Three-Dimensional Modeling of Whiskey Evaporation and Esterification

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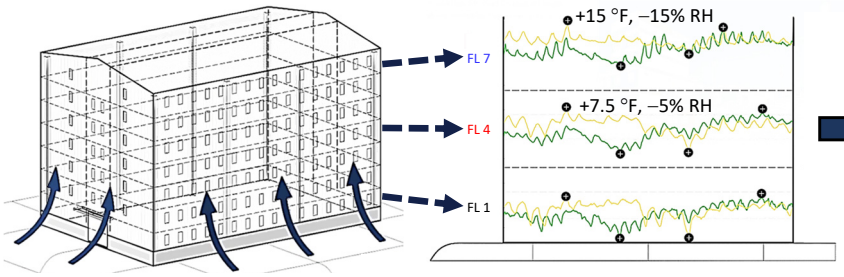
- Global sales projected to hit $128 billion by 2028
- Compound annual estimated growth rate > 6%
- Customer demand increasing for premium spirts and innovative whiskey varieties

In combination with master distillers, predictive modeling of whiskey evaporation and esterification can help *tweak* whiskey characteristics

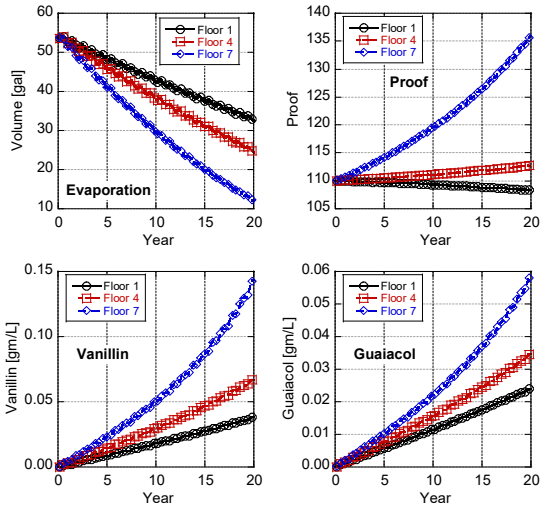
Estimate barrel characteristics in rickhouse

- Any temperature and relative humidity profile possible
- Ethanol and water evaporate distinctly: predict ABV & ABW
- Chemistry tracks with surface area-to-volume ratio



Natural convection within rickhouse with confined barrels

Different rickhouse monthly temperature profiles at various floors



Model predicts rickhouse ageing (2-methoxy-4-methylphenol, eugenol, syringaldehyde also simulated)

- Years are simulated in minutes! 20 years = 1 hr run time

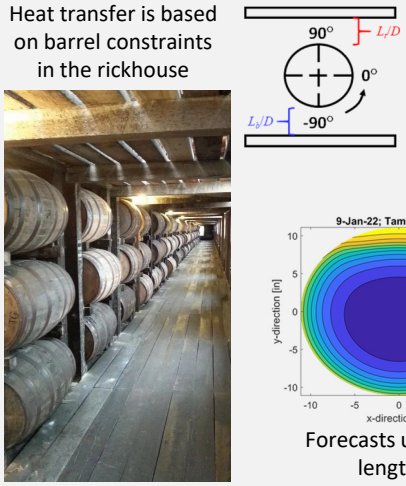
Model capabilities

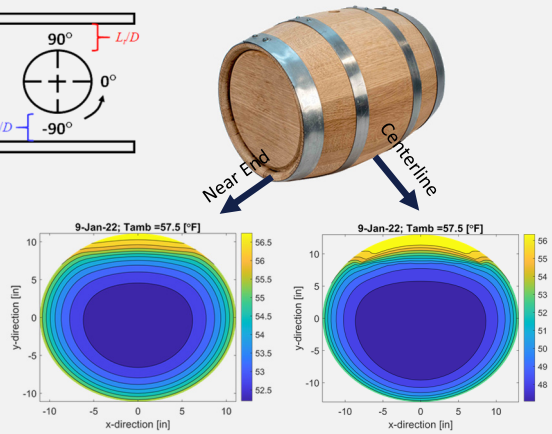
- Vertical and horizontal barrels both available
- Any size barrel (e.g., 2-gal vs. 50-gal)
- Captures surface area during evaporation
- Numerically stable – any time-step allowed!
- Runs on desktop computer

Collaborate on model improvements

- Fast computational time facilitates calibration to available data
- Enhance chemistry based on char level
- Change type of staves and properties
- *How do you want to use the model*?

Heat transfer is based on barrel constraints in the rickhouse

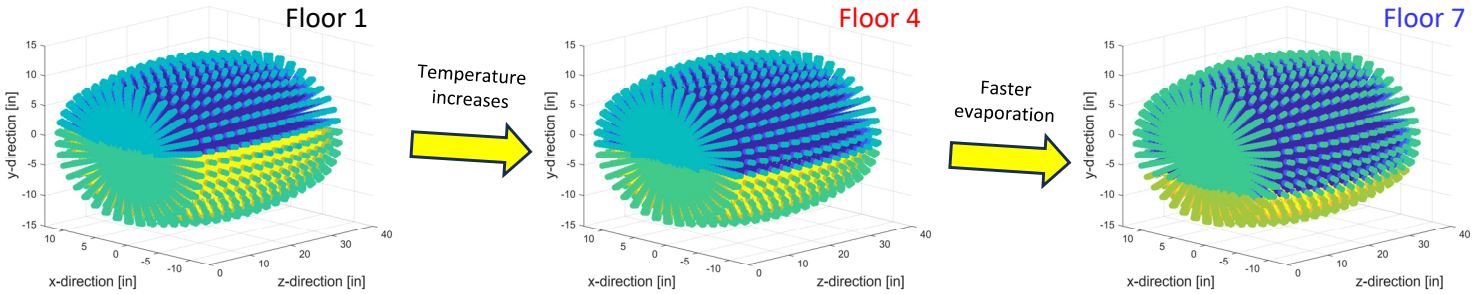




Forecasts unique temperature profiles along barrel length as ambient temperature changes

Predict evaporation before it happens

- Run forecasts as often as desired
- No special software needed
- Simulate unique rickhouses, diverse barrel locations
- Watch whiskey characteristics change dynamically



Level of whiskey in barrels on different floors after 20 years of simulation time (whiskey, air gap, unsaturated staves, saturated staves)

Looking for collaborators, data for model improvements, commercialization potential

Watch a short presentation on the model!

*Ph.D. ME, M.S. AE, M.S. ME @ Univ. of Michigan, ASME Fellow, World's Top 2% Scientist, 130 peer reviewed papers (catalysis, CFD, thermodynamics), over 3000 citations, 20+ years experience