Increasing Corn Throughput in Dry Grind Ethanol Process

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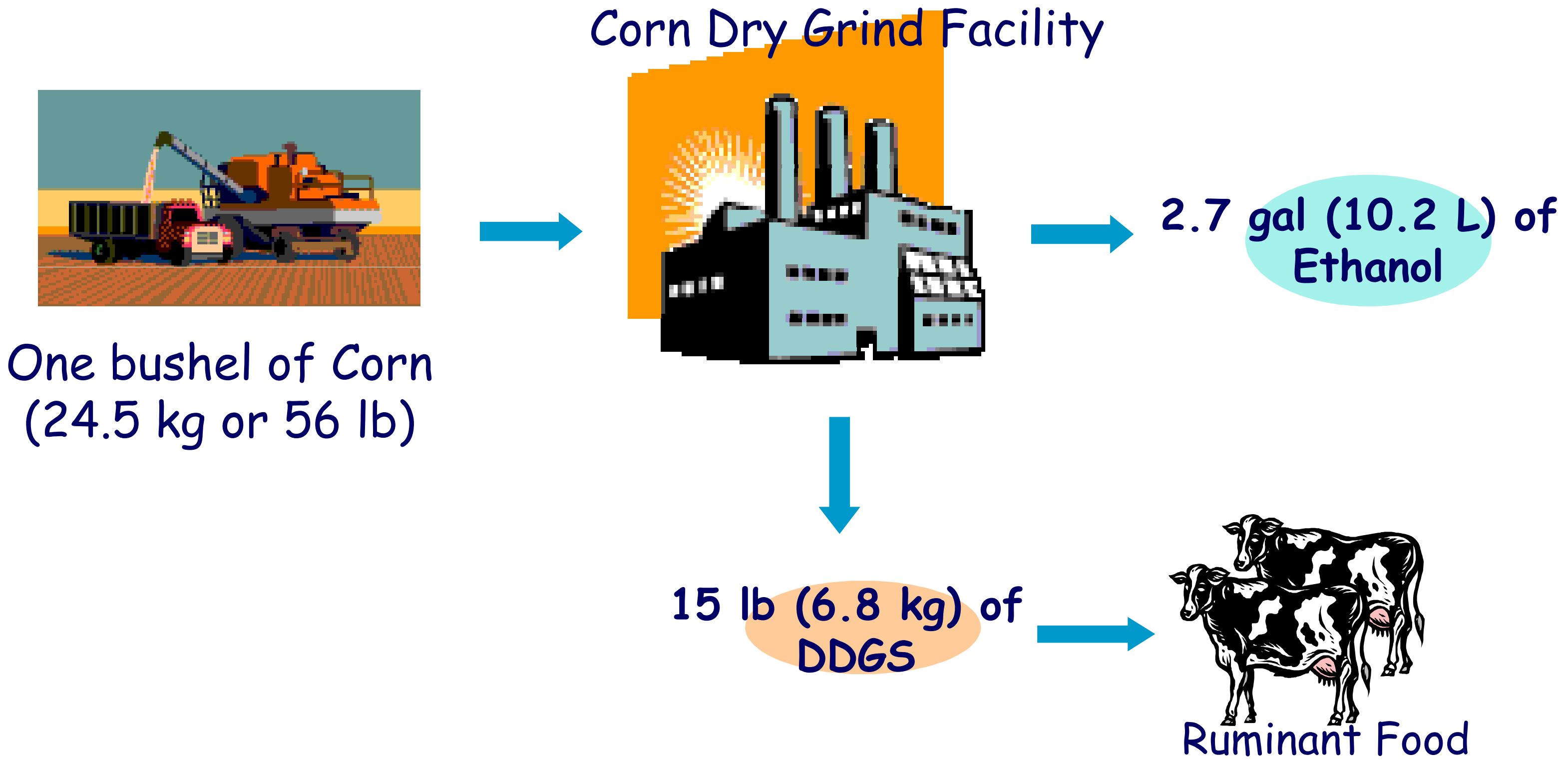
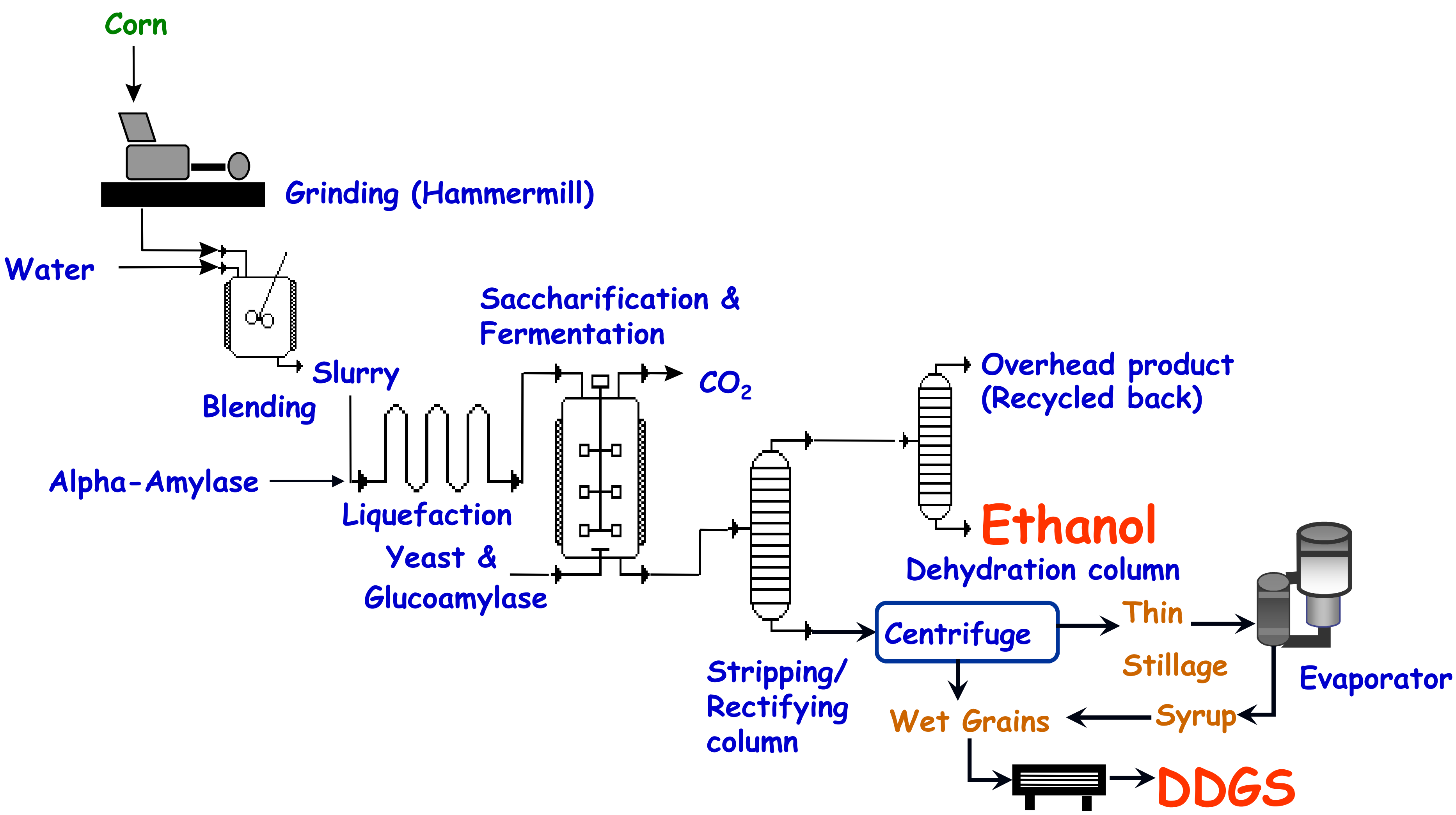
Dry Grind Ethanol Process

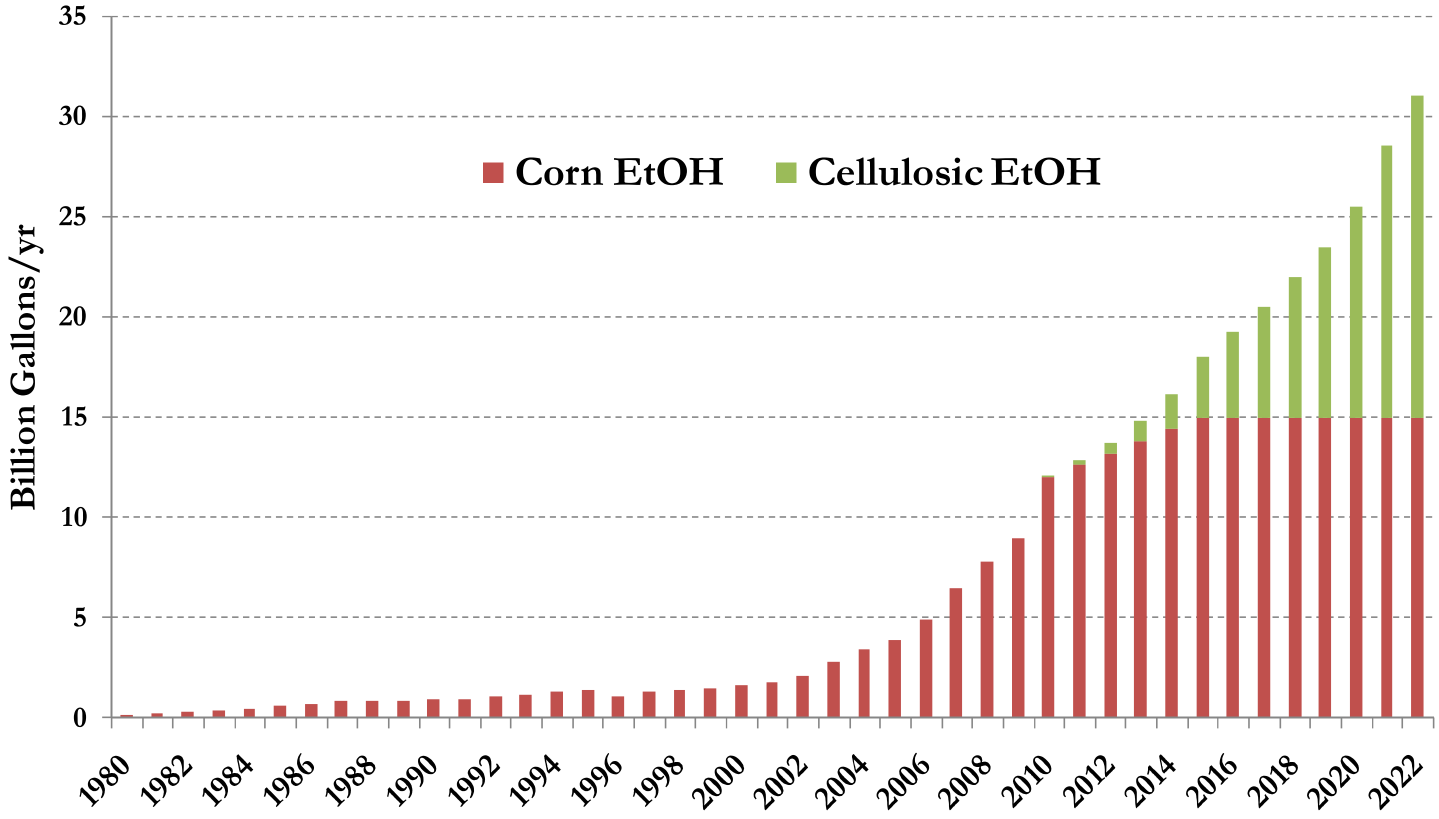


Conventional Dry Grind Corn Process



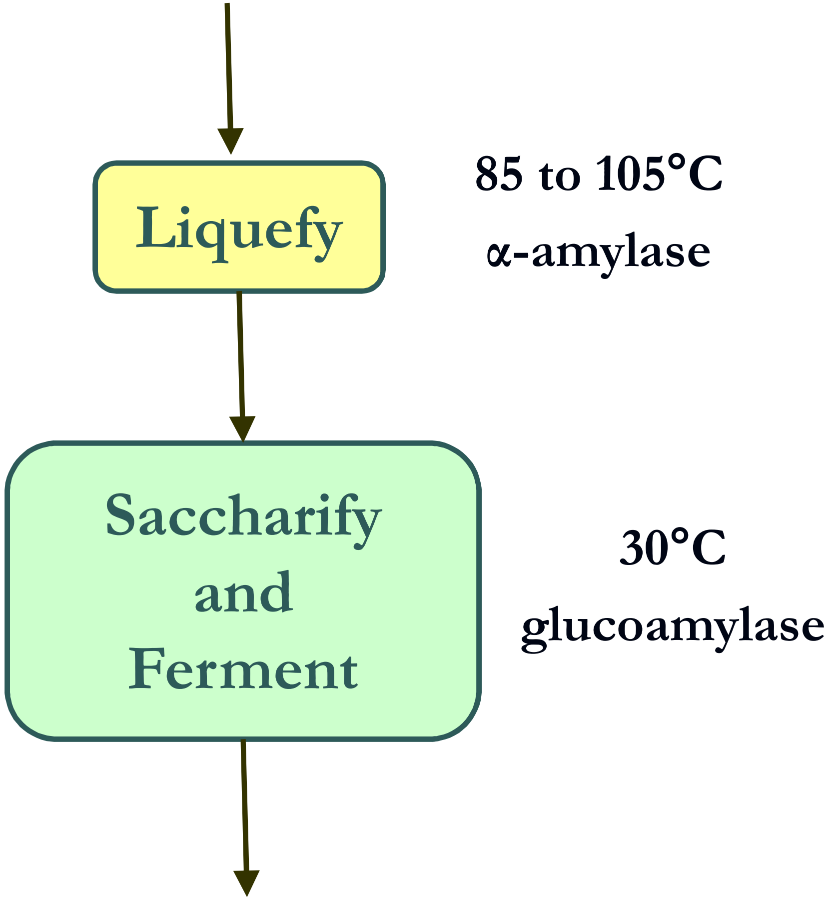
Ethanol Production in the US

- Currently 10.5 billion gals/yr production capacity
- Increase in ethanol production is coming for construction of new dry grind ethanol plants



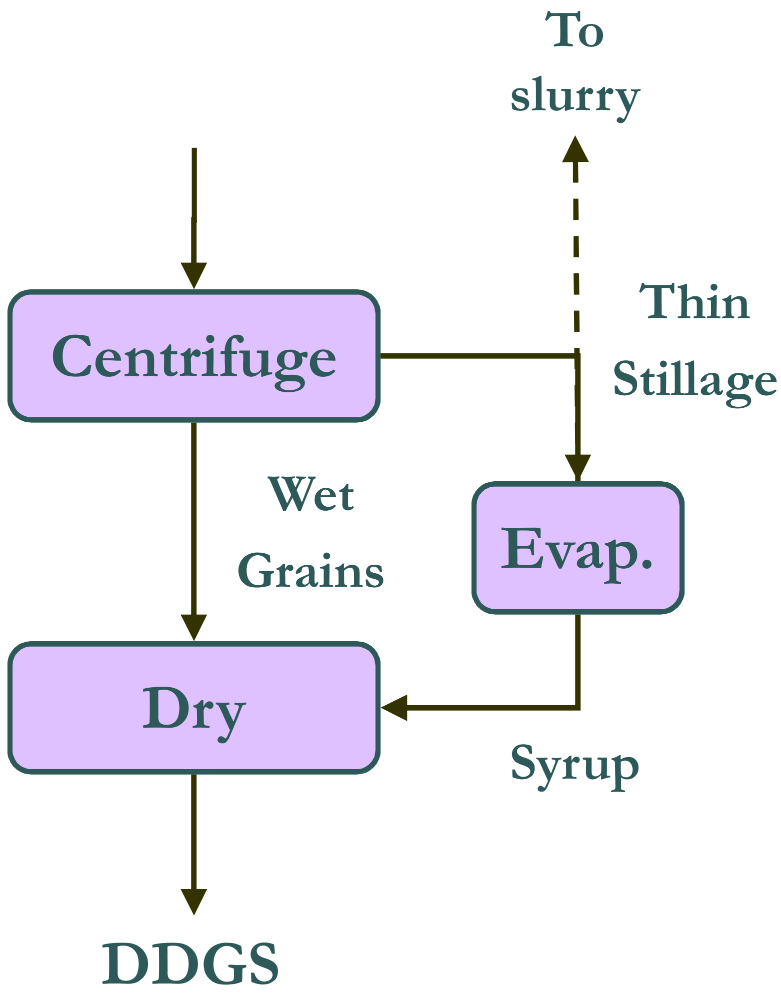
Limitations to Dry Grind

- Liquefaction
  - High temperatures
  - Glucose inhibition
  - Slurry viscosity
- Fermentation
  - Ethanol inhibition
  - Metabolite inhibition

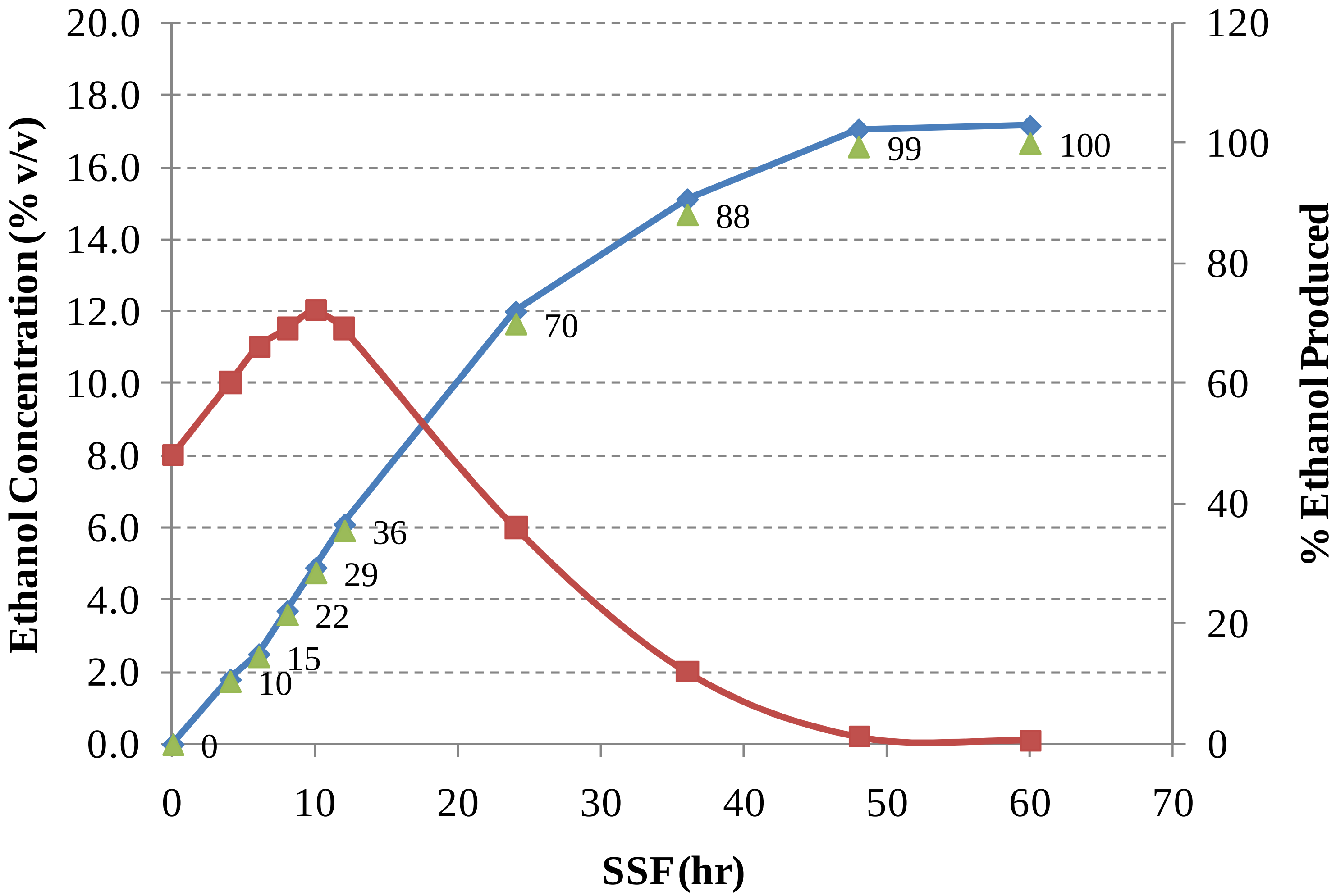


Limitations to Dry Grind

- Dewatering (thin stillage)
  - Recycling of inhibitory components
  - Fouling during concentration to syrup
- Coproduct processing
  - High temperatures
  - High capital cost



Typical Fermentation Profile



Effect of Solids Content

- Higher solids result in higher glucose
  - Produced during liquefaction (up to 15% w/v)
  - Above 15% w/v inhibits yeast
  - Affects yeast growth, cell viability, total ethanol production
  - Osmotic stress and enzymatic inhibition
- 32 to 34% maximum solids
- Viscosity maximum

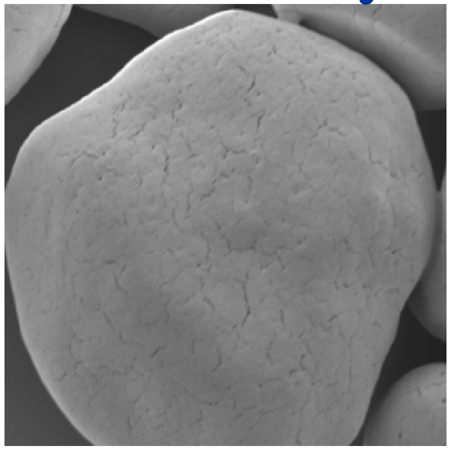
Effect of Ethanol

- Ethanol controls fermentation completion
  - Increases yeast membrane fluidity
  - Reduces membrane surface activity
  - Inhibition begins 10 to 13% v/v
- 18 to 21% v/v maximum
- Affects yeast viability and vitality
- Reduces enzyme performance

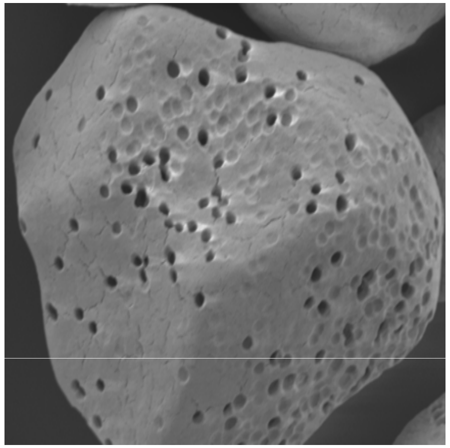
Overcoming Solids Limits

- Conventional enzymes
  - Separate processes, separate enzymes
  - 85°C liquefaction temperature
  - Produce high glucose concentrations
- Granular starch hydrolyzing enzyme (GSHE)
  - Mixture of enzymes
  - 48°C liquefaction or simultaneous with SSF
  - Lower glucose concentrations
  - Potential for higher solids

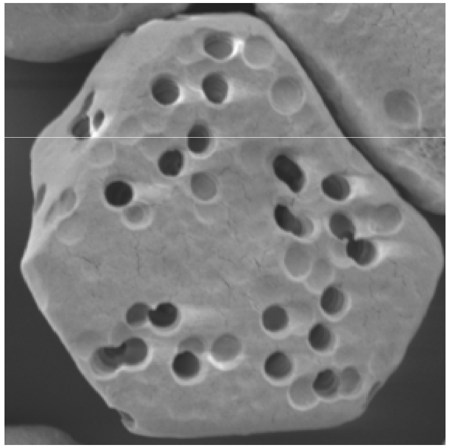
Corn Starch Treated with Granular Starch Hydrolyzing Alpha and Glucoamylase pH 4.5, 32°C



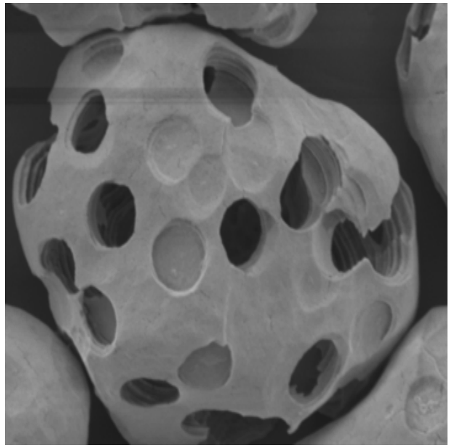
Granular Starch



Granular Starch Incubated with GSHE, 2 hr



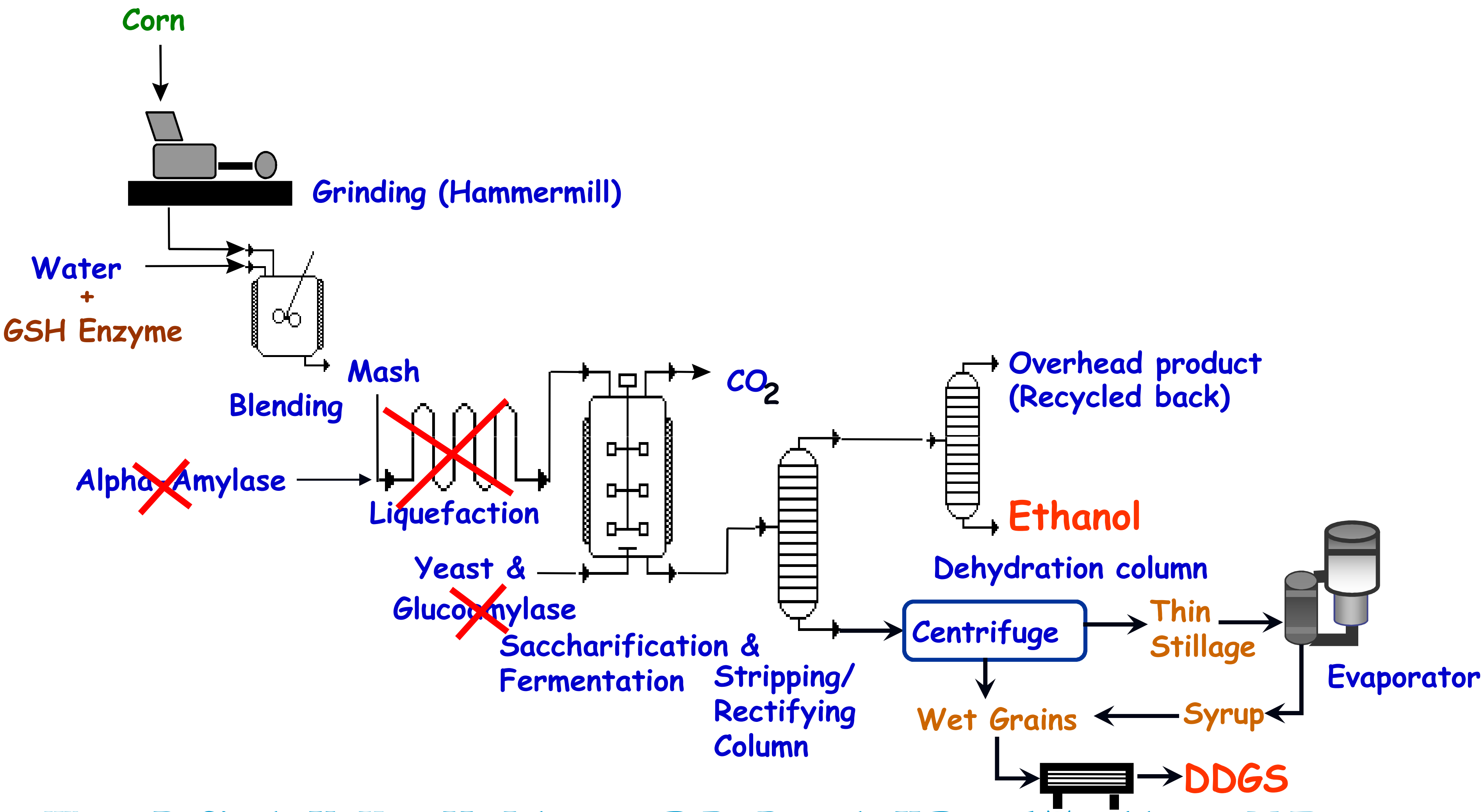
Granular Starch Incubated with GSHE, 4 hr



Granular Starch Incubated with GSHE, 8 hr

Source: USDA/ARS/ERRC and Genencor International

Granular Starch Hydrolyzing Enzymes



Wang, P., Singh, V., Xue, H., Johnston, D.B., Rausch, K.D. and Tumbleson, M.E. 2006. Comparison of raw starch hydrolyzing enzyme with conventional liquefaction and saccharification enzymes in dry grind corn processing. Cereal Chem. 84(1):10-14.

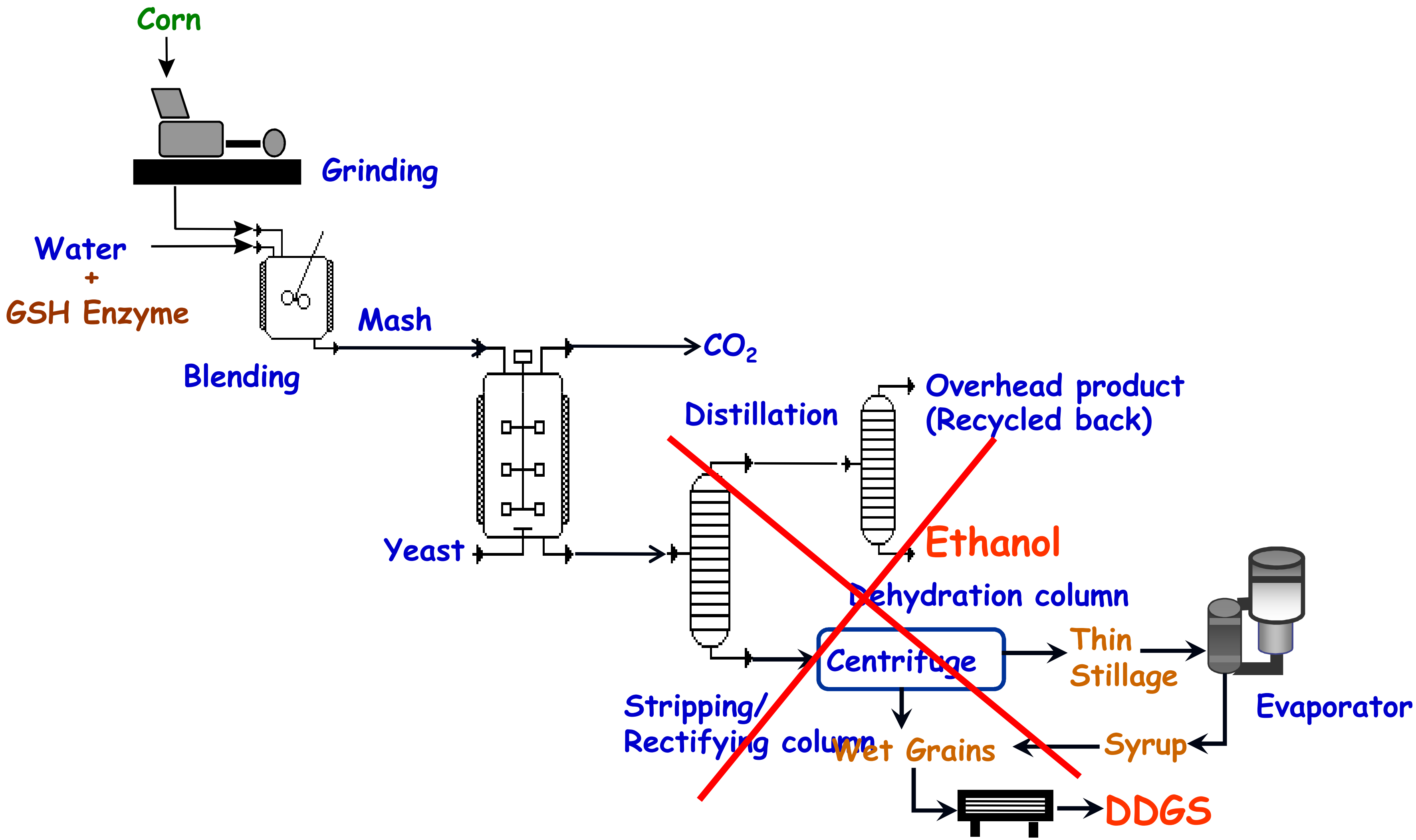
Overcoming Ethanol Limits

- Ethanol production and inhibition
  - Inhibition starts at 10 to 13% v/v
  - Interferes with glucose uptake
- In situ ethanol removal
- Vacuum stripping
  - Apply reduced pressure
  - Collect condensate
  - Cycle to control ethanol concentrations

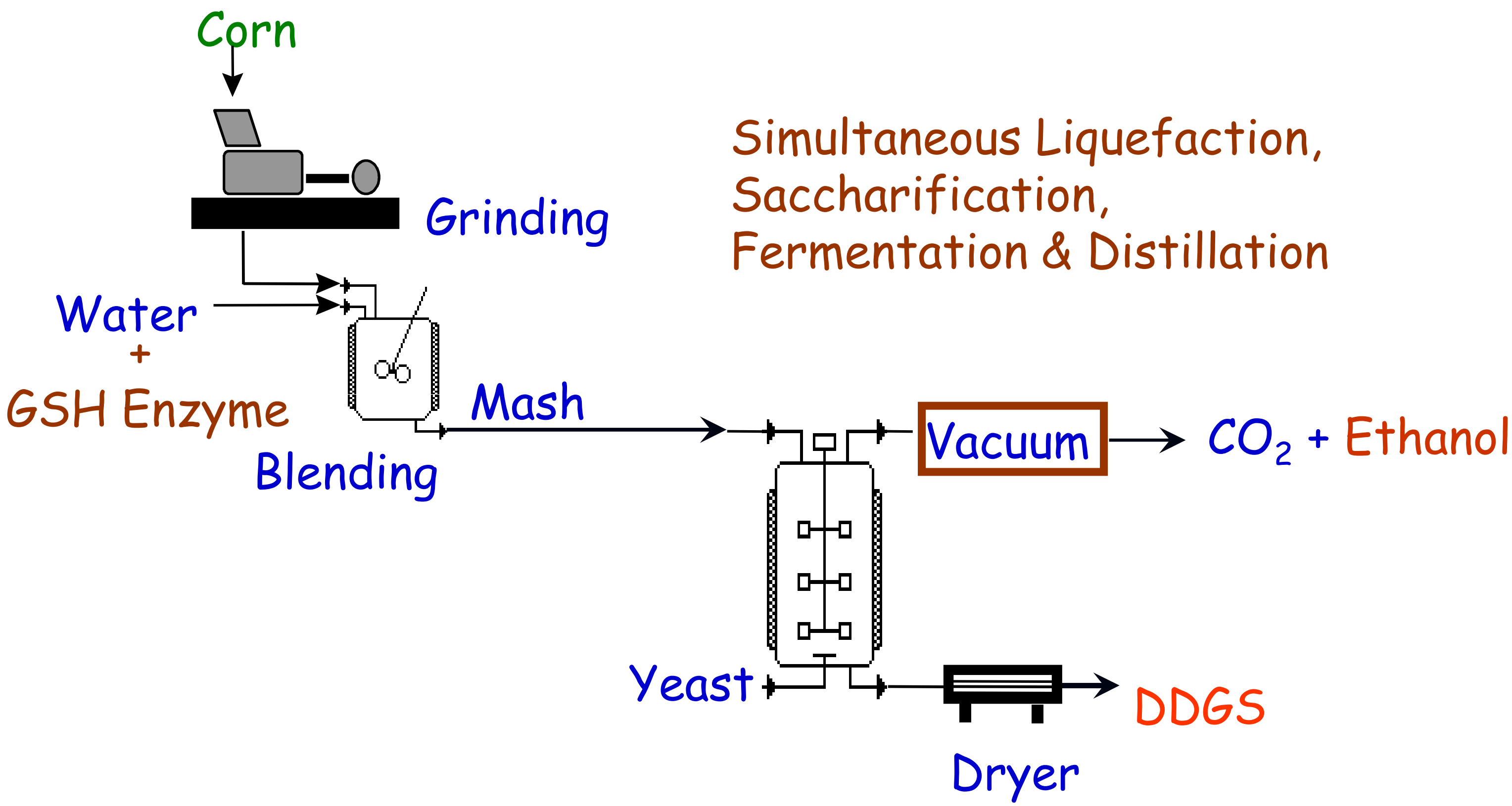
GSHE and Vacuum Stripping

- Use GSHE for high solids fermentations
- Higher solids → higher ethanol productivity
- Use vacuum stripping to keep ethanol low
- Obtain high ethanol yields at high solids

GSHE and Vacuum Stripping Process

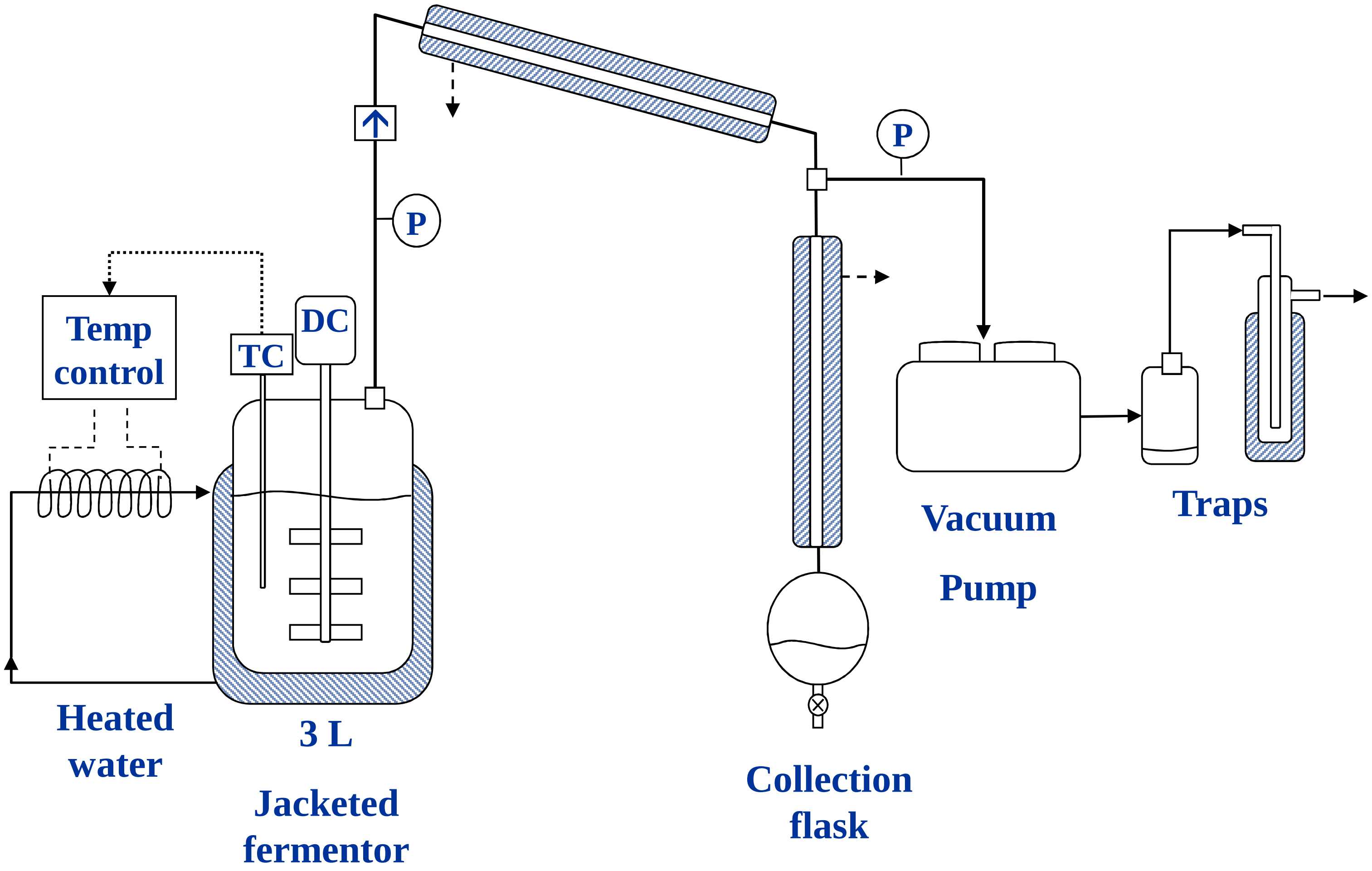


GSHE and Vacuum Stripping Process

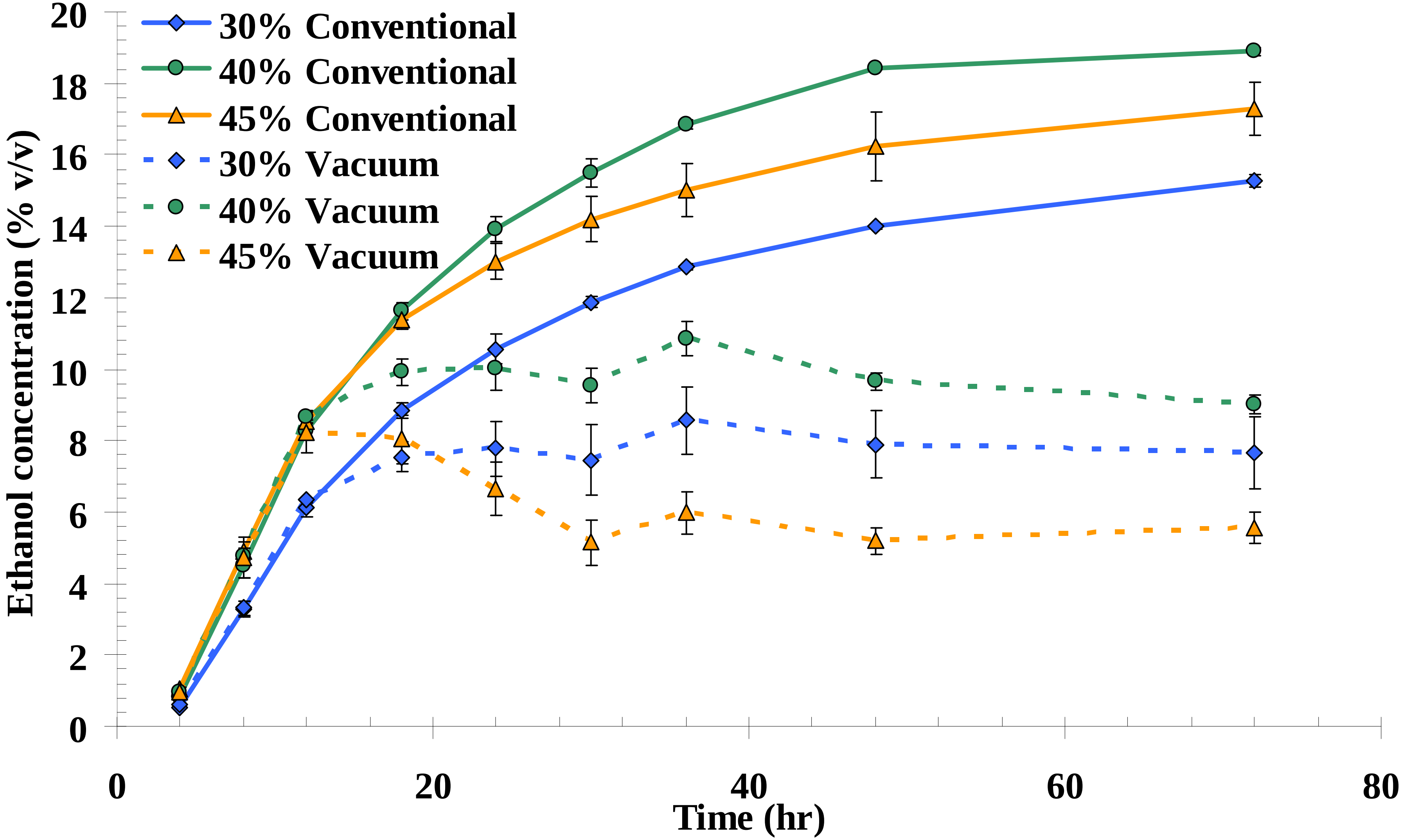


Shihadeh, J.K., Rausch K.D., Tumbleson, M.E. and Singh, V. 2007. Vacuum fermentation for in situ removal of ethanol during simultaneous liquefaction, saccharification, and fermentation. Proc. American Association of Cereal Chemists. Abstract No. 52:A28. San Antonio, TX.

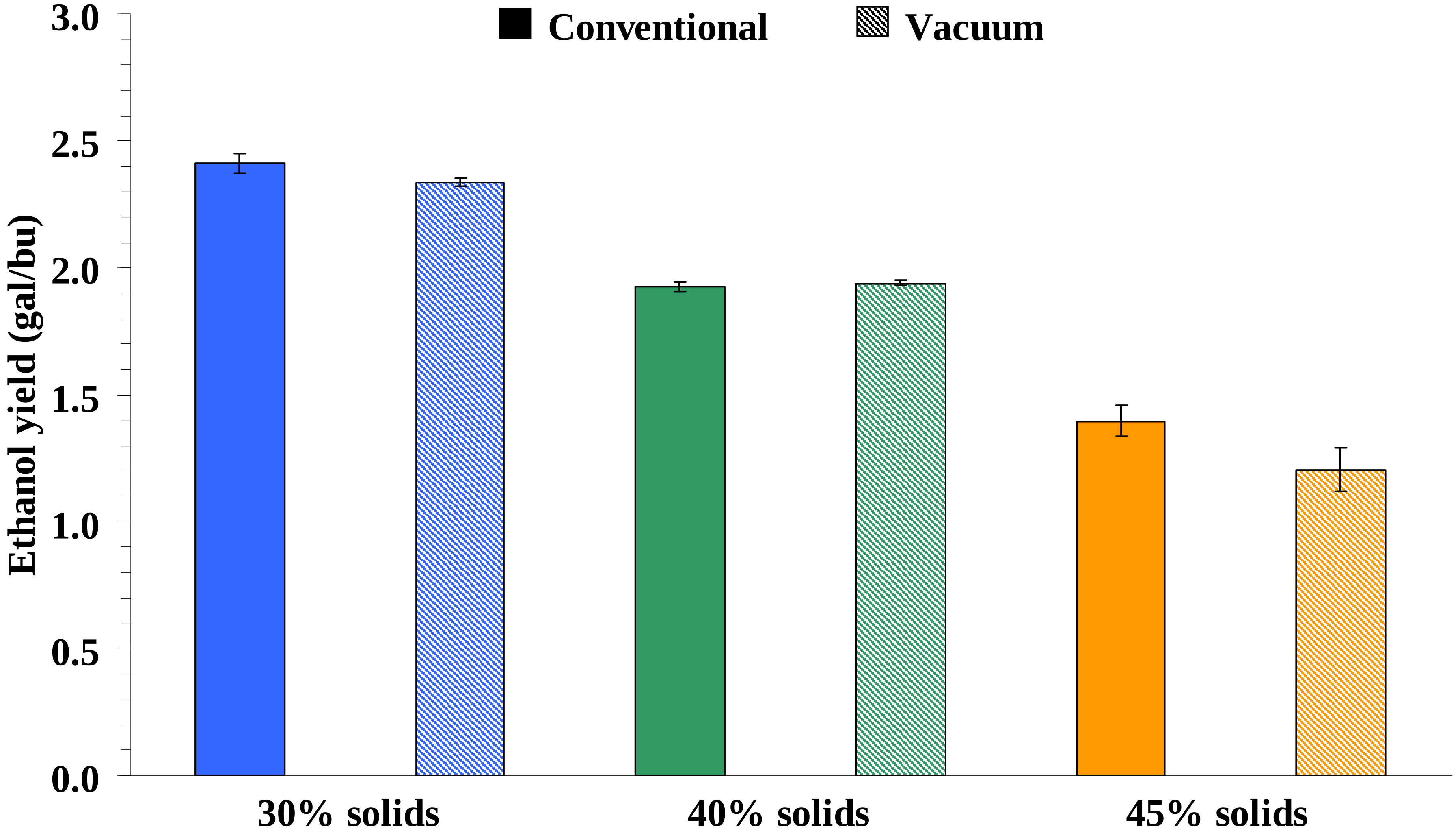
Vacuum Stripping System



Ethanol Profiles



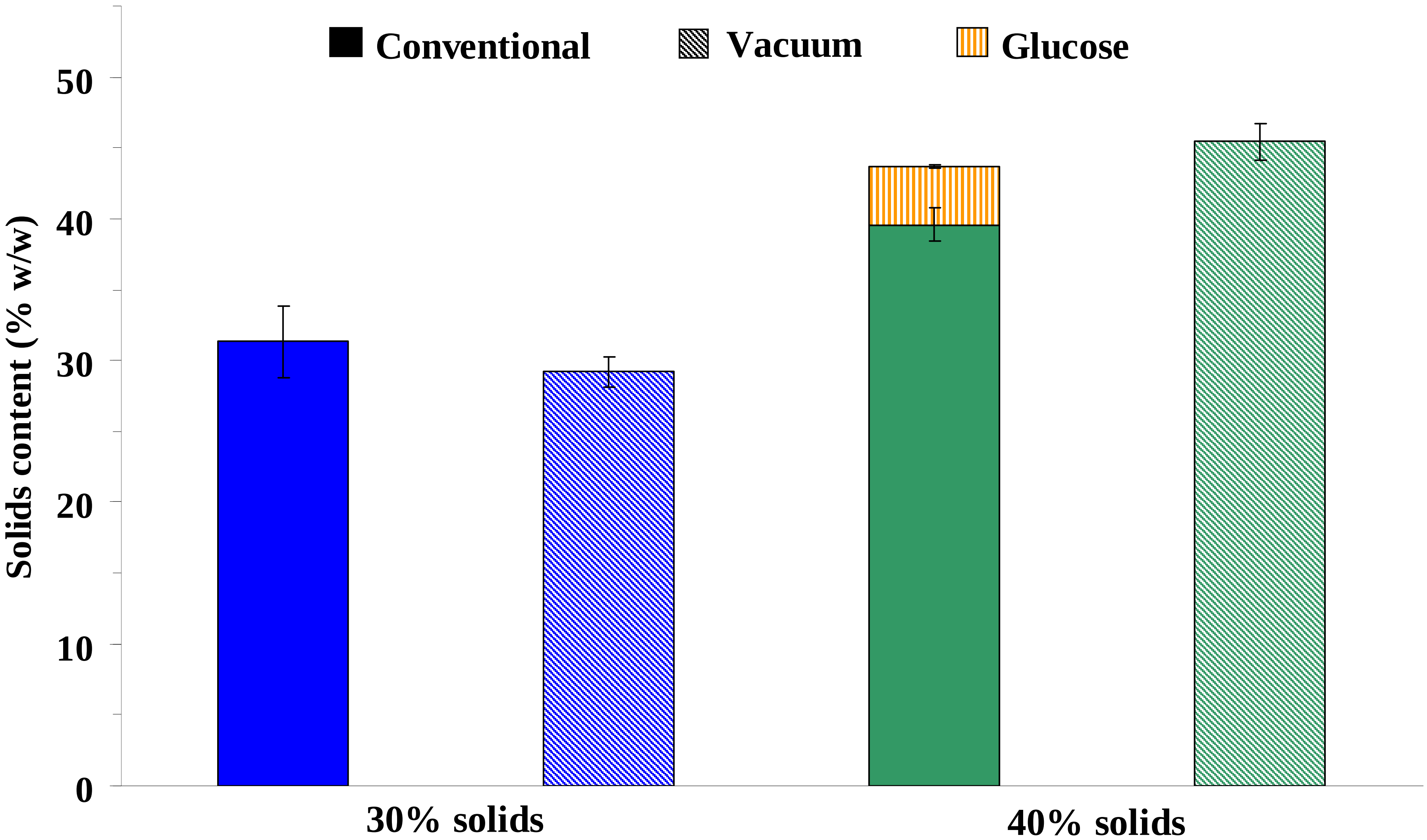
Ethanol Yield



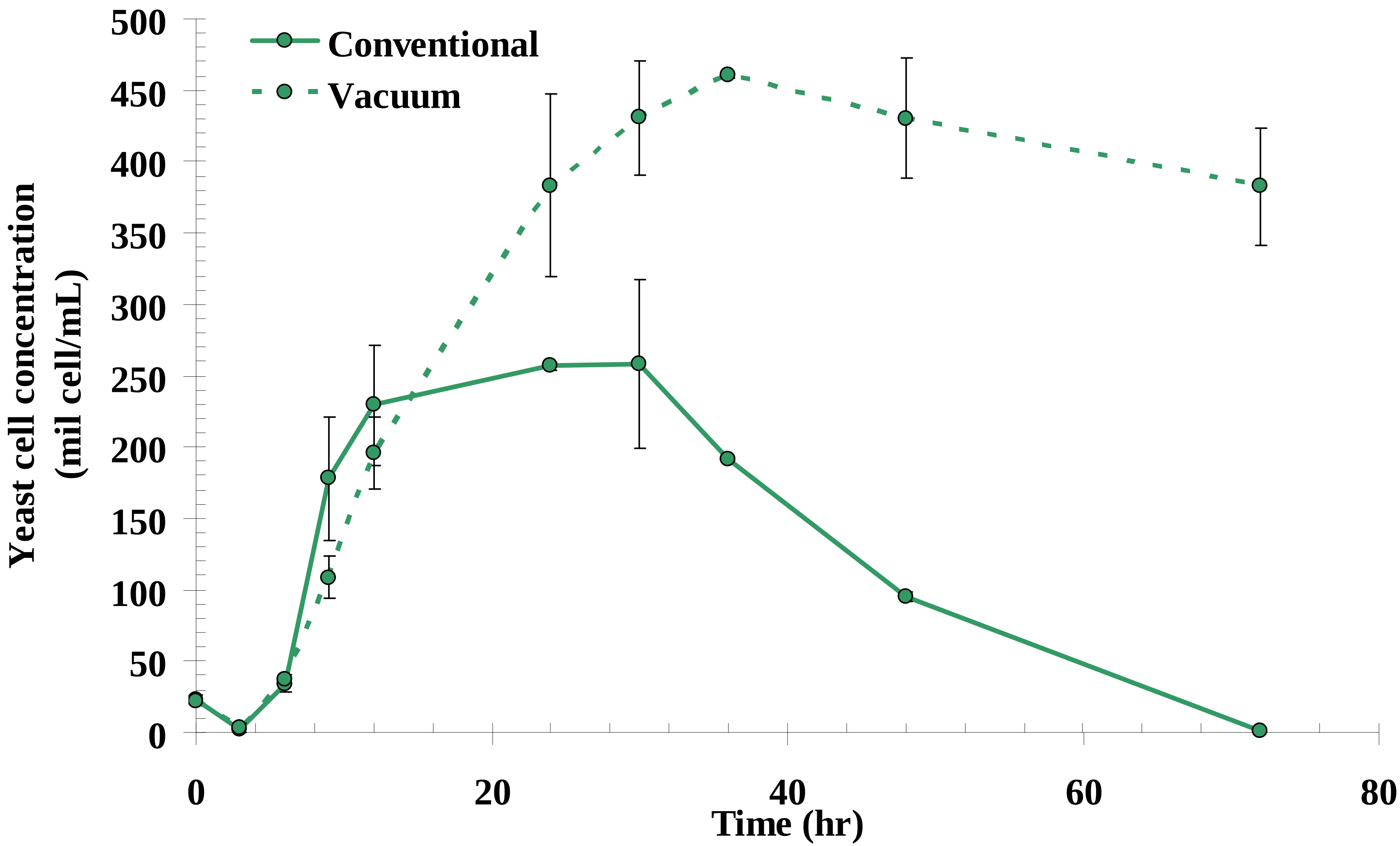
Possible Causes of Similar Ethanol Yields

- Oxygen from air
- Enzyme performance
- Yeast density

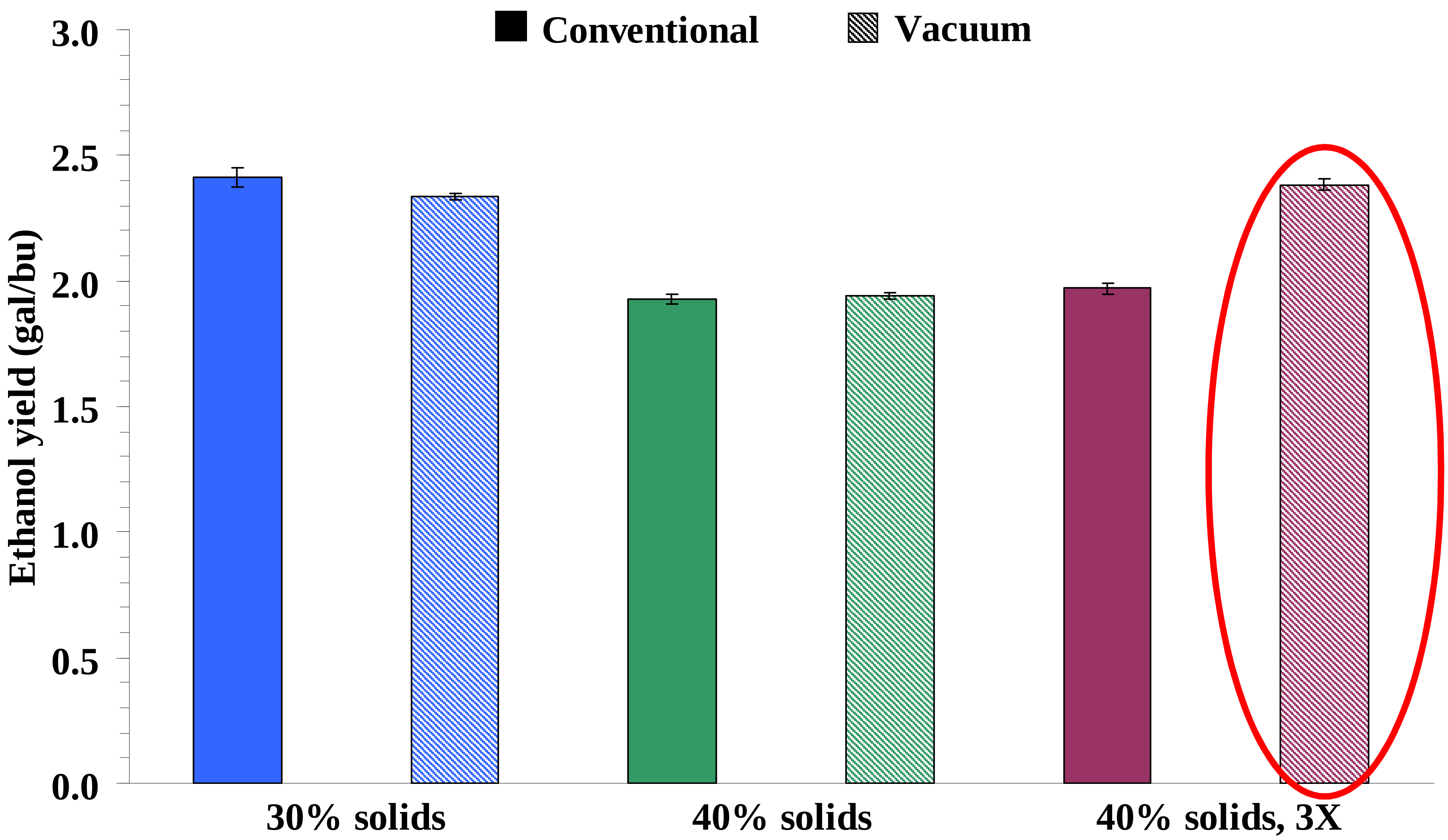
Residual Starch Analysis



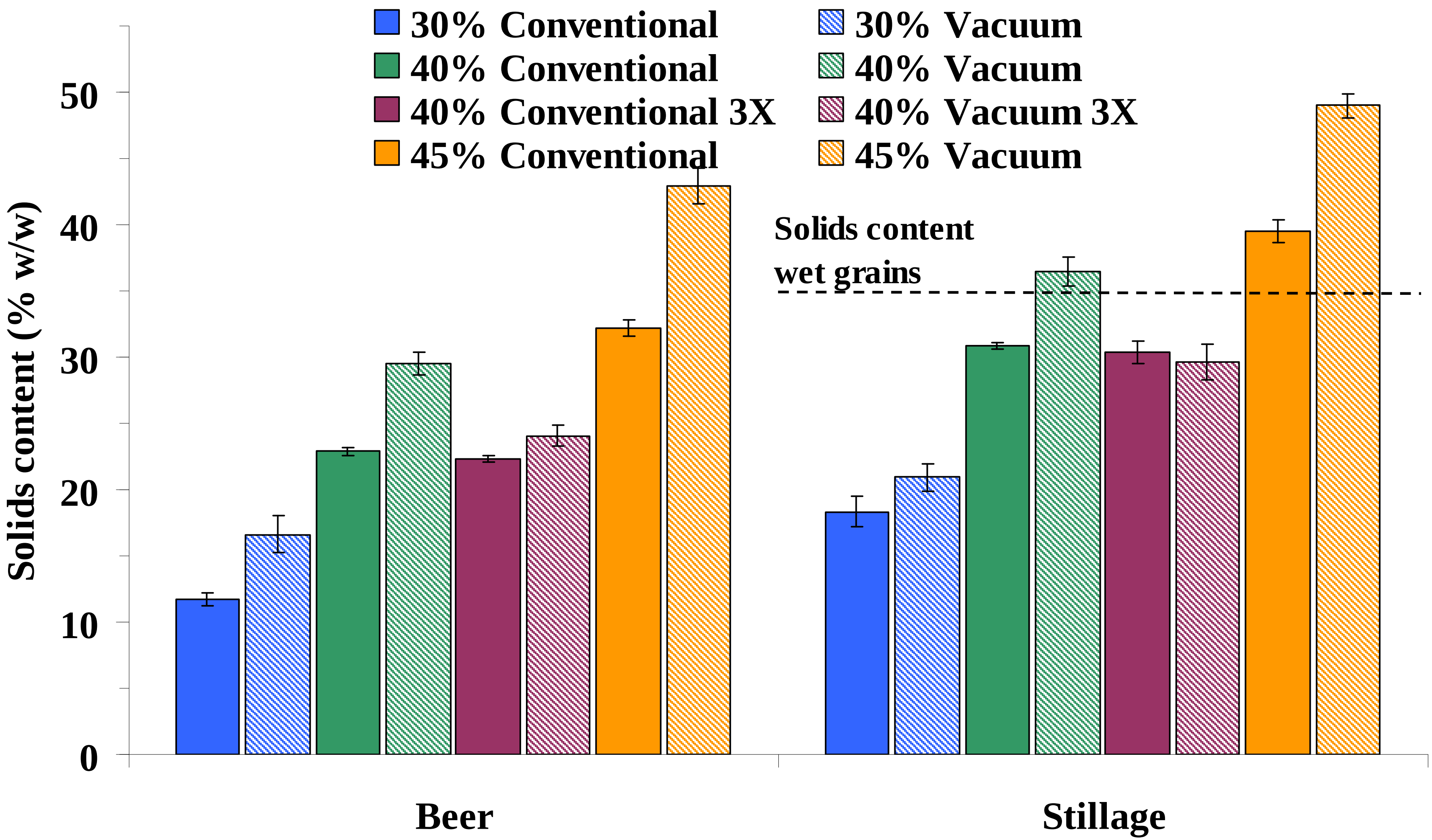
Yeast Density Profiles



Ethanol Yields at
3X dose, ½ inoculate



Solids Content



Process Implications

- Higher slurry solids
  - Reduced capital (smaller fermenter, distillation and other unit operations)
- Higher whole stillage solids
  - Less thin stillage
  - Reduced dewatering and drying costs
  - Wet grains sold directly as food for ruminants