PETFOOD FORUM

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#petfoodforum

Starch gelatinization in extrusion cooking of pet foods:

Balancing quality and sustainability

— Ed de Souza

April 28-30, 2025, Kansas City, Missouri, USA

Agenda:

Topic Overview:

Importance of starch gelatinization in pet food production

Its role in digestibility, texture, and palatability

Key Objectives:

Address challenges of over-shearing

Explore solutions for sustainable and profitable extrusion cooking

Starch Gelatinization

- **Definition:**
  - Heat and water cause starch granules to break down and swell.
- **Importance in Pet Food:**
  - Enhances digestibility
  - Improves texture and palatability (flavor)
- **Quality Control Parameter:**
  - Standard practice: achieving specific gelatinization levels: lab testing & feeding trials.

Extrusion, a Unique process!

- **Thermal + Mechanical Energy:**
  - Specific Thermal Energy **(STE)** is essentially Steam Cooking
  - Specific Mechanical Energy **(SME)** is fundamentally Electricity
- **Versatility:**
  - Complex formulations and high number of raw materials
  - High Temperature + Short Time Process (HTST)
  - Shelf-Stable and nutritious pet foods (12-24 months).

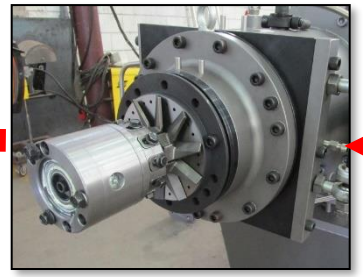
An Extrusion system key components:

- ✓ Feeding System
- ✓ Pre-conditioner
- ✓ Extruder
- ✓ Formatting & Cutting system
- ✓ Essential Process Tools

1. Dry Formula Feeding System

2. Pre-conditioning System
Thermal Energy

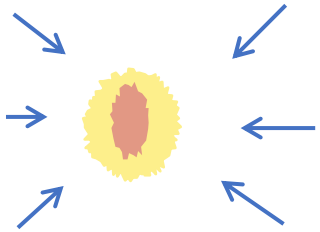
4. Back Pressure Valve (BPV) **Fine Specific Mechanical Energy Control**



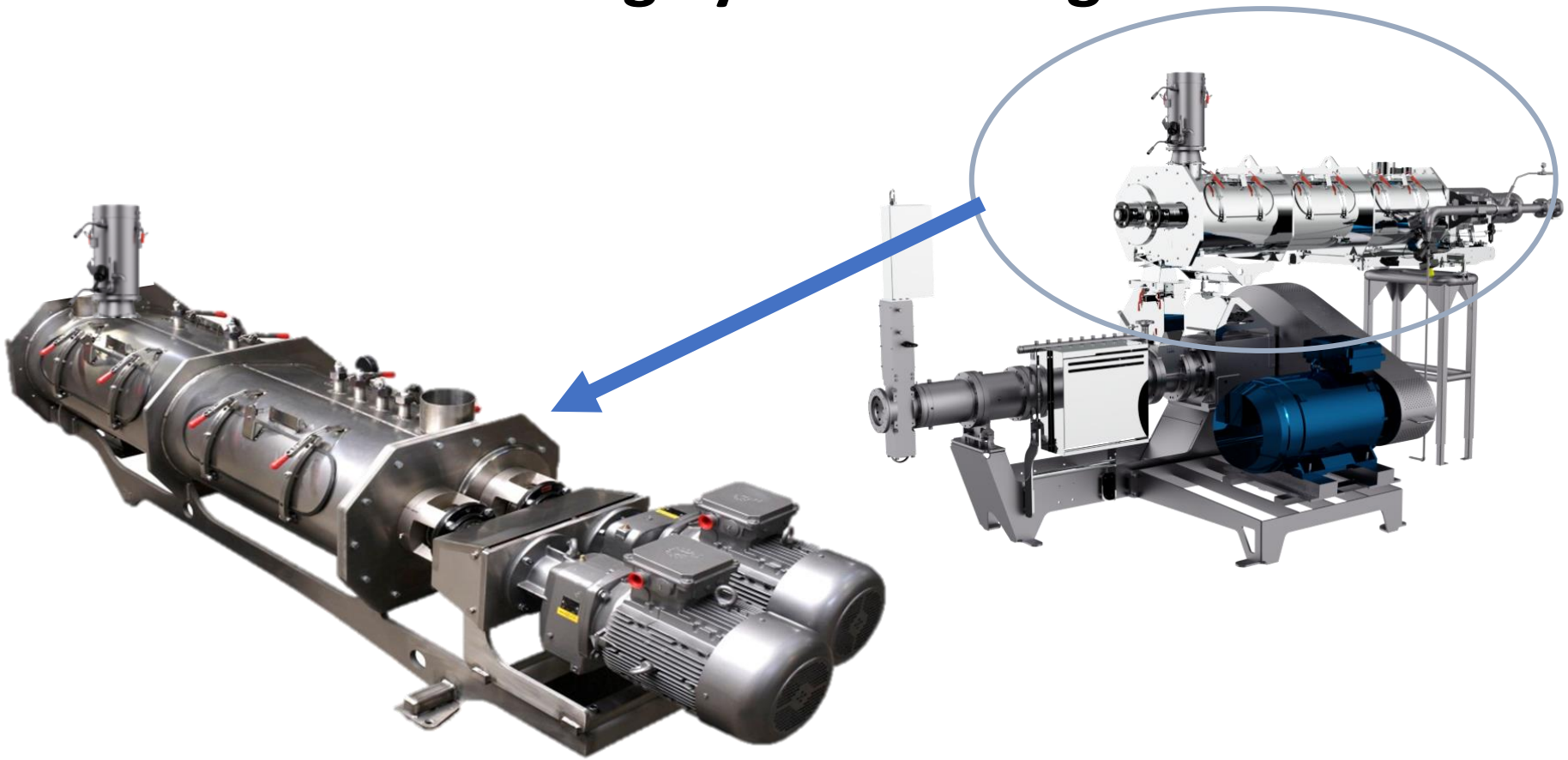
3. Extrusion
Mechanical Energy

5. Cutting Formatting

Advancements in Preconditioning Systems Design



- Mix
- Hydrate
- Heat



High Intensity Preconditioner **(HIP)**

✓ **A Key component to the Thermal Cook Extrusion**

Effects of HIP Radial Speeds on Mixing Efficiency

1. Shaft Speed – Directly impacts distributive mixing and uniformity.
2. Differential Speeds – Improve distribution and homogeneity **(FIFO)**.
3. Retention Time (Eureka!) – Longer retention, combined with higher mixing intensity, enhances consistency.
4. Hydration – Greater mixing intensity enhances ingredient integration.
5. Clumping – Controlled intensity prevents unwanted clumping.

The Challenge of Over-Gelatinization:

Key Points:

- Excessive shearing and overcooking
- Nutrient degradation
- Loss of functional properties
- Reduced product quality

Impact on Quality:

- Compromises formatting and texture
- Off spec Products

- Starchy mixtures under extrusion conditions exhibit non-Newtonian behavior, which results in reduction of viscosity as shear stress increases (also known as **shear-thinning)**

Economic and Environmental Impact of Over-Shearing:

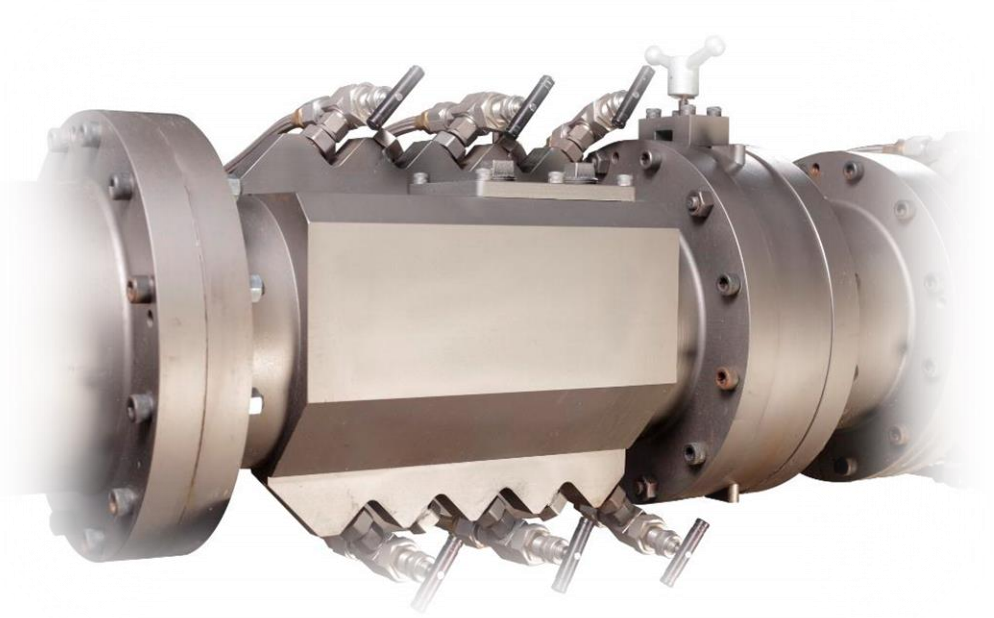
- **Energy Consumption:**
  - Over-processing increases energy use
  - Higher operational costs
- **Sustainability Concerns:**
  - Contradicts eco-conscious goals
  - Increased waste and reprocessing
  - Decrease lifespan of extrusion equipment

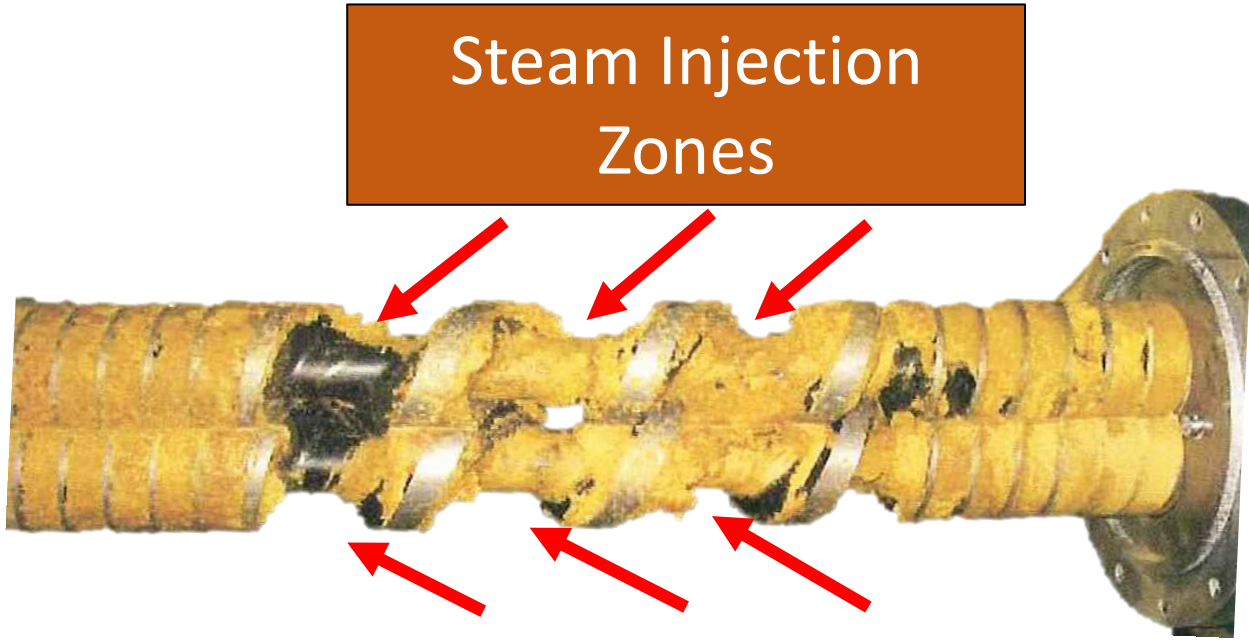
Balancing Gelatinization for Optimal Results

- **Optimized Gelatinization:**
  - Retains nutrients
  - Minimizes waste
  - May generate Resistant Starch (RS)
- **Benefits:**
  - Improved nutritional profiles
  - Cost efficiency and profitability
  - Reduced environmental impact
  - Gut Flora substrate

The Thermal Cooking Extrusion

- Low Shear/High Thermal Extruder
- Typically, a longer L/D (barrel length)
- Unique screw profile
- High-capacity barrel steam injection (up to 12%)
- 300% increase in steam injection.





Cost Calculation: Baseline vs. Optimized Process

- **How Rebalancing Energy Usage Reduces Costs and Improves Product Quality**

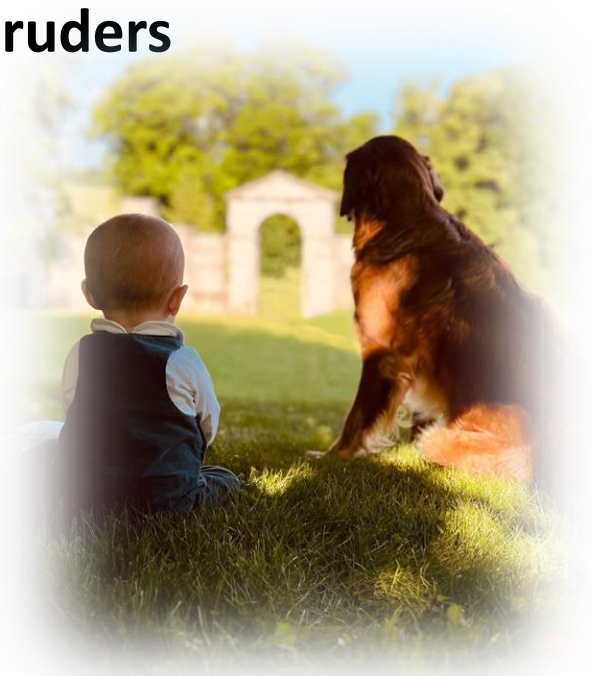
Calculations:

Baseline: Legacy Extrusion System: Single Screw or Twin-Screw extruders

- ✓ **SME Cost**: 30 kWh x $**0.08/kWh = $2.40**
- ✓ **STE Cost**: 60 kWh x $**0.032/kWh = $1.92**

Cost of Energy/Ton
$4.32

- 66.7% SME



Optimized: WENGER THERMAL-TWIN TT-3630™

- ✓ **SME Cost**: 10 kWh x $**0.08/kWh = $0.80**
- ✓ **STE Cost**: 80 kWh x $**0.032/kWh = $2.56**

Cost of Energy/Ton
$3.36

- **Thermal Energy is 60% cheaper per kW-h than SME (electricity). Utilizing more Thermal Energy and less mechanical energy can reduce overall energy costs by 29%!**

Central U.S.: Electricity (Industrial): ~$0.078 per kWh (7.8 cents) Steam from Natural Gas (85% Boiler Efficiency): ~$0.0321 per kWh (3.21 cents)

Cost Calculation: Baseline vs. Optimized Process

- **How Rebalancing Energy Usage Reduces Costs and Improves Product Quality**
  - 1. Energy Cost Comparison (Central USA, March 2025)

SCENARIO	SME (Electricity) kW-h/Ton	STE (Steam) kW-h/Ton	Total Energy Cost ($)
Baseline 30 kW-h (SME)/60 kW-h (STE)	30	60	4.32
Optimized 10 kW-h (SME)/80 kW-h (STE)	10	80	3.36
ENERGY SAVINGS PER TON			$0.96

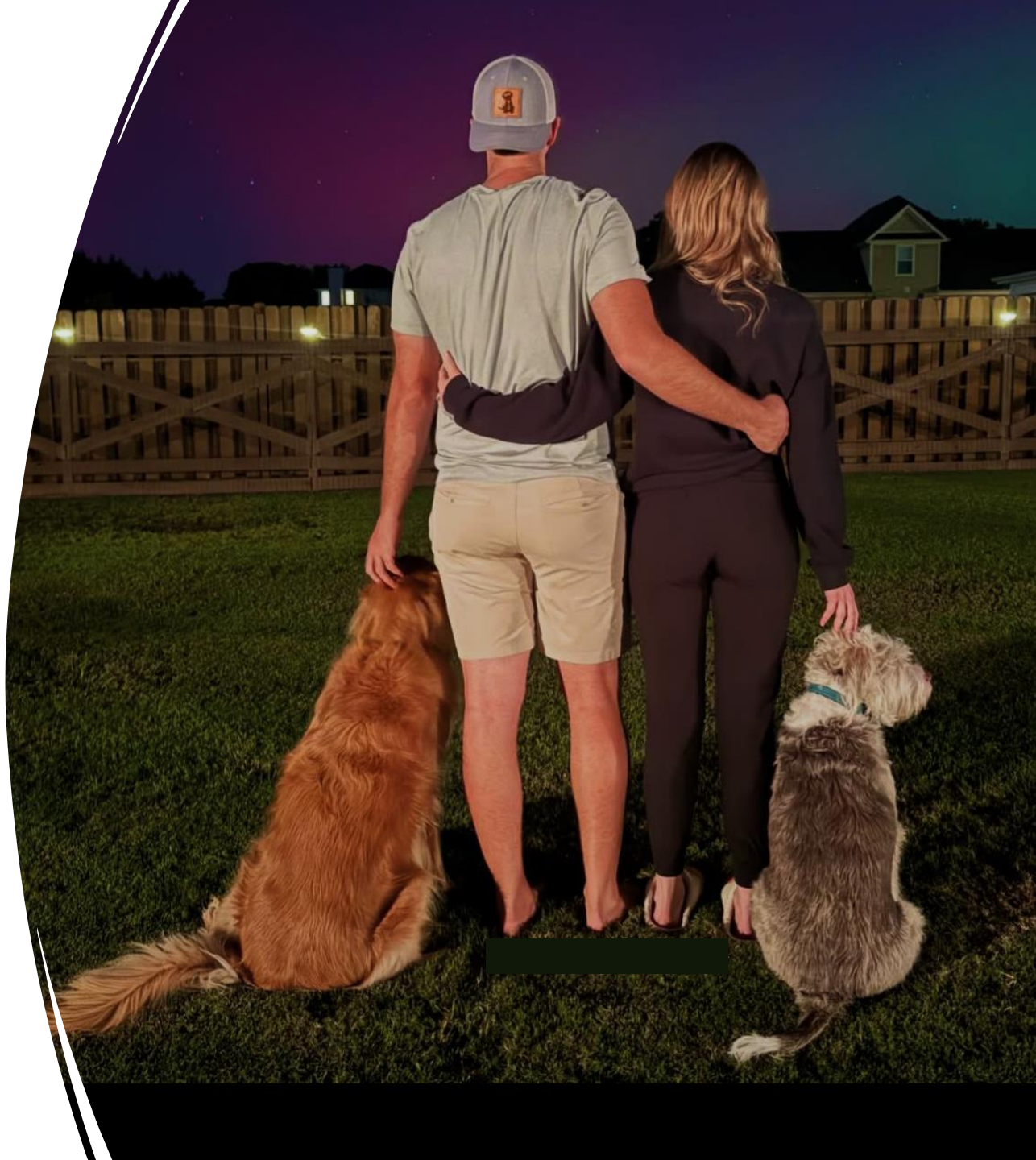
STEPS towards Energy Efficiency & Decarbonization Corporate Plan:

- ✓ **Energy Cost reduced by approximately 29% = 0.96 (4.32 – 3.36).**
- ✓ **Energy Savings of $115,000 every 120,000 tons produced!**

Science and Technology in Extrusion Cooking

- **Technological Solutions:**
  - Advanced cooking technologies
  - Precision control of cooking levels
  - Energy-smart practices in extrusion
- **Scientific Insights:**

- Dialing in gelatinization levels for specific product needs is the key to a more sustainable extrusion with health benefits!



Thermally Cooked Pet Food Grain-Free Based Recipe

Recipe	% DRY
Chicken Meal Low Ash	35.000
Whole potato flour (WPF100)	30.000
Tapioca Starch	15.000
Pea Protein Concentrate (50% min -75% max)	10.000
Oat Fiber	8.000
Flax meal	2.000
Total	100.000

- ✓ Low/Low Shear Processing
- ✓ Grain-Free Diet @ $1,500.00/Ton
- ✓ No meat
- ✓ Fine grind
- ✓ Dried & Oil Coated

Thermally Cooked Pet Food Grain-Based Recipe

Recipe	% DRY
Ground Corn	38.000
Chicken Meal Low Ash	28.000
Ground wheat	18.000
Wheat midds	16.00
Total	100.000

- ✓ Low Low Shear Processing
- ✓ Grain-based Diet @ $700.00/Ton
- ✓ No meat
- ✓ Fine grind
- ✓ Dried & Oil Coated

Thermally Cooked 70% Meat Grain-Free Based Recipe

Recipe	% DRY
Chicken Meal Low Ash	35.000
Whole potato flour (WPF100)	30.000
Tapioca Starch	15.000
Pea Protein Concentrate (50% min -75% max)	10.000
Oat Fiber	8.000
Flax meal	2.000
Total	100.000

- ✓ Low/Low Shear Processing
- ✓ Grain free
- ✓ 700 kg of meat to 1000 kg of dry formula (70% meat) @ $600.00/Ton
- ✓ Fine grind
- ✓ Dried & Oil Coated

Thermal Cooked 70% Meat on Grain-Based Recipe

Recipe	% DRY
Ground Corn	38.000
Chicken Meal Low Ash	28.000
Ground wheat	18.000
Wheat midds	16.00
Total	100.000

- ✓ Low/low Shear Processing
- ✓ Grain-based diet
- ✓ 700 kg of meat to 1000 kg of dry formula (70% meat)
- ✓ Fine grind
- ✓ Wet off-Extruder

Key Takeaways:

- Thermal cooking extrusion enhances efficiency, quality, and sustainability
- Ideal for high-performance pet food production
- A smart investment for future-proofing extrusion operations
- Solid STEPS towards Energy Efficiency & Decarbonization Corporate Plan!

Case Study

- Examples of successful optimization in pet food manufacturing
- Results: Improved taste, palatability, quality, sustainability, and profitability

Road Map to Enhancing Gut Flora and Gut Health

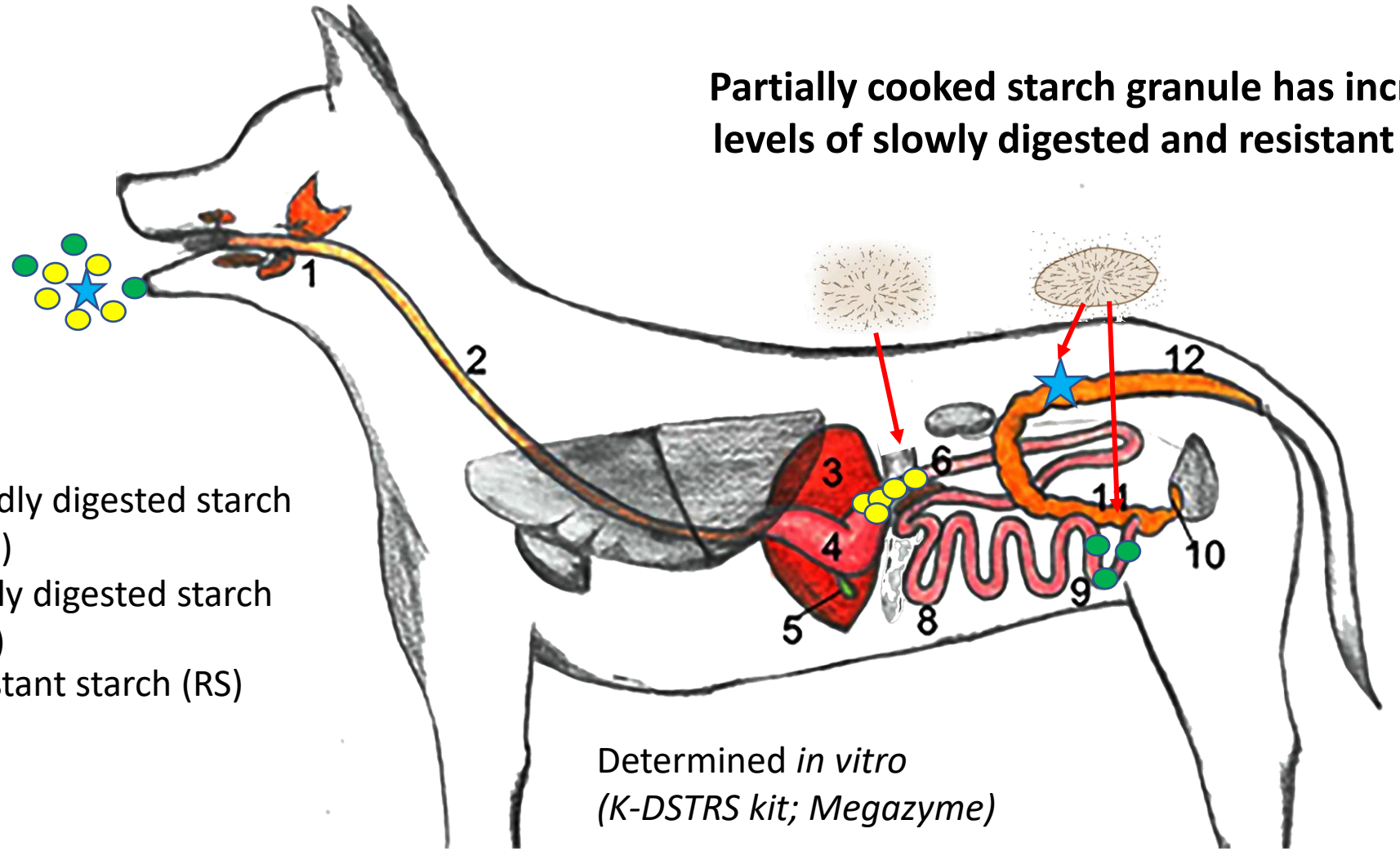
A low to medium shear extruded kibble with greater resistant starch type II leads to improvements in the gut health of dogs

- Isabella Corsato Alvarenga, PhD DVM
- Post-doc at Colorado State University, 2024
- PhD, Kansas State University, 2021
- M.S., Kansas State University, 2016
- DVM, University of São Paulo, 2012

Credit & Courtesy: Isabella Corsato Alvarenga, PhD DVM

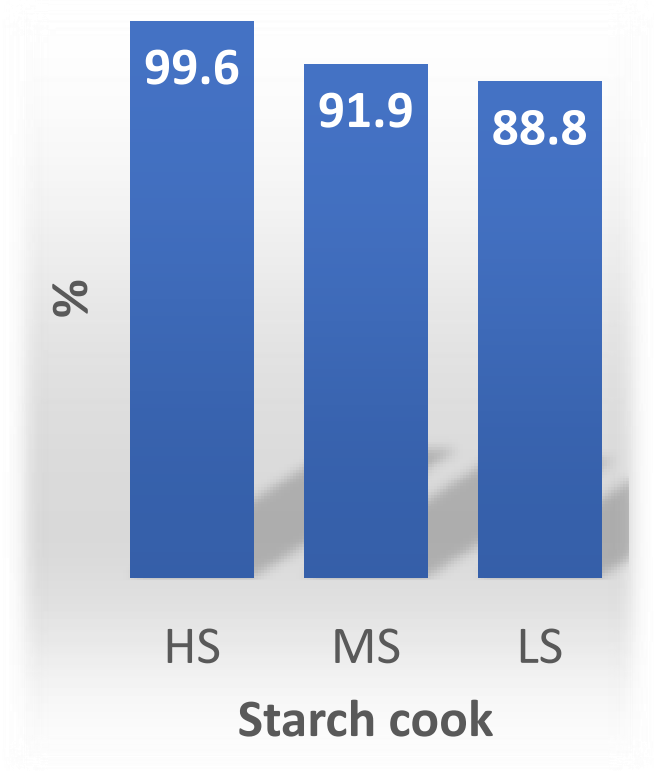
Starch gelatinization affects nutrition

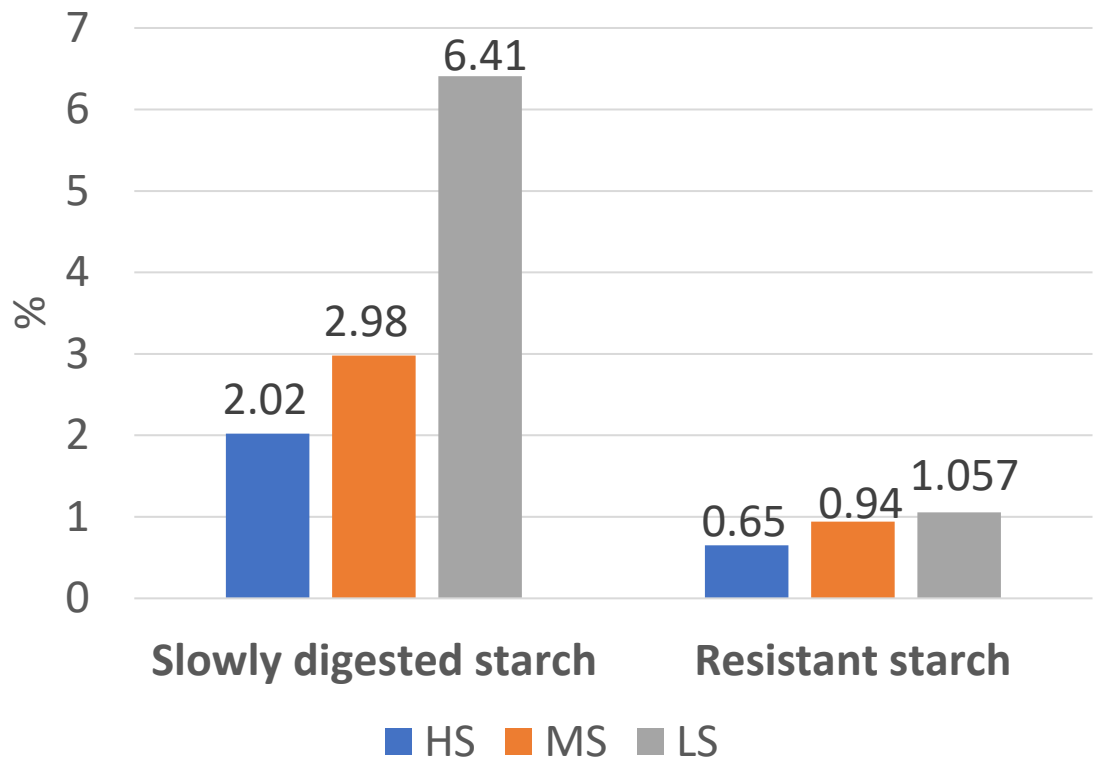
Partially cooked starch granule has increased levels of slowly digested and resistant starch



Credit & Courtesy: Isabella Corsato Alvarenga, PhD DVM

Different extrusion parameters applied to a single recipe created targeted levels of starch fractions





In-vitro starch analyses

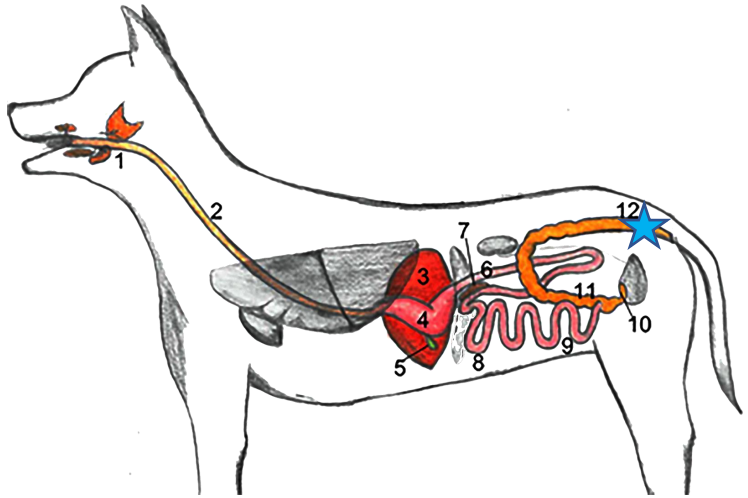
Rapidly (RDS), slowly (SDS) and resistant (RS) starches measured by enzymatic kit (K-DSTRS Megazyme Inc.)

Starch cook (Glucoamylase method; Mason and Rokey, 1982)

Credit & Courtesy: Isabella Corsato Alvarenga, PhD DVM

Study Summary

	High shear	Medium shear	Low shear
Process moisture	▼	▲	▲
Mechanical energy	▲	▬	▼
Kibble expansion	▲	▼	▼
Starch cook	▲	▬	▼
Resistant starch	▼	▬	▲
Slowly digested starch	▼	▬	▲



MS and LS Foods:

- SDS and RS
- Saccharolysis & fecal butyrate

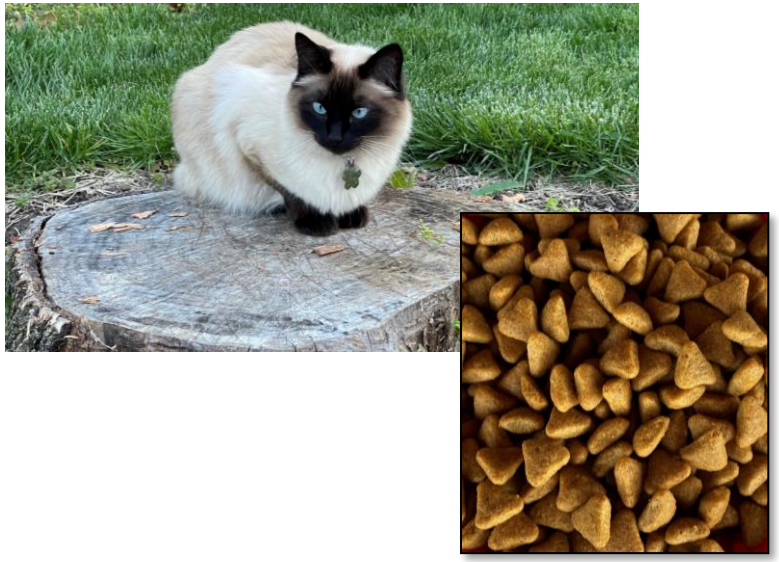
Credit & Courtesy: Isabella Corsato Alvarenga, PhD DVM

Thermal Cook Experiment
Chicken Meat vs. Chicken Meal in Cat Foods

1) Chicken meat at 0, 40, 80, and 120% replaced chicken meal in a balanced diet

2) Equivalent to 0, 13.3, 26.7, and 40.0% meal in the diet

Ingredient	Total Tract Apparent Digestibility of Crude Protein	Apparent Metabolizable Energy
Chicken Meal	73.90%	3,500 kcal/kg
Chicken Meat	91.27% **(+ 23.5%)**	5,432 kcal/kg **(+55.2%)**



Highly digestible protein and high energy density

*UNESP-WENGER RESEARCH led by:

Priscilla Martins Ribeiro – PHD Student under Aulus Advisory.

Contributions on the Scientific Research by:

Galen Rokey – Former Pet Food Extrusion Processing Director at Wenger Mfg, LLC.

Aulus Carciofi – Professor at University of the State of Sao Paulo – UNESP, researcher, cat and dog nutritionist.

Fabiano Sa, Thaila Putarov, Fernanda S. Mendonça – Nutritionists for Dog & Cat.

Implementation Strategies

- **Steps for Manufacturers:**
  - Monitor and measure energy levels
  - Monitor and measure gelatinization levels
  - Optimize extruder settings (Legacy)
  - Invest in energy-efficient technologies
- **Industry Best Practices:**
  - Balancing quality, cost, and sustainability goals

Key Takeaways

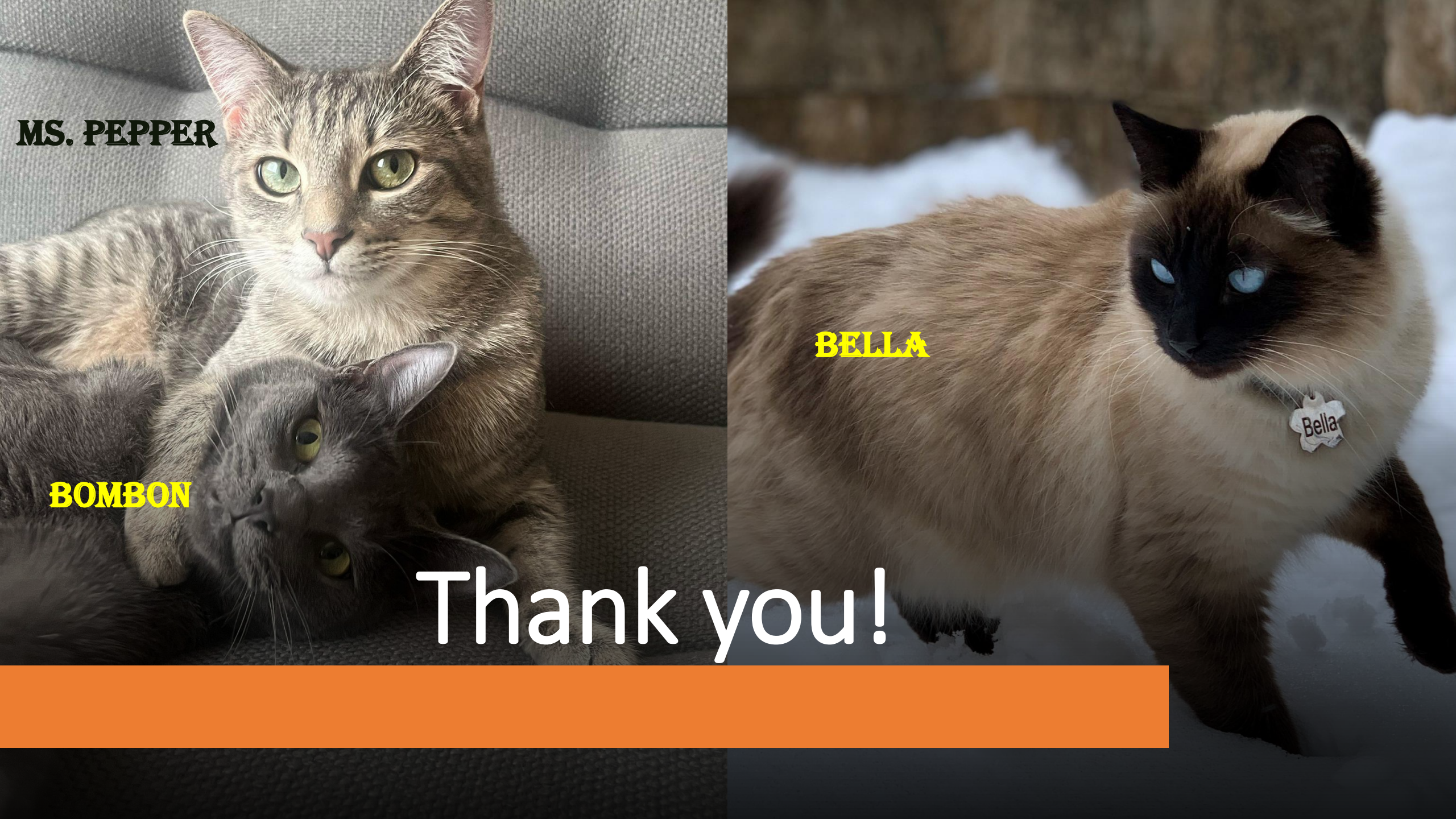
- **Summary:**
  - Starch gelatinization is a critical process parameter
  - Over-gelatinization leads to quality and cost challenges
  - Optimization achieves quality, efficiency, and sustainability
- **Future Outlook:**
  - Advancements in science and technology
  - Continued industry improvement
  - **AI** to fine tune process conditions

Conclusion

- Reinforce the importance of controlled gelatinization
- Highlight the benefits for pets, manufacturers, and the planet
- Call to action for adopting optimized practices

Q&A

- Open floor for questions



Thank you!