Predicting phosphorus and calcium requirements for broilers

"Evaluation of a mechanistic model predicting phosphorus and calcium requirements for bone mineralization of growing broilers"

M. Reis, N. Sakomura, I. Bouvarel, R. Angel, A. Narcy, M. Létourneau Montminy

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Background

General duty of a nutritionist

- Decision making
- The implementation of those decisions

How to take a decision?

- Consequences of all alternatives
  - experience
  - experiments
  - models

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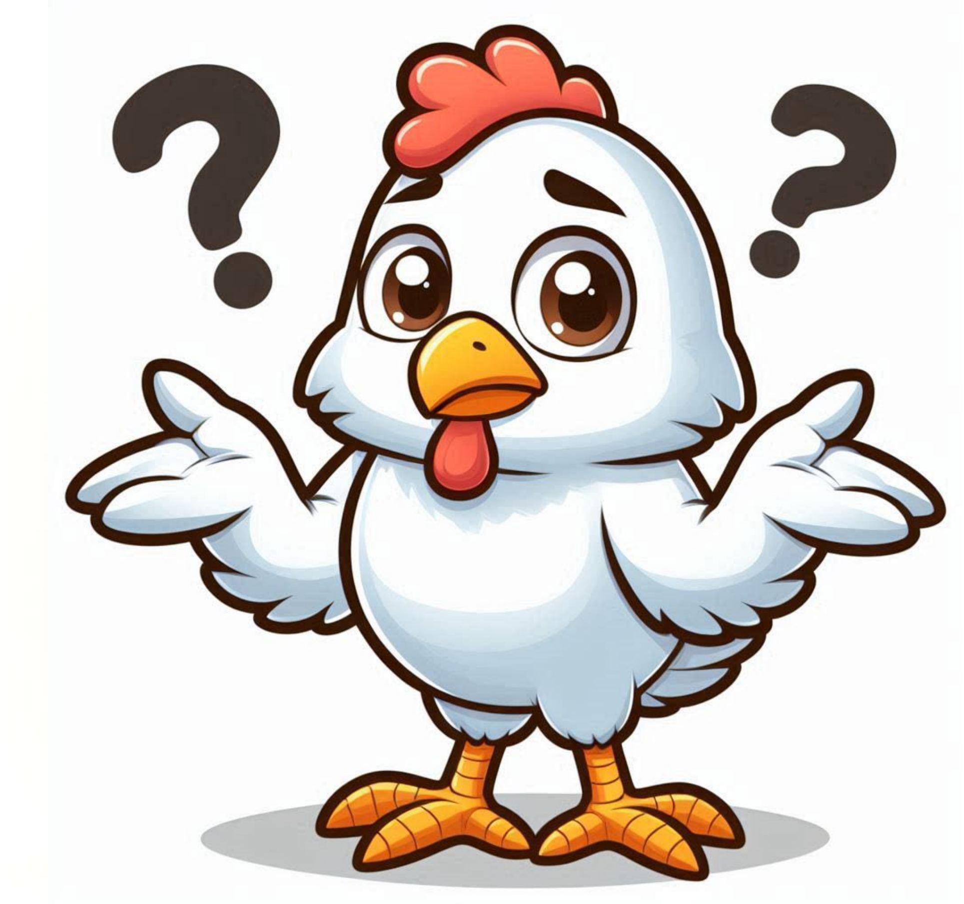
Background

Simulation models available

- Broiler Growth Model – UNESP
- EFG software – Rob Gous
- NutriOpt Broiler Model – Trouw Nutrition
- Other options…



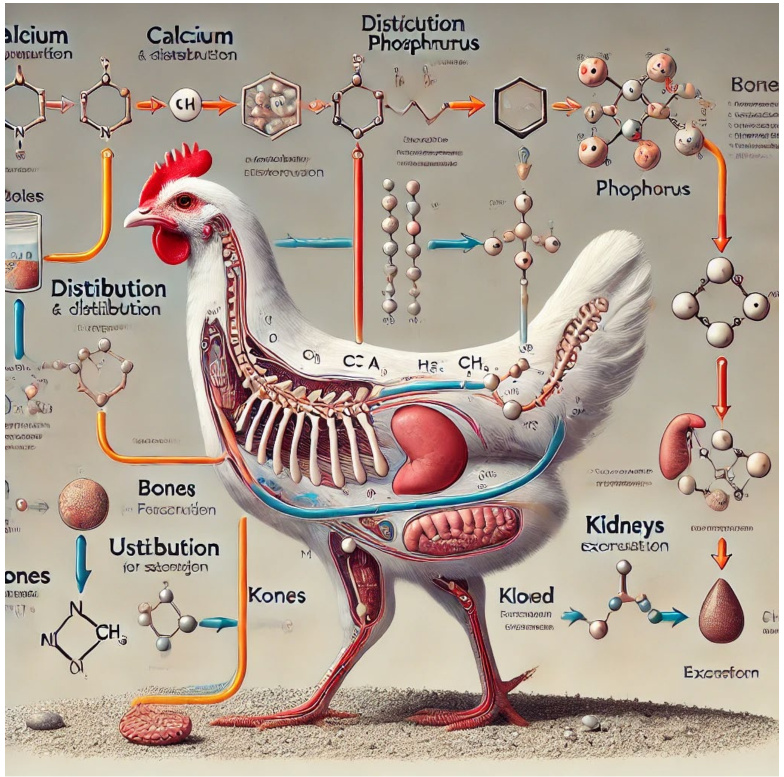
What they have in common?

- Does not account for dietary P or Ca.

Background

First model was produced (Reis et al., 2023)

- Predict the metabolic fate of P and Ca
  - Digestion
  - Dynamics in Soft tissue and Bone ash



Helps to understand the mineral excretion

- Requirement model still need to be developed
  - Estimating the cause and consequences
  - Advising on a better decision-making

Objective

MODEL OVERVIEW (INVERSION TO CALCULATE REQUIREMENTS)

DEMONSTRATE A MODEL BEHAVIOR

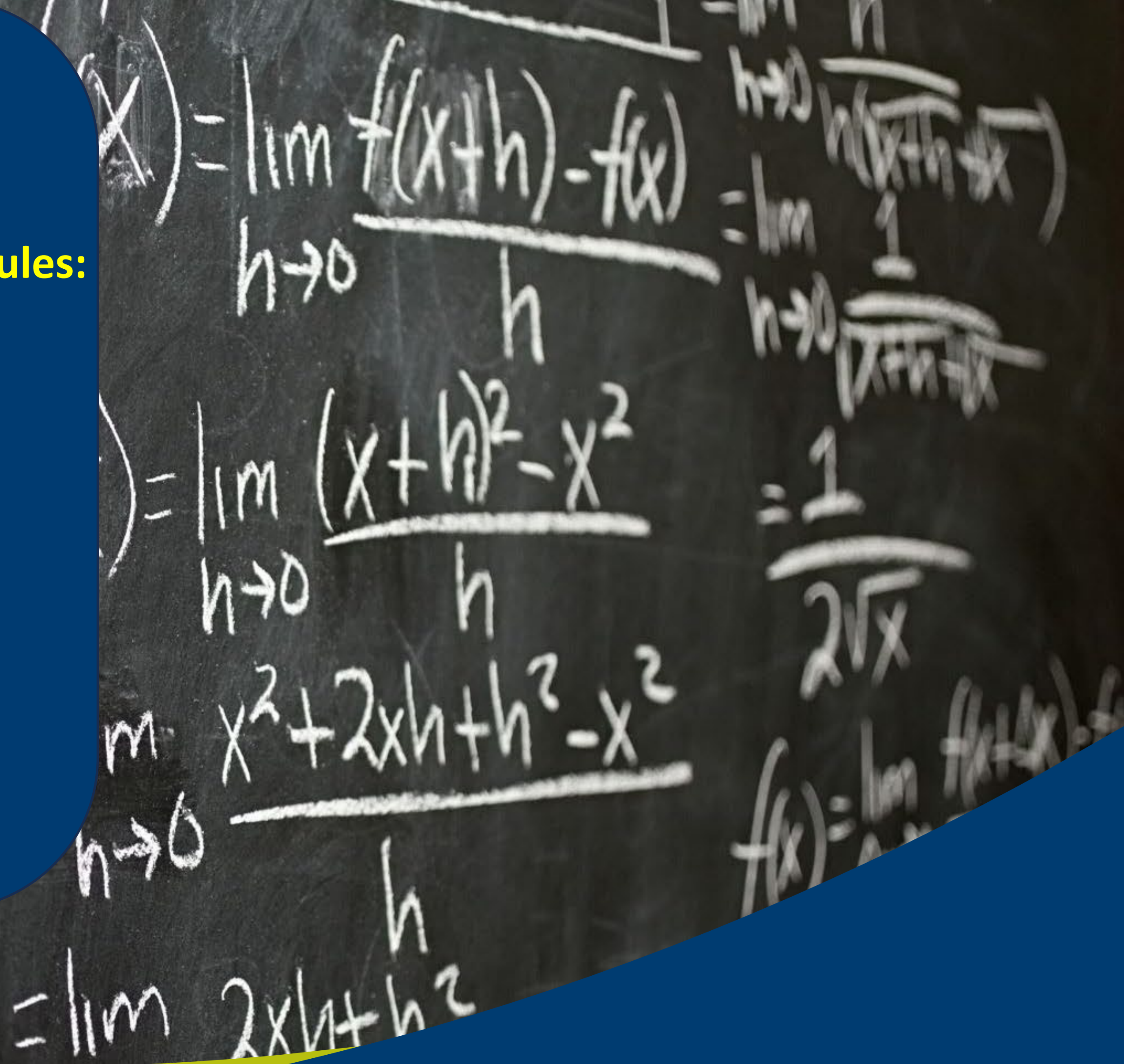
GLOBAL SENSITIVITY ANALYSIS

CALCULATE REQUIREMENT

Model Overview

The model comprehend three interconnected modules:

- **Digestion (ULaval and INRAe)**
- **Soft tissue (UNESP – Brazil)**
- **Body ash (ULaval, INRAe, and UMaryland)**



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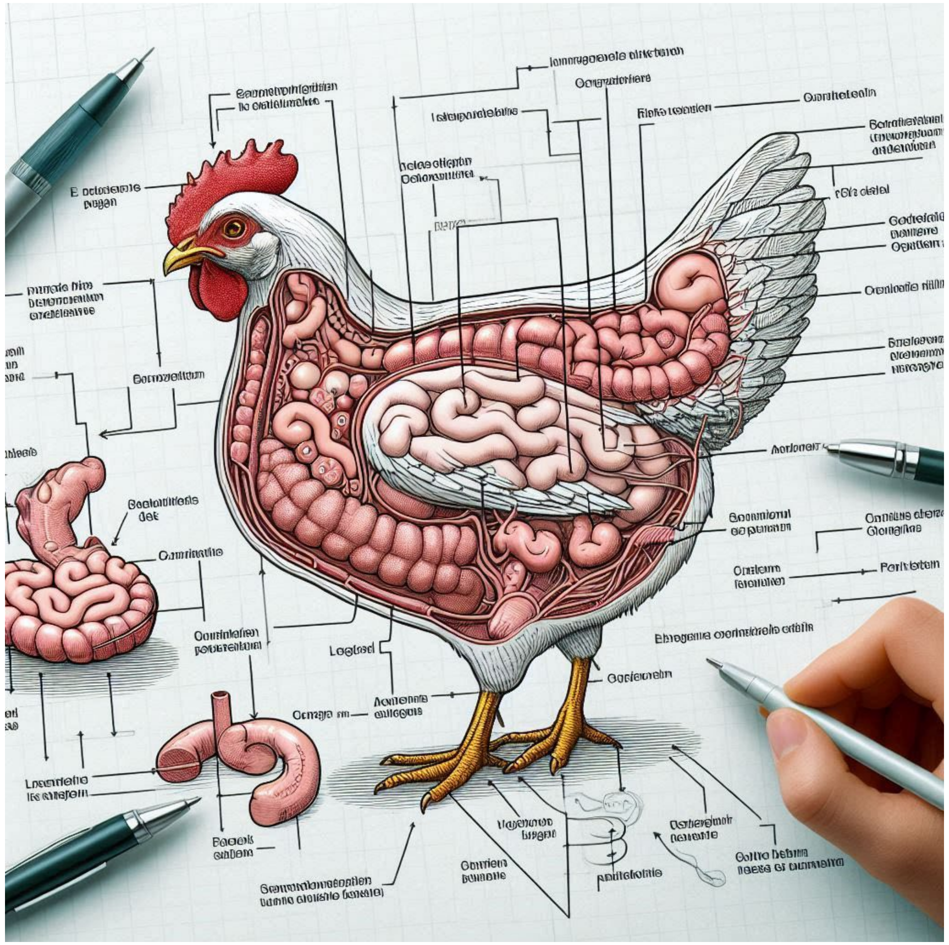
Digestive Module

- Apparent Total Tract Digestibility :
  - Metanalysis (Khaksar et al., 2022)

- Endogenous Losses:
  - Khaksar et al. (2017)
  - Anward (2016, 2017, and 2018)

- Absorption:
  - $Mineral_{Abs}\,(\frac{g}{day}) = (ATTD * FI) - End_{losses}$



Soft Tissue Module

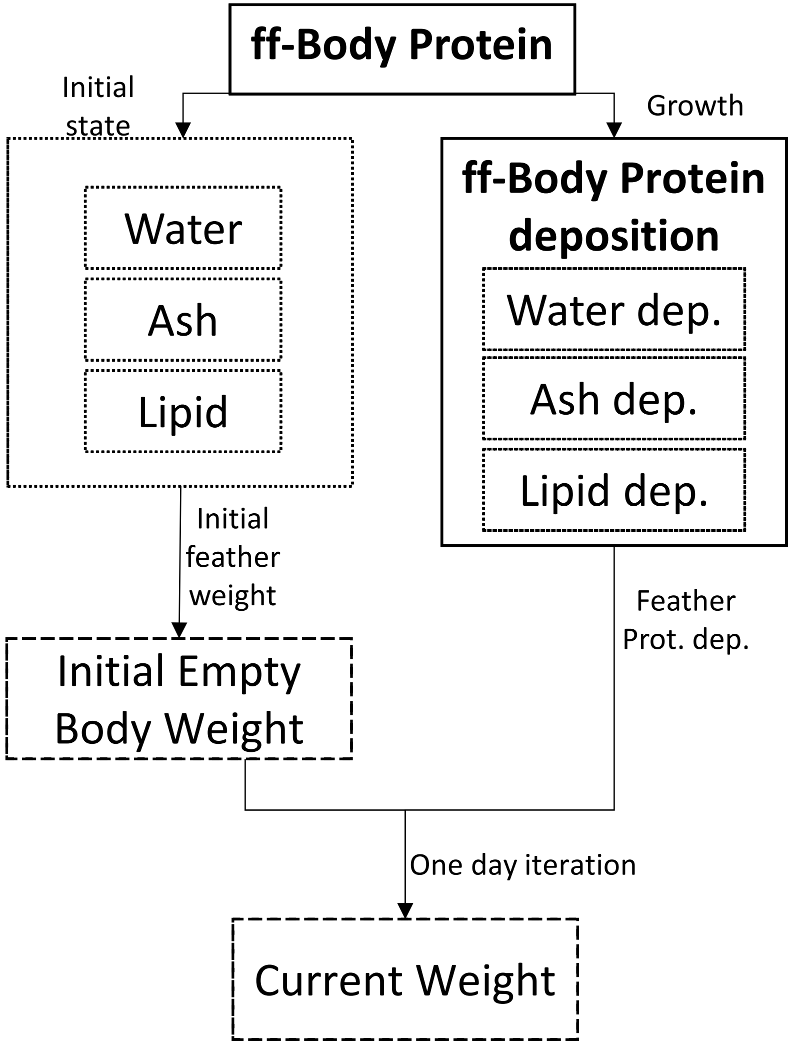
- Protein is the driving force in predicting feather-free body weight:
  - Gompertz function: $P_t = P_m * Exp\left(-Exp\left(LN\left(-LN(P_0/P_m)\right) - b * age\right)\right)$
  - Allometry: Water/ash = $a * (P_d)^b$
  - Allometry for lipid allowing a compensatory gain

- Feather weight is predicted in function of feather protein:
  - Gompertz for feather protein
  - Feather weight = $FP/0.86$

  - $\boldsymbol{P_d = B\ x\ P_t\ \mathrm{x}\ ln(P_m/P_t)}$

- Body weight gain = P_d + W_d + A_d + L_d + Feather gain

- Euler's integration method (1 day): $BW_t = BW_{t-1} + BWG$



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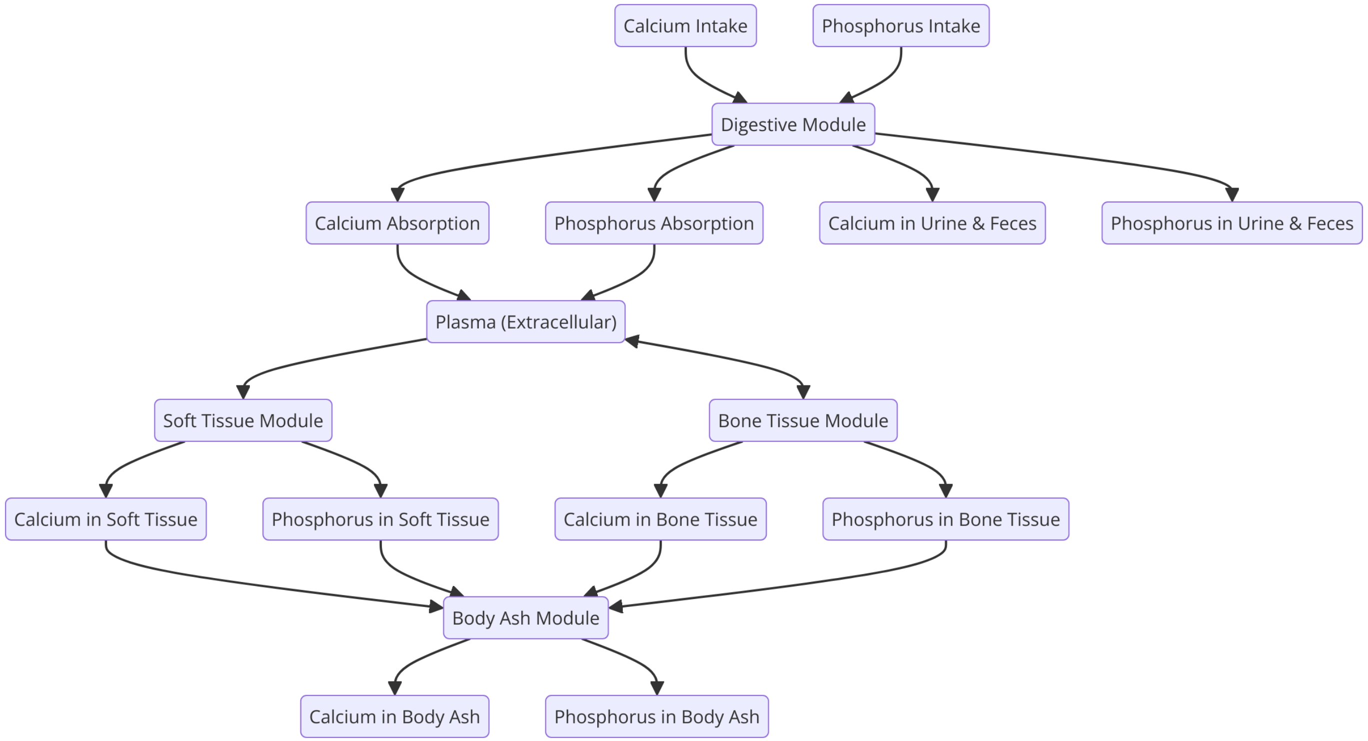
Body Ash Module

- Bone Ash in function of Body Protein:
  - $Ash_{Body} = a * (P_{Body})^b$
  - $Ca_{Bn} = Ash_{Body} * 0.22$
  - $Pho_{Bn} = Ca_{Bn}/2.15$
  - $Miscelaneous_{Bn} = \left(\frac{Ca_{Bn}+Pho_{Bn}}{0.52}\right) * 0.48$
  - $Ash_{BN} = Ca_{BN} + Pho_{BN} + Misc_{BN}$
- Ash in Soft Tissue
  - $Ca_{BP} = [Ca_{BP}] * BP$
  - $Ca_{BL} = [Ca_{BL}] * BL$
  - $Ca_{FP} = [Ca_{FP}] * FP$
  - $Ca_{ST} = Ca_{BP} + Ca_{BL} + Ca_{FP}$ … the same for Pho_{ST} and $Misc_{ST}$
  - $Ash_{ST} = Ca_{ST} + Pho_{ST} + Misc_{ST}$



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Model Inversion - Requirement

$$STTD_{Min}\left(\frac{mg}{day}\right) = Maintenance_{Min} + Gain_{Min} + End_{Min}$$

- mineral Standardized Total Tract Digestible ($STTD_{Min}$)
- mineral maintenance ($Maintenance_{Min}$)
- mineral gain ($Gain_{Min}$)
- mineral endogenous losses (End_{Min})
- total calcium calculated as STTD * 0.50

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Sensitivity Analysis

<u>Global sensitivity analysis – Sobol’ Indices</u>

- Responses evaluated
  - Standardized total tract digestibility of phosphorus
  - total calcium
- Parameters
  - protein maturity ratio of feather-free body protein
  - concentration of P in body protein
  - concentration of Ca in body ash
- ± 1.5% of parameters` standard deviation

Model Behavior

Steps:

- Simulate scenarios
  - Simulate the broilers consuming a feed with increasing levels of Ca and constant non-phytate phosphorus and vice-versa.

- Responses predicted
  - The fate of Ca and P in broilers' metabolism.
    - Excretion in urine and feces.
    - Deposition in bone and soft tissue.

Requirement Calculation

Broiler chicken description

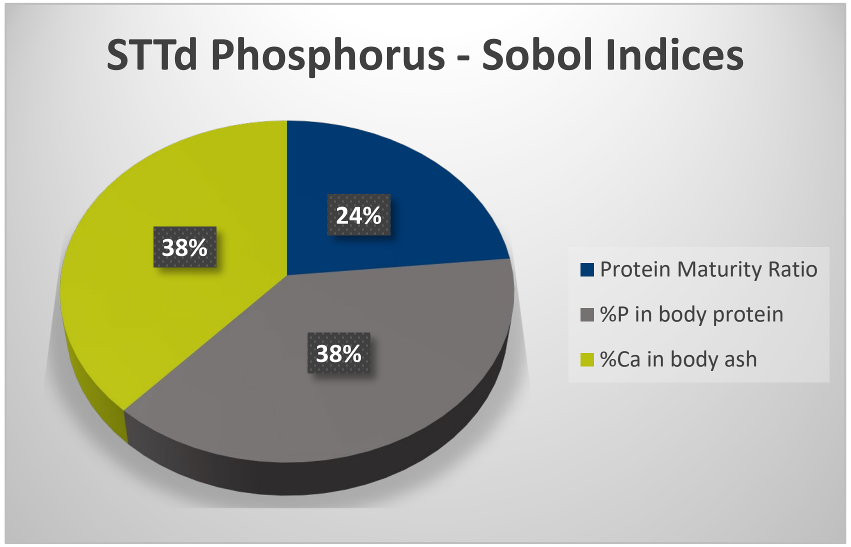
Age, days	Body Weight, g	Body Weight Gain, g/d	Deposition, g/d			
			Protein	Protein Feather	Lipid	Ash
0	44.6	0.000	1.21	0.286	0.555	0.000
7	155	22.7	3.03	0.657	1.77	0.631
14	407	47.3	6.62	1.32	4.83	1.30
21	859	77.8	11.2	2.11	9.73	2.10
28	1520	106	15.6	2.81	15.4	2.82
35	2346	125	18.7	3.24	20.3	3.31
42	3254	131	19.7	3.35	23.1	3.48
49	4161	127	19.1	3.18	23.6	3.38
56	5000	114	17.2	2.84	22.2	3.08

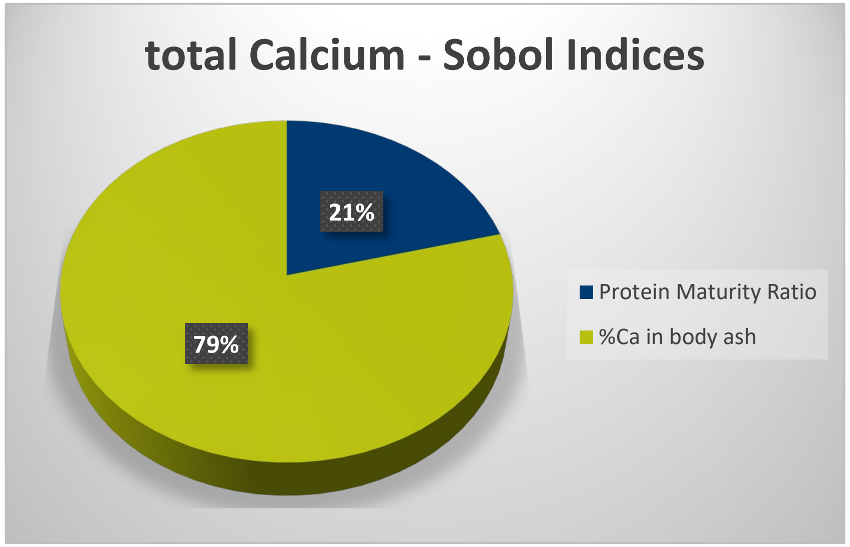
- Visual comparison with literature recommendation
  - Data and literature was plotted together
    - Simulated
    - Ross 308 (2022)
    - Cobb 500 (2022)
    - Brazilian Tables (2024)

Results

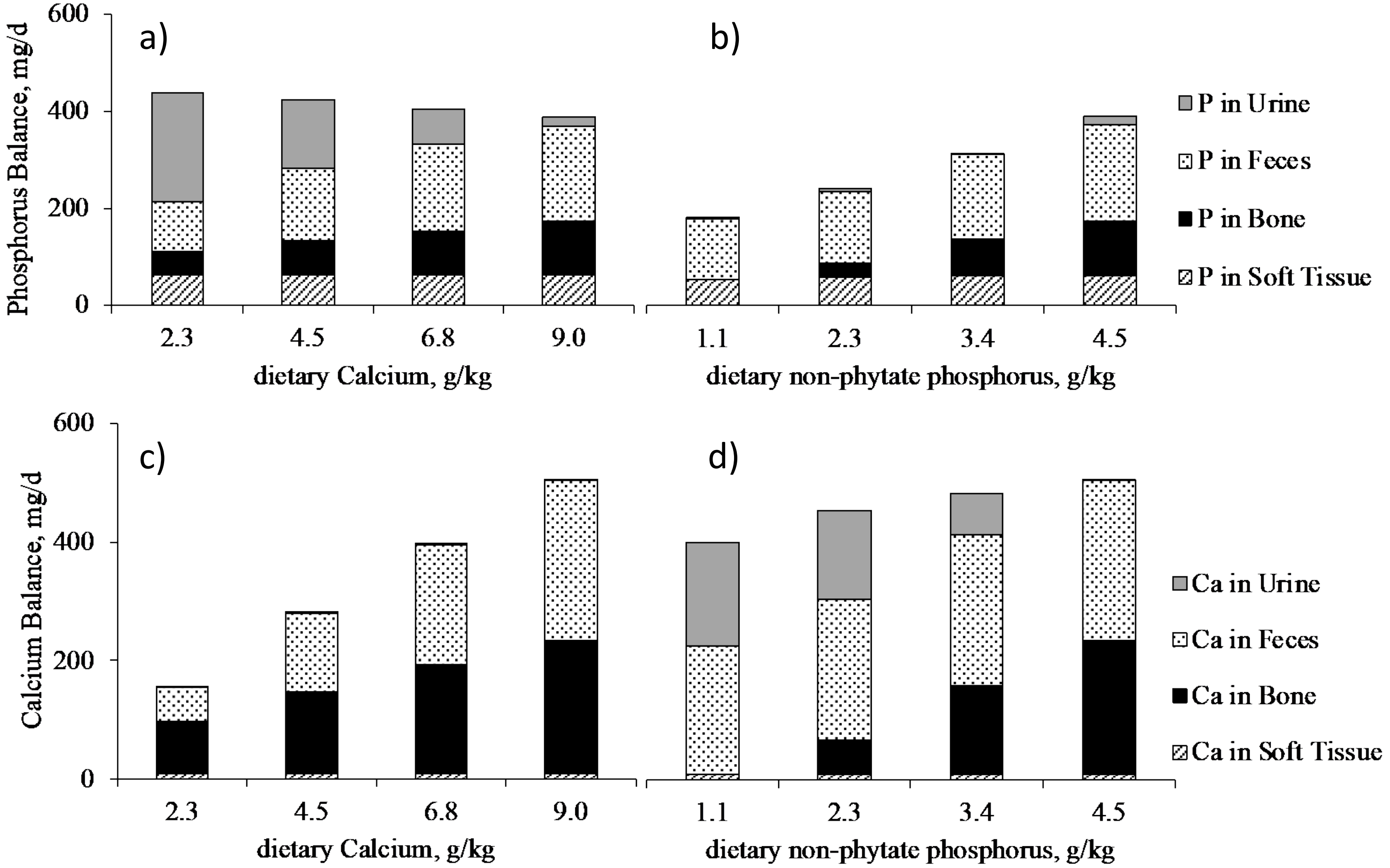
Sensitivity Analysis

Response, mg/day	Model Parameters					
	Protein maturity ratio		%P in body protein		%Ca in body ash	
	-1.5 SD	+1.5 SD	-1.5 SD	+1.5 SD	-1.5 SD	+1.5 SD
STT P	330	383	325	387	325	387
total Ca	812	939	875	874	751	998





Model Behavior



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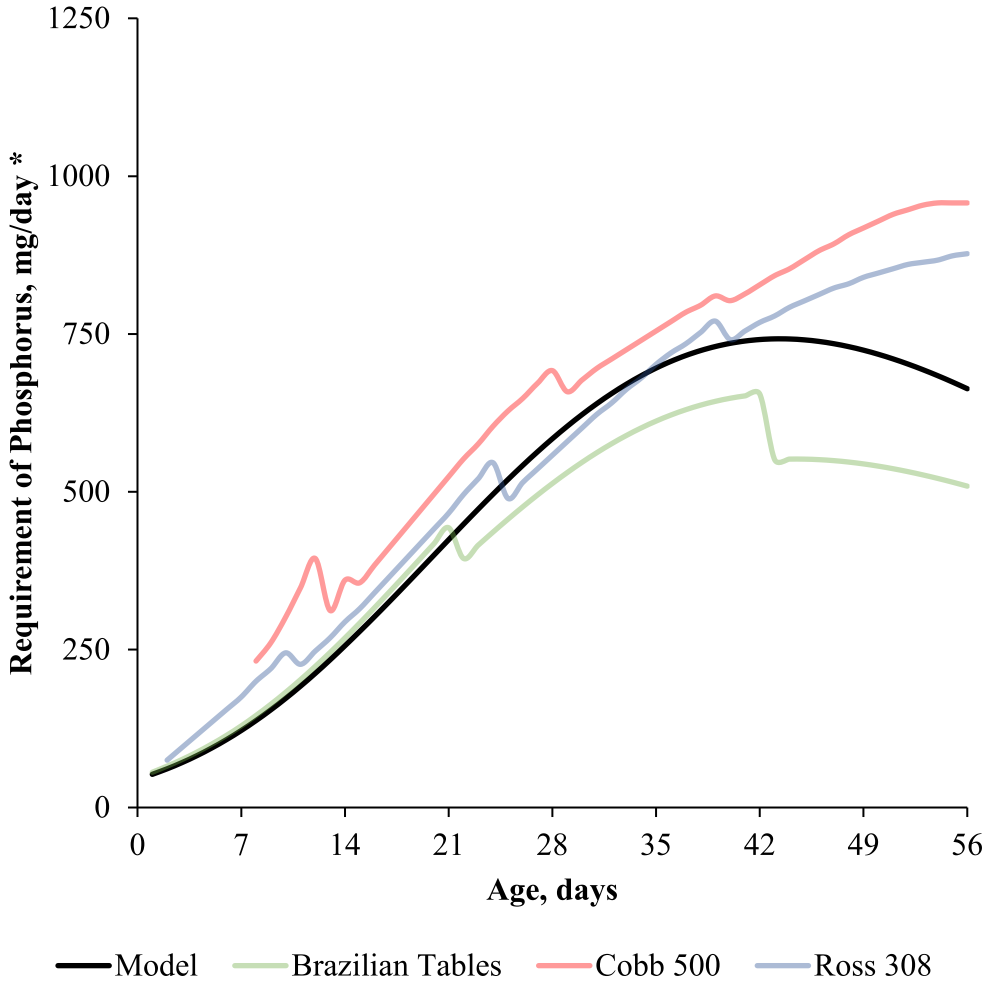
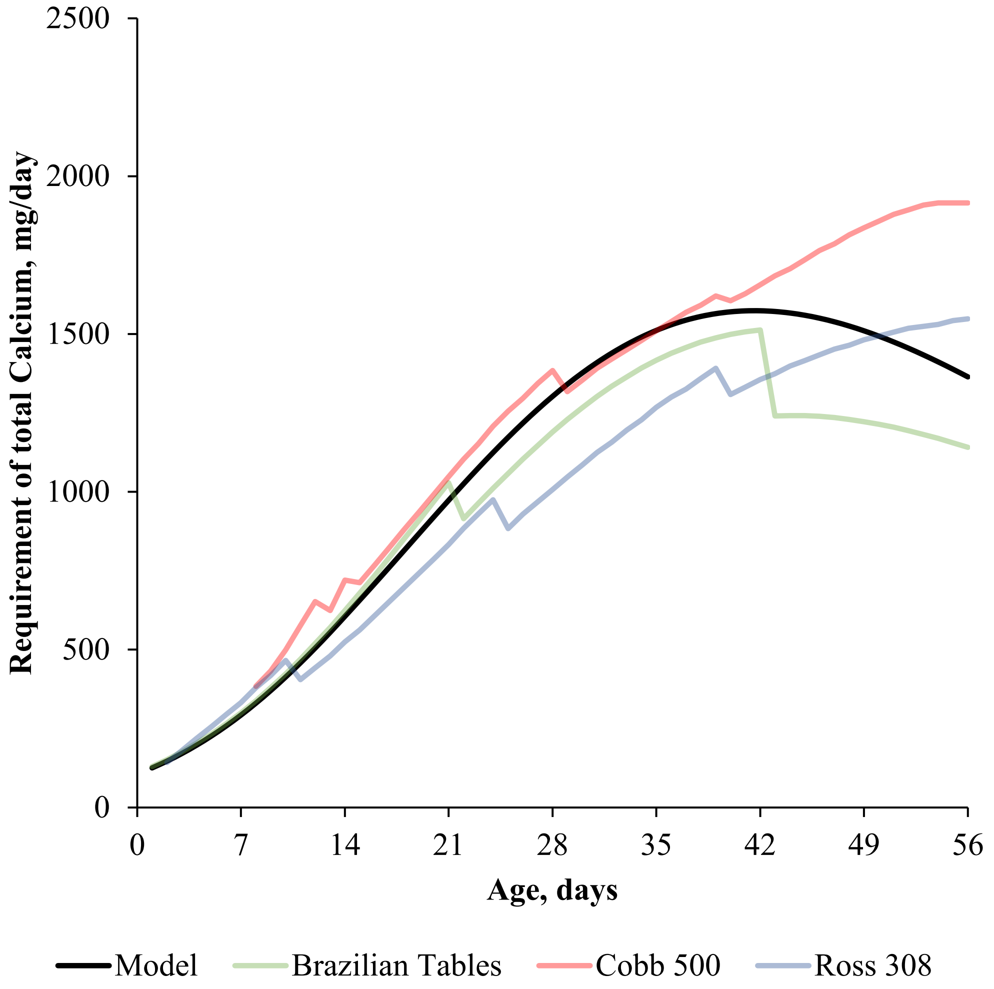
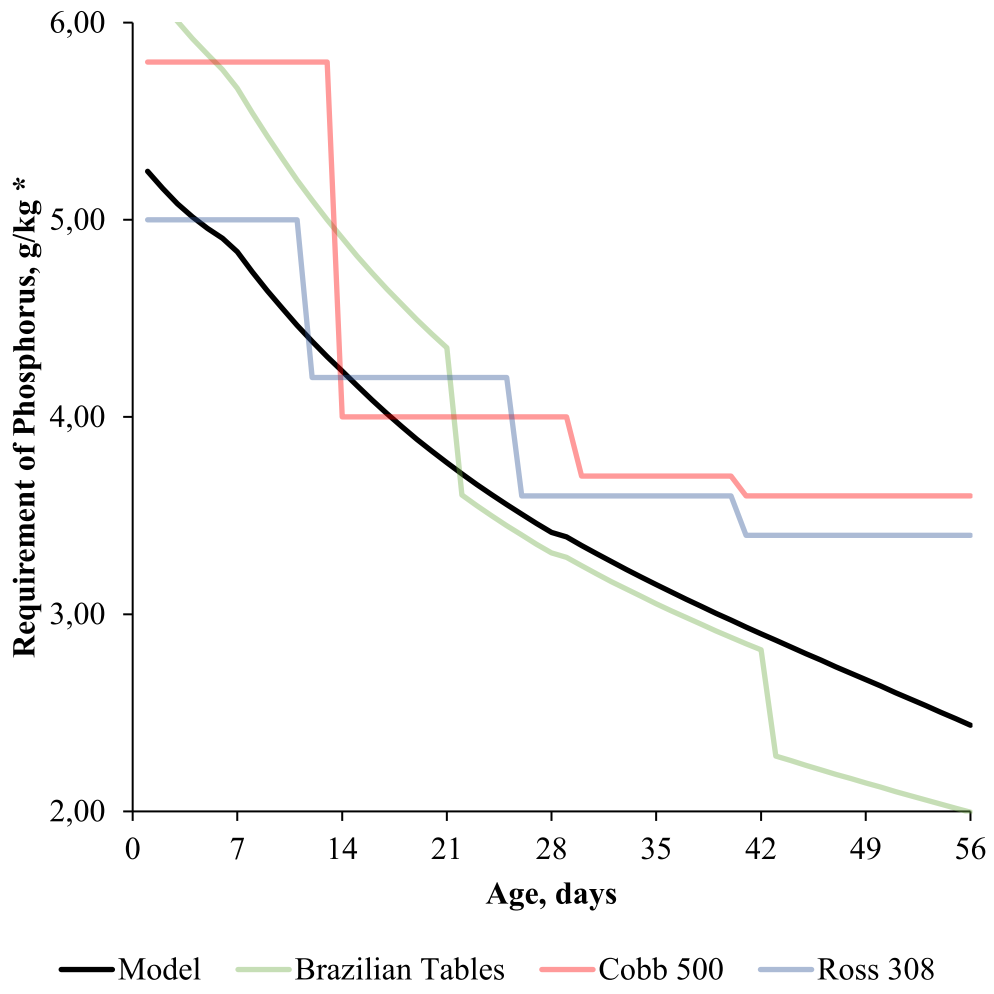
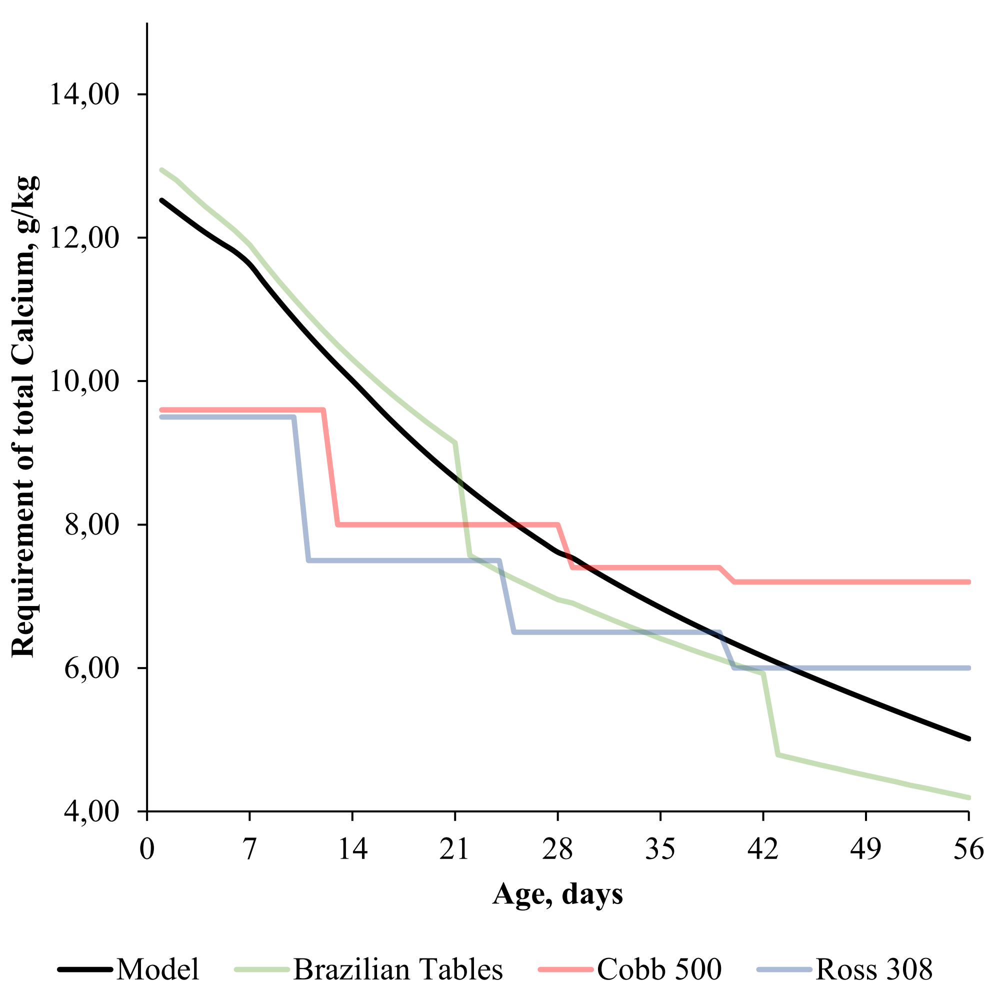
Requirement





Requirement





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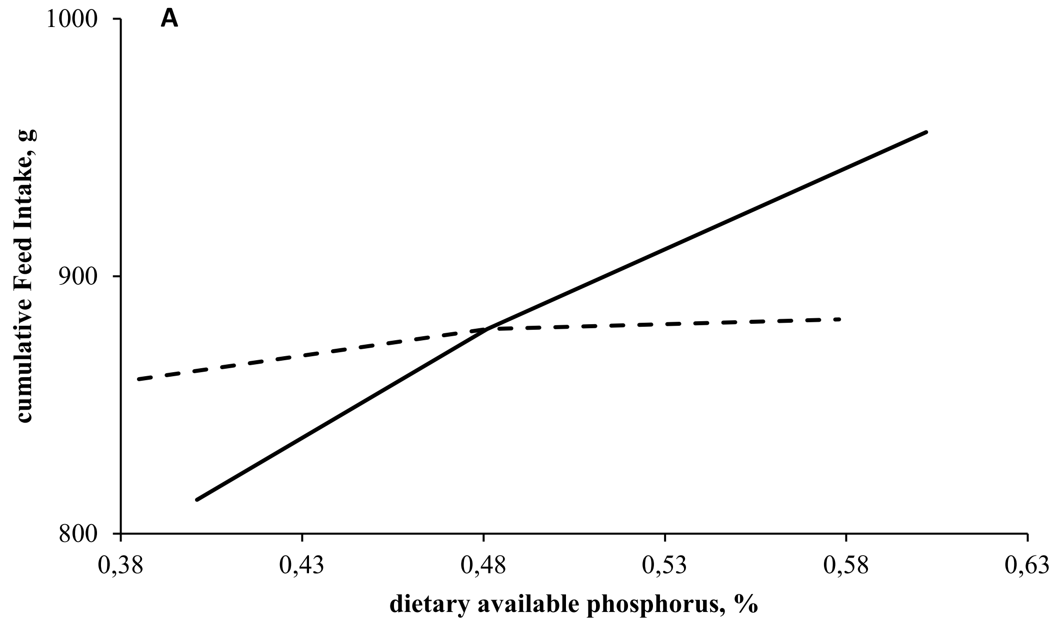
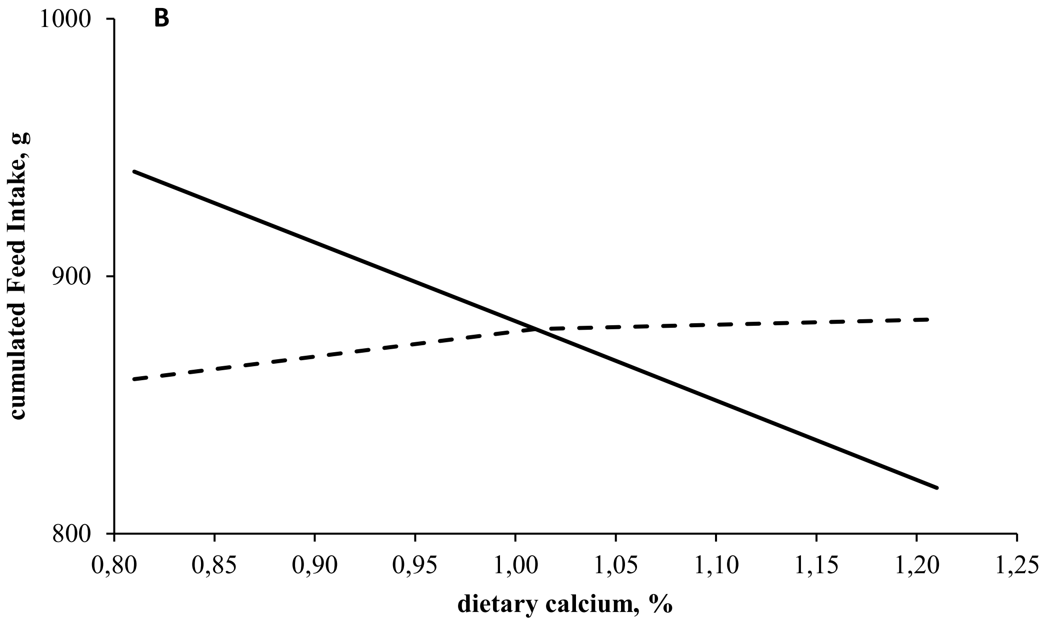
Extra Mechanism

- The problem of feed intake:
  - Estimate the expected feed intake
  - Predict the consequences of the dietary P and Ca
    - P anorexia (Chen and Moran, 1995; Bertechini et al., 2022; Aderibigbe et al., 2022)
    - Ca appetite (Lobaugh et al., 1981)
  - Database comprising 53 publications, 58 experiments, and 342 treatments (Hedhli et al., 2019)
    - relative feed intake

Extra Mechanism





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Conclusions

Protein maturity ratio of feather-free body protein, concentration of P in body protein, and concentration of Ca in body ash represent the the biggest variation in the present model

The behavior of the model indicated a logic outcome of the model

Results obtained with the inversion of the model were similar to recommendation

External evaluation is ongoing

Contributors

- Trouw Nutrition
- Marie-Pierre Létourneau Montminy – ULaval (Canada)
- Agnes Narcy – INRAE (France)
- Nilva Sakomura – UNESP (Brazil)
- Roselina Angel – U Maryland (USA)