IOWA STATE UNIVERSITY

Department of Agricultural and Biosystems Engineering

Beyond DDGS, Corn Gluten Meal, and Corn Gluten Feed: Current and Evolving Products from Corn Processing

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OUR END USERS

OVERVIEW

1. Motivations
2. Manufacturing processes and coproducts
3. Economics & markets
4. Issues & challenges
5. Evolving processes & new opportunities
6. Other issues

MOTIVATIONS

MOTIVATIONS

- Ruminants or monogastrics

Animal

MOTIVATIONS

- Ruminants or monogastrics

MOTIVATIONS

- Ruminants or monogastrics

MOTIVATIONS

- Beef Cattle:
  - Maximum potential inclusion rate: 20-40%
- Dairy Cows:
  - Maximum potential inclusion rate: 10-30%
- Market Swine:
  - Maximum potential inclusion rate: 10-40%
- Poultry (Layers, Broilers, Turkeys):
  - Maximum potential inclusion rate: 10-15%

Depends on many factors:

- Age
- Health
- Other ingredients

MOTIVATIONS

Main products

Byproducts / coproducts

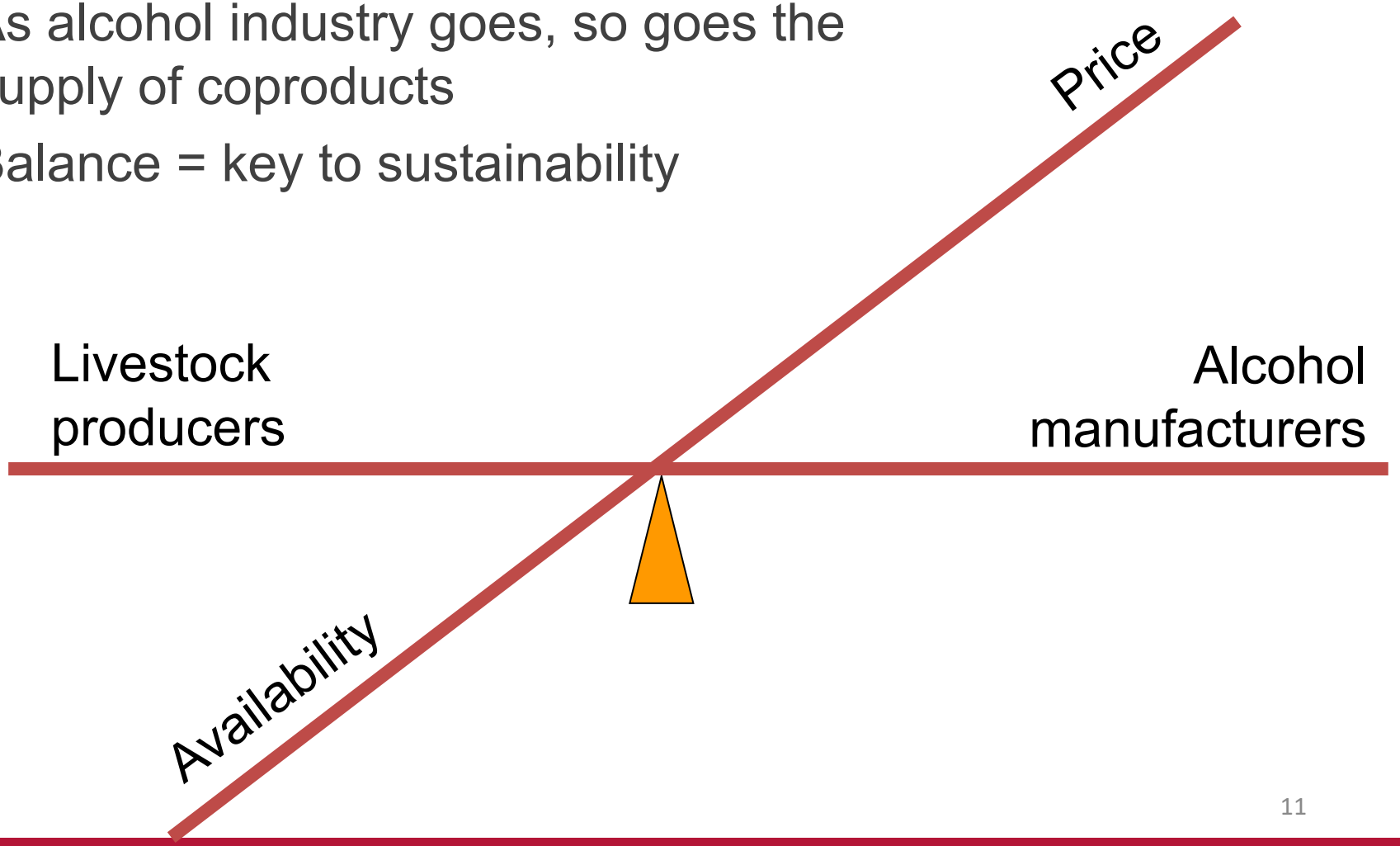
MOTIVATIONS

Alcohol

Non-fermentable components

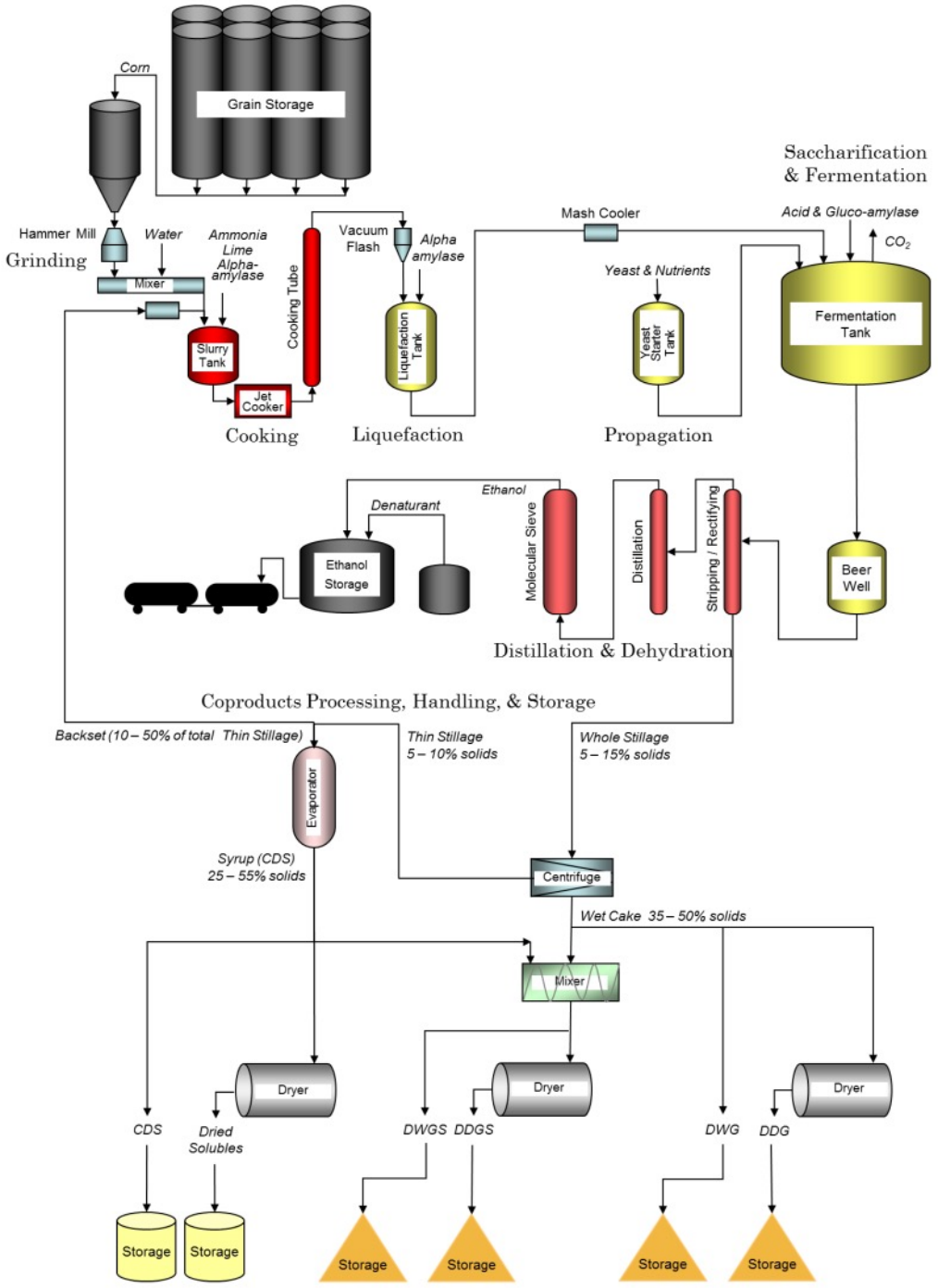
MOTIVATIONS

- As alcohol industry goes, so goes the supply of coproducts
- Balance = key to sustainability



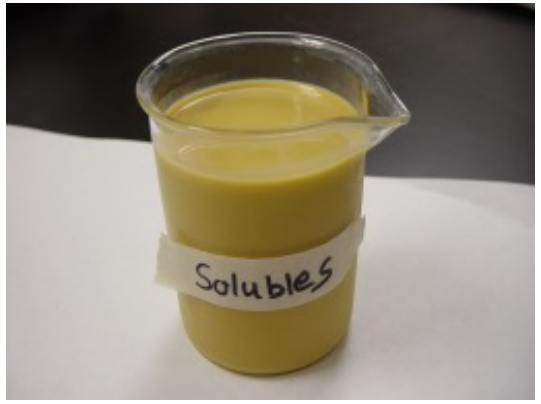
MANUFACTURING PROCESSES and COPRODUCTS

MANUFACTURING
Dry Grind Ethanol



ETHANOL COPRODUCTS

Condensed Distillers Solubles



Distillers Wet Grains

Distillers Dried Grains with Solubles

COPRODUCT COMPOSITION

	Unit	Condensed Solubles (CDS)	Thin Stillage	DWG
Dry matter	% as fed	32.0	5.0	35.0
Crude protein	% DM	20.4	17.9	44.0
Amino acids	% DM			
Arginine	% protein			3.4
Histidine	% protein			2.4
Isoleucine	% protein			3.5
Leucine	% protein			12.0
Lysine	% protein			2.6
Methionine	% protein			1.9
Phenylalanine	% protein			4.6
Threonine	% protein			3.2
Tryptophan	% protein			0.5
Tyrosine	% protein			4.1
Valine	% protein			4.4
NDF	% DM	4.2	12.5	28.8
Fat (ether extract)	% DM	17.3	9.2	5.1
Ash	% DM	9.5	6.3	2.6
Ca	% DM	0.11		0.2
P	% DM	1.53		4.2
K	% DM	2.21		3.9
Mg	% DM	0.67		1.1
Na (ppm)	g/kg DM	2.0		1.3
Zn (ppm)	mg/kg DM	61.0		39.0
Mn (ppm)	mg/kg DM	24.0		6.0
Cu (ppm)	mg/kg DM	5.2		3.0
Fe (ppm)	mg/kg DM	76.0		53.0

Source: http://www.feedipedia.org/

COPRODUCT COMPOSITION

DDGS					
	Unit	**Avg**	**SD**	**Min**	**Max**
Dry matter	% as fed	89.0	1.4	86.6	91.9
Crude protein	% DM	29.5	1.8	25.2	33.5
Amino acids					
Arginine	% protein	4.3	0.3	3.4	5.1
Histidine	% protein	2.7	0.2	2.2	3.1
Isoleucine	% protein	3.8	0.3	3.2	4.3
Leucine	% protein	11.6	0.6	10.1	13.3
Lysine	% protein	3.0	0.3	2.1	3.7
Methionine	% protein	2.0	0.2	1.7	2.7
Phenylalanine	% protein	4.8	0.2	4.3	5.4
Threonine	% protein	3.7	0.1	3.3	4.0
Tryptophan	% protein	0.8	0.1	0.6	0.9
Tyrosine	% protein	3.9	0.5	3.1	4.7
Valine	% protein	5.1	0.3	4.3	5.6
NDF	% DM	34.2	6.8	18.3	47.4
Fat (ether extract)	% DM	11.1	2.2	7.1	15.7
Ash	% DM	5.4	1.0	3.4	7.5
Ca	g/kg DM	1.6	1.6	0.2	5.5
P	g/kg DM	7.9	1.0	4.9	9.8
K	g/kg DM	10.3	1.1	7.1	12.7
Mg	g/kg DM	3.3	0.4	1.9	3.9
Na (ppm)	g/kg DM	2.4	1.8	0.6	7.2
Zn (ppm)	mg/kg DM	62	16	43	105
Mn (ppm)	mg/kg DM	21	8	12	44
Cu (ppm)	mg/kg DM	6	2	3	10
Fe (ppm)	mg/kg DM	123	41	70	239

Source: http://www.feedipedia.org/

FERMENTATION PRODUCTS

Theoretical Yields

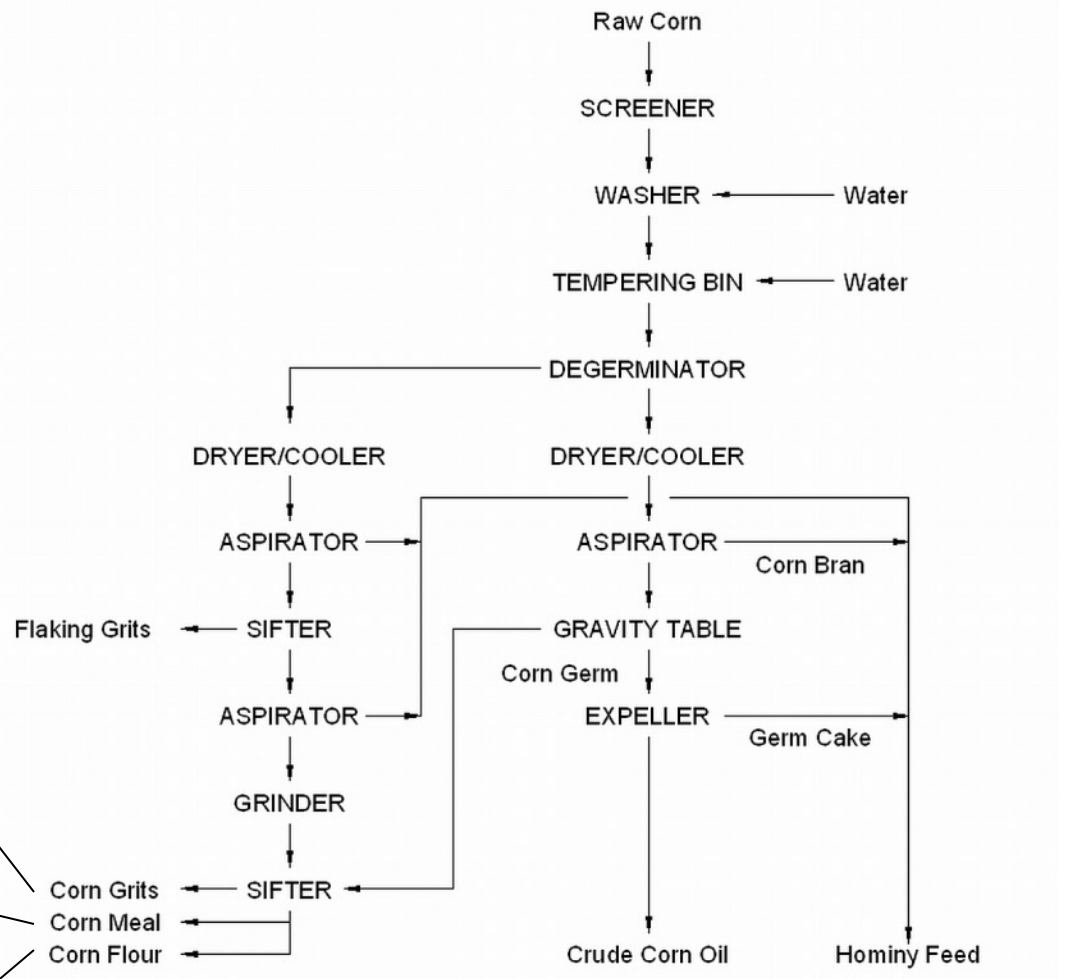
1 kg glucose = 0.51 kg alcohol
+ 0.49 kg carbon dioxide

Practical Yields

90 – 95% of theoretical
+ yeast cell mass
+ secondary products

Anecdotally:	
1 kg maize = 1/3 kg alcohol + 1/3 kg CO_2 + 1/3 kg DDGS	1 lb maize = 1/3 lb alcohol + 1/3 lb CO_2 + 1/3 lb DDGS
1 bu maize = 25.4 kg = 11 L alcohol + 7.7-8.2 kg CO_2 + 7.7-8.2 kg DDGS	1 bu maize = 56 lb = 2.9 gal alcohol + 17-18 lb CO_2 + 17-18 lb DDGS

MANUFACTURING
Maize Dry Milling



COPRODUCT COMPOSITION

Corn Bran

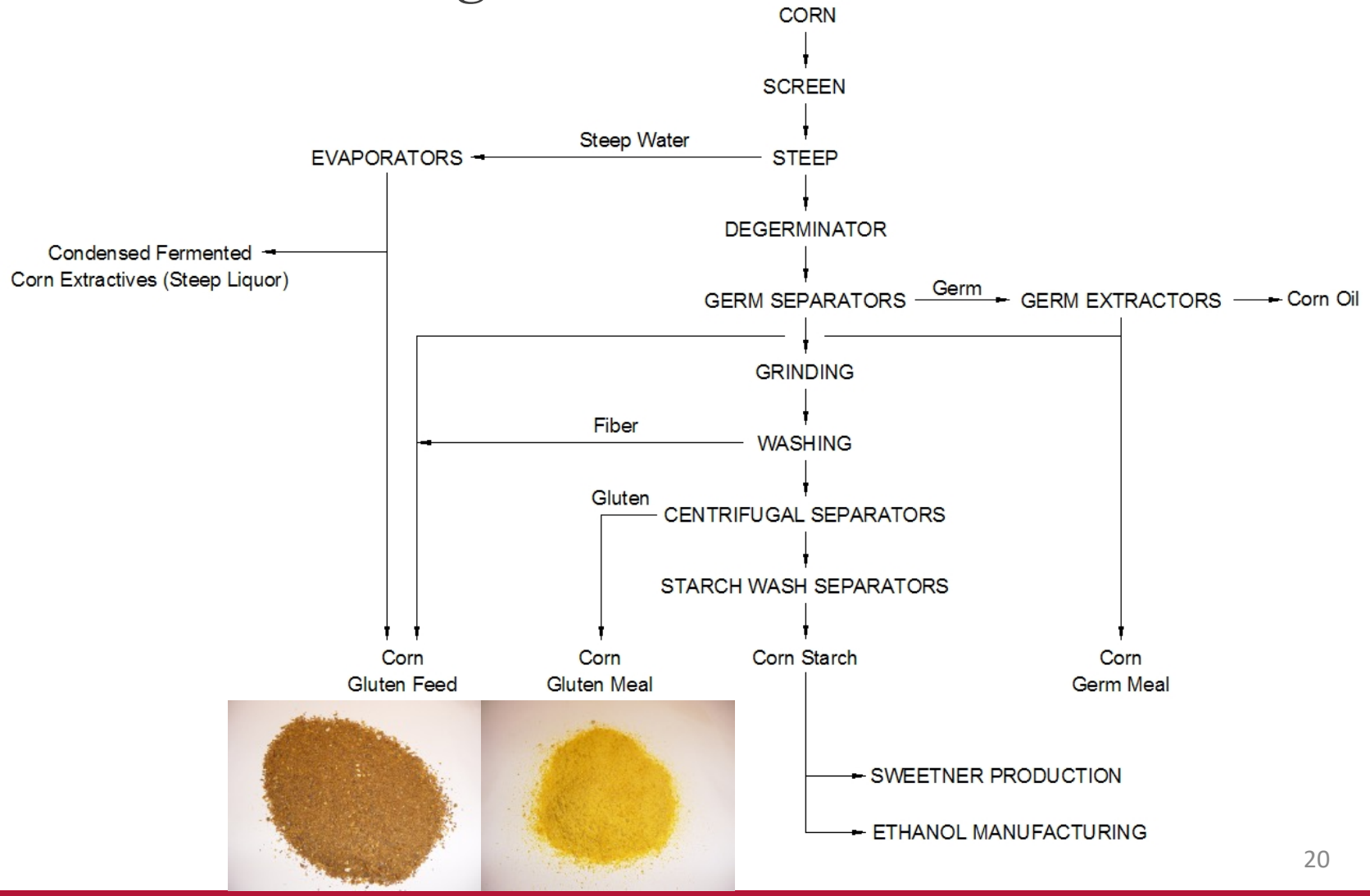
	Unit	Avg	SD	Min	Max
Dry matter	% as fed	88.7	2.1	85.6	95.6
Crude protein	% DM	11.9	1.9	8.6	17.6
Crude fibre	% DM	12.3	4.4	4.8	20.7
NDF	% DM	44.2	10.4	22.2	60.2
ADF	% DM	14.5	3.7	6.4	19.3
Lignin	% DM	2.2	0.8	0.9	4.1
Ether extract	% DM	4.6	1.7	2.4	9.7
Ash	% DM	5.8	2.2	2.3	10.7
Starch (polarimetry)	% DM	35.0	8.8	16.6	54.8
Total sugars	% DM	2.8	0.8	1.4	5.0
Gross energy	MJ/kg DM	18.5	1.1	18.5	22.4

Hominy Feed

	Unit	Avg	SD	Min	Max
Dry matter	% as fed	89.3	0.8	87.5	91.2
Crude protein	% DM	15.2	1.3	12.4	18.2
Crude fibre	% DM	6.5	1.2	4.9	9.8
NDF	% DM	30.7	9.2	15.1	53.5
ADF	% DM	8.9	2.1	3.4	11.1
Lignin	% DM	1.1	0.6	0.2	2.0
Ether extract	% DM	5.8	1.8	1.6	7.8
Ash	% DM	6.0	2.1	3.7	13.6
Starch (polarimetry)	% DM	40.5	3.2	30.4	45.9
Total sugars	% DM	4.8	2.5	1.6	8.5
Gross energy	MJ/kg DM	18.7	1.8	17.3	21.9

Source: http://www.feedipedia.org/

MANUFACTURING
Maize Wet Milling



COPRODUCT COMPOSITION

CGF

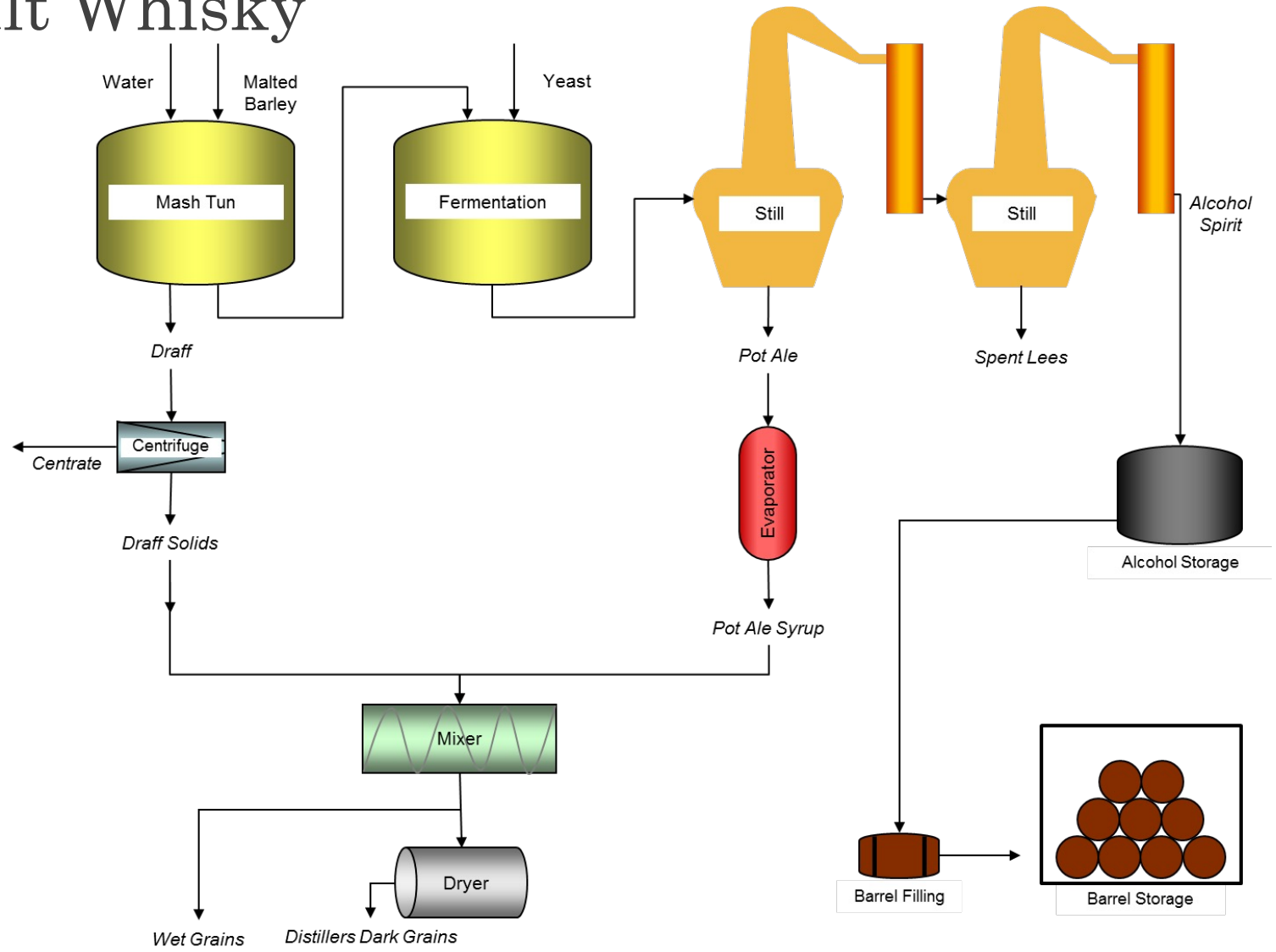
	Unit	Avg	SD	Min	Max
Dry matter	% as fed	88.3	1.5	84.3	94.5
Crude protein	% DM	21.7	1.5	17.3	27.2
Crude fibre	% DM	8.3	1.0	5.3	11.4
NDF	% DM	39.6	4.3	31.0	49.1
ADF	% DM	10.6	1.3	8.4	13.3
Lignin	% DM	1.2	0.5	0.6	2.7
Ether extract	% DM	3.4	0.9	1.5	6.9
Ether extract, HCl hydrolysis	% DM	4.1	0.6	3.0	5.4
Ash	% DM	6.9	1.3	4.0	10.3
Starch (polarimetry)	% DM	21.5	3.7	11.0	33.8
Total sugars	% DM	1.8	0.8	0.7	4.4
Gross energy	MJ/kg DM	18.8	0.3	18.3	19.5

CGM

	Unit	Avg	SD	Min	Max
Dry matter	% as fed	90.0	1.7	87.3	96.2
Crude protein	% DM	67.2	2.9	56.9	76.2
Crude fibre	% DM	1.2	0.5	0.4	2.7
NDF	% DM	4.1	2.5	1.1	8.6
ADF	% DM	1.6	1.1	0.3	3.7
Lignin	% DM	0.3	0.1	0.2	0.6
Ether extract	% DM	2.9	1.2	1.0	6.5
Ash	% DM	2.1	0.8	1.1	4.6
Starch (polarimetry)	% DM	17.6	3.5	9.1	26.0
Total sugars	% DM	0.5	0.2	0.2	1.2
Gross energy	MJ/kg DM	23.1	0.8	21.2	24.1

Source: http://www.feedipedia.org/

MANUFACTURING
Malt Whisky



WHISKY COPRODUCTS

Pot Ale Syrup

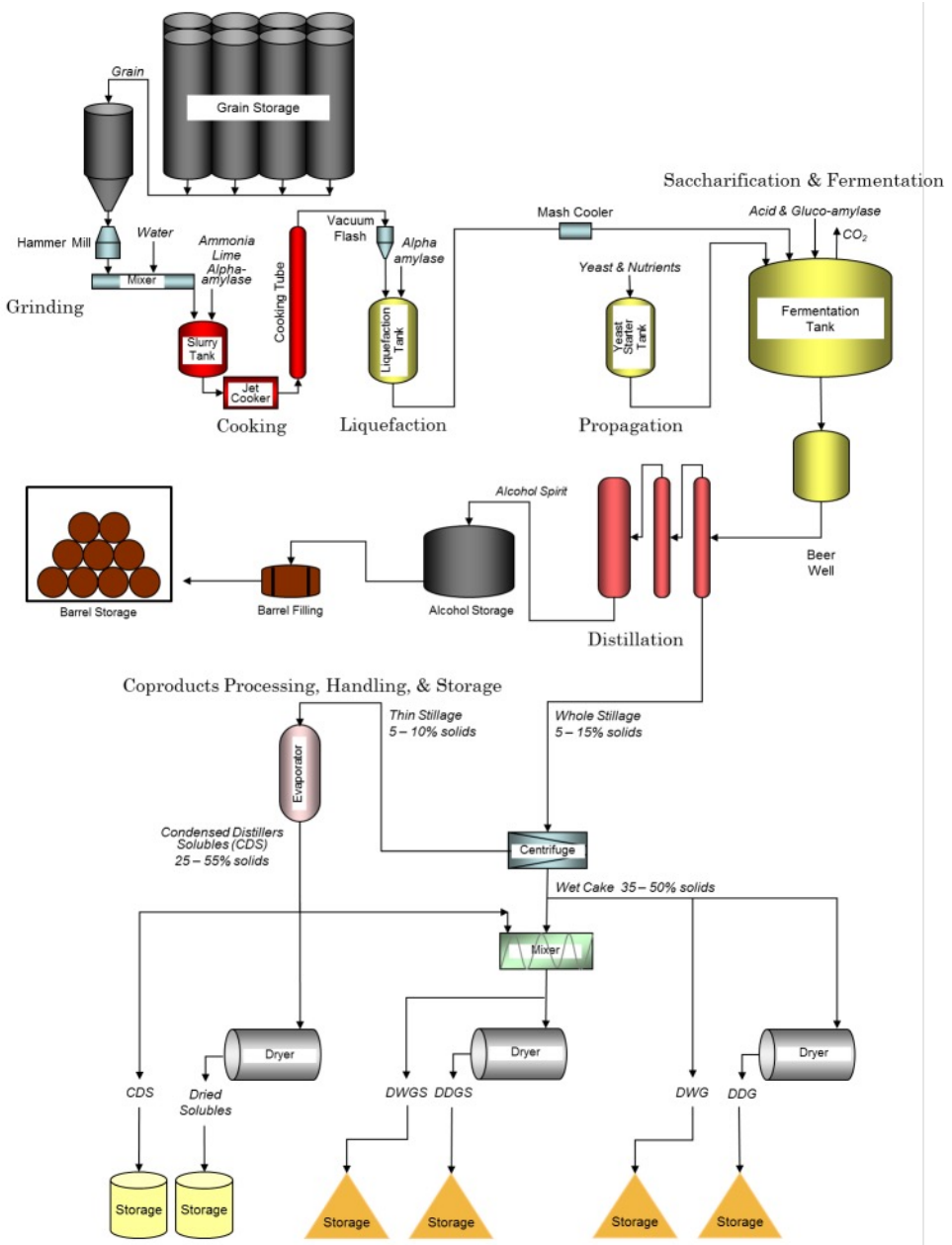
Draff at Glenturret Distillery in Perthshire

COPRODUCT COMPOSITION

	Unit	Pot Ale Syrup	Draff (wet)	Distillers Dark Grains (dried)
Dry matter	% as fed	48.3	24.1	90.7
Crude protein	% DM	37.4	20.3	27.8
Crude fibre	% DM	0.2	17.6	11.6
NDF	% DM	0.6	65.1	39.7
ADF	% DM	0.7	26.4	15.5
Lignin	% DM	1.5	5.9	3.8
Starch	% DM		1.8	3.2
Total sugars	% DM	2.3	0.5	4.3
Fat (ether extract)	% DM	0.2	8.2	8.5
Ash	% DM	9.5	3.3	5.8
Gross energy	MJ/kg DM	20.0	21.5	21.3

Source: http://www.feedipedia.org/

MANUFACTURING
Grain Whiskey/Spirits



COPRODUCT ECONOMICS

Markets

Dry and Wet Mill, Corn Consumed – United States: January 2023 with Comparisons

Purpose	January 2022	December 2022	January 2023
	(1,000 bushels)	(1,000 bushels)	(1,000 bushels)
Consumed for alcohol production			
Beverage alcohol	3,787	4,448	6,082
Fuel alcohol	463,512	425,295	443,551
Dry mill	427,804	391,326	406,481
Wet mill	35,708	33,969	37,070
Industrial alcohol	8,238	5,988	5,582
Consumed for other purposes			
Total wet mill products other than fuel	40,836	38,299	38,839

Dry Mill, Sorghum Consumed – United States: January 2023 with Comparisons

Purpose	January 2022	December 2022	January 2023
	(1,000 cwt)	(1,000 cwt)	(1,000 cwt)
Consumed for alcohol production			
Fuel alcohol	(D)	(D)	(D)

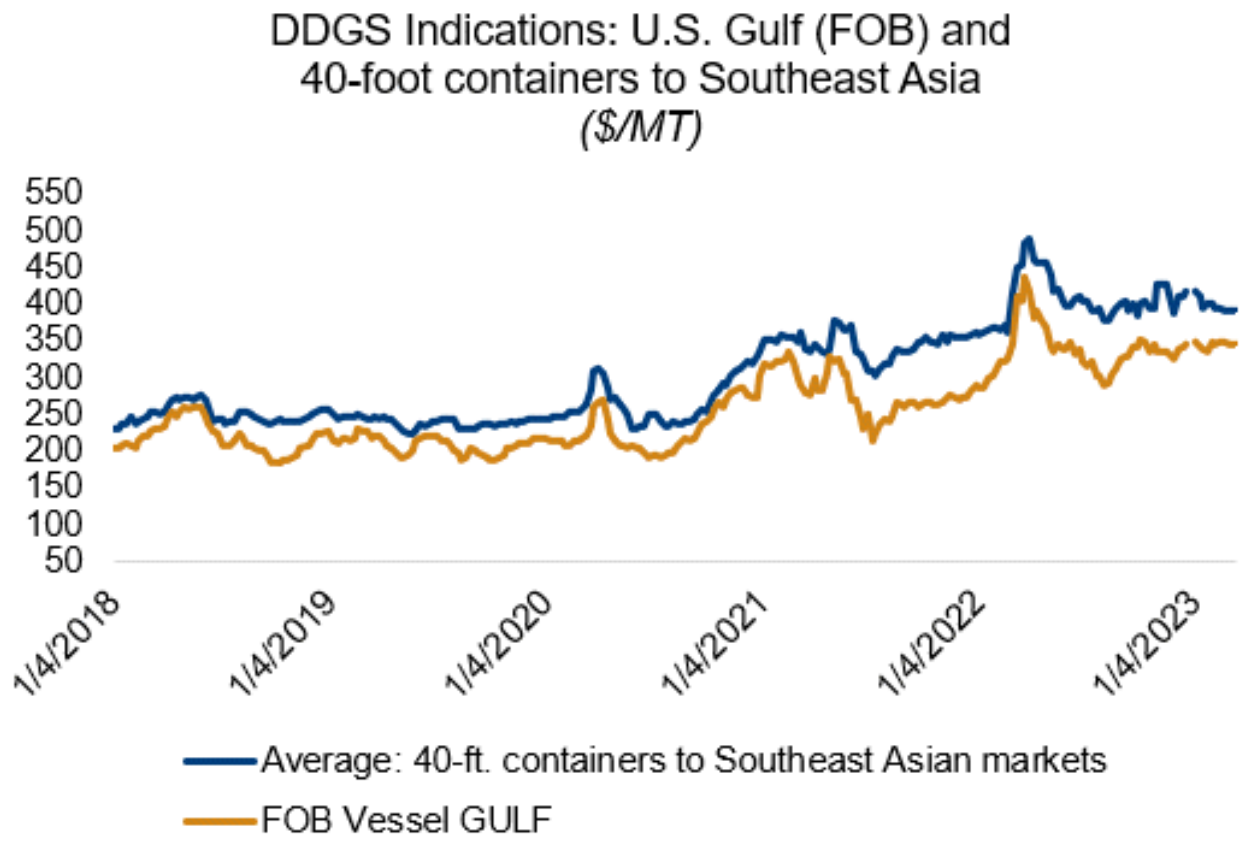
(D) Withheld to avoid disclosing data for individual operations.

Dry and Wet Mill, Co-products and Products Produced – United States: January 2023 with Comparisons

Co-products and products	January 2022	December 2022	January 2023
	(tons)	(tons)	(tons)
Dry mill			
Condensed distillers solubles (CDS - syrup)	100,263	96,964	100,116
Corn oil (Corn Distillers Oil - CDO)	175,110	174,416	172,399
Distillers dried grains (DDG)	356,957	317,504	374,753
Distillers dried grains with solubles (DDGS)	1,929,115	1,679,600	1,714,389
Distillers wet grains (DWG) 65% or more moisture	1,425,897	1,363,421	1,262,056
Modified distillers wet grains (DWG) 40% to 64% moisture	535,036	576,406	582,926
Wet mill			
Corn germ meal	53,504	48,546	48,319
Corn gluten feed	271,890	252,788	268,446
Corn gluten meal	102,711	99,585	117,945
Wet corn gluten feed 40% to 60% moisture	197,175	188,584	208,090
Dry and wet mill			
Carbon dioxide captured	229,006	213,799	213,294

NASS/USDA MONTHLY CO-PRODUCTS PRODUCTION
https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Current_Agricultural_Industrial_Reports/Grain_Crushings/index.php

Markets



Source: World Perspectives, Inc.

FOB

Yellow Corn (USD/MT FOB Vessel*)				
YC FOB Vessel Max. 15.0% Moisture	GULF		PNW	
	Basis (#2 YC)	Flat Price (#2 YC)	Basis (#2 YC)	Flat Price (#2 YC)
March	0.93+H	$279.91	1.59+H	$305.89
April	0.94+K	$277.54	1.60+K	$303.53
May	0.92+K	$276.76	1.57+K	$302.35
June	0.96+N	$274.69	1.63+N	$300.87
July	0.93+N	$273.51	1.59+N	$299.29
August	1.32+U	$272.92	1.99+U	$299.10

Sorghum (USD/MT FOB Vessel*)				
#2 YGS FOB Vessel Max 14.0% Moisture	NOLA		TEXAS	
	Basis	Flat Price	Basis	Flat Price
March	N/A	N/A	2.35+H	$336.00
April	N/A	N/A	2.30+K	$331.28
May	N/A	N/A	2.25+K	$329.31

#2 White Corn (U.S. $/MT FOB Vessel*)			
Max. 15.0% Moisture	March	April	May
Gulf	N/A	N/A	N/A

Corn Gluten Feed Pellets (CGFP) (FOB Vessel U.S. $/MT*)			
	March	April	May
New Orleans	$275	$275	$275
Quantity 5,000 MT			

Corn Gluten Meal (CGM) (FOB Vessel U.S. $/MT*)			
Bulk 60% Pro.	March	April	May
New Orleans	$800	$800	$800
**5-10,000 MT Minimum*			

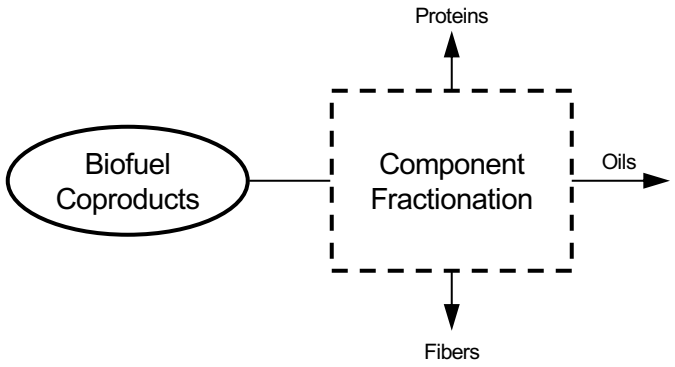
**Prices are based on offer indications only. Quoted prices are believed to reflect current market conditions but may vary from actual offers. Terms of delivery, payment, and quality may vary from one supplier to another, impacting the actual value of the price.*

DDGS Price Table: March 9, 2023 (USD/MT) (Quantity, availability, payment, and delivery terms vary)			
Delivery Point Quality Min. 35% Pro-fat combined	March	April	May
Barge CIF New Orleans	338	333	331
FOB Vessel GULF	344	340	338
Rail delivered PNW	350	347	345
Rail delivered California	358	354	352
Mid-Bridge Laredo, TX	350	345	346
FOB Lethbridge, Alberta	N/A	N/A	N/A
40 ft. Containers to South Korea (Busan)	380	377	377
40 ft. Containers to Taiwan (Kaohsiung)	420	417	417
40 ft. Containers to Philippines (Manila)	400	397	397
40 ft. Containers to Indonesia (Jakarta)	384	381	381
40 ft. Containers to Malaysia (Port Kelang)	396	393	393
40 ft. Containers to Vietnam (HCMC)	388	385	385
40 ft. Containers to Japan (Yokohama)	N/A	N/A	N/A
40 ft. containers to Thailand (LCMB)	400	397	397
40 ft. Containers to China (Shanghai)	N/A	N/A	N/A
40 ft. Containers to Bangladesh (Chittagong)	N/A	N/A	N/A
40 ft. Containers to Myanmar (Yangon)	380	377	377
KC Rail Yard (delivered ramp)	335	335	335
Elwood, IL Rail Yard (delivered ramp)	326	326	325

*Source: World Perspectives, Inc. *Prices are based on offer indications only; terms of delivery, payment and quality may vary from one supplier to another, impacting the actual value of the price.*

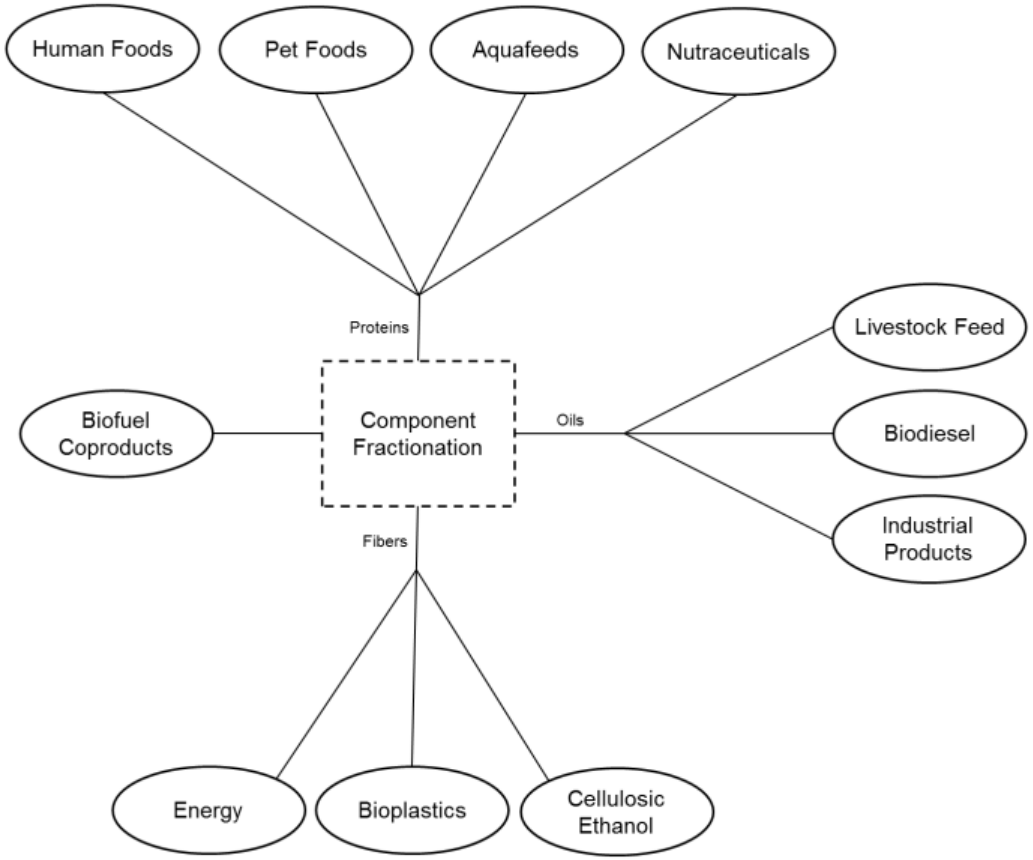
EVOLVING PROCESSES & NEW OPPORTUNITIES

FRACTIONATION

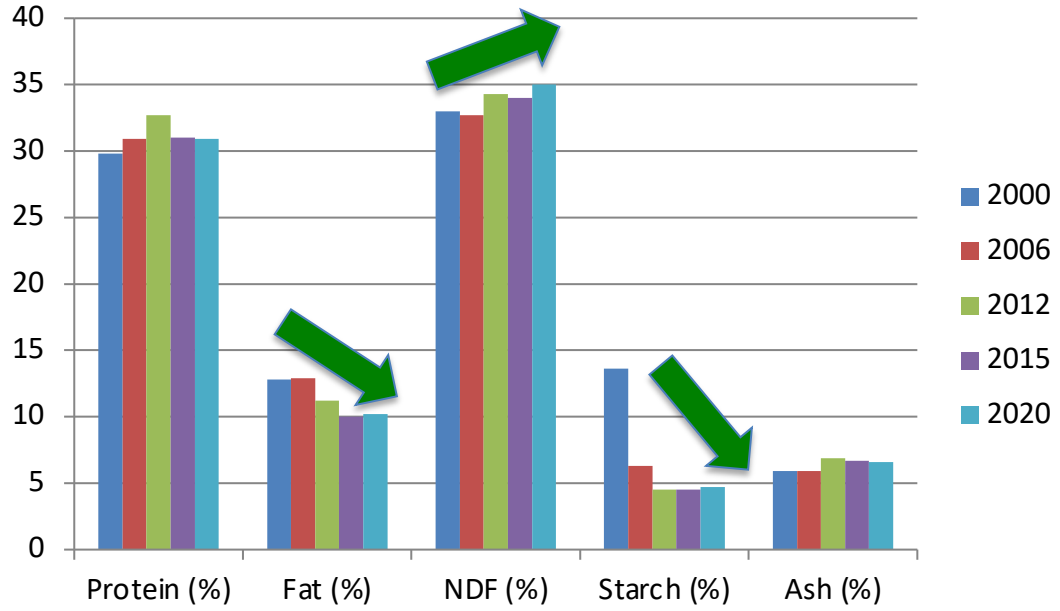


What else besides livestock feed?

FRACTIONATION



EVOLVING COMPOSITIONS

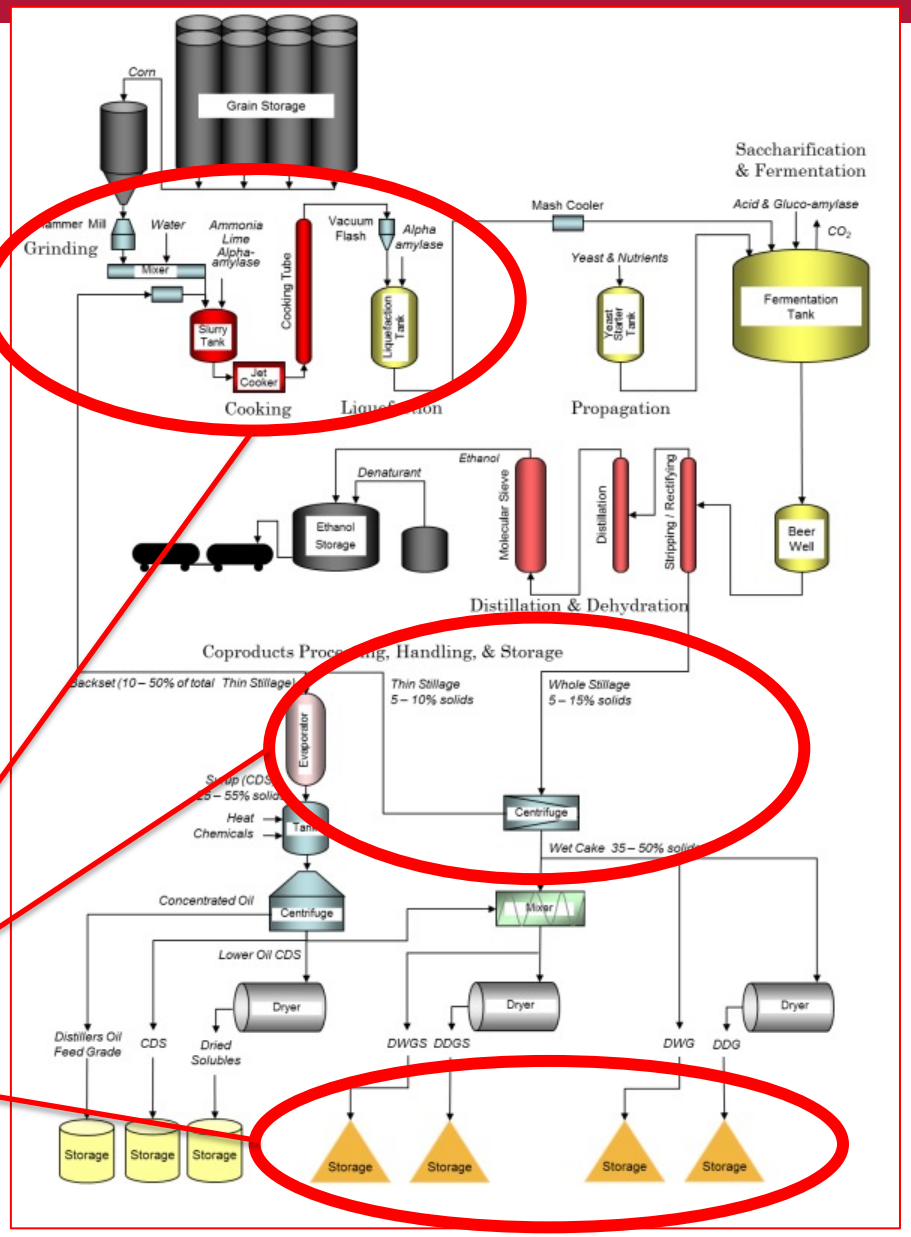


Source: http://www.dairyone.com

EVOLVING PROCESSES

- Fiber & protein separations

Current focus



EVOLVING PROCESSES

- Fiber & protein separation

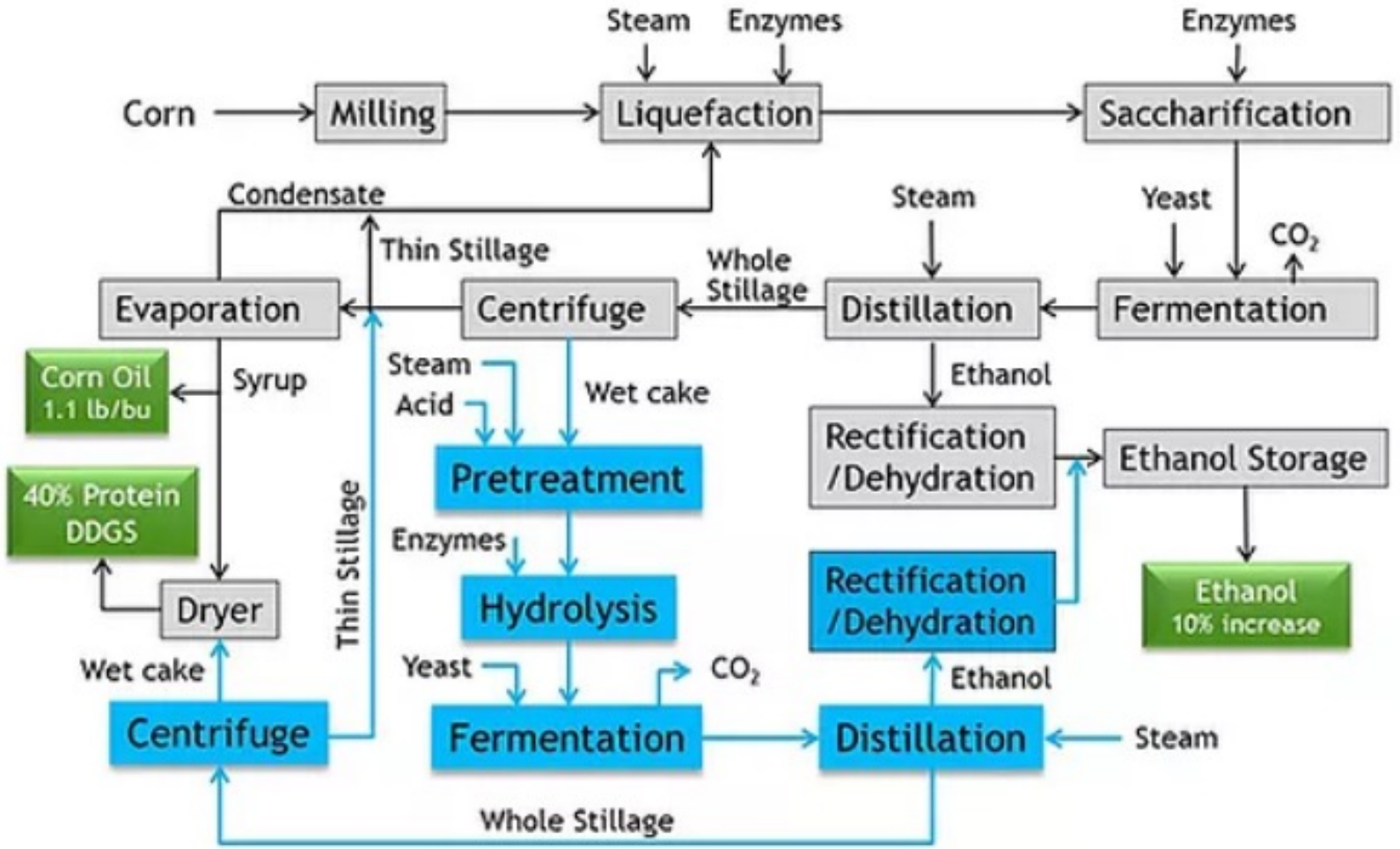
- Several technologies
  - D3Max
  - Fluid Quip Tech
  - Marquis

  Post-fermentation

  - ICM
  - Quad County

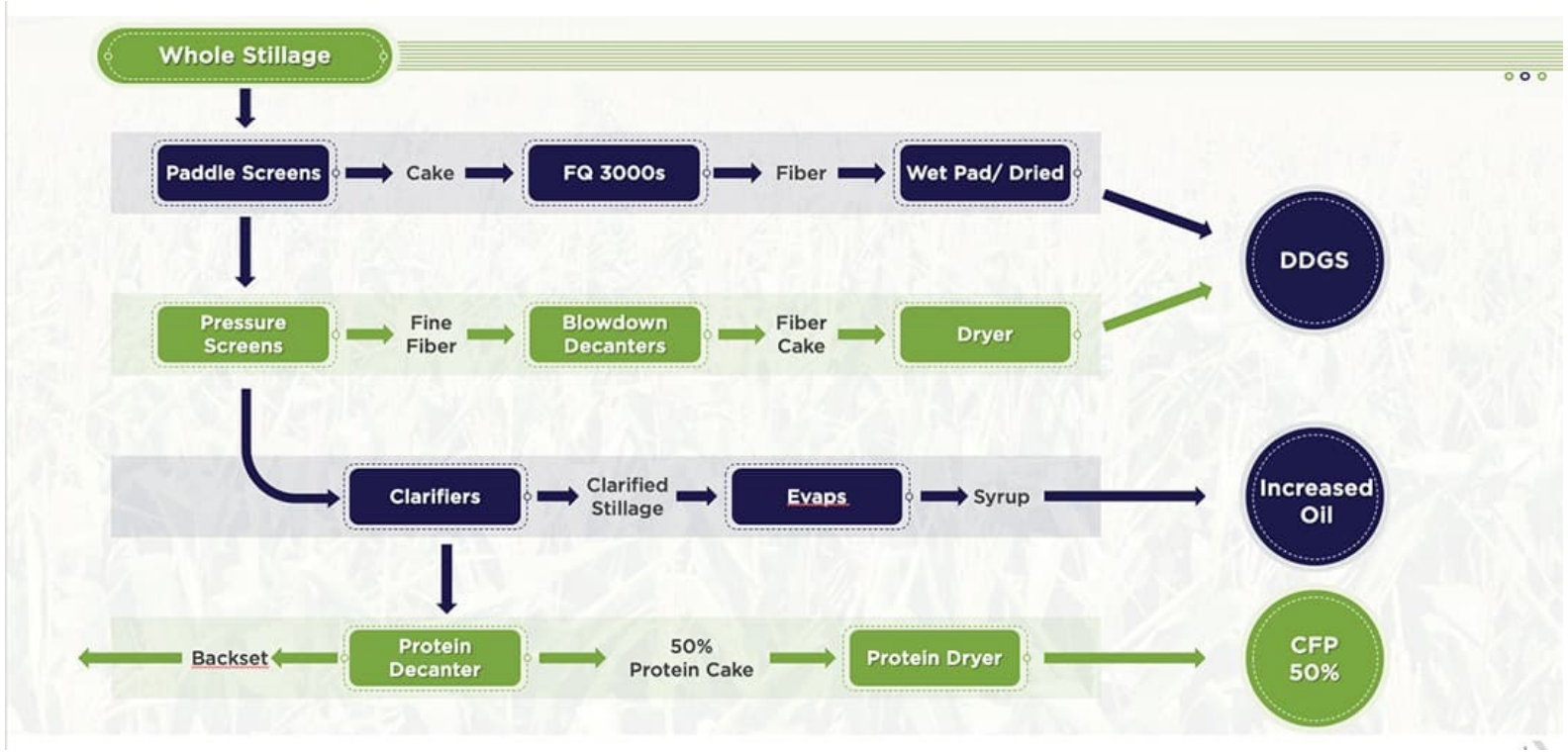
  Pre-fermentation

Protein levels (CP): ~38 to > 50%
Fat levels (CF): 5-7%



https://www.d3maxllc.com/technology

FLUID QUIP TECHNOLOGIES



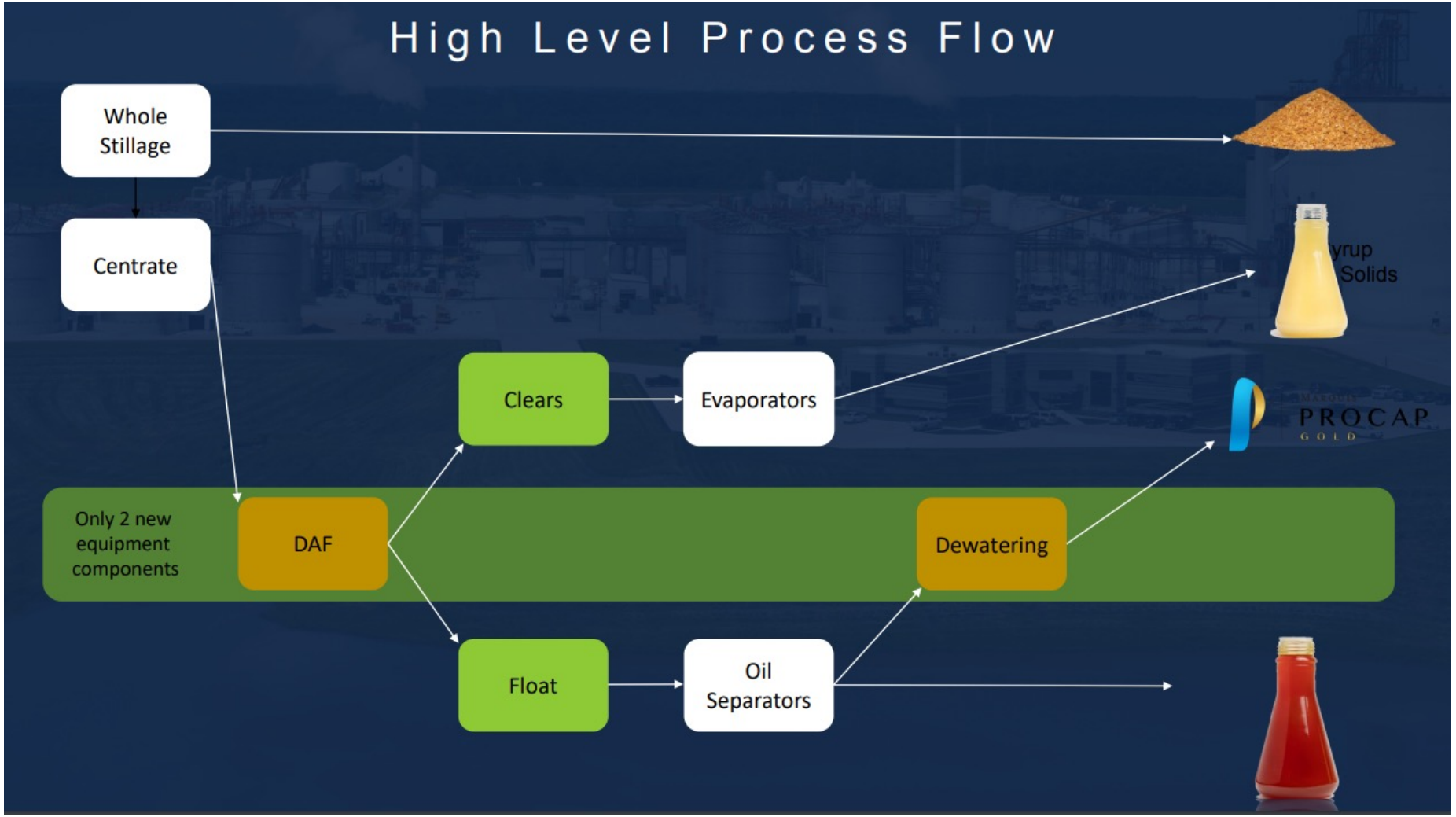
Still Pro 50™ Protein
- 3-4 lb/bu
- 50+% protein
- Various feeding trials

DDGS
- 28% Protein
- 7% Fat

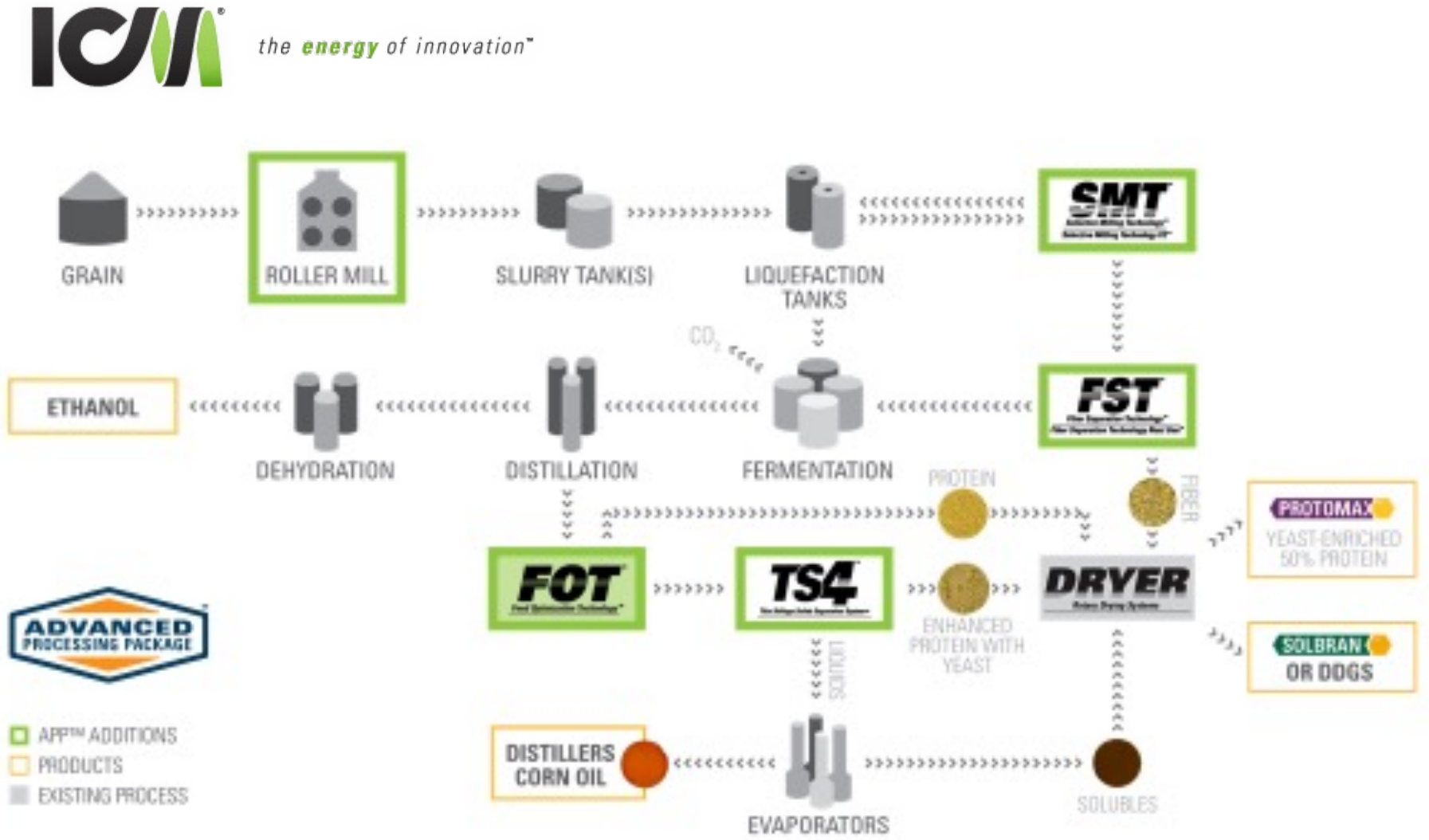
OIL
- Yield over 1.0 lb/bu

https://fluidquiptechnologies.com

MARQUIS – PROCAP PROCESS

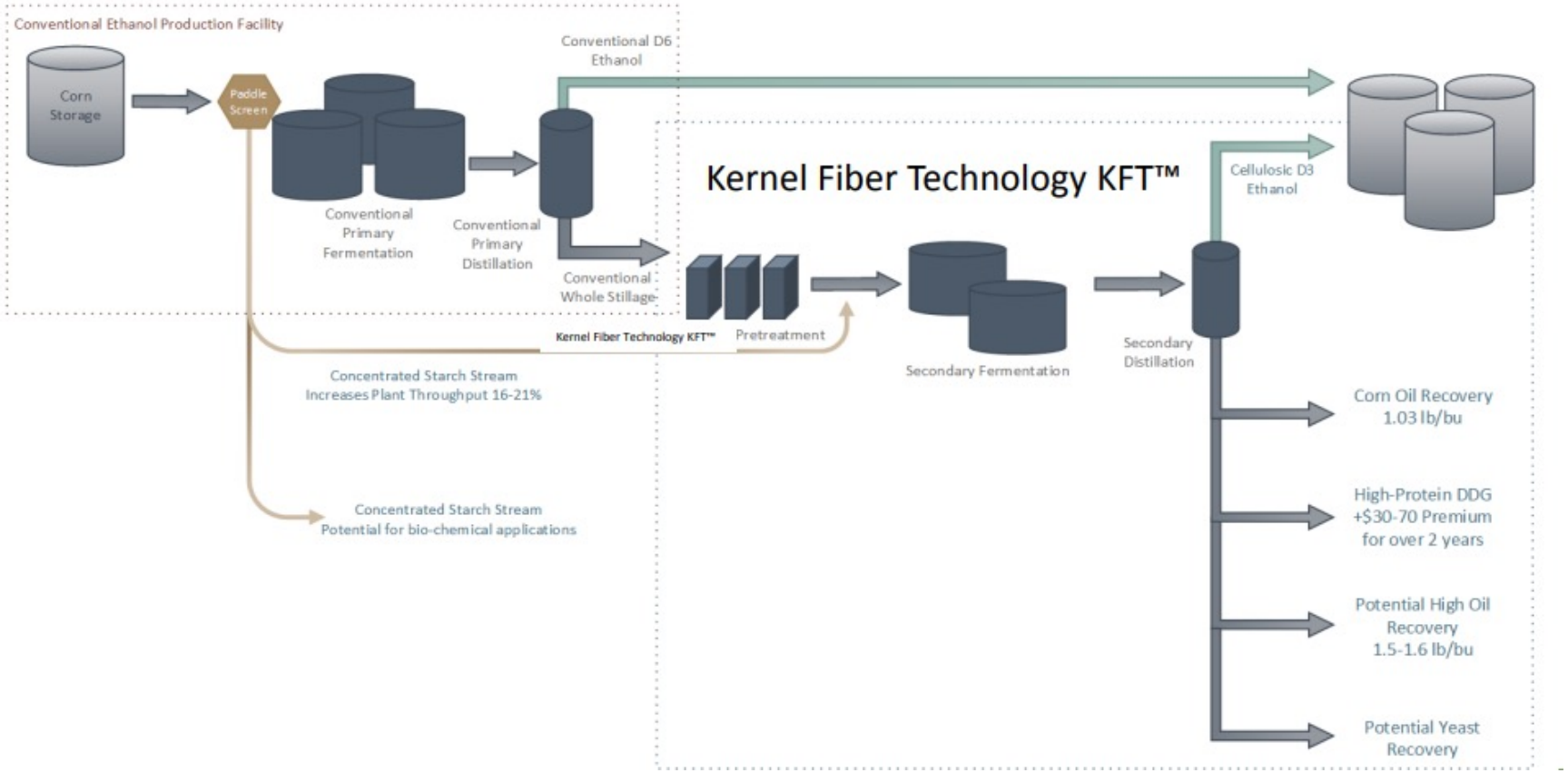


https://www.marquisincorporated.com



https://icminc.com/process-technologies/).

QUAD COUNTY



https://www.quad-county.com

VS.

www.distillersgrains.org

Distillers & Biorefinery Products - February 2021

Dried Distillers Grain Products

Industry Name	Common Analysis (As Fed) %Protein	%Fat	% Crude Fiber	Current AAFCO Definition	General Description
DDGS	23-36	3-9	<14	27.6, 27.8	Distillers grains with condensed distillers solubles with a portion of oil removed. Can be in dry or wet form (dry form common analysis displayed).
Full Fat DDGS	21-34	8-12	<14	27.6, 27.8	Distillers grains with condensed distillers solubles. No oil has been removed. Can be in dry or wet form (dry form common analysis displayed).
Deoiled DDGS	26-36	<3	<14	27.9	Solvent extracted DDGS.
DDGS with Bran	23-36	3-16	<14	27.6, 27.8, 48.2	DDGS mixed with bran separated by plant prior to fermentation. Can be in dry or wet form (dry form common analysis displayed).
DDGS Mechanically Separated	24-48	3-8	<14	27.5, 27.4	Post distillation residual whole stillage resulting from the mechanical separation of fiber and protein. Contains condensed distillers solubles.
DDG	24-35	4-8	<14	27.5	Distillers grain. May have a portion of oil removed. Does not contain condensed distillers solubles.
HiPro DDG	36-48	4-6	<12	27.5	Distillers grain. Portion of fiber and oil removed which concentrates protein. Does not contain condensed distillers solubles.

Other Distillers Products

Industry Name	Common Analysis (As Fed) %Protein	%Fat	% Crude Fiber	Current AAFCO Definition	General Description
Syrup (CDS)	5-25	3-23	0-4	27.7	Condensed thin stillage.
Distillers Yeast	40-55	0-8	0-6	96.5	Inactive *Saccharomyces cerevisiae* yeast removed from the process stream after fermentation either before or after distillation.
	%Total Fatty Acids	%Unsaponifiable Matter	%Insoluble Impurities		
Distillers Oil	>85	<2.5	<1	33.10	Oil removed by centrifugation from the condensed distillers solubles stream or by solvent extraction of DDGS.

VS.

Other Distillers Products

Industry Name	Common Analysis (As Fed) %Protein	%Fat	% Crude Fiber	Current AAFCO Definition	General Description
Syrup (CDS)	5-25	3-23	0-4	27.7	Condensed thin stillage.
Distillers Yeast	40-55	0-8	0-6	96.5	Inactive *Saccharomyces cerevisiae* yeast removed from the process stream after fermentation either before or after distillation.
	%Total Fatty Acids	%Unsaponifiable Matter	%Insoluble Impurities		
Distillers Oil	>85	<2.5	<1	33.10	Oil removed by centrifugation from the condensed distillers solubles stream or by solvent extraction of DDGS.

High Fiber Distillers Products

Industry Name	Common Analysis (As Fed) %Protein	%Fat	% Crude Fiber	Current AAFCO Definition	General Description
Bran/Fiber with Syrup	18-28	4-9	15-20	48.2, 27.7	Bran separated by plant prior to fermentation mixed with condensed distillers solubles. Can be in dry or wet form (dry form common analysis displayed).
Fermented Fiber Mechanically Separated	<24	2-7	10-20	27.5, 27.4	Post distillation mechanical separation of the whole stillage resulting in a concentration of fiber. Does not contain distilllers solubles unless listed.

Fermented Protein Products

Industry Name	Common Analysis (As Fed) %Protein	%Fat	% Crude Fiber	Current AAFCO Definition	General Description
Fermented Protein	48+	3-8	<8	27.5	Portions of fiber and oil removed by concentrating residual grain and yeast proteins by methods commonly used in distilling industry. Contains concentrated spent yeast products. Does not contain condensed distillers solubles unless listed.
Fermented Protein Mechanically Separated	48+	1-5	<8	27.5	Post distillation separation of protein from the whole stillage, utilizing only mechanical separation. Will contain spent yeast products, no non-mechanical methods utilized post distillation. Does not contain distillers solubles unless listed.

This table is meant for informational purposes only and does not convey any regulatory or specification requirements. The information listed is not all inclusive and is current as of date displayed in title and will be updated as industry innovation continues. The Distillers Grain Technology Council does not endorse any specific product or brands of feed products.

2/11/2021

EVOLVING COPRODUCTS

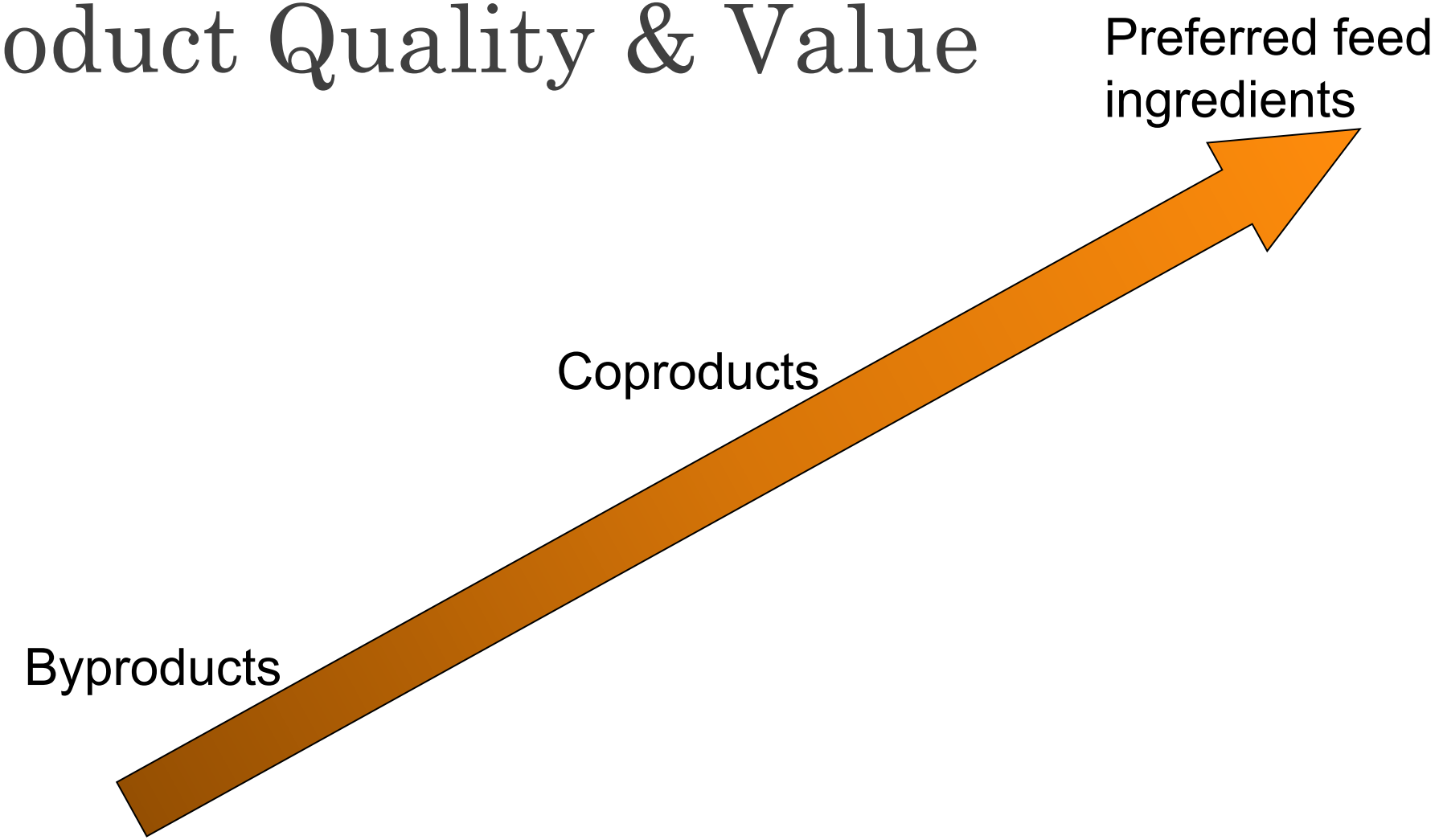
- Using coproducts (wet or dry) to grow other organisms
  - Algae
  - Single-cell proteins
  - Fermentation of DDGS & soybean meal
  - Fungal cells for protein

- Concentrated protein streams
- Concentrated fiber streams

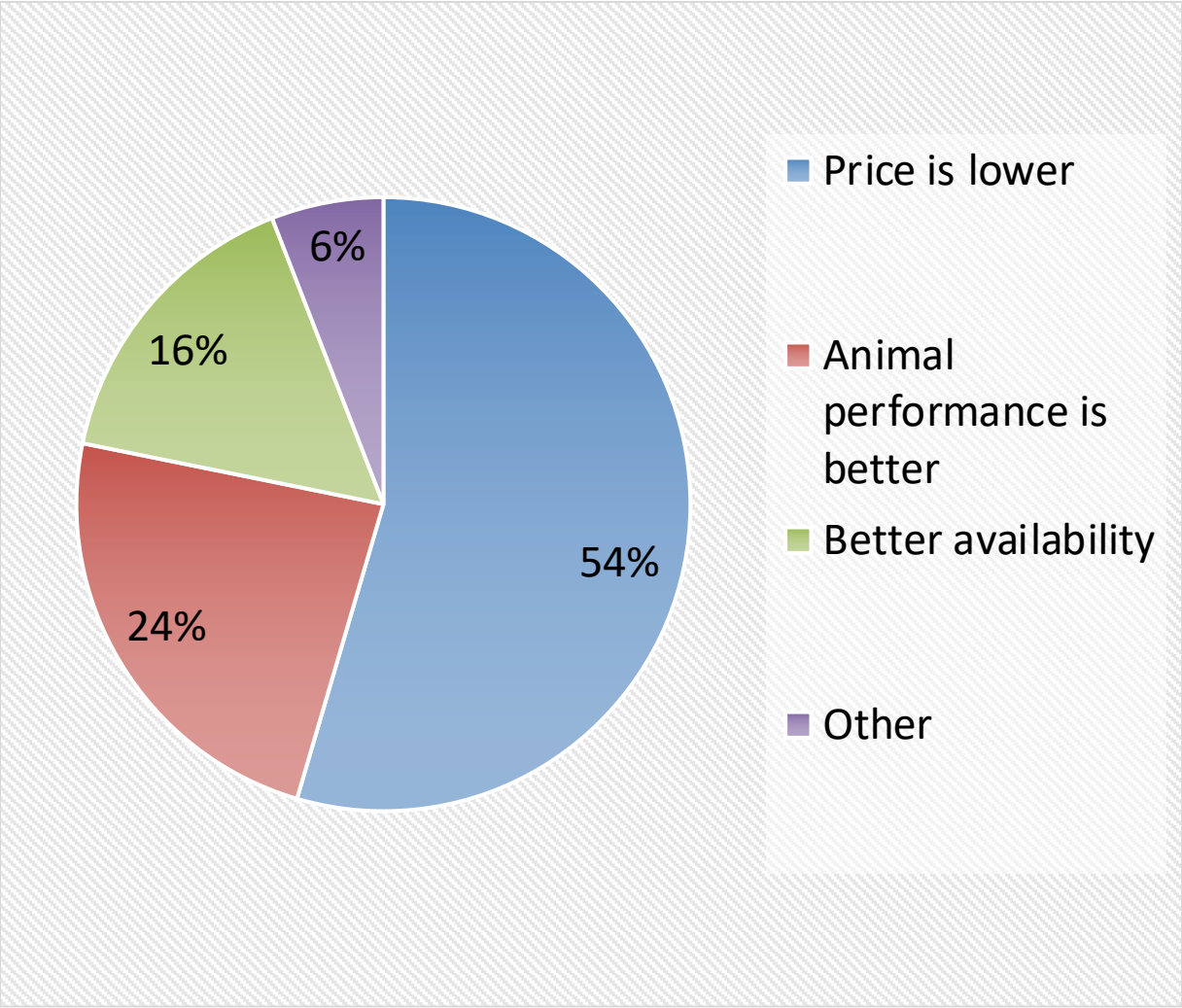
- Not DDGS anymore

- Regulatory issues
  - AAFC/FDA

Final Thoughts: Coproduct Quality & Value



Why do you feed coproducts?



- *54% of those who responded to this question said that the main reason they feed coproducts is price or price related*
- *Response listed as "other" is health benefits*
- *24% said that they feed coproducts due to increased animal performance – this is compatible with the 22% who said that they did in fact see increased animal performance)*

THANK YOU

Questions?

Comments?

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