Achieving circularity in the mushroom industry: Biochar production from spent mushroom substrates

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4pm to 4:25 pm on 2/13/2024

Team members

Rochester Institute of Technology (RIT)

- Harshal J. Kansara
- Yvan D. Hernandez-Charpak
- Madan M. Manipati

} Students

- Tom A. Trabold (Research professor, Principal Investigator)

Empire Medicinals (Rochester, NY)

- Christoper Carter (VP and Board member)
- Luke Luft (Lead mycologist) and Team

Biomass Controls (Woodstock, CT)

- Jeff Hallowell (Founder and CEO)
- Robert Aldi (Engineer)

Problem

160 t/year spent mushroom substrate (SMS) landfilled by Empire Medicinals every year. Expected to increase to ~1800 t/yr over next 3-5 years.

Proposed circular solution

SMS collected

Mushroom grown

Excess Heat

Pyrolysis

Biochar recycled

Excess Biochar

Culinary mushrooms selected

Hericium Erinaceus

Lion's Mane (LM)

Pleurotus Ostreatus

Blue Oyster (BO)

Pyrolysis System

Biogenic refinery (Biomass Control PBC)

INSTALLED SINCE 2018

FLUE GAS FLOW

FORCED AIR HEAT EXCHANGER

CATALYST UNIT

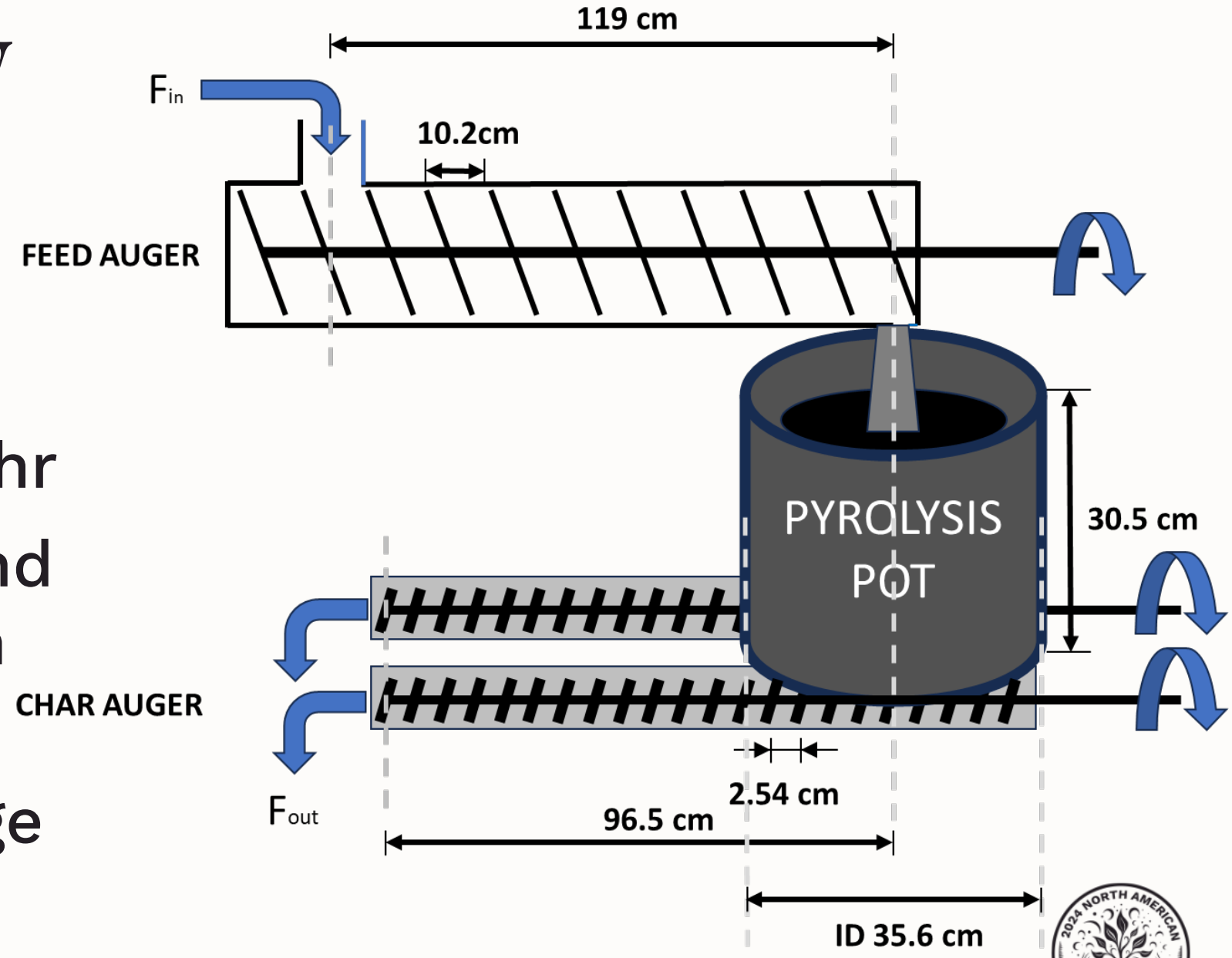
PYROLYSIS POT

CHAR BOX

POWERED BY FEEDSTOCK ENERGY

Material flow

- Maximum substrate feed F_{in} ~ 50 kg/hr
- Maximum biochar output F_{out} ~13.1 kg/hr
- Actuators control and data logging through internet
- Total residence range 30-115 min



Side view of Biogenic Refinery (BR) at RIT since 2018

RIT team in action

Pyrolysis of SMS

Pyrolysis trial details

- 50 kg SMS prepped for each –
  - Blue Oyster SMS
  - Blue Oyster SMS+ 4% (dry w/w) HDPE
  - Lion's mane SMS
- Process steps -
  - Debagging and drying (~35% final H_2O)
  - Grinding (<1 mm)
  - Moisture test
  - Pyrolysis

Madan M. cools fresh biochar

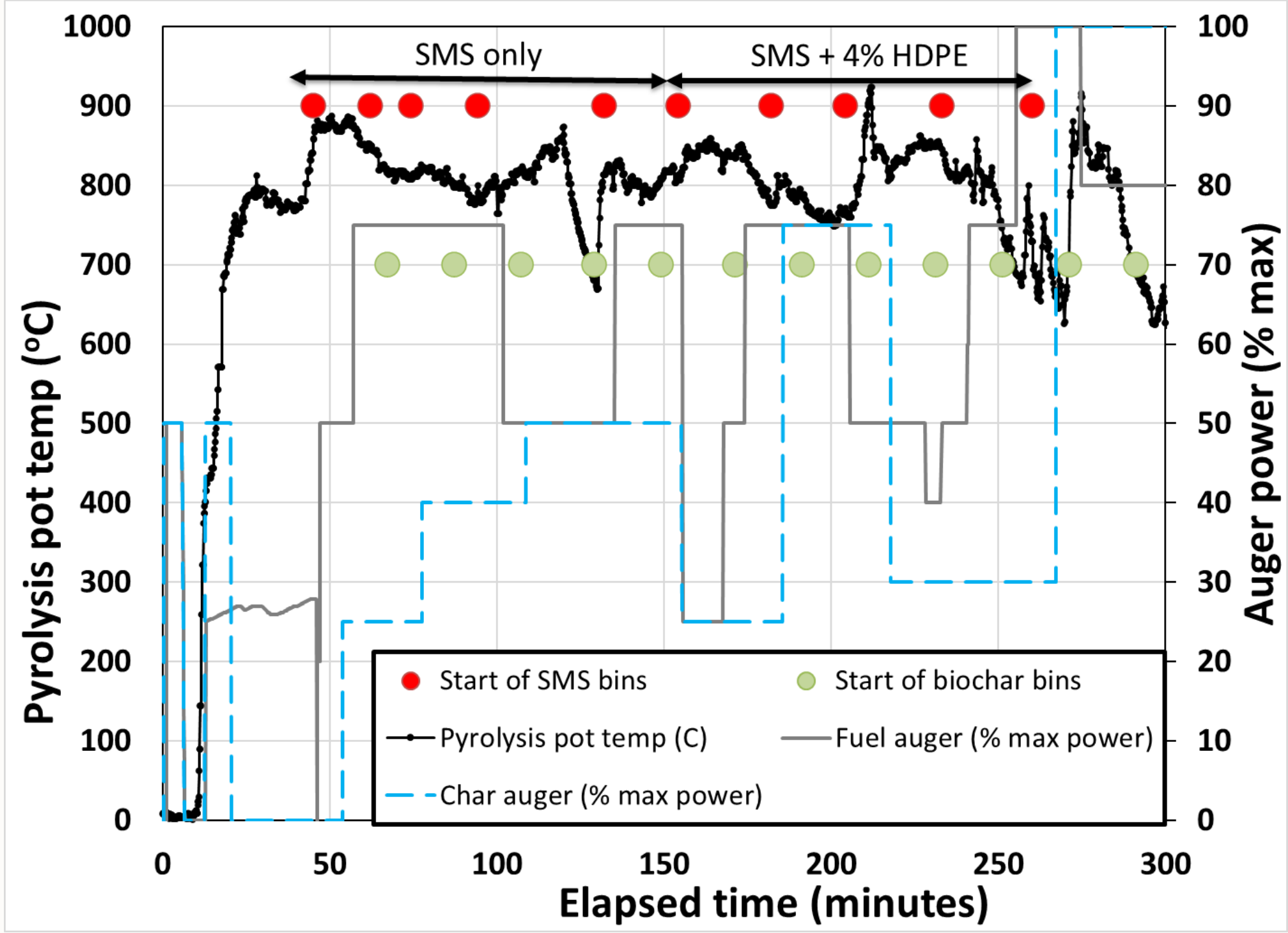
SMS prep for pyrolysis

Debagging & Drying

Grinding

Pyrolysis

BR system data



SMS biochar analysis

SMS biochar properties

PAPRAMETERS	UNITS	SENECA FARMS (2023)	LION'S MANE (2023)	BLUE OYSTER (2023)	BLUE OYS + HDPE (2023)	BLUE OYSTER (2022)
Pyrolysis temperature	°C	-	762.8±77.1 (10.1%)	812.5±41.7 (5.1%)	799.4±54.0 (6.8%)	790.9±66.2 (8.4%)
Organic carbon	%	78.1	62.8	61.8	65.2	61.4
H:C ratio	Molar ratio	0.47	0.68	0.78	0.62	0.39
Ash content	%	5.3	18	15	15.3	24.4
pH	units	9.01	8.29	8.34	8.49	9.83
Surface area	m^2/g	304	201	176	171	221
Particle size (<0.5mm)	%	5.0	52.5	49.1	51.1	54

Comparison of biochar used in mushroom growth trial (2023)

Analysis of data

- % yield increases, pH drops, and HC rises.
- % yield increases, % ash decrease (EPA 503)
- Res. time direct relation to many variables
- Low HC may not be desirable for indoor farming
- Optimize production with simple system process change. eg. – Gear ratios.

Harshal K. inspects SMS biochar

Mushroom growth trial setup

Trial details

- ~100 baglogs per treatment
  - Total 700 baglogs
- 5% wood chip substituted with 5% biochar
- All baglogs ~2.5 kgs
- 0.05 kg spawn in each bag
- Mushroom mass collected
  - First flush complete
  - Second in progress

Mushroom Species	Treatments - % Biochar (w/w) in baglog mixture
Lion's Mane	Zero (Control)
	5% Seneca Farms (commercial baseline)
	5% Lion's Mane SMS
Blue Oyster	Zero (Control)
	5% Seneca Farms (commercial baseline)
	5% Blue Oyster SMS
	5% Blue Oyster SMS + 4% HDPE
	5% Blue Oyster SMS + extra water

Substrate mixing and bagging

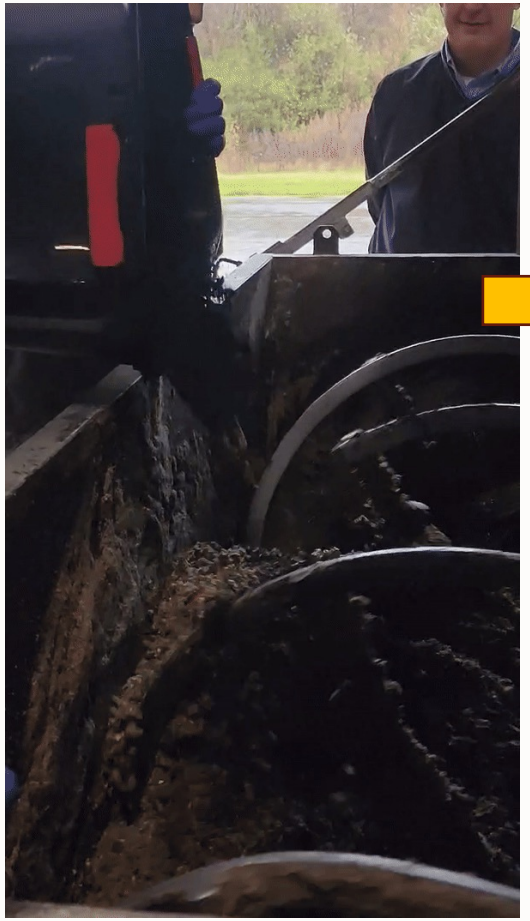
Nutrients (~6.6%)

Wood chips (~23.4%)

Water (~65%)

Biochar (~5%)

Substrate composition (w/w)



Ribbon blender

Bag and weigh (~2.5kgs)

~100 baglogs per treatment

Sterilize, inoculate, spawn, and harvest

Inoculation

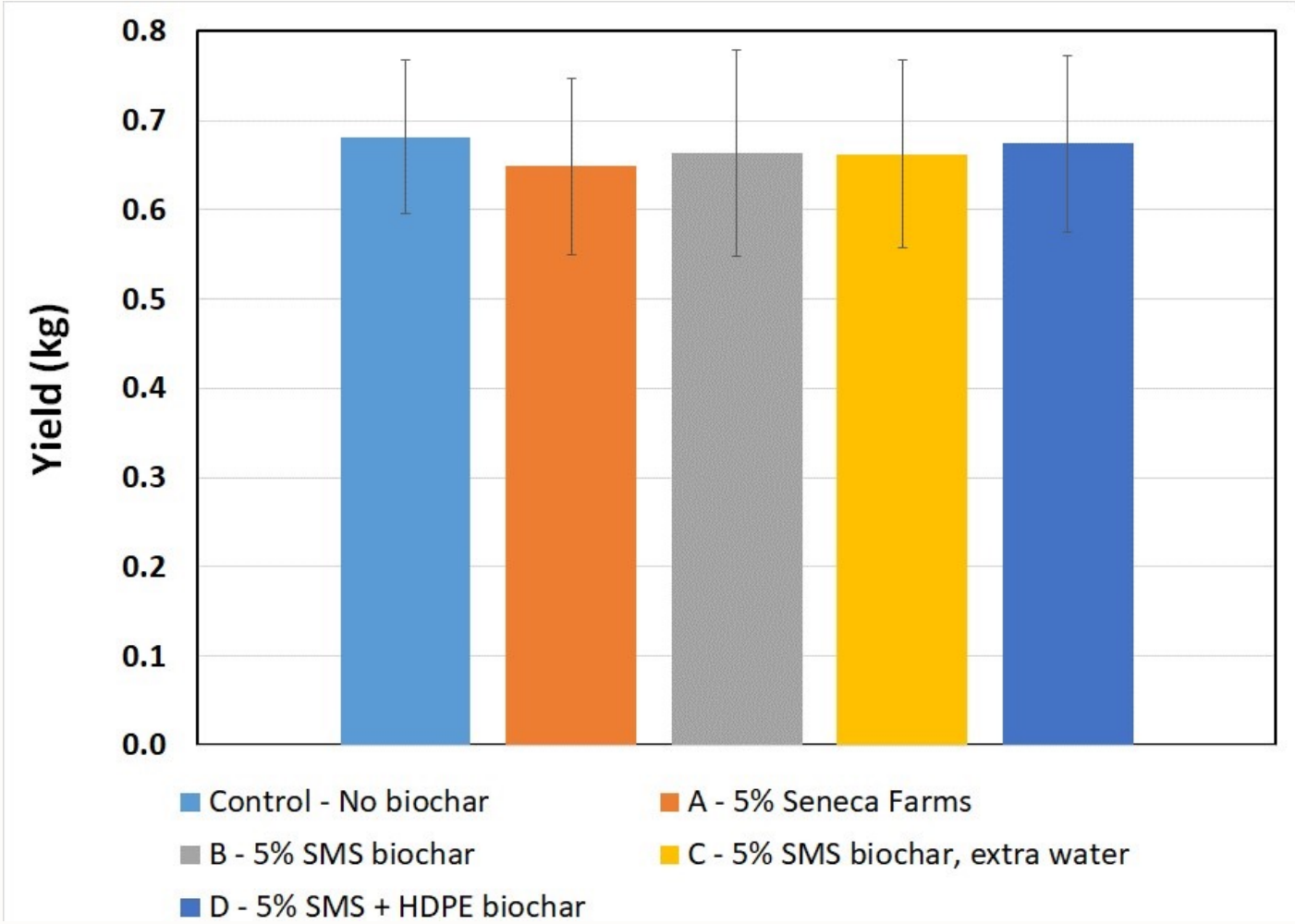
Spawn and myelination

Harvest

Mushroom growth trial results

Blue Oyster harvest

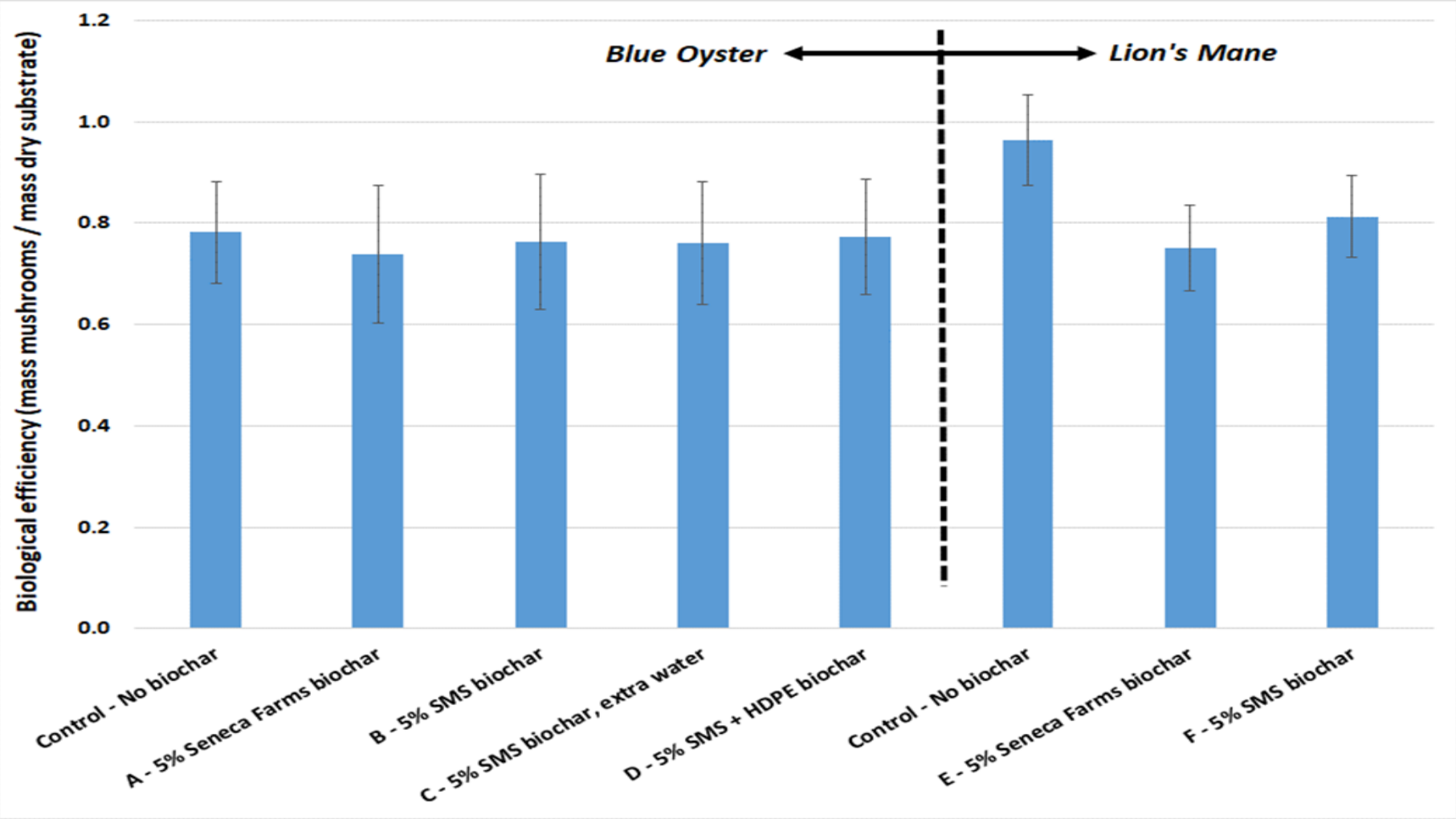
- No significant yield improvement with BC
- However, evidence of faster myceliation rate with BC added
  - Bulk density increases
  - Similar trend noted in literature
- Lion's Mane yield (data not shown) decreased slightly with BC



1 photo every ½ hour for 44 days. Timelapse: 1 sec = 2 days

Biological efficiency (BE)

$$BE\ (\%) = \frac{Mass\ of\ fruited\ body\ per\ bag}{Dry\ mass\ of\ substrate\ per\ bag}$$



Conclusion

- Biochar no effect on Blue Oyster yield (first flush)
- Biochar has a small negative effect on Lion's Mane yield (first flush)
- Current mushroom growth process highly optimized
- **Biochar from SMS is a great example of circular food production**
  - **Waste heat + disposal cost avoidance + secondary revenue stream**

Thank you for your attention!

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LinkedIn

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