific growth rate, *D* (1/d) is a developmental parameter and *C* (1/h) is a parameter representing the effect of the environment on the weight

Material & Methods

Mathematical model approach: A perturbed model

To represent the moment at which the animal is perturbed and the moment at which it recovers from the perturbation, we assumed **two time windows**. Mathematically modelled in the parameter *C*

$$C > 0 \text{ if } t \leq t_s$$

$$C = 0 \text{ if } t > t_s$$

Where t_s is the time of switch and is assumed to be specific for each animal

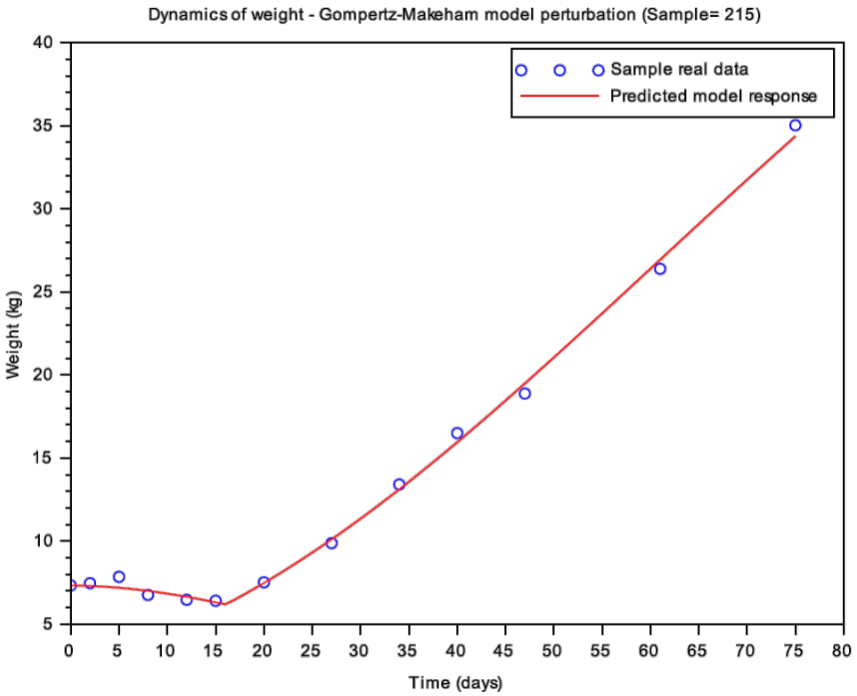
Results

Perturbed model: parameters

Gompertz-Makeham law consider the effect of a disturbing environment (weaning)

Parameters

- *Model Error*: Level of fitting of the model
- *C*: Discriminative of the level of perturbation
- t_s: Indicates the moment at which the animal recovers from the perturbation



|**Figure 1**| Dynamics of weight using perturbed Gompertz-Makeham law

Results

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Gompertz-Makeham law consider the effect of a disturbing environment (weaning)

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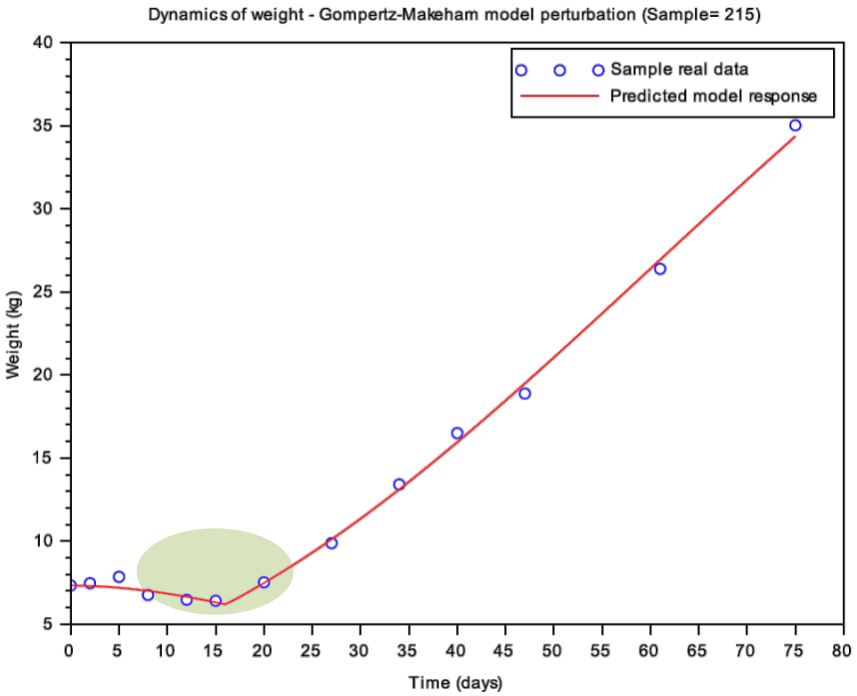

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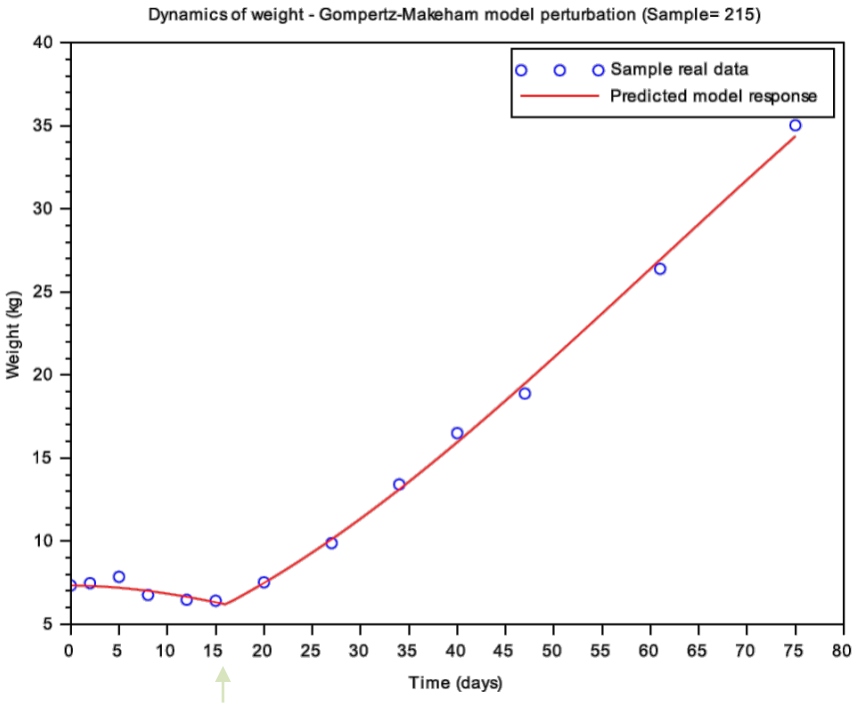
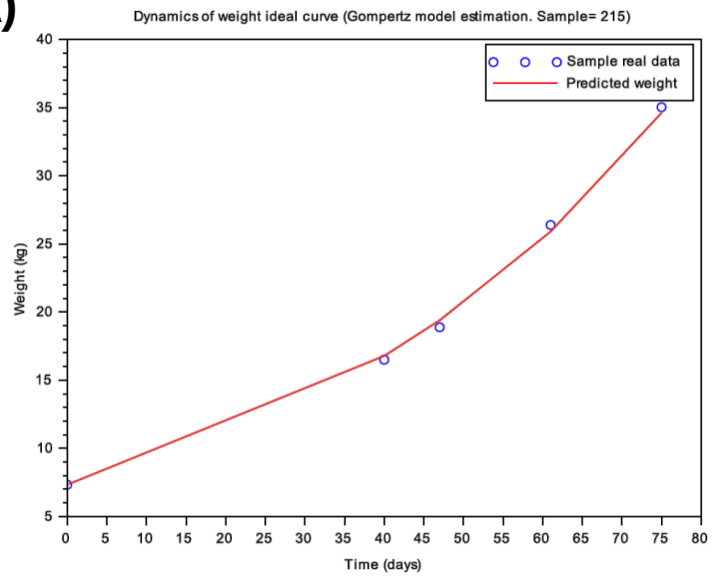


|**Figure 1**| Dynamics of weight using perturbed Gompertz-Makeham law

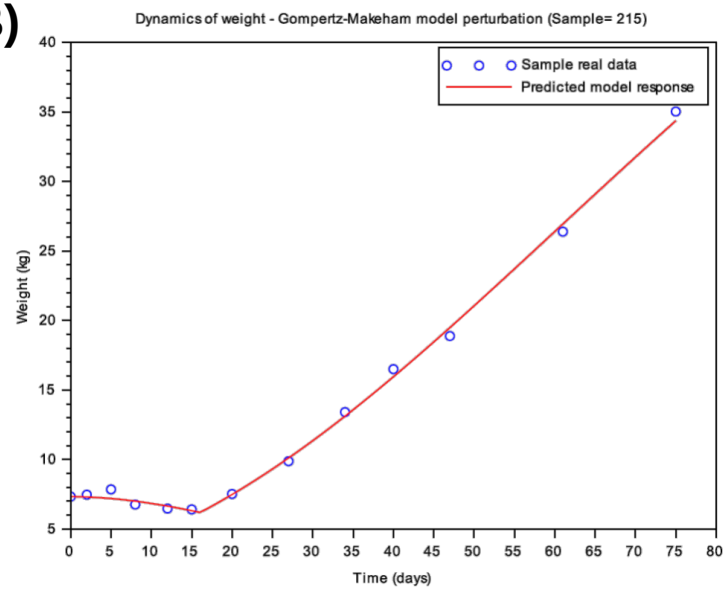
Results

Theoretical growth rate curve (Unperturbed) and Gompertz-Makeham model (Perturbed)

A)



B)

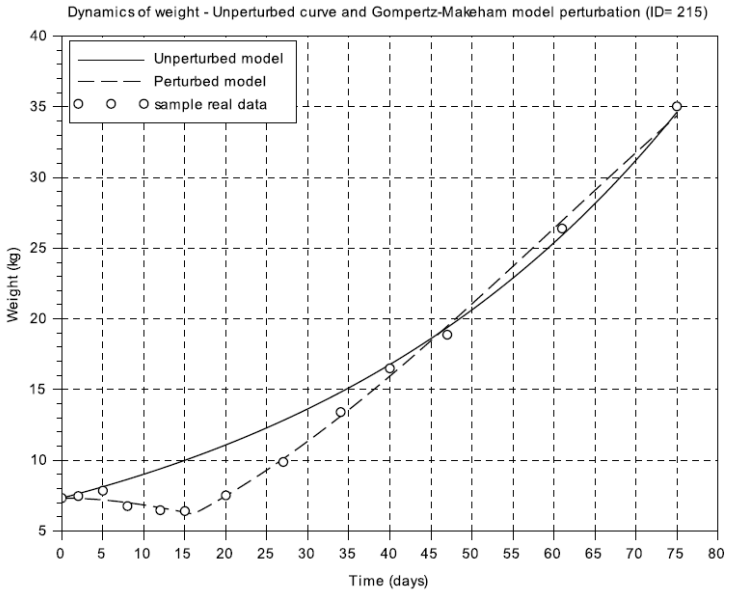


|**Figure 2**| Example of the dynamics of weight for one animal (sample= 215). **A)** Theoretical growth rate curve (Unperturbed) using Gompertz equation. **B)** Predicted response using Gompertz-Makeham law (Perturbed)

Results

Area between curves (*ABC*) parameter

- The area between curves (***ABC***) parameter is an index that balances goodness of fitting of the model
- **Robustness index**
- Inform on the animal capabilities in terms on the amplitude and length of perturbation, and the rate of animal recovery

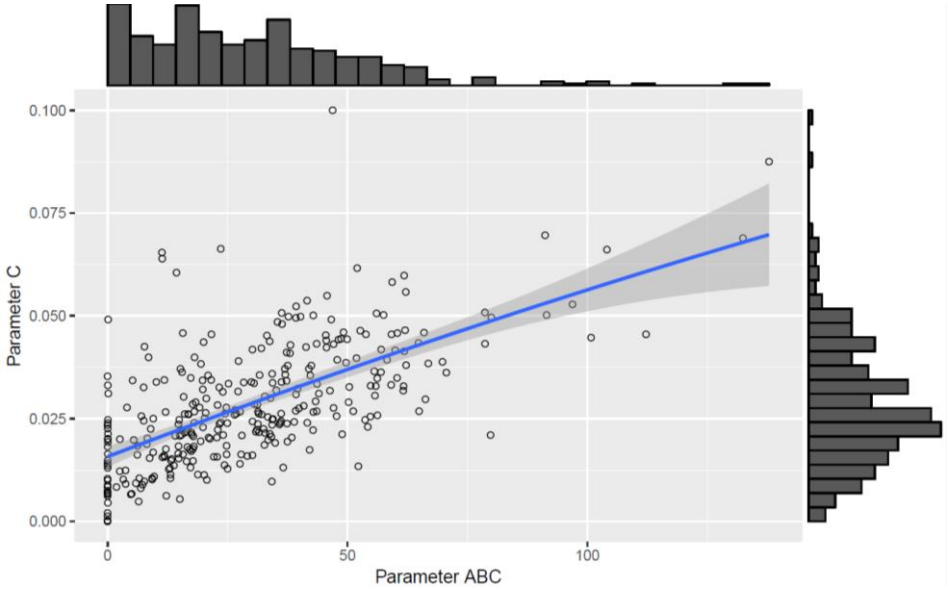


|**Figure 3**| Comparison of the weight dynamics as predicted by the unperturbed and the Gompertz-Makeman (perturbed) models. ID= 215 is represented

Results

Perturbed model: parameters correlation

- High positive correlation (r= 0.64; *p*-value= $3.34x10^{-17}$) between Parameter *C* and Parameter *ABC*
- High proportion of animals with a moderate degree of perturbation

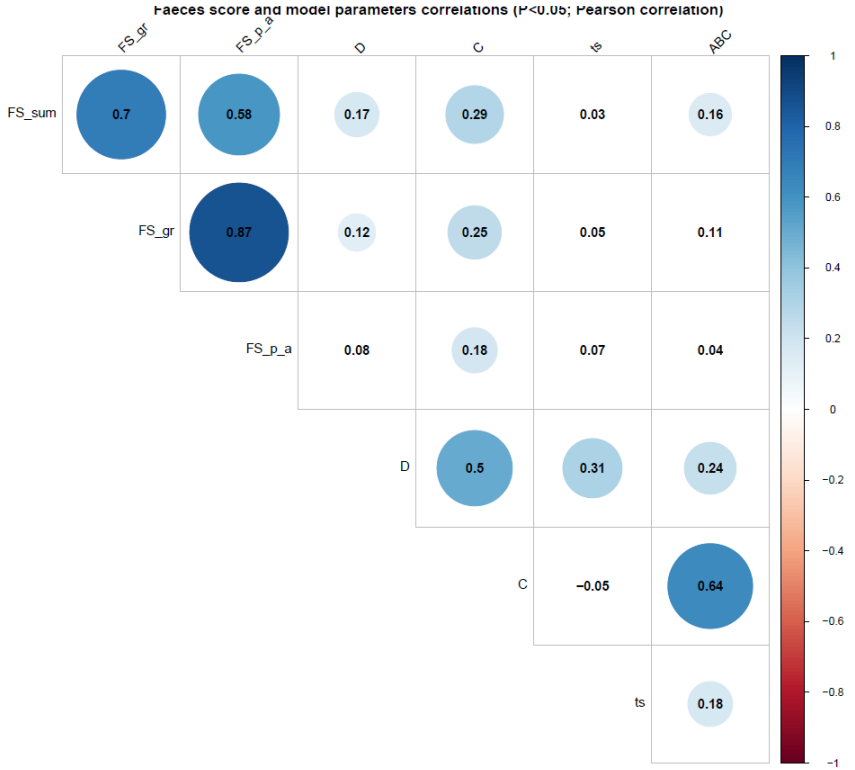


|**Figure 4**| Scatter plot with marginal histograms illustrating the relationship between: Parameter *C* and Parameter *ABC*

Results

Correlation analyses: Faeces Score

- The **Model Parameters** and **Faeces Score correlations** revealed significant positive associations
- Faeces Score data:
  - *FS_sum*: Number of diarrhoea measurements, corrected by number of observations per each animal
  - *FS_group* (3 levels):
    - 0: No diarrhoea observation
    - 1: One diarrhoea register
    - 2: Two or more diarrhoea registers
  - *FS_p_a* (2 levels): Presence/absence

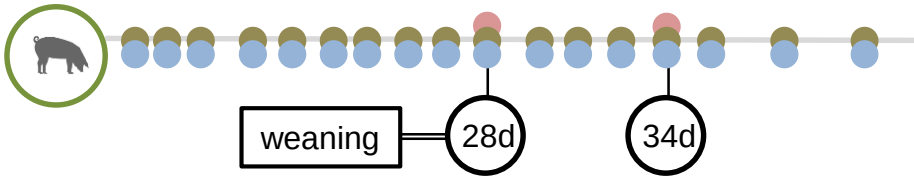


|**Figure 5**| Correlations among Model Parameters and Faeces Score data

Results

Correlation analyses: Health status measurements

- The **Model Parameters** and **health status** measurements revealed significant associations



Date Measurements	Model Parameter	Health status measures	Correlation	Bibliography
28d	*ABC*	Hematocrit (Hct)	-0.38***	High association with average daily gain in the three weeks post-weaning[9]
		Hemoglobin (Hgb)	-0.32***	
34d	*ABC*	Monocytes (Mon)	-0.30***	Estimator of the animal health status[10]

[9] Bhattarai & Nielsen: *Livest Sci.* 2015, 182:64-68.
[10] Chamorro *et al.*: *Immunology* 2005, 114:63-71.

Conclusions

- We have create an **animal ranking** with respect to the distance between the population data and the model
- This work provides **biological parameters** derived by modelling piglet body weight trajectories from weaning
- These parameters inform on the **amplitude** and **length of perturbation**, and the rate of animal recovery
- We have identified **significant correlations** between the model **parameters index** and individual **diarrhoea scores** and **health status** measurements

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