Soy Excellence Center
SEC Feed Manufacturing Track – Basic Level

SOY EXCELLENCE CENTER
A USSOY program

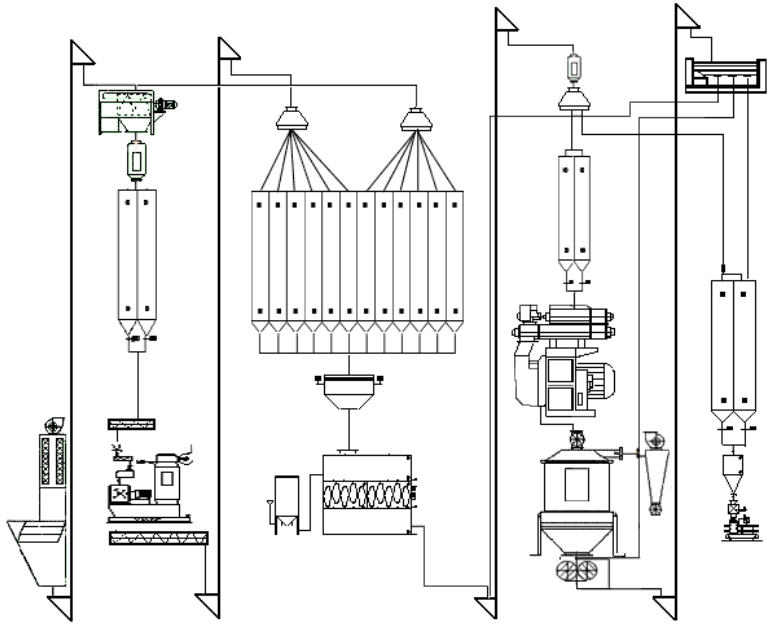
Animal Nutrition for Feed Manufacturing

“Understanding feed ingredients used for each feed formulation”

Patrick Clark, PhD

Feed Mills

- Feed is the single greatest expense in poultry production
  - Ingredients - Major cost
  - Processing – Significative cost



Feed Ingredients

- **Soybean Meal:**
  - Excellent balance of amino acids
  - 44 to 48% protein
- **Corn:**
  - High energy
  - 8.5% protein
- **Alternative Ingredients**

Soybean Meal

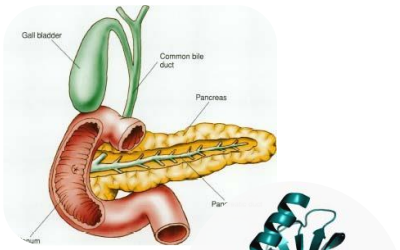
- The most commonly source of protein in poultry diets worldwide
  - High CP content
  - Excellent amino acid (AA) profile that complements cereal grains
  - High AA digestibility
- In a typical corn-soybean meal broiler diet, SBM contributes up to 70% of the dietary CP
- Minimal anti-nutritional factors if properly processed

Protein Quality

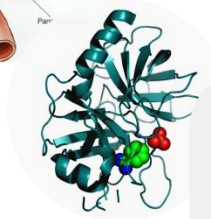
- Regardless of the process used to extract the oil (solvent vs. extrude/expeller), SBM must be properly heated to eliminate trypsin inhibitors
- Overheating results in deterioration of protein quality by destroying heat-sensitive amino acids
  - Result in a decrease in both concentration and digestibility of several AA, especially lysine
  - The reduction in digestibility is due to the Maillard reaction which binds free amino acids to free carbonyl groups (i.e., from carbohydrates)
  - The Maillard reaction-end products are not bio-available for all livestock species

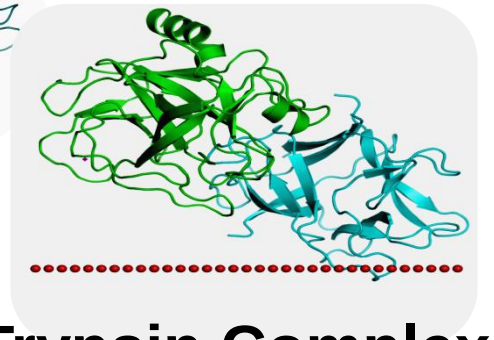
Trypsin Inhibitors

- Most important group of antinutritional factors present in raw beans
  - Inactivated by heat
  - Lower trypsin inhibitor levels = better nutrient digestibility



Trypsin





Trypsin Complex

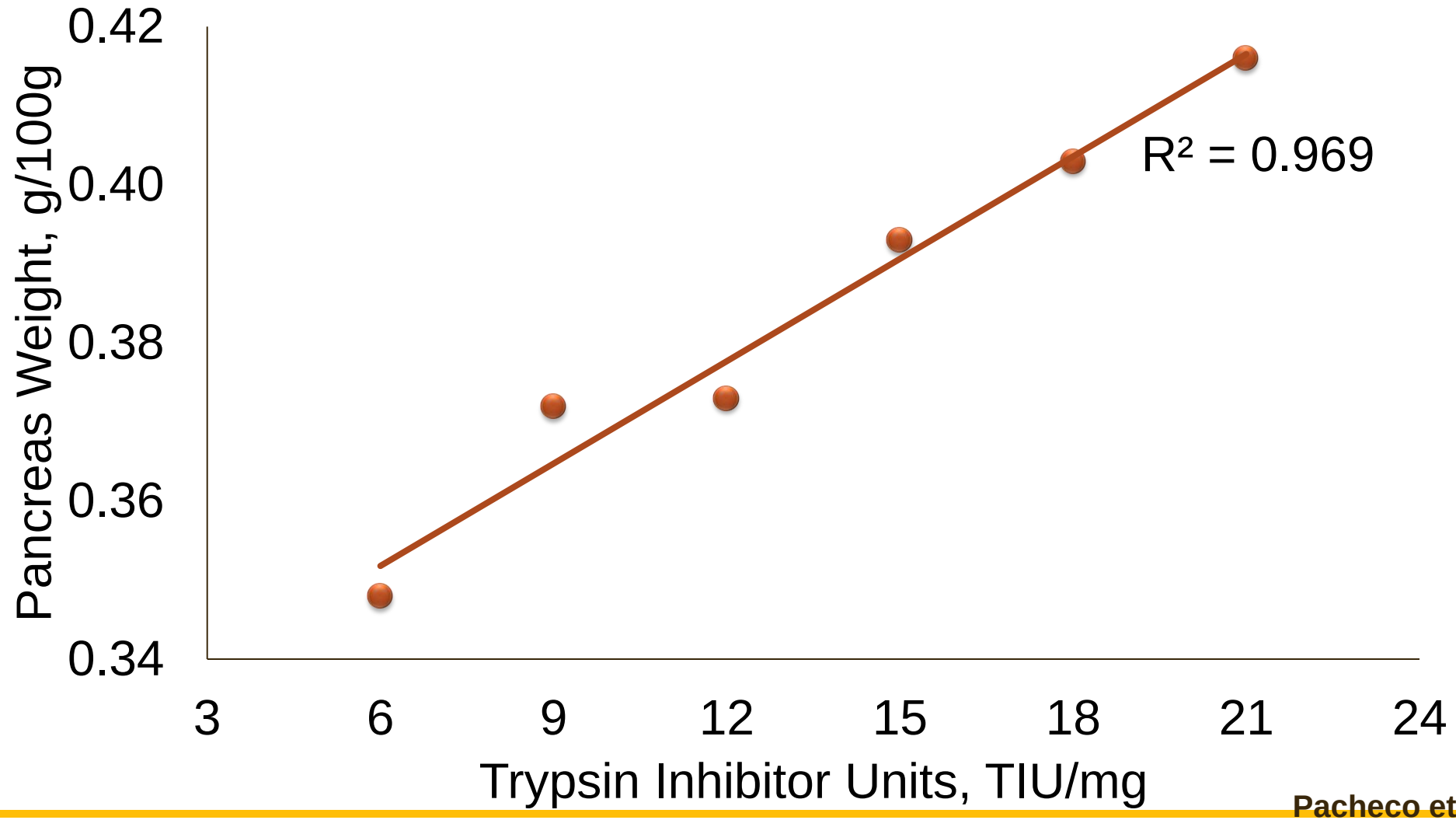
Trypsin Inhibitor

Soybean Processing

- Underheating soybean meal reduces the nutritional value by decreasing amino acid digestibility
- Trypsin inhibitors bind with trypsin to form an inactive complex
  - Induces pancreatic hypertrophy
  - Increases trypsin and chymotrypsin production and secretion
  - Increases cysteine and methionine losses
  - Have been correlated with the occurrence of "rapid feed passage" syndrome in broilers
- Deactivated by sufficient heat treatment
  - 80°C for 10 minutes (solvent extraction)
  - Extruder – might vary on design

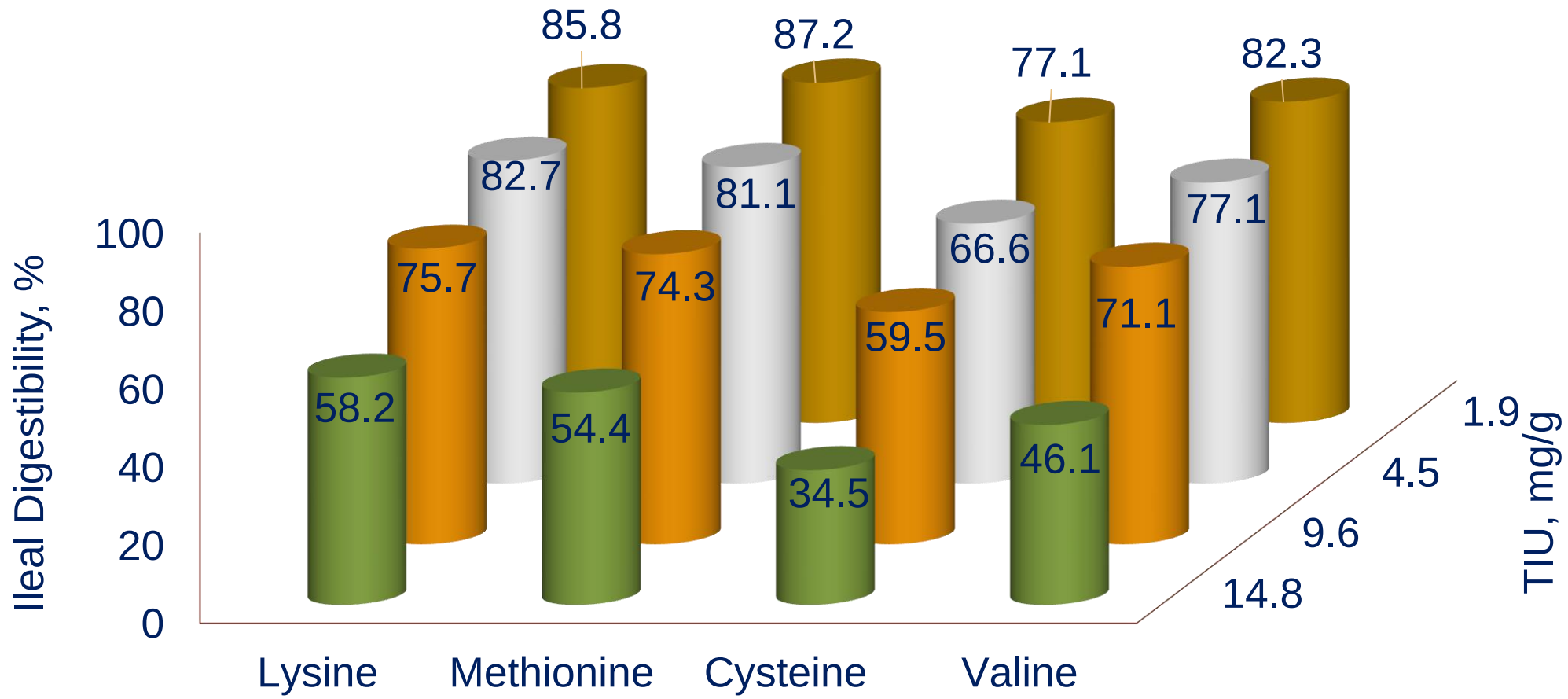
http://www.intechopen.com/books/soybean-and-nutrition/soybean-meal-quality-and-analytical-techniques

Trypsin Inhibitors and Pancreas Weight



Pacheco et al., , 2014

TIA and AA Digestibility of Broilers from 19 to 25 d of Age



Clark and Wiseman, 2007

Soybean Processing

Over-processed soybean meal will be darker in color

- Maillard reaction
  - Reduces AA digestibility

http://www.intechopen.com/books/soybean-and-nutrition/soybean-meal-quality-and-analytical-techniques

Indirect Methods for Quality Evaluation

- Urease activity
  - Preferred method to evaluate SBM quality
    - Range (0.05 to 0.10 ΔpH)
  - Urea is not an ANF in poultry and its presence does not affect productivity
  - Inactivation resembles the inactivation of trypsin inhibitors
  - High urease values = high levels of trypsin inhibitors)
  - Values close to zero can indicate adequate processing or over-processing
- Protein dispersibility index (PDI)
  - Range15 to 30% - National Soybean Processor Association
- Protein solubility in KOH (KOH)
  - Range 78 to 85%
  - Both methods estimate the solubility of the protein faction in SBM
  - High values = under processing
  - Low values = over processing

Recommended Specifications for Dehulled SBM

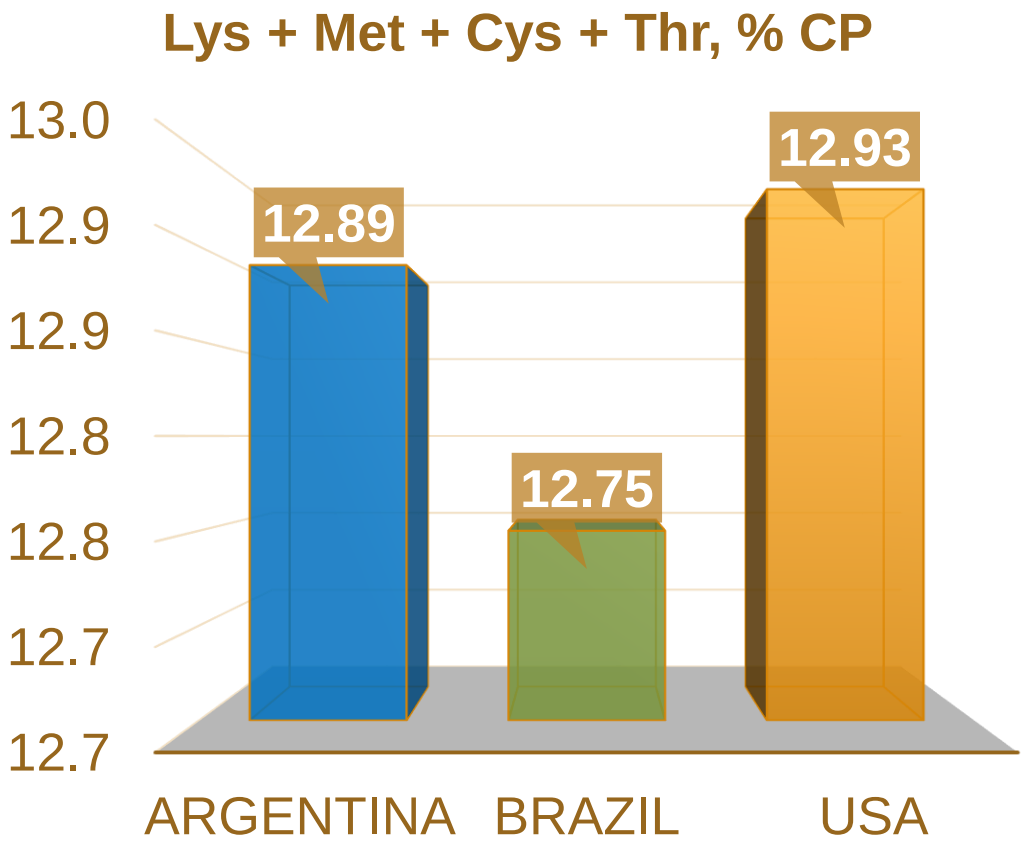
Parameter	Level
Crude Protein	47.5 to 49.0%
Total Lysine, 88% DM	>2.85%
Digestible Lysine, %	>88%
Ash	<7.5%
Protein solubility in 0.2% KOH	78-85%
Urease activity, pH unit rise	0.00 – 0.01
Trypsin inhibitors, mg/g	1.75 – 2.50
Mycotoxins	Aflatoxin (<20 ppb), DON (< 2ppm)
Texture	Uniform, free flowing, no lumps, cake, dust
Color	Light tan to light Brown
Odor	Fresh, not musty, sour, ammonia, burned

Source: National Oil Processors Association

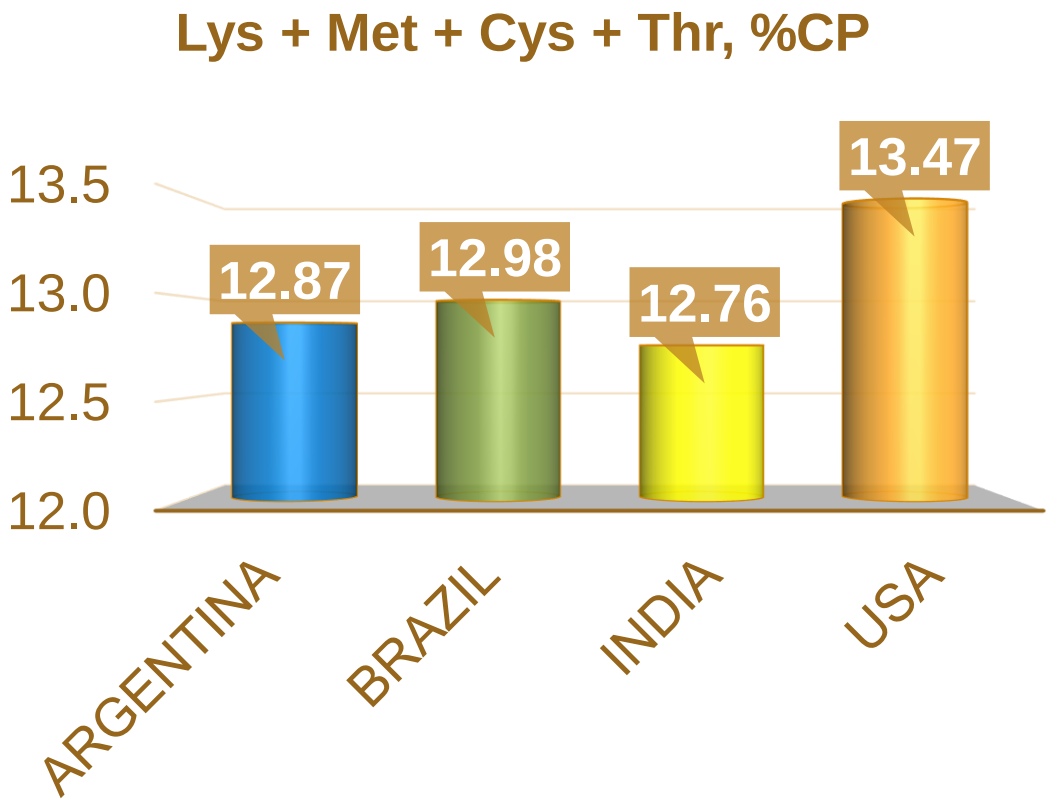
Crude Protein and AA Digestibility

- Crude protein is influenced by:
  - Cultivar
  - Agronomic and soil conditions
  - Climate
  - Post-Harvest management
  - Processing conditions

Soybean Meal



Mateos – 2007-2011



Ravindran, 2011

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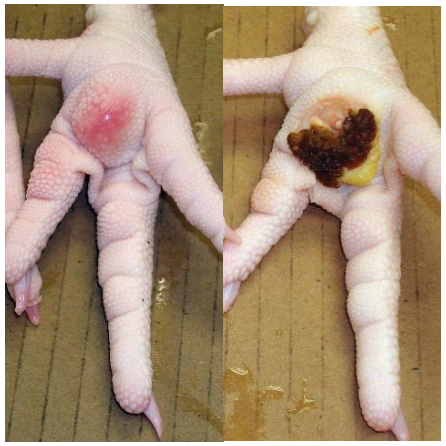
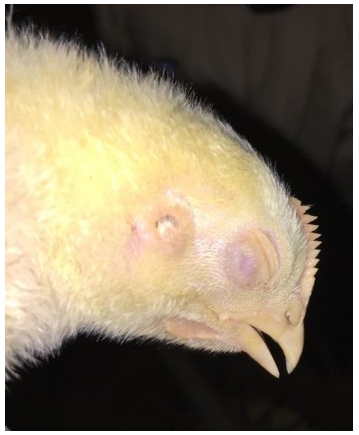
Better AA Digestibility = Less N in the Litter





Animal Welfare

Economic Value

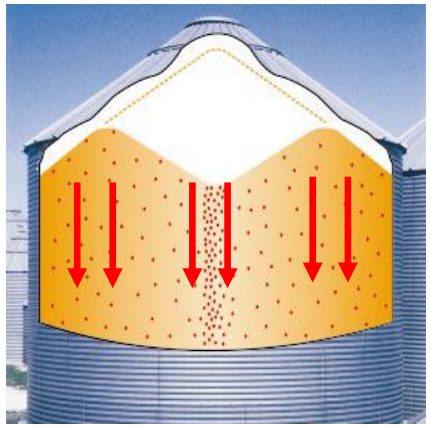
Suggested Nutritional Values for SBM

Nutrient	US	Argentina	Brazil
Moisture, %	12.5	12.0	11.2
Crude Protein, %	46.7	46.0	47.1
Lysine, %	2.99	2.83	2.86
TSAA, %	1.35	1.35	1.34
Trypthopan, %	0.65	0.63	0.63
Threonine, %	1.82	1.82	1.82
Crude Fat, %	1.63	1.60	1.90
Sugars, %	7.90	6.70	5.30
AME broiler, kcal/kg	2000	1910	1970
AME layer, kcal/kg	2325	2242	2320

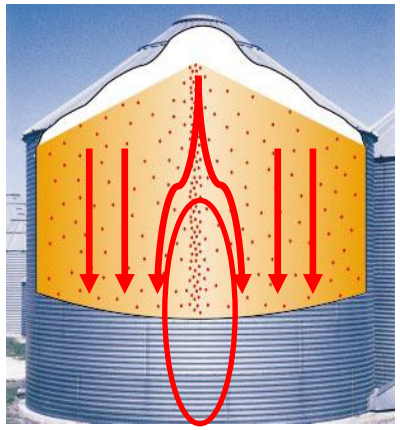
Source: G.G. Mateos (425 samples taken between 2007-2012)

Soybeans Receiving and Processing

Inverted Cone – Steel Silo

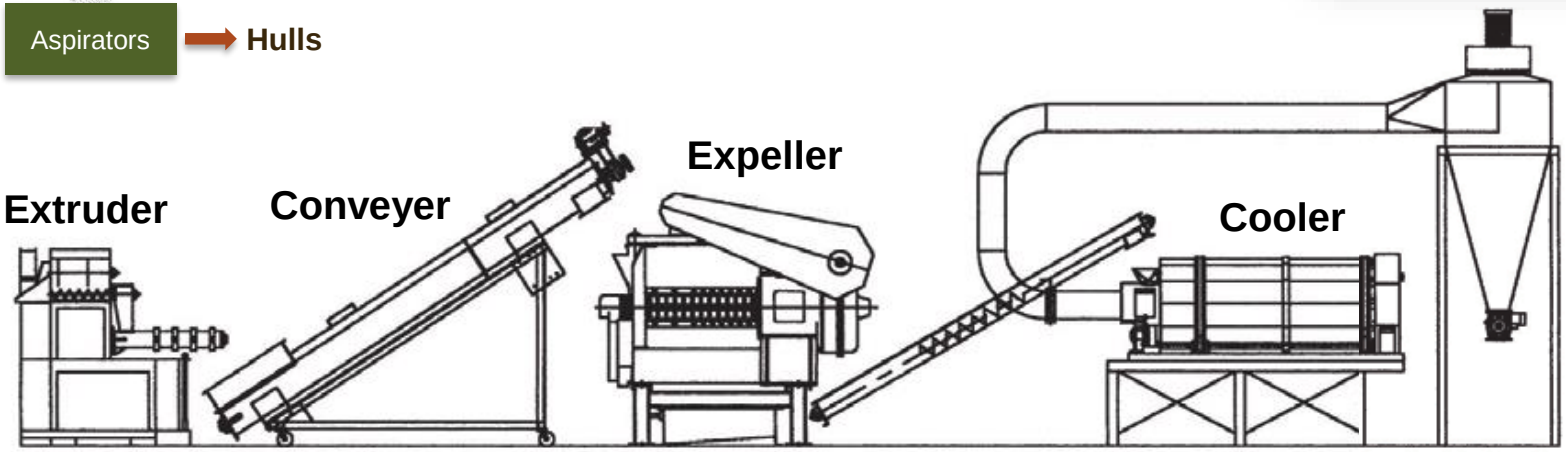


Center Column – Steel Silo

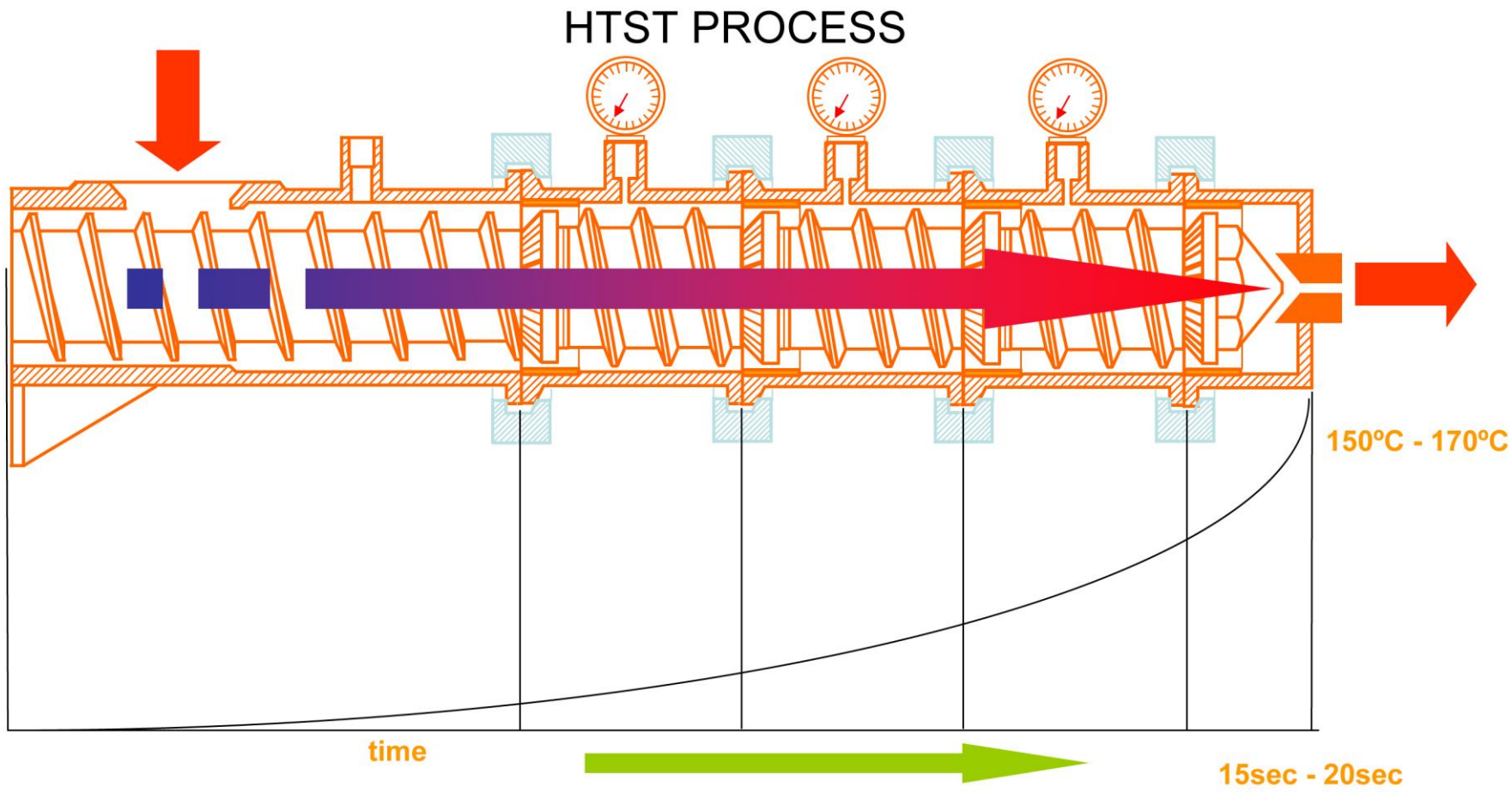


Soybeans with ~10% moisture

Aspirators → **Hulls**



Heat Treatment in the Extruder



Effect of Extrusion Temperature
Full Fat Soybean Meal

Indicators	Range	135°C	145°C	155°C	160°C	165°C	170°C
PDI, %	**20-35% (adequately process)**	40.27	36.05	33.47	32.25	28.61	26.47
KOH Protein Solubility, %	**< 65% (overprocesing)**	79.09	73.50	74.57	77.58	68.29	57.04
Trypsin inhibitor, mg/g	**1 to 3.5 mg/g**	3.76	3.91	3.65	3.52	2.26	0.50
Crude Protein, %		40.57	41.74	41.59	41.61	43.85	45.23
Moisture, %		5.32	4.93	4.40	4.25	3.85	3.57
Lys:CP ratio	**>6 (Protein quality)**	6.53	6.07	6.27	6.44	6.05	6.00

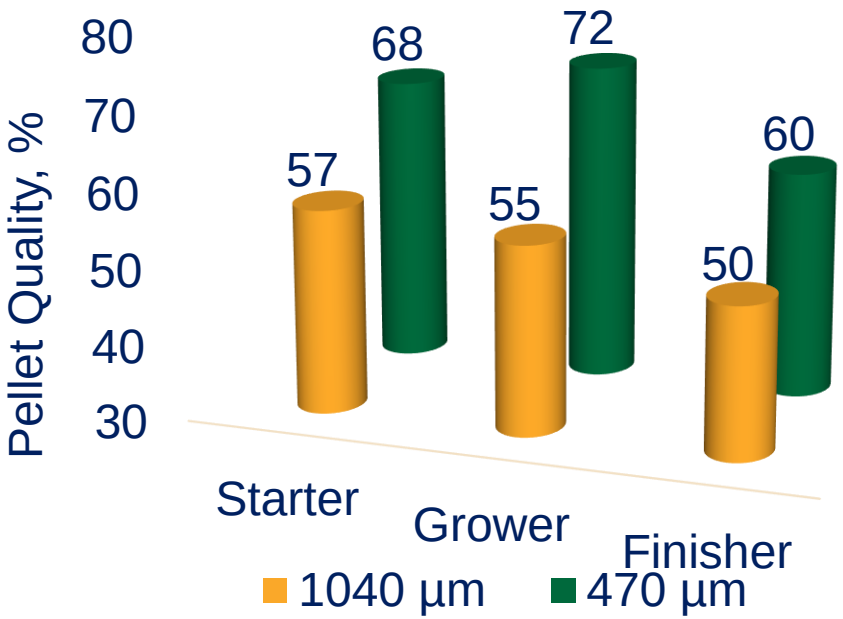
Patiño et al., , 2022

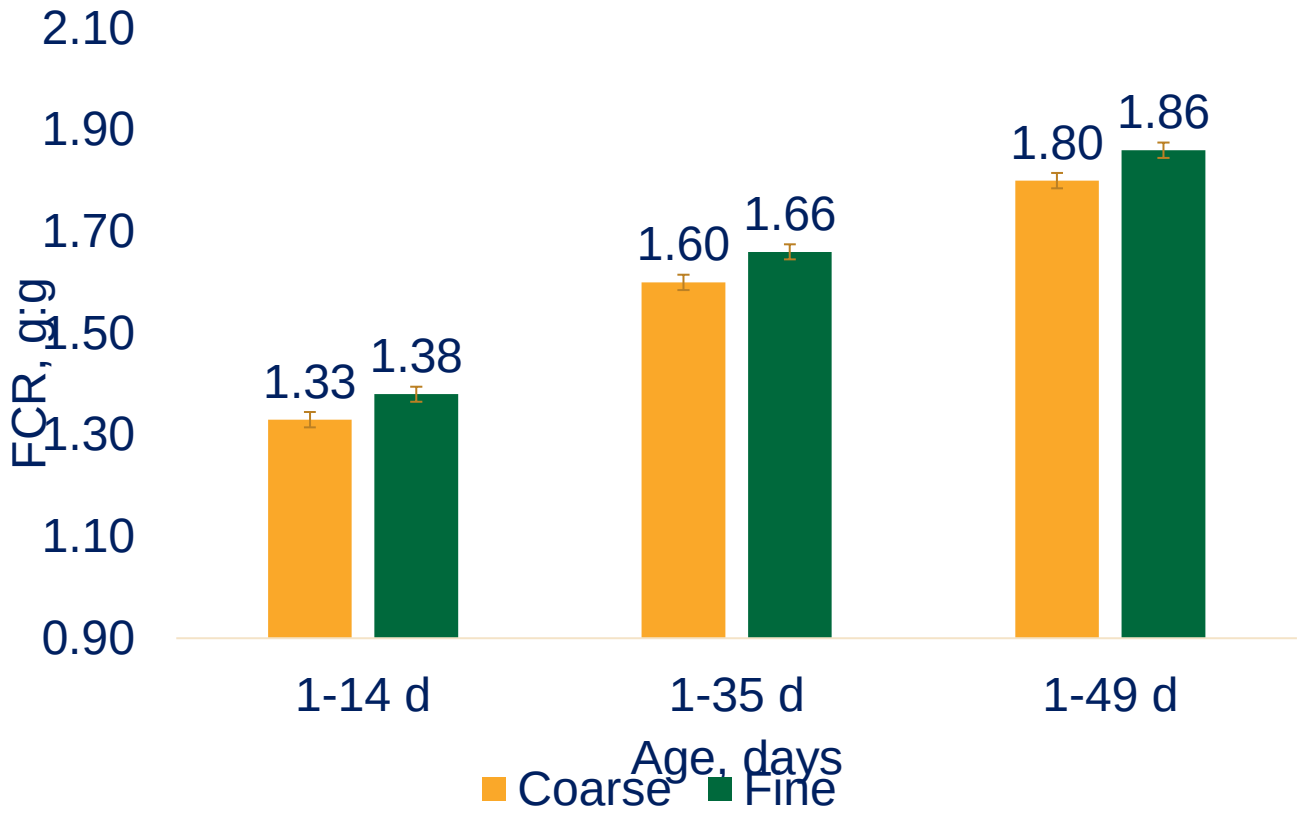
Effect of Extrusion Temperature
Full Fat Soybean Meal

Indicators	Range	135°C	145°C	155°C	160°C	165°C	170°C
PDI, %	20-35% (adequately process)	✗	✗	✓	✓	✓	✓
KOH Protein Solubility, %	< 65% (overprocesing)	✓	✓	✓	✓	✗	✗
Trypsin inhibitor, mg/g	1 to 3.5 mg/g	✗	✗	✗	✓	✓	✗
Lys:CP ratio	>6 (Protein quality)	✓	✓	✓	✓	✓	✗

Patiño et al., , 2022

SBM Particle Size





Pacheco et al., 2013

Yellow Corn

- **Good source of:**
- **Energy: 1,535 kcal/lb**
  - Primary feed energy source of all animal feeds
  - No antinutritional factors that limit dietary inclusion
- **Protein, fiber, calcium, phosphorus**
- **Very low in lysine: 0.25%**
- **Provides carotene and xanthophyll**

•Due to its high and consistent energy content, corn has been established as the standard for other cereals and cereal by products

Yellow Corn	
DM	86
Energy	1535
CP	7.5
EE	3.5
CF	1.9
Ca	0.01
Met	0.18
Lys	0.25

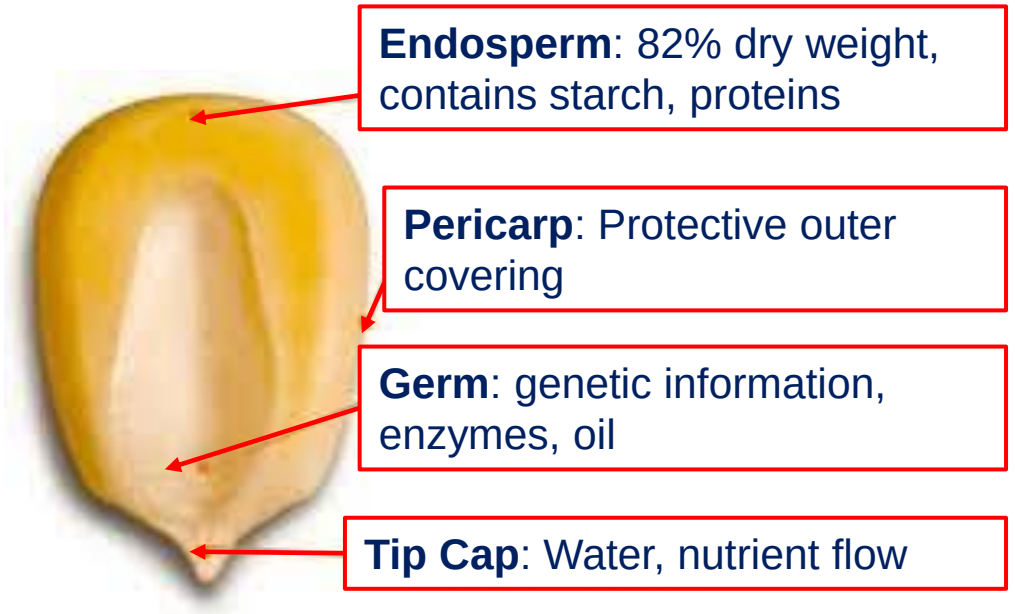
Yellow Corn – Potential Issues

- **Molds and mycotoxins: Excessive rain coupled with high temperatures late in production**
  - **DON**
  - **Aflatoxin**
  - **Zearalenone**
- **Corn-based diets have lower pellet quality**

Corn Composition

- **Nutritional composition is influenced by:**
  - Type
  - Color
  - Moisture content
  - Drying temperature
  - Grinding method
  - Particle Size (Amerah et al., 2007a).

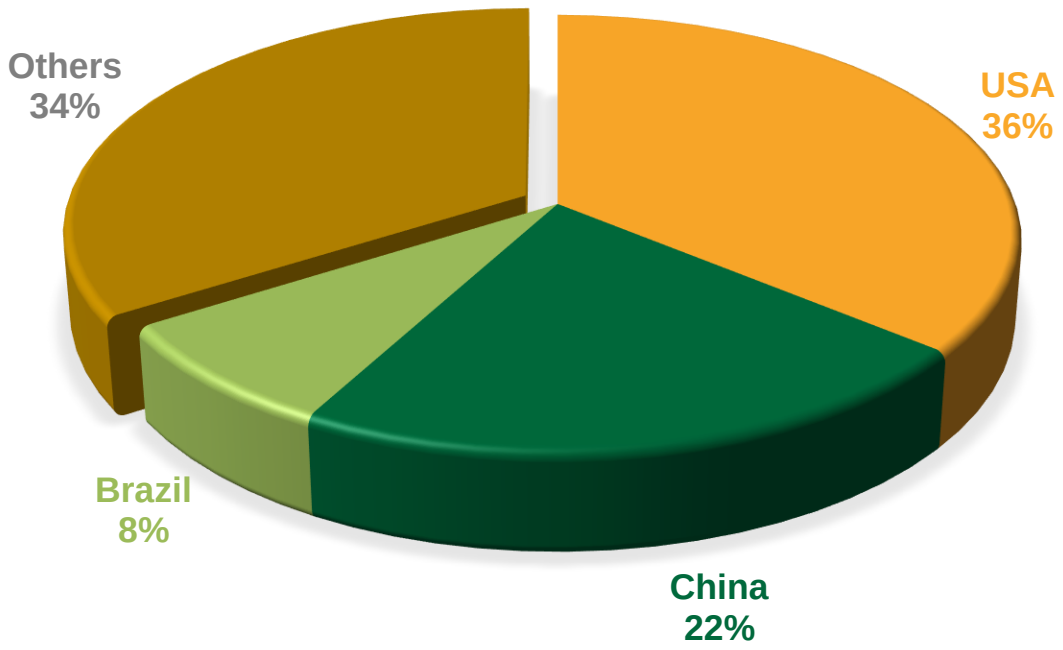
- **Major components:**
  - Endosperm
  - Germ
  - Pericarp
  - Tip Cap



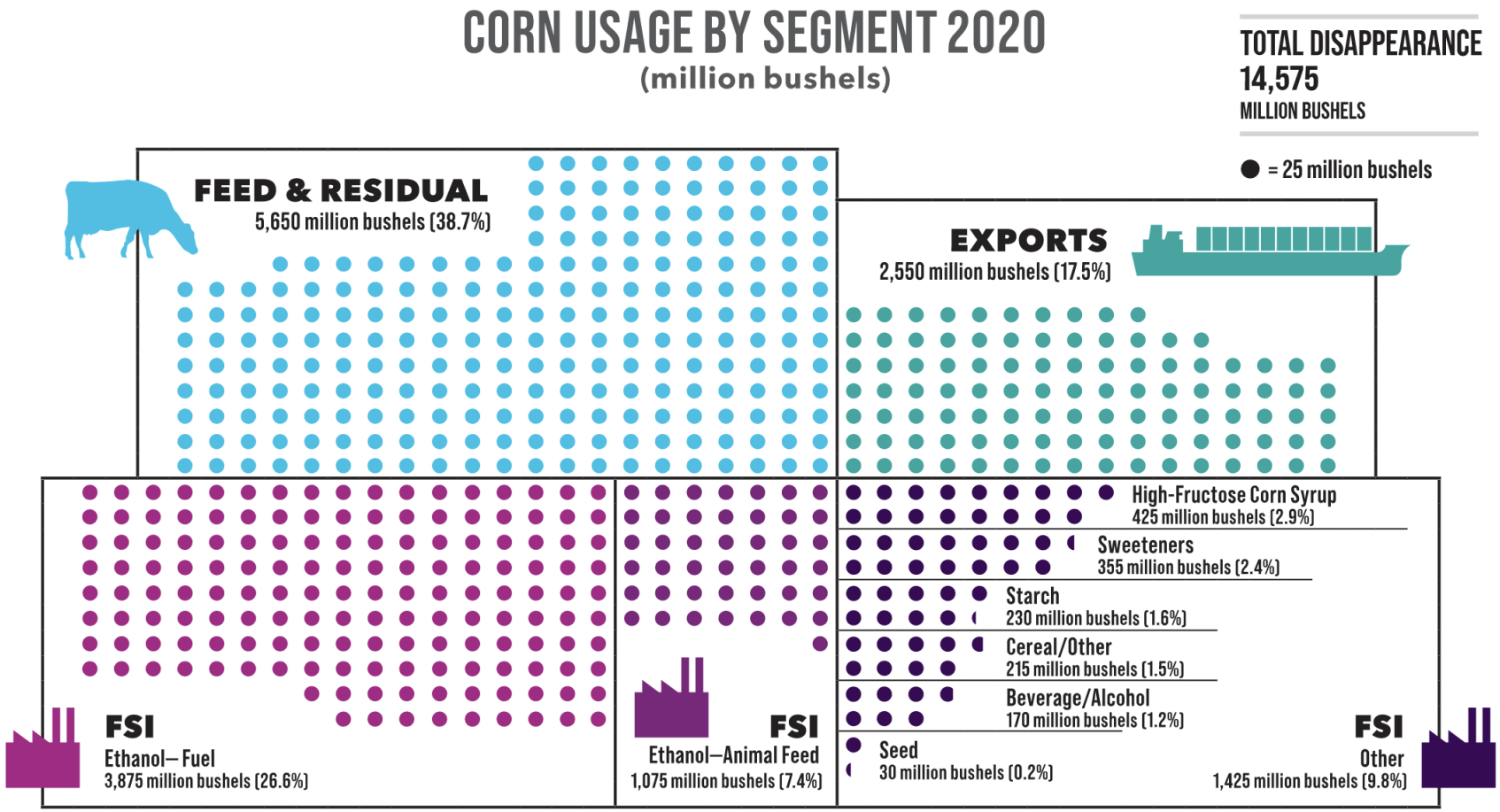
Corn Production

- Corn is considered the third most important cereal grain worldwide and a main feed ingredient in the livestock diets (Suleiman et al., 2013)

- Global production 2017-2018
  - 1.03 billion metric tons



Corn Usage in USA



Source: USDA, ERS Feed Outlook, Jan. 15, 2021; ProExporter Network, Projected Crop Year Ending Aug. 31, 2021

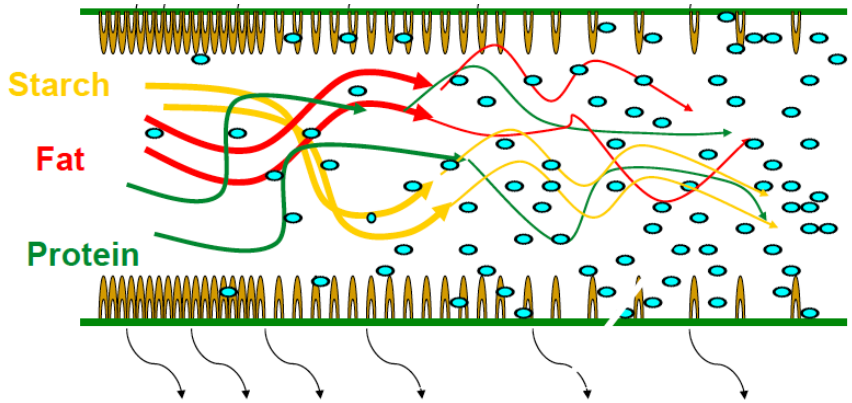
Wheat

- 95% of the energy value to corn
- Higher in protein and lysine than corn
- Diets containing wheat have good quality pellets
- In some countries, wheat is fed up to 40%

Wheat vs. Corn

Wheat – Common Issues

- Wheat contains no yellow pigments
- Starch digestibility may be variable with young birds
- Nutrient content can be variable
- During drought conditions, less carbohydrate and more protein content



Sorghum

- ME is about 96-97% of corn
- Protein level is higher than corn but less than wheat
- With Lys and Met supplementation, sorghum can be used with soybean meal

Sorghum – Common Issues

- Some varieties are high in tannic acid, which prevents mold, and are bird resistant
- Tannins bind with protein and reduce amino acid digestibility
- Low in Arginine
  - 4th limiting AA in sorghum based diets

Barley

- **Better amino acid balance than corn or wheat**
  - CP: 11-12%
  - Lysine: 0.35-0.40%
- **Common Issues:**
  - High content of NSP’s
  - β-glucanases can be added to diets to enhance β-glucan digestibility

Fats and Oils

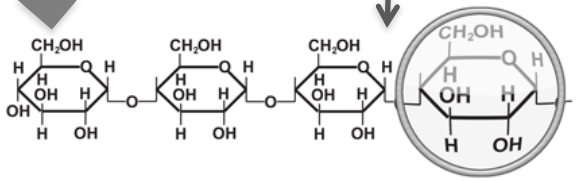
- **Sources**
  - Animal
  - Vegetable
  - Blended
- 2.25 times as much energy as carbohydrate
- Antioxidant must be added
- Added to mixer and sprayed on post-pelleting
  - Mixer fat addition increases pellet throughput, but reduces pellet quality

Bakery Meal

- **By-product from the bakery industry:**
  - Breads
  - Snacks
  - Cookies
  - Chips
- These products are usually broken or not suited for human consumption
- Good source of energy due to its starch and fat contents
- **Common issues:**
  - High nutrient variability
  - Can contain high levels of sodium
    - This can lead to wet litter if sodium level is underestimated

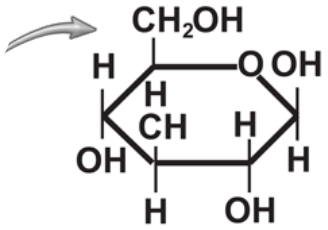
DDGS

Amylolytic Enzymes



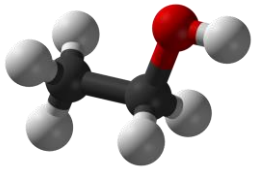
Starch

Glucose

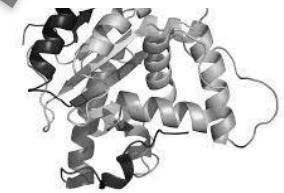


Glucose

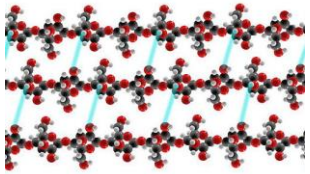
Yeast



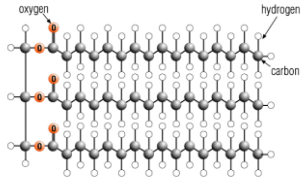
Ethanol



Protein



Fiber

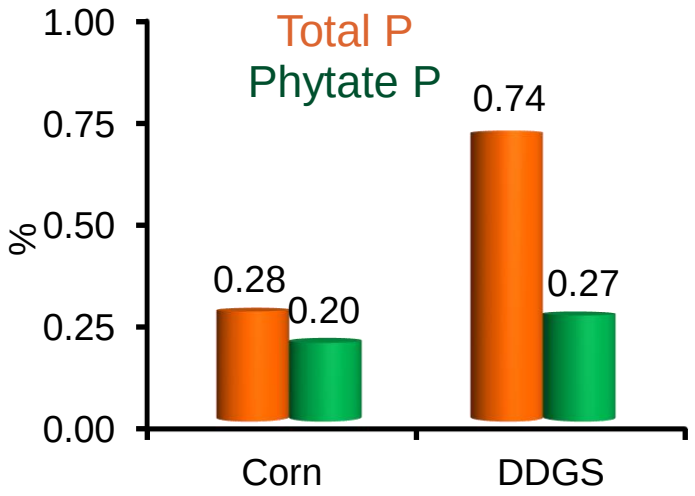


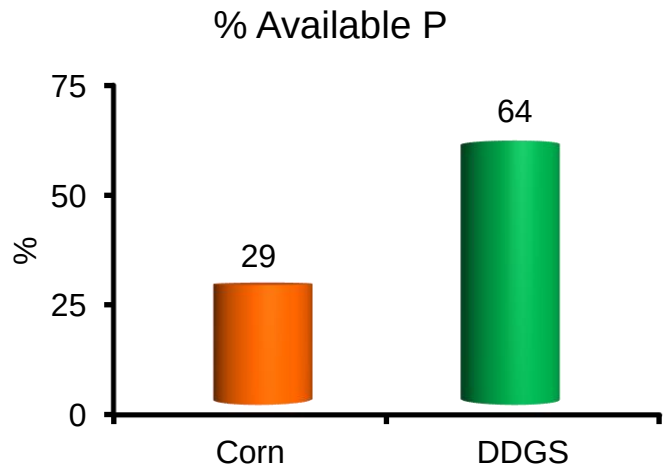
Fat

Minerals

DDGS

- **Good source of:**
  - Protein – ~3x the protein content of corn
  - Phosphorus
  - Energy
- **Common issues:**
  - Nutrient variability
    - Lower lysine digestibility
  - Mycotoxins
    - Purchase from the same provider to reduce variability
  - Can reduce pellet quality
    - Low starch content





Animal By-Product Meals

- **Meat and Bone Meal:**
  - No blood, hair, hoof, horn, hide, manure, or stomach contents
  - > 4.0% phosphorus
  - Ca level should not exceed 2.2 times the P content
- **Meat Meal:**
  - About the same as meat and bone meal
  - Does not include bone
  - High connective tissue

Common Issues:

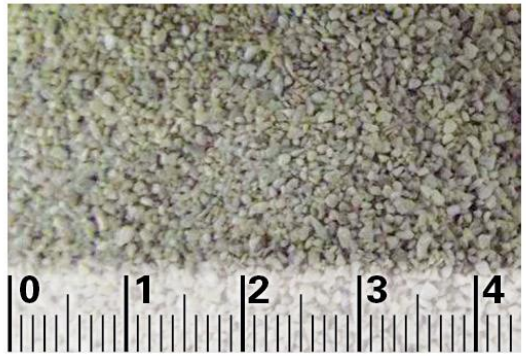
- Nutrient uniformity is a primary concern
- Microbial contamination can be a problem

Macro Minerals – Phosphorus Sources

- Dicalcium phosphate
- Monocalcium phosphate
- Defluorinated phosphate
  - Dicalcium phosphate has higher in phosphate availability
  - Defluorinated phosphate improves pelleting throughput by polishing pellet dies
    - The inclusion of phytase enzymes has reduced the level of phosphorus
    - Other alternatives have become available to increase production rate
      - Azomite
        - Hydrated sodium calcium aluminosilicate
      - Surfactants
        - »Reduce surface tension for better steam penetration

Calcium Sources

- The appropriate particle size depends on the solubility of limestone
  - Fine: Broilers
  - Coarse: Layers
- Oyster shell and other marine shells are good sources of soluble calcium
- Limestone dark in color is geologically older, containing more impurities (typically magnesium) and is generally lower in solubility and calcium availability (Mohiti, 2021)



Broilers

Layers

Sodium

- Sodium chloride: 39% Na

- Sodium bicarbonate: 27% Na

Conclusions

- Ingredients represent the major cost in poultry production

- It is important to know the nutritional content of the ingredient and their effect on feed quality and poultry performance

Thanks

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