

# Three-Dimensional Modeling of Whiskey Evaporation and Esterification

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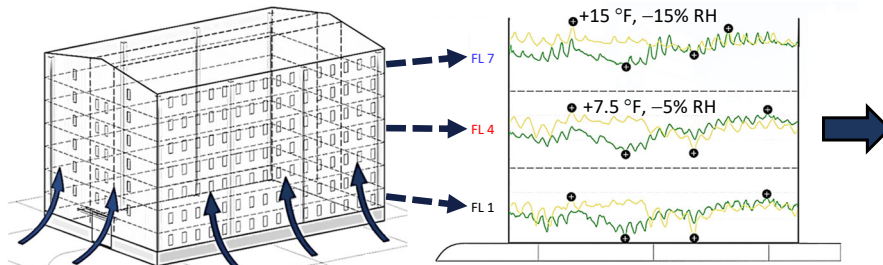
- Global sales projected to hit \$128 billion by 2028
- Compound annual estimated growth rate > 6%
- Customer demand increasing for premium spirits and innovative whiskey varieties



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

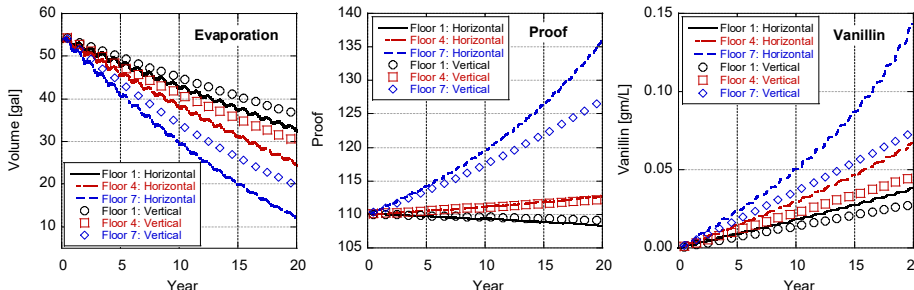
## Estimate horizontal and vertical barrel characteristics in rickhouse

- Any temperature and relative humidity profile possible
- Ethanol and water evaporate distinctly: predict ABV & ABW
- Chemistry tracks with surface area-to-volume ratio
- Years are simulated in minutes! 20 years = 1 hr run time
- Simulate unique rickhouses, diverse barrel locations
- No special software needed

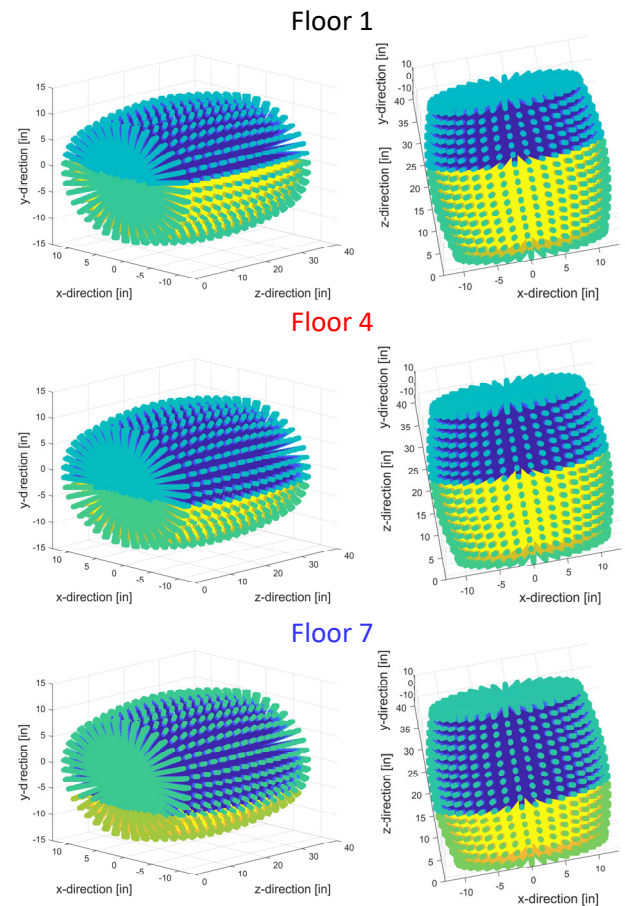


Natural convection within rickhouse with confined barrels

Different rickhouse monthly temperature profiles at various floors



Ageing predictions (guaiacol, 2-methoxy-4-methylphenol, eugenol, syringaldehyde also available)



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

## Predict evaporation before it happens

- Run forecasts as often as desired
- Change the ambient temperature and relative humidity
- Watch whiskey characteristics change dynamically

### Model is adaptive!

- Barrel and stave sizes can be changed
- Incorporate different types of wood
- Simulate rum, tequila, gin, vodka, and other liquors!

Let us work together to add your unique insights and requirements into the model

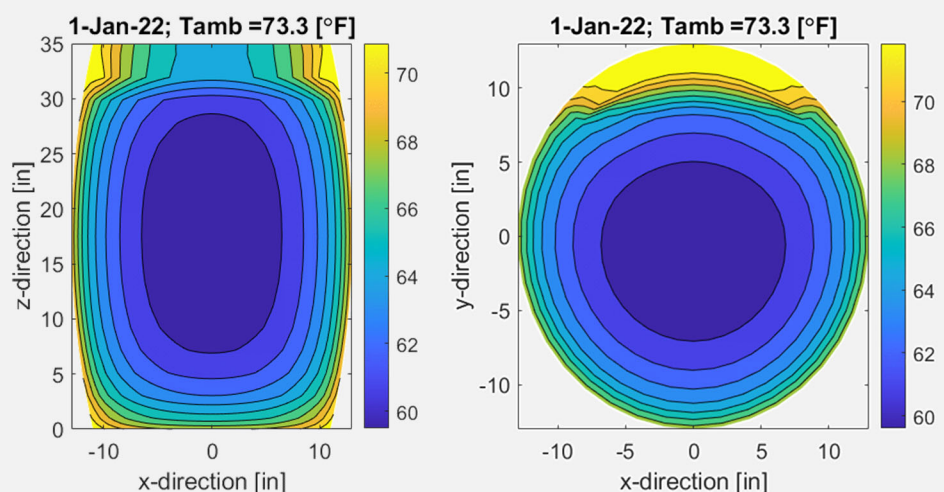


Illustration of temperature contours at the centerline under the same ambient conditions for vertical and horizontal barrels on Floor 7

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