Research Initiatives & Issues Associated with Distillers Co-Products

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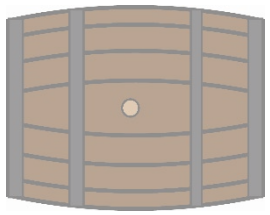
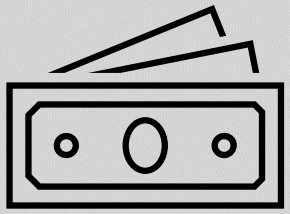
Bourbon is big in Kentucky

In 2026...

120+ distilleries
24,000 jobs



3 million barrels filled
17 million barrels in storage = 3.7/person



$372 million state & local tax
$2 billion Federal tax

The official state drink of Kentucky is… **Milk**

Leading the global advancement of the American whiskey industry through workforce education, scientific discovery, environmental sustainability, community and social responsibility.

SUNTORY
GLOBAL SPIRITS

Pigman College of Engineering

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Martin-Gatton College of Agriculture, Food and Environment

Gatton College of Business and Economics

College of Arts and Sciences

CAMPARI GROUP

CASTLE & KEY DISTILLERY

HEAVEN HILL BRANDS

BUFFALO TRACE DISTILLERY

WILD TURKEY

KENTUCKY DISTILLERS' ASSOCIATION KDA EST 1880

BARDSTOWN BOURBON COMPANY

FOUR ROSES

WOODFORD RESERVE

SUNTORY GLOBAL SPIRITS

Oregon State University OSU

Pigman College of Engineering

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Martin-Gatton College of Agriculture, Food and Environment

LSU LOUISIANA STATE UNIVERSITY

HARTWICK COLLEGE

IOWA STATE UNIVERSITY

UNIVERSITY OF LOUISVILLE

Gatton College of Business and Economics

College of Arts and Sciences

THE Scotch Whisky RESEARCH INSTITUTE

MIAMI UNIVERSITY

CENTRE COLLEGE

Undergraduate Certificate in Distillation, Wine and Brewing Studies (DWBS)

2 Required Courses

- Distillation, Wine and Brewing Science
- Spirit Chemistry

Pick any 2 Electives from the Following Courses

Brewing
1) Brewing Science & Technology*

Distilling
2) Bourbon Production Engineering
3) Distilled Spirits Production: Gin*

Food Systems
4) Food Fermentation
5) Sensory Evaluation of Foods

Wine
6) Introduction to Viticulture
7) Introduction of Enology*
8) Wine Appreciation*

General Topics
4) DWBS Independent Research
5) DWBS Experiential Learning
6) Craft Writing
7) Beer, Wine and Spirits Tourism*

*Must be 21 by first day of class

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INDEPENDENT STAVE COMPANY
BOSWELL FAMILY
BARREL WAREHOUSE

Distillery Scale Operations

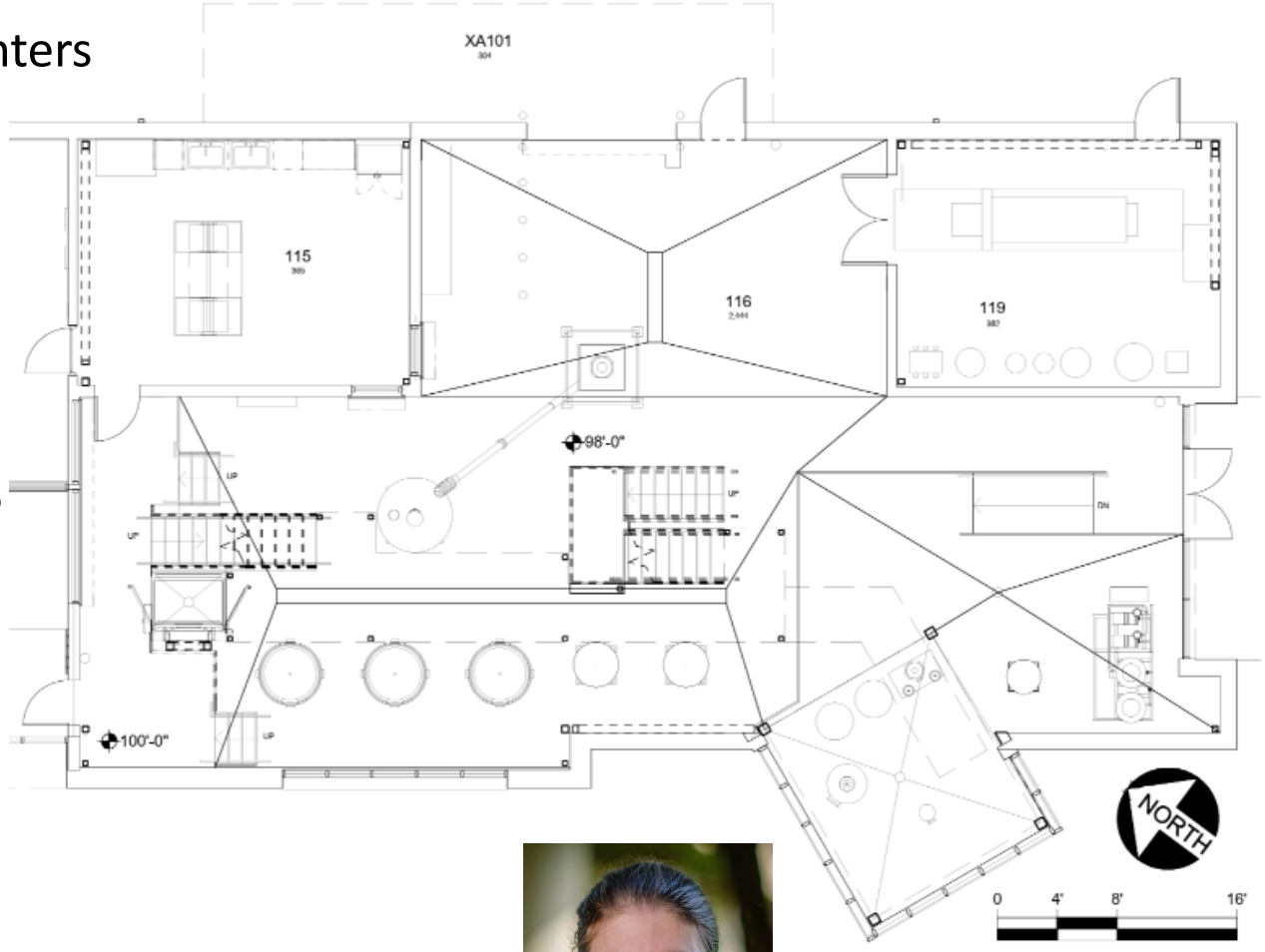
- 450 gallon cooker and temperature controlled fermenters
- 12 inch / 30 cm distillation column with doubler
- On site maturation for 660 Barrels

Featured Studies:

- Raw materials trials (yeast, grains, water, oak)
- Automated spirit proofing skid in 2021
- Tested hydrogen blend fuel on boiler in summer 2025
- Discussions on MVR and TVR trials
- **Stillage Processing**

Raw materials donations:

- Brooks grain – corn, rye, wheat and milling
- Malteurop – malt
- ISC - Barrels
- Lallemand, Fermentis, AB Biotek – Yeast



Bourbon Innovation

BOURBON PRODUCTION

Modern Bourbon Grain Bill:

- 70-80% yellow dent corn
- 10-20% rye / wheat
- 5-20% malt

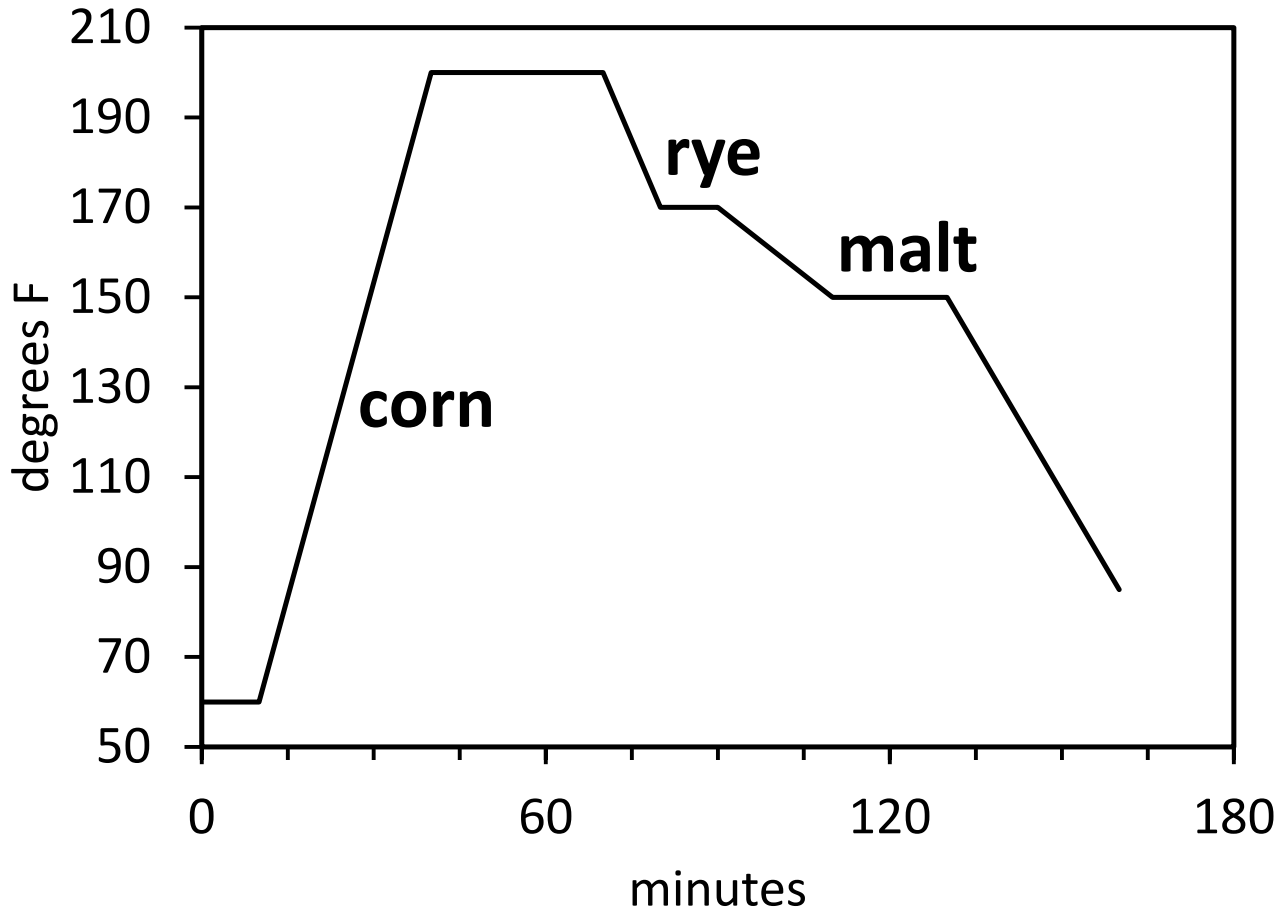
No bourbon without grains

Traditional Bourbon Cooking

- Standard sequence of times and temperatures
- Grain gel temps vary

Fox, G. P. (2025). *Variation in barley quality and its impact on malting and brewing*

Cereal type	Onset temperature (°C)	Peak temperature (°C)	Offset temperature (°C)
Barley	55-60	60-65	62-70
Wheat	54-60	58-64	60-66
Rye	54-60	58-64	60-66
Rice	68-74	72-78	78-86
Corn	68-64	72-80	77-86



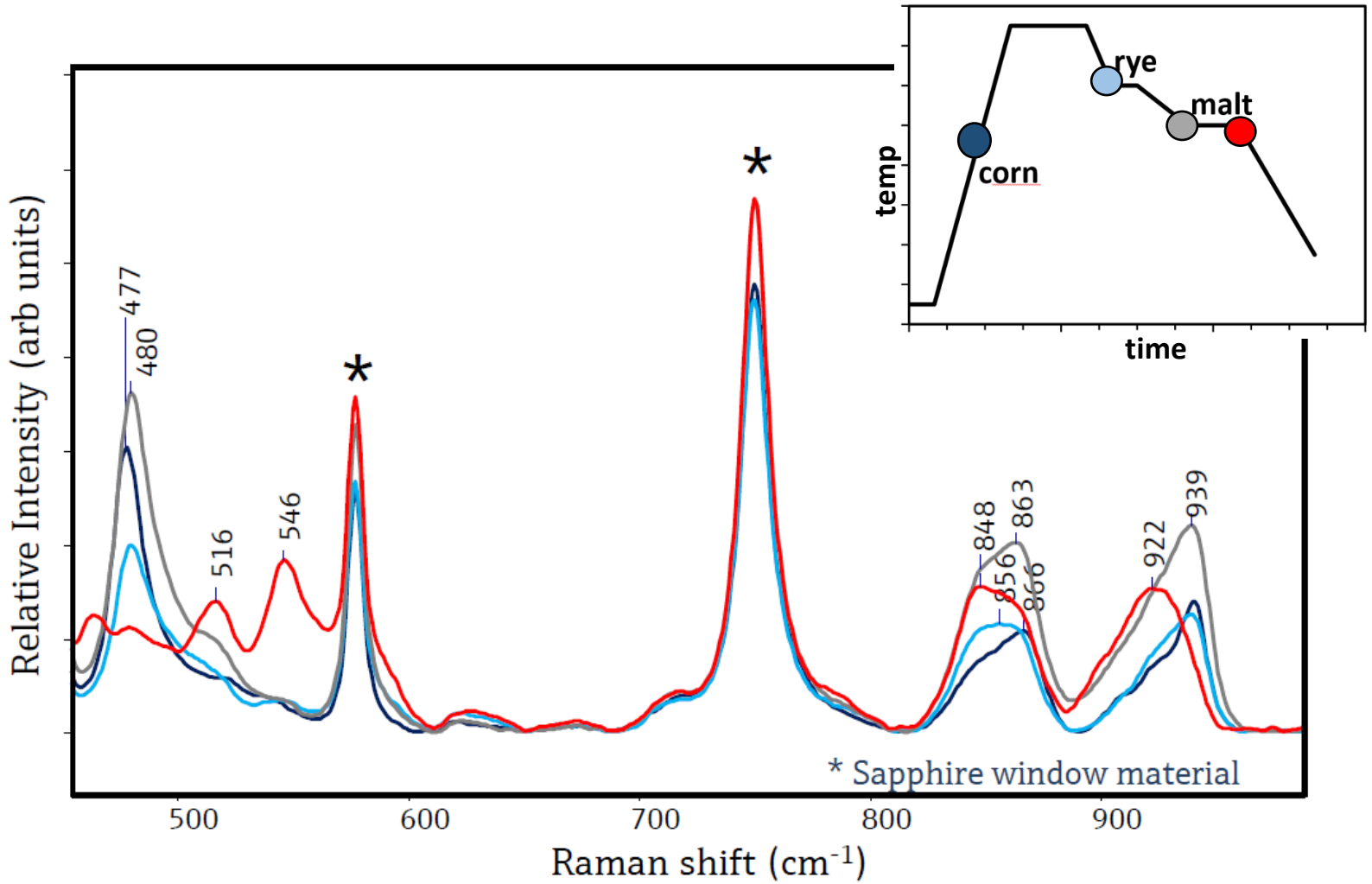
People for Process Automation

Real-time cook analysis

Raman Spectroscopy:

- Gelatinization of grains
- Conversion of starch into sugar

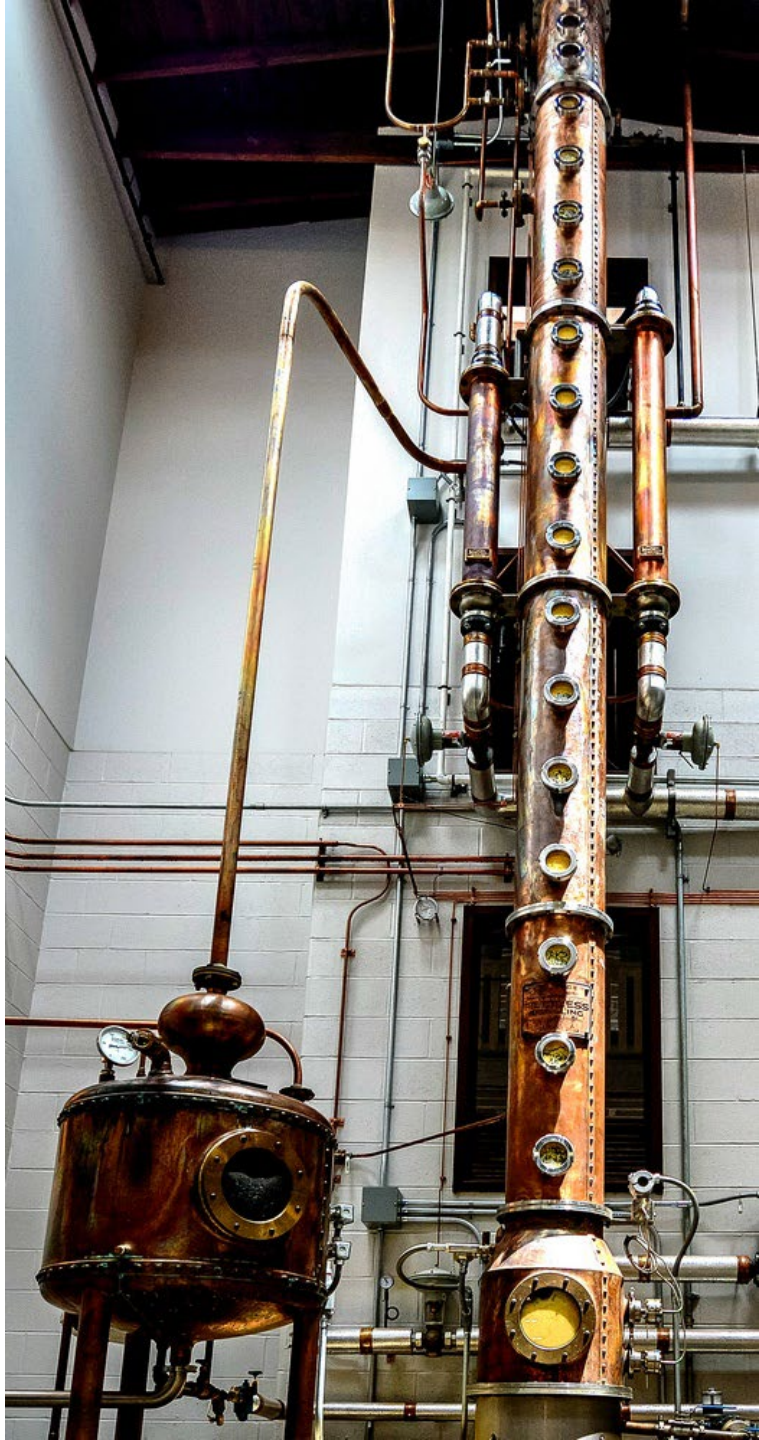
- Real time quality
- Shorten cycle time



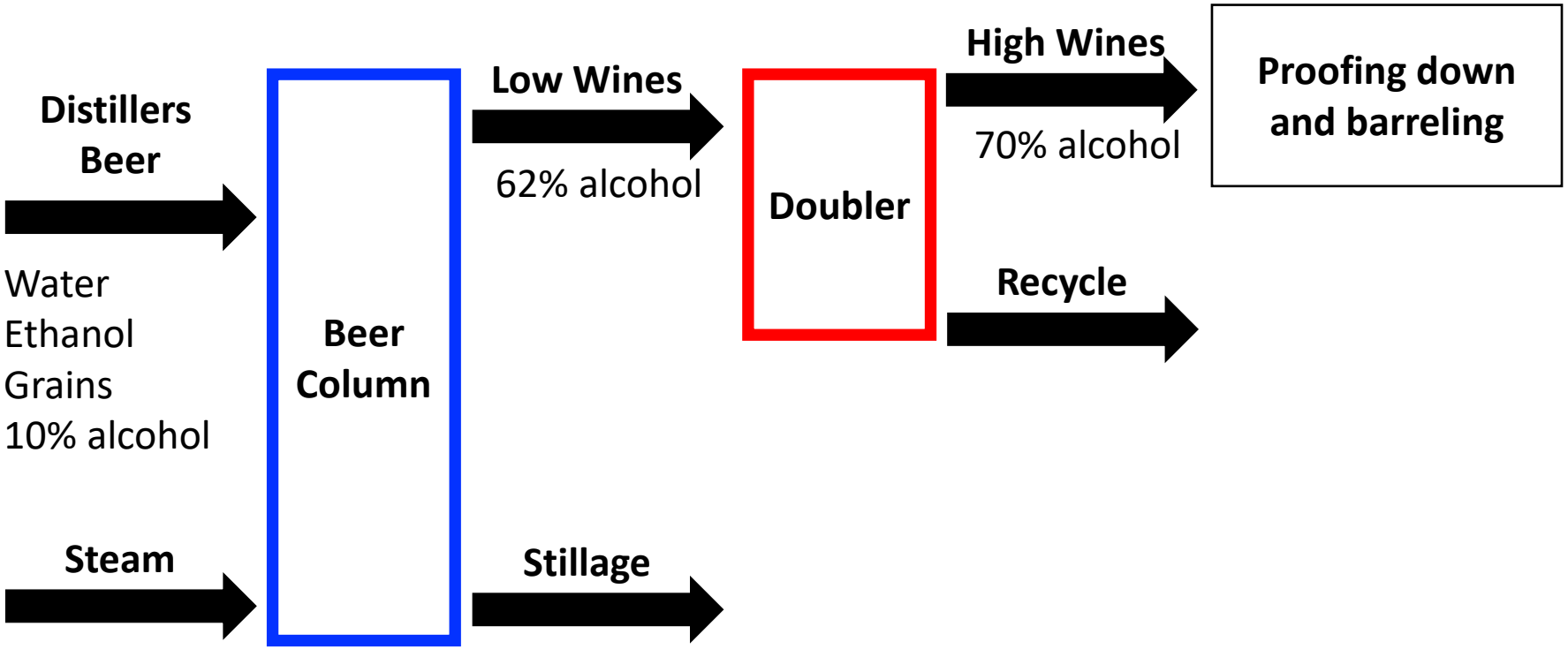
Endress+Hauser
People for Process Automation

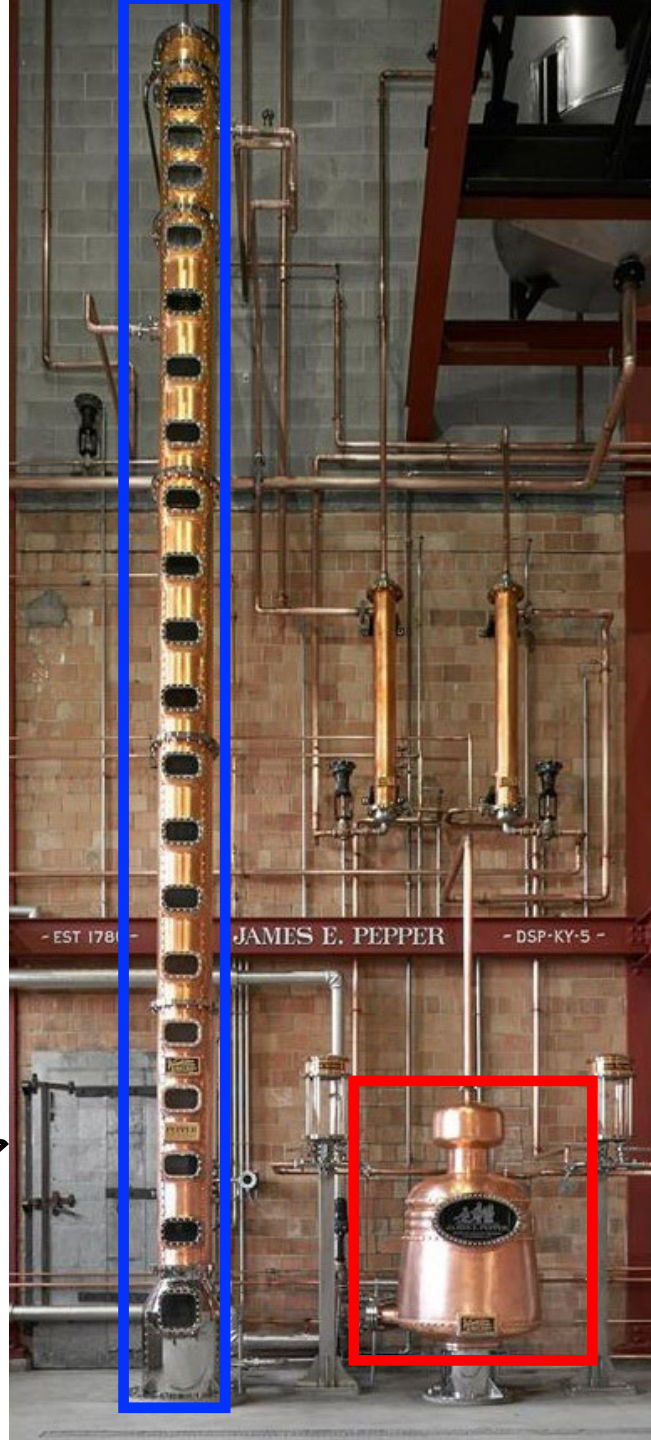
Distillation

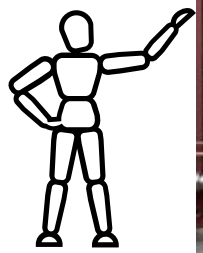
- Stills are used to enrich a 10% beer to ~62% alcohol
- >95% of bourbon made on a column still
- Copper is flavor-reactive
  - Oxidizes meaty sulfur compounds
- Distilled “on-grain”



Distillation – Column Still Operation

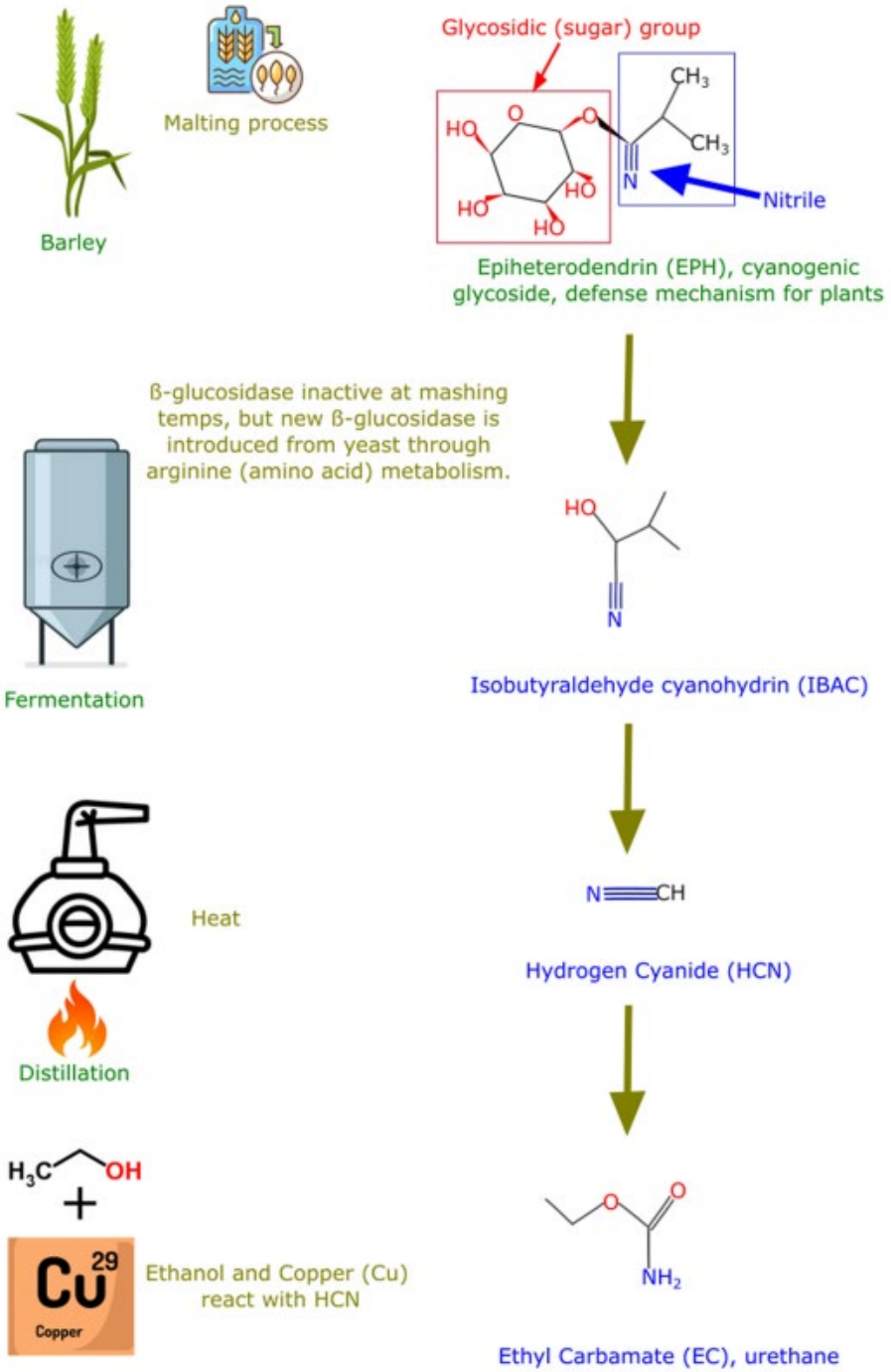






James E. Pepper Distillery, Lexington, KY

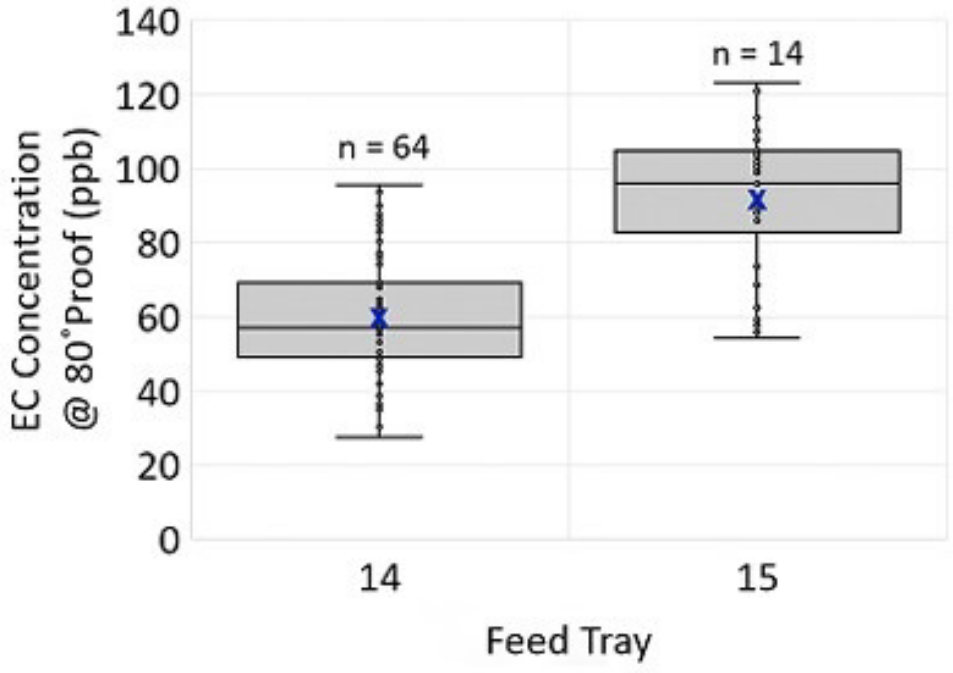
Ethyl Carbamate

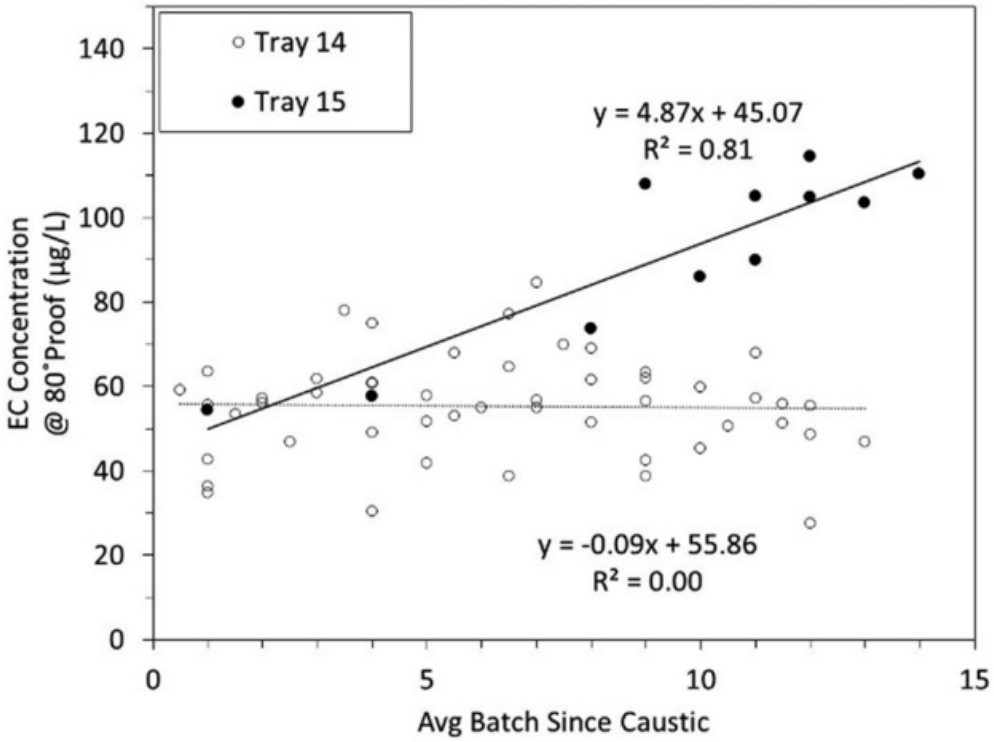


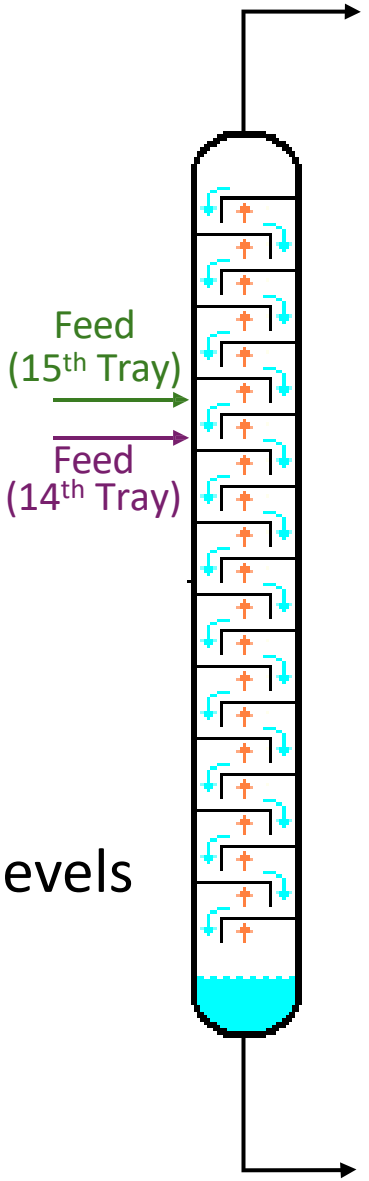
- EC identified as Class 2A carcinogen, leading to regulatic
  - Canada: limit of 150 ppb
  - US: voluntary limit of 125 ppb
- Glycosidic nitrile (GN) main pathway for EC formation
  - Particularly relevant in spirits production-use of copper stills and high temperatures
- HCN: high relative volatility leads to presence in distillat product and EC levels can continue to rise during maturation
- EC: low relative volatility allows elimination in bottoms products = **<u>STILLAGE COPRODUCTS</u>**

Berron et al. (2025). *Journal of the American Society of Brewing Chemists.*

Impact of Still Operations on EC Levels







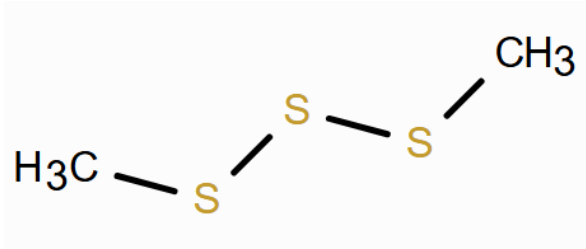
- Beer fed into higher tray in the column leads to significantly higher cistern EC levels
- Higher feed tray—reduced copper interaction
- Effect of beer feed stage more pronounced with increased time since caustic cleaning—further supports need for interaction with clean copper

Berron et al. (2025). *Journal of the American Society of Brewing Chemists.*

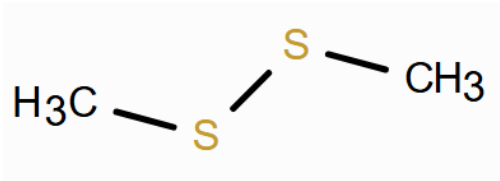
Sulfur Conversion

- Many sulfur compounds have undesired flavors
- Reaction with copper produces nonvolatile or insoluble complexes

$$H_2S + Cu^{2+} \rightarrow CuS + 2H^+$$



dimethyl trisulfide (DMTS)
rotten vegetables, meat



dimethyl disulfide (DMDS)
garlic, sewer gas

H_2S

hydrogen sulfide
rotten eggs

Diversity of Spent Grains Needs

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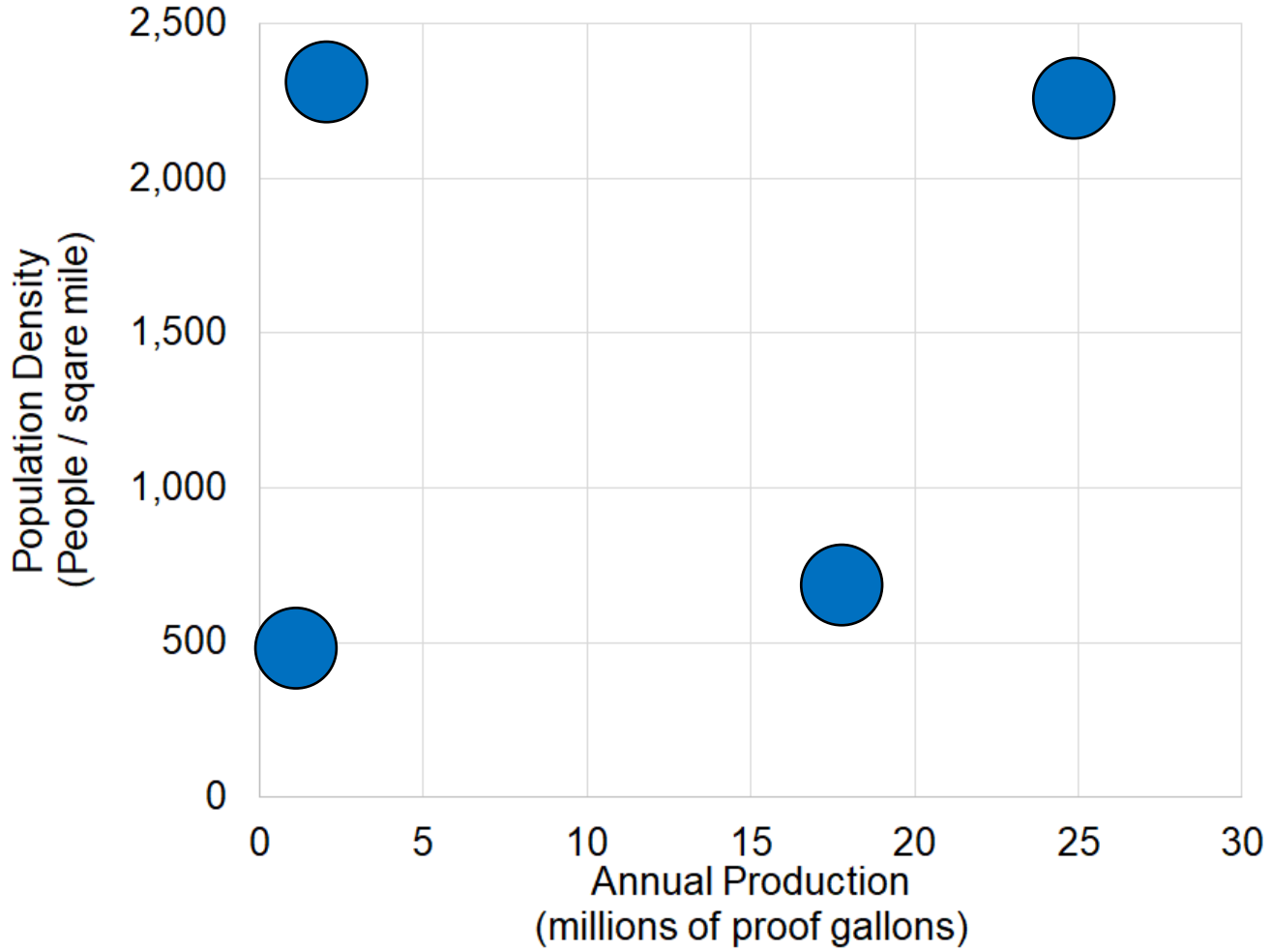
Small Distillery Needs

- Urban challenges of transportation and footprint
- Rural challenges of sewer capacity
- Too small for many large scale solutions
- Co-ops are a possible path to scale
- Dewatering alleviates some transportation challenges

Large Distillery Needs

- Volume exceeds local outlets
- Urban challenges of transportation and footprint
- Rural challenges of sewer capacity



Need a portfolio of solutions to address the needs of the KDA membership

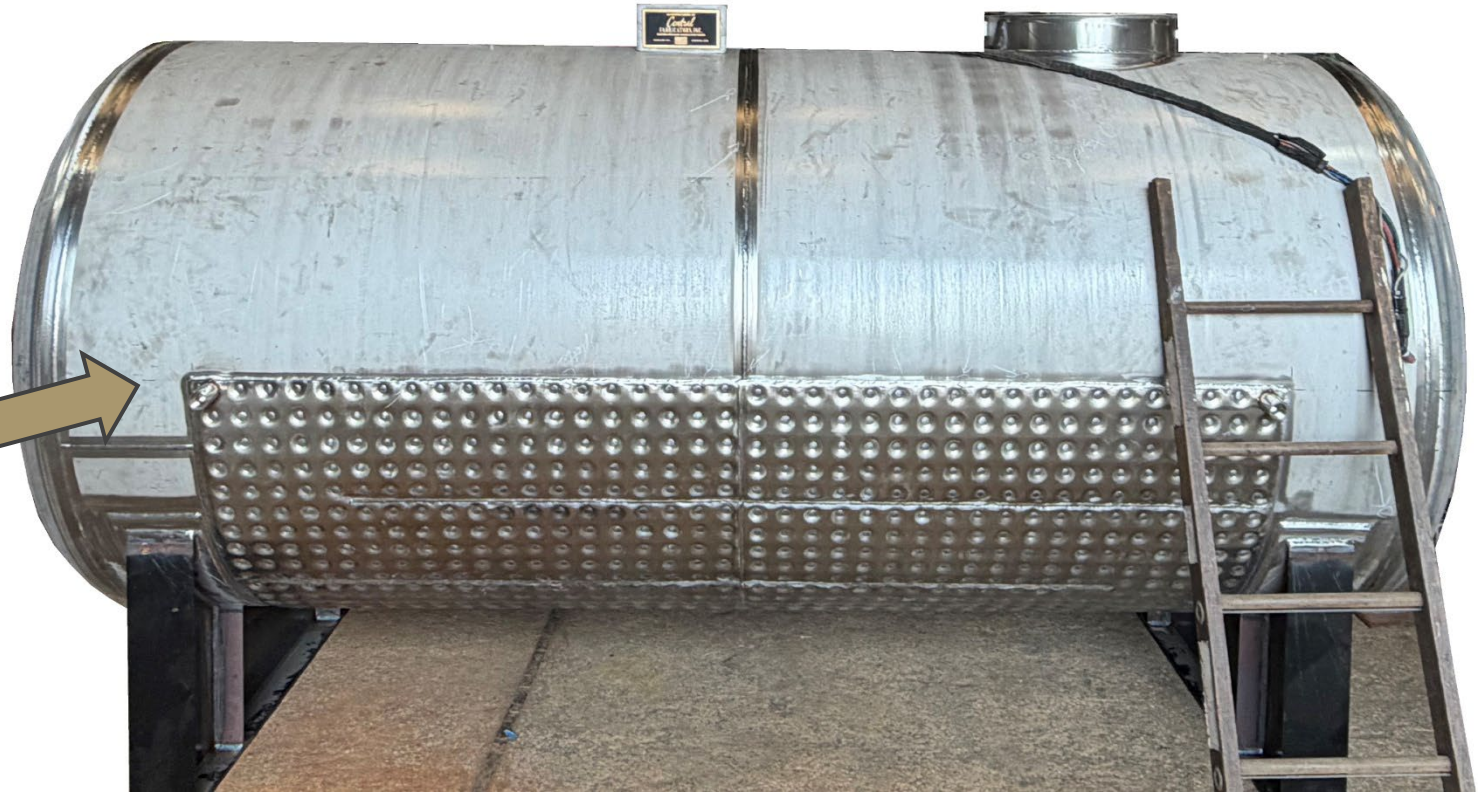
Beverage Stillage Products at Scale

Organics

-Bio Gas
-Bio Coal
-Protein Enriched Feed
-Omega 3
-Sweetener
-Activated Carbon

Inorganics

-NPK Fertilizers



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Bourbon Distillers' Grains Contain Useful Nutrients

- Bourbon distiller spent grain is a rich source of **Protein** (20-30%) and **Fiber** (40-70%)
- Blend in spent grain to increase protein and fiber content in commercial food products

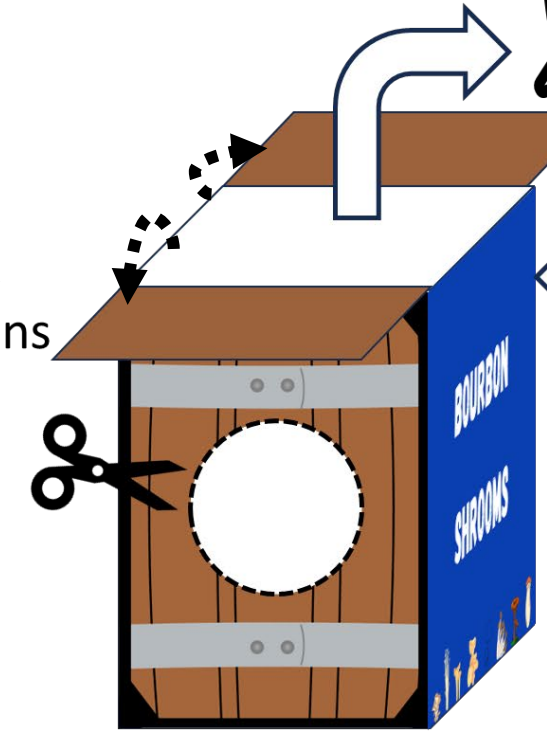
+

beaminstitute.ca.uky.edu

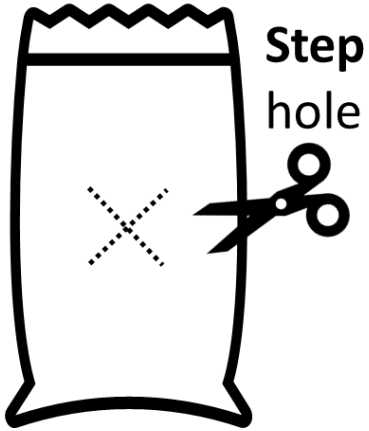
Contact:
Dr. Akinbode Adedeji
Biosys & Ag. Eng.
akinbode.adedeji@uky.edu

Distillers' Grain into "Bourbon Shrooms"

Step 1: Tear box along perforations



Step 2: Remove Mushroom bag



Step 3: Cut air hole in an X

Step 4: Replace bag to box

Step 5: Mist regularly with water

Step 6: Harvest & repeat

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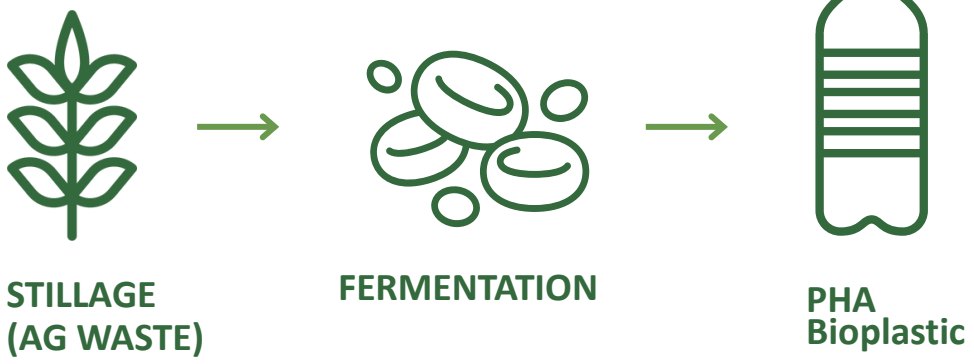
Stillage to Bioplastic Project

- Spirited, Inc. is partnered with University of Kentucky to create PHA from distillery stillage. USDA Phase 1 Grant and AgTech Grant recipient.
- Spirited is based in Lexington, Ky.
- PHA has a $400 Billion addressable market (Pepsi, Kimberly Clark).



PHA degrading

PHA Pellet

Angels' Share

Angel's share is the whisky lost during maturation.

In Kentucky:

- Half of the liquid flows through the wood
- Half is liquid through the joints between wood
- 4% a year

Diffusion through wood

Measured spirit flow through wood in a warehouse in Kentucky, USA

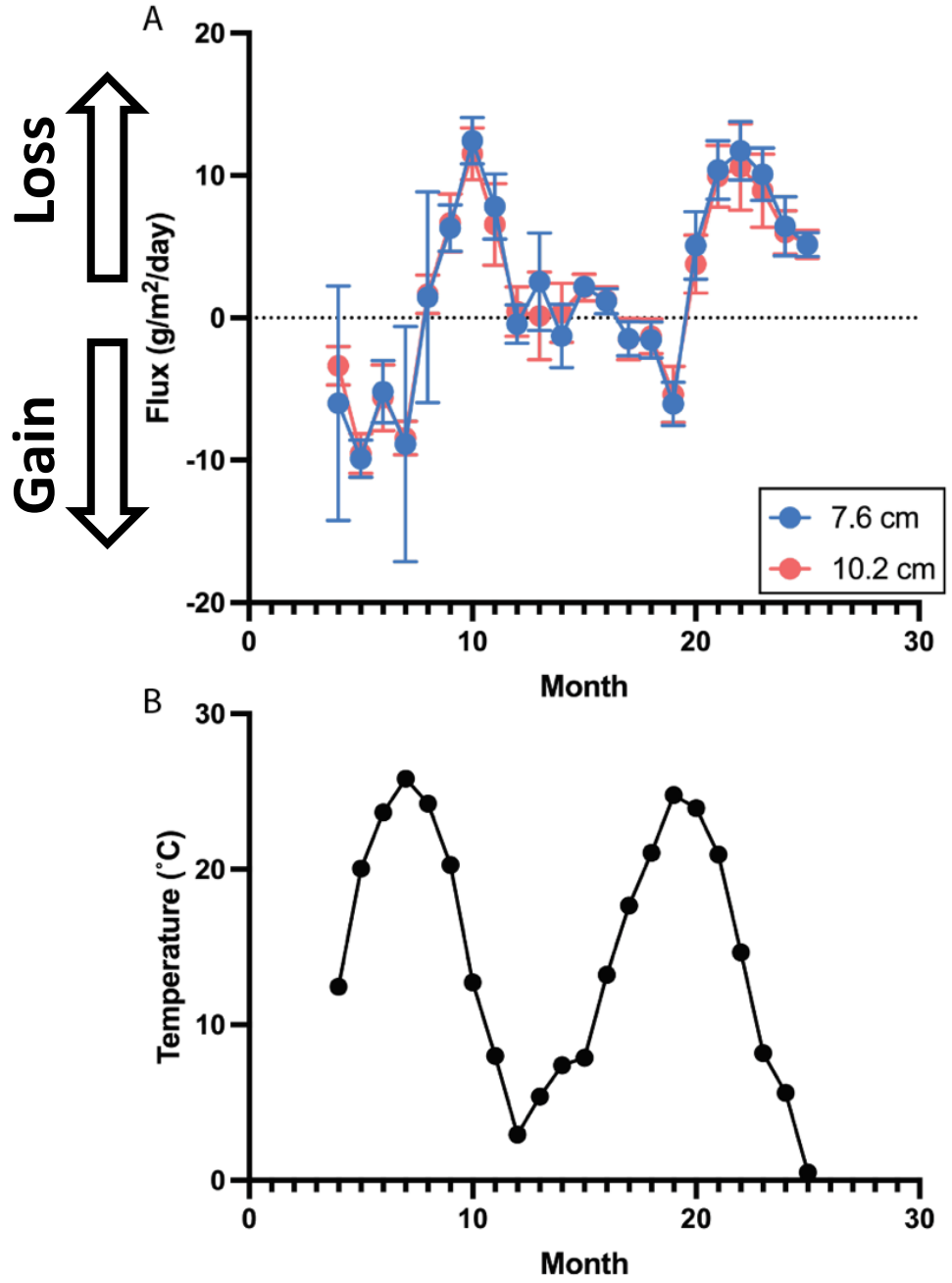
Movement of spirit through oak is seasonal

January = Months 1, 13, 25

High outside temperatures increases losses

Delay by ~2 months in a 58,800 barrel warehouse

Other trends by wood type, char, etc.



Scott et al., J Inst Brewing 2026

Thank you

ABCs of bourbon:

A. Made in America
B. Aged in new charred oak Barrels
C. At least 51% Corn
D. Distilled to less than 80% alcohol
E. Enters the barrel at less than 62.5% alcohol
F. Final product at least 40% alcohol
G. Is a Genuine product (no flavorings, colors, additives)

Brad Berron

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What's always on my shelf:

- ***Basil Haydens Malted Rye ($60)***
- ***Four Roses Small Batch ($40)***
- ***Makers Mark ($25)***