Can Cellulosic Fermentable Sugars Compete Economically Against Established Glucose Supply Chains?

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Recognized by many of the world’s major companies as experts, LMC provides business with strategic insights unavailable elsewhere.
As the bio-based chemicals industry emerges at a commercial scale, feedstock strategy has proven fundamental to economic success – yet even before the industry has had a chance to develop, questions and expectations are being asked…

➢ “Will your chemical production switch to second generation feedstocks?”

Often the answer given is:

“Yes. The plant will switch when it's economically feasible – in other words, the cellulosic fermentable sugar supply must be delivered at a price point compatible with carbohydrate sugars.”

With this strategy in mind, we ask if a future, mature 2nd generation sector can supply sufficient cellulosic sugars to meet both fuel & chemical demand? And in reliable commercial quantities and at competitive prices?
But why move away from 1\textsuperscript{st} generation materials? One driver is land use: 2002 world arable (oilseeds & grains) land area was comparable to 1980 – but demand growth then exceeded yield growth resulting in ~90 million new hectares being used between 2002-2013.

Other drivers include:

- Food vs. non-food & sustainability
- Feedstock diversification
- Belief in lower price &/or volatility
- End-user/consumer demands
- The biofuel experience
- Government polices
- Myths and legends…
Cellulosic Raw Materials – Wood & Residues: Supply, demand, competing end-uses, logistics, price
After examining numerous regions (in collaboration with Ecostrat), the 5 lowest cost woody biomass supply chains were identified – based on supply volumes and logistical infrastructure:

- **Canada – South BC Interior**
- **Scandinavia – South Finland**
- **Russia – Northwest Russia**
- **US – Mississippi/Alabama**
- **Brazil – Tocantins/Goiás**
Agricultural residues and their cost drivers:

• By 2030, under high yield scenarios, US corn stover supply could reach ~ 245 million dry tonnes – strong potential supply

• Residues tend to have a lower energy density than woody biomass – limiting their transport distance

• Whereas woody biomass is available all year round, residues must be stored – the exception being palm biomass

• The value of straw/stover is determined by its cost of collection and its nutrient replacement – however, where markets have developed, prices exceed these price points

• Principally, the value of bagasse and palm biomass are determined by their opportunity costs as electricity sources – particularly in Brazil
Cellulosic Biomass Processing Technologies & Costs: Gasification, Pyrolysis & Enzymatic Hydrolysis
Cellulosic sugar production costs, for a US standalone hydrolysis plant, are projected to fall by 35% between 2012-2025 – largely based on cheaper enzymes.

**Note:** Based on a fixed price for delivered biomass of $65 per bone dry tonne.
Comparing estimated ethanol production costs, on an ethanol equivalent basis, cellulosic hydrolysis should be competitive with gasification and pyrolysis.

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So? Can cellulosic sugars be cost competitive with glucose?
Fermentable sugar yields from corn (wet milling) are ~1.5X higher today than from corn stover hydrolysis – this yield differential should narrow over time as shown by plotting sugar yields from both corn (blue) & corn stover (yellow).

However, no matter advancements in biomass process technology, 1st gen fermentable sugar yields will exceed their 2nd gen counterparts because of raw material stoichiometric differences.
To rank fermentable sugar production costs, it is necessary to determine their production cost profiles, which differ significantly between 1\textsuperscript{st} & 2\textsuperscript{nd} generation processes – as shown here for the US.

1\textsuperscript{st} Gen: Fermentable sugar cost profile (corn, wet milling)

2\textsuperscript{nd} Gen: Fermentable sugar cost profile (corn stover, enzymatic hydrolysis)

Burning lignin by-products provides energy self-sufficiency for enzymatic hydrolysis.
By forecasting (2025) raw material, logistics and processing costs before benchmarking against projected glucose costs, we can conclude certain 2nd gen strategies should be highly competitive.

US$ per dry tonne of biomass sugars or glucose

- First generation glucose
- Second generation biomass sugars
Final thoughts…

supply chains, integration, logistics, trade, competition
Implications for the bio-based chemical sector as the cellulosic ethanol industry commercialises:

- Initial capacity is based primarily on hydrolysis – potentially creating cellulosic sugar volumes which can be diverted towards chemicals & aid in the technology commercialisation.
  - Cellulosic ethanol uses a subsidy/mandate as it competes against gasoline/glucose-derived ethanol, hence its outlook could change as political support weakens in the US & EU – creating opportunities for chemicals perhaps?
  - The old adage: why make a $1 fuel when you can make a $5 chemical?
2nd gen supply chain strongly favours downstream production at source – creating barriers for an imagined merchant market supplying plants located anywhere

- Processing biomass is expensive and renders otherwise cheap raw materials more costly
- Frequently, biomass prices will be determined by alternate values, such as power generation or animal feed, increasing the price above the collection cost
- Logistics costs add significantly to the delivered cost of biomass
- The most promising cellulosic feedstocks are Brazilian bagasse & US corn stover with processing local to raw material source – arguably downstream to the final chemical material
Outlook for 1st gen feedstocks: The main challenge facing global agriculture is growing crop demand from income growth & government-backed biofuel demand – but:

• If demand grows too fast to avoid sustained price increases, demand will slow:
  
  • Higher crop prices dampen income growth & thus weakens demand for some foods
  
  • Biofuel programmes are government led – can be rolled back if demands on agriculture are too high

• Crucially, agricultural demand is reactionary – the outlook for one crop is outlook for all (possibly not palm)

• However, currently, there are sufficient supplies to meet demand if the industrial consumer can afford a price point set by subsidised biofuel players
A final shout out to some of the companies active in the commercial development of second generation cellulosic sugars:
Thank you for your kind attention

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• Carbohydrate Outlook: Prices & Processing Costs
• Global Markets for Starch & Fermentation Products
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• The Global Market for Industrial Ethanol
• The Global Sugar Outlook – including life after EU sugar quotas
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