Testing of Norris Thermal Technologies Pilot Scale Torrefier at Big Lagoon, CA

Mark Severy
Research Engineer
Schatz Energy Research Center
Humboldt State University

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Outline

1. Testing Background
2. Reactor Temperature Profile
3. Results: Torrefied Biomass Characteristics
4. Conclusions
5. Lessons Learned from Testing

Torrefaction Testing Site

- » Old mill in Big Lagoon, CA
- » July – August 2015
- » Tested with multiple feedstocks
- » Feedstocks obtained from nearby forests

Torrefaction Testing Site

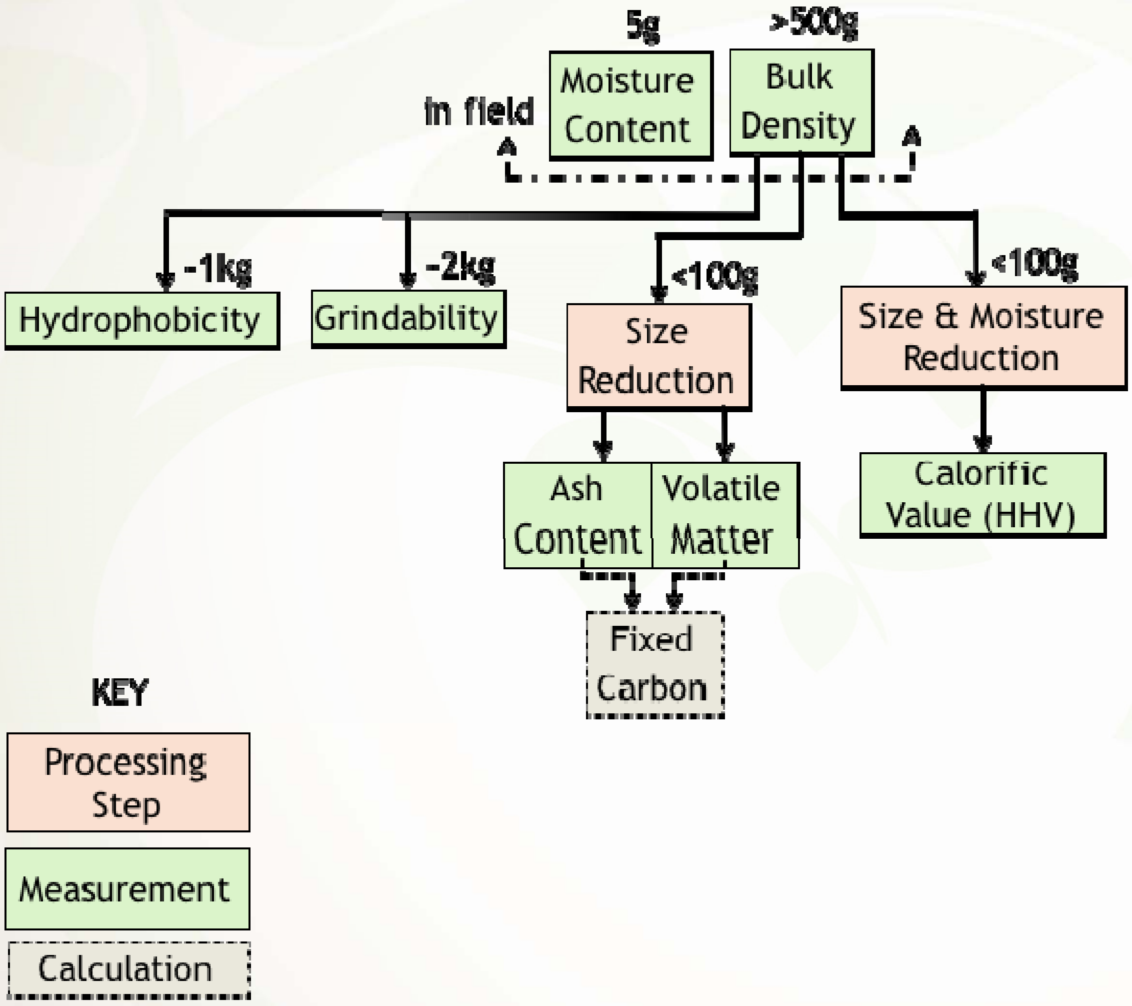
- Test Objectives:
  - Understand pilot scale unit to inform construction of larger torrefier
  - Feedstock tolerance
  - Product characterization
  - Mass and energy balance

Test Matrix

Tests were conducted with various feedstocks at different residence times and reactor temperatures.

Species	Douglas Fir		Redwood		Tan Oak		Slash	
Comminution Method	Chipped & Screened		Chipped & Screened		Chipped & Screened		Chipped & Screened	
Contaminant	none		none		none		none added	
Moisture Content	4-9%	10-27%	3-9%	18-32%	4-7%	~11%	6-7%	10-15%
Residence Time (min)	3 - 6	8 - 15	6	8	6	8	6	8
Target Temp. (ºC)	300	400	300	350	300	400	300	400

Torrefaction Lab Analysis Plan



5g

Moisture Content

>500g

Bulk Density

in field

~1kg

Hydrophobicity

~2kg

Grindability

<100g

Size Reduction

<100g

Size & Moisture Reduction

Ash Content

Volatile Matter

Calorific Value (HHV)

Fixed Carbon

KEY

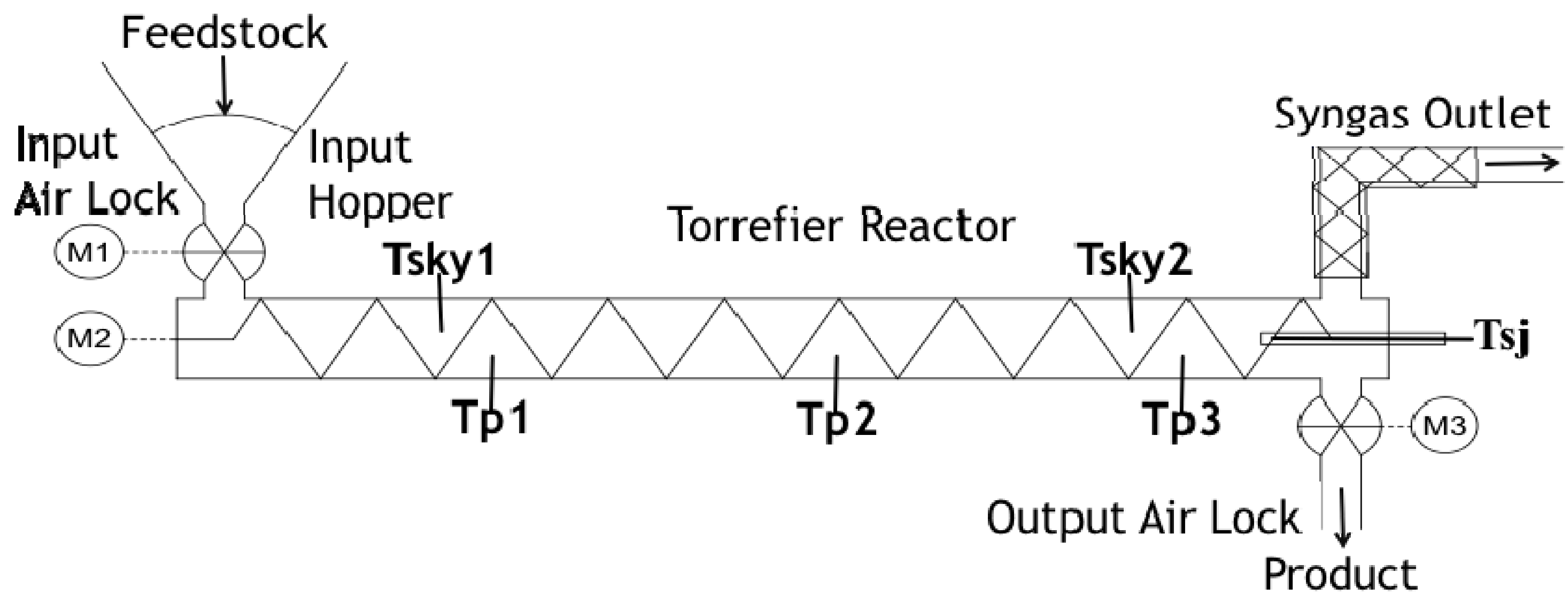
Processing Step

Measurement

Calculation

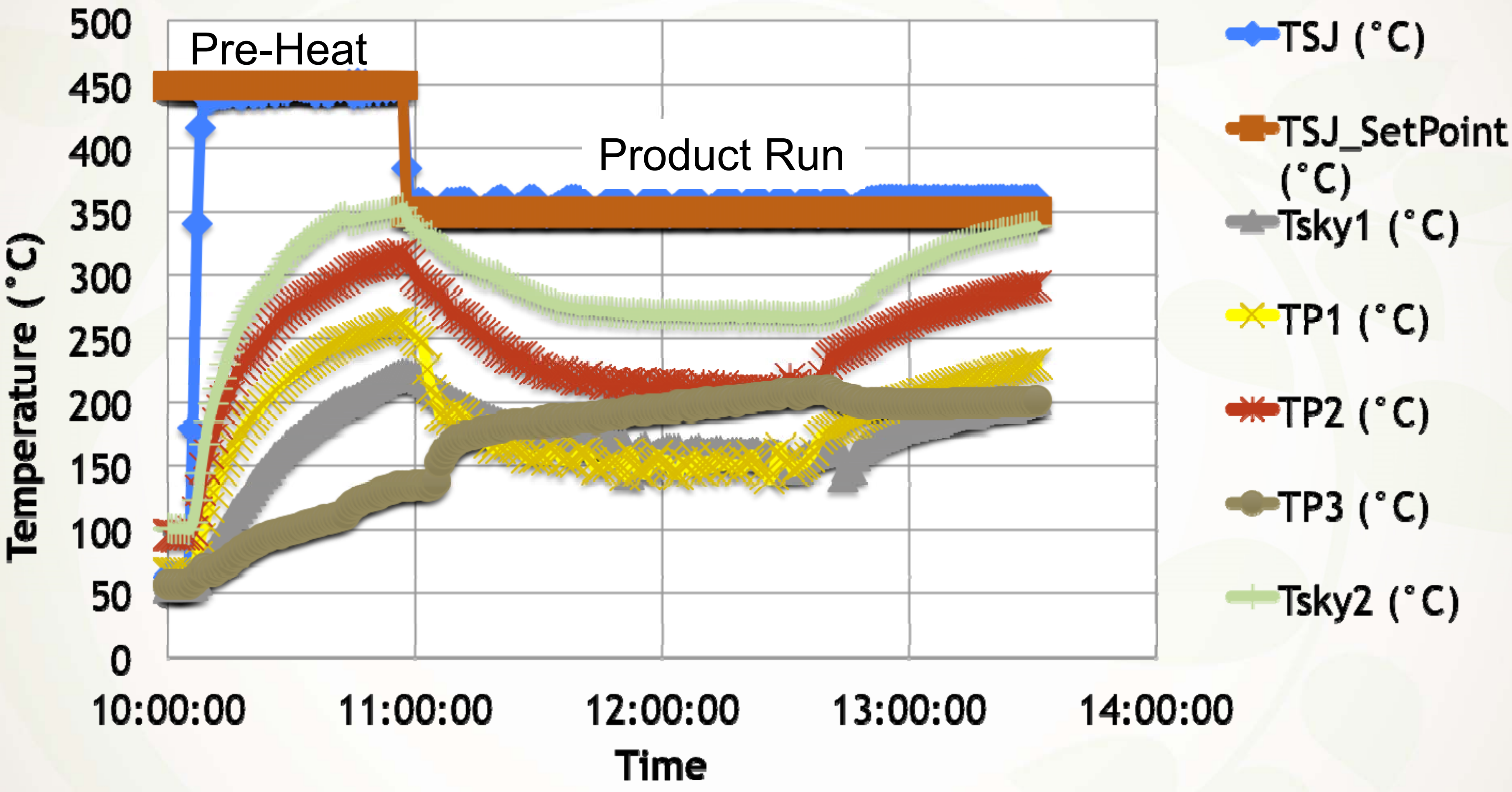
Process Instrumentation and Material Flow

- » Torrefaction Partner: Norris Thermal Technologies
- » Technology: Pilot Scale Pyrolytic Screw
- » Screw length: ~160 cm



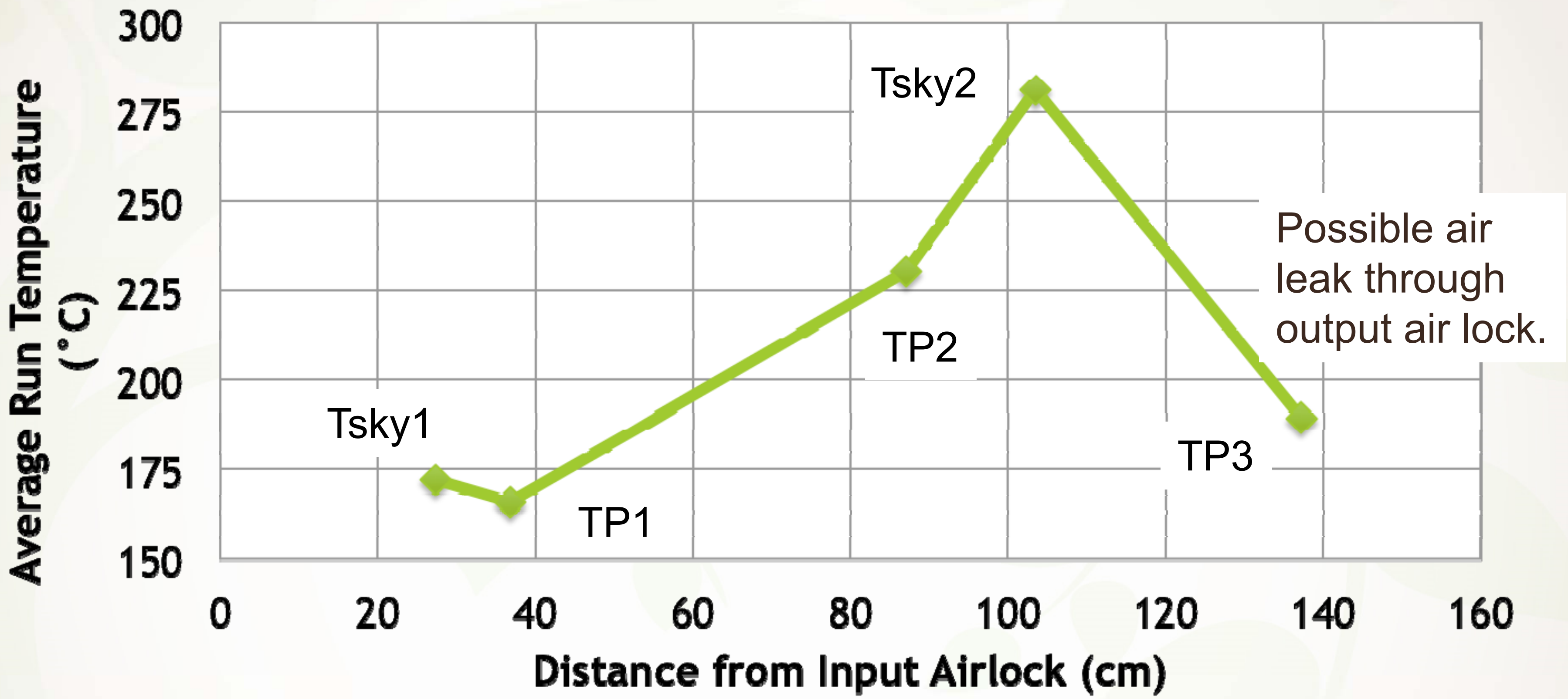
Reactor Temperatures versus Time

Reactor temperatures vary with time and position.

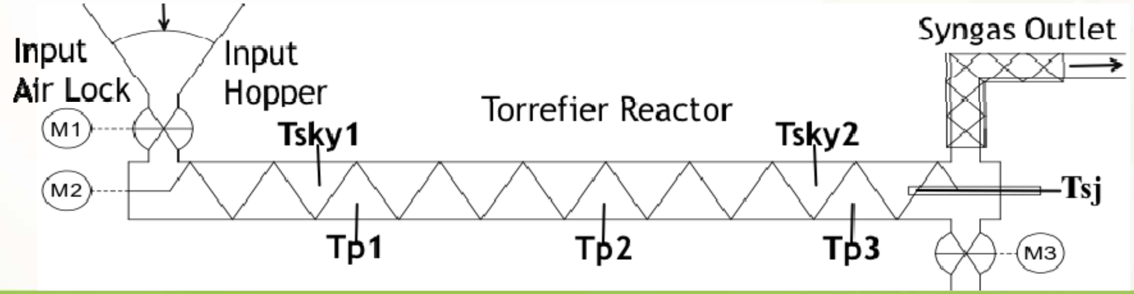


Test data for slash feedstock at 7% moisture with 6 minute residence time at 350 ºC.

Reactor Temperature Profile

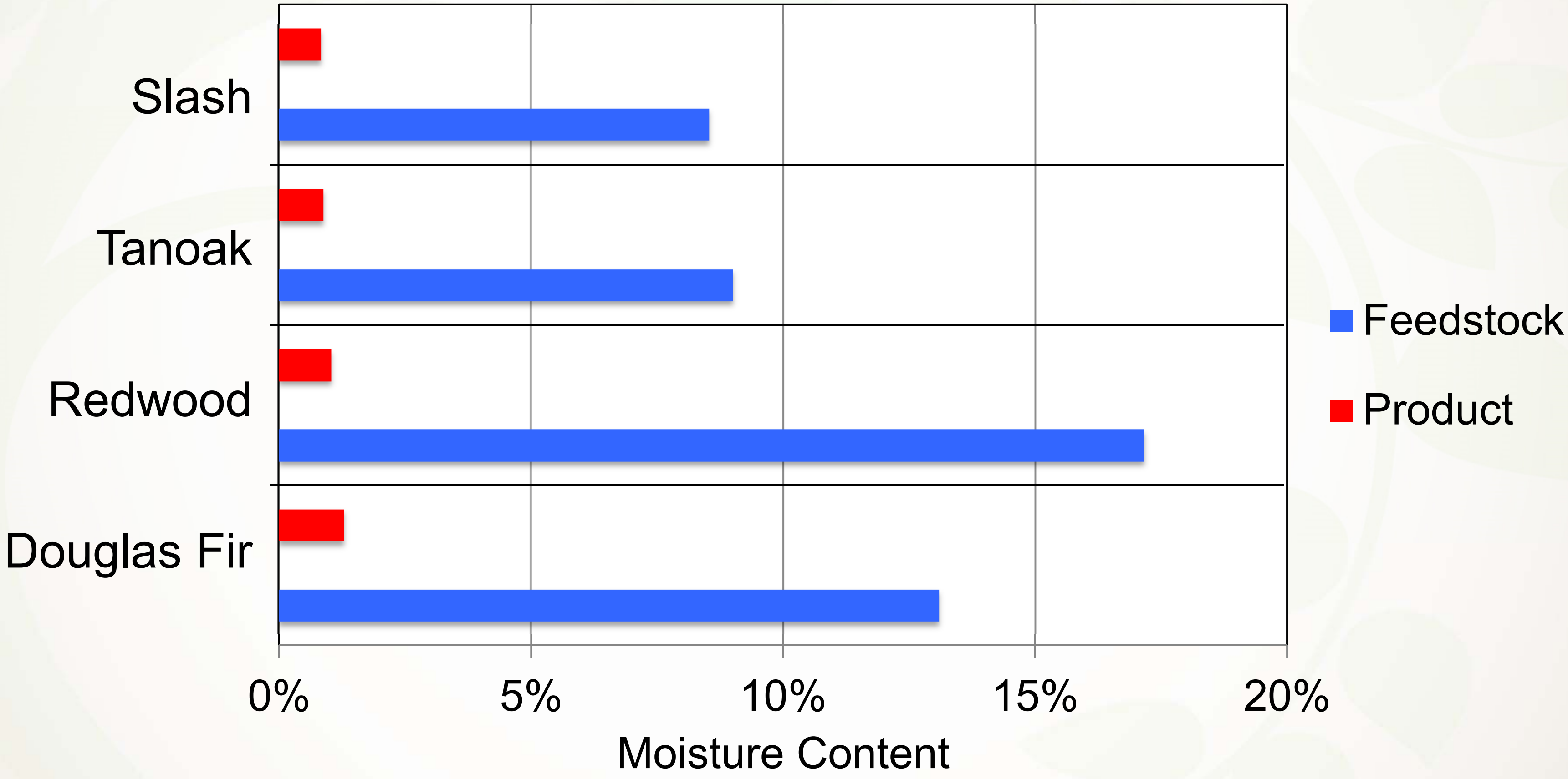


Possible air leak through output air lock.



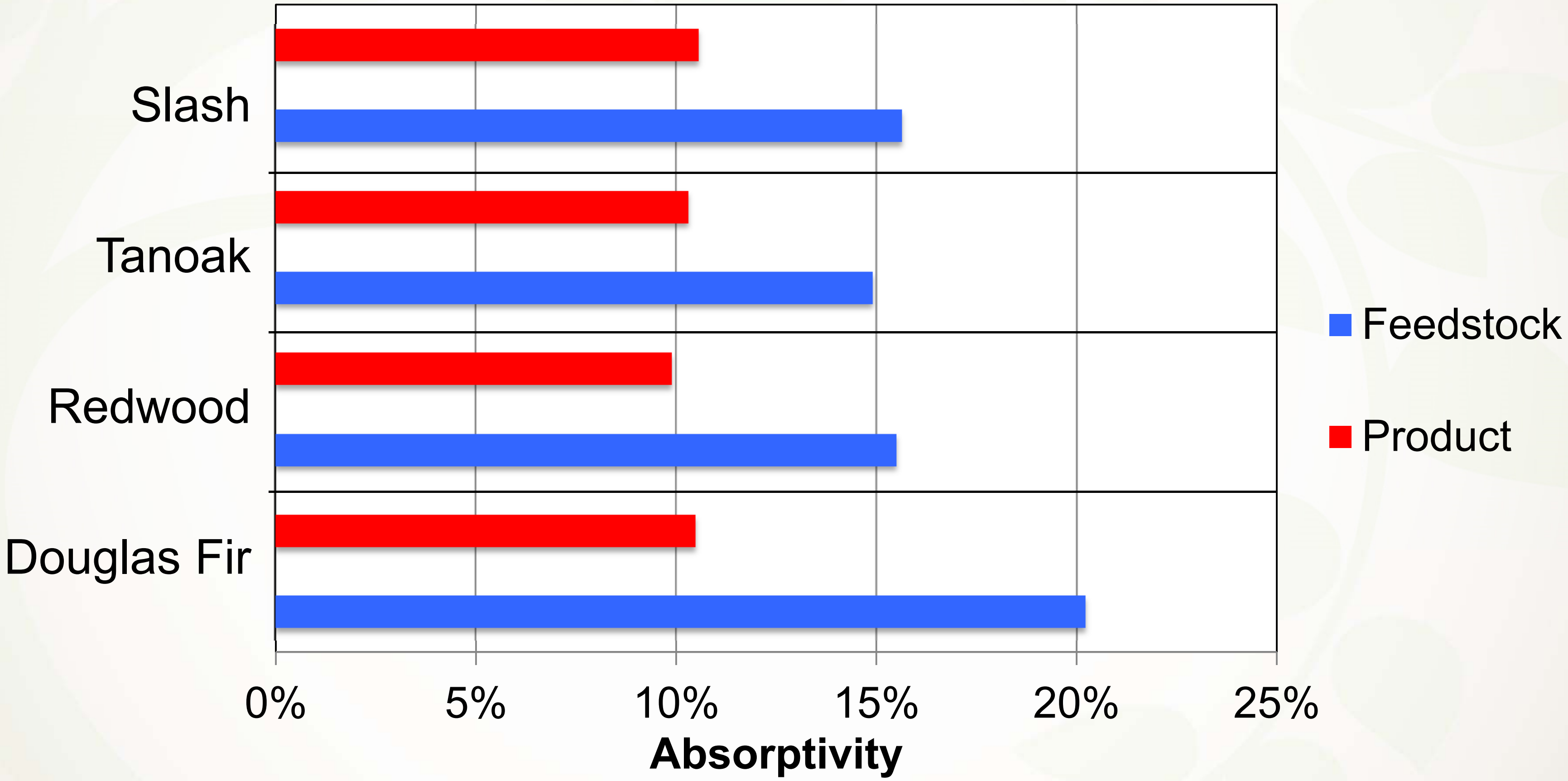
Moisture Content

Product moisture content averaged 1%.



Water Absorptivity

Product absorptivity averaged 30-50% lower than feedstock



Energy Density of Torrefied Biomass

Higher heating value of torrefied biomass varies with residence time, reactor temperature, and species

Variable	Units	Estimate	Standard Error	t	p	Lower Limit 95%	Upper Limit 95%
Douglas Fir	MJ/kg	7.74	2.04	3.80	0.058%	2.96	12.52
Tan Oak	MJ/kg	8.45	1.94	4.36	0.012%	3.90	13.00
Redwood	MJ/kg	9.21	1.87	4.91	0.002%	4.81	13.61
Slash	MJ/kg	8.46	1.97	4.29	0.015%	3.83	13.10
Tsky2	(MJ/kg)/K	0.0333	0.0060	5.58	0.0003%	0.0193	0.0474
Residence Time	(MJ/kg)/min	0.347	0.102	3.39	0.18%	0.107	0.588
Moisture Content	(MJ/kg)/%	4.22	2.28	1.85	7.32%	-1.13	9.58

Yield Rate

Yield rate influenced by reactor temperature and species.

Variable	Units	Estimate	Standard Error	t	p	Lower Limit 95%	Upper Limit 95%
Douglas Fir	-	1.93	0.17	11.45	4.9E-13	1.54	2.33
Tan Oak	-	1.82	0.16	11.36	6.1E-13	1.45	2.20
Redwood	-	1.90	0.16	12.20	9.0E-14	1.53	2.26
Slash	-	1.88	0.16	11.46	4.8E-13	1.49	2.26
Tsky2	1/K	-0.0036	0.0005	-7.26	2.5E-08	-0.0048	-0.0024
Residence Time	1/min	-0.0090	0.0085	-1.06	30%	-0.029	0.011
Moisture Content	1/%	-0.22	0.19	-1.15	26%	-0.66	0.23

Conclusions

- Pilot system can process 120 kg/day with moisture content up to 25%.
  - New system designed to process 16 ton/day.
- Electrical demand is approximately 1 kWh/kg of feedstock for heating.
  - New system may have lower specific energy demand due to decreased reactor length to throughput ratio.

Lessons Learned

» Torrefier intolerant of larger particles > 1” due to bridging in the hopper.

  » Feeding system is redesigned to widen the range of acceptable feedstocks.

» Air locks leaked excess oxygen into the reactor causing combustion.

  » New system includes improved air locks and automated control to maintain neutral pressure in the reactor.

» Temperature control thermocouple was inadvertently electrically heated.

  » New system insulates the thermocouple from electrical heating.

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