Group Presentation:
Practical Distillery Sustainability Approaches: Optimizing conversion/fermentation processes in order to reduce environmental impacts of distillery coproducts and wastewater streams.

Practical Conversion & Fermentation Process Optimization

Kevin Brent Smith

Director of Distilling & Brewing

COMPANY DISTILLING™

Improved substrate utilization is the single most impactful sustainability focus

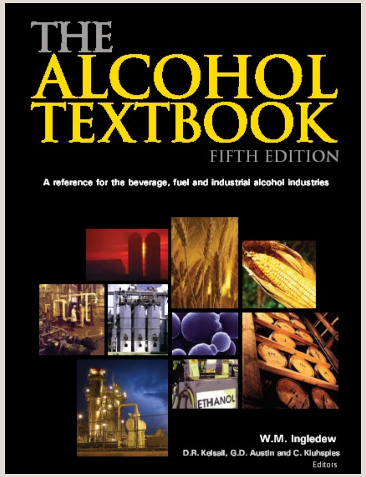

GRAND OPENING
COMPANY
DISTILLING
JULY 2022
TOWNSEND TN
COME GATHER AROUND
COMPANY
DISTILLING
8351

Yield & Residual Sugars

	Proof Gallons/ Bushel	Absolute Gallons/ Bushel	Liters Absolute EtOH/ Metric Ton	EtOH(g)/ Grain(g)	Residual Sugar %	Residual Sugar (lbs) in a 10,000 gallon fermentor assuming 26 BG beer
Maximum Theoretical Yield	6.11	3.06	455.1	0.3592	0.0%	0 lbs
Fuel Ethanol Industry Benchmark Yield	6.00	3.00	446.9	0.3527	1.3%	96 lbs
Distilled Spirits Industry Benchmark @93% Yield Efficiency	5.68	2.84	423.2	0.3341	4.9%	372 lbs
Primary Conversion/Fermentation Only	4.80	2.40	357.5	0.2822	15.1%	1,140 lbs
Distilled Spirits Industry Basement Yield Performance	4.20	2.10	312.8	0.2469	22.0%	1,662 lbs

Assumptions:
Corn: 74% starch
14% Moisture

Residual sugars subjected to the heat of distillation are often the single largest source of spirit defects and inconsistency!



Starch to Ethanol

		Purchased industrial enzymes		**Yeast** (12 internal yeast enzymes)		
$(C_6H_{10}O_5)n$ +	$(n\text{-}1)H_2O$	$\rightarrow$	$n\ C_6H_{12}O_6$	$\rightarrow$	$2n\ CH_3CH_2OH$ +	$2n\ CO_2$
Starch	*Water*		*Glucose*		*Ethanol*	*Carbon dioxide*

Taking glucose to be represented as 100 parts by weight, the equivalent weights of the reactants would then be

90	10	100	51.1	48.9

The theoretical maximum yield of ethanol from 100 parts of substrate is therefore 56.7 from starch and 51.1 from glucose.

Maximum Theoretical Yield - Stoichiometric

Maximum Theoretical Yield

	Bushel wt	Grain Moisture Content												
	56.0 lbs/bu	18.0	17.5	17.0	16.5	16.0	15.5	15.0	14.5	14.0	13.5	13.0	12.5	12.0
Grain D.M. Starch Content	65.0	5.12	5.15	5.18	5.21	5.25	5.28	5.31	5.34	5.37	5.40	5.43	5.46	5.49
	66.0	5.20	5.23	5.26	5.29	5.33	5.36	5.39	5.42	5.45	5.48	5.52	5.55	5.58
	67.0	5.28	5.31	5.34	5.37	5.41	5.44	5.47	5.50	5.54	5.57	5.60	5.63	5.66
	68.0	5.36	5.39	5.42	5.45	5.49	5.52	5.55	5.59	5.62	5.65	5.68	5.72	5.75
	69.0	5.44	5.47	5.50	5.53	5.57	5.60	5.63	5.67	5.70	5.73	5.77	5.80	5.83
	70.0	5.51	5.55	5.58	5.62	5.65	5.68	5.72	5.75	5.78	5.82	5.85	5.88	5.92
	71.0	5.59	5.63	5.66	5.70	5.73	5.76	5.80	5.83	5.87	5.90	5.93	5.97	6.00
	72.0	5.67	5.71	5.74	5.78	5.81	5.84	5.88	5.91	5.95	5.98	6.02	6.05	6.09
	73.0	5.75	5.79	5.82	5.86	5.89	5.93	5.96	6.00	6.03	6.07	6.10	6.14	6.17
	74.0	5.83	5.86	5.90	5.94	5.97	6.01	6.04	6.08	6.11	6.15	6.18	6.22	6.26
	75.0	5.91	5.94	5.98	6.02	6.05	6.09	6.12	6.16	6.20	6.23	6.27	6.30	6.34

Practical Yield @ 93% Efficiency

Potential Yield at 93% Yield Efficiency

Grain D.M. Starch Content	Bushel wt 56.0 lbs/bu	Grain Moisture Content 18.0	17.5	17.0	16.5	16.0	15.5	15.0	14.5	14.0	13.5	13.0	12.5	12.0
	65.0	4.76	4.79	4.82	4.85	4.88	4.91	4.94	4.97	4.99	5.02	5.05	5.08	5.11
	66.0	4.84	4.86	4.89	4.92	4.95	4.98	5.01	5.04	5.07	5.10	5.13	5.16	5.19
	67.0	4.91	4.94	4.97	5.00	5.03	5.06	5.09	5.12	5.15	5.18	5.21	5.24	5.27
	68.0	4.98	5.01	5.04	5.07	5.10	5.13	5.16	5.19	5.22	5.26	5.29	5.32	5.35
	69.0	5.05	5.09	5.12	5.15	5.18	5.21	5.24	5.27	5.30	5.33	5.36	5.39	5.42
	70.0	5.13	5.16	5.19	5.22	5.25	5.28	5.32	5.35	5.38	5.41	5.44	5.47	5.50
	71.0	5.20	5.23	5.26	5.30	5.33	5.36	5.39	5.42	5.46	5.49	5.52	5.55	5.58
	72.0	5.27	5.31	5.34	5.37	5.40	5.44	5.47	5.50	5.53	5.56	5.60	5.63	5.66
	73.0	5.35	5.38	5.41	5.45	5.48	5.51	5.54	5.58	5.61	5.64	5.67	5.71	5.74
	74.0	5.42	5.45	5.49	5.52	5.55	5.59	5.62	5.65	5.69	5.72	5.75	5.78	5.82
	75.0	5.49	5.53	5.56	5.59	5.63	5.66	5.70	5.73	5.76	5.80	5.83	5.86	5.90

Distillery Yield Metrics

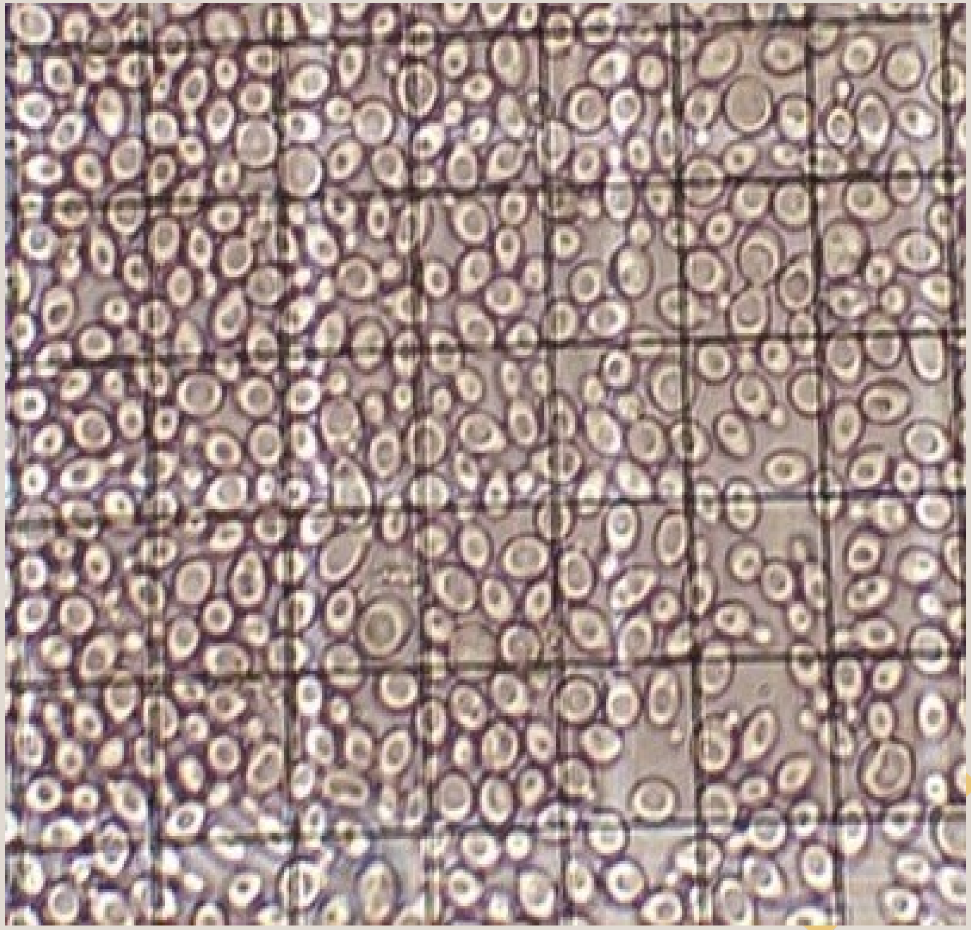
- **Theoretical Yield:** stoichiometric yield, the absolute yield potential
- **Practical Yield:** Actual distillery yield using standard metrics
- **Yield Efficiency:** Practical yield/Theoretical yield (conventional 93%)
- **Per Fermentor Yield:** Discrete metric of unit fermentor performance
- **Daily Production Yield:** Broader yield metric. Average over daily production.
- **Mass Balance Yield:** Monthly metric - Ethanol sold per Bushels of grain purchased

Trend/Compare Yield Metrics to troubleshoot validate metrics

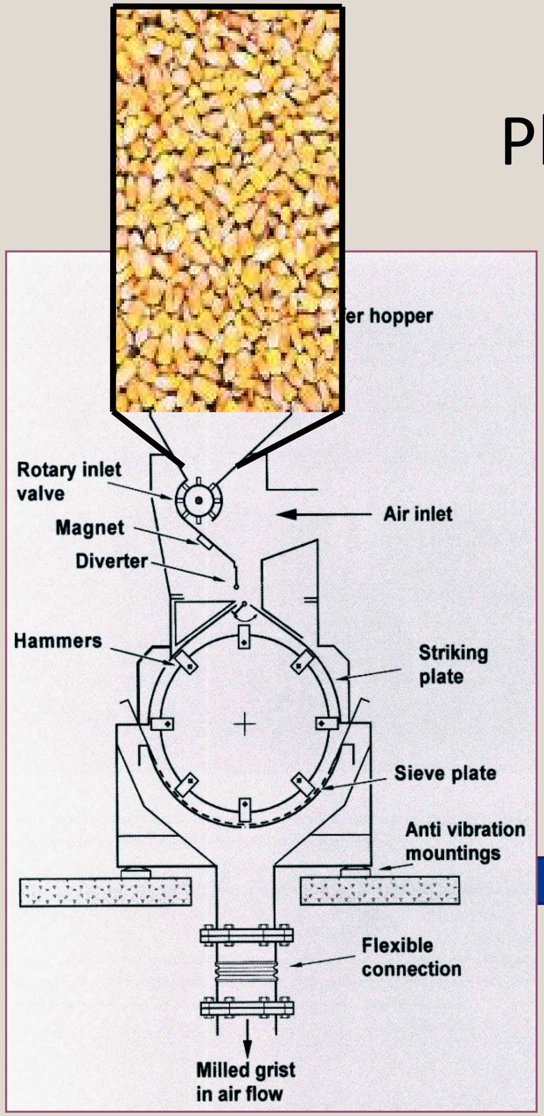
Factors Affecting Distillery Yield

- Grain quality
- Fermentation Time
- Grist Size
- Advanced Technologies (Process/equipment, enzymes, yeast
- Optimized Fermentation Kinetics

Yeast Quality and Conditioning



Yield Factors – Accessing Starch



Physically accessing Corn Starch

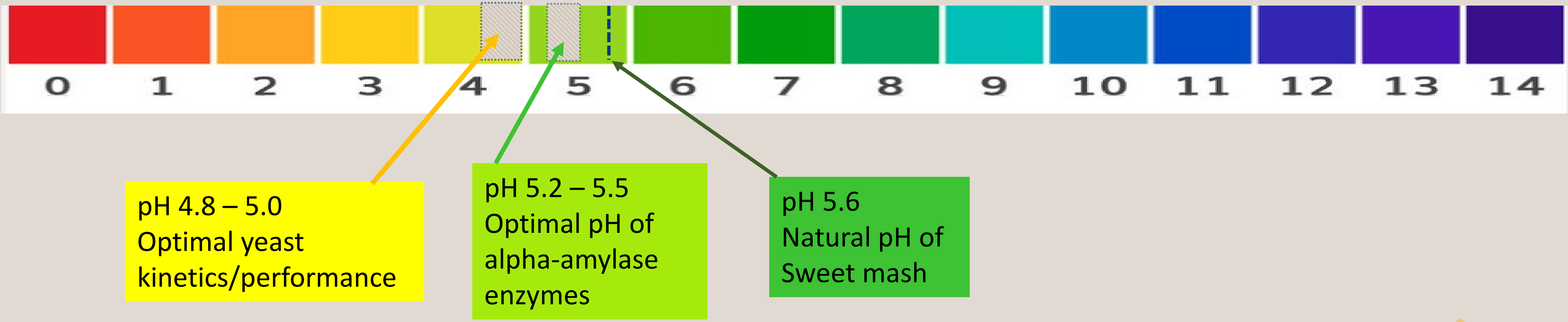
- Grinding technology
  - fine grind vs. course grind
- Mashing technology
  - temperature, pressure, shear

Corn Quality & Grade

- Moisture content
- Starch content
- Foreign matter
- Drying temperatures
- Storage conditions

Defining the Term “Souring”

- Acidification of the mashing or fermentation environment
- Lowering pH to maximize enzymatic kinetics and yeast performance



What is Sweet Mash? A sub-optimized process lacking proper pH balance

…. often demonstrates lower pH, lower yield, and poor sensory character distillate versus sour mash

Typical Means of Souring

- Backset – return of spent (thin) stillage to mashing or fermentation environment
- Backstock – recycling of yeast or lactic inoculum from one fermentation to the next mash, yeast mash, or fermentor
- Acidification via the lactic sour mash process
- Acidification via addition of acids (lactic acid, etc.)

Historical Timeline on Fermentation Microbiology

Timeline

c. 7000 BC — Archeological evidence of fermentation - China

c. 4000 BC — Chemical evidence of fermentation - Mesopotamia

c. 1673 — Leeuwenhoek's microscope - Father of Microbiology

c. 1857 — Pasteur proves fermentation caused by microbes

Only 170 Years!

Modern Fermentation Sciences Era

Modern Pressure Driving Process Change:

- Biotech (enzymes, grain, yeast)
- advanced Industrial capabilities & automation
- sustainability initiatives
- increased cost cutting pressures
- high gravity fermentation

Historical Timeline on Fermentation Microbiology

Evolution & Iterations of Sour Mashing over Fermentation Timeline:

Natural spontaneous fermentation – Sweet Mash

Backstocking – Fermentor to fermentor

- Recycled Ferments
- primarily as inoculum
- Recycle microbial consortium to initiate fermentation
- Recycled organic acids lower pH of fermentation vessel affects pH balance

Backset – Stillage to Fermentor or Mash Cooker

- Recycled stillage (eventually thin stillage)
- Primarily for pH balance, nutrient enhancement, and freshwater make-up reduction

Spirit Category Constraints

Bourbon

- Product of the U.S.
- Mash with 51%+ corn
- Aged in newly charred, American white oak barrels
- Distilled at < 160° Proof
- Barreled at < 125° Proof
- Bottled at > 80° Proof
- Twice Distilled
- No coloring can be added.
- Age: typically 4+ years

Spirit Category Definitions Do Not Require Sour Mashing

Tennessee Whiskey

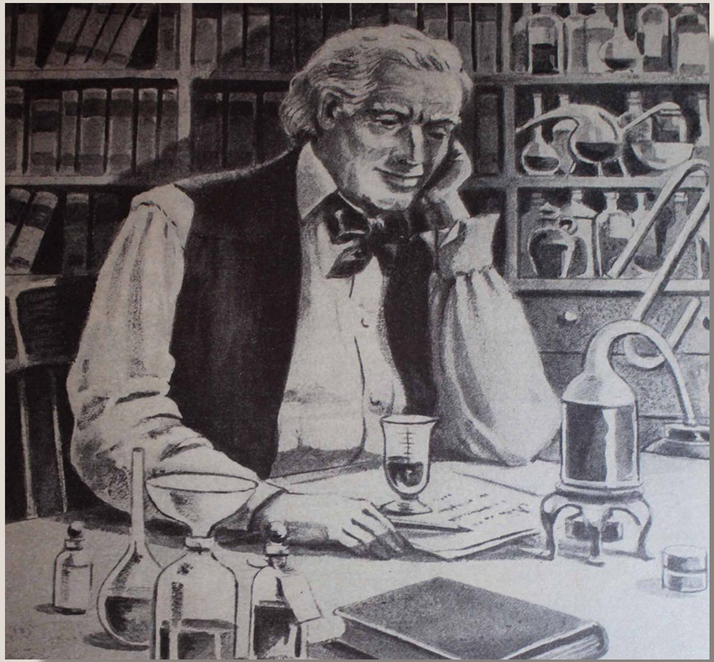
- Charcoal Mellowed
- Produced/Mature in TN

The Sour Mash Whiskey Process – Part I

- Souring Part I – The use of **Backset** in mash
- Backset: Thin stillage from still bottoms is 10% - 30% of mash volume
- Backset advantages:
    - pH Balance:
        - adjusts fresh mash pH
        - buffers pH in beer throughout fermentation
    - Yeast Nutrient recycled
    - Reclaimed heat and water
    - Improved lubricity and wetting of grain meal

Backset History

- Sour mash backset process 1st used in early 1800s
- Dr. James Crow – scientific approach to whiskey making
  - Use of pH to monitor and control fermentation
  - Use of backset (earliest use of backset was added directly to fermentor rather than to cooker)



Dr. James Crow

Backset Process

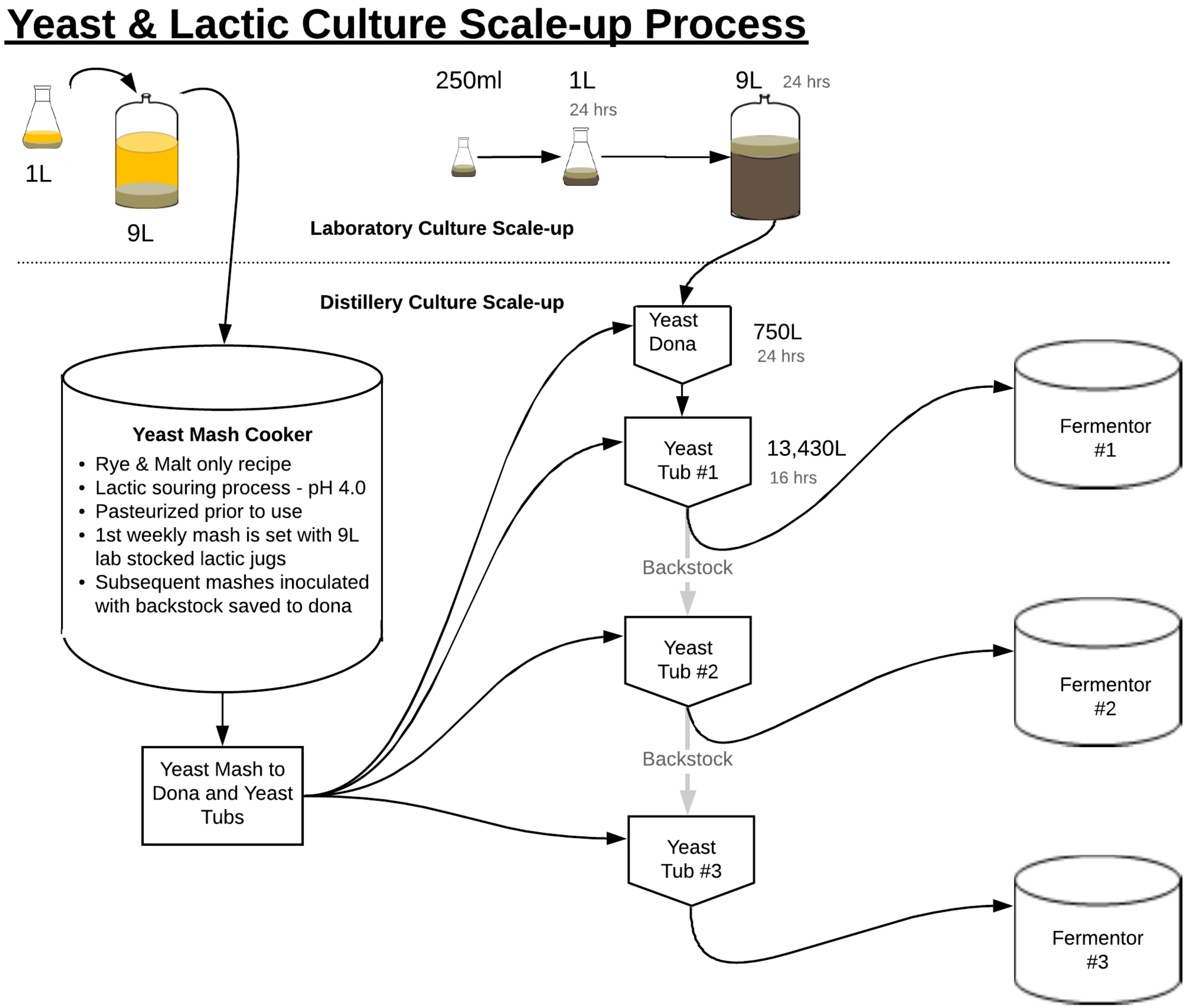
- Typically, 10-30 % backset rate
- Gravity screens widely used instead of centrifugation
- Viscosity challenges

	TS	TDS	TSS
Whole Stillage	11.3%	3.7%	7.6%
Thin Stillage	5.6%	2.5%	2.1

The Sour Mash Whiskey Process – Part II

- Souring Part II – Lactic Soured Yeast Mash
- *Lactobacillus delbrueckii* culture – part of the sour mash whiskey tradition
- Lactic souring advantages:
  - pH balance in mashing and fermentation
  - Abatement of contaminants bacteria within the yeasting system processes
  - Added sensory character – controlled sensory influence of lactic bacteria versus late souring effect in fermentor

Flow Chart of Distillery Yeast Process



Sour Mash Process -Lactic Souring

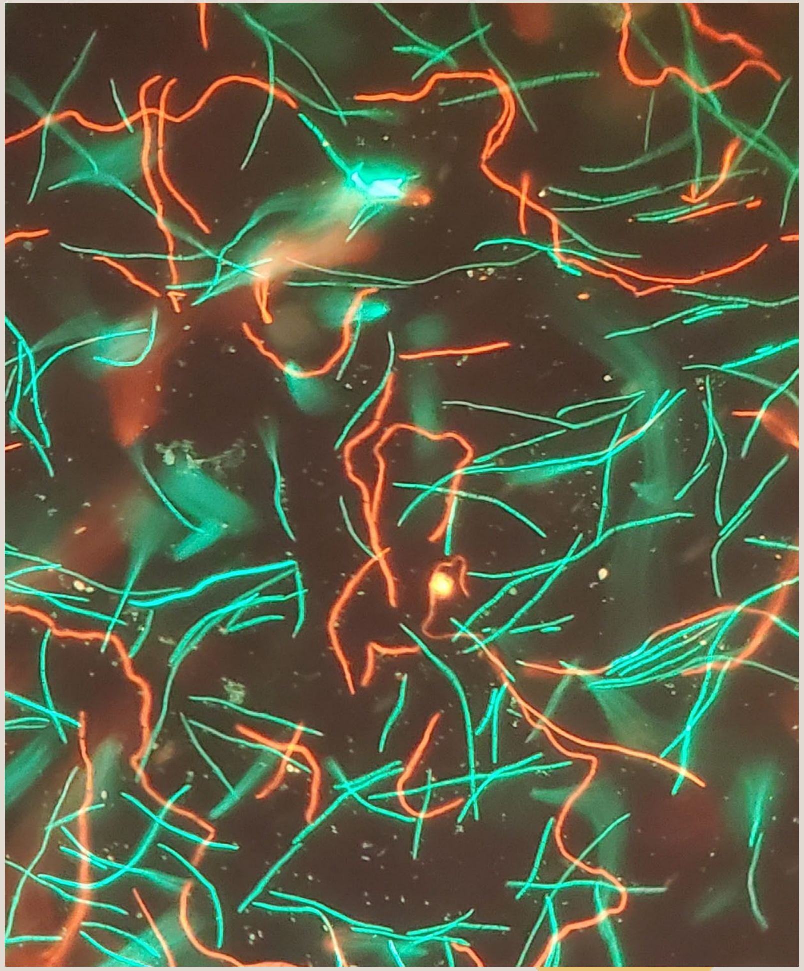
Use of Lactic bacteria to sour yeast mash

- Produce lactic acid lowering pH of yeast mash

Example:

In a 1,000L vessel

- Inoculated with 100ml
- > 10Kg of lactic acid (1%wt/vol LA)

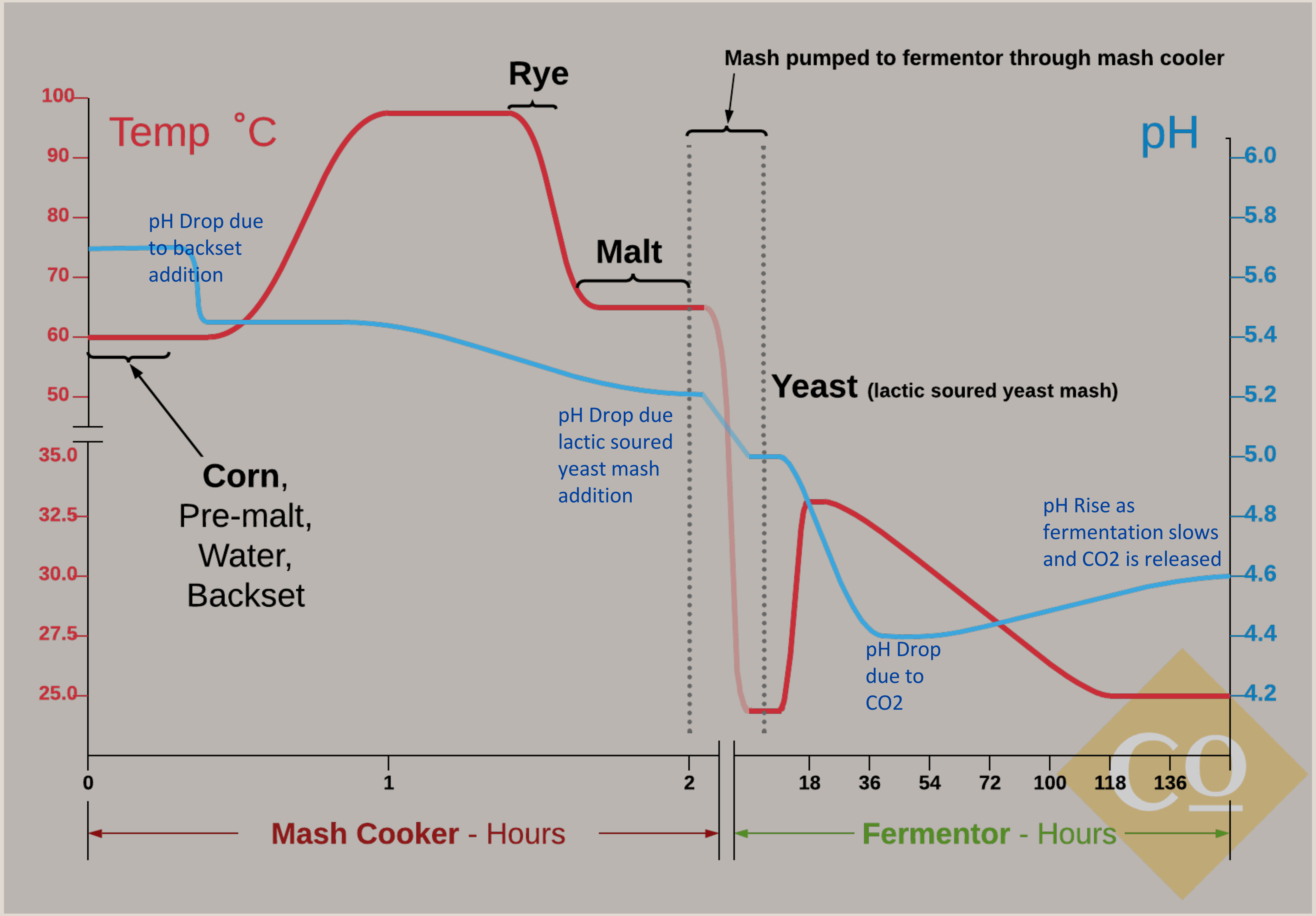


Smith & Preston, 2019

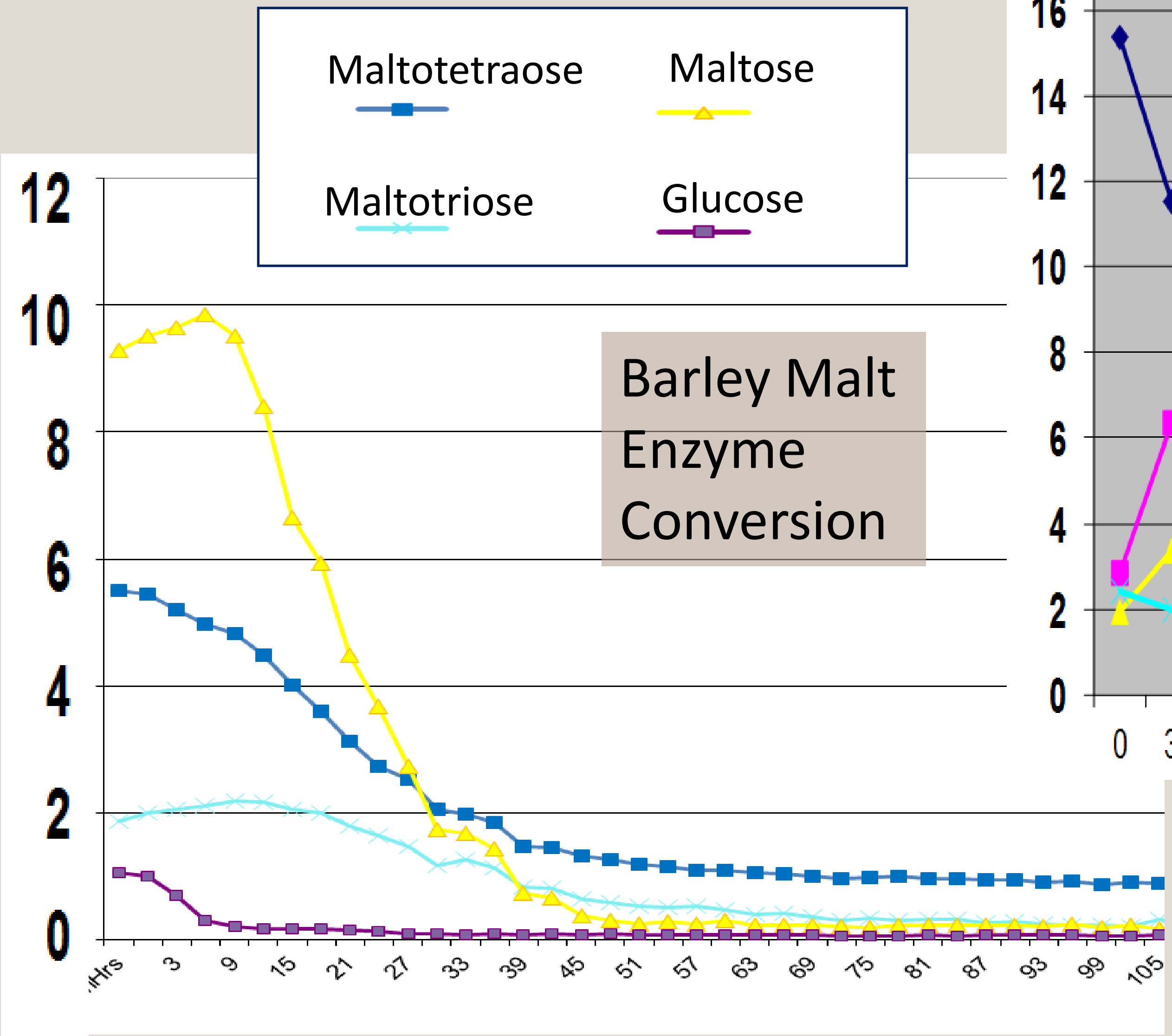
pH/Temp Profiles throughout Mashing & Fermentation

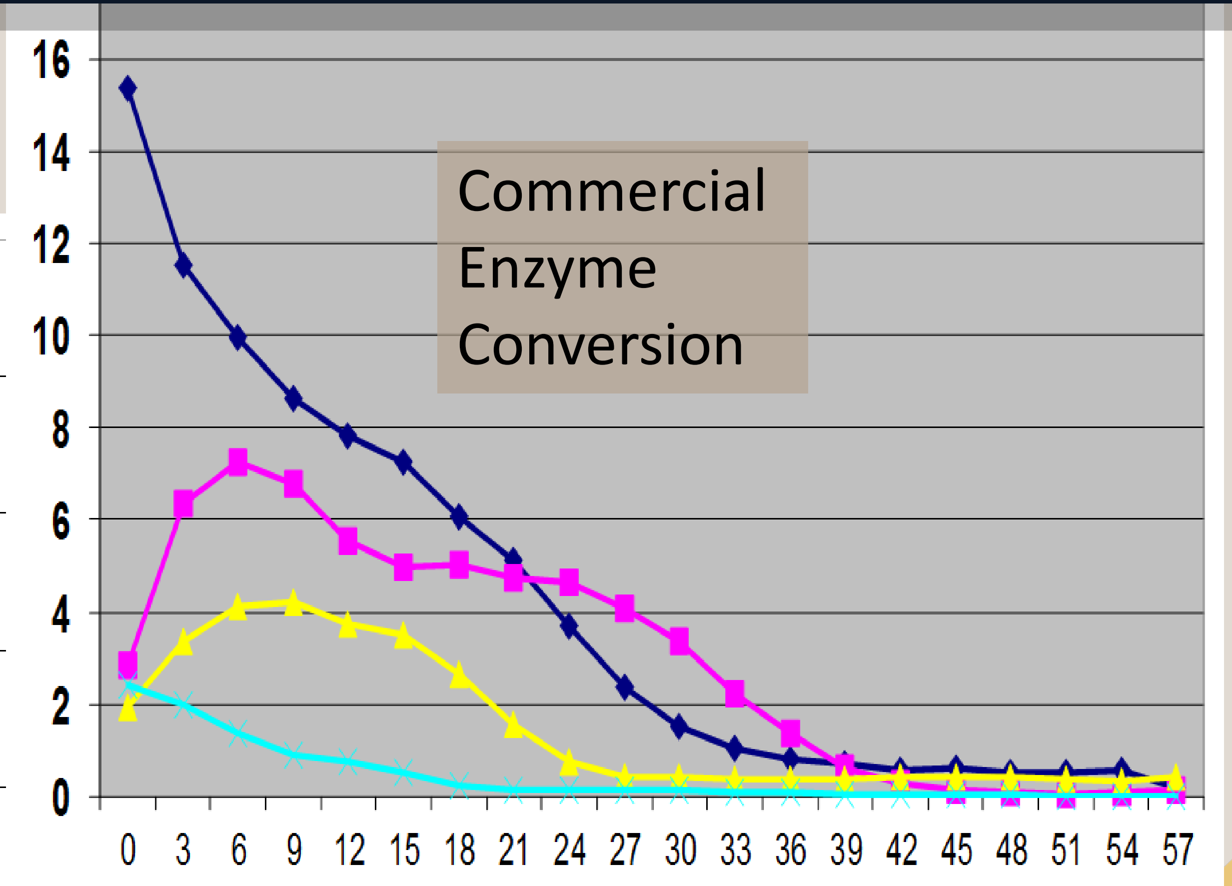
Grain-in Mashing Considerations

- Distiller's malt (10-12% inclusion) provides conversion power for balance of cereal grains
- Primary conversion in mash cooker
- Secondary conversion throughout fermentation as starch solubilizes over 4 to 6 days
- **pH balance is the key to successful secondary conversion and new whiskey consistency/quality**



Fermentation Sugar Profiles by HPLC of Malted Barley vs. Commercial Enzymes





Dextrins/Sugars Report as
Wt./Vol. % per Time of Fermentation

Yield & Residual Sugars

	Proof Gallons/ Bushel	Absolute Gallons/ Bushel	Liters Absolute EtOH/ Metric Ton	EtOH(g)/ Grain(g)	Residual Sugar %	Residual Sugar (lbs) in a 10,000 gallon fermentor assuming 26 BG beer
Maximum Theoretical Yield	6.11	3.06	455.1	0.3592	0.0%	0 lbs
Fuel Ethanol Industry Benchmark Yield	6.00	3.00	446.9	0.3527	1.3%	96 lbs
Distilled Spirits Industry Benchmark @93% Yield Efficiency	5.68	2.84	423.2	0.3341	4.9%	372 lbs
Primary Conversion/Fermentation Only	4.80	2.40	357.5	0.2822	15.1%	1,140 lbs
Distilled Spirits Industry Basement Yield Performance	4.20	2.10	312.8	0.2469	22.0%	1,662 lbs

Assumptions:

Corn: 74% starch
14% Moisture

Residual sugars subjected to the heat of distillation are often the single largest source of spirit defects and inconsistency!

In Summary

- pH balance is the key to optimizing distillery conversion/fermentation processes
- Result is high yield and consistent sensory character
- Optimized yield = Low residual starch/sugars
- Low residuals = improved distiller's feed products quality/consistency

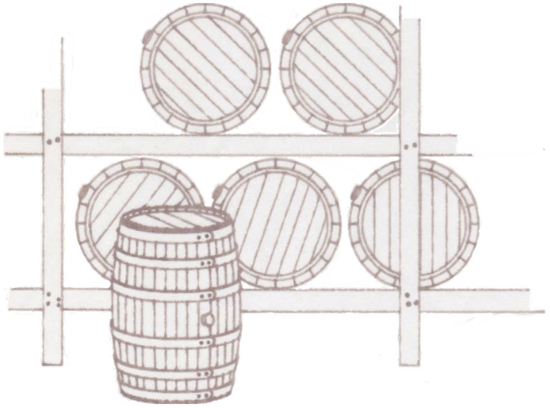
Thank You!

Contact Information:

Kevin Brent Smith

KSmith@CompanyDistilling.com

Phone: 931.307.8582



GATHER

CO

AROUND™