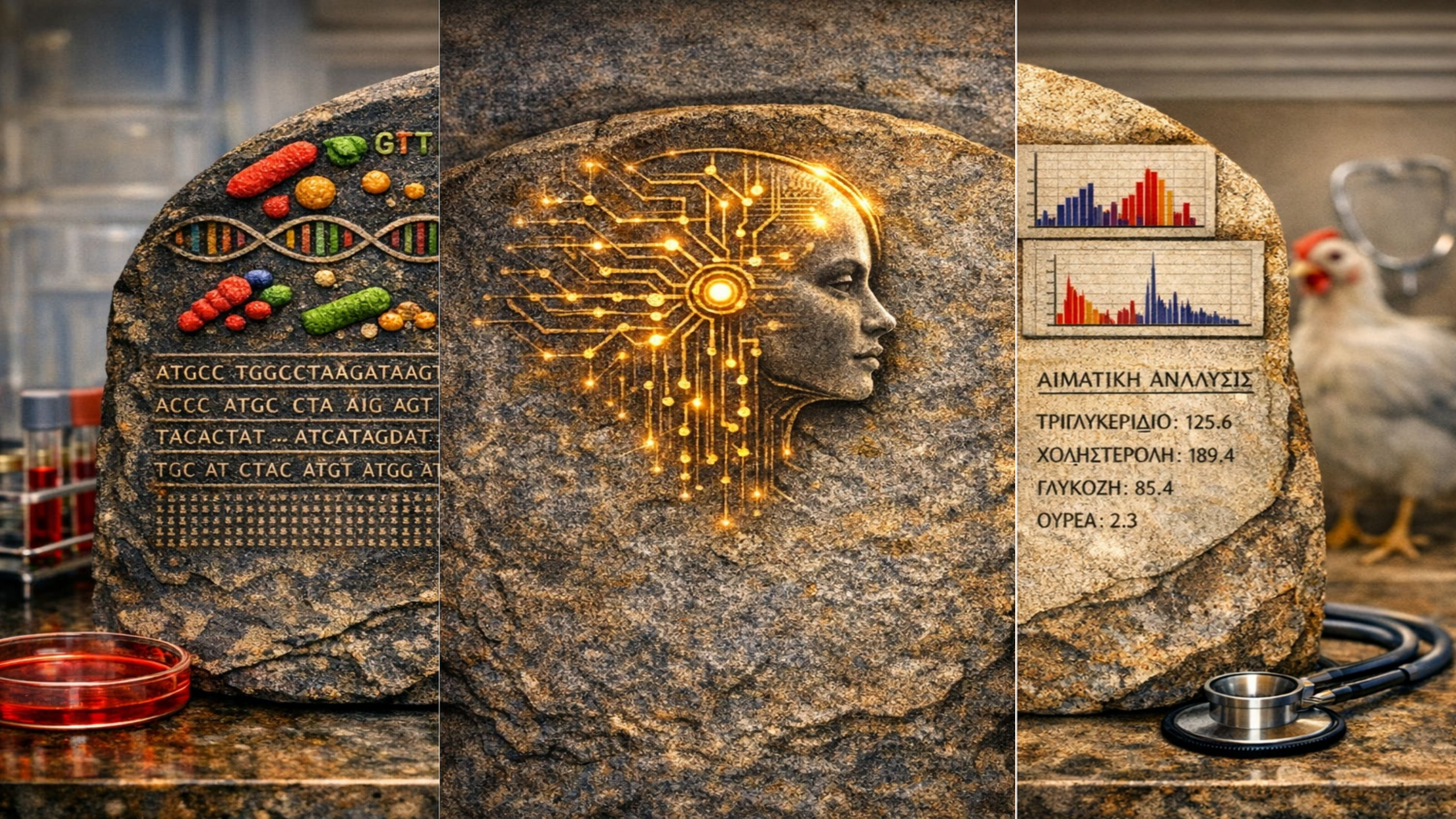


AI in the interpretation of results



Aaron J. Cowieson, Chelsea Phillips, Bertrand Greiner & Alessio Milanese
Digital Consultancy & Solutions



GTT

ATGCC TGGCCTAAGATAAG
ACCC ATGC CTA AIG AGT
TACACTAT ... ATCATAGDAT
TGC AT CTAC ATGT ATGG A

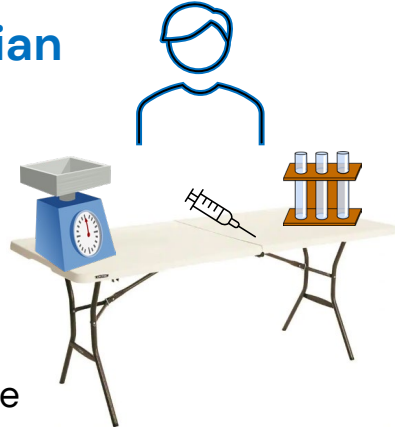


ΑΙΜΑΤΙΚΗ ΑΝΑΛΥΣΙΣ

ΤΡΙΓΛΥΚΕΡΙΔΙΟ: 125.6
ΧΟΛΗΣΤΕΡΟΛΗ: 189.4
ΓΛΥΚΟΖΗ: 85.4
ΟΥΡΕΑ: 2.3

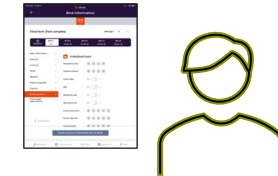
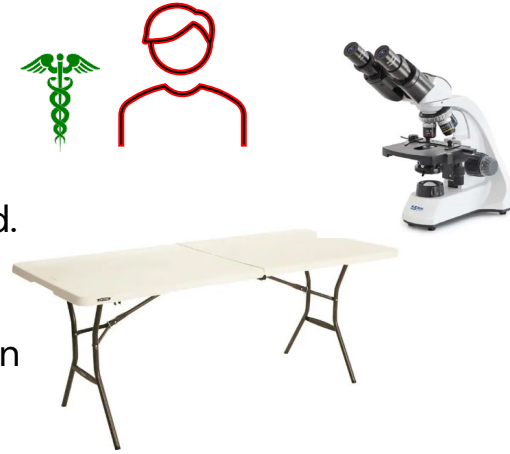
1. Bleeding Technician

- Label and weigh each bird
- Record farm data
- Sample blood
- Some countries require a Vet to bleed



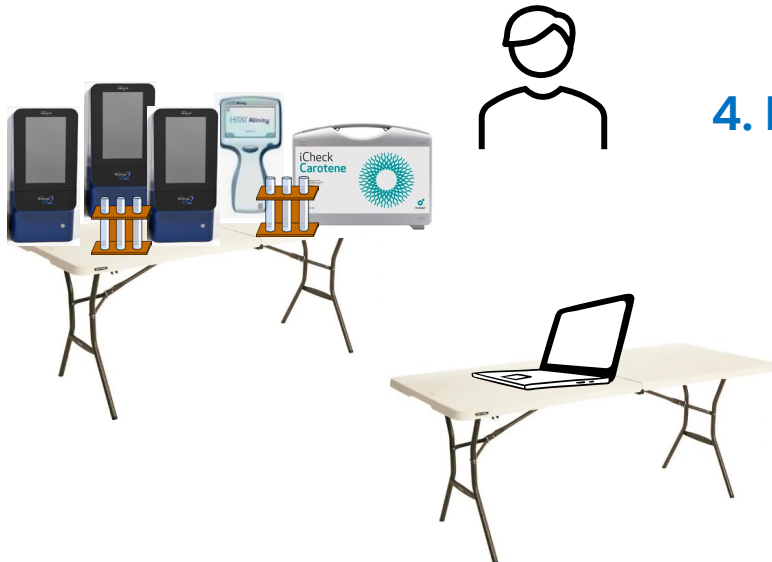
2. Necropsy Veterinarian

- Perform necropsy on each bird.
- Call out observations to Recorder
- Record microscopic maxima on each bird.
- Must be a Vet



4. Blood Analysis Technician

- Analyze blood on Vetscan2, iStat and iCheck
- Upload data to cloud after sampling
- For sessions >50 birds, need 2 Technicians and more devices



3. iPad Recorder

- Enter Vet observations into app
- Monitor flow of all processes

What other data we have to put into the system ?

Coccidiosis (6)



Digestive Health (9)



Skeletal Health (7)



Meat Quality (2)



Figure 1 – As the severity of WB and WS can vary, simple scales have been developed to rank their degree and severity (commonly a 0, 1, 2, 3 scale, Petracci et al., 2019).

Welfare (3)



Immunity (6)

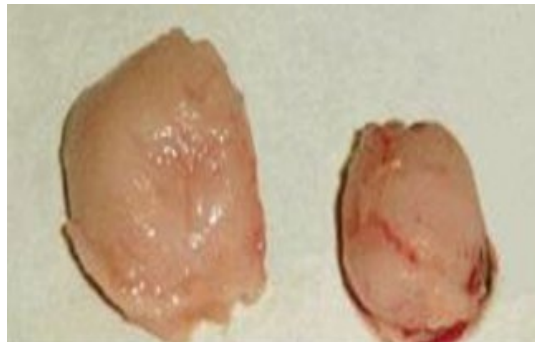


Figure 3. Left= Normal bursa. Right= Atrophied and hemorrhagic bursa

Respiratory (3)



Other Factors (7)



Verax analyzes 23 blood biomarkers that provide insights on different challenges

Biomarkers analyzed by Verax

- Albumin
- Anion Gap
- AST
- Calcium
- Carotenoids
- Chloride
- Creatine Kinase
- Globulin
- Glucose
- Hematocrit
- Hemoglobin
- Ionized Calcium
- Phosphorus
- Potassium
- Sodium
- Total Carbon Dioxide
- Total Protein
- Uric Acid
- pH
- dCO2
- BE
- SID
- Albumin-adjusted anion gap

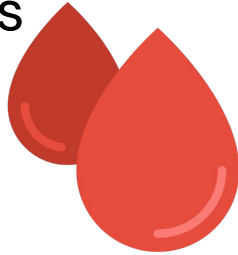
Challenges

Verax focuses on challenges in health, nutrition and welfare / sustainability, such as:

- Growth & Absorption
- Skeletal Health
- Electrolyte Balance
- Muscle & Liver Health
- Oxidative Stress & Inflammation
- Acid/Base Balance
- Respiratory/Metabolic Issues
- Renal function
- Hepatic function

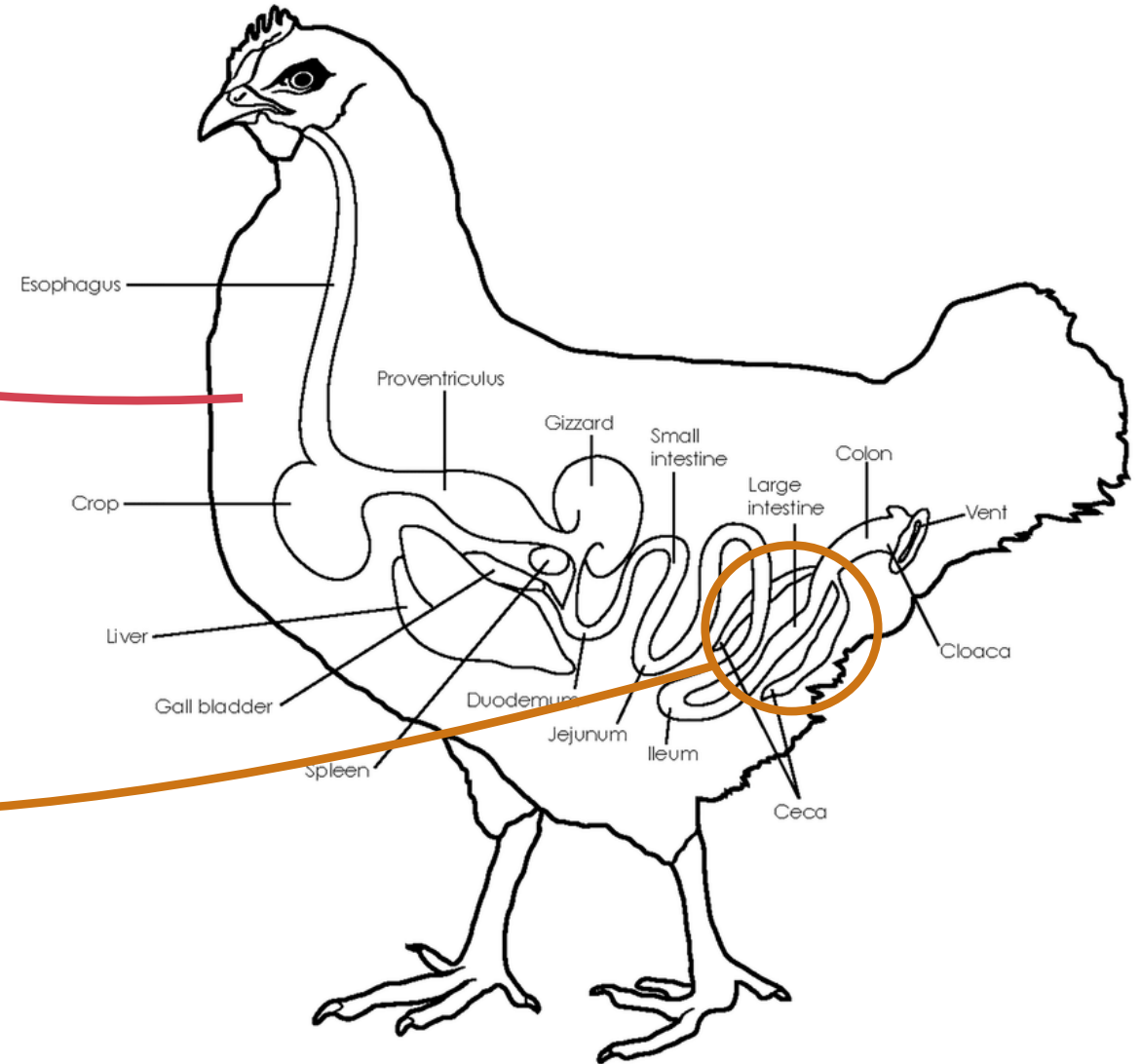
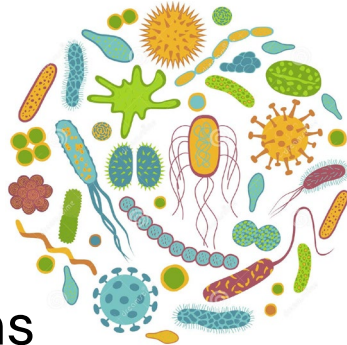
Making the invisible, visible

- Blood biomarkers



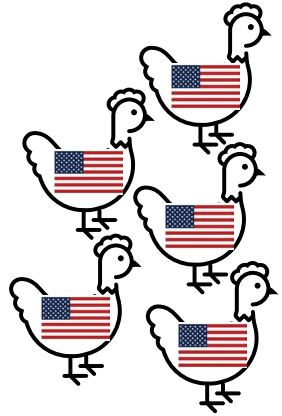
- Cecal microbiome:

- Microbial species
- Microbial functions



ML models can struggle to generalize to novel data

Training data

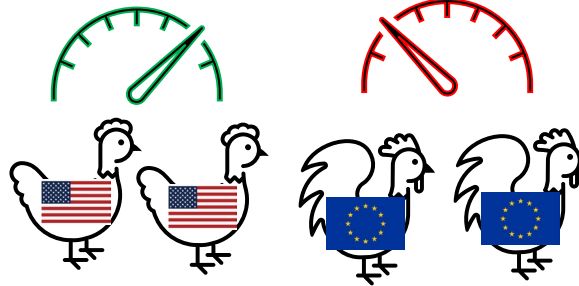


Training Algorithm

Model



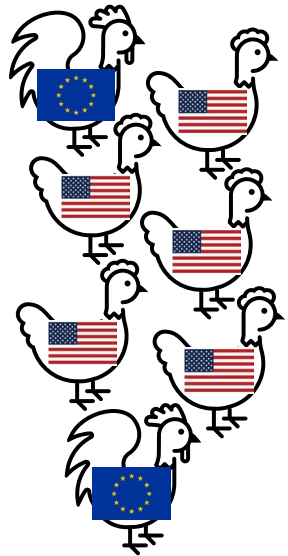
Model Performance



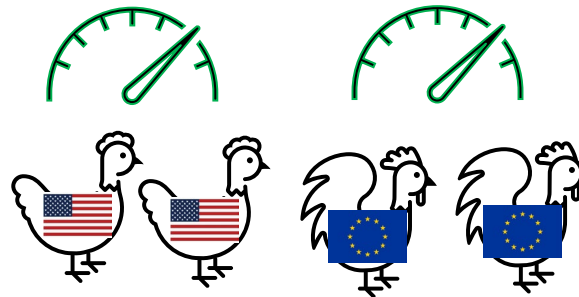
It is important that the training data is representative

Potential sources of bias:

- Age
- Gender
- Breed
- Diet
- Management practices
- Region



Training Algorithm



To account for this:

- Carefully design the benchmark dataset used in model validation
- Collect as much metadata as possible
- Use the metadata as features in the model

Customer Use Cases:

Coccidiosis

Metabolic acidosis

**Bacterial chondronecrosis
with osteomyelitis**

Customer Use Cases:

Coccidiosis

Metabolic acidosis

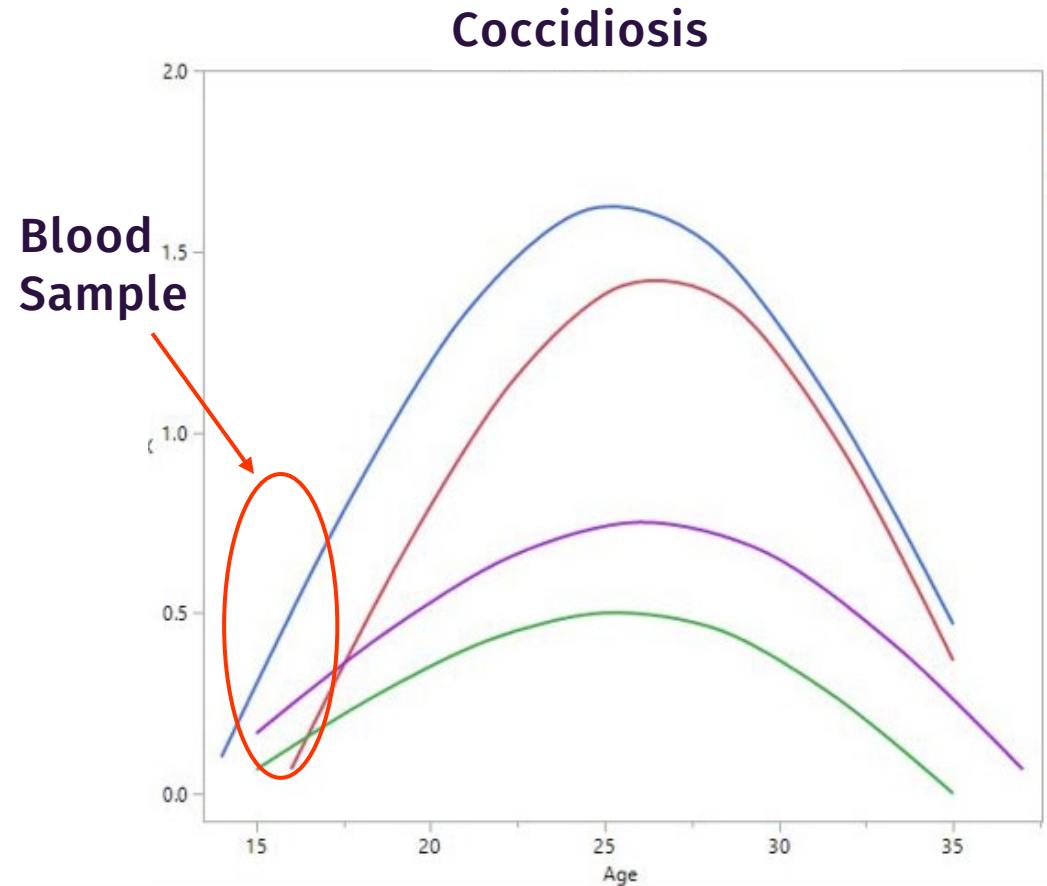
**Bacterial chondronecrosis
with osteomyelitis**

Early Warning System

A large boiler integrator in the US wanted to know if we take a blood sample at 14d and predict coccidiosis at 28d?

For three of the four farms tested, the model correctly indicated the 28d cocci condition.

Currently we are determining when the most ideal time period is to sample for forecasting of many field conditions. These time points have to be optimized for model performance and for producers. We are also enhancing model performance via supervised machine learning.



Blood Biomarker Response to Cocci Challenge

- Certain plasma biomarkers, including potassium and carotenoids, respond to coccidiosis:
- These biomarkers began to shift 3–7d prior to obvious symptoms of coccidiosis

Effect of coccidial challenge and vaccination on the performance, veterinary postmortem scores, and blood biochemistry of broiler chickens

A. J. Cowieson,^{*,1} M. L. Livingston,[†] B. Nogal,[‡] V. Hoang,[‡] Y.-T. Wang,[†] R. Crespo,[§] and K. A. Livingston[¶]

^{*}DSM Nutritional Products, 4303 Kaiseraugst, Switzerland; [†]DSM Nutritional Products, Parsippany, NJ; [‡]Inside Tracker, Cambridge, MA; [§]Department of Population and Health Pathobiology, College of Veterinary Medicine, NC State University, Raleigh, NC 27607; and [¶]Prestage Department of Poultry Science, NC State University, Raleigh, NC 27695-7608

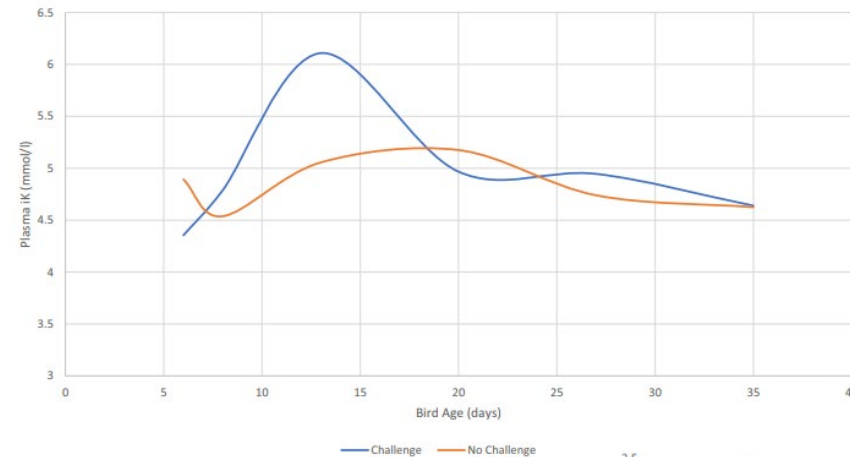


Figure 1. Effect of age and a mixed-species coccidial challenge (introduced on day 7) on broiler chickens. A significant age $\times$ challenge interaction was observed, which was generated

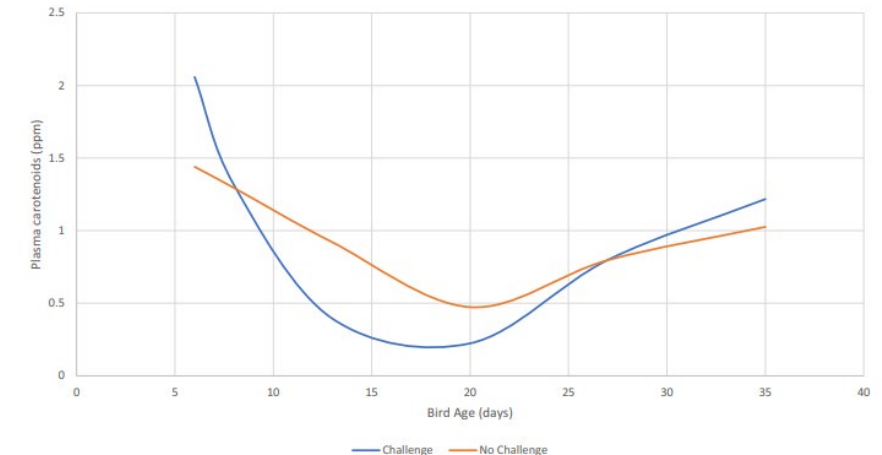
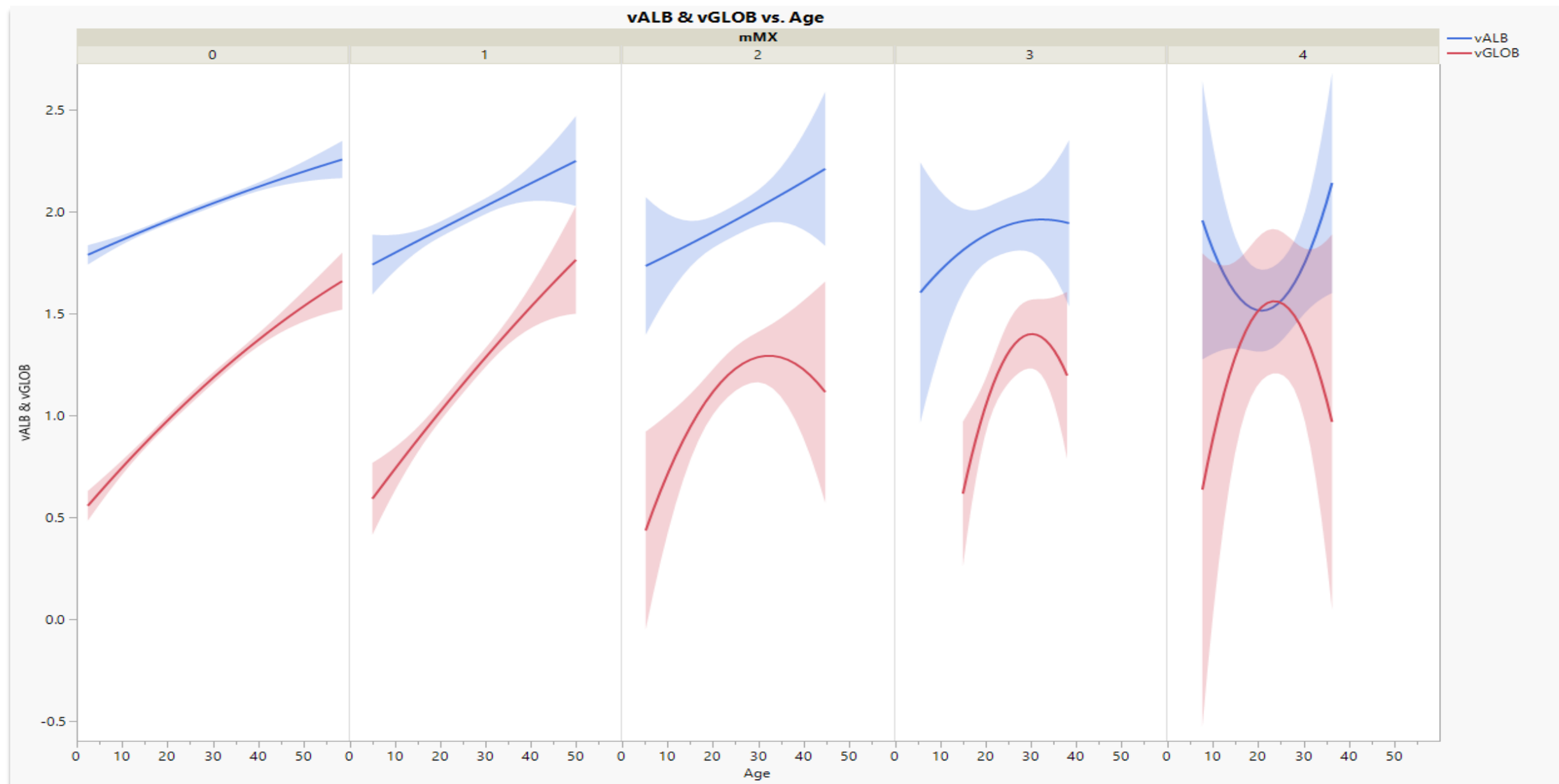


Figure 2. Effect of age and a mixed-species coccidial challenge (introduced on day 7) on plasma carotenoid concentration in male Cobb 500 broiler chickens. A significant age $\times$ challenge interaction was observed, which was generated by the transient decrease from day 13 to day 20.

VERAX Database: GLOB and ALB

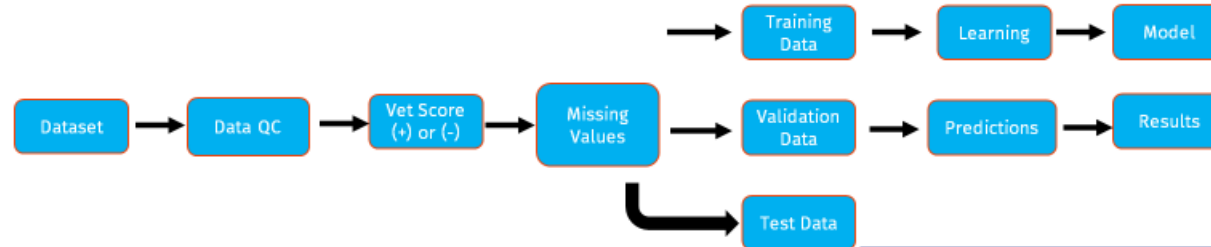


Building the Data Pipeline

Importance of positive cases

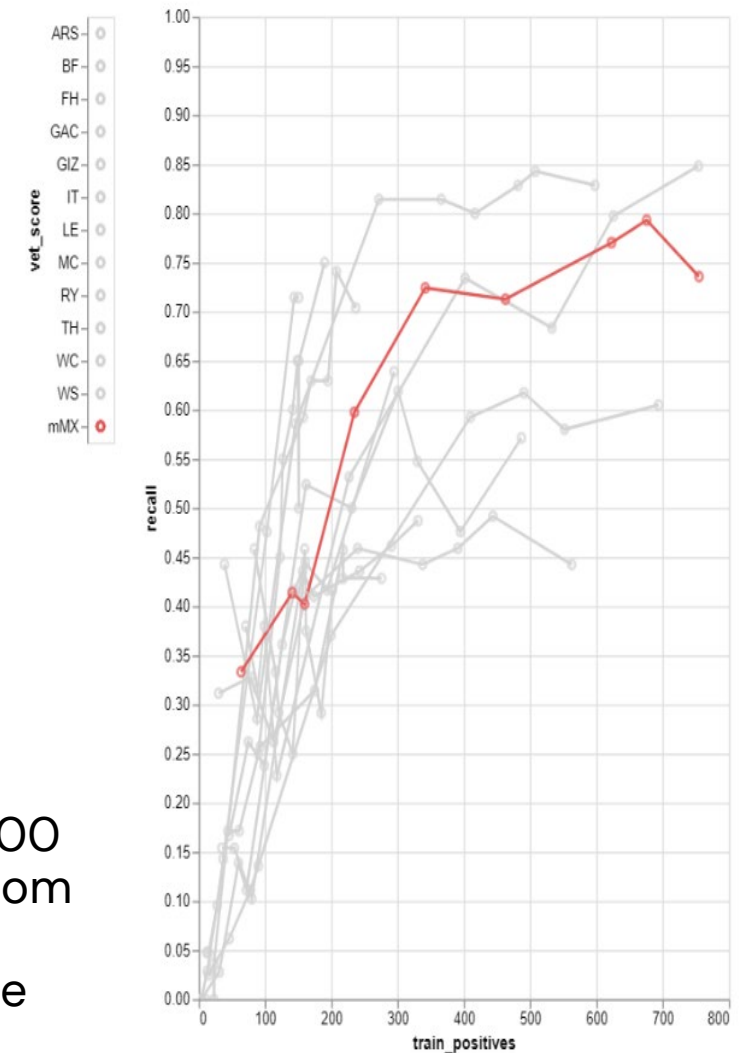
Verax Supervised Machine Learning Pipeline

For Internal Use Only

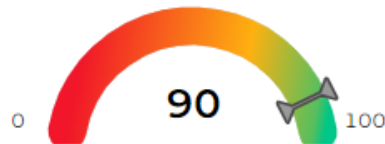


Dataset	Vet Score	Prediction
Bird 1	3	positive
Bird 2	3	positive
Bird 3	3	positive
Bird 4	0	positive
Bird 5	1	negative
Bird 6	0	negative
Bird 7	3	negative

- Currently, we have a large well annotated database from more than 10,000 commercial broiler farms to test and train our models. These birds are from various producers, different seasons, and span from 1-60 days of age.
- Of these, a large portion of samples are positive for mMX and the rest are healthy. The mMX data is modeled as it comes in and the models are monitored for improvement in accuracy, precision, and recall as the dataset increases in size.



Production Model User Interface



Coccidiosis-GAC score

Moderate

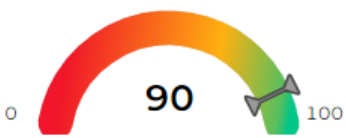
↑ +9 from sampling September 23, 2021

Our GAC score indicates your birds are experiencing moderate effects by GAC on biomarkers. Biomarkers that are predicted to be affected by GAC (based on the analysis of this sampling) are displayed.

Biomarker Impact History of Results

⬆ Increases score:

⬇ Decreases score:



Coccidiosis-GAC score

Moderate

↑ +9 from sampling September 23, 2021

Our GAC score indicates your birds are experiencing moderate effects by GAC on biomarkers. Biomarkers that are predicted to be affected by GAC (based on the analysis of this sampling) are displayed.

Biomarker Impact History of Results



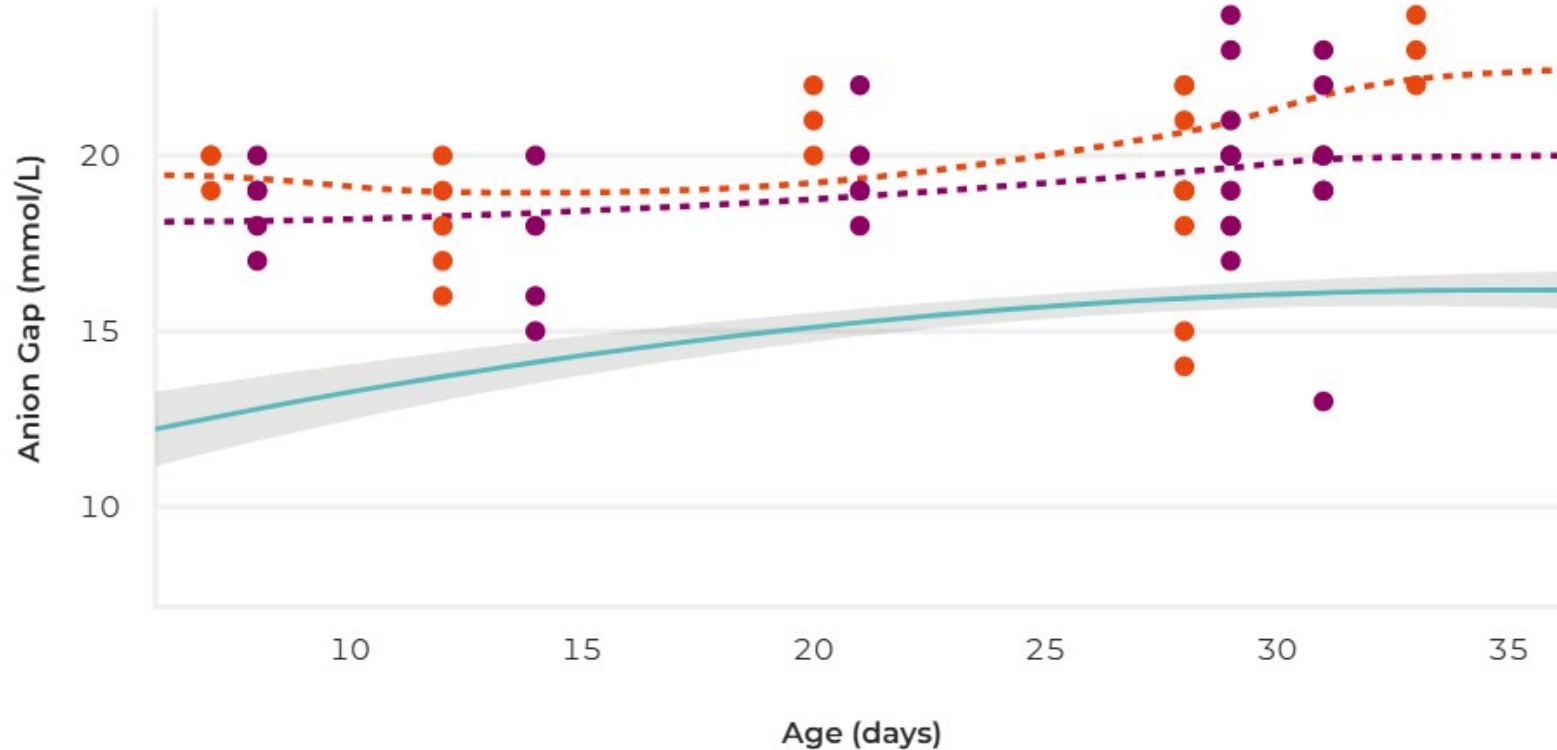
Customer Use Cases:

Coccidiosis

Metabolic acidosis

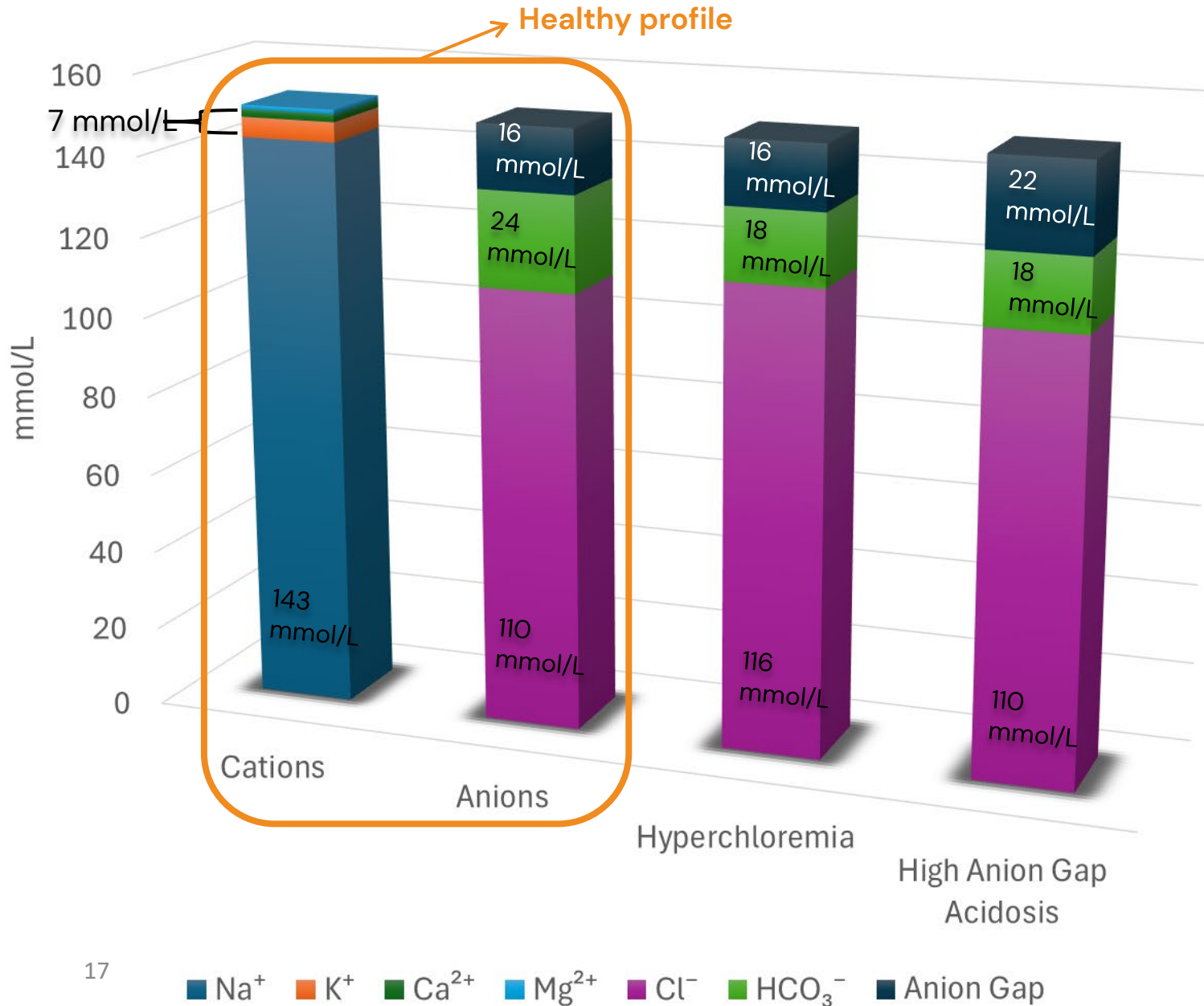
**Bacterial chondronecrosis
with osteomyelitis**

Systemic high anion gap metabolic acidosis observed in a large broiler integrator in SE Asia (2025)



- The anion gap is 17–22 mmol/L and is persistently high at all bird ages and across all production locations
- This anion gap is at least 50% higher than baselines for both Cobb and Ross genetics
- Associated with very marginal HCO_3 concentrations and low blood pH
- Uric acid was normal, albumin was normal
- Suspected lactate acidosis

What is the context for metabolic acidosis?

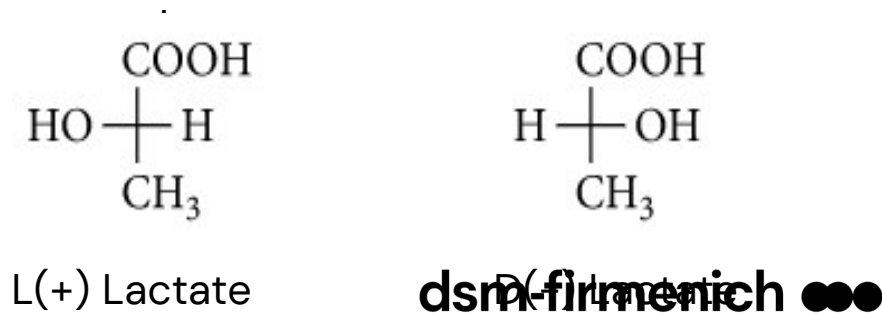


- Specifically, when the anion gap is elevated, causing acidosis, lactate accumulation can be a proximate cause
- Plasma lactate in birds is typically 1-2 mmol/L but can be as high as 8-10 mmol/L
- Requires additional exploration, including microbiome sequencing

Blood lactate in broilers (meta-analysis of 11 peer reviewed papers)

Plasma lactate (mmol/L)	Interpretation
< 2.0	Normal / baseline
2.0–4.0	Stress / handling effect likely
> 4.0	Significant metabolic stress, hypoxia, heat load, or shock

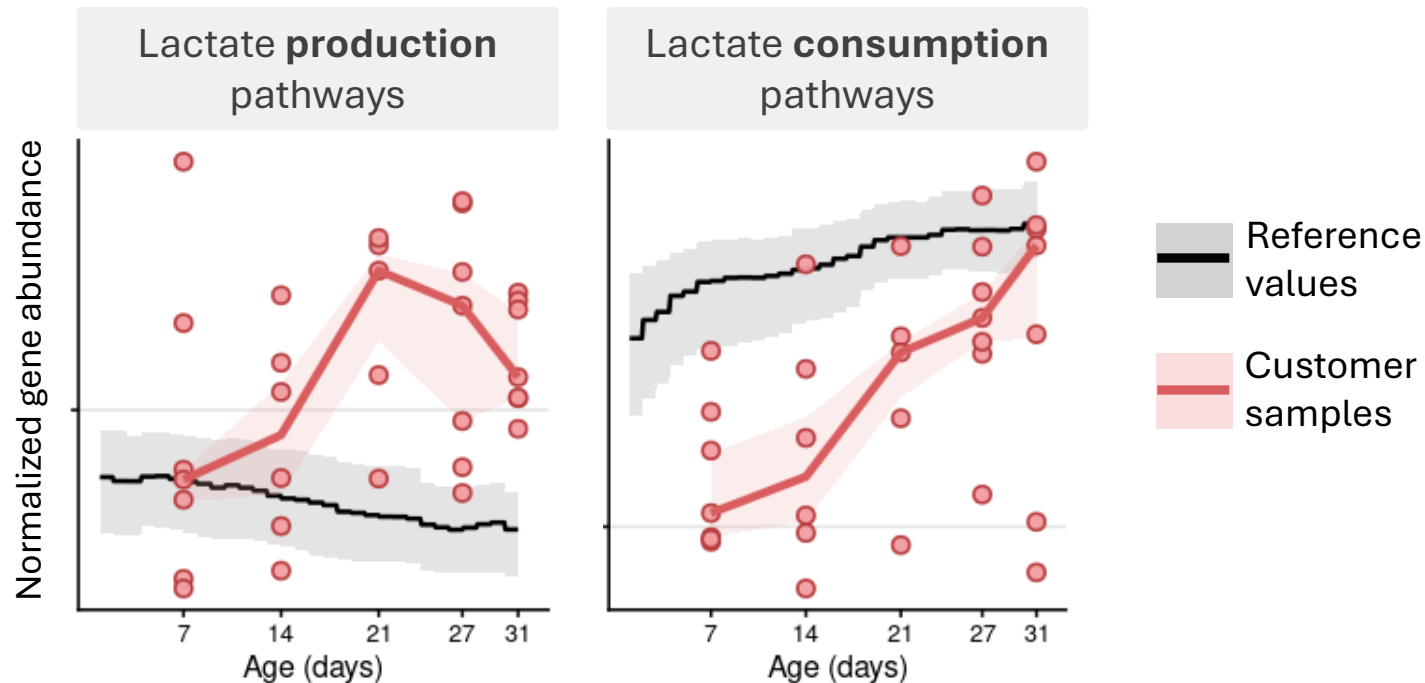
- L-lactate (host) and D-lactate (microbiome) are the two stereoisomers found in blood
- Can be elevated under hypoxia e.g. poor air quality, high altitude etc, activity, vitamin deficiencies or with microbiome derangement (high lactate production, low butyrate production)
- Improving starch digestion in the proximal GIT and supplemental B vitamins and minerals can help e.g. B2 and Mn are essential co-factors for D-lactate dehydrogenase whereas L-lactate dehydrogenase benefits from B3 and Zn. Vitamin B1 can also help with lactate clearance t



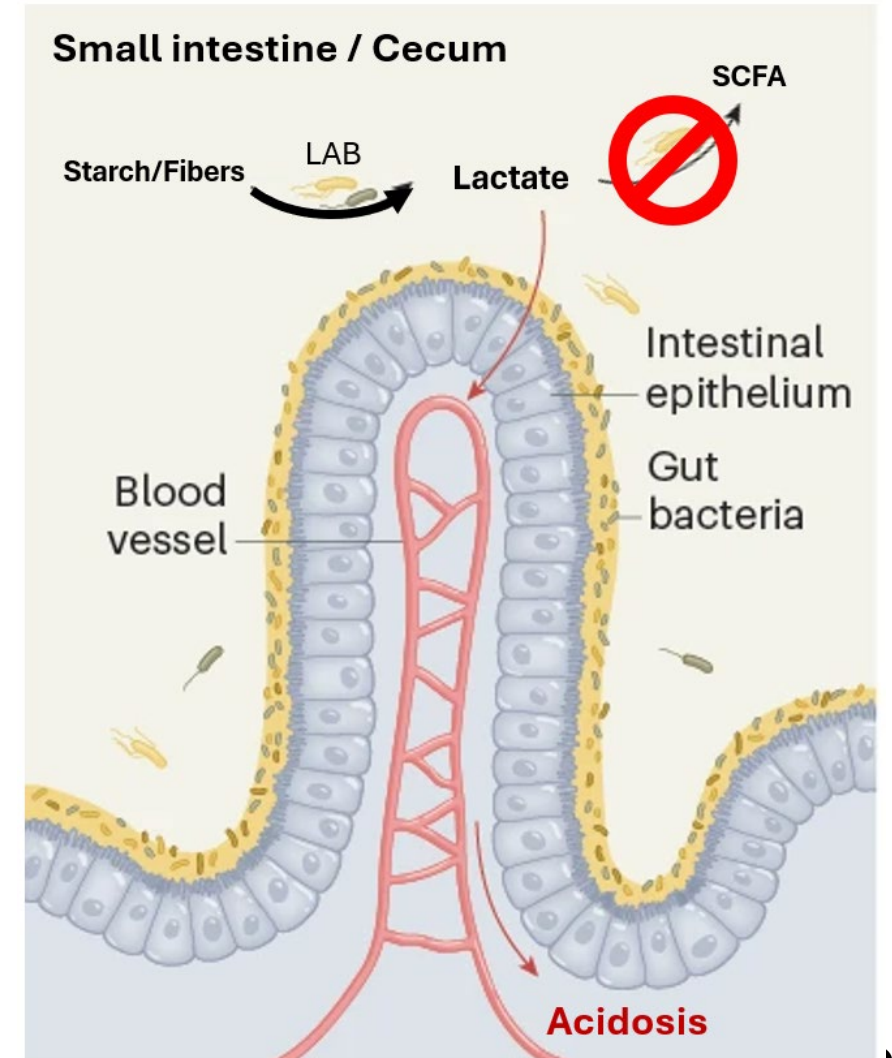
Using precision microbiome profiling to predict health in commercial broiler production

One example

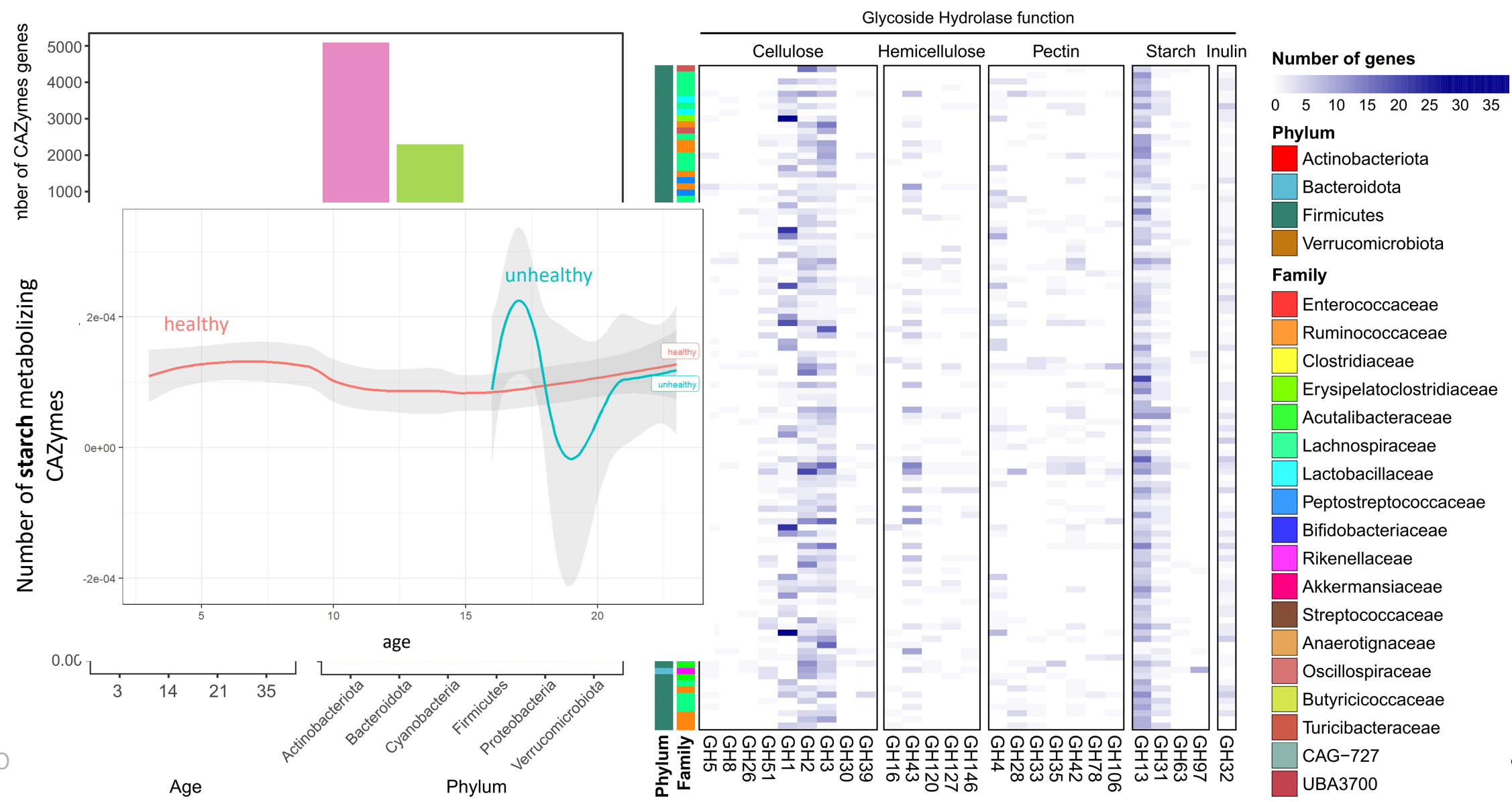
- **Reduced performance** observed, associated with **severe blood acidosis**; underlying cause of acidosis not identified.
- ➔ Microbiome showed **extremely high levels of lactic acid-producing bacteria**; excess lactate entered the bloodstream, contributing to acidosis
- ➔ Key microbial pathways driving **lactate imbalance** identified:



Lactate-induced blood acidosis



Segura-Wang et al. (2021) Abundance of carbohydrate associated enzymes in the broiler caecal microbiome, revealing the importance of GH2, GH3 and GH13 hydrolases



Customer Use Cases:

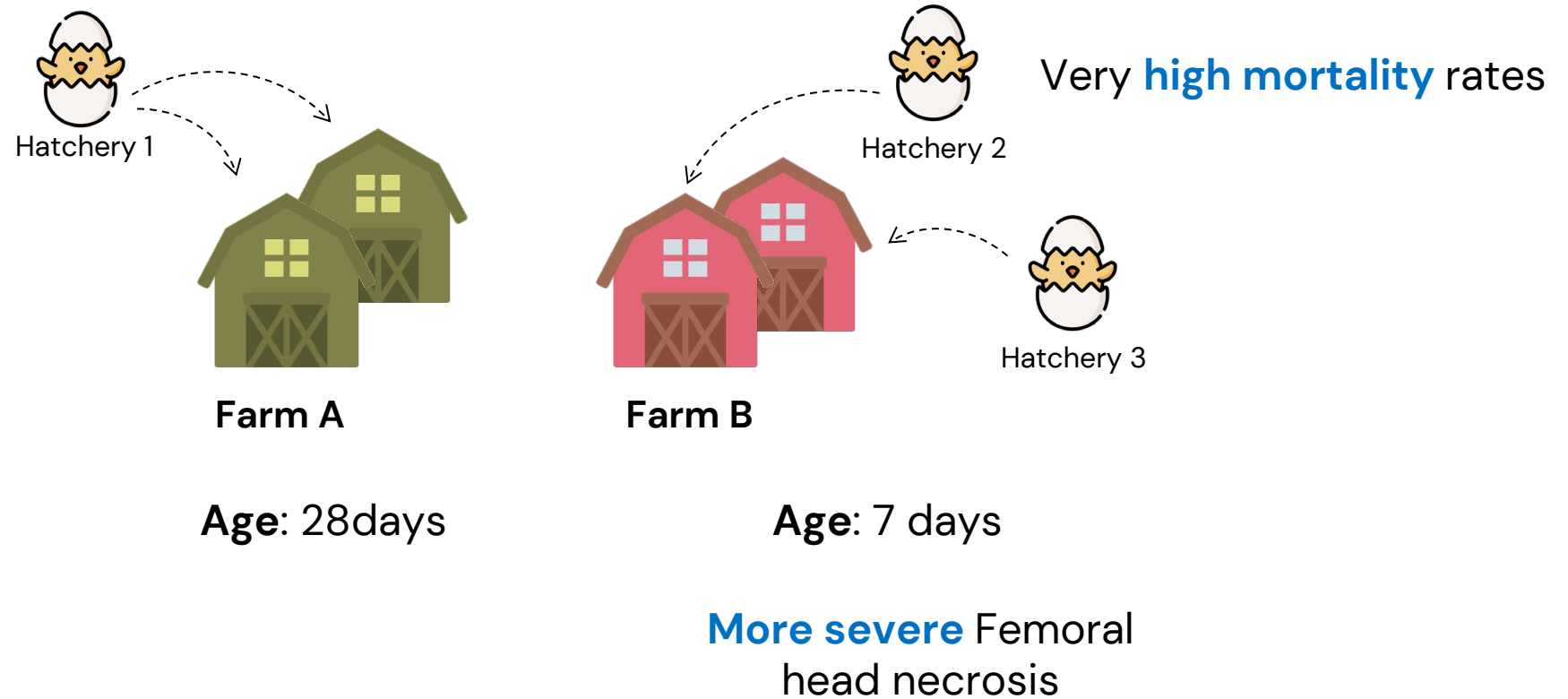
Coccidiosis

Metabolic acidosis

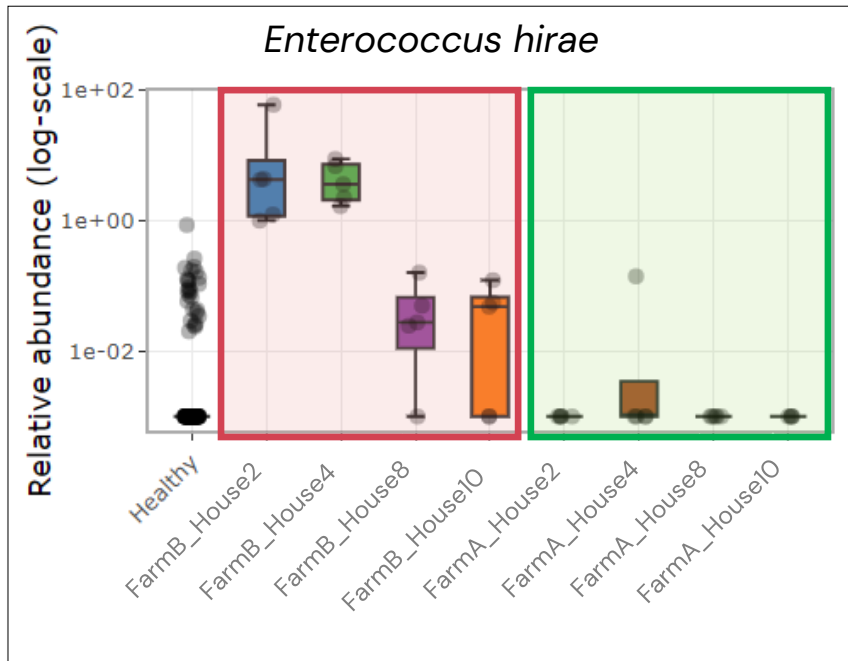
**Bacterial chondronecrosis
with osteomyelitis**

Case Study: Microbiome Biomarkers Reveal Potential Root Cause for Severe Femoral Head Necrosis

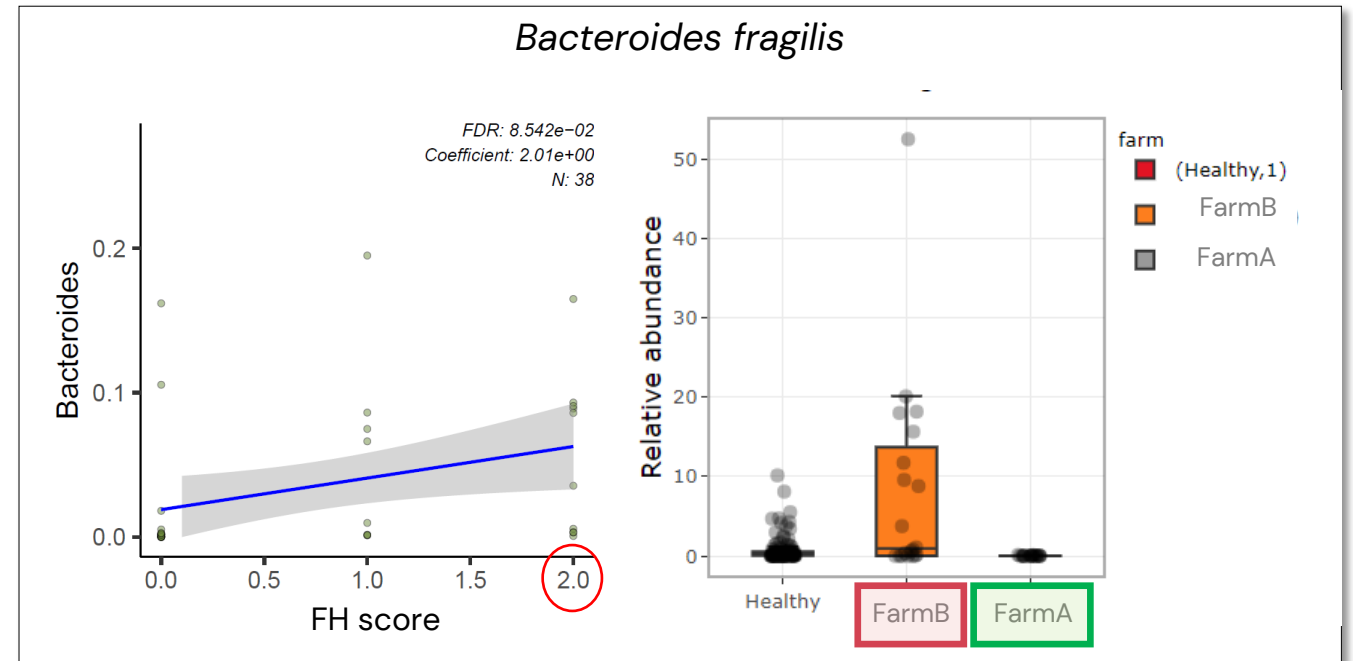
- 40 animals in total
- 2 different farms
- 3 different hatcheries



Enterococcus hirae and *Bacteroides fragilis* might be the reason for severe femoral head necrosis in young birds



- Very high levels in **Farm B**, mainly found in **House 2** and **House 4**, which had higher number of **severe FH**.
- *Enterococcus hirae* is not the most typical pathogen, but it is known to increase mortality, and cause locomotion problems.

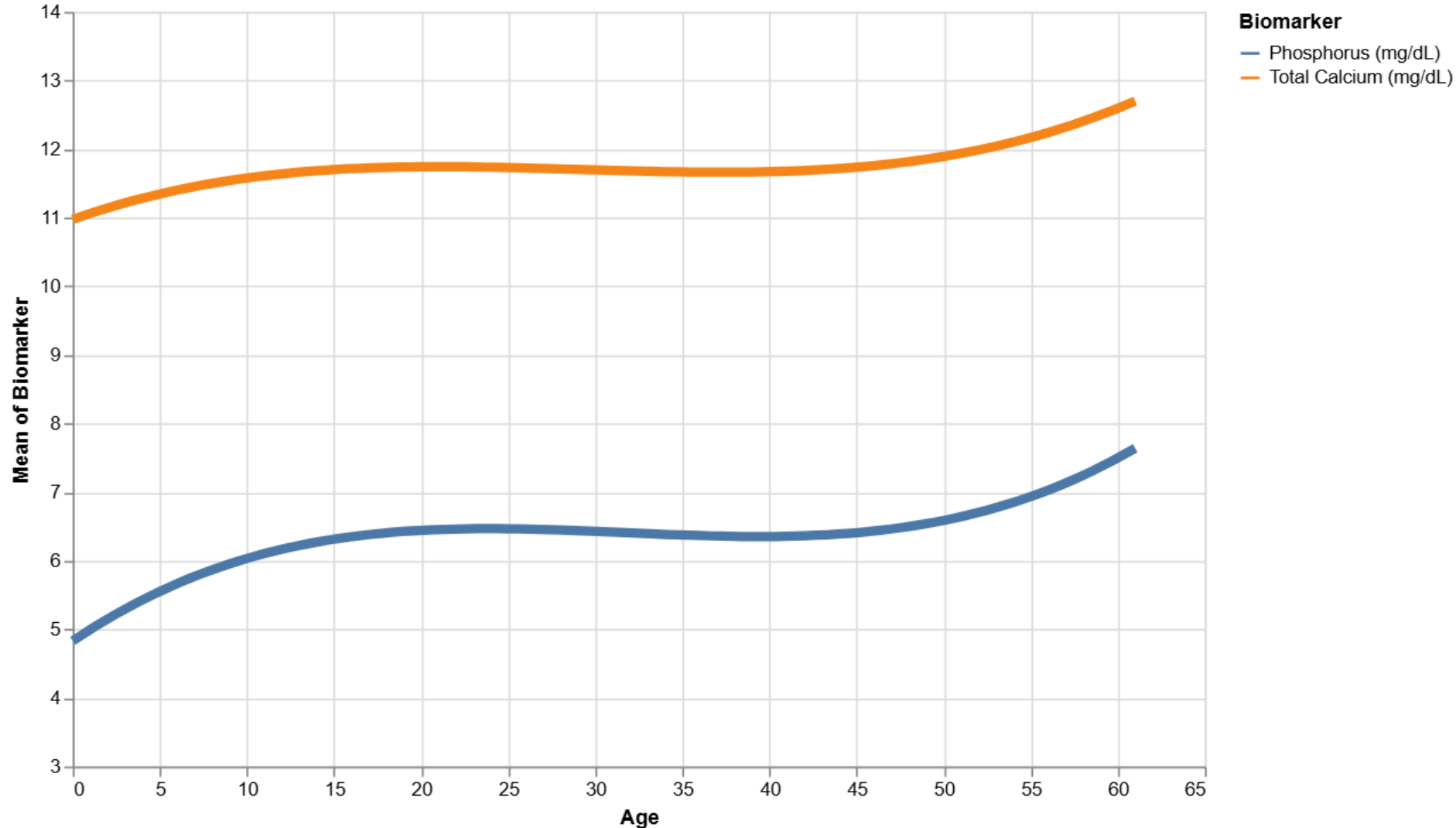


- Birds severely affected by FH (score 2) have a significant higher level of *Bacteroides fragilis*.
- Also, mainly found in **Farm B**.
- *Bacteroides fragilis* is an opportunistic pathogen that has been reported to cause osteomyelitis.

Optimisation of Ca and P status of broilers



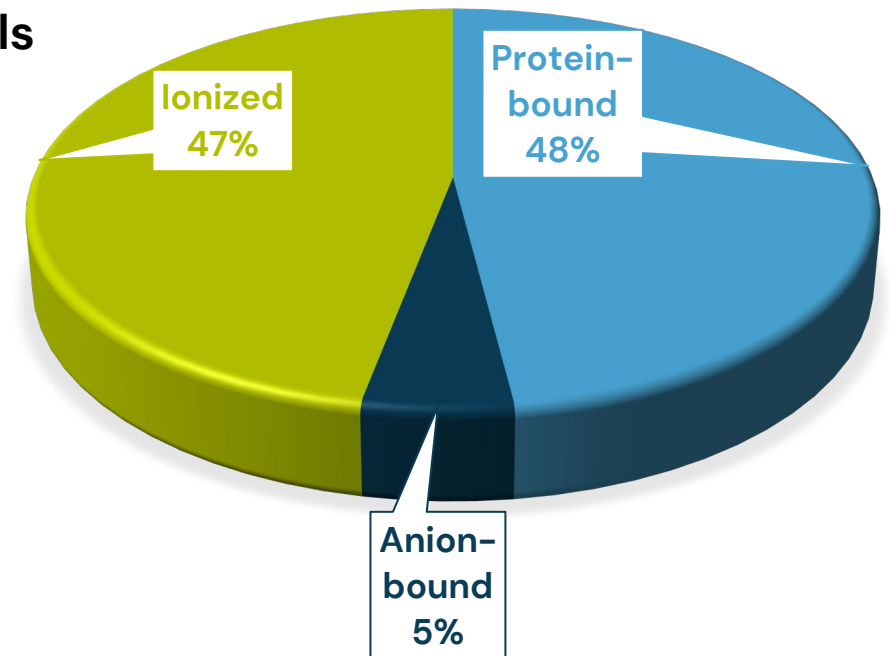
- Blood phosphorus in broilers is optimized around 6.5–7 mg/dl and blood calcium around 11.5–12.0 mg/dl (~10,000 commercial broiler farms)



Ionized calcium

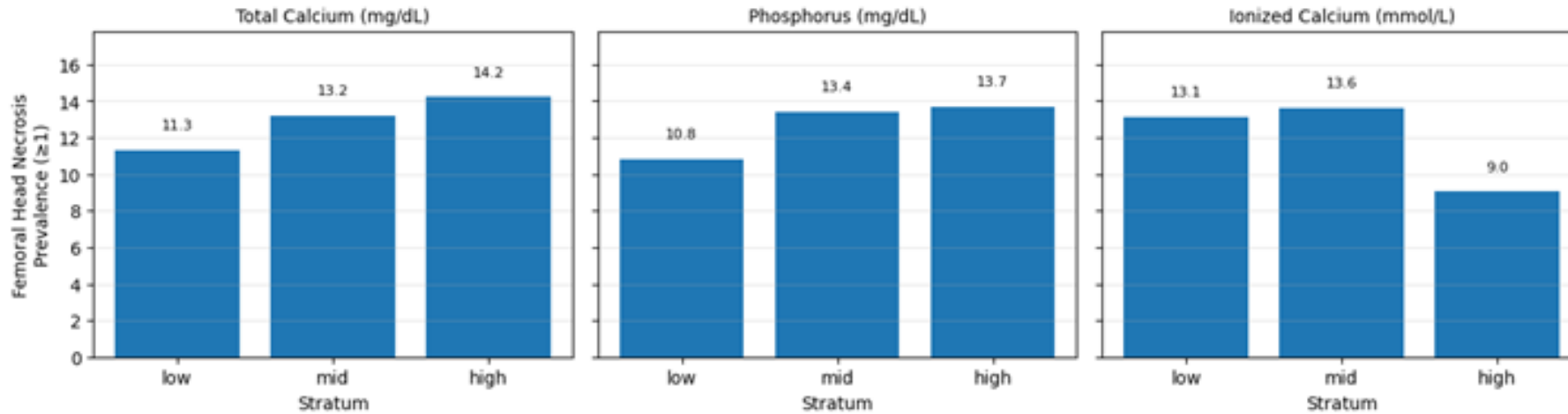


- 99% of body calcium is found in the skeleton
- The remaining 1% is distributed between extracellular and intracellular pools:
 - Intracellular calcium is used for e.g. cell division, muscle contraction, enzyme function etc
 - Extracellular calcium circulates in blood
- When we measure total blood calcium it is this extracellular calcium pool that is quantified i.e. around 11.5mg/dl of blood
- Total blood calcium is further divided into three distinct pools
 - Protein-bound
 - Anion-bound
 - Ionized (~5.5mg/dl or 1.35 mmol/l)
- Albumin is the primary plasma protein responsible for calcium binding (around 80% of protein-bound calcium is covalently associated with albumin)
- The anion-bound calcium is associated with e.g. phosphate, lactate, citrate and free fatty acids



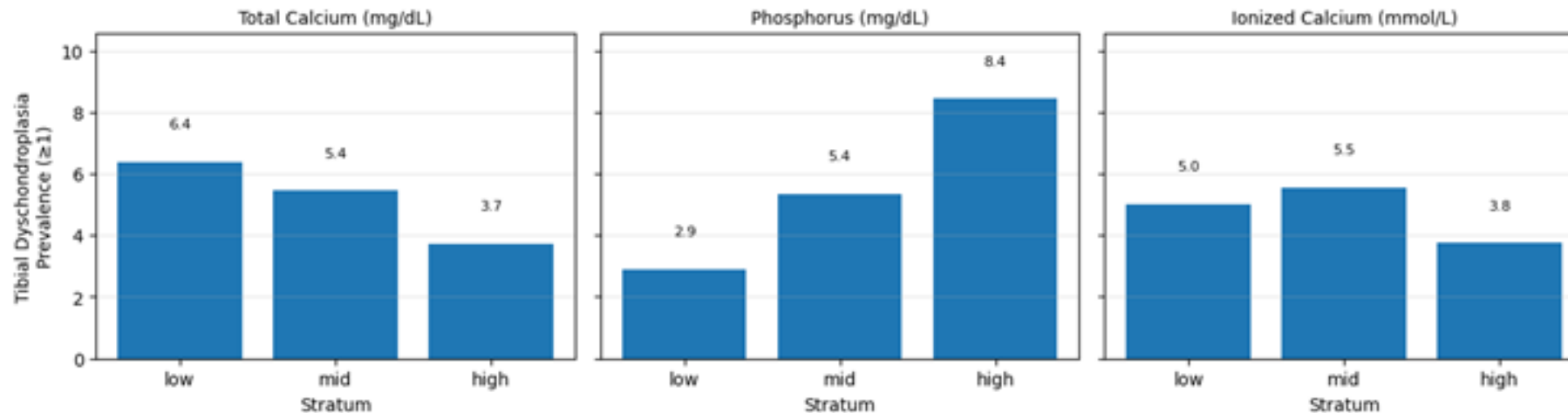
Skeletal abnormalities are statistically associated with blood Ca and P derangement

Femoral Head Necrosis: prevalence by biomarker strata



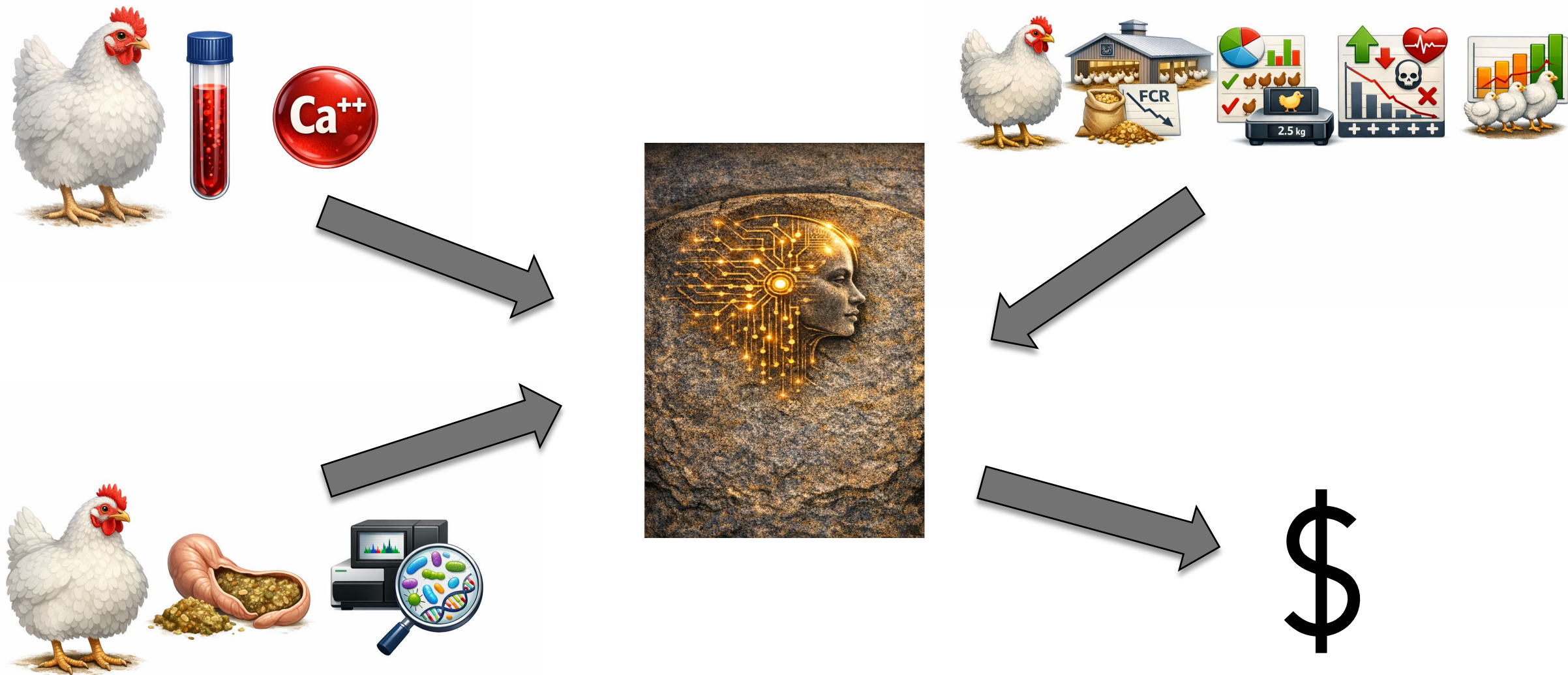
- To minimize FHN we need to aim for maximizing plasma ionized calcium which involves more than simply increasing mass calcium supply

Tibial Dyschondroplasia: prevalence by biomarker strata



- To minimize TDS we need to avoid hyperphosphataemia and hypocalcaemia – much lower involvement of ionized calcium per se

Value of AI and machine learning, supported by FAIR data



Take Home Messages

- Strategic intervention in nutrition, live production or veterinary domains requires access to more granular and predictive data streams
- Metabolomics and meta-genomics, combined with systematic meta-data capture offers unique insights that our industry has not previously had access to
- AI and machine learning capabilities are now widely available and play a critical enabling role to convert complex multi-dimensional data into actionable insights
- The future success of our industry will depend on FAIR data practices and enhanced collaboration between primary producers and the allied industry
- Please reach out to us to learn more!

We bring progress to life