Ethanol production from steam-pretreated ensiled meadow grass

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Why use grass silage for ethanol production?

- To broaden the choice of raw materials
- Excess of grasses in Sweden

- Advantages of ensiling
  - low-cost storage method
  - preservation method
- Drawback
  - reduced ethanol potential?

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Questions to answer in this project

- What is the ethanol potential of ensiled meadow grass (EMG) compared to that of dry meadow grass (DMG)?

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Questions to answer in this project

- What is the ethanol potential of ensiled meadow grass (EMG) compared to that of dry meadow grass (DMG)?
  - How to steam pretreat EMG and DMG?
  - Can EMG be pretreated without addition of extra acid?
  - Is it possible to obtain at least 40 g/L ethanol and an overall ethanol yield of 80% in the fermentation (SSF) step?

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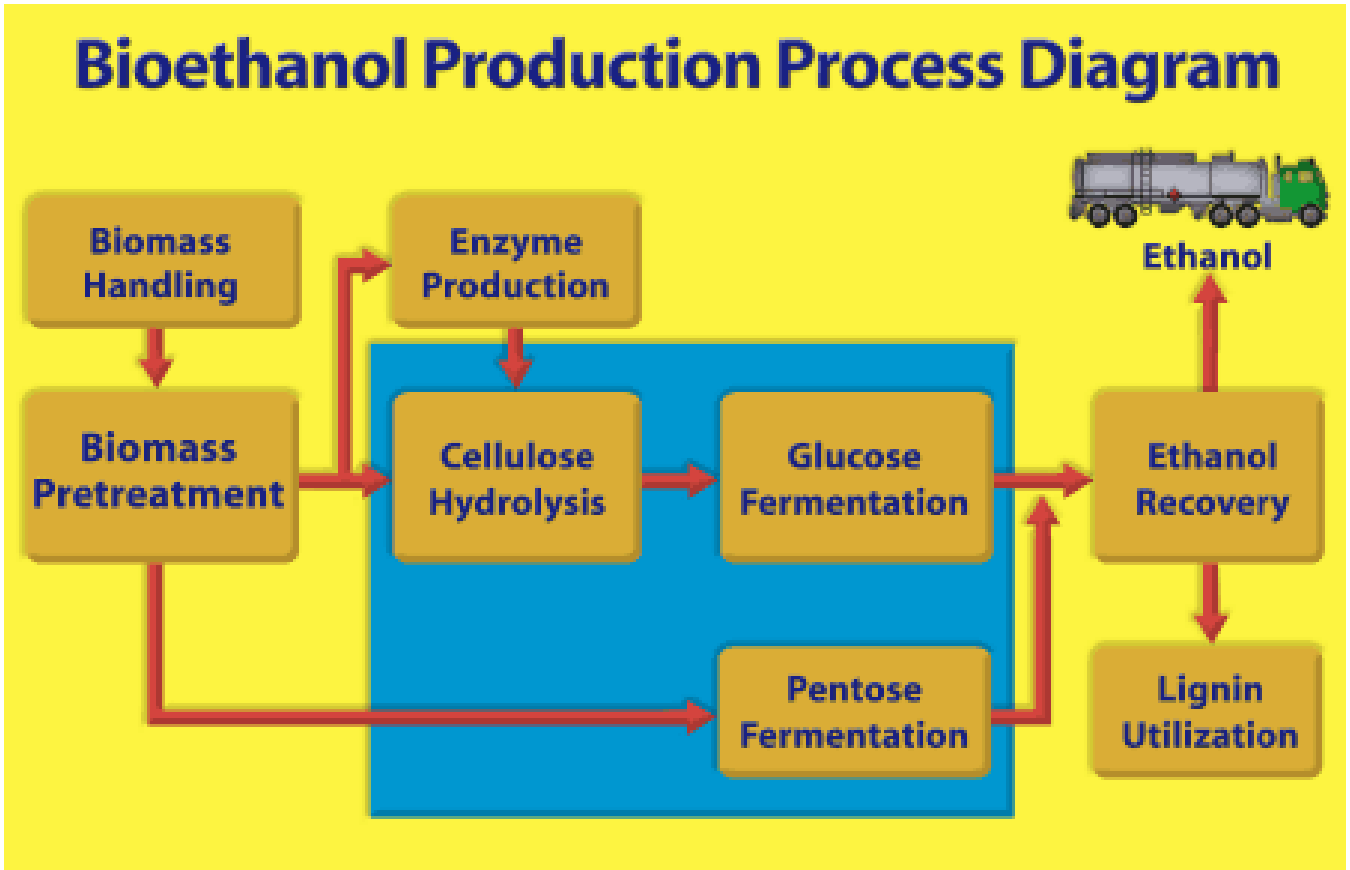
Cellulosic ethanol production process



Simultaneous Saccharification and Fermentation (SSF)

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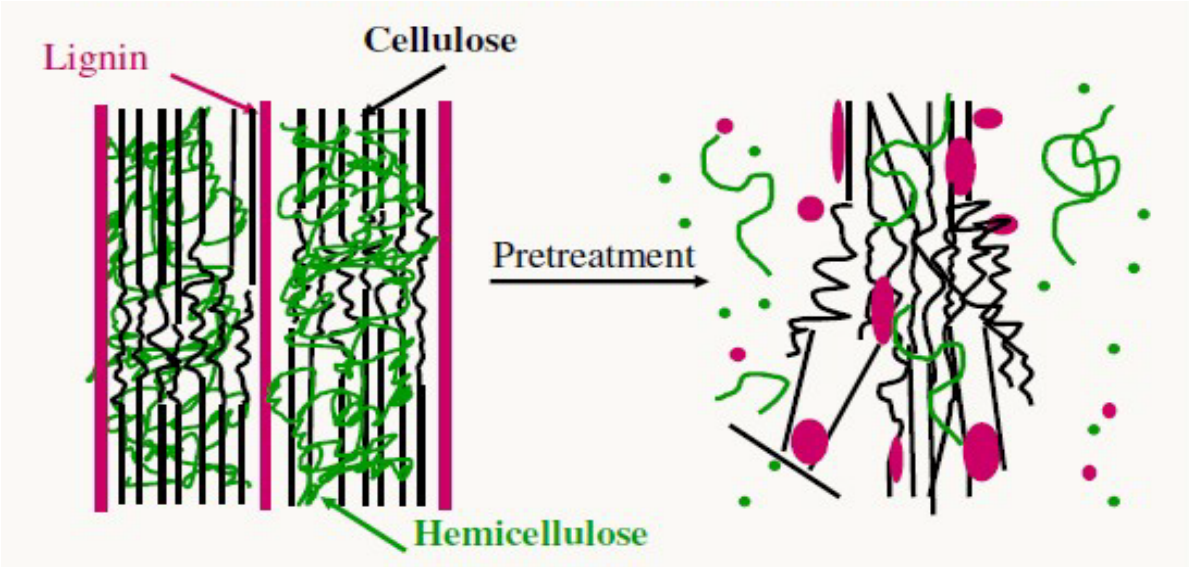
Cellulosic ethanol production process
Steam pretreatment



Steam at high pressure
T: 150-210°C
5-10 min
Acid catalyst

Steam-pretreated material contains potential inhibitors

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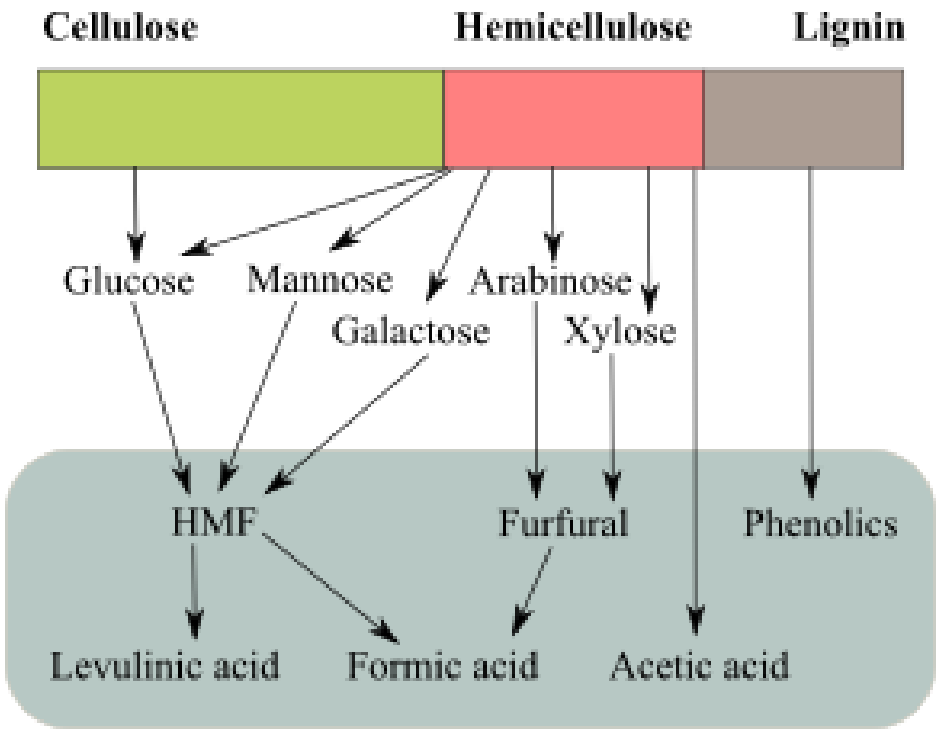
Cellulosic ethanol production process
Inhibitors

Sugar degradation products
- Furfural
- HMF (5-hydroxy-methylfurfural)

Lignin degradation products
- Phenolic compounds

Organic acids
- Acetic acid
- Formic acid
- Levulinic acid



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3 process steps to evaluate ethanol potential of DMG and EMG

1. Find best steam pretreatment conditions for DMG and EMG
2. Enzymatic hydrolysis to evaluate pretreatment
3. SSF on the best pretreated materials

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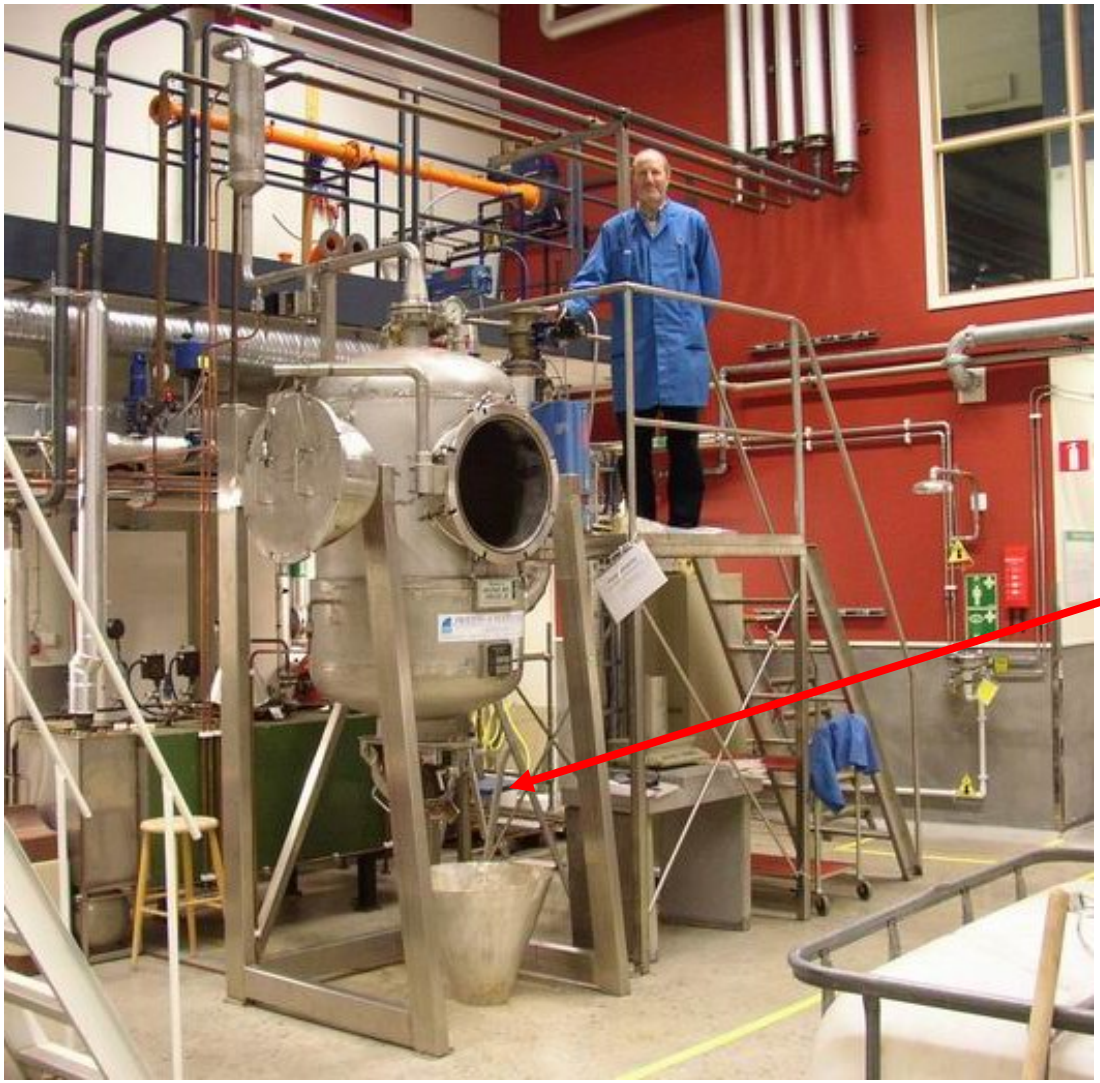
Steam pretreatment unit at the Dept. of Chemical Engineering, LTH



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Composition of the solid fractions of steam-pretreated DMG and EMG

	DMG1	DMG2	DMG3	DMG4	DMG5	EMG6	EMG7	EMG8	EMG9
catalyst	1% HAc	1% HAc	1% HAc	1% HAc	1% HAc	no cat	no cat	no cat	no cat
T (oC)	190	190	200	200	210	190	190	200	210
t (min)	5	10	5	10	5	5	10	5	5
pH	4.0	3.9	3.8	3.7	4.0	4.5	4.3	4.3	4.2
WIS slurry (%)	12.8	8.9	10.6	8.4	8.7	10.0	7.6	8.1	7.9
WIS recovery (%)	71.6	57.2	59.0	58.9	55.5	63.4	55.1	55.9	54.3
Composition of the solid fraction (in % of DM)									
	DMG1	DMG2	DMG3	DMG4	DMG5	EMG6	EMG7	EMG8	EMG9
Glucan	51.9	54.0	54.3	55.3	59.3	48.2	52.2	54.6	57.1
Xylan	9.7	6.9	6.3	4.9	4.3	16.6	10.5	10.5	5.1
Galactan	0.2	0.1	0.1	0.0	0.3	0.4	0.2	0.6	0.4
Arabinan	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0
Mannan	2.8	2.4	2.3	2.4	1.5	3.0	2.4	2.0	1.6
Lignin	29.3	31.2	31.7	33.0	31.4	25.1	28.3	27.1	30.6
Ash	1.1	1.2	1.3	0.8	2.0	2.2	3.2	2.9	4.3
Total	94.9	95.8	96.0	96.4	98.8	96.0	96.8	97.7	99.0

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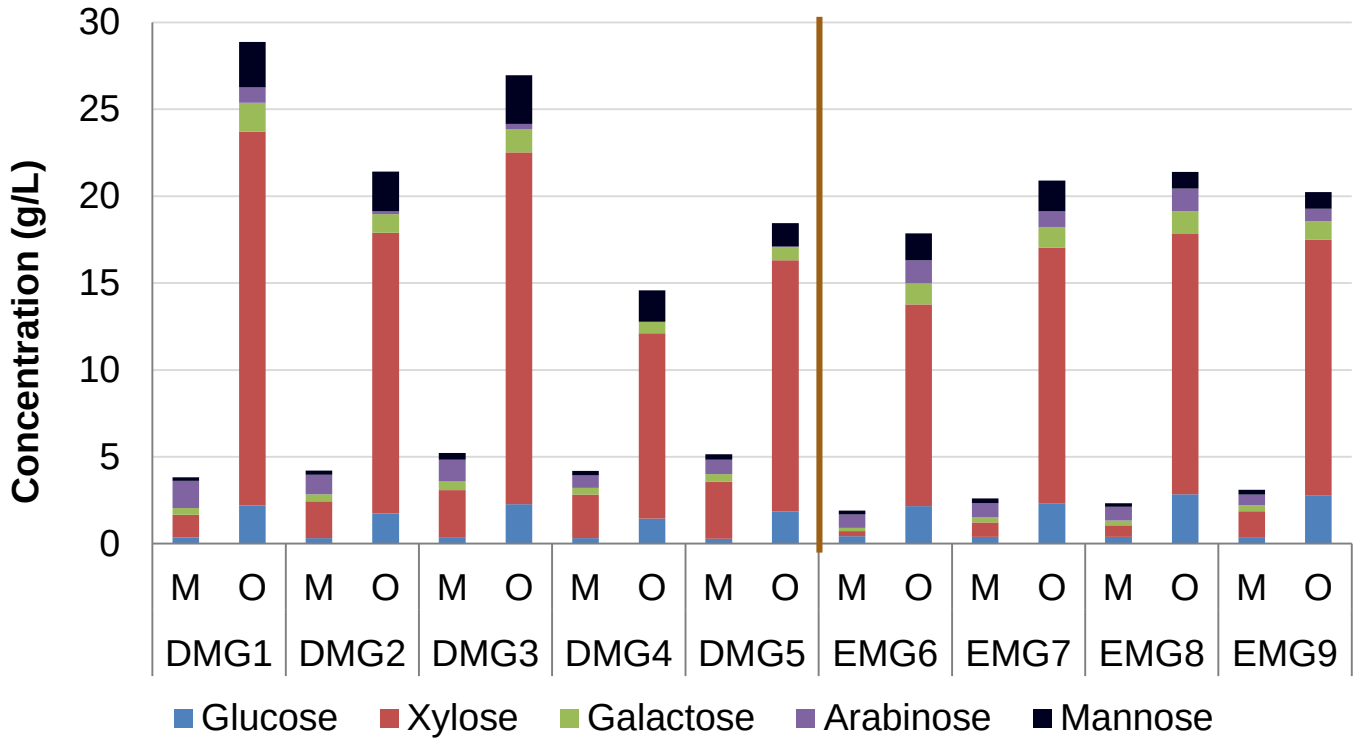
Sugar content in the liquid fractions of steam-pretreated DMG and EMG



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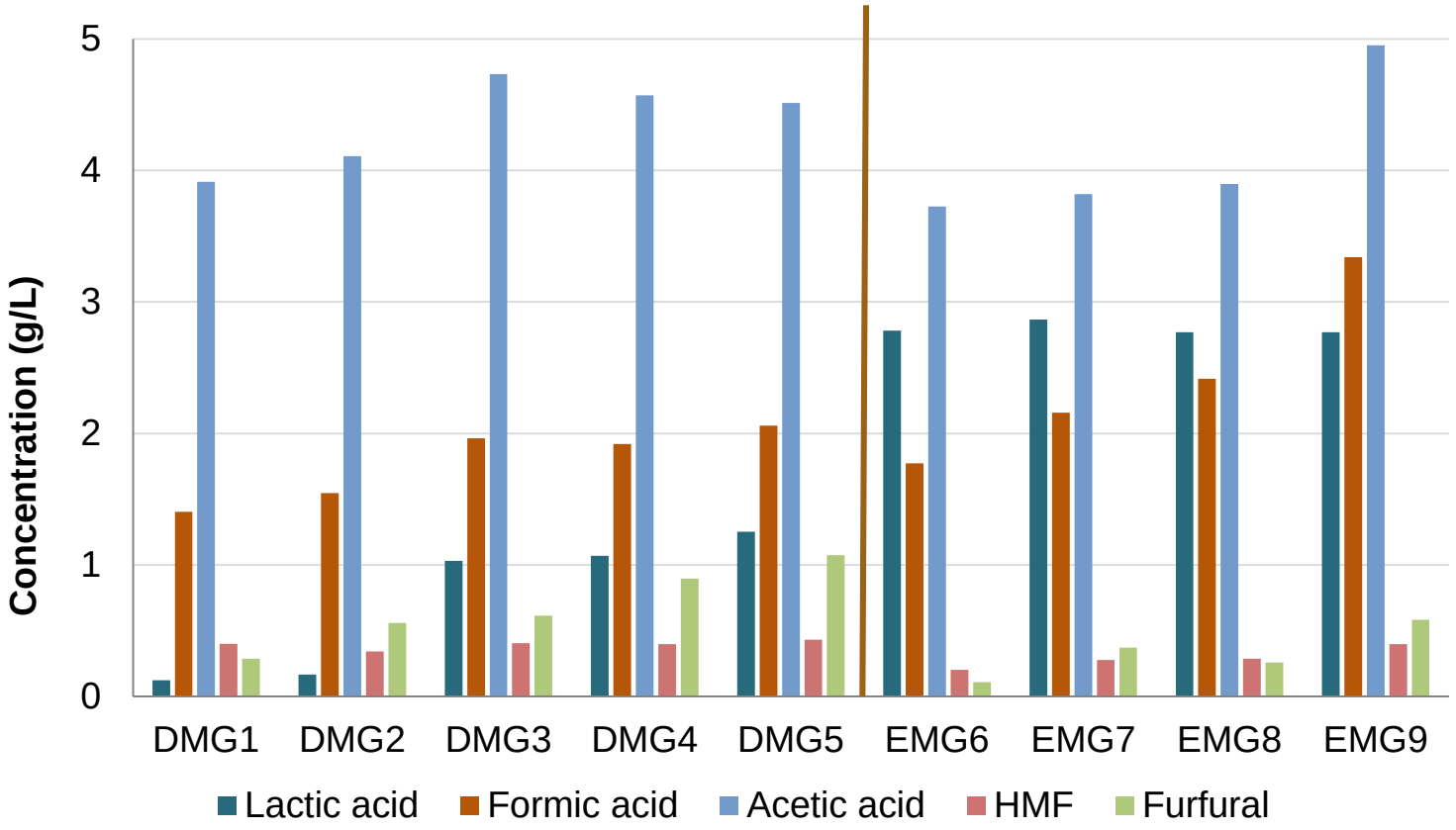
Concentrations of organic acids and sugar-degradation products in the liquids



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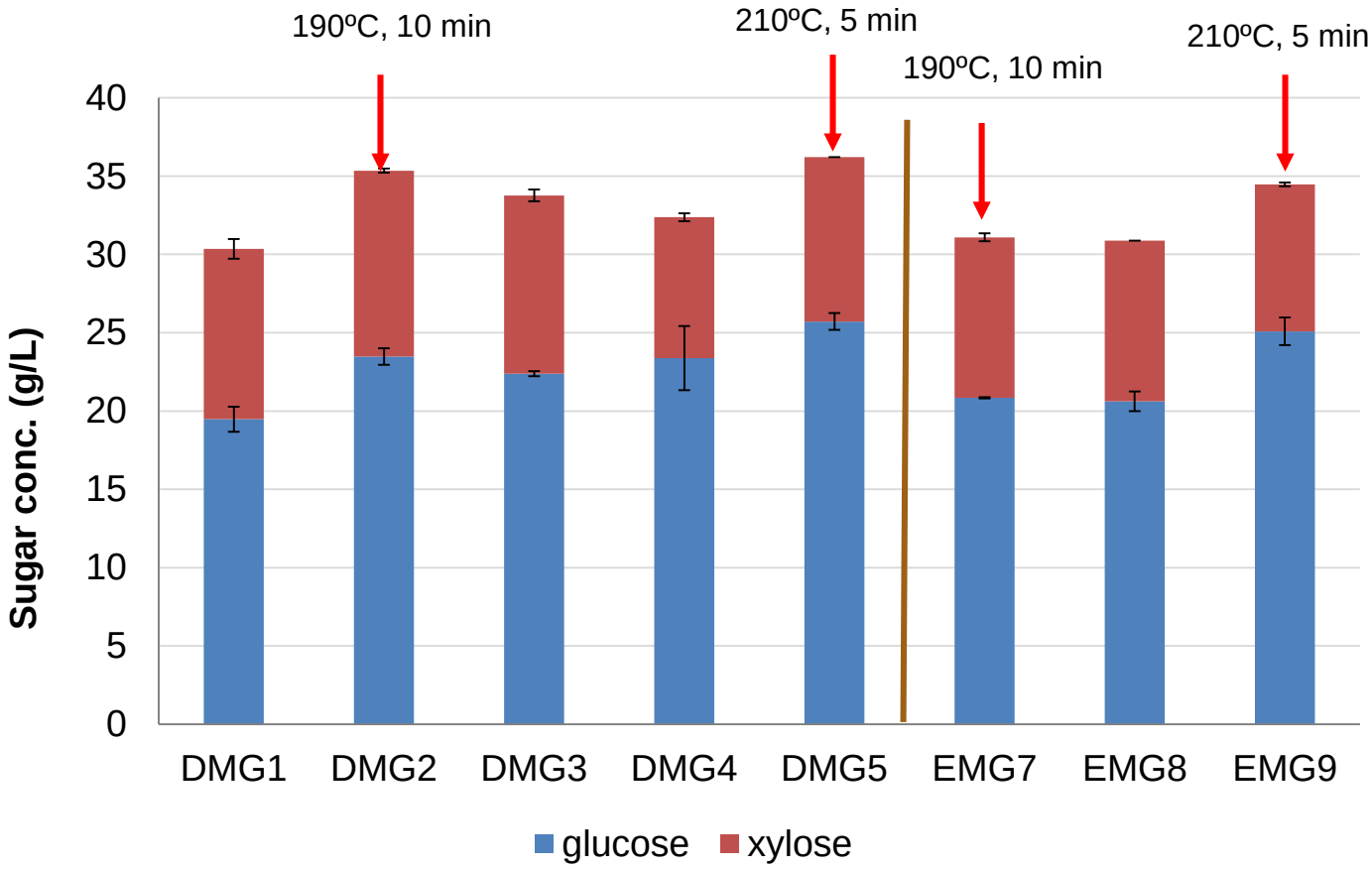
Enzymatic hydrolysis of steam-pretreated DMG and EMG



Conditions:

45ºC

pH 4.8

180 rpm

5% WIS

Enzyme: Cellic Ctec2 at 10 FPU/g WIS

96 hours

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Simultaneous Saccharification and Fermentation of DMG and EMG

Conditions:

35ºC, pH 4.8, 300 rpm, 96 hours

5% WIS

Enzyme: Cellic Ctec2 at 10 FPU/g WIS

Yeast: Ethanol Red at 5 g/L

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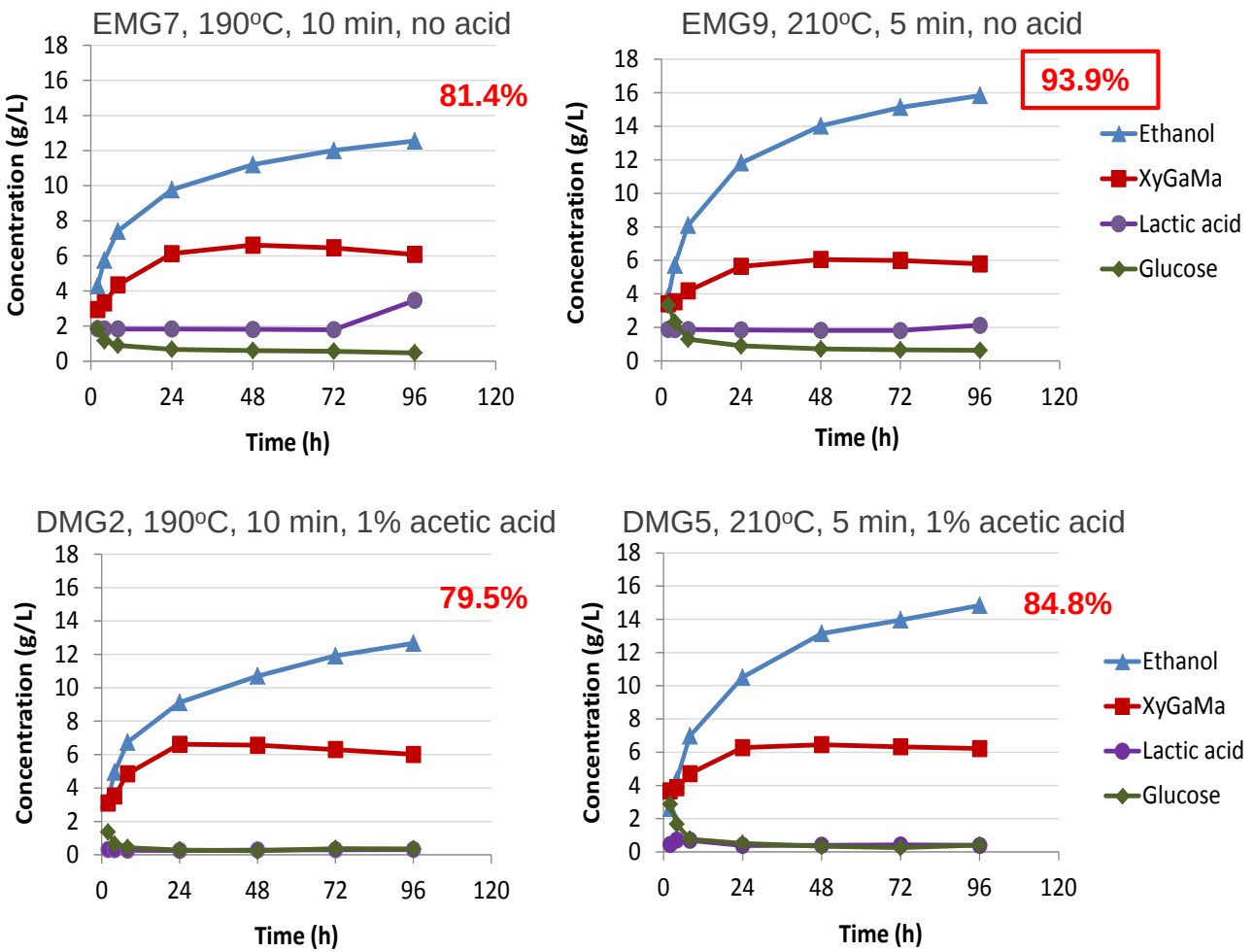
Higher ethanol concentrations on EMG Pretreatment at 210ºC is better

SSF at 5% WIS content



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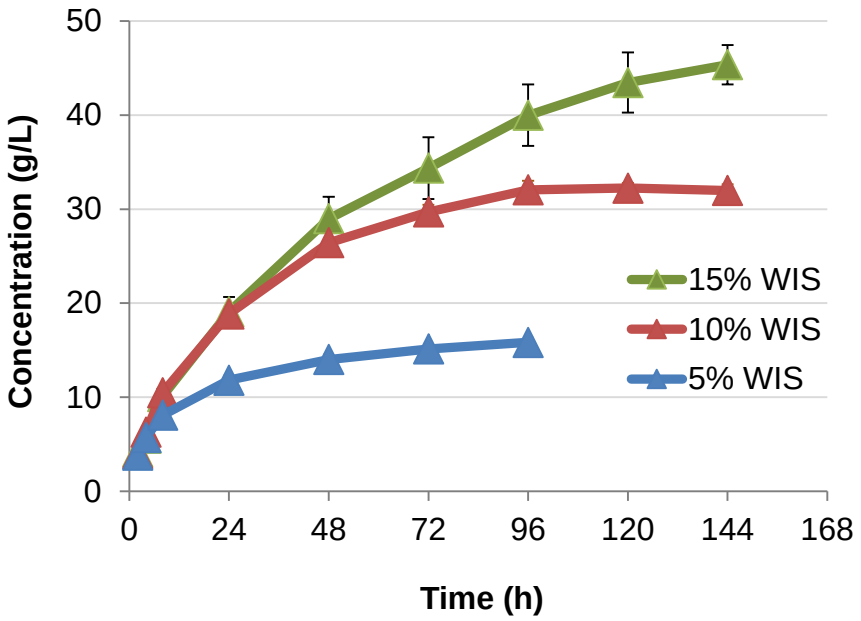
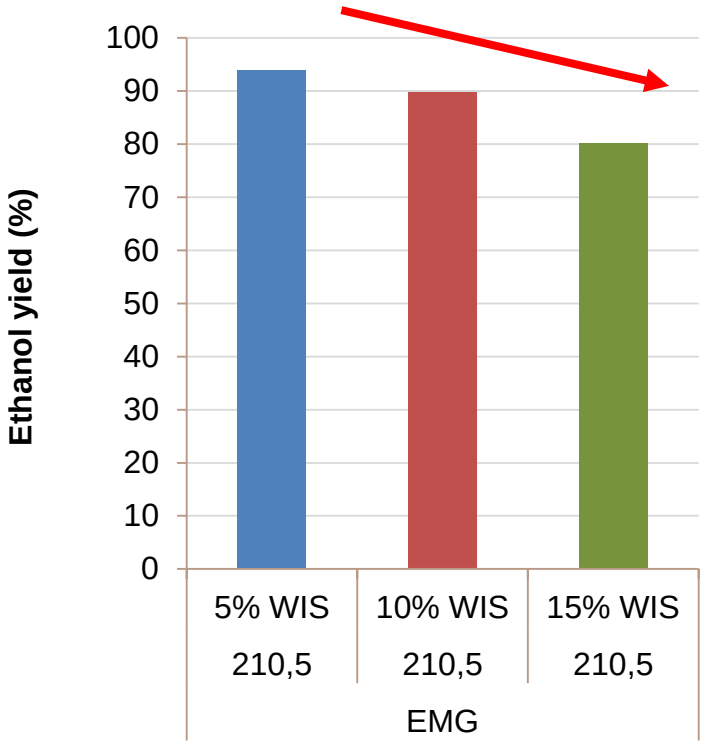
Increasing solids concentration in SSF of EMG to obtain at least 40 g/L ethanol





At 15% WIS:

45.4 g/L ethanol

80.2% yield in SSF

BUT: longer residence time needed

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Comparison of ethanol potential of DMG and EMG - Conclusions

- Better fermentability of steam-pretreated EMG than DMG

	DMG	EMG
Highest overall ethanol yield	156 g/kg DMG	163 g/kg EMG
Assuming 5% DM loss in ensiling		155 g/kg DMG
Assuming 10% DM loss in ensiling		147 g/kg DMG

- Ethanol potential of EMG is very similar to that of DMG
- Acid impregnation not needed for EMG, which is advantageous from an economical perspective

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