2017 THE ALMOND CONFERENCE

ALMOND BIOMASS – THE REAL, WEIRD AND WONDERFUL OPPORTUNITIES FOR GREATER UTILIZATION

Room 308-309 | December 5 2017

california almonds
Almond Board of California

growing ADVANTAGE
The Almond Conference

CEUs – New Process

Certified Crop Advisor (CCA)

- Sign in and out of each session you attend.
- Pickup verification sheet at conclusion of each session.
- *Repeat this process for each session, and each day you with to receive credits.*

Pest Control Advisor (PCA), Qualified Applicator (QA), Private Applicator (PA)

- Pickup scantron at the start of the day at first session you attend; complete form.
- Sign in and out of each session you attend.
- Pickup verification sheet at conclusion of each session.
- Turn in your scantron at the end of the day at the last session you attend.

Sign in sheets and verification sheets are located at the back of each session room.

AGENDA

- **Guangwei Huang,** Almond Board of California, and **Kelly Covello**, Almond Alliance of California, moderator
- **Jean VanderGheynst**, UC Davis
- **Chris Simmons**, UC Davis
- **Bor-sen Chiou**, UniverUSDA Albany

Production of black soldier fly larvae on almond by-products

Jean VanderGheynst, PhD

Biological & Agricultural Engineering
UC Davis

December 5, 2017

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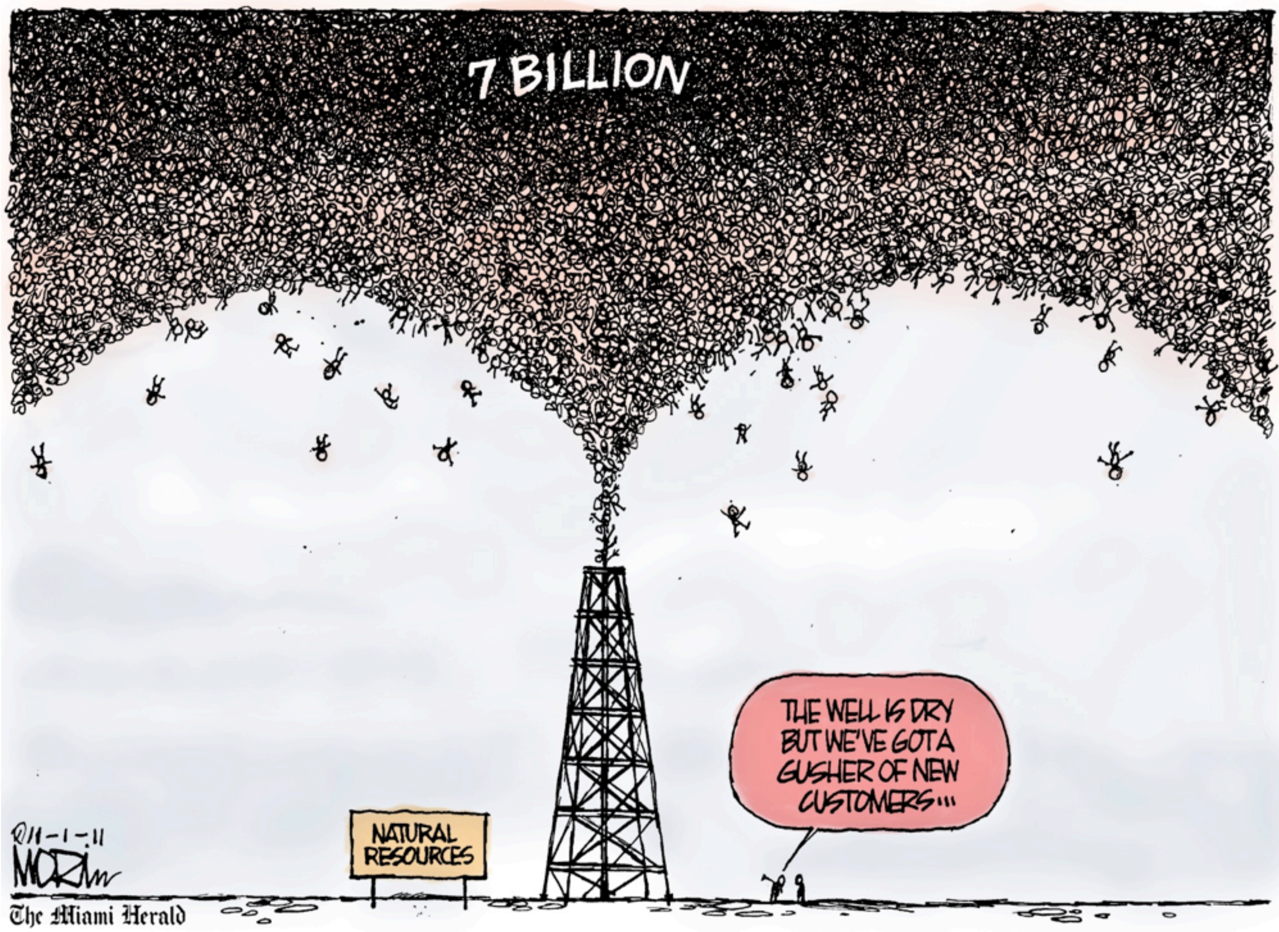
Almond Board of California

- World population is expected to grow to 9 billion by 2050
- Demand for animal protein is projected to increase by 76% by 2050
- Livestock production currently uses more than 2/3 of agricultural land

van Huis, 2016. Proc. Nutr. Soc.



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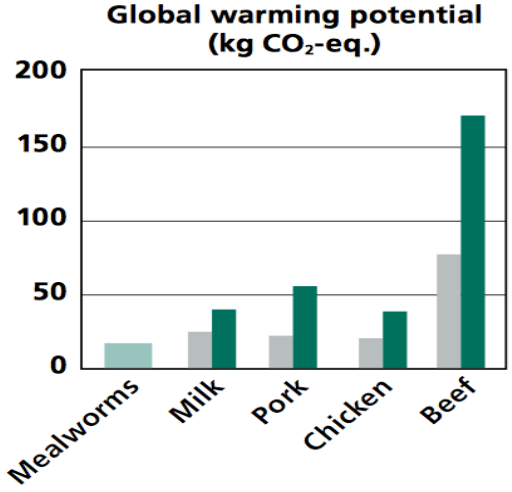
Addressing food insecurity will require innovative approaches to food production that are more sustainable than current practices while still yielding nutritious food

Insect production offers one potential solution to food insecurity

- Insects have high conversion efficiency
  - Cattle require 8 kg of feed to produce 1 kg of edible weight
  - Insects require 1.5 kg of feed to produce 1 kg of edible weight
- Insects are a natural component of diet for fish and poultry
- Insect farming requires less land and water and results in less greenhouse gas emissions compared to livestock farming



Greenhouse gas production per kg protein produced (Oonincx and de Boer, 2012)

ENVIRONMENT

The Rise Of The Incredible Edible Insect

Start-ups are marketing an unlikely new protein. It's nutrient-rich, all natural, and six-legged.

By Brooke Borel *May 12, 2015*

popsci.com

The future of animal feed? Fly farming

By Tara Duggan | May 3, 2017 | Updated: May 3, 2017 2:12pm

sfchronicle.com

French company Ynsect keen to replace fish and pet foods with crushed insects

Share on Facebook Share on Twitter

ABC Rural By Clint Jasper

Updated 22 January 2017 at 3:55 pm

First posted 22 January 2017 at 2:57 pm

abc.net.eu

New proteins

News | 29 Mar 2017 | 6990 views | 3 comments

AgriProtein to build 20 fly farms in US and Canada

allaboutfeed.net

https://www.eatgrub.co.uk

https://chirpschips.com

http://focusonbelgium.be

Insects at Commercial or Near Commercial Production

- Crickets
- Grasshoppers
- Mealworms
- House fly
- Silkworm
- Black soldier fly larvae (BSFL)

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Characteristics of BSF that Make Them Ideal for Production

- Non-pest insect
- Do not carry harmful pathogens
- Enhance organic matter decomposition process
- Grow on many types of organic matter
- Nutritional value for feed

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BSFL Nutritional Value

Percentage of dry weight depending on production feedstock

- Crude protein: 39 – 43%
- Methionine: 0.5 – 0.9%
- Calcium: 0.12 – 6.6%

Challenges

- Composition varies with production environment
- A consistently sourced feedstock is needed to achieve consistent larvae composition

Spranghers et al. 2017. J. Sci. Food Ag.

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In 2016, the CA almond industry produced 3.37 billion pounds of almond hulls and 1.35 billion pounds of almond shells (CA Almond Board, 2017)

By-products from the almond industry are a potential resource for insect production

Preliminary Studies

- Preliminary studies done in May, 2017 indicated larvae will grow on almond hulls and shells
- Requested funds from ABC for additional research

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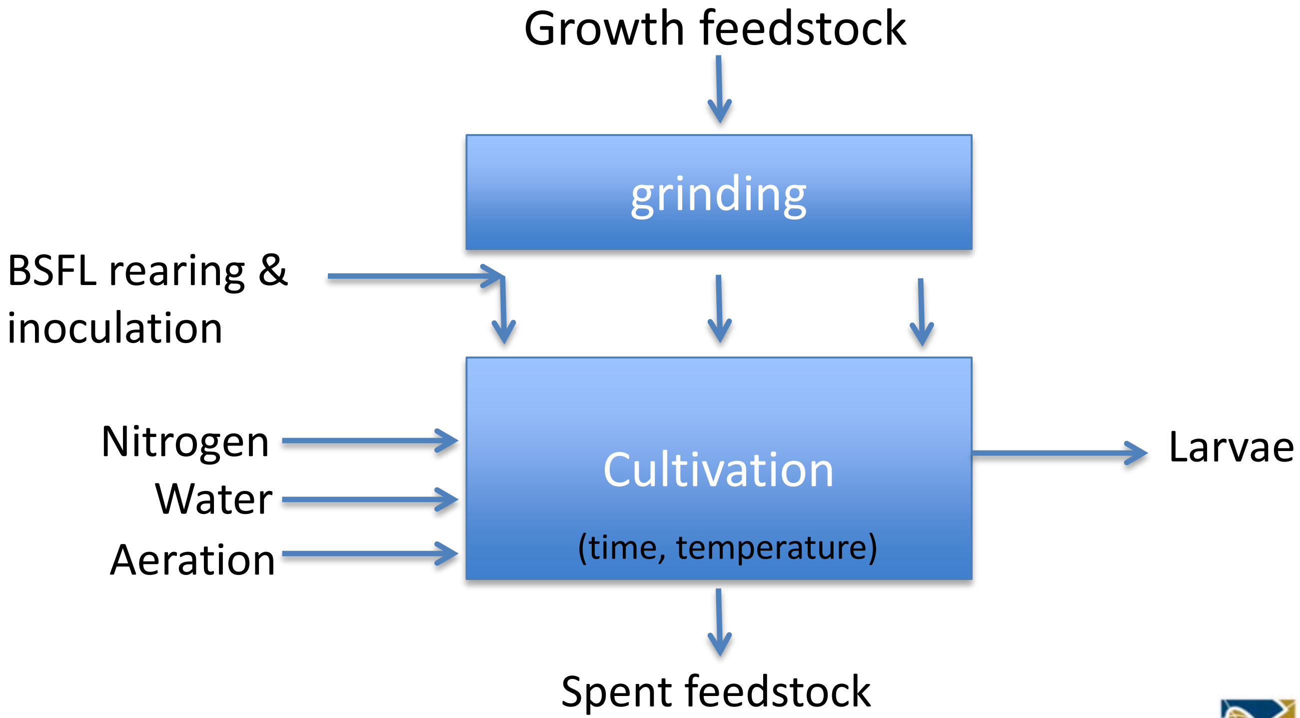
Management steps and variables in larvae production



Processing steps

- Pollinator variety hulls obtained from processor in Chico, CA in June 2017. Material had been stored outdoors under roof
- Material was ground
  - Used hammer mill (1/4 inch screen). Additional small batch grinding with coffee grinder
- Water and nitrogen added and equilibrated overnight at 4°C prior to each experiment

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Processing steps

- BSF eggs purchased from commercial supplier
- Larvae reared from eggs and separated from feed prior to inoculation onto moistened hulls

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Processing steps

- Larvae inoculation onto hulls
- Incubation and larvae cultivation

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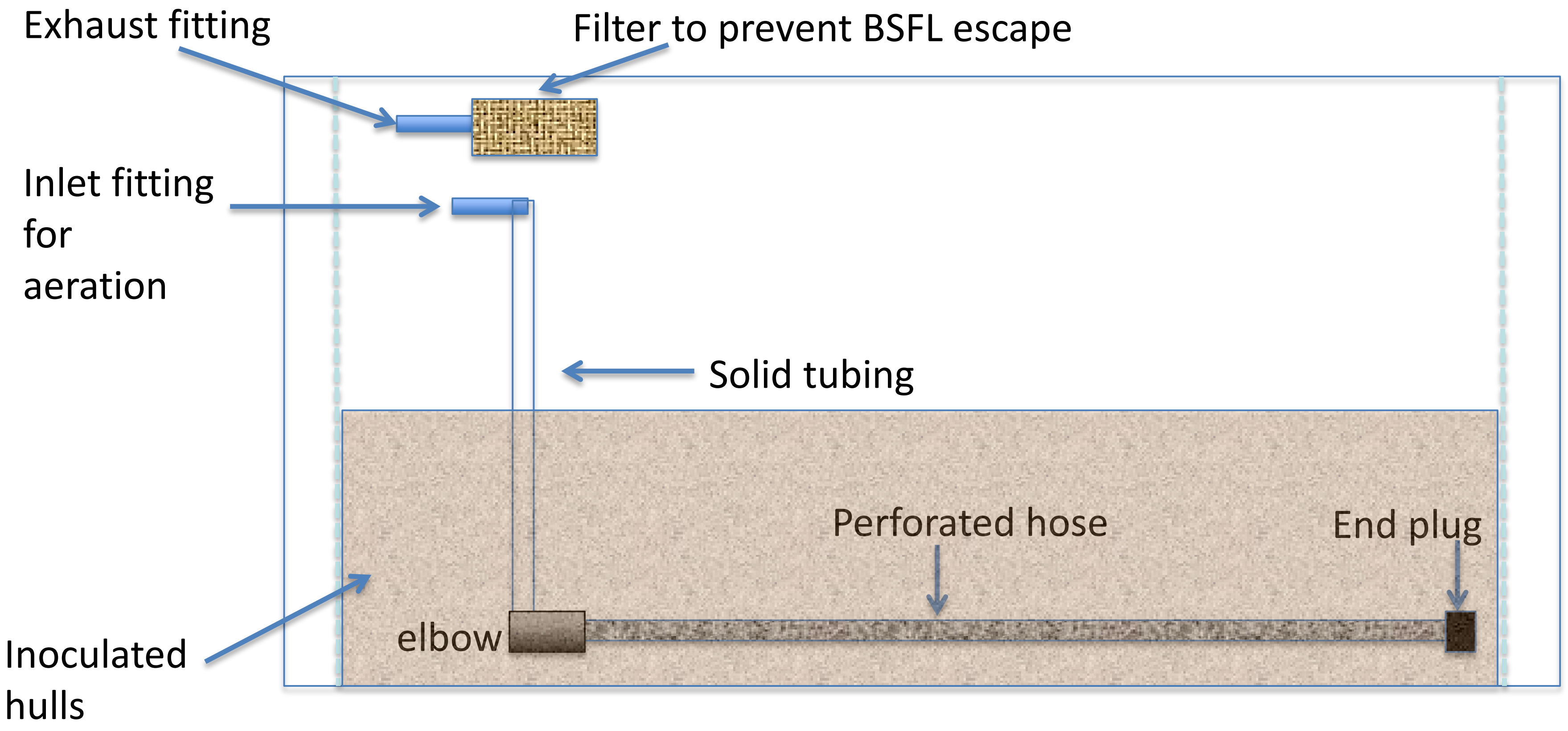
BSFL Cultivation Reactors



Larvae Cultivation Reactors

Production Array

BSF Life Cycle

https://taxo4254.wikispaces.com/Hermetia+Illucens

Larvae harvest

- Developed baiting system for harvest
- Larvae also collected manually

Measurements

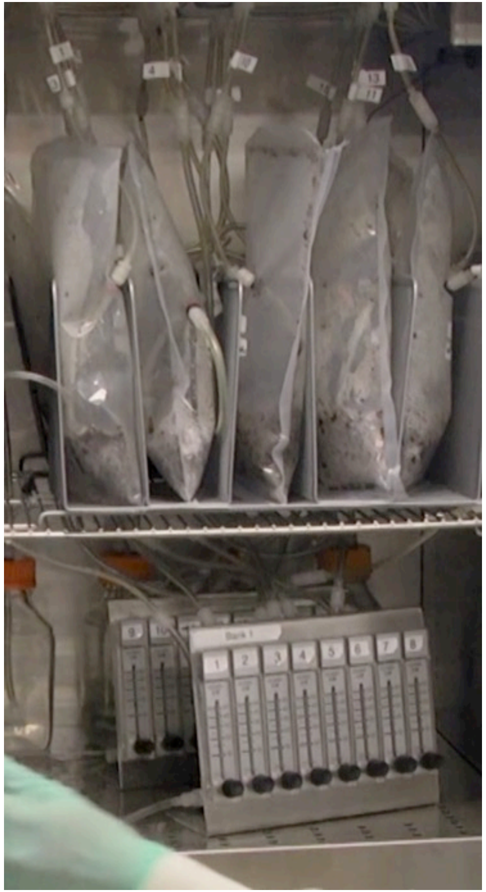
- Larvae specific growth:
  - change in larvae mass per mass inoculated onto hulls
- Yield:
  - change in larvae mass per change in hull mass
- Calcium and amino acids in harvested larvae
- Hull consumption
- Change in hull composition

Experimental Variables

- Aeration (oxygen supply)
- Moisture
- Particle size
- Nitrogen supplementation
- Feeding rate

Aeration

- Metabolism of hulls is expected to increase with increasing air supply
- Experiments were completed with varying aeration levels



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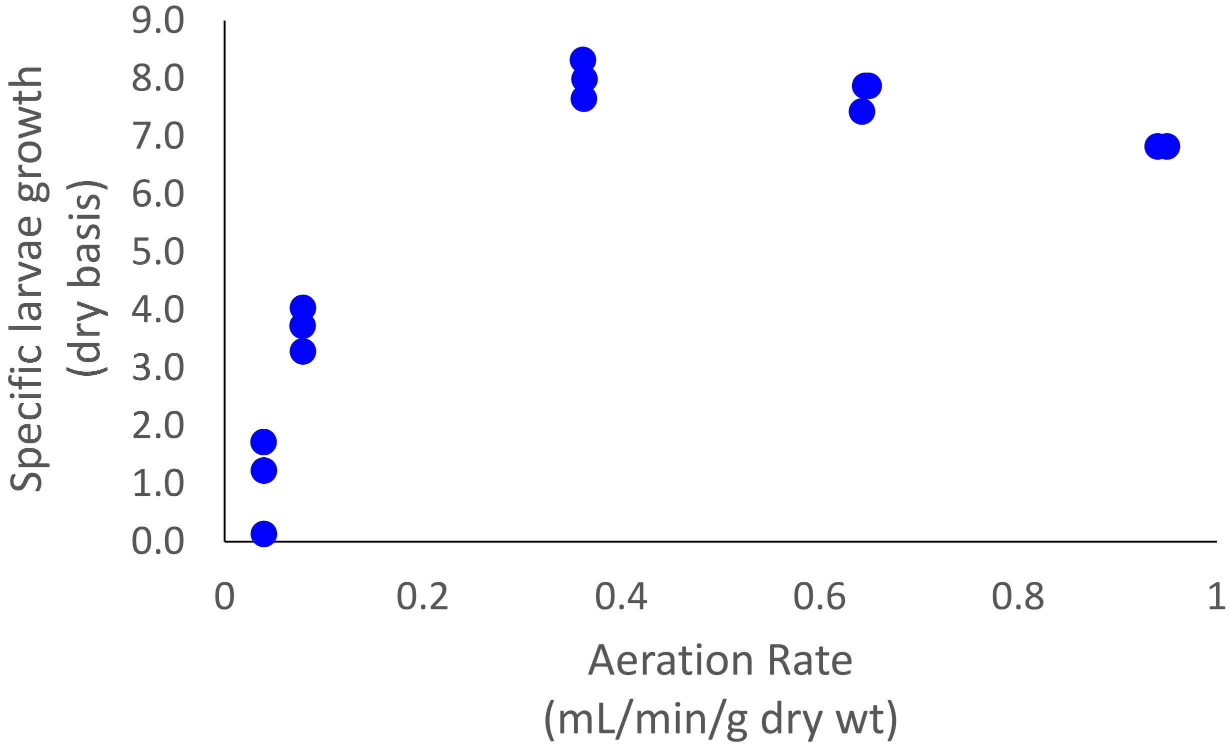
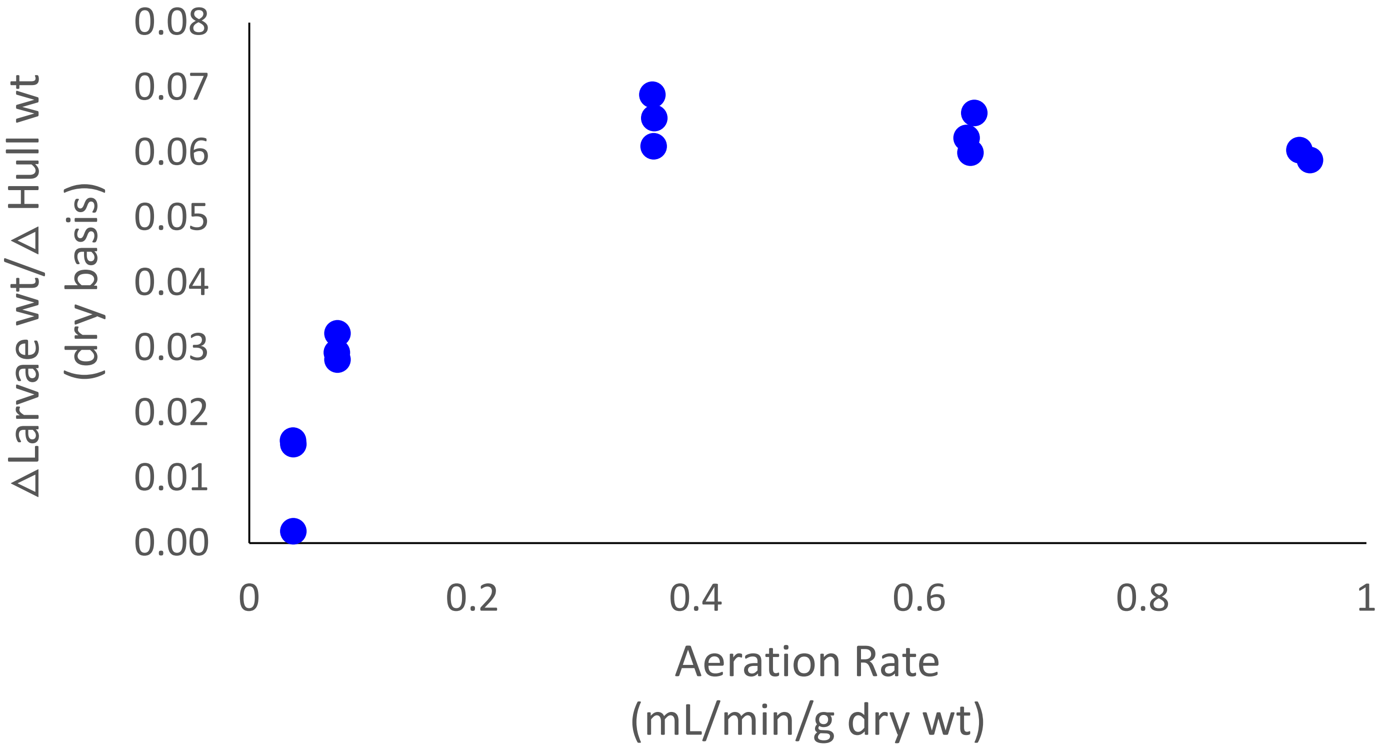
Aeration increases larvae growth



Aeration increases larvae yield from hulls



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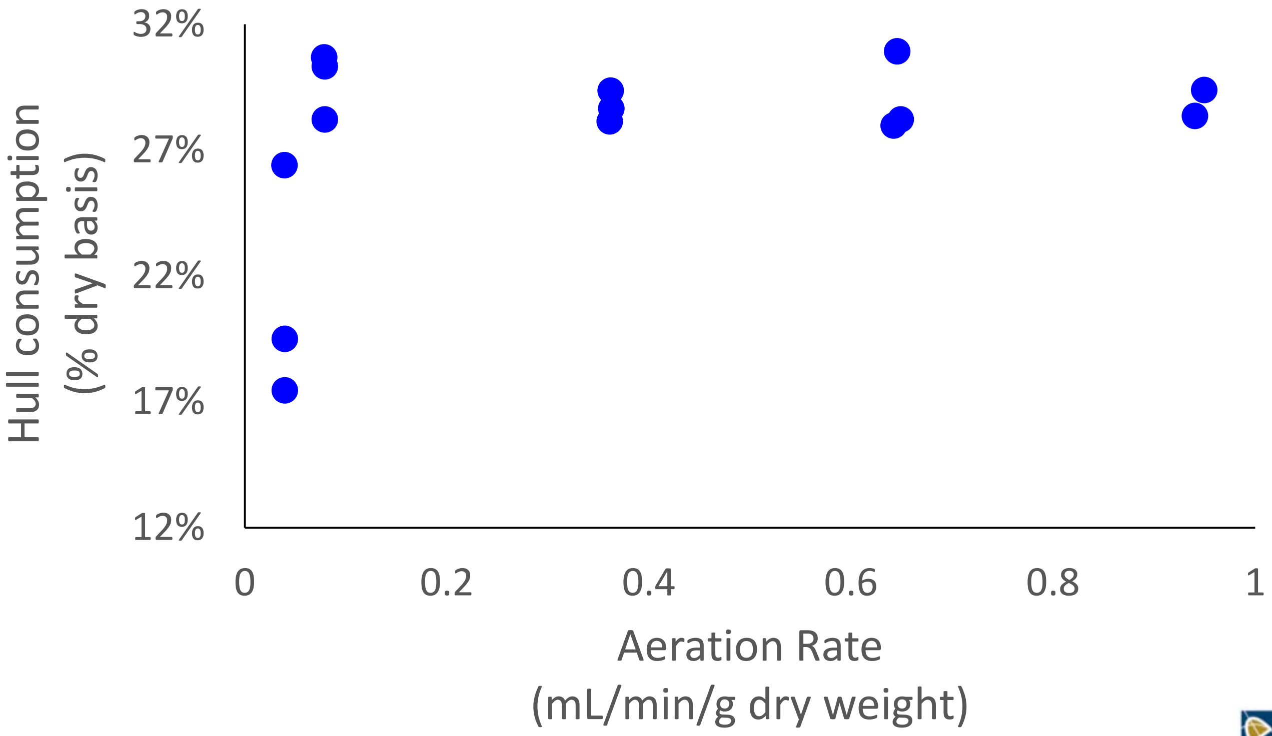
Aeration increases hull consumption



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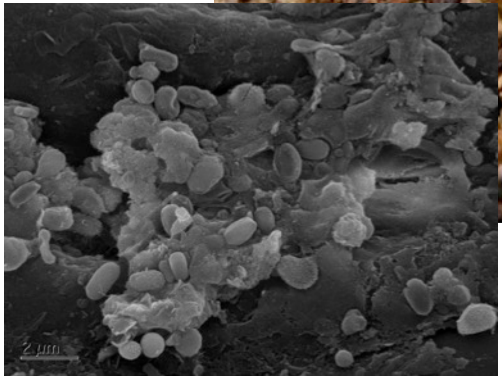
Microorganism synergy or competition with larvae?

- Microorganisms are growing simultaneously with larvae
- Do certain conditions support microorganism growth over larvae growth?



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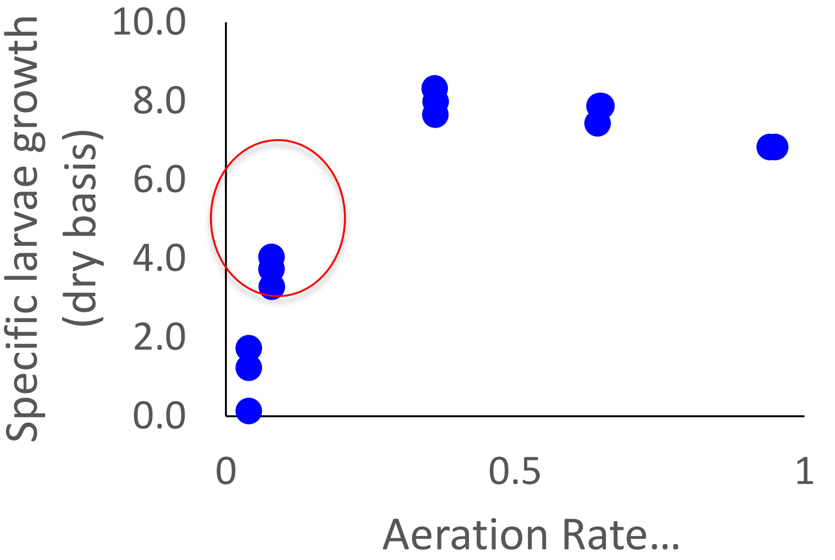
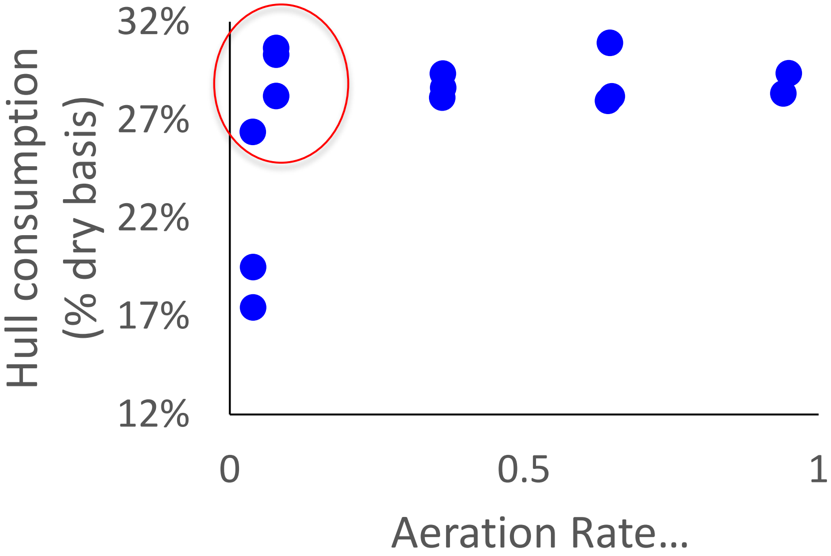
Low aeration supports microbial consumption of hulls over larvae consumption





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Moisture

- Water is essential for growth and breakdown of hulls by microorganisms and larvae
- As received moisture content of hulls was <20% wet basis
- Experiments were completed to test larvae growth at varying moisture levels
  - Incubations were completed with and without larvae

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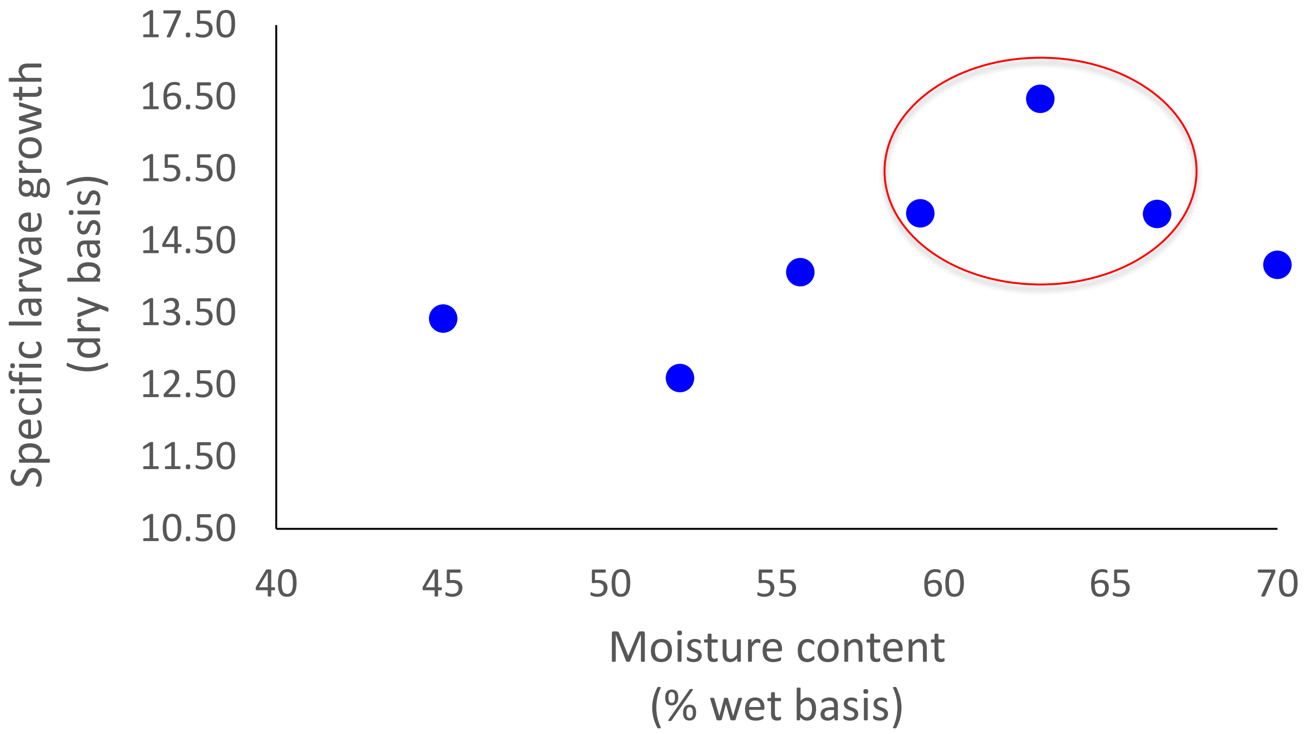
There is an optimum moisture for larvae growth on hulls



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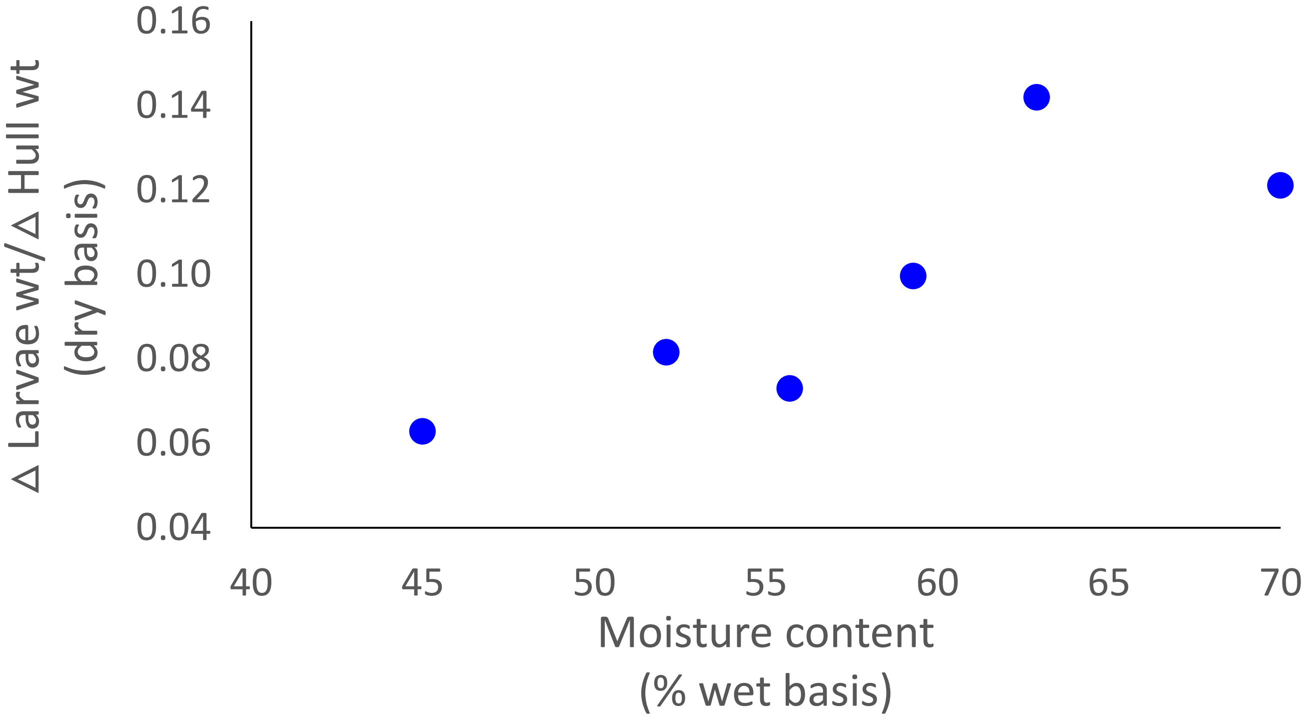
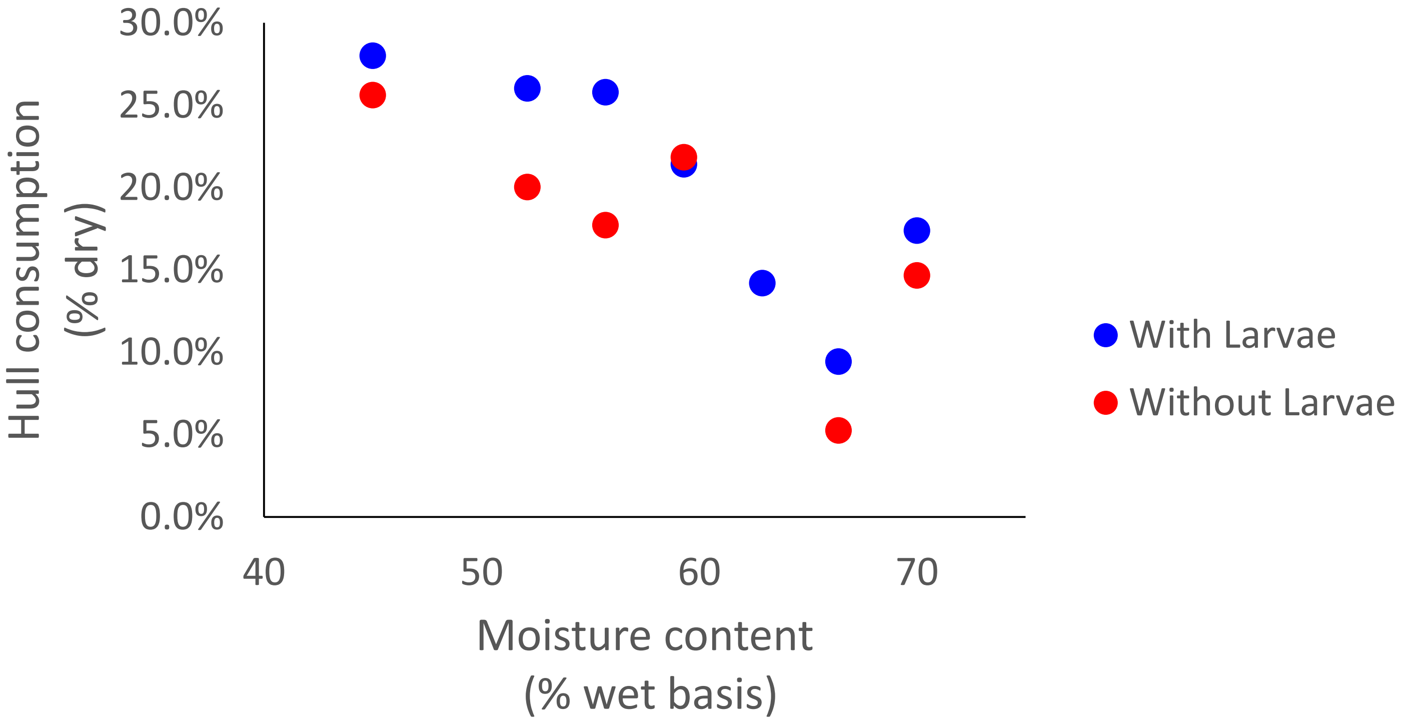
Larvae yield increases with moisture



Larvae enhance the decomposition of hulls



Potential mechanisms for enhanced decomposition

- Synergy with microorganisms
- Microorganisms in the gut of larvae contribute to decomposition
- Increased mixing associated with larvae results in improved distribution of nutrients required for all organisms to grow

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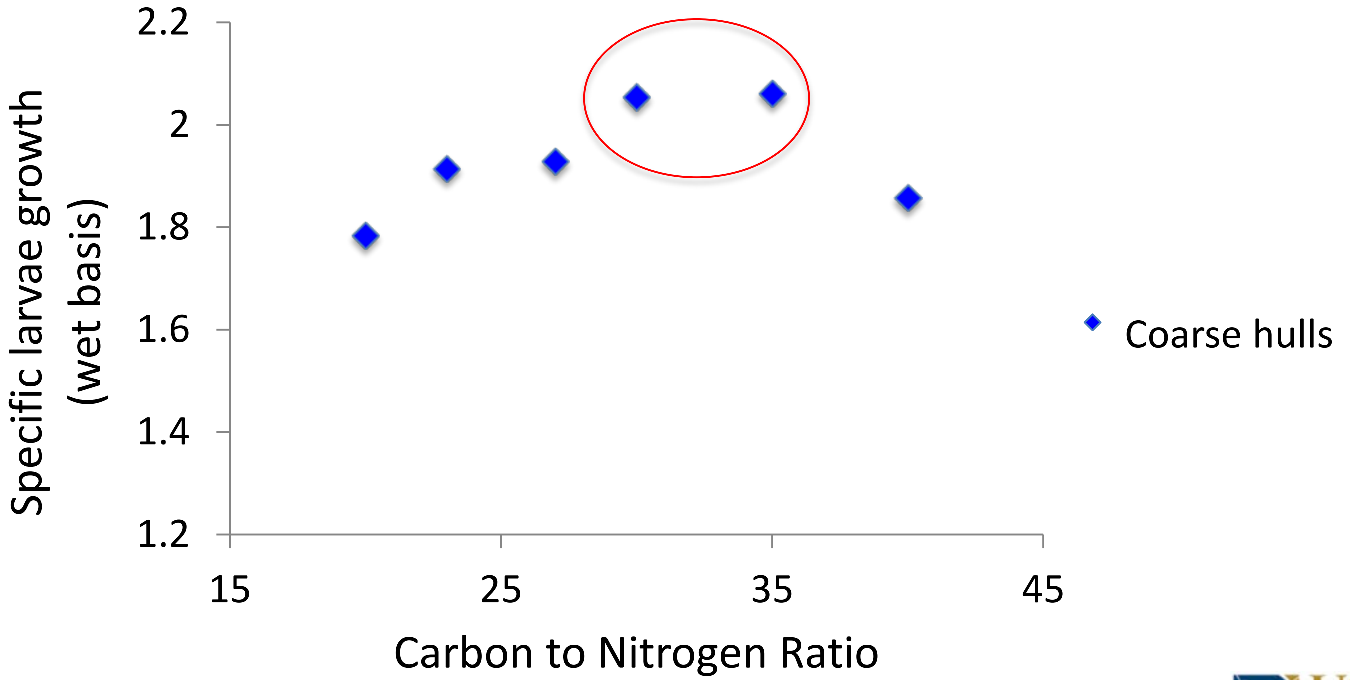
Nitrogen supplementation

- Nitrogen is important for the synthesis of enzymes necessary to breakdown hulls
- The carbon to nitrogen ratio (C/N) of as-received hulls was 60
- Experiments were completed to test larvae growth on hulls amended with urea to achieve different C/N levels
  - Two particle sizes of hulls were also tested

There is an optimum C/N for larvae growth on hulls



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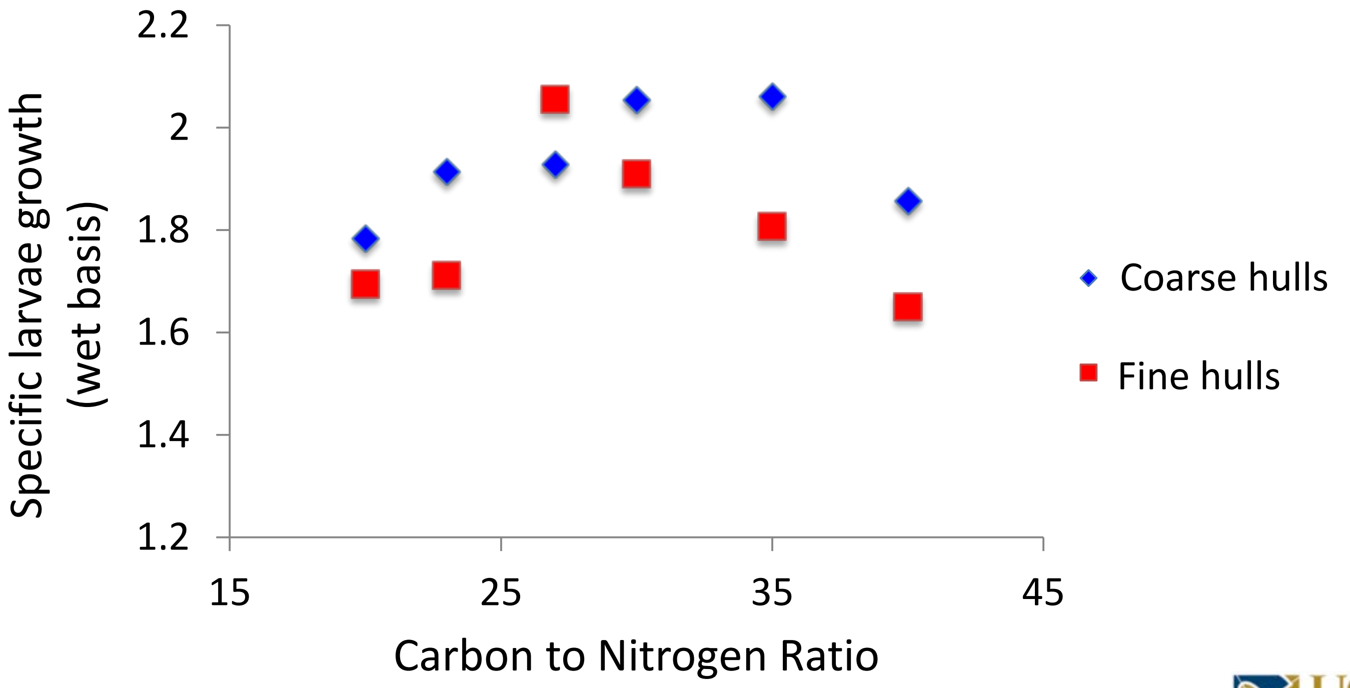
Coarse hulls support greater larvae growth than fine hulls



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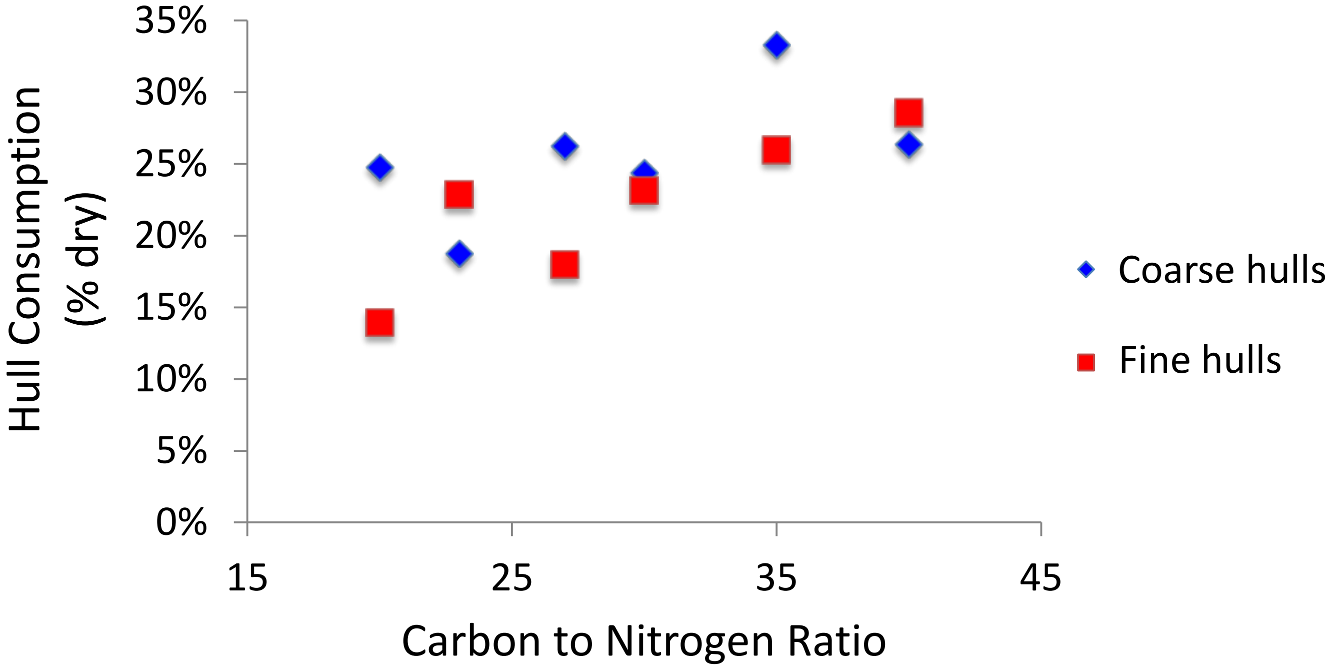
Hull consumption increases with C/N



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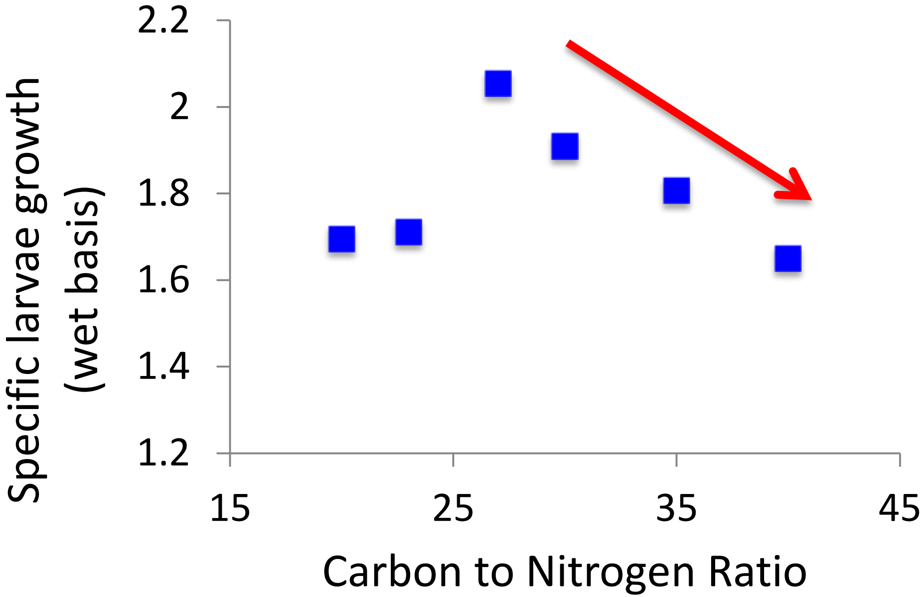
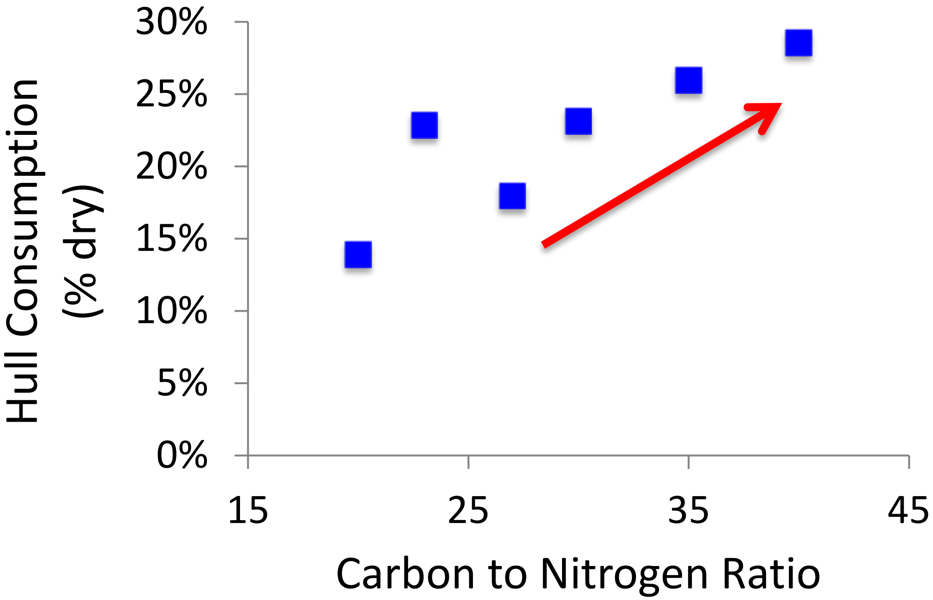
Increasing C/N supports microbial growth on hulls over larvae growth





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Summary

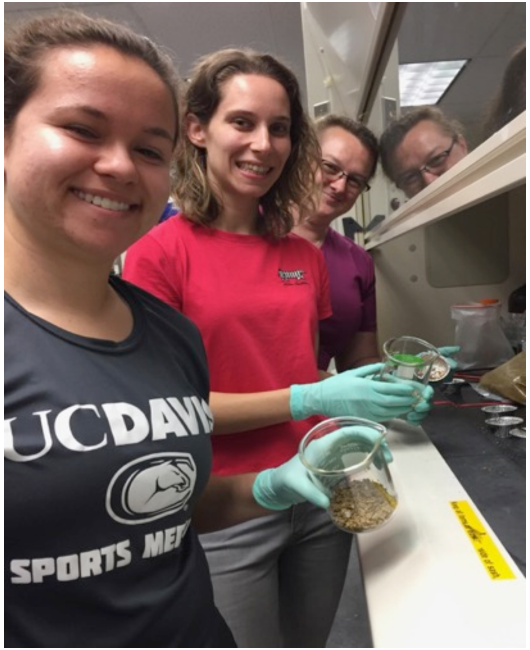
- Black soldier fly larvae can be cultivated on almond by-products
- Cultivation variables (aeration, moisture and C/N) impact growth and yield from hulls
- Cultivation conditions play a role in consumption of hulls by microorganisms versus larvae

Future Research

- Additional variables to examine for impact on larvae growth and hull consumption
  - Almond by-product sources
  - Alternative nitrogen sources
  - Cultivation time and temperature

Acknowledgements

- BSFL production team
  - Deb Niemeier
  - Maurice Pitesky
  - Lydia Palma
  - Shannon Ceballos
  - Paulina Johnson
  - Sara Pace
  - Matt Paddock
  - Suzy Karagosian
- Financial support
  - CA Almond Board
  - Methionine project



Thank you!

California Almonds
Almond Board of California

Biosolarization - a method to recycle almond waste biomass and disinfest orchards during replant

Christopher Simmons
Department of Food Science and Technology, UC Davis

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Almond Board of California

Christopher Simmons (PI)
Department of Food Science and Technology

Amanda Hodson (Co-PI)
Department of Entomology and Nematology

Jim Stapleton (Co-PI)
Division of Agricultural and Natural Resources

Jean VanderGheynst (Co-PI)
Department of Biological and Agricultural Engineering

In collaboration with
& with support from

california almonds
Almond Board of California

Western Center for
Agricultural
Health & Safety

Biosolarization

Biosolarization uses soil amendments to induce microbial activity.

Field soil

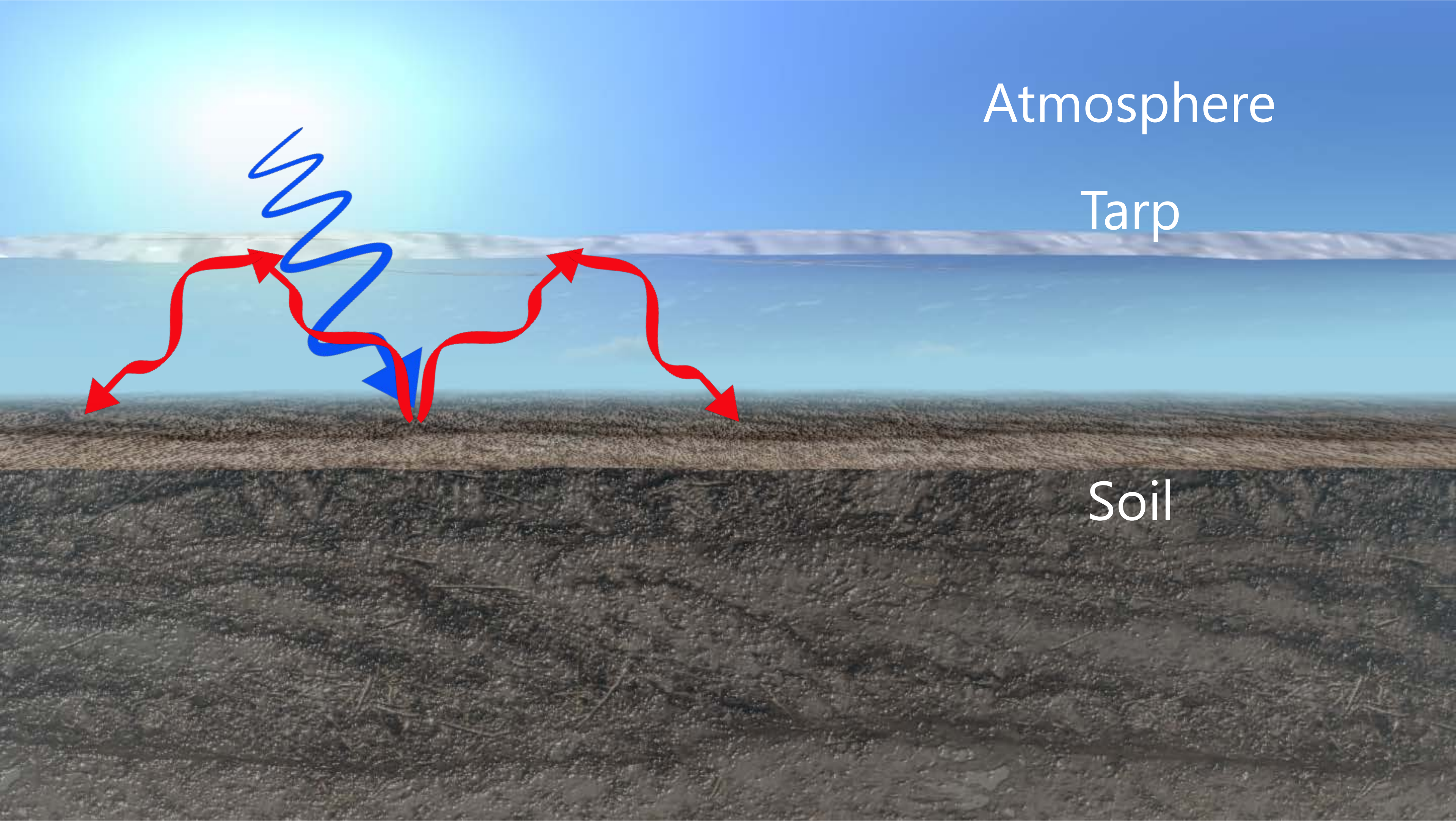
+

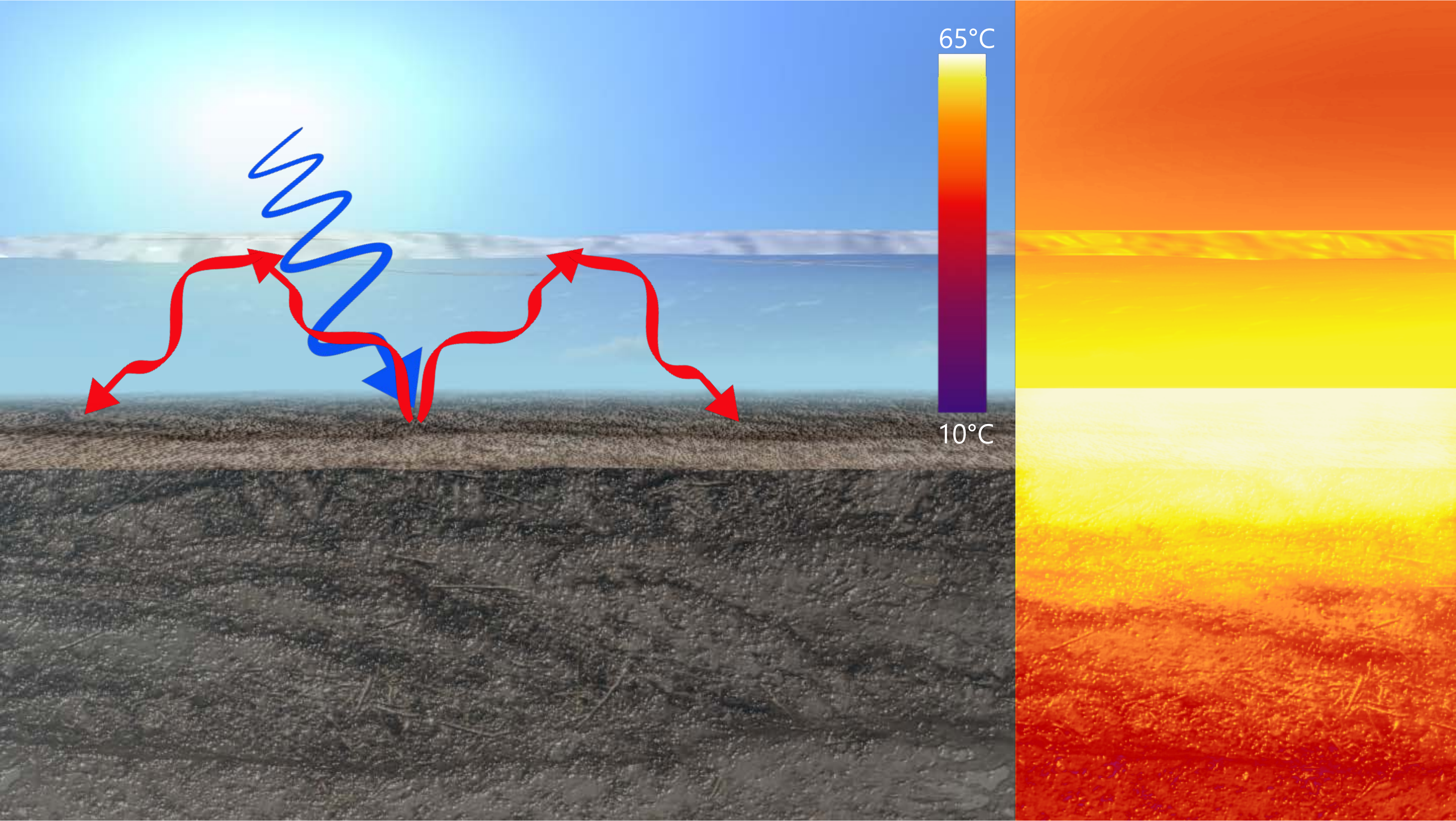
Compost inoculum (optional)

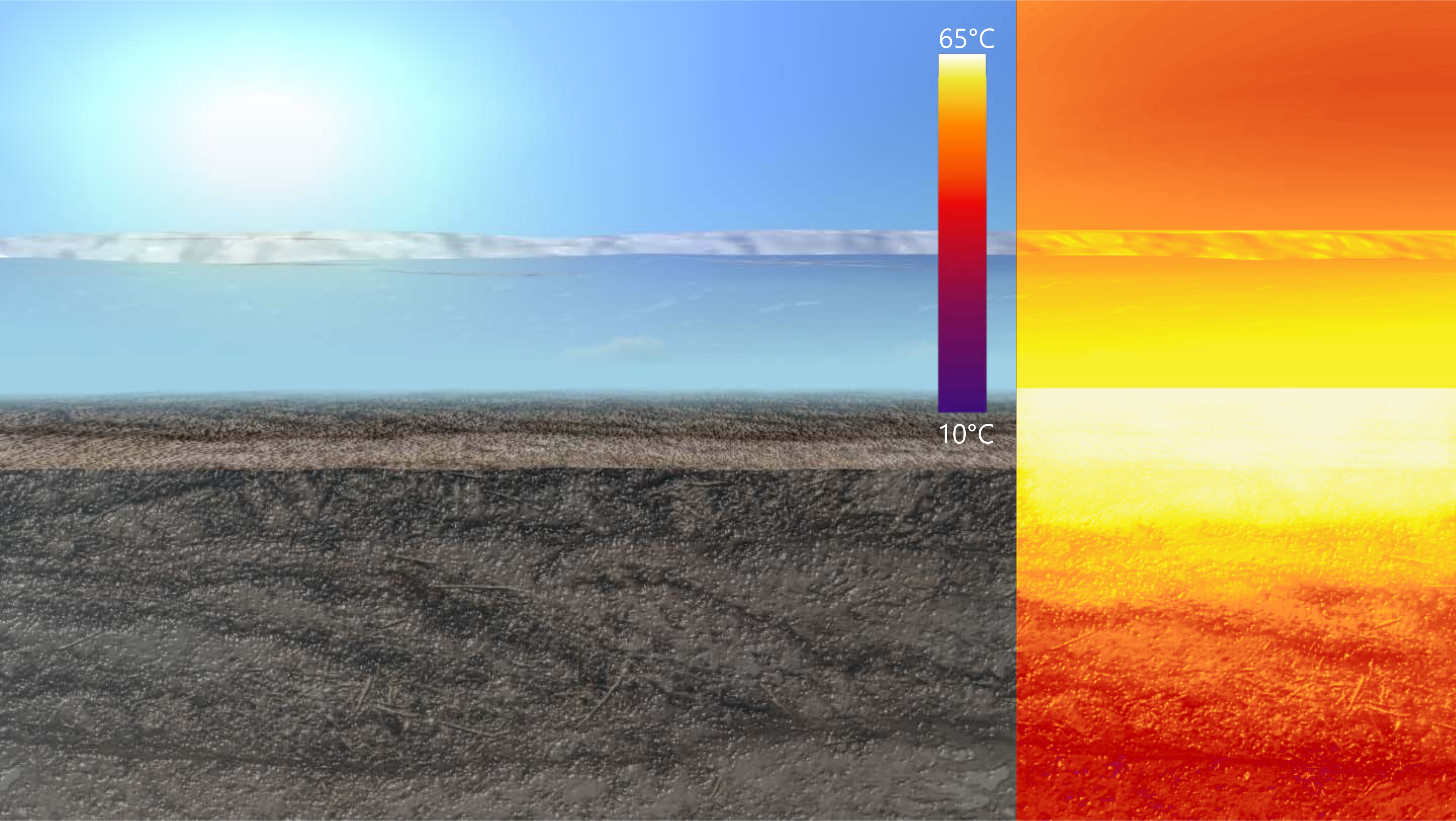
+

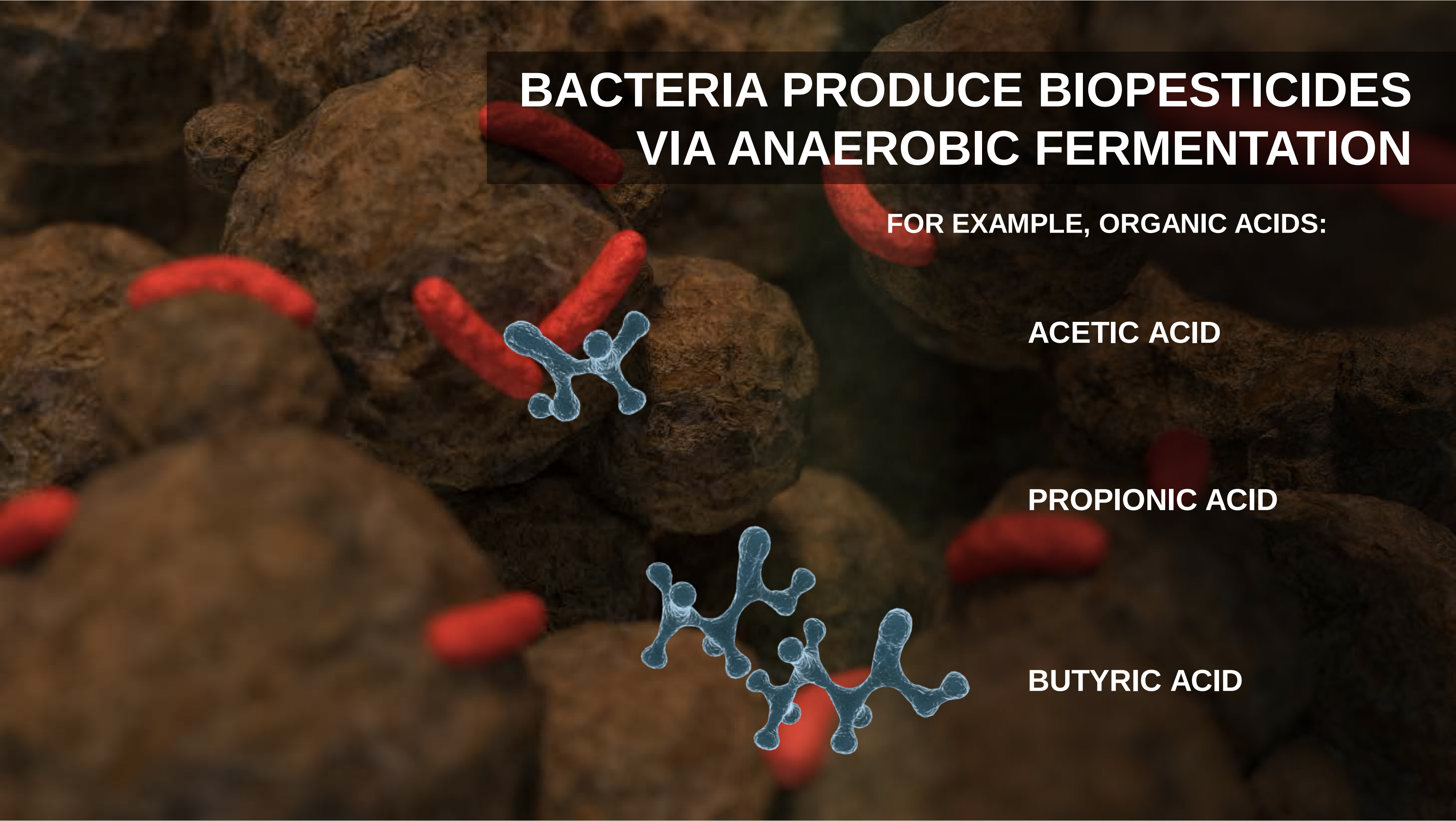
Agricultural or food processing organic residues


APPLY CLEAR FILM AND
IRRIGATE TO FIELD CAPACITY


Atmosphere
Tarp
Soil


65°C
10°C


65°C
10°C

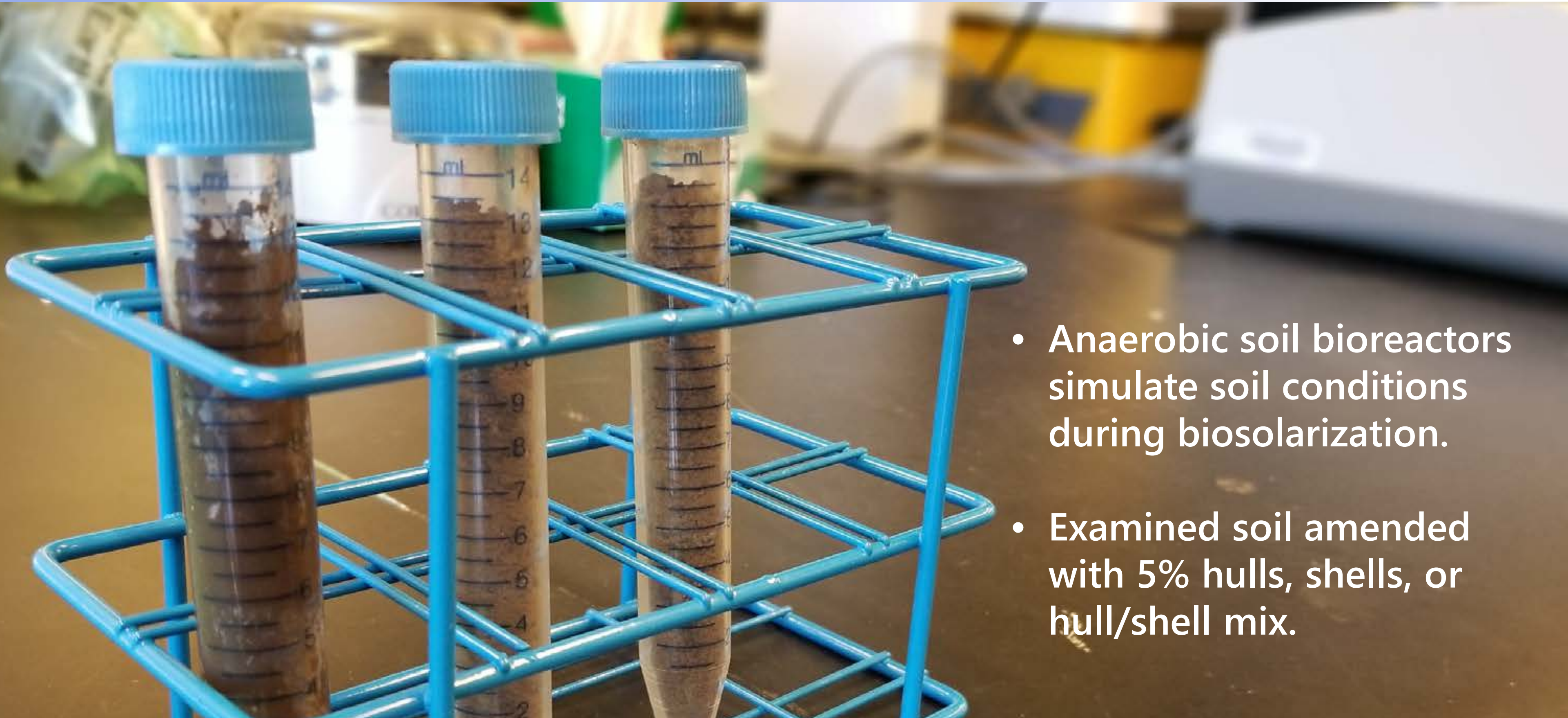

BACTERIA PRODUCE BIOPESTICIDES
VIA ANAEROBIC FERMENTATION
FOR EXAMPLE, ORGANIC ACIDS:
ACETIC ACID
PROPIONIC ACID
BUTYRIC ACID

How can we maximize biosolarization performance when using almond processing residues?

Initial screening of almond processing residues

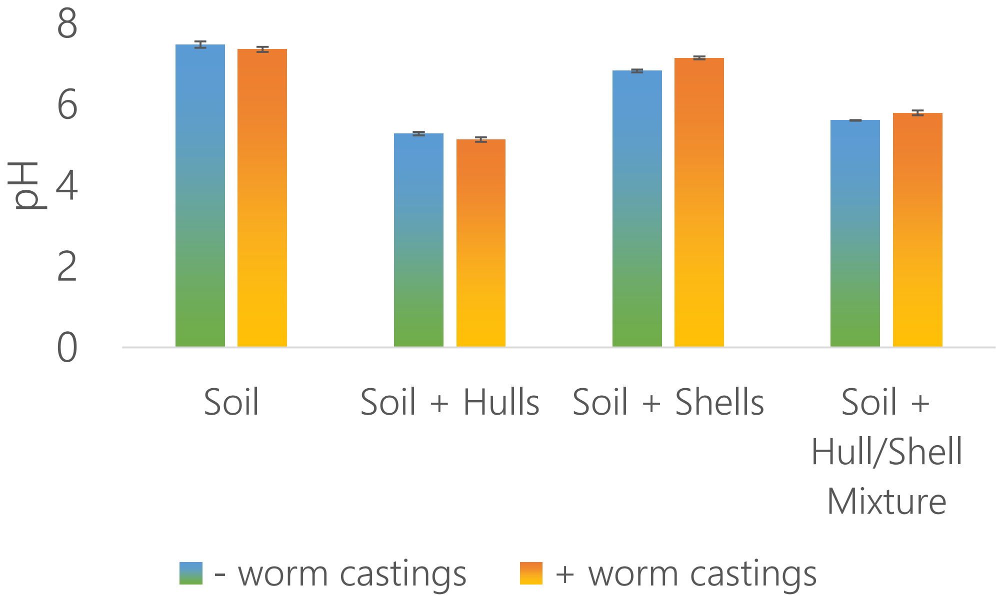
Material	N (% dw)	C (% dw)	C/N	Moisture content (g water/g fresh weight)	VS content (% dw)	Water holding capacity (g water/g dw soil)	pH
Soil	0.13	1.52	12.07	0.12	9.57	0.44	7.01
Pollinator shells	0.58	48.73	84.51	0.12	96.46	1.44	4.70
Pollinator shells and hulls	0.60	46.00	76.67	0.12	94.26	1.51	4.71
Nonpareil hulls	0.65	43.07	65.92	0.14	90.60	2.02	4.81

Initial screening of almond processing residues



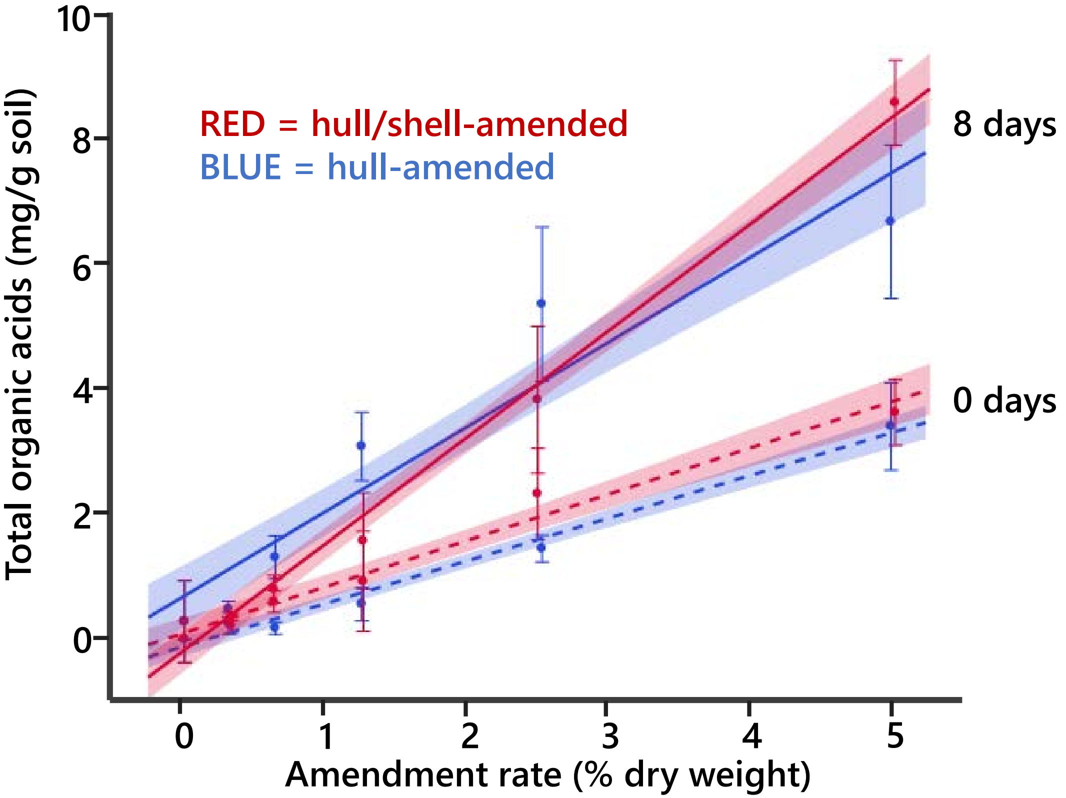
- Anaerobic soil bioreactors simulate soil conditions during biosolarization.
- Examined soil amended with 5% hulls, shells, or hull/shell mix.

Hulls and hull/shell mix are sufficiently biodegradable to drive soil fermentation during biosolarization



Acidification after 8 days simulated biosolarization is a predictor of pest inactivation in the field.

Hull- and hull/shell mix-amendments lead to accumulation of organic acids in the soil



Endogenous organic acids on almond residues provide immediate acidification of the soil, which may improve pest inactivation kinetics.

Root lesion nematode (*Pratylenchus* spp.) inactivation

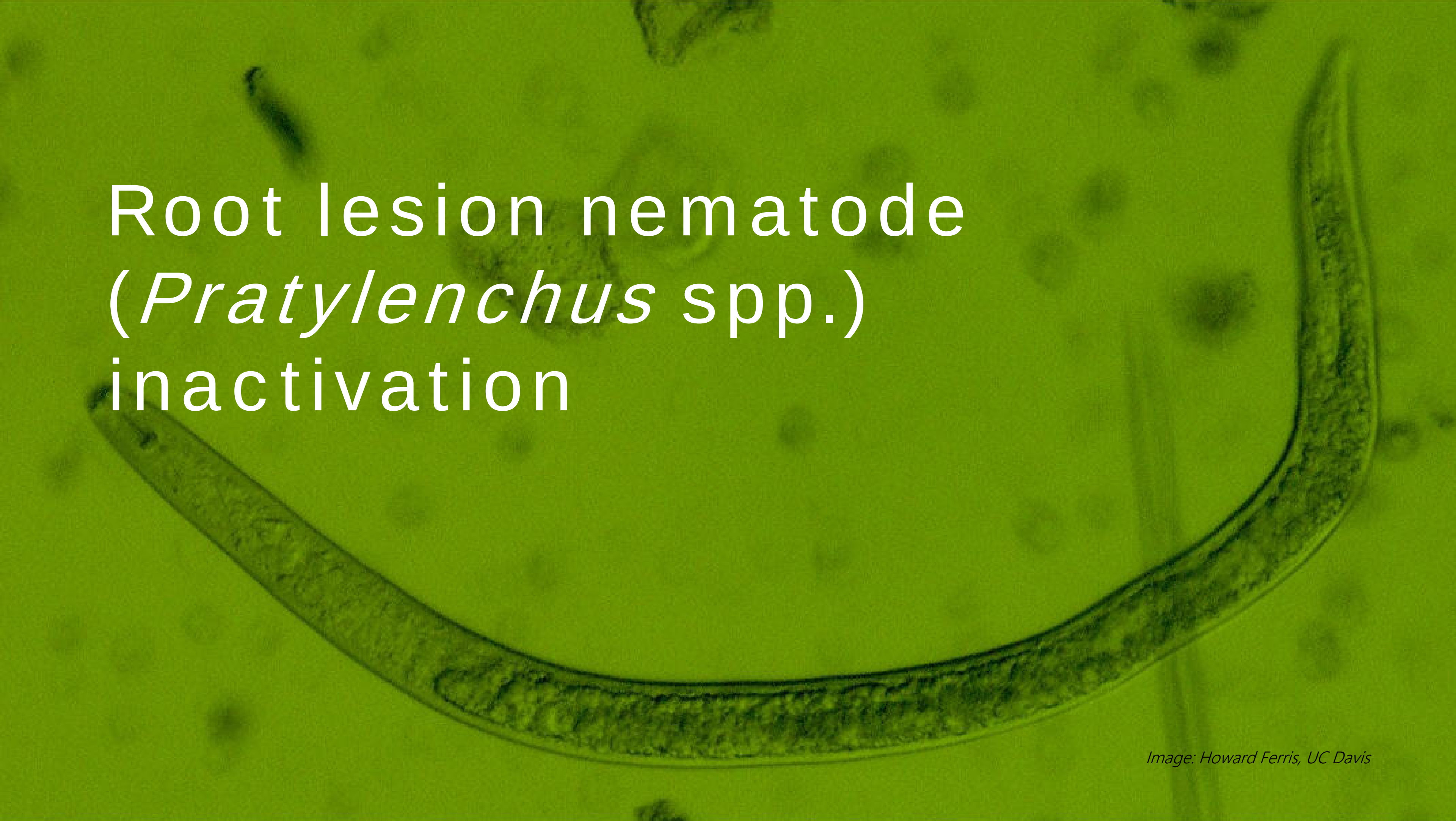
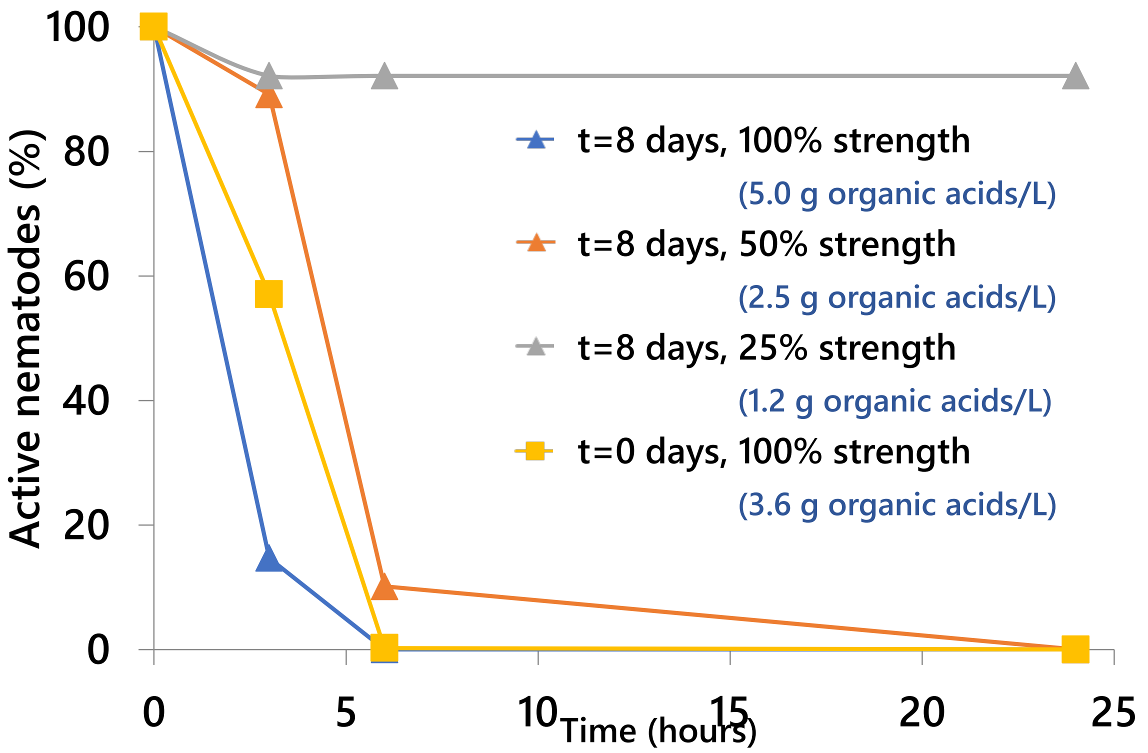


Image: Howard Ferris, UC Davis

Extracts from amended soils exhibit robust nematocidal activity



- Soil amended with nonpareil hulls (5% dw).
- Aqueous extracts taken immediately after amendment and after 8 days of anaerobic incubation.

Biosolarization field work

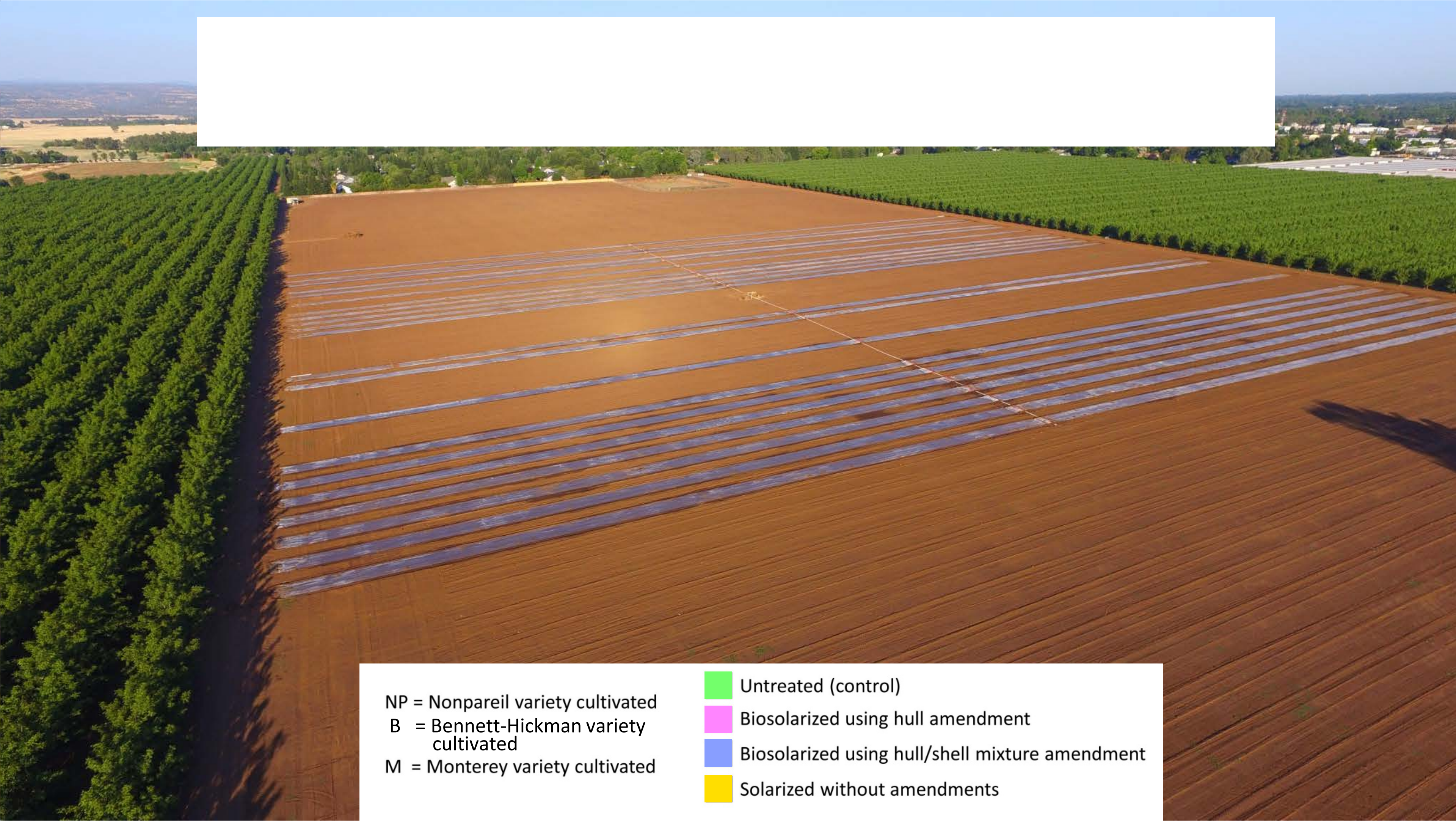
Current field work in collaboration with

Image: Nicolaus Nut Co.

Biosolarization field work

- Kittyhawk Ranch
- 50 acre orchard
- Recently removed walnut orchard
- Slated for replanting with Nonpareil, Bennett-Hickman, and Monterey varieties

- Grower offered 8.9 acres for biosolarization trial


NP = Nonpareil variety cultivated
B = Bennett-Hickman variety cultivated
M = Monterey variety cultivated
Untreated (control)
Biosolarized using hull amendment
Biosolarized using hull/shell mixture amendment
Solarized without amendments

Biosolarization field work – soil responses

Image: Nicolaus Nut Co.

Pest levels:
- Total and phytoparasitic nematodes
- Pathogenic microbes
- Weed coverage

Pest stresses:
- Soil heating
- Soil acidification

Pending

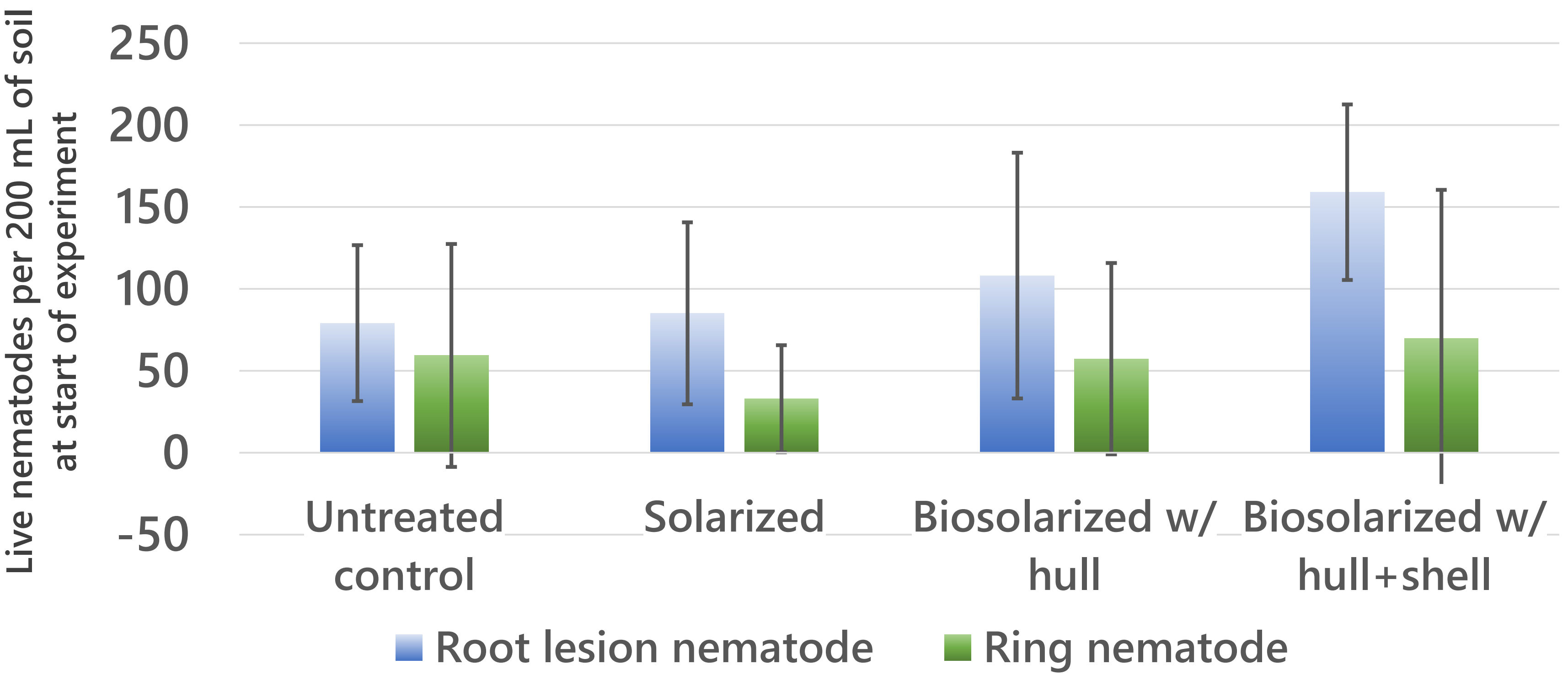
Microbiome:
- Diversity
- Pathogenic taxa
- Enrichment of microbes involved in mineralization

Phytonutrients:
- Total and mineral N
- Extractable P and K

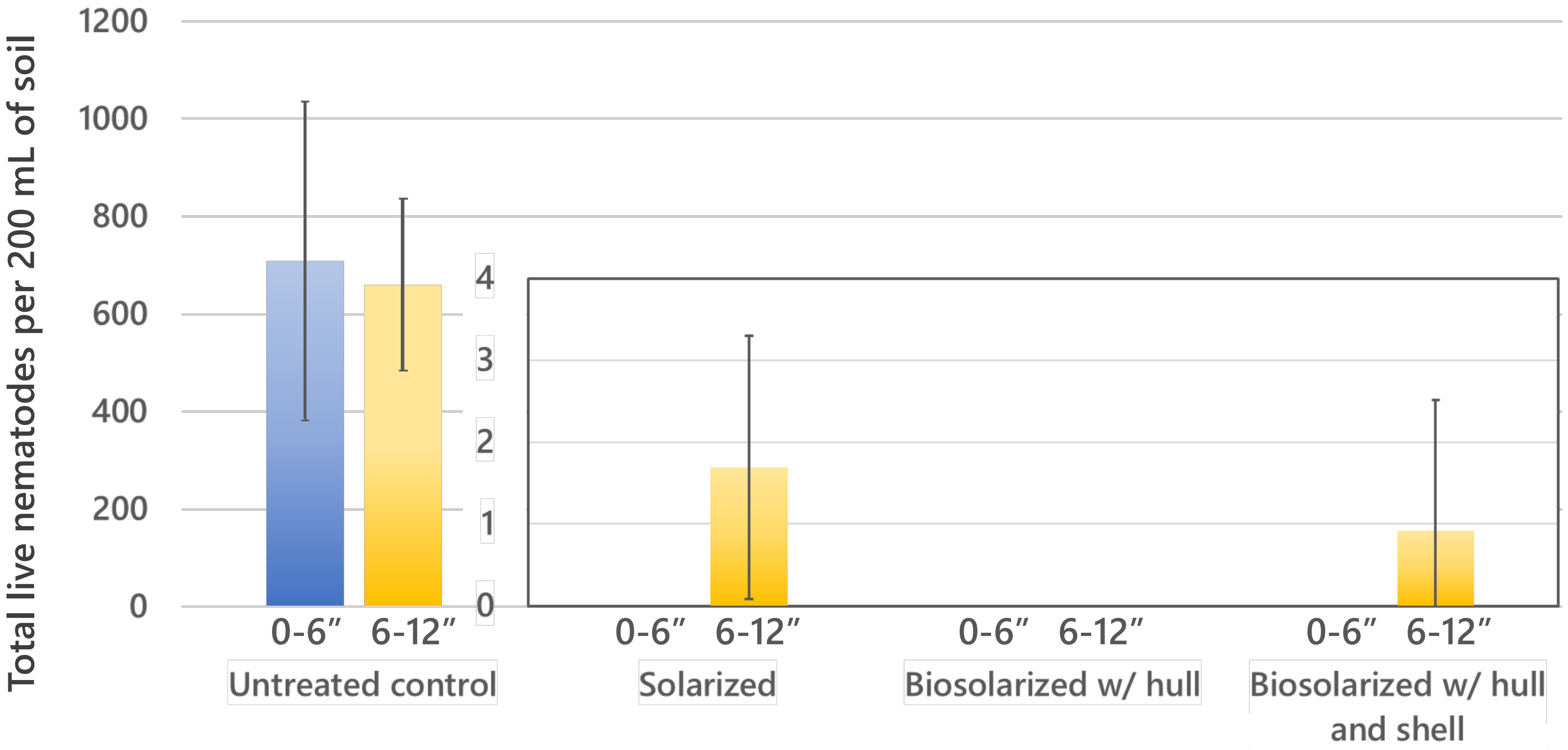
Weed inactivation


untreated
solarized
biosolarized w/ hull
untreated
biosolarized w/ hull & shell
untreated

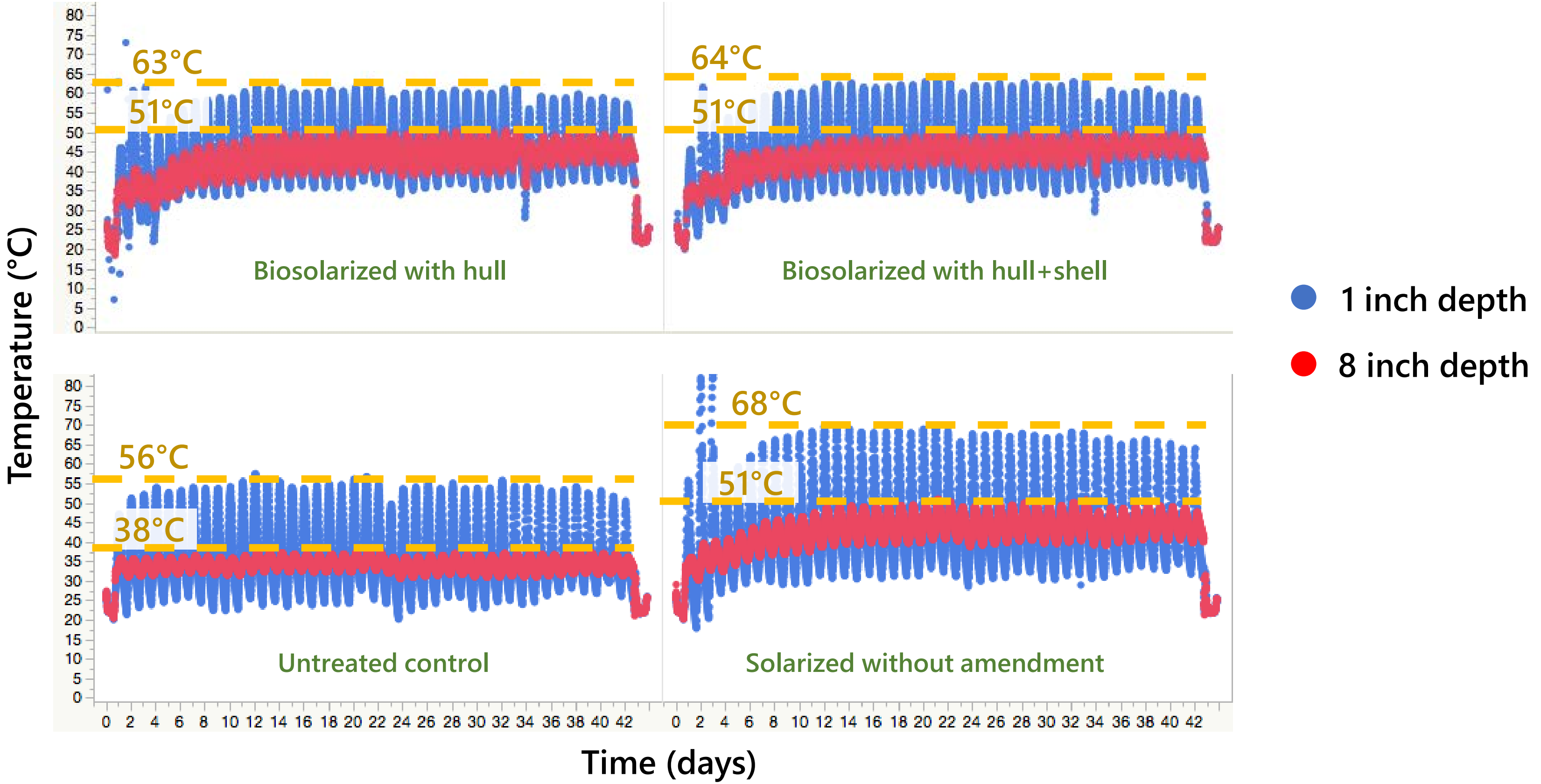
Field plots were initially infested with plant parasitic nematodes



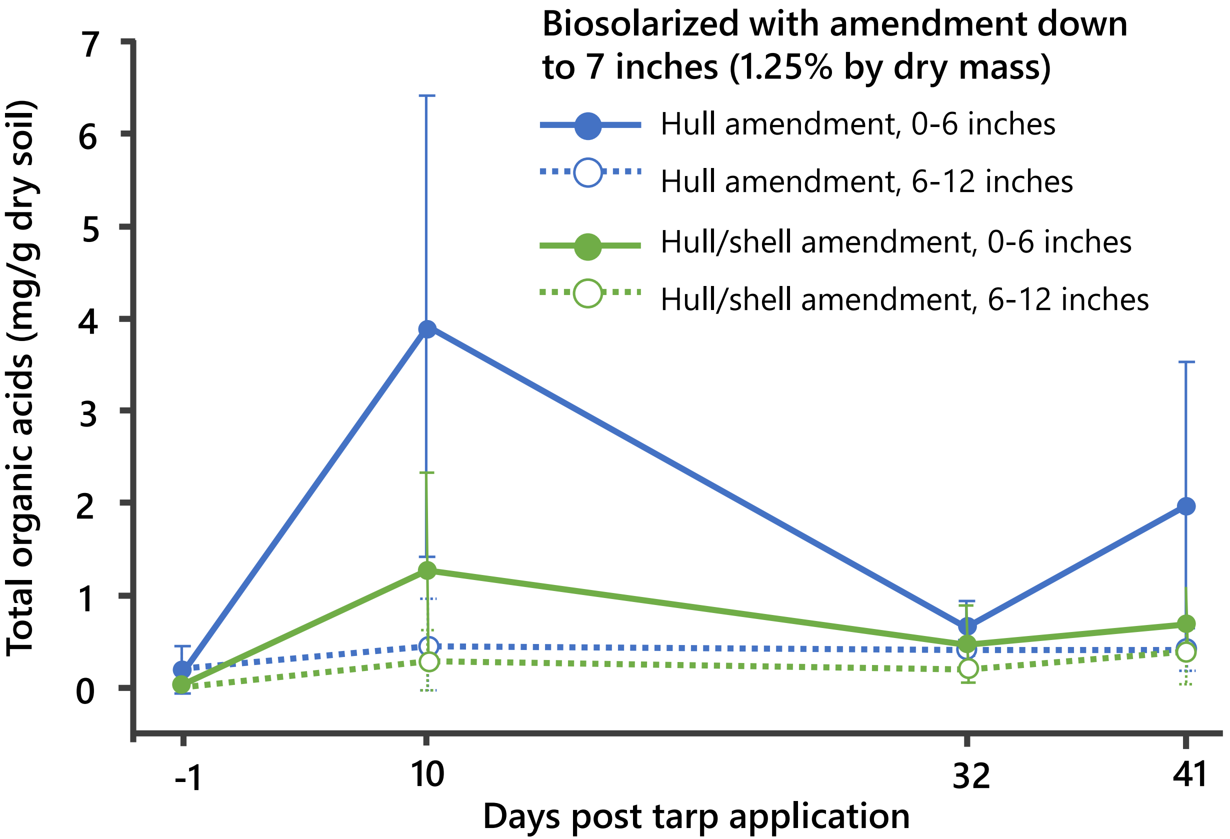
Significant nematode reduction in treated plots by 10 days of treatment



Solar heating elevated peak and average soil temperatures

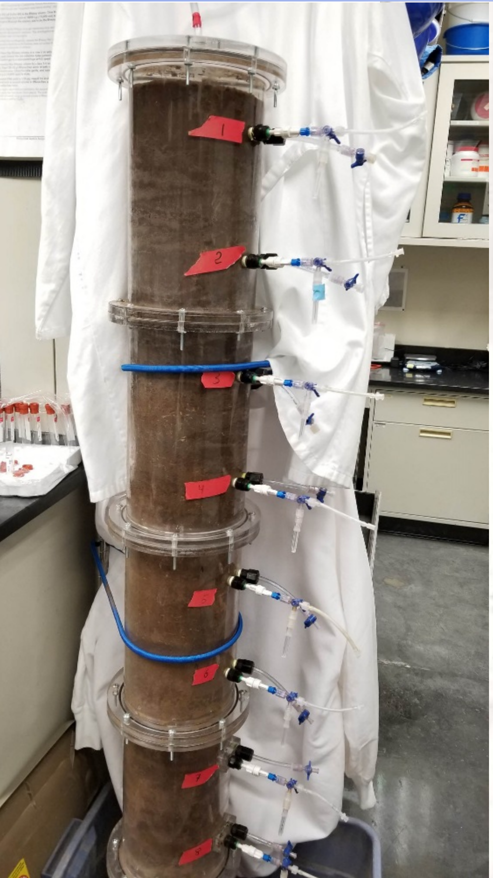


Organic acids accumulated in biosolarized soils



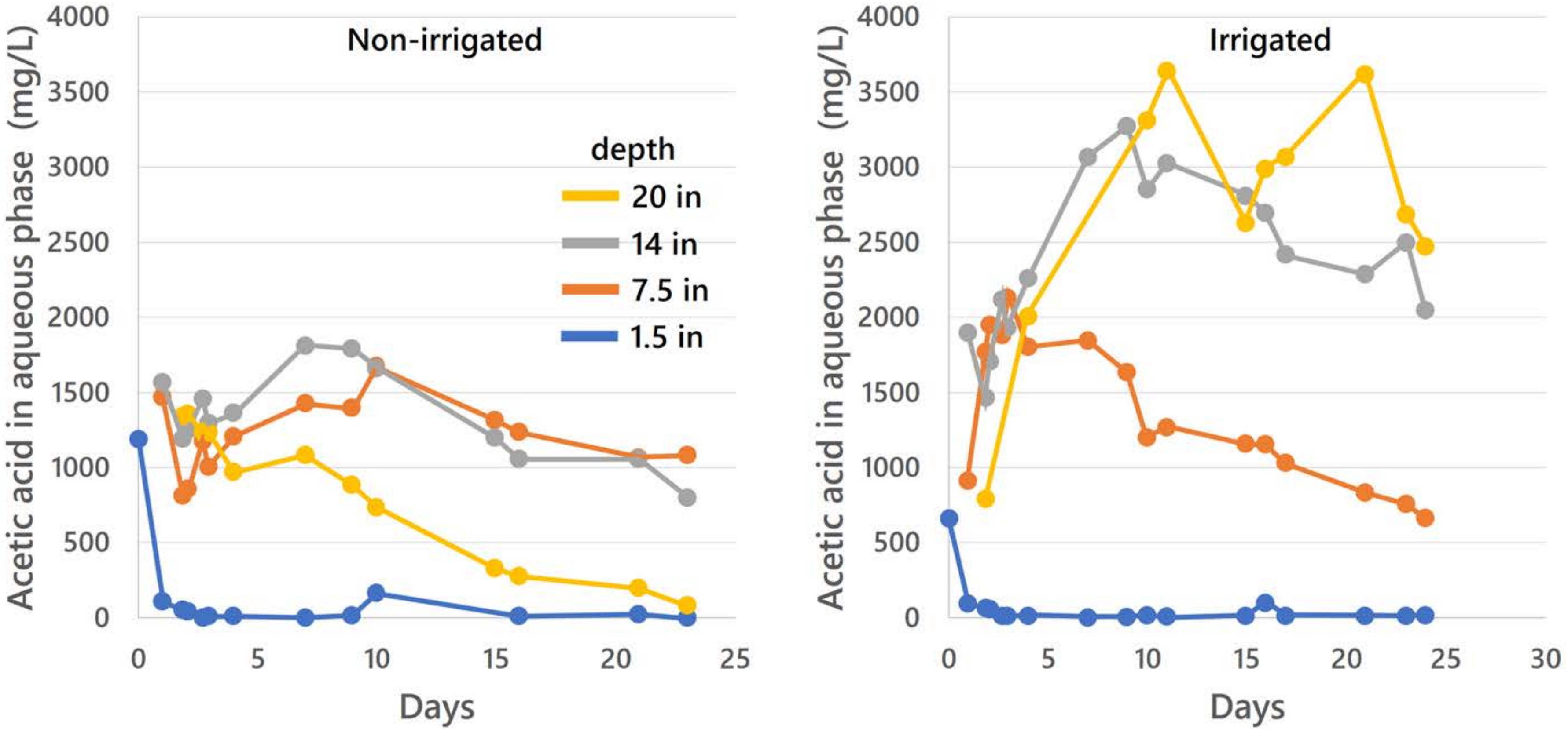
*No acids were detected in non-amended soils

Soil column bioreactors are used to study biosolarization effects as a function of soil depth



- **Columns allow aqueous sampling every 6 inches down to 5 ft depth.**
- **Irrigation can be controlled and tracked throughout the column.**

Irrigation during biosolarization can leach biopesticidal organic acids deeper into the soil



Biosolarization field work - responses

Direct and drone-based measures of tree vigor:
- Trunk diameter
- Canopy area
- Chlorophyll index
- Indicators of disease
    - Stunting
    - Thinning
    - Yellowing/dieback
- Yield (eventually)

Biosolarization field work - value

- Benefits
- True translational study with all farm operations and materials that would be used at commercial scale.

- Measure interactions between biosolarization treatments and almond varieties.

Image: Nicolaus Nut Co.

Acknowledgements

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Kelley Hestmark
Tara Randall
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Jim Stapleton (Co-PI)

Deborah Bennett (Co-PI)

Amanda Hodson (Co-PI on Almond Board project)
Janina Milkereit

Nicolaus Nut Co.
Rory Crowley
George Nicolaus

Almond Board of California
Guangwei Huang
Karen Lapsley
Gabriele Ludwig

california almonds®

Western Center for Agricultural Health and Safety

National Institute for Occupational Safety and Health
NIOSH

Thank you

Contact: cwsimmons@ucdavis.edu

Torrefaction of Almond Shells: Properties and Applications

Adding Value to Almond Co-Products

Bor-Sen Chiou[1], Zach McCaffrey[1], Trung Cao[1], Diana Valenzuela-Medina[1], Mark Wechsler[2], Cristina Bilbao-Sainz[1], Tina Williams[1], Delilah Wood[1], Greg Glenn[1], William Orts[1]

[1]Bioproducts Research, USDA, Albany, CA

[2]Renewable Fuel Technologies, San Mateo, CA

Acknowledgements

- Almond Board of California
- California Walnuts
- California Department of Food and Agriculture
- CRADA with Renewable Fuel Technologies

Outline

– The Issue

– Torrefied biomass-polymer composites

- Improving heat stability of plastics using shells
- Improving their mechanical properties too

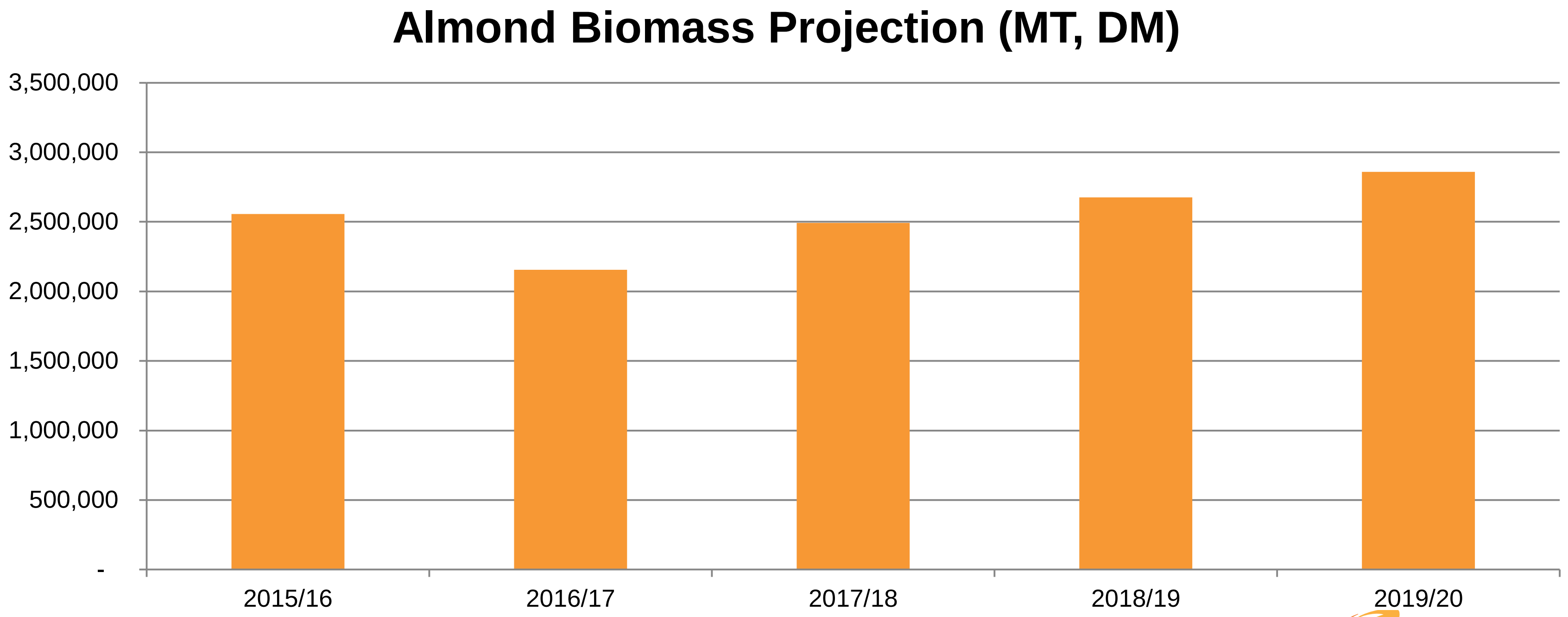
– Scale up to Pilot-scale

– Potential commercial production

- Current and future work

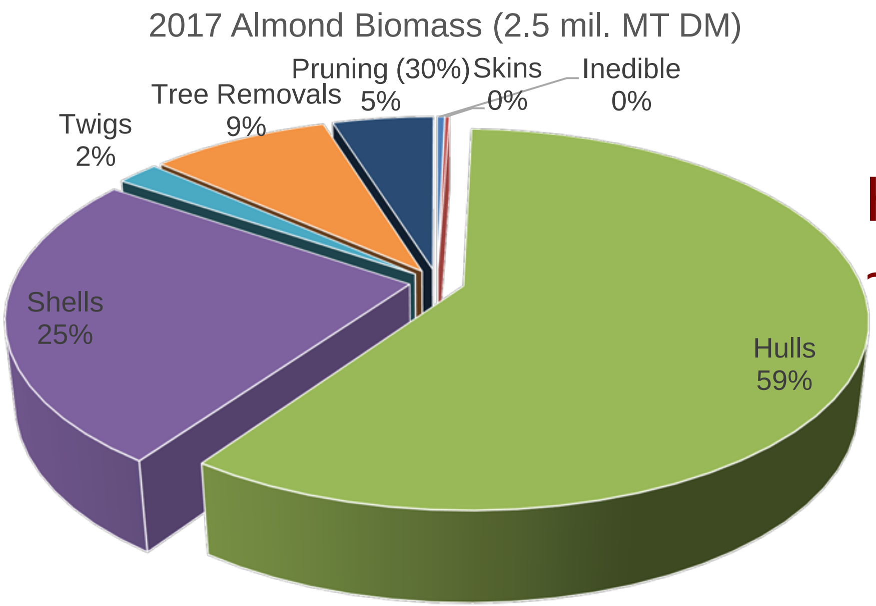
– Conclusions

The Issue: Almond Biomass is Increasing ⇔ Good News!



The Relative Value of Co-Products is Decreasing

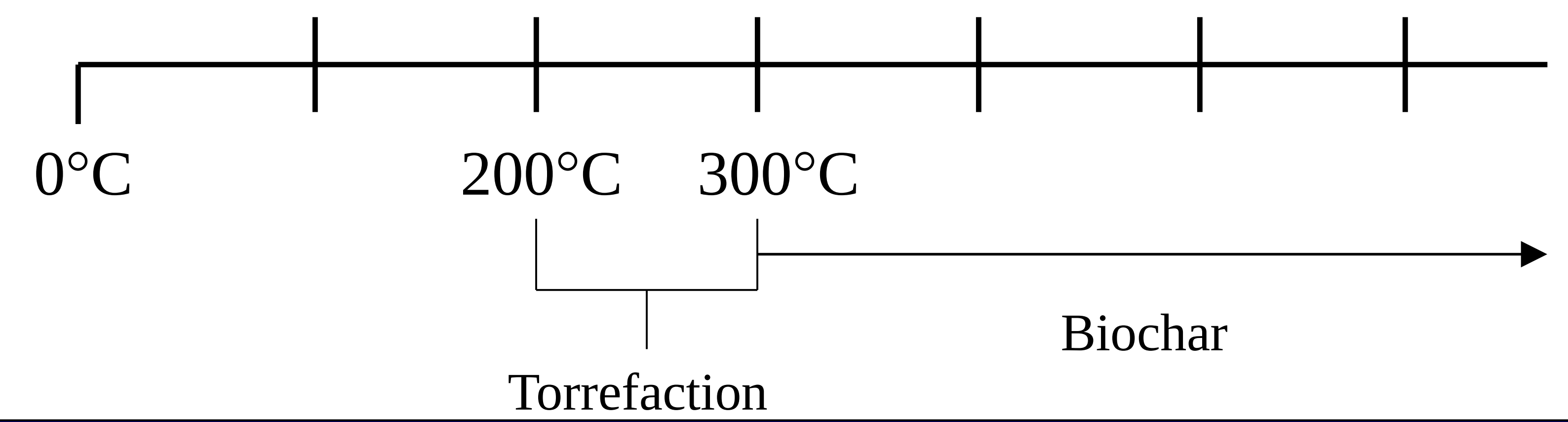
Our Goal:
Add value to shells >$25/ton



Hulls once fetched ~$125/ton

The industry is losing millions in potential revenue……

Torrefaction



- Torrefaction: 200ºC to 300ºC under inert atmosphere
- Removes moisture and volatiles → stable to microbial attack
- Densify torrefied biomass → cheaper to transport
- Energy value ~ low rank coal

Torrefied Almond Shells

230^{o}C

260^{o}C

290^{o}C

60 min 80 min 100 min

Torrefied Biomass-Polymer Composites

- Alternative to wood-polymer composites
- Wood-polymer composites: > 1 million tons annually for non-structural applications
- Torrefied biomass: process composites over 200°C, more hydrophobic, lower moisture

Making plastic parts with almond shell additives

Torrefied biomass:

Almond shells at 280°C

Walnut shells 260-280°C

Polymer:

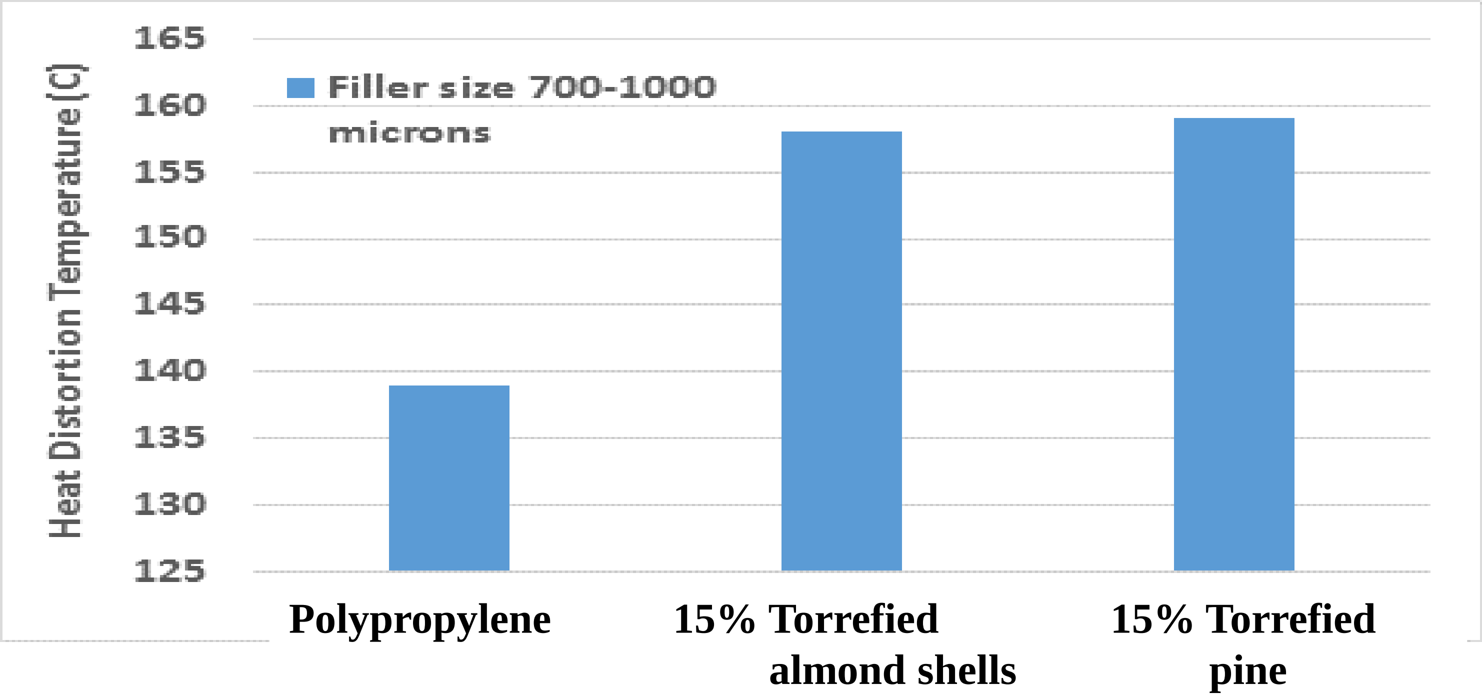
Polypropylene

Bor-Sen Chiou

The Softening Point of Recycled Plastic

a.k.a. ⇔ the heat distortion temperature

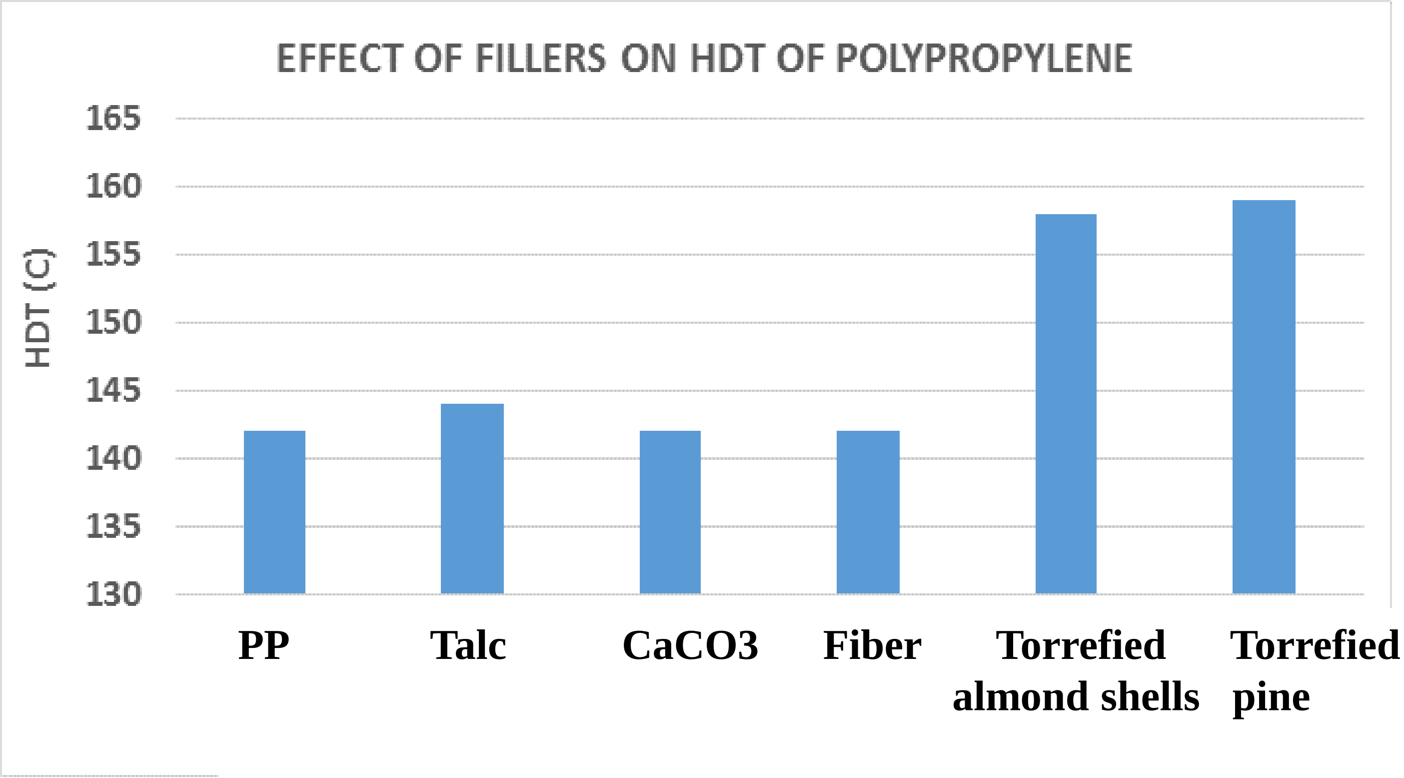
Temperature at which material deforms under specific load



The Softening Point of Recycled Plastic

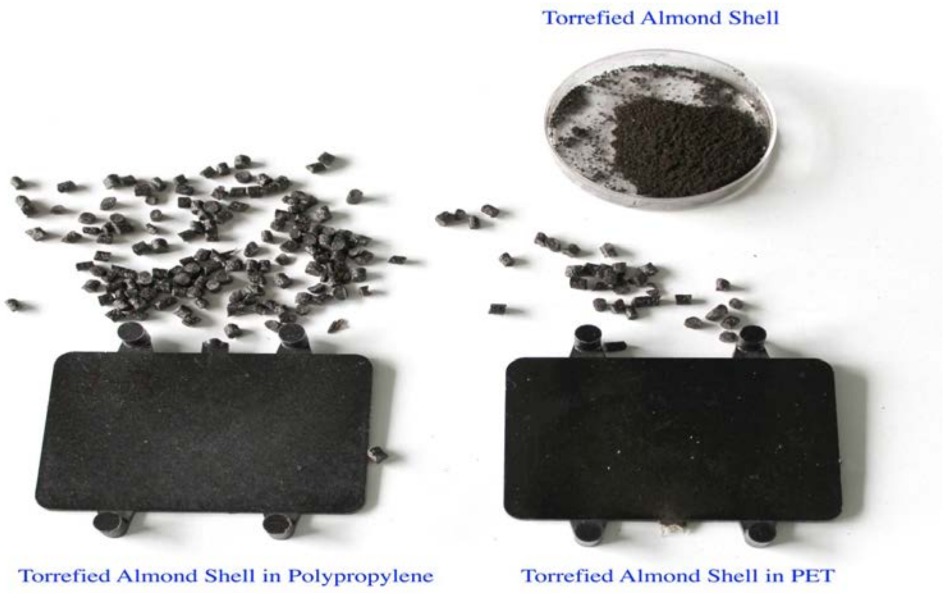
a.k.a. ⇔ the heat distortion temperature

Temperature at which material deforms under specific load



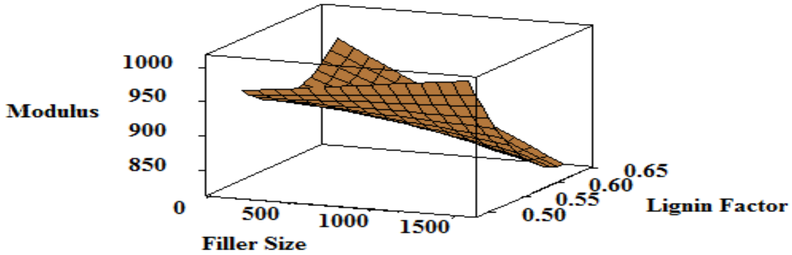
Early Research – Lab Scale

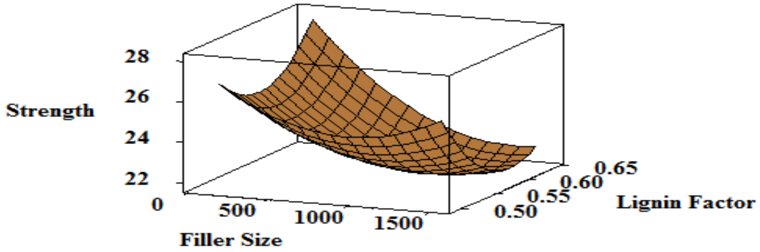
- Different torrefied biomass sources improved the properties of plastics at lab scale
- Problems with brittleness were identified



Tensile Properties

12.5 % (w/w) torrefied almond shells



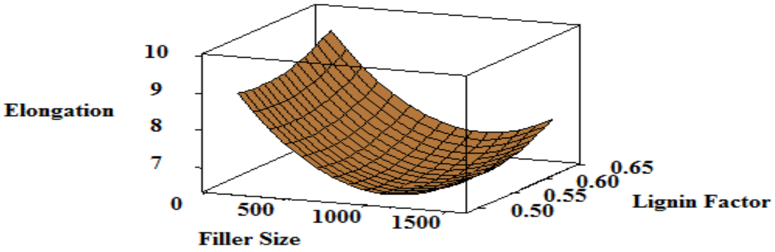


Polypropylene:

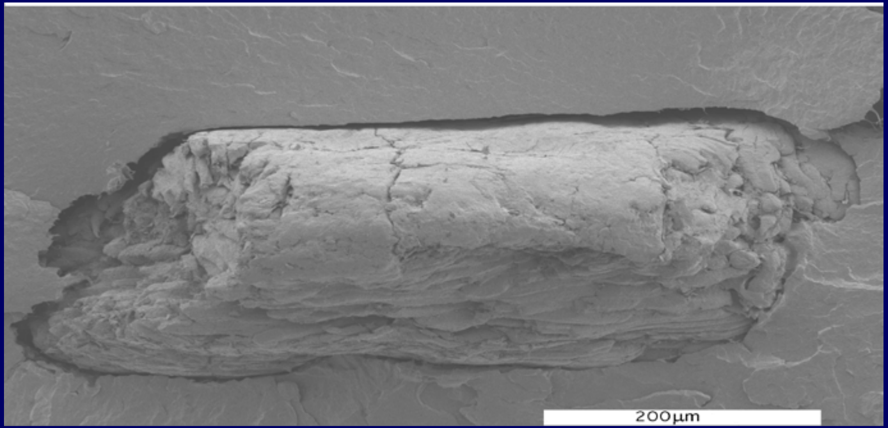
Modulus: 909 MPa

Strength: 36 MPa

Elongation: 715%

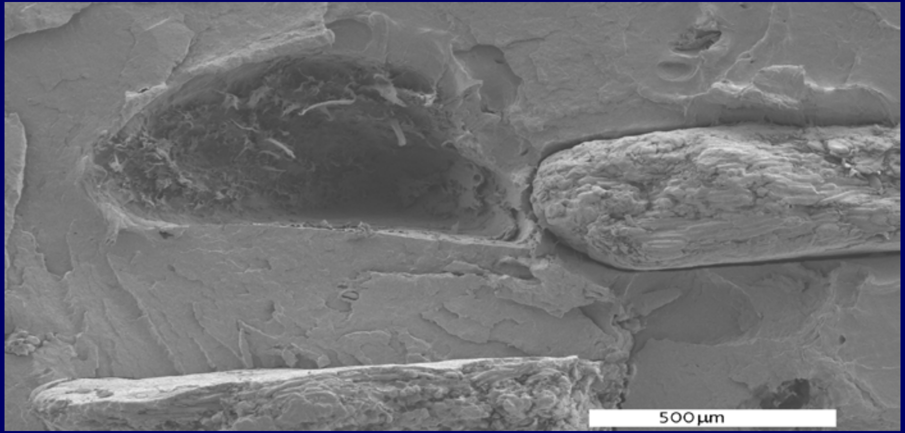


Scanning Electron Micrographs of Composites



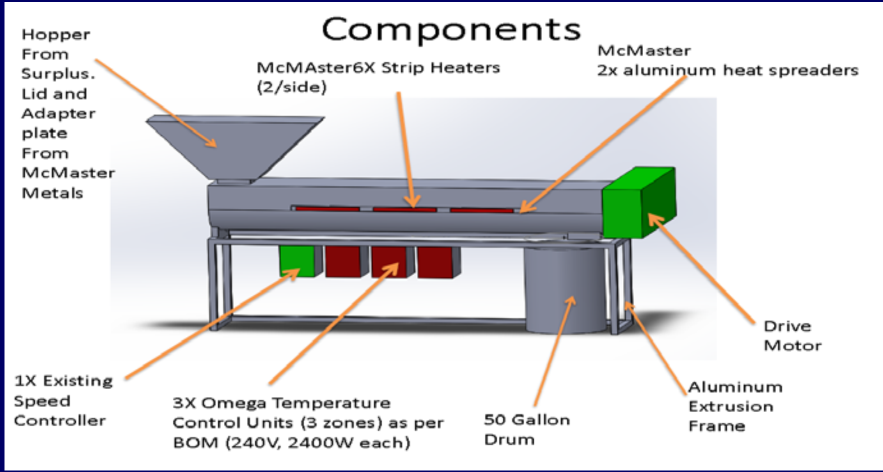
– Space between filler + polymer→ weak interfacial adhesion

– Consistent with tensile properties



– Polymer strands in filler space→ some adhesion between filler + polymer

Pilot-scale Torrefaction Reactor



– Three heating zones to control temperature

– Produce 10-20 lbs of torrefied shells/hour

– Provide consistent samples for optimization studies

How? Next Step – Scaled R&D

- Produce tons of Material
  - Torrefied material was provided under contract from Earth Care Products using a DOE-funded torrefaction ‘truck
  - The USDA has been offered a “Free” lease on this

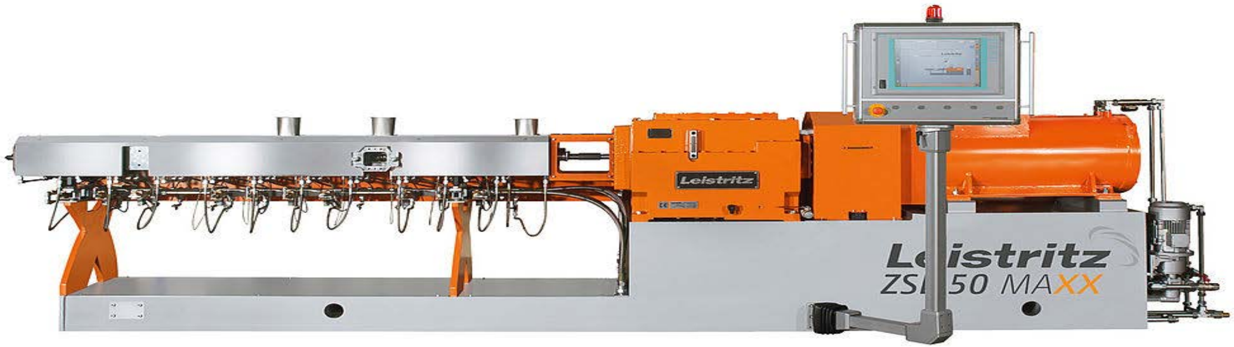
Recent Research – Pilot Scale

- We challenged the industry to create “buckets” of material, which have been processed
- We produced sheet capable of making high quality parts at pilot scale.

Converting plastic sheets into products

F-D-S Manufacturing Co.
Since 1950

Commercial Application



- Grow Plastics and FDS Manufacturing are purchasing a compounding extrusion sheet line capable of 1,000 lbs/hour
- This will likely justify a sheet production facility in Northern California that adds torrefied almond shells into plastic sheets

Current and Future Work

– Optimize properties of torrefied shell-polymer composites
  - Polyethylene terephthalate (PET)

– Optimize scale-up in the pilot plant
  - Test pilot-scale prototype materials from varied biomass sources

– Create commercial prototypes and work with companies toward commercialization scale

Conclusions

– Produced composites with high levels of torrefied shells
  - Composites had higher modulus and T_d, but lower strength and elongation
  - Some interactions between filler + polymer matrix

– Pilot-scale torrefaction reactor is to be used to provide consistent samples

Thank you!

What's Next

Tuesday, December 5 at 1:45 p.m.

- Common Errors in Orchard Set Up– Room 308-309
- Repositioning Plant-Based Protein – Room 306-307
- The Science and Practice of Intentional Recharge in Almond Orchards – Room 312-313
- Produce Safety Rule for Farms: How to Comply and What About the Grower Exemption? – Room 314

CEUs – New Process

Certified Crop Advisor (CCA)

- <u>Sign in and out of each session you attend.</u>
- Pickup verification sheet at conclusion of each session.
- *Repeat this process for each session, and each day you with to receive credits.*

Pest Control Advisor (PCA), Qualified Applicator (QA), Private Applicator (PA)

- Pickup scantron at the start of the day at first session you attend; complete form.
- <u>Sign in and out of each session you attend.</u>
- Pickup verification sheet at conclusion of each session.
- Turn in your scantron at the end of the day at the last session you attend.

Sign in sheets and verification sheets are located at the back of each session room.