Does densification (pelletisation) restrict the biochemical conversion of biomass?

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Outline

* Steam pretreatment – A compromise

  (Hemicellulose recovery/good cellulose hydrolysis)

* Steam pretreatment stabilises pellets

  (Enhances durability/stability)

* Does pelletisation restrict bioconversion?

* Steaming enhances pellet properties and allows its ready bioconversion to sugars

UBC-SO_2 Catalyzed Steam pretreatment

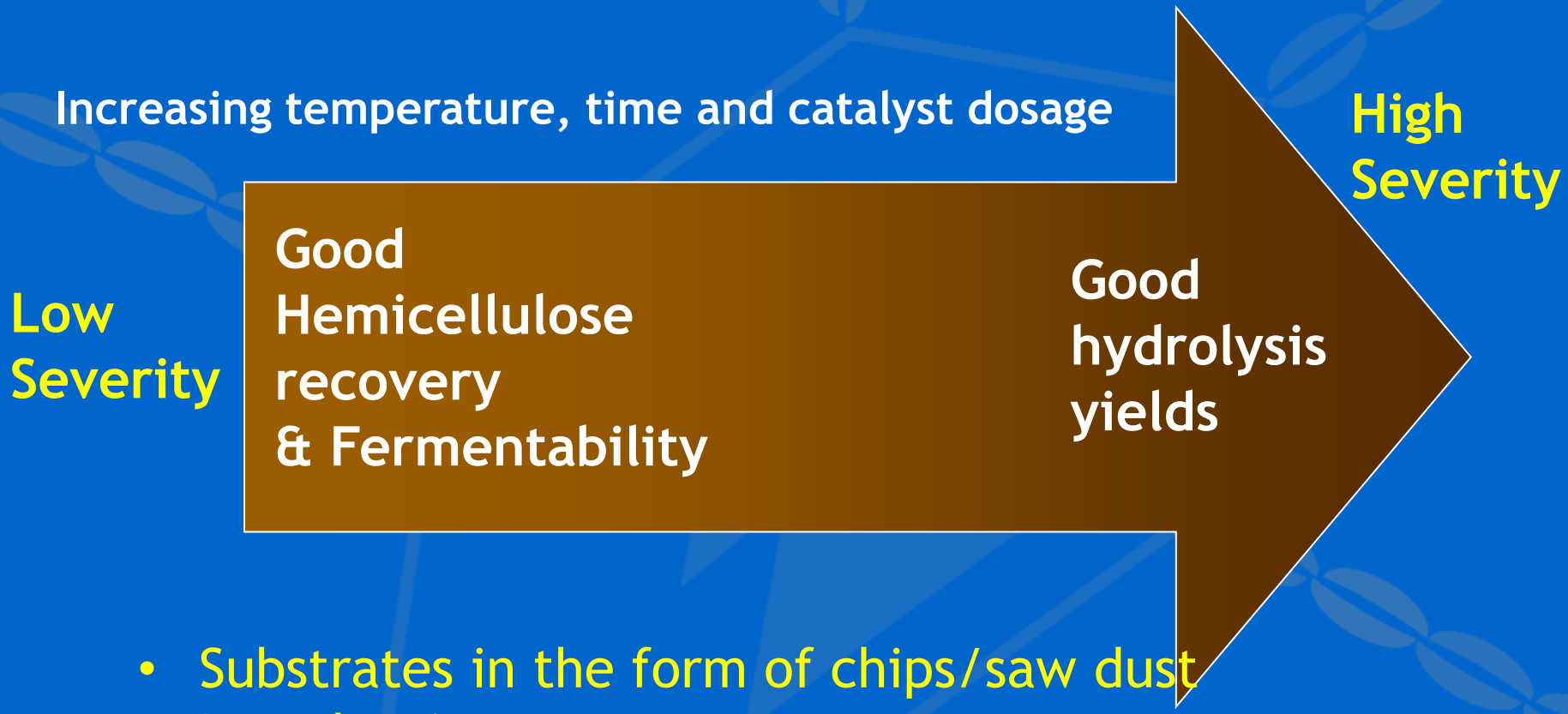
UBC-FPB research for the past 30 years

- Limited chemical and energy consumption
- Hemicellulose recovery
- Increases cellulase accessibility
- Pulp chips typically used as a substrate

SO_2 Impregnation

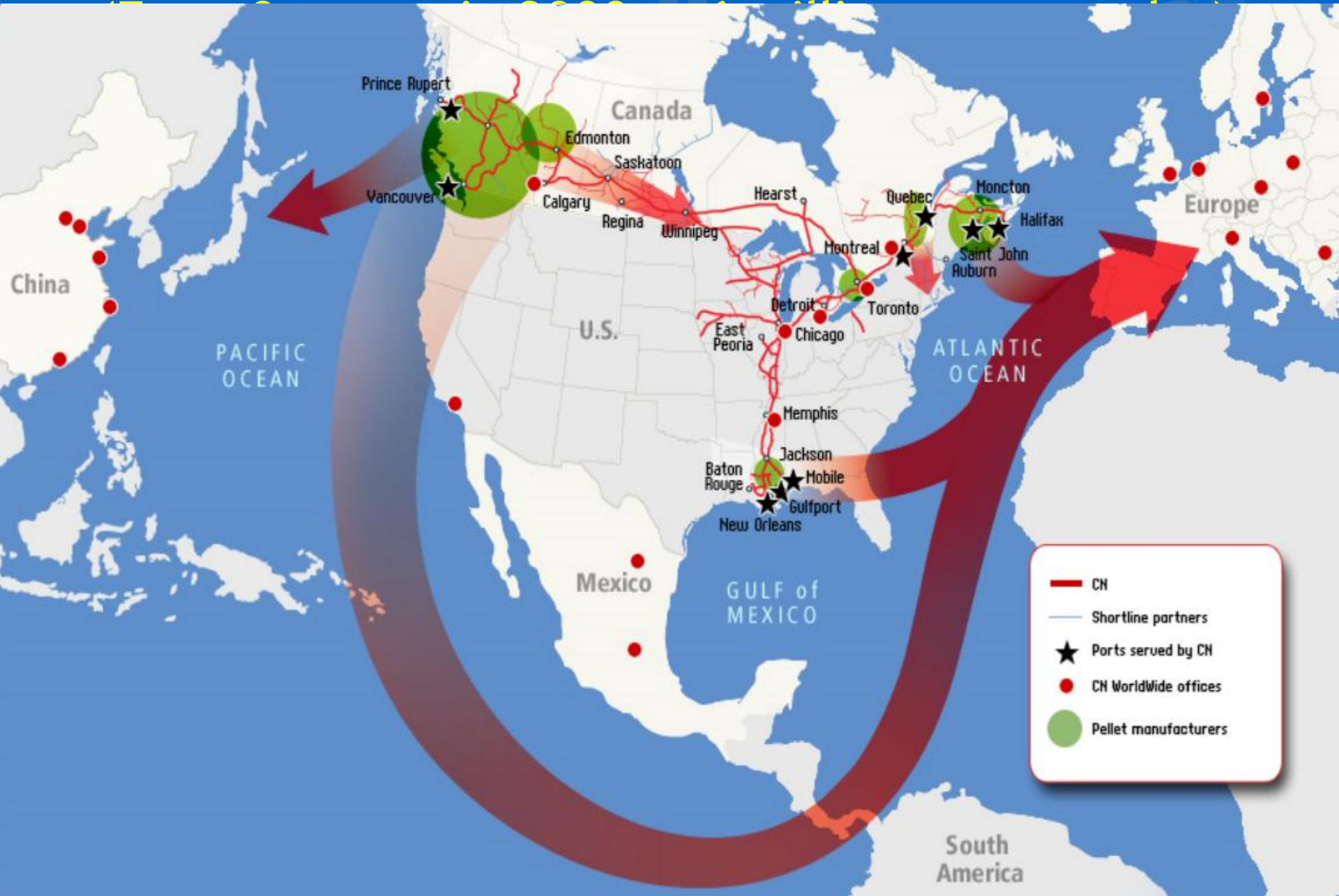
- Lower treatment temperatures and reaction times
- Improves hemicellulose recovery
- Softwood hemicellulose can be fermented directly
- Cellulosic component readily hydrolysed

Pretreatment: A Compromise



- Substrates in the form of chips/saw dust
- Low density
- Cannot be transported for long distances
- For economies of scale, plants of >2000 tonnes/day

Pellet production and export in North America



Biomass pellets are used for heat and electricity generation

Pelletisation process

- Applying pressure to force the raw material through the holes of the die
- Pressure and friction increases the temperature of the material (90 – 120°C) which is above the Tg of lignin
- Lignin softens and acts as a binder to compact the material

Wood pellets as a tradable biomass commodity

- **Densified biomass**
  - Higher bulk density and transportable commodity (600 – 700 kg/m^3 compared to 150 – 200 kg/m^3 for wood chips)
- Heating value is important for thermal applications
- **Primarily used for combustion (residential and industrial)**
- **Also used for combined heat and power (CHP)**
- **Co-firing without the need for significant retrofit to coal fired power plants**

Lower stability of the pellets is a major challenge in the pellet industry

Collaboration with Prof. Shahab Sokhansanj, BBRG, UBC

- Disintegration & generation of fines lead to loss of material during transport and storage
- Broken pellets aggravate problems with dust explosion and increase fire risk
- Water absorption, subsequent disintegration, and microbial growth
- **Pellets need improved stability for long term storage and transport and pre-steaming could be a solution!**

Research questions/approach

1. Does pre-steaming enhance pellet properties?
2. Does densification result in the loss of hemicellulose sugars ?
3. Does the cellulose become more difficult to hydrolyse (Hornification, fibre collapse, lignin restricting accessibility)?

(We anticipated pellets would be worse for bioconversion; We were wrong!)

Approach to increase the pellet durability

Drying

↓

Grinding

↓

Pelletisation

Steam pretreatment

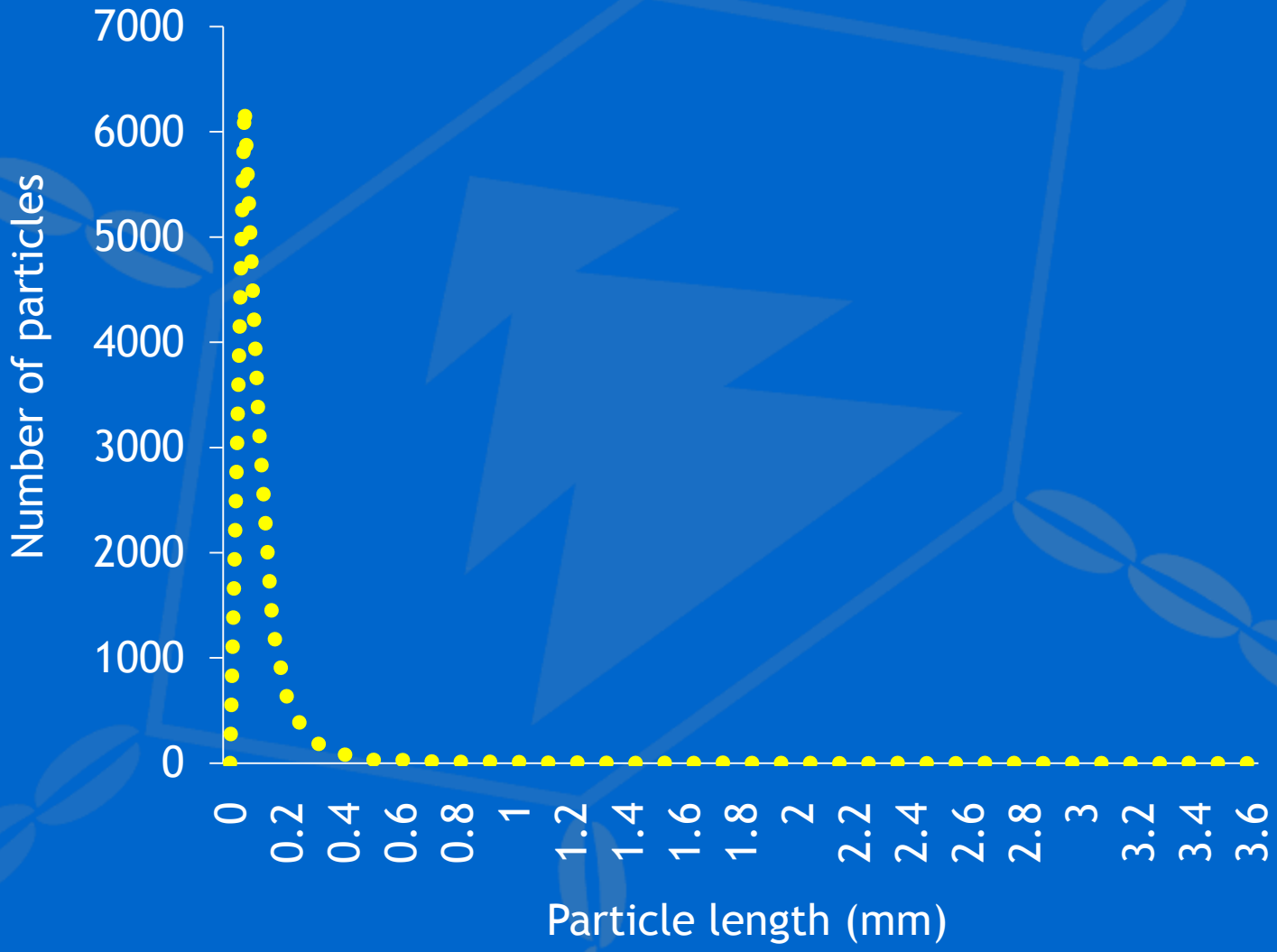
↓

Drying

↓

Pelletisation

SO_2 catalysed steam pretreatment significantly reduced the particle size to enable a direct pelletisation



Steaming increased the mechanical strength and durability of the pellets

	Pellet density (g/cm^3)	Max. breaking force (N)	Compression energy ($J.cm^3/g$)	Expulsion energy ($J.cm^3/g$)
Untreated	1.21 (0.01)	684.8 (104.4)	22.4 (1.7)	6.6 (3.3)
Steam stabilized	1.34 (0.01)	1341.6 (168.8)	17.9 (2.7)	3.9 (2.1)

Regular pellets

Steam stabilized pellets

Research questions/approach

1. Does pre-steaming enhance pellet properties? Yes!
2. Does densification result in the loss of hemicellulose sugars ?
3. Does the cellulose become more difficult to hydrolyse (Hornification, fibre collapse, lignin restricting accessibility)?

Pelletisation did not significantly degrade the carbohydrates present in steam pretreated softwood

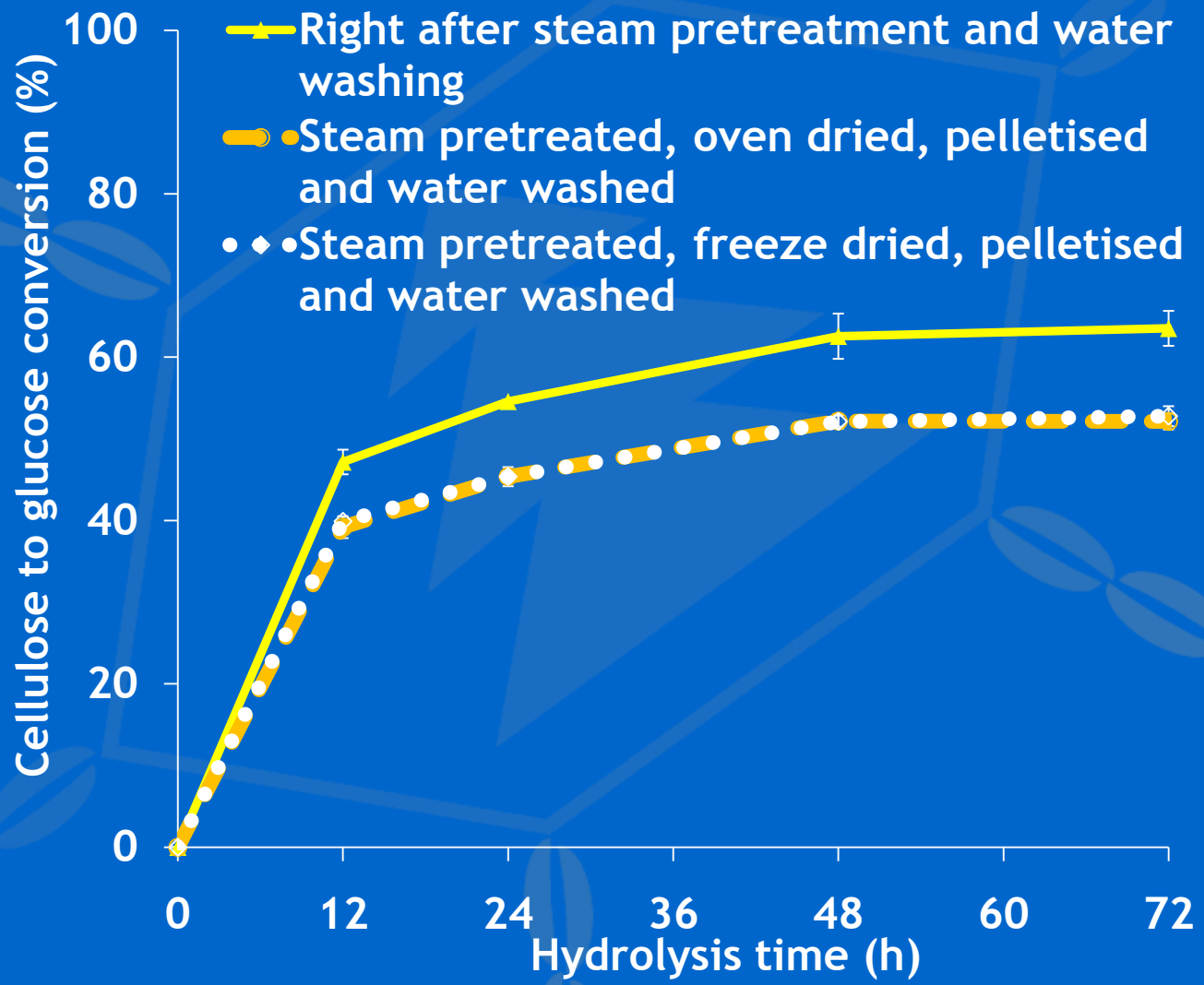
	Hemicellulosic sugars	Glucan	Lignin
Untreated wood chips	19.5 (0.4)	47.3 (0.4)	29.8 (0.8)
Steam pretreated substrate	13.3 (0.3)	44.1 (0.7)	32.1 (0.2)
Steam pretreated, dried and pelletised	13.0 (0.6)	45.2 (0.8)	30.4 (0.9)

Research questions/approach

1. Does pre-steaming enhance pellet properties? Yes

2. Does densification result in the loss of hemicellulose sugars ?
   Not really!
3. Does the cellulose become more difficult to hydrolyse
   (Hornification, fibre collapse, lignin restricting accessibility)?

Enzymatic hydrolysis of the cellulosic component of steam stabilised pellets



Conclusions

- Steam pretreatment of wood chips resulted in significant size reduction to enable a direct pelletisation without a further size reduction step
- Steam pretreatment increased stability and durability of the pellets
- Pelletisation did not result in the significant loss of hemicellulosic sugars
- Cellulosic component in the pellets could be as readily hydrolysed as steam pretreated pulp chips

Future considerations

- For economies of scale, future cellulosic biofuel plant will likely require densified biomass as one of the substrate options
- Preliminary work using softwood derived pellets indicate that majority of the hemicellulose and cellulose sugars can be recovered.
- It is likely that agricultural and hardwood derived pellets will be even more readily converted
- Steam pretreatment enhances both pellet properties (durability) and acts as pre-processing step in a steam pretreatment-biomass-to-ethanol process

Thank You!, Questions?