

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 conditions¹
- Practice at around 3-4 weeks of age. Natural weaning occurs around 17 weeks after birth²



¹ Lallès *et al.*: *Proc Nutr Soc.* 2007, 66:260-268.

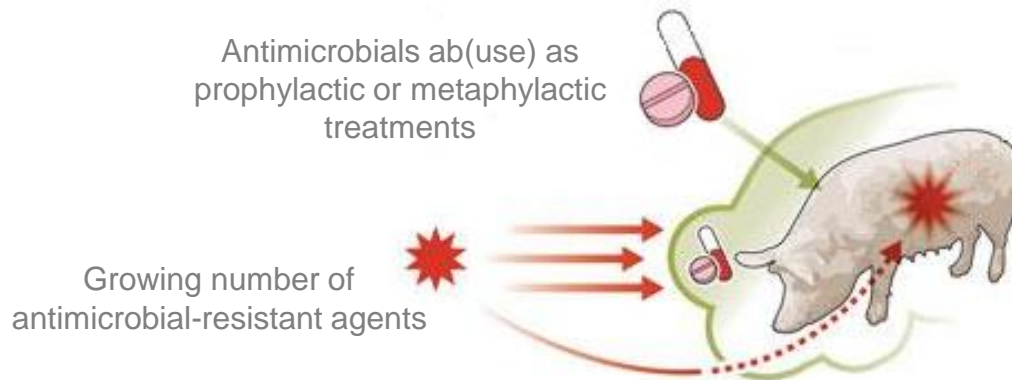
² Jensen: *Appl Anim Behav Sci.* 1986, 16:131-142.



Introduction

Weaning: a critical period

- Weaning is a sudden, stressful, short, and complex event characterized by changes in diet, social, and environmental life conditions³
- 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

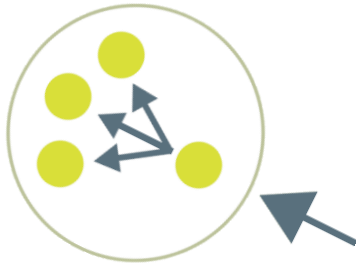




Introduction

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 wellbeing⁵



- Elements of robustness:
 - The potential to keep functioning (**resistance**) and take short periods to recover (**resilience**) under varying environmental conditions⁶
- **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**

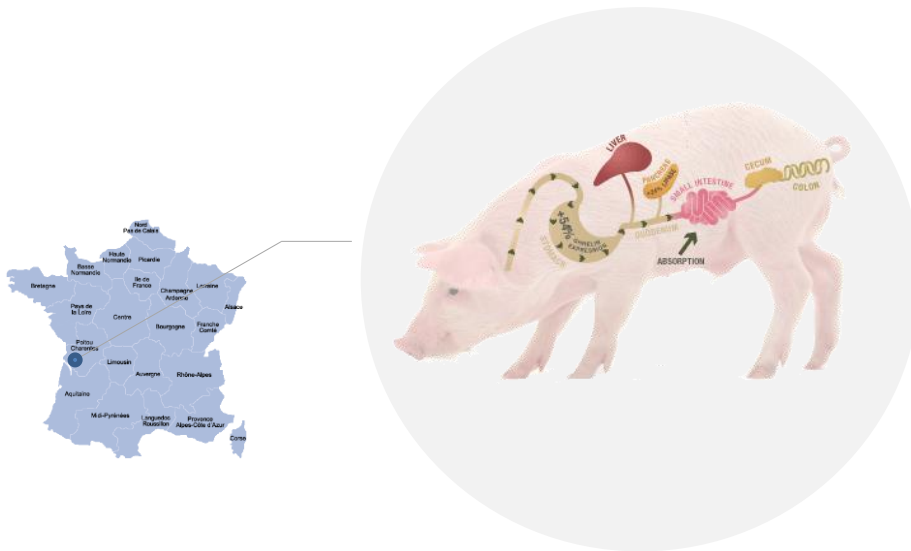
Construct a perturbed model in order to provide biological parameters that inform on the amplitude and length of the perturbation



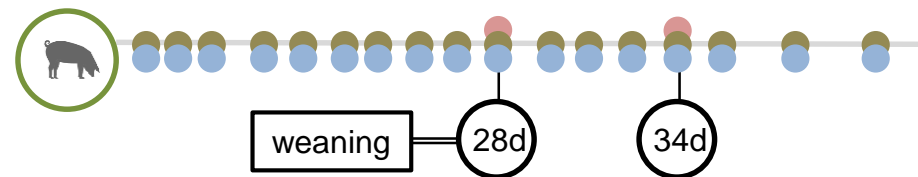
Material & Methods

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



Perturbed model Gompertz-Makeham equation

Normalized Error function (i)

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

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)

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

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

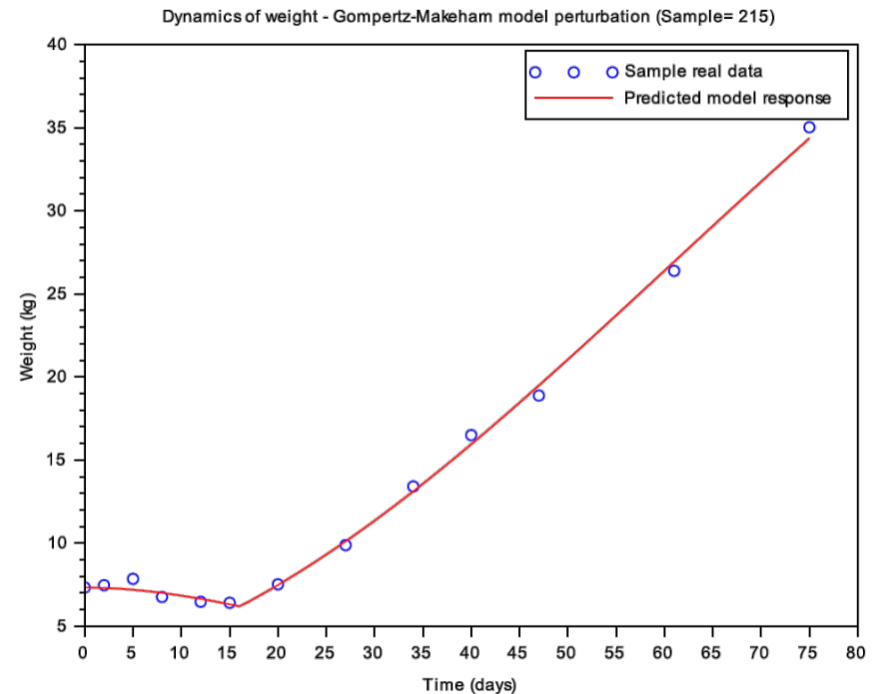


Figure 1 | Dynamics of weight using perturbed Gompertz-Makeham law



Results

Perturbed model: parameters

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

Parameters

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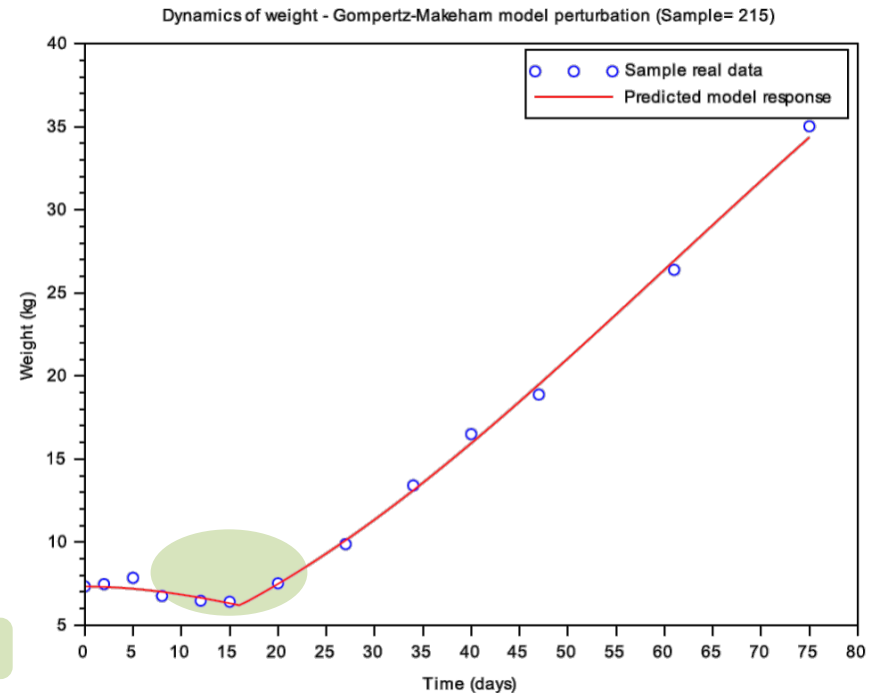


Figure 1 | Dynamics of weight using perturbed Gompertz-Makeham law



Results

Perturbed model: parameters

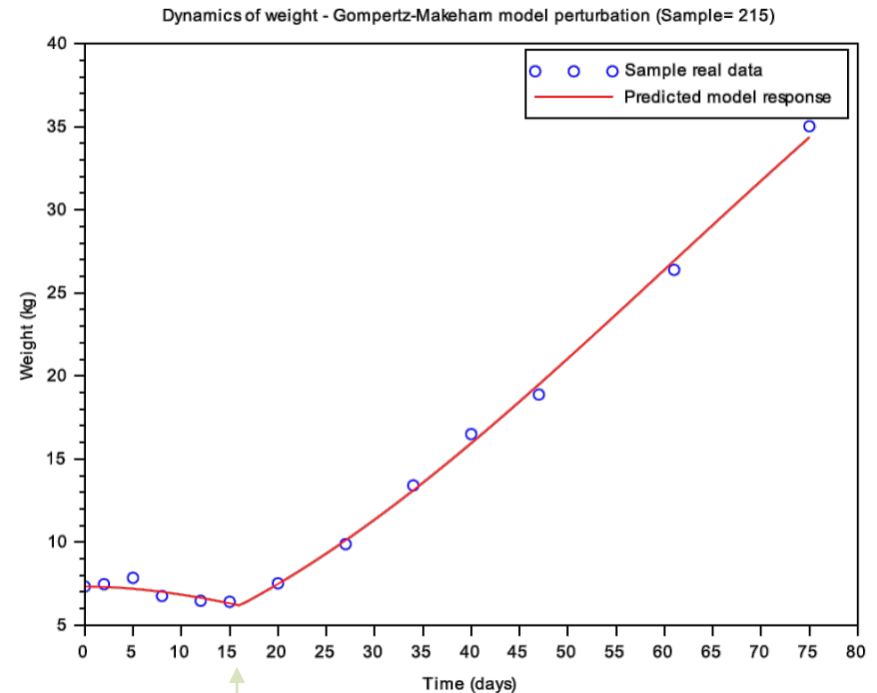
Gompertz-Makeham law consider the effect of a disturbing environment (weaning)

Parameters

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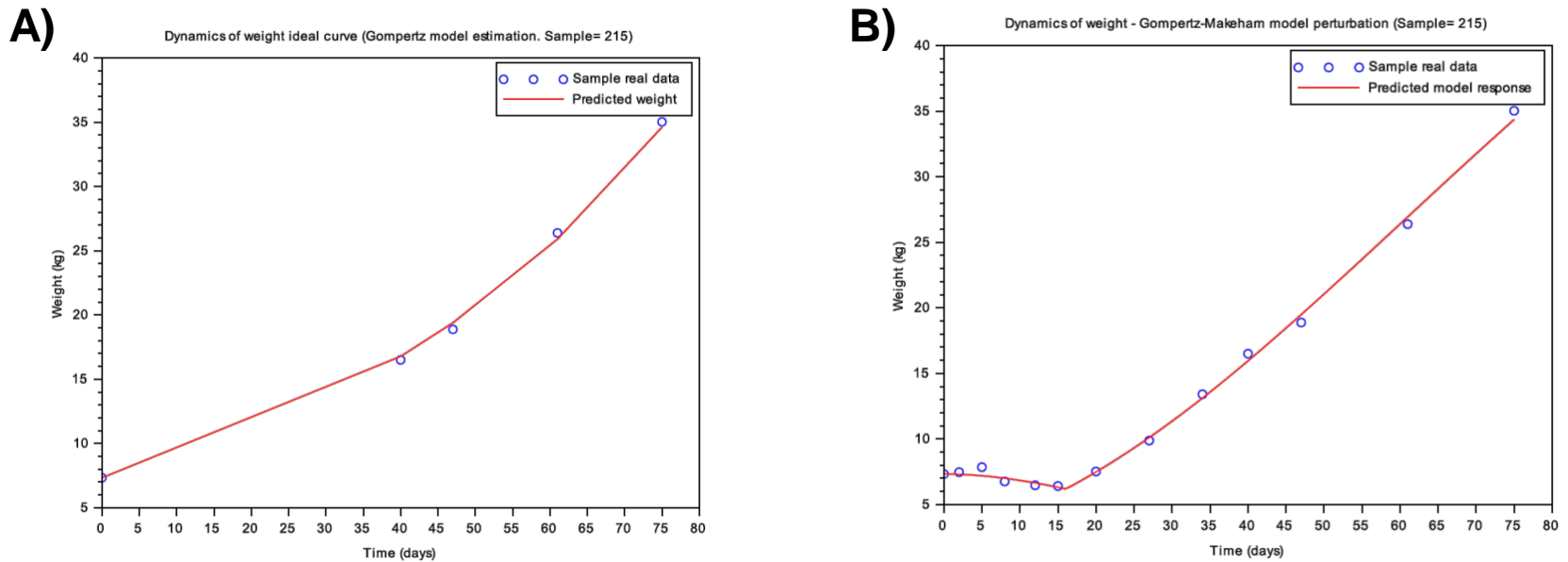
t_s : Indicates the moment at which the animal recovers from the perturbation



[Figure 1] Dynamics of weight using perturbed Gompertz-Makeham law

Results

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



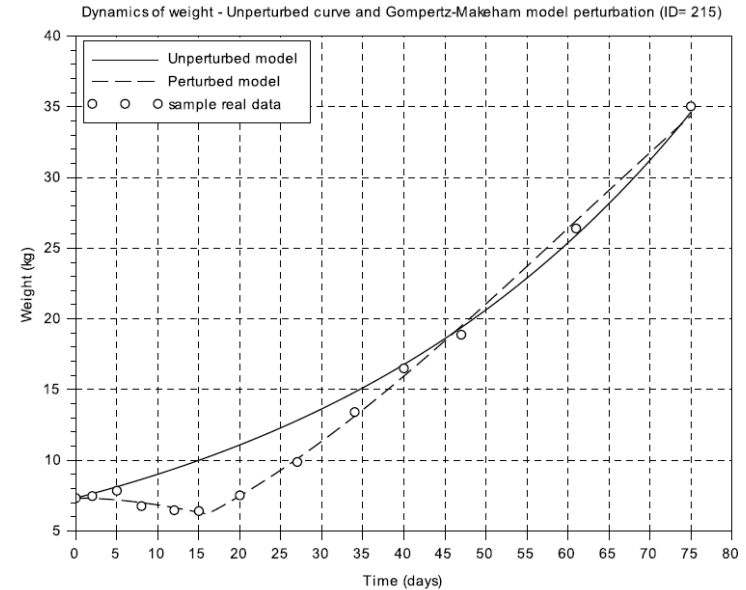
[Figure 2] Example of the dynamics of weight for one animal (sample= 215). **A)** Theoretical growth rate curve (Unperturbed) using Gompertz equation. **B)** Predicted response using Gompertz-Makeham law (Perturbed)



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



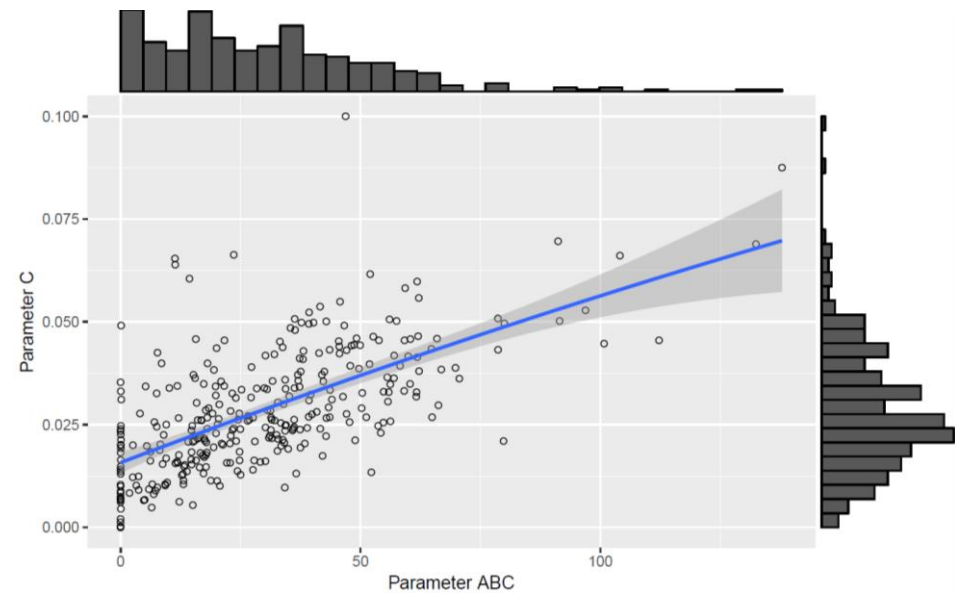
[Figure 3] Comparison of the weight dynamics as predicted by the unperturbed and the Gompertz-Makeman (perturbed) models. ID= 215 is represented



Results

Perturbed model: parameters correlation

- High positive correlation ($r= 0.64$; $p\text{-value}= 3.34 \times 10^{-17}$) between Parameter C and Parameter ABC
- High proportion of animals with a moderate degree of perturbation



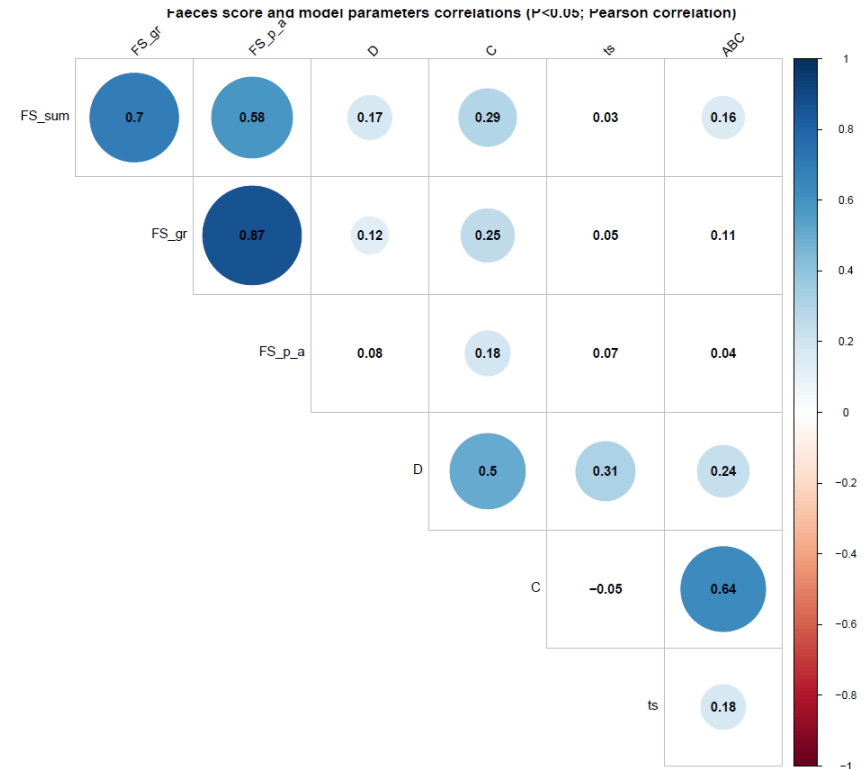
[Figure 4] Scatter plot with marginal histograms illustrating the relationship between: Parameter C and Parameter ABC



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



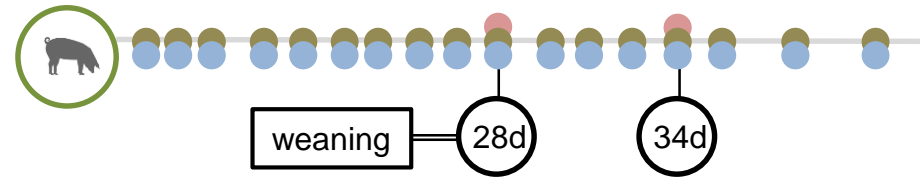
[Figure 5] Correlations among Model Parameters and Faeces Score data



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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With the collaboration of





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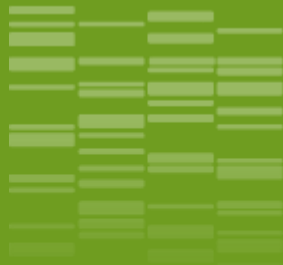
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