Harnessing the Unique Actions of Carbohydrases in Monogastric Nutrition

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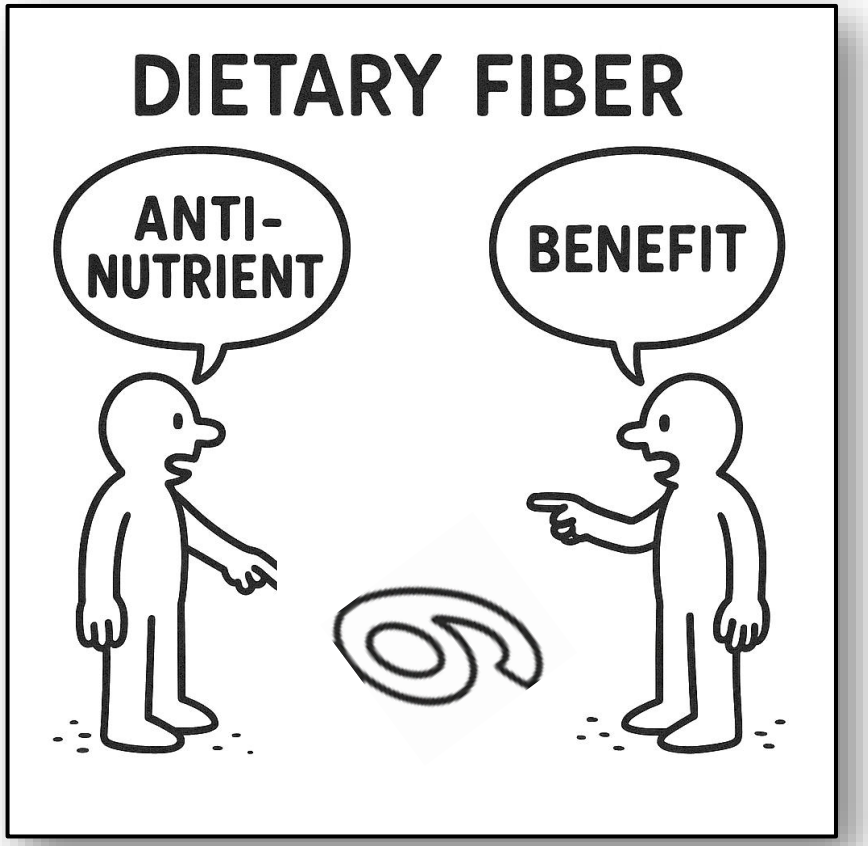
AFGA Nutrition Seminar

Outline

- Rethinking dietary fiber in monogastric nutrition
- What is really driving energy uplift with enzyme supplementation?
- Capitalizing on causative MOA of carbohydrases
- Considerations for evaluating and successful use of carbohydrases
- Looking ahead, what is the future of enzymes?

The Fiber Dilemma

- ↓ Dilutes Dietary Energy
- ↑ Heat Increment
- ↓ Reduces Feed Intake
- ↓ Reduces Growth Performance



- ↓ Pathogen adhesion
- ↑ "Gut health"
- ↓ Inflammation
- ↑ Beneficial Microbiota

…. Both perspectives are valid….

So, how do we balance them?

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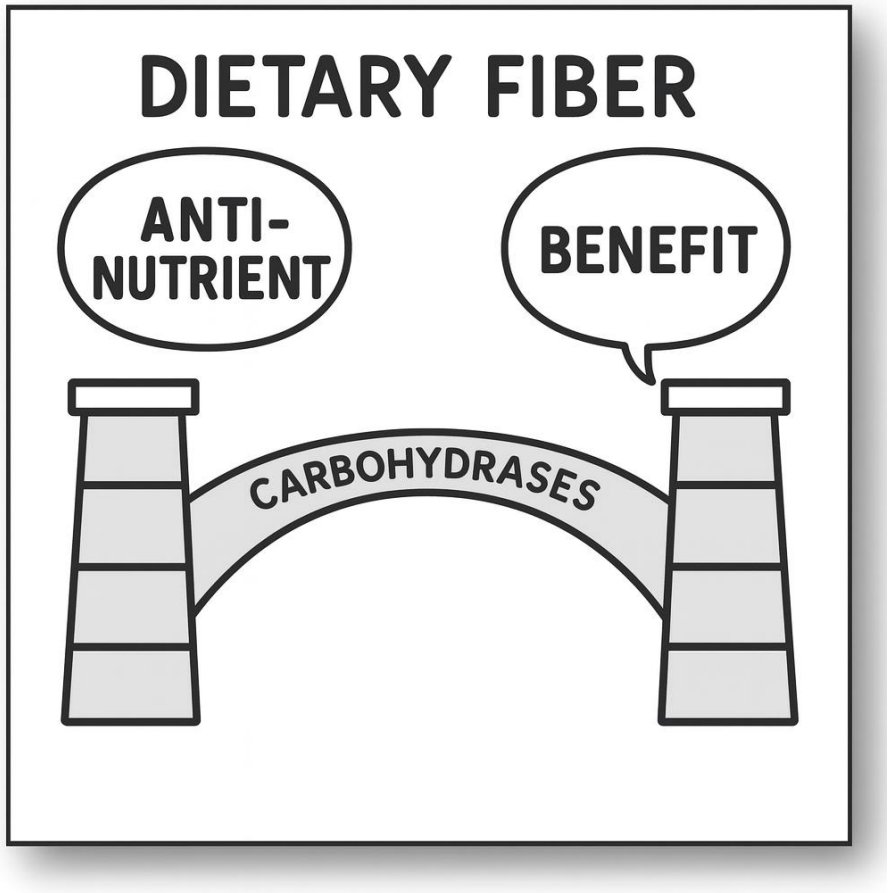

- ↓ Pathogen adhesion
- ↑ "Gut health"
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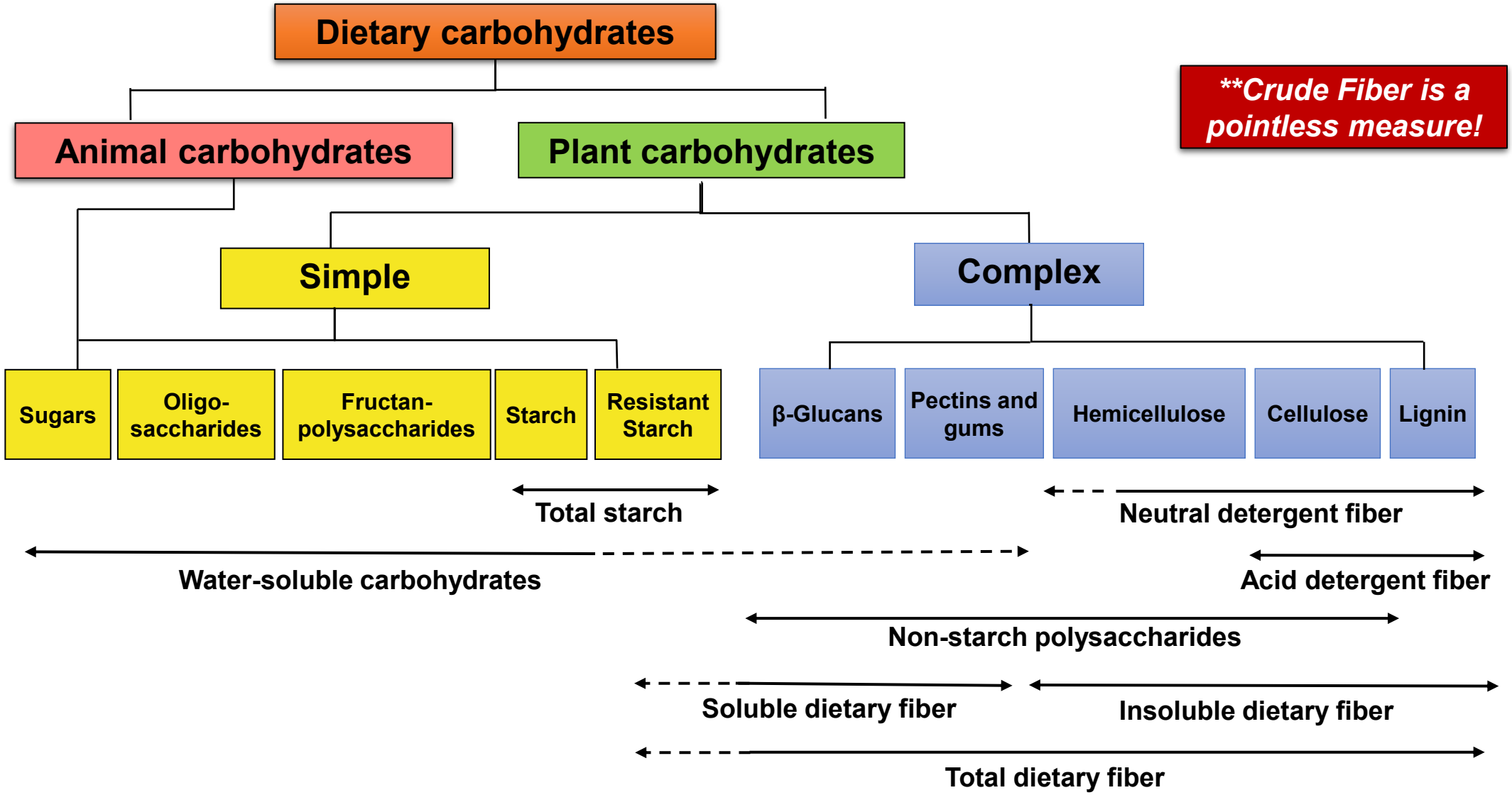
- ↑ Beneficial Microbiota

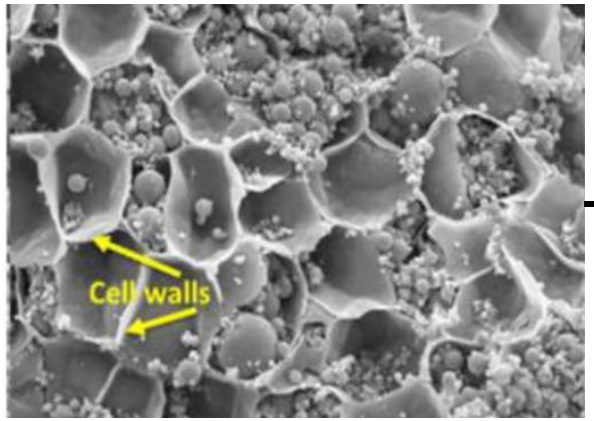
Carbohydrases are one technology that can aid in bridging these aspects of dietary fiber

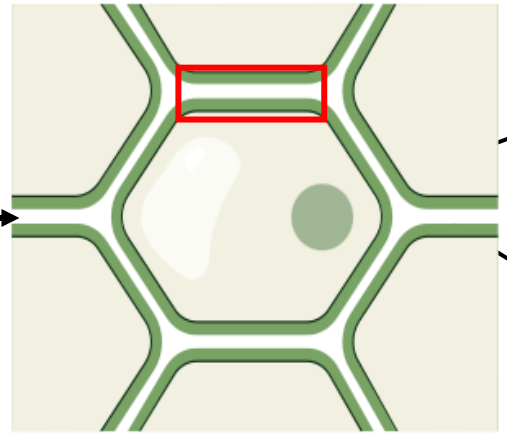
All fiber is not created equal… looking beyond 'fiber' assays

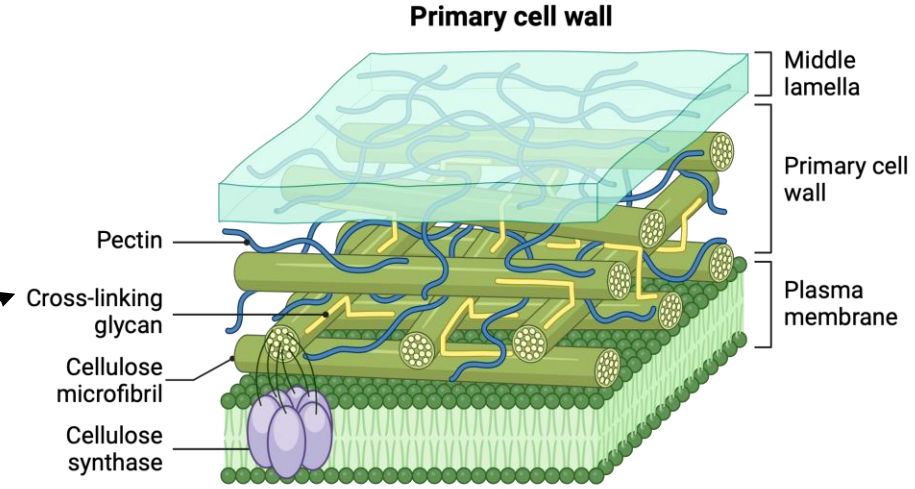


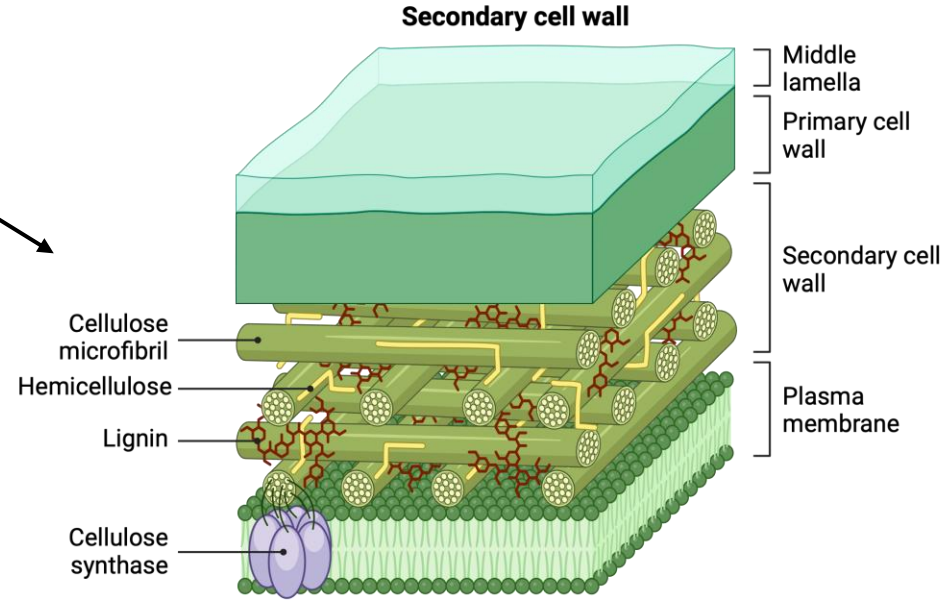
Appreciating Fiber for its dimensionality

Fiber is complicated!
Because nature intended it to be!









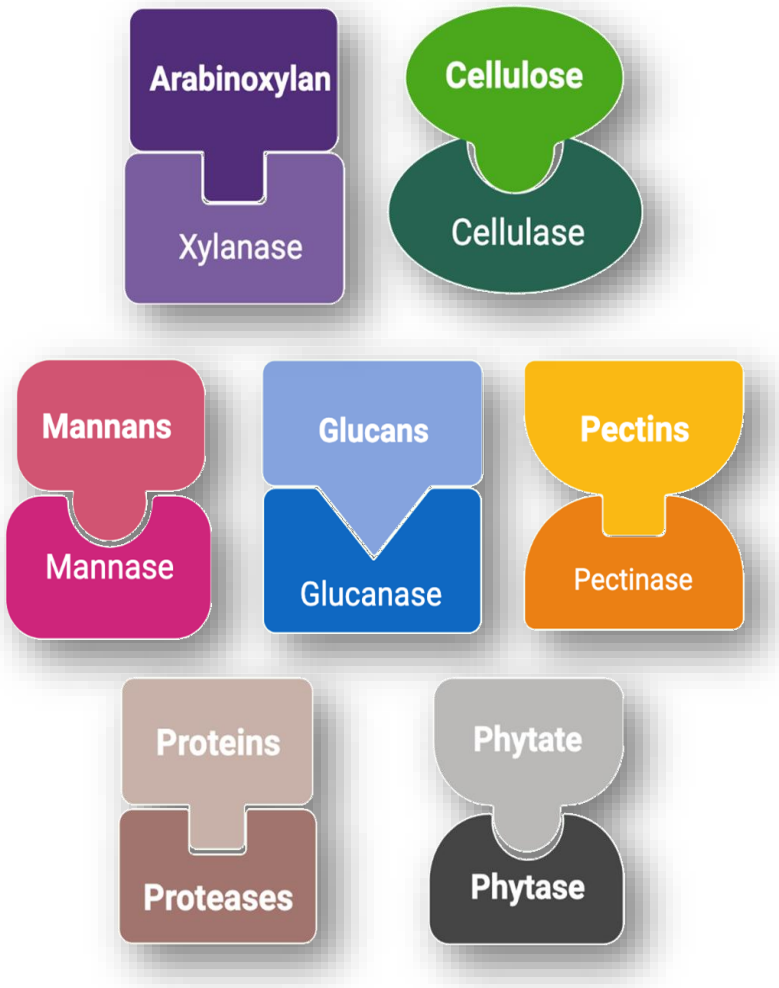
There are 14 unique NSP that can make up the cell wall of common plants, and over 60 enzymes that can target them!

(Puhlmann and de Vos, 2022)

To effectively apply feed enzymes... *we must first understand what substrates we have!*

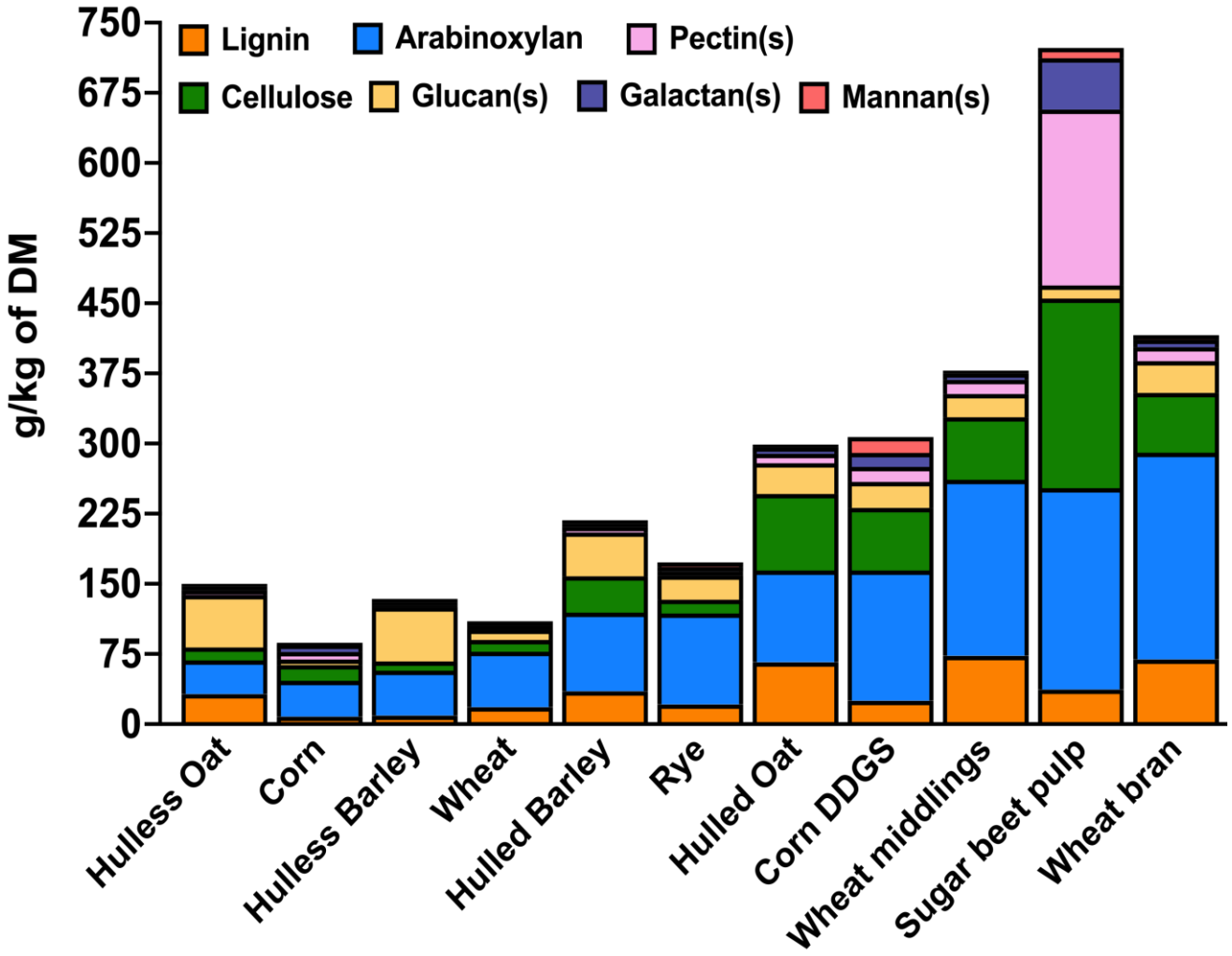
- **Foundational questions to consider when deciding which enzyme(s) to adopt:**
  - What are the primary substrates in my diet?
  - What feedstuffs are providing those substrates?
  - What enzymes match those substrates?
  - What ***specific*** objectives do I want to achieve with an enzyme?
  - Are their responses additive?
    More is not necessarily better!

1+1 ≠ 2 with enzymes!!
Law of diminishing returns



Fiber composition of common energy & fiber sources

- **Arabinoxylan**
  - Accounts for 25 to 60% of DF
- **Cellulose**
  - Accounts for 5 to 30% of DF
- **β-Mannans**
  - Less than 5%
- **Mixed β-Glucans**
  - Accounts for 1 to 20% of DF
- **Galactooligosaccharides**
  - Less than 10% (soy heavy diets)



(Petry and Patience, 2020)

What are the primary NSPs we can target with an enzyme?

Ingredient, %	TDF,%	Arabinoxylan,%	Cellulose,%	β-Mannans,%	Mixed β-Glucans,%	GOS,%
Corn	10	**3.8**	**2.2**	1.0	0.6	0.0
Wheat	11	**5.9**	**2.3**	0.5	1.1	0.0
Sorghum	11	**3.0**	**2.5**	0.4	1.0	0.0
Soybean Meal	18	**0.0**	**7.2**	1.1	0.0	**8.0**
Wheat Midds	28	**18.8**	**6.9**	1.0	2.5	0.0
Corn DDGS	27	**13.9**	**6.7**	3.2	2.8	0.0
Corn Germ Meal	37	**29.1**	**8.1**	0.4	1.5	0.0

30-50% of dietary fiber in US typical diets is arabinoxylan!

(Petry and Patience, 2020)

How do ‘carbohydrases’ work in poultry?

Main carbohydrase(s) mechanisms include…

Energy

1. **Energy Uplift-** Hydrolysis of NSPs into fermentable components
2. **Viscosity reduction** - Attenuating antinutrient effects of DF
3. **Anti-caging effect**- Disturbing the nutrient encapsulation effect of DF, improving bioavailability of nutrients

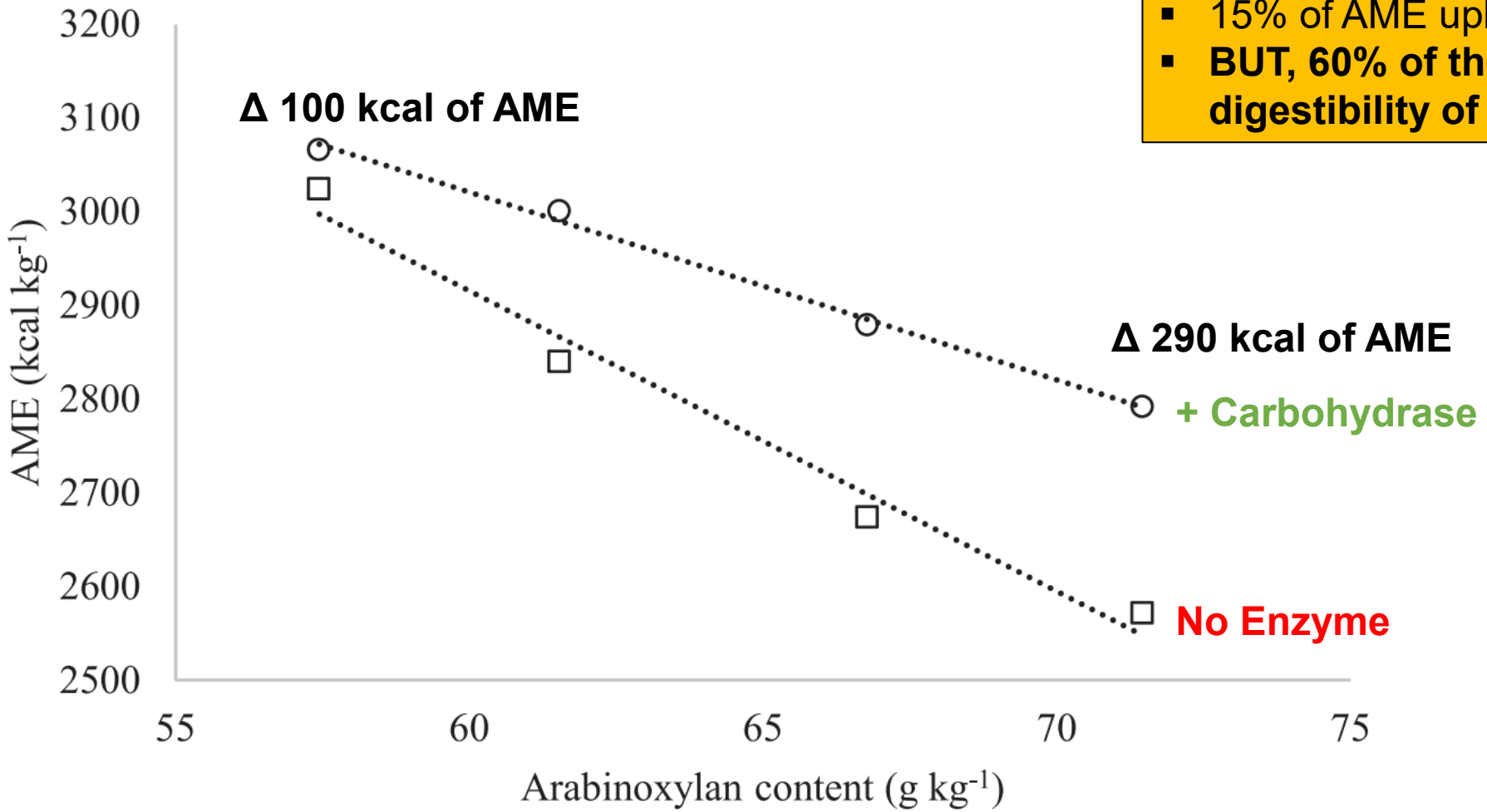
Health

4. **Prebiotic Effect** -Release products modulate microbiota in a manner that confers a health benefit
5. **Stimbiotic Effect-** Stimulate microbiota to ferment fiber beyond the fermentation of it’s release products alone

All Mechanisms of Actions for a NSPase are interconnected!

Energy uplift from carbohydrases is multifactorial!

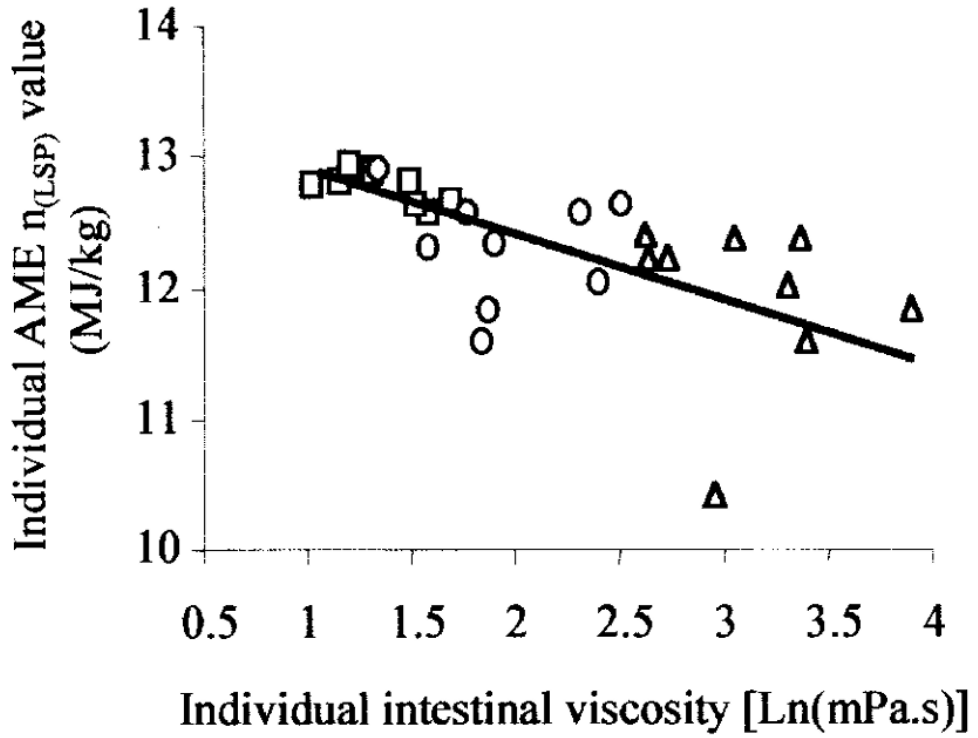
- 15% of AME uplift is from Fiber Digestibility
- **BUT, 60% of the uplift in energy is from digestibility of other nutrients!**



(Cozannett, 2017)

Viscosity reduction is the historical premise of enzyme development

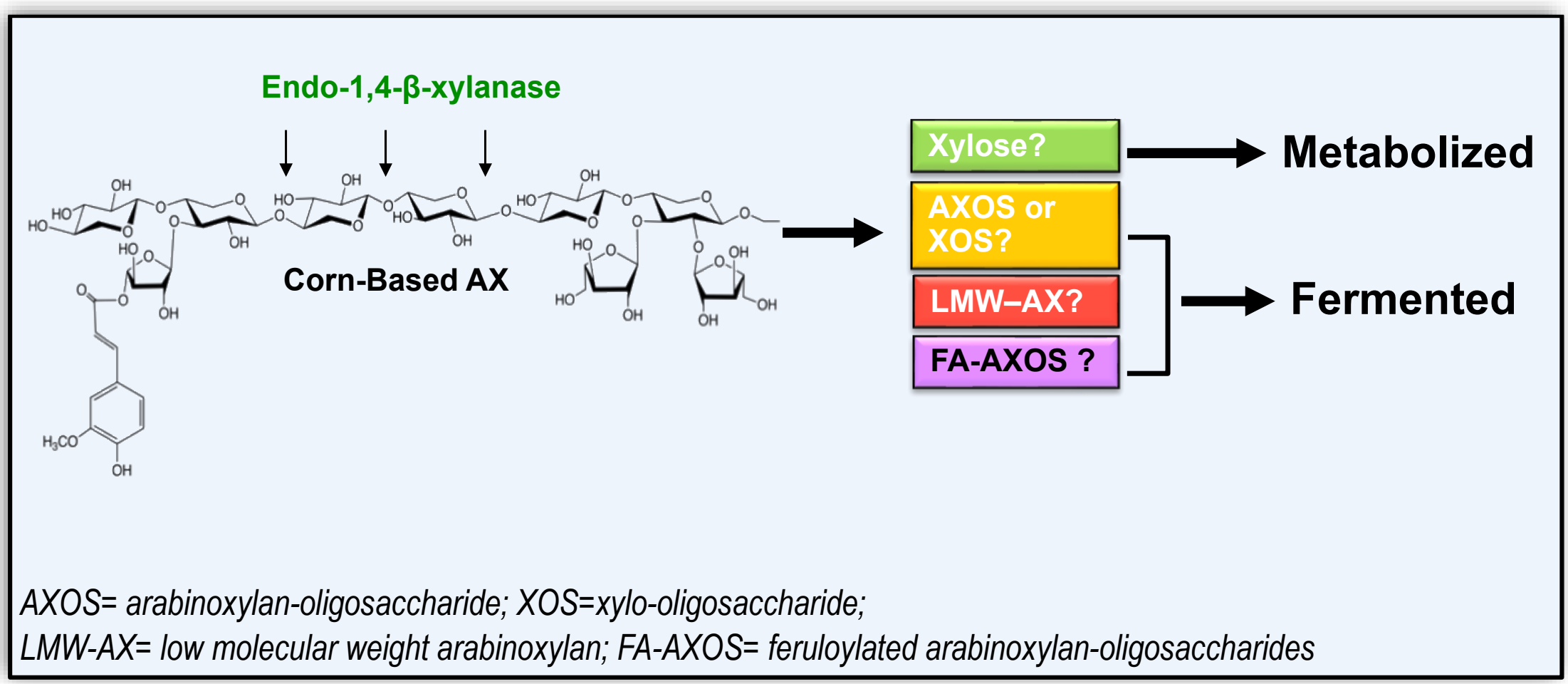
- **Viscosity refers to the 'thickness' or resistance to flow of digesta in the gastrointestinal tract**
  - Soluble NSPs from cereals like wheat, rye, and barley increase digesta viscosity
  - High viscosity slows nutrient diffusion and reduces the mixing of enzymes with substrates
  - Increased viscosity decreases nutrient digestibility and absorption efficiency
  - Enzyme action lowers digesta viscosity and improves nutrient availability



The effect of NSPases on broiler performance is most pronounced in viscous grains such as *wheat, rye, and barley.*

(Bedford, 1997; Petersen et al., 1999)

Xylanase a primary strategy for improving fiber utilization



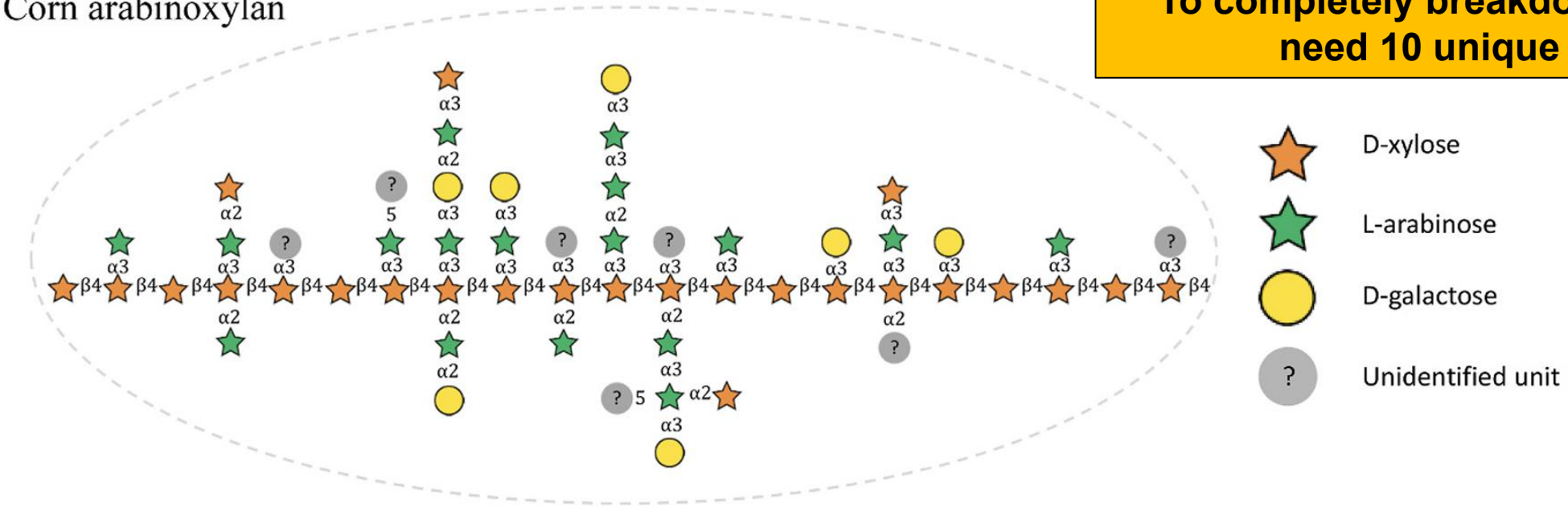
AXOS= arabinoxylan-oligosaccharide; XOS=xylo-oligosaccharide;
LMW-AX= low molecular weight arabinoxylan; FA-AXOS= feruloylated arabinoxylan-oligosaccharides

(Petry et al., 2023)

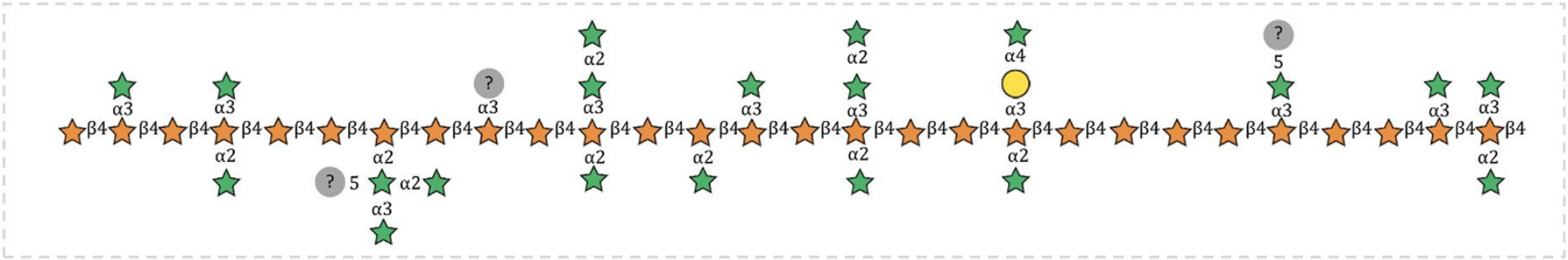
Arabinoxylans are one of the most abundant NSP in feeds

To completely breakdown corn AX you need 10 unique enzymes!

Corn arabinoxylan

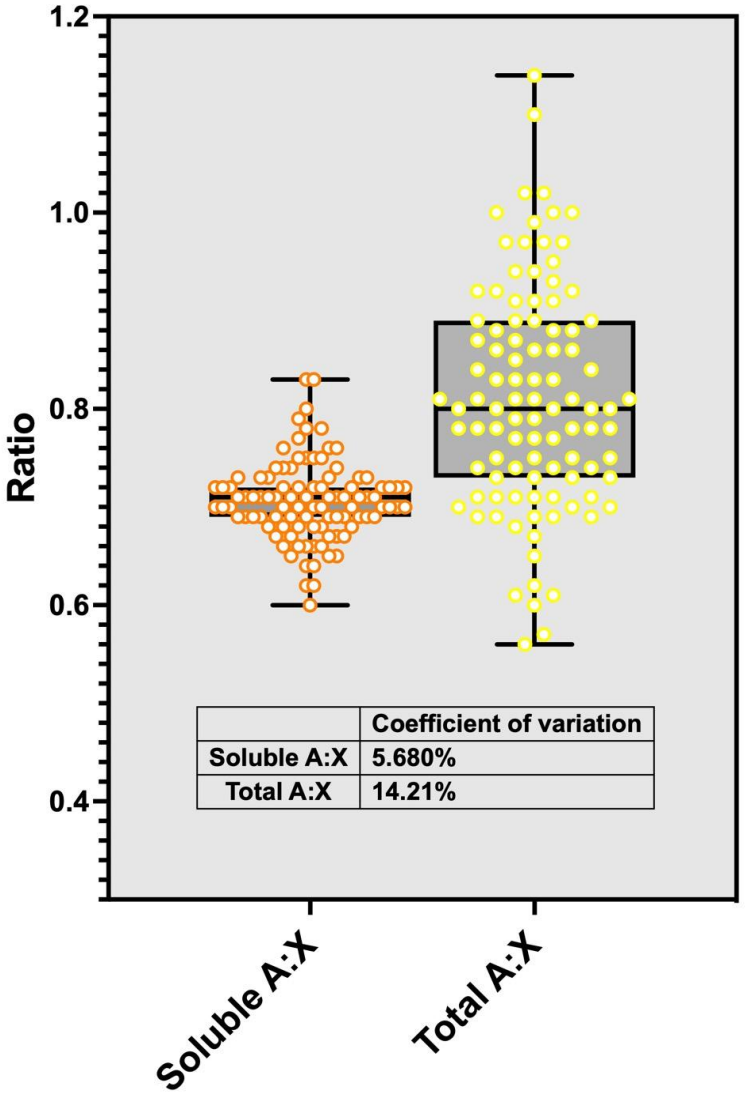


Wheat arabinoxylan

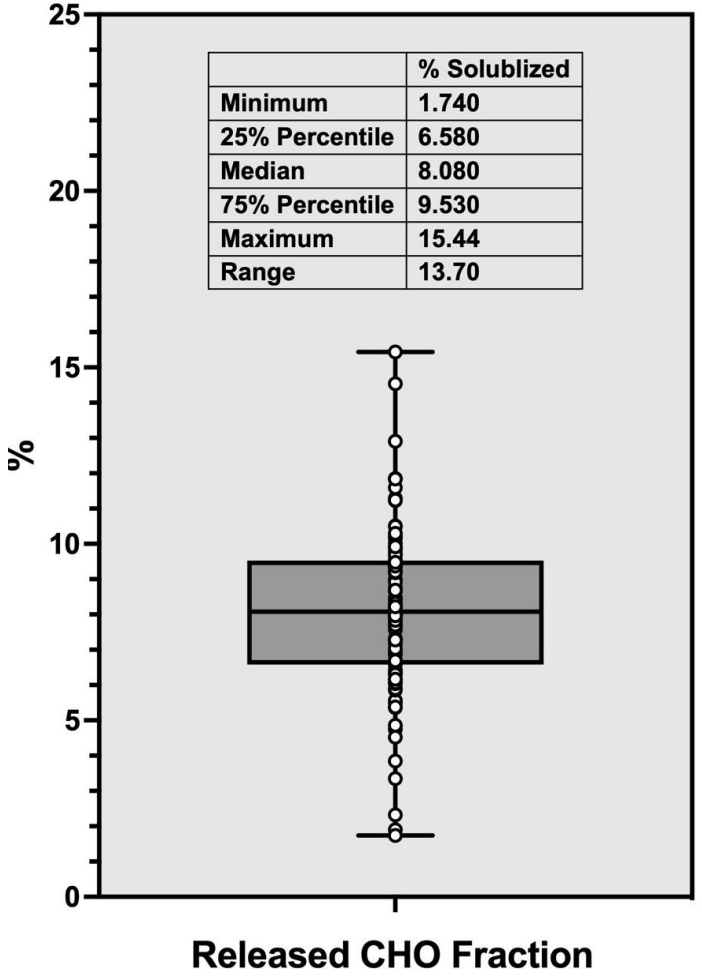


(Cozannett, 2017)

Ratio of A:X predicts efficacy of xylanase with DDGS

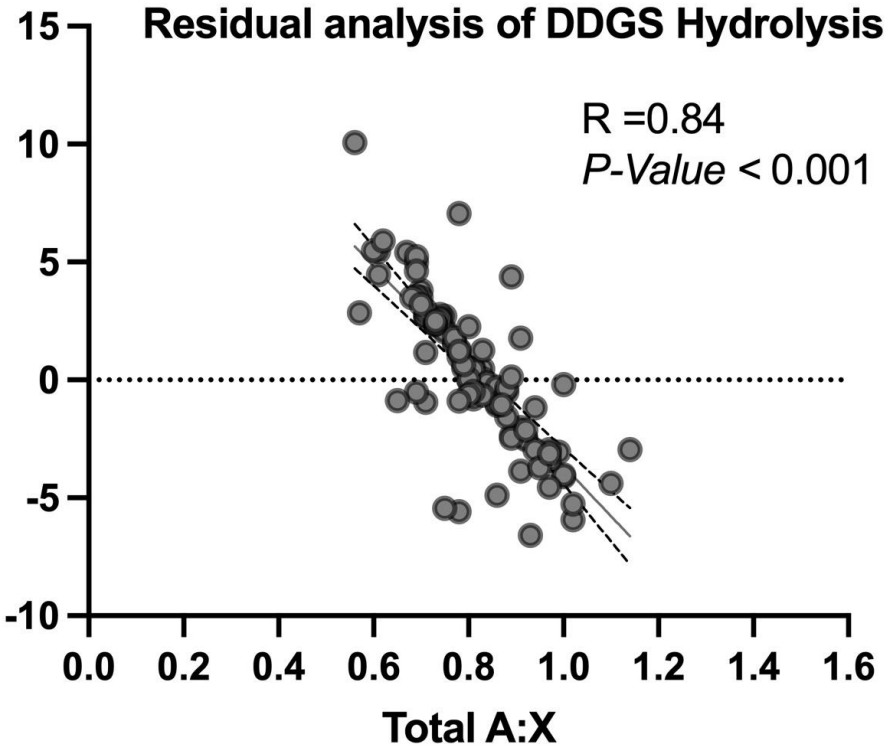


	Coefficient of variation
Soluble A:X	5.680%
Total A:X	14.21%



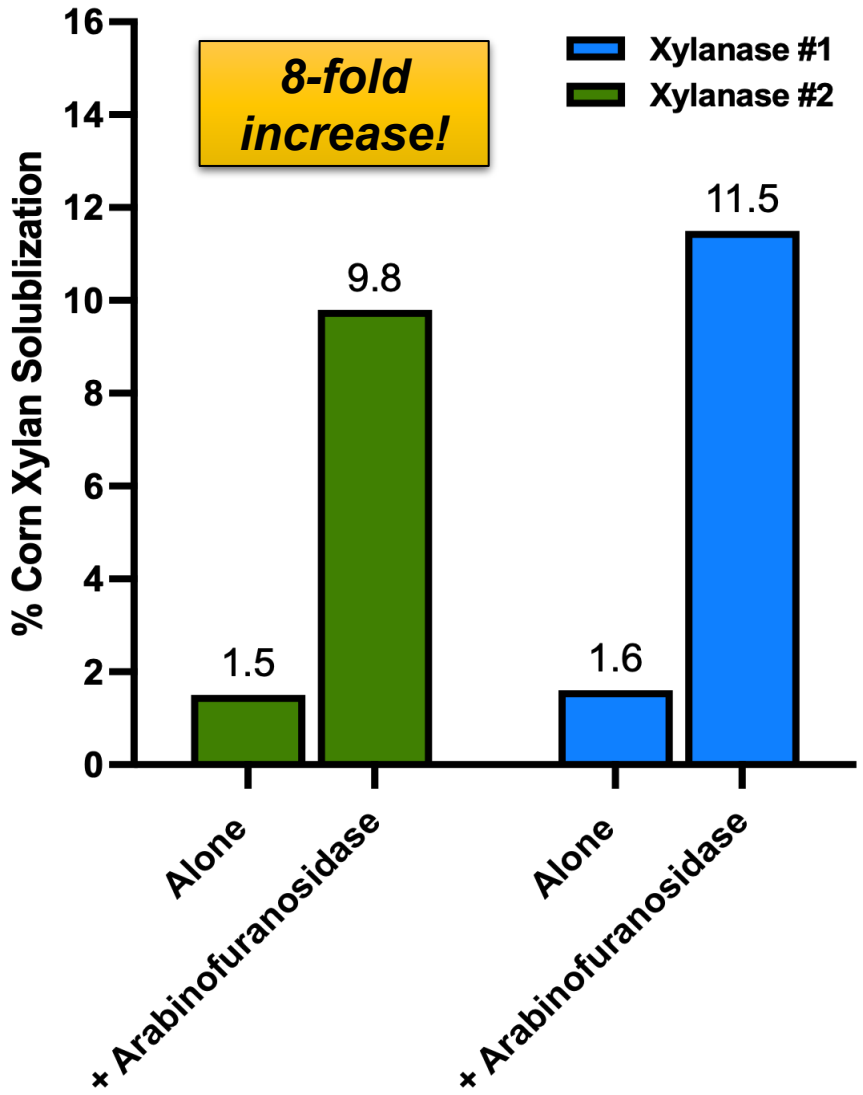
	% Solublized
Minimum	1.740
25% Percentile	6.580
Median	8.080
75% Percentile	9.530
Maximum	15.44
Range	13.70

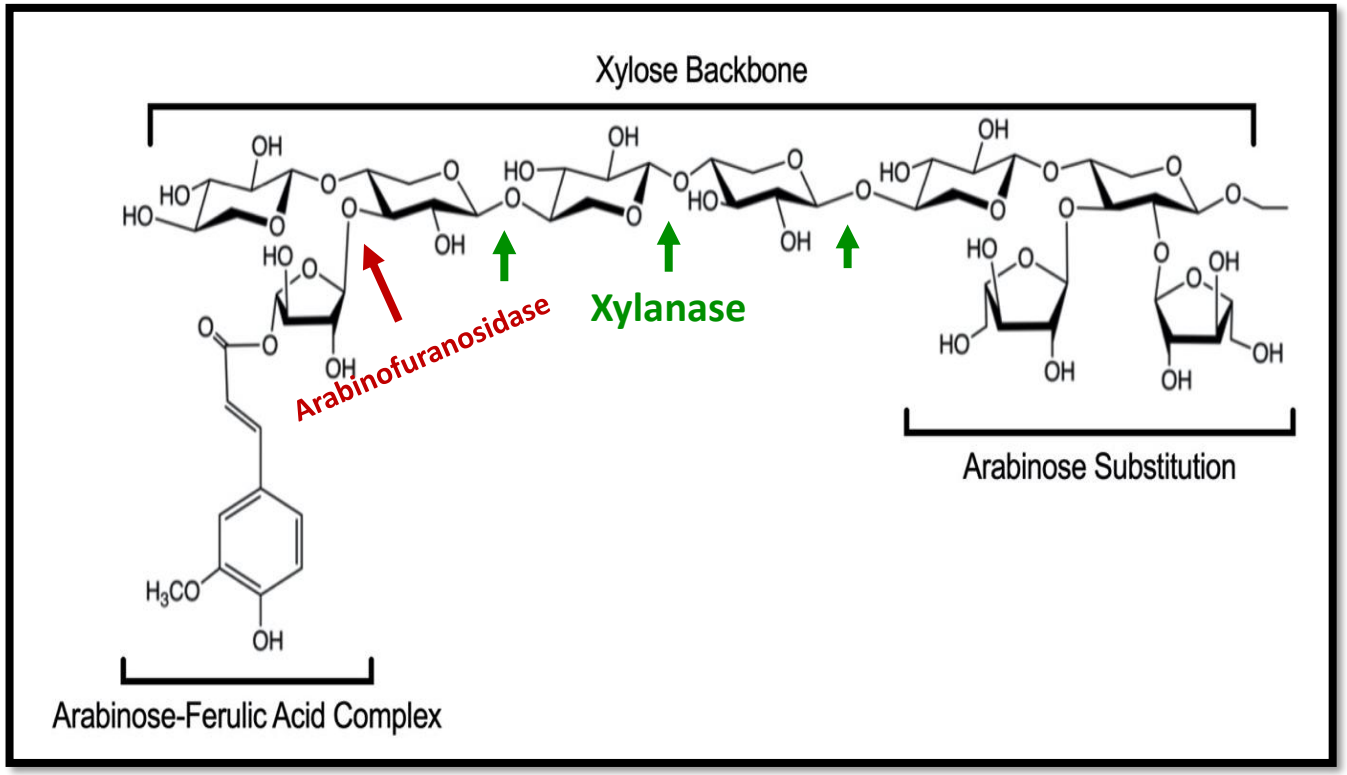
RSD of Solublization %



Branching of AX is a primary determinate of how well xylanase will work with corn based NSP!

Accessory enzymes for arabinoxylan improve digestibility





(Ward, 2021; Pederson, 2016)

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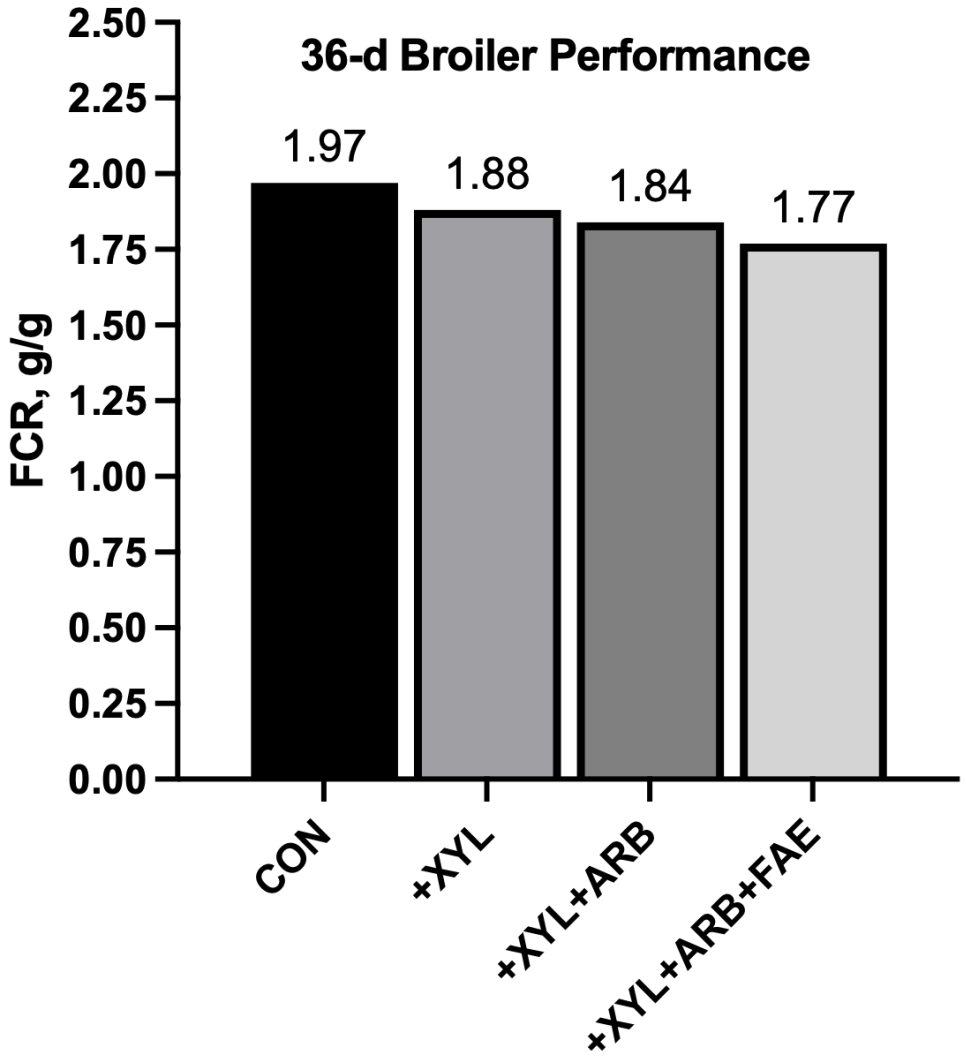
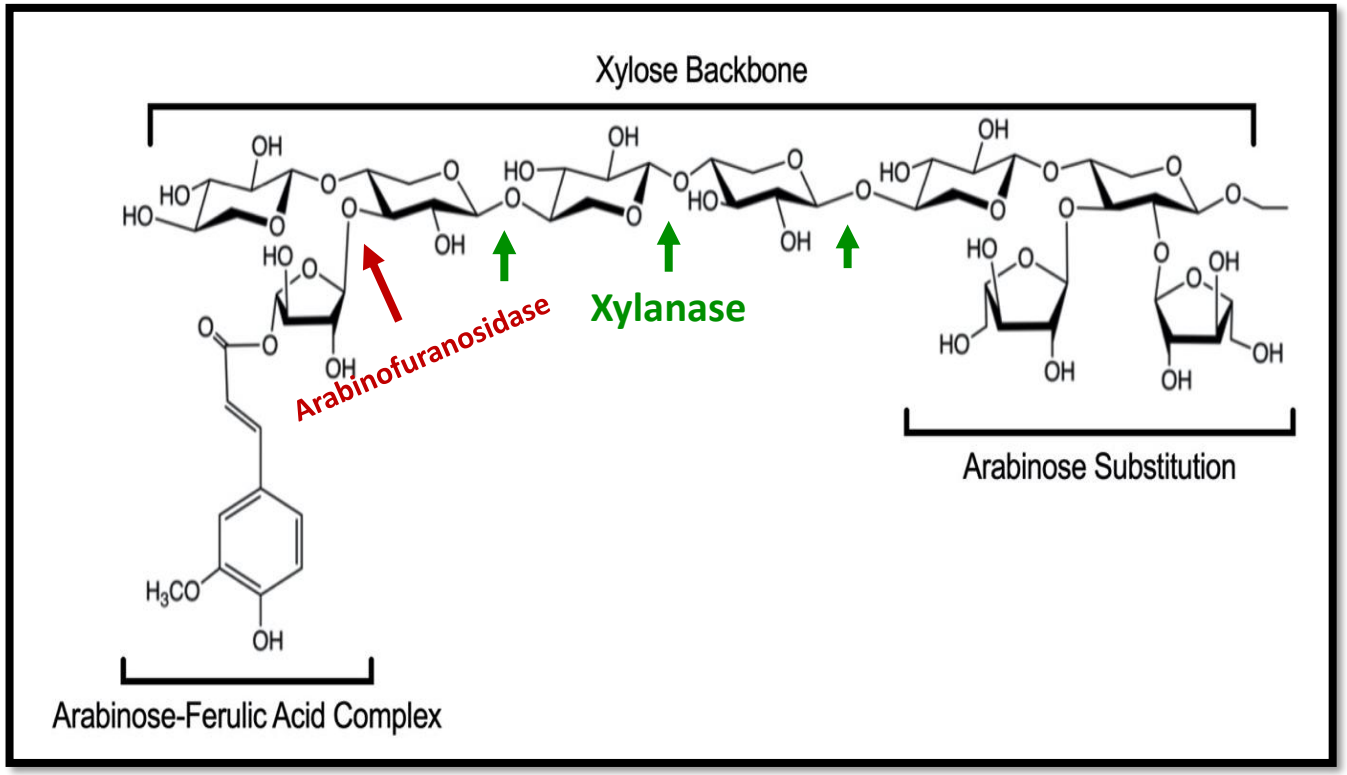
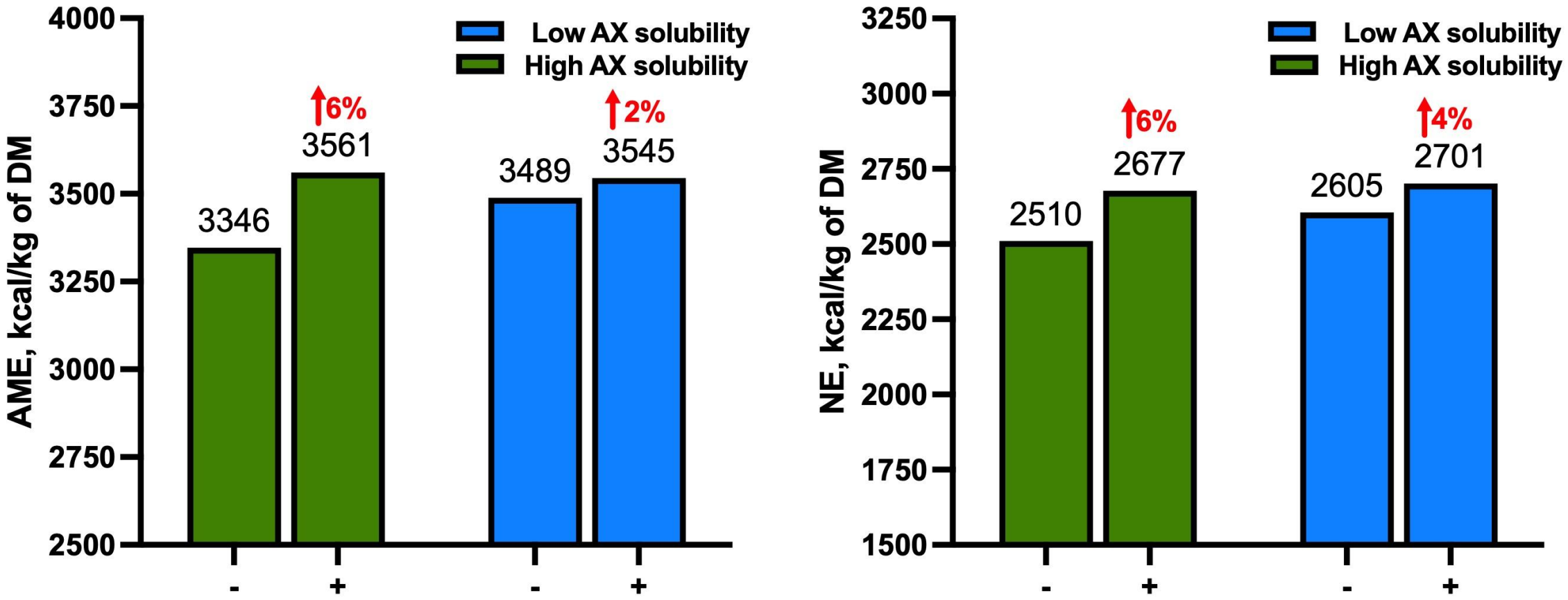




(Ward, 2021; Pederson, 2016)

AX solubility will change where the energy uplift comes from

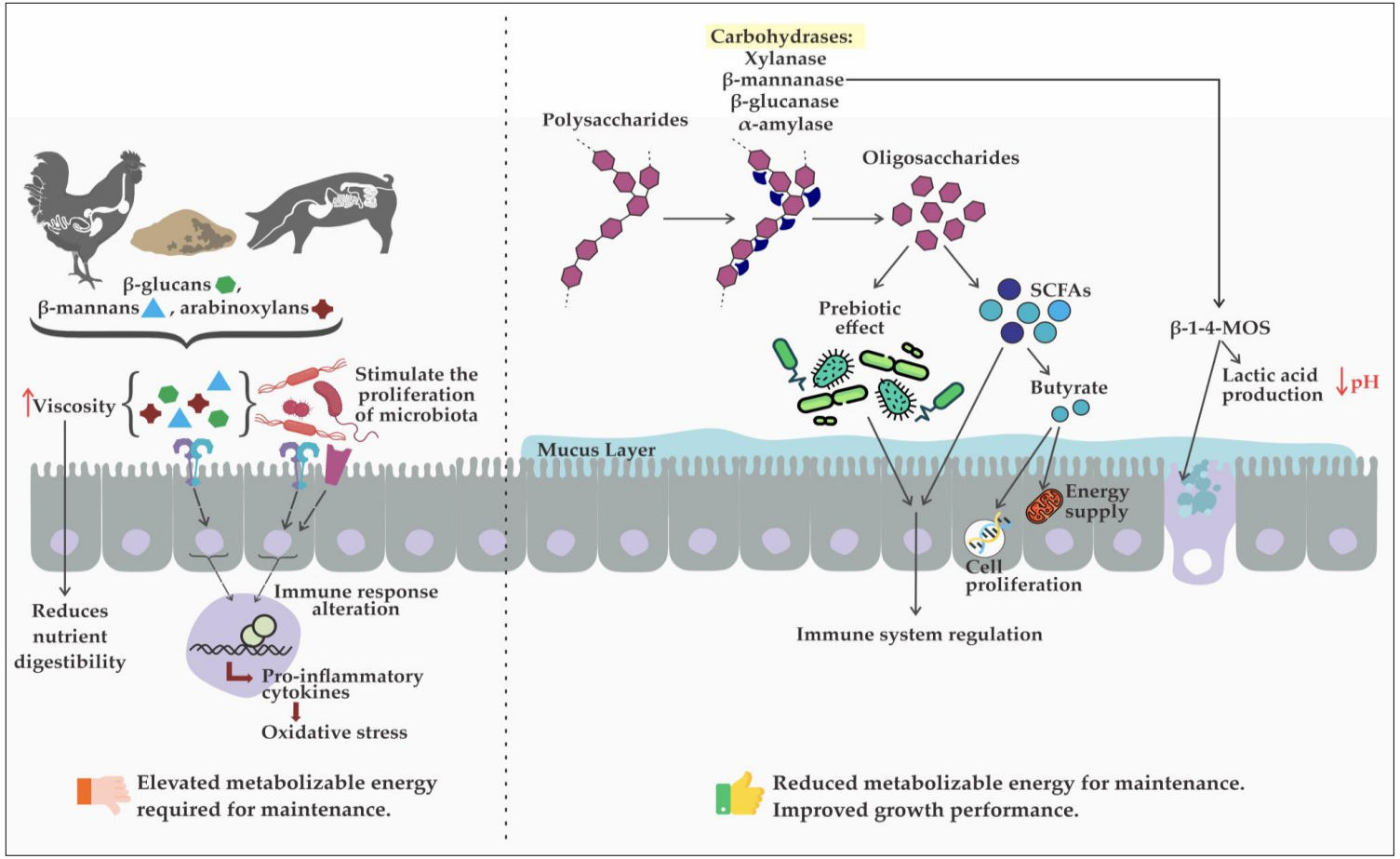


The impact of carbohydrases in 'corn like ingredients' is valued greater on a NE Basis! But why?

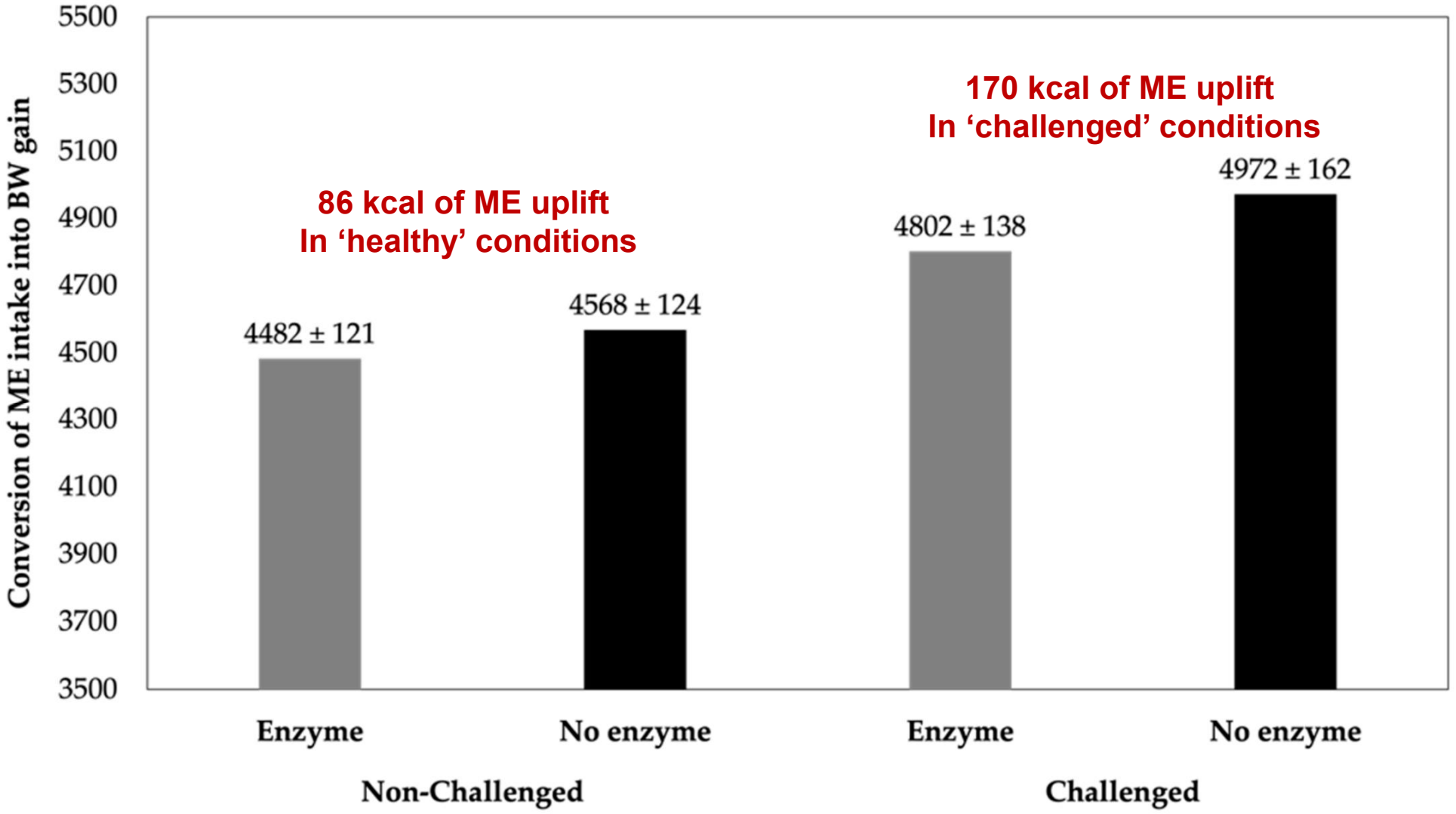
(Cozannett et al, 2020)

Health effect of carbohydrases impact energy uplift!

- β-glucans, β-mannans, and AX can overstimulate the gut immune system, leading to pro-inflammatory cascades
- This immune activation diverts AME to maintenance rather than growth
- Carbohydrases break NSPs into prebiotic oligosaccharides
- Improved microbial balance & SCFA production lower gut pH, inhibiting pathogens.
- Net effect is improved energy partitioning toward growth!

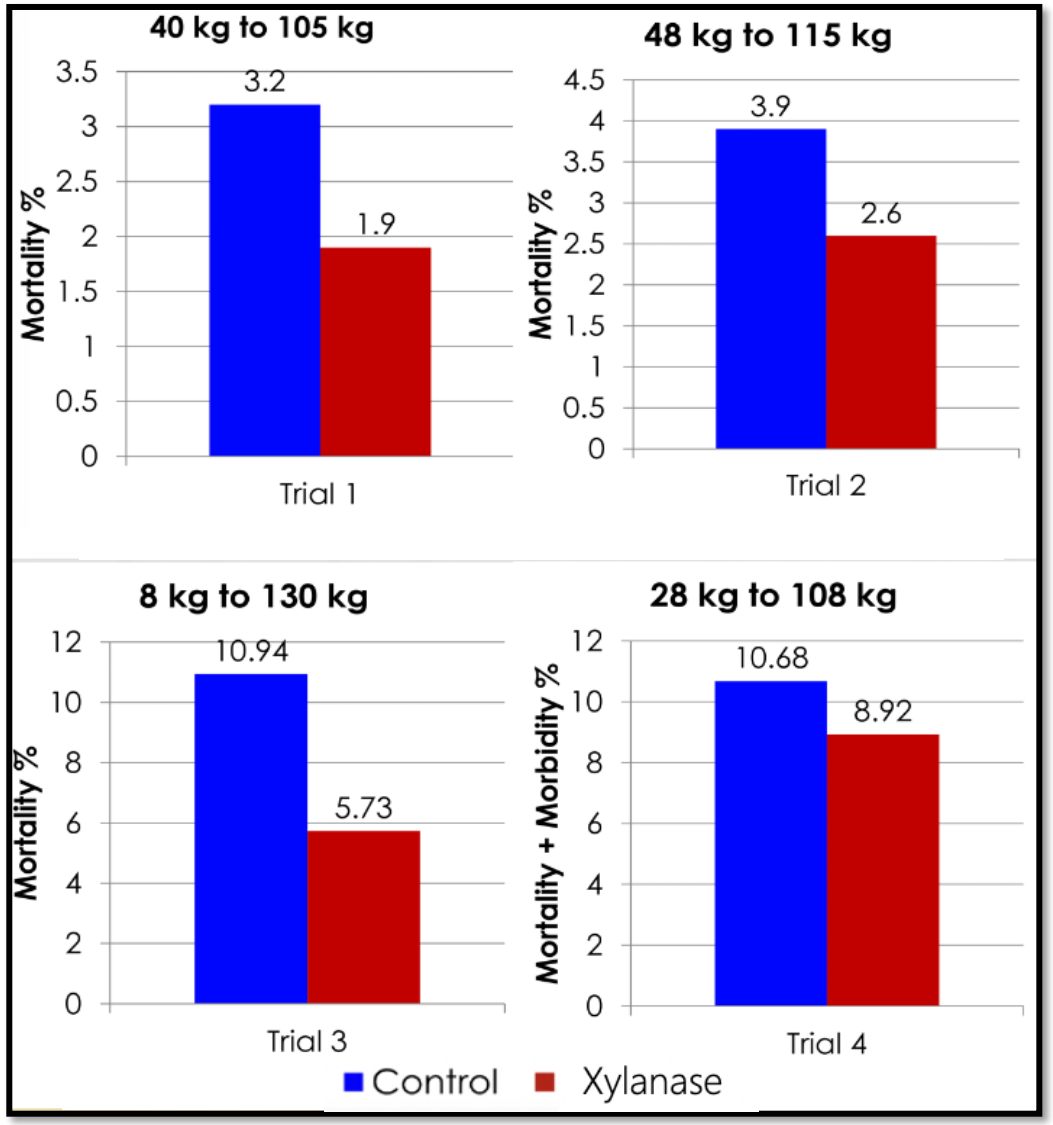


Caloric efficiency improvements from enzymes is greater in health challenge conditions in monogastrics

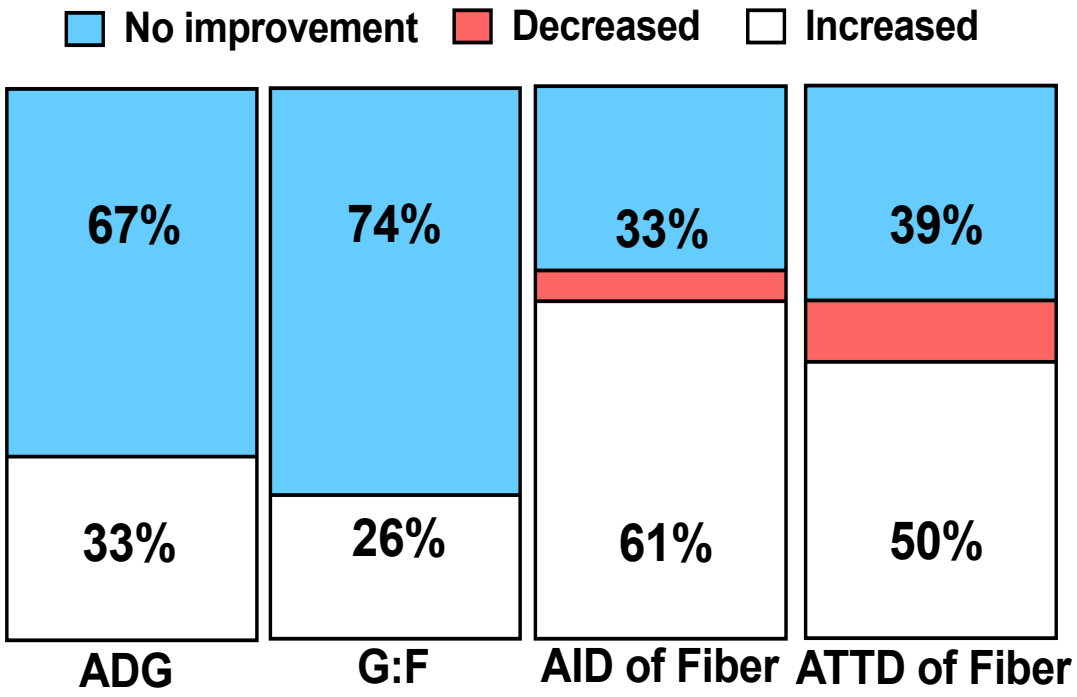


(Junior et al., 2024)

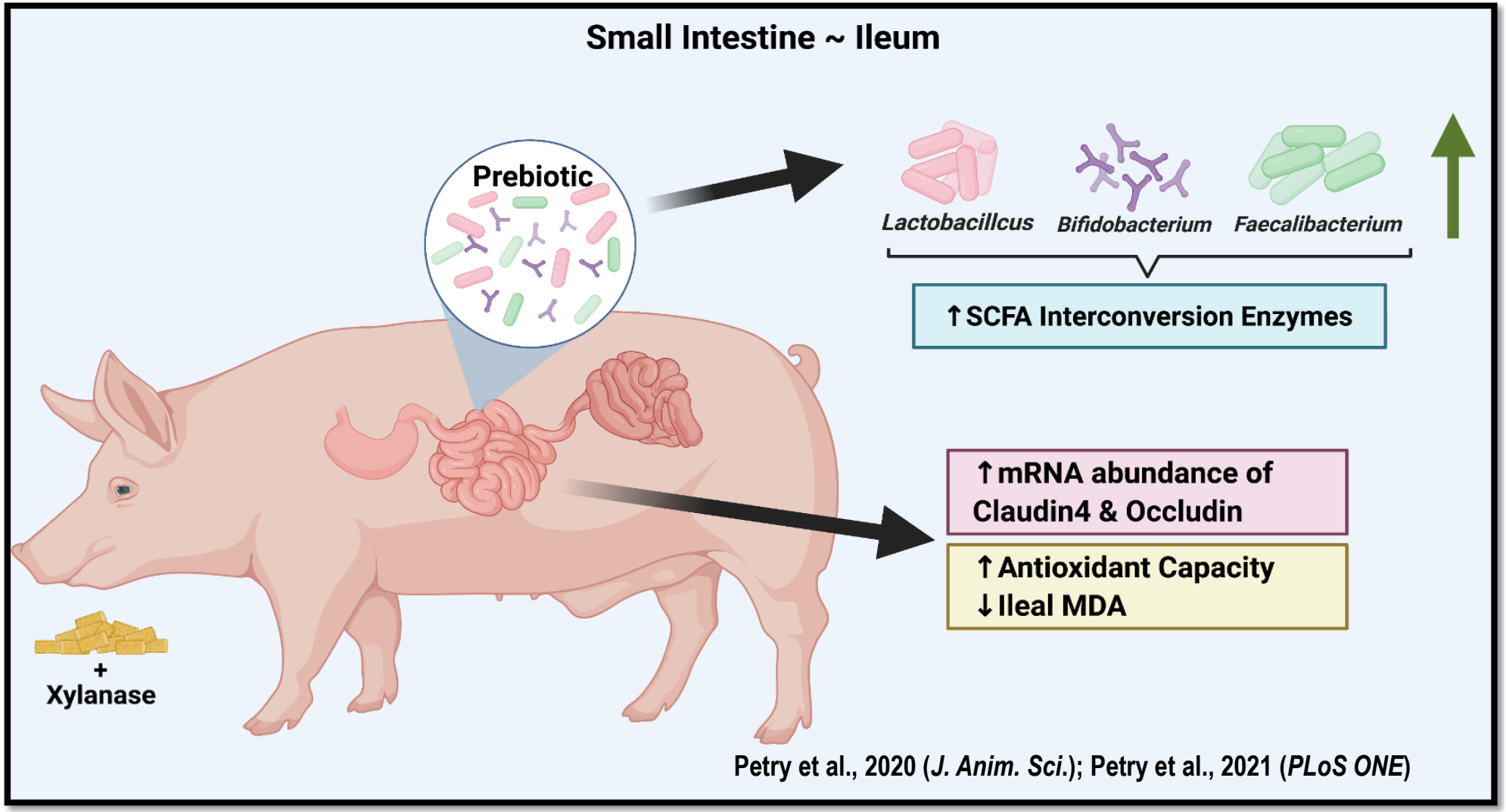
Xylanase Mortality Response in Swine– 'Cheap Health Insurance'



Aware of 24 out of 27 validation trials that show a reduction in mortality with xylanase supplementation…
but only 35% show improvement in FCR!

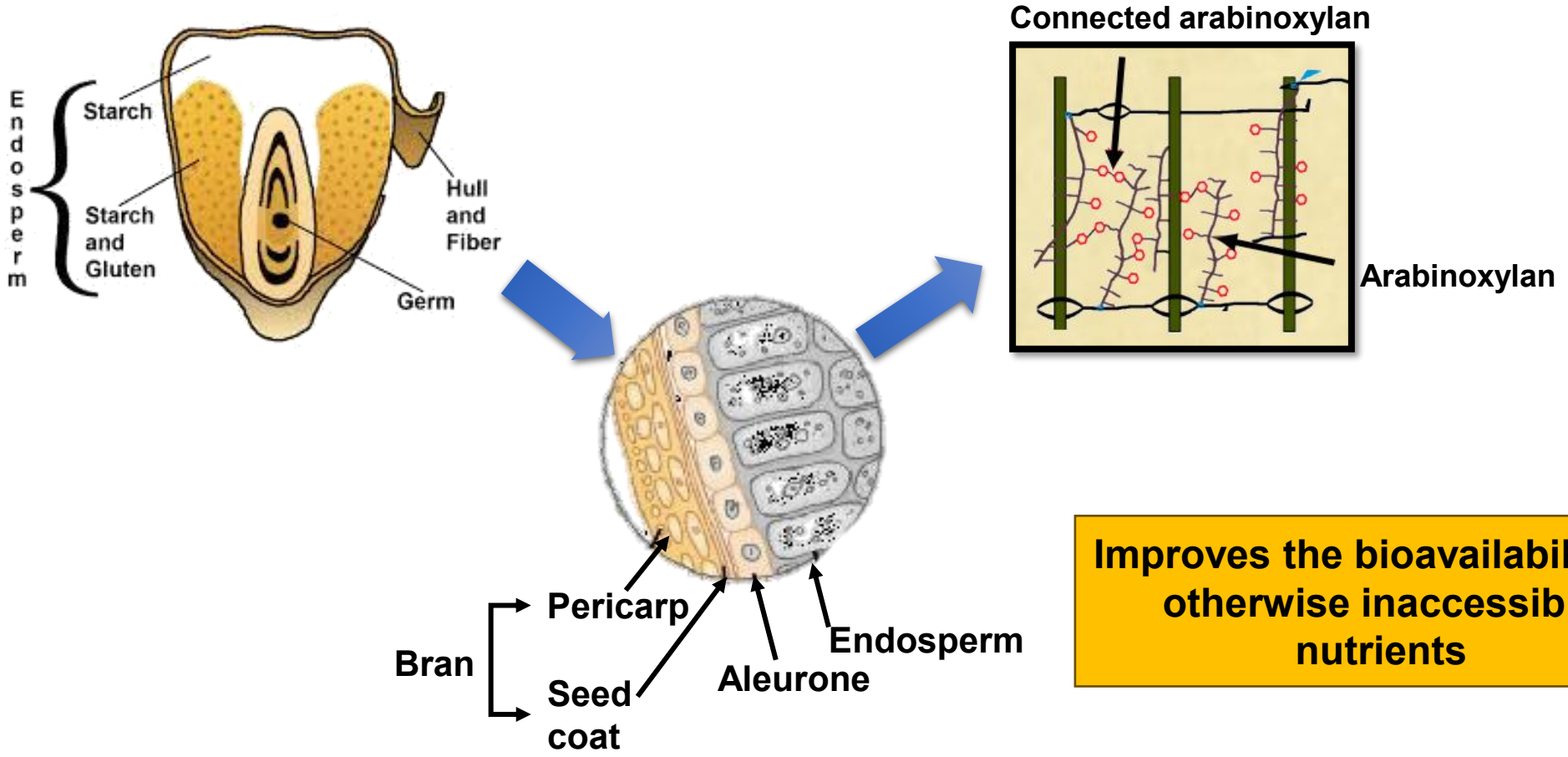


Prebiotic effect is primary reason for swine utilization of xylanase



Anti-caging mechanism of action of NSPases

The NSP within the cell walls of corn preclude the digestion of intracellular components by host digestive enzymes, but fiber degradation through enzymes may mitigate this effect.



Improves the bioavailability of otherwise inaccessible nutrients

(Petry et al., 2022)

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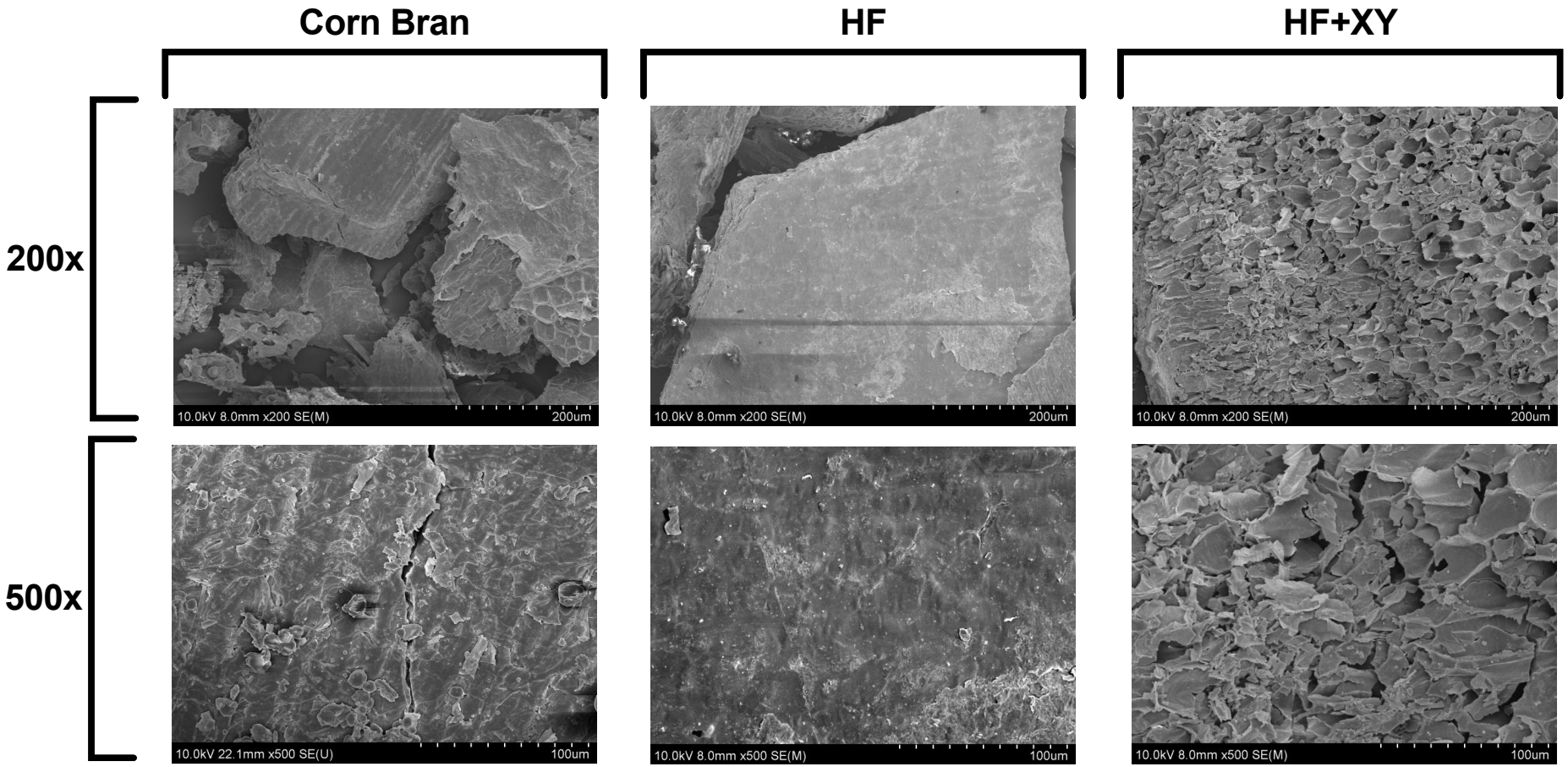
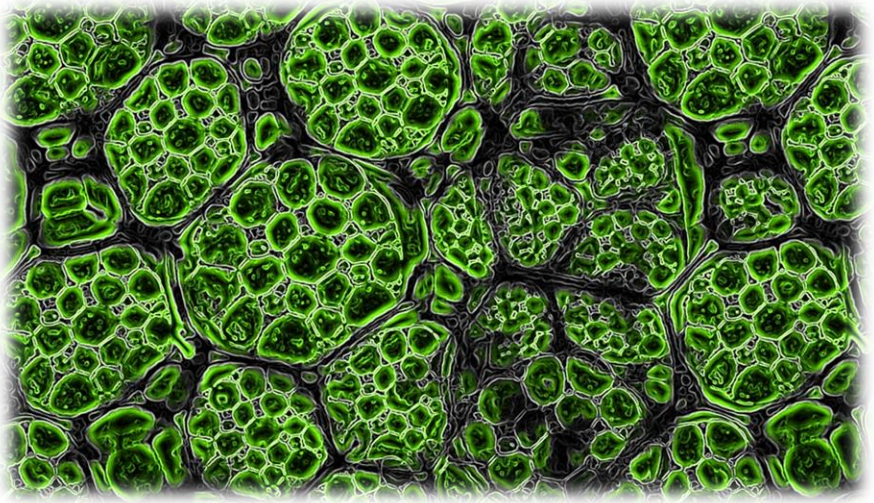


(Petry et al., 2022)

Cellulase in livestock nutrition… not a separate solution

- **Research with Cellulase has lagged in animal nutrition and are considered supportive rather than primary enzymes**
  - Most cellulases come in an enzyme cocktail or multi-fermentation product- *they are difficult to isolate!*
  - Activity is variable and not often guaranteed
  - Endogenous proteases denature cellulases, so encapsulation is helpful!
  - They are often additive with xylanases….
    but data are very mixed!
  - Potential benefits are more apparent in diets high in fibrous by-products (e.g., DDGS, wheat middlings)



1 g of cellulose has the same surface area as the footprint of a modest 3-bedroom bungalow!

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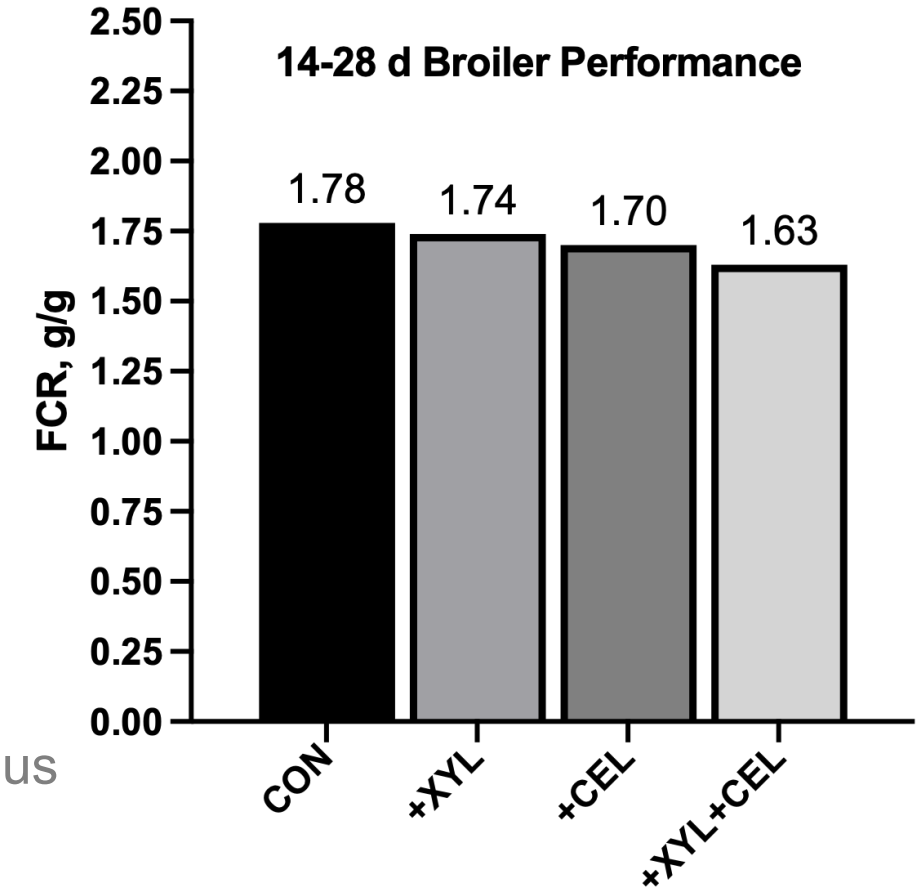
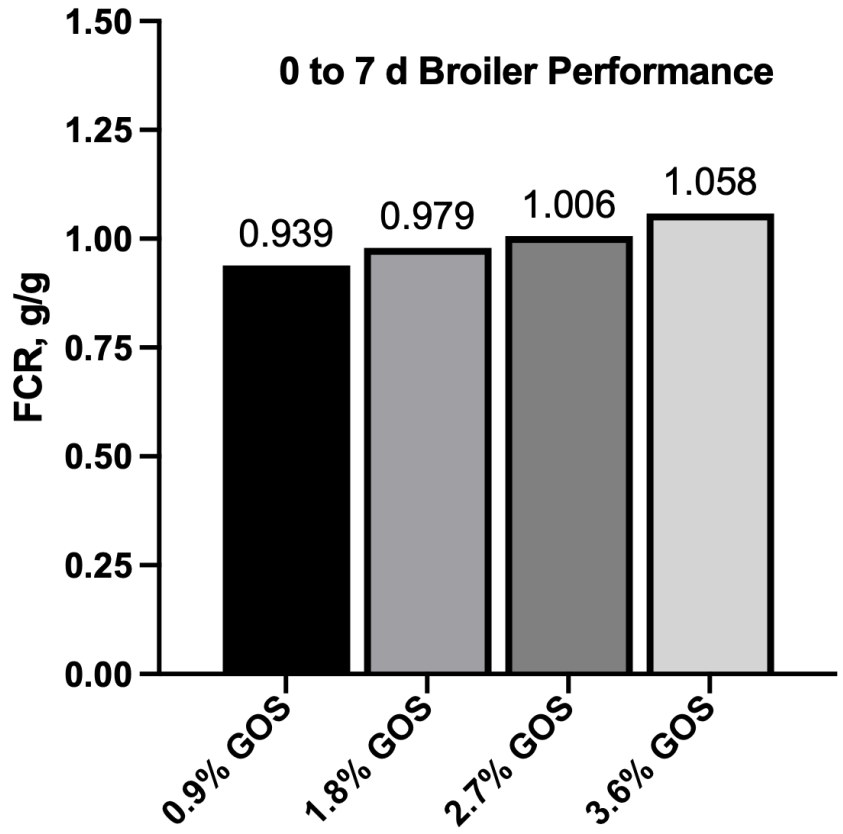


(Lapett et al., 2018)

Alpha Galactosidase in Soybean Meal heavy diets maybe advantageous

- **Soybean Meal can be rich in GOS- 5-10% of CHO fraction**
  - Phase 1 diets rich in GOS impair FCR in broilers and increase inflammation
- **Alpha Galactosidase have been shown to improve FCR in young birds**
  - They are often additive with xylanases…. but data are very mixed!
  - They may not work well if you super dose phytase, but data needs further validation



α-galactosidase improves broiler FCR by 0.05 to 0.1 points and uplifts AME by ~50–80 kcal/kg.

(Llamas-Moya et al., 2021)

Considerations for testing enzymes for evaluation in your system

1. **Consider suppliers who evaluated dosing of their products *in vivo* under commercial conditions in the presence of phytase.**
    - *In vitro* data is a starting point and does not always translate well to *in vivo*!
2. **Understand how the carbohydrase you are testing works with your ingredient matrix**
    - Corn vs. wheat efficacy with xylanase
3. **Thermostability matters with enzyme efficacy. Test the enzyme activity at the mill, after manufacturing, from the bin, and at the feeder level.**
    - *Always send blind and control samples when testing enzyme activity!*
4. **Consider how you value the carbohydrase in your system. What KPIs are you basing your ROI on?**
    - *Mortality responses in swine have different ROI then FCR alone!*

Considerations for formulating with carbohydrases

1. **Your energy release value will be dependent on how much/ type of NSPs are in your matrix!**
   - *More Target NSP in the matrix the more kcals likely to get from enzyme... But there is a limit!*
2. **Be cautious with release values for other 'nutrients' and validate those values in your system**
   - *These values are not 1 for 1 with every ingredient!*
3. **Consider the MOAs of all the feed additives you have in your matrix. They may be counteractive to each other!**
   - *Sufficient data in swine that some carbohydrases are not additive in the presences of several DFMs, Proteases, and Ionophores.*
4. **Consider the prevalence of enteric disease pressure in the system you are formulating for**
   - *Might get more from the enzyme you are working with… or wash the effect out all together*

Future R&D considerations ~ *how can we push the envelope?*

1. **Fiber depolymerization or products for optimal host-microbiome symbiosis? Can we achieve both?**
   - *Health Outcomes vs. Feed Efficiency*

2. ***In vitro* studies, do not consistently translate to *in vivo* . Where is the disconnect?**
   - *Comprehensive multidisciplinary in vivo research is needed. Can we improve our in vitro models?*

3. **Can we get to an equivalent basis to evaluate carbohydrases?**
   - *12 different units for Xylanase alone in the literature!*

4. **More R&D with cellulases and debranching enzymes can help to push energy values from fiber**
   - *Glucose release in the small intestine is energetically favorable*

5. **What are the limitations of using carbohydrases with other feed additives?**
   - *Competitive OR complementary MOA? Phytase considerations*

Questions?

- **Dr. Natalie Morgan**
- **Dr. Pete Wilcock**

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