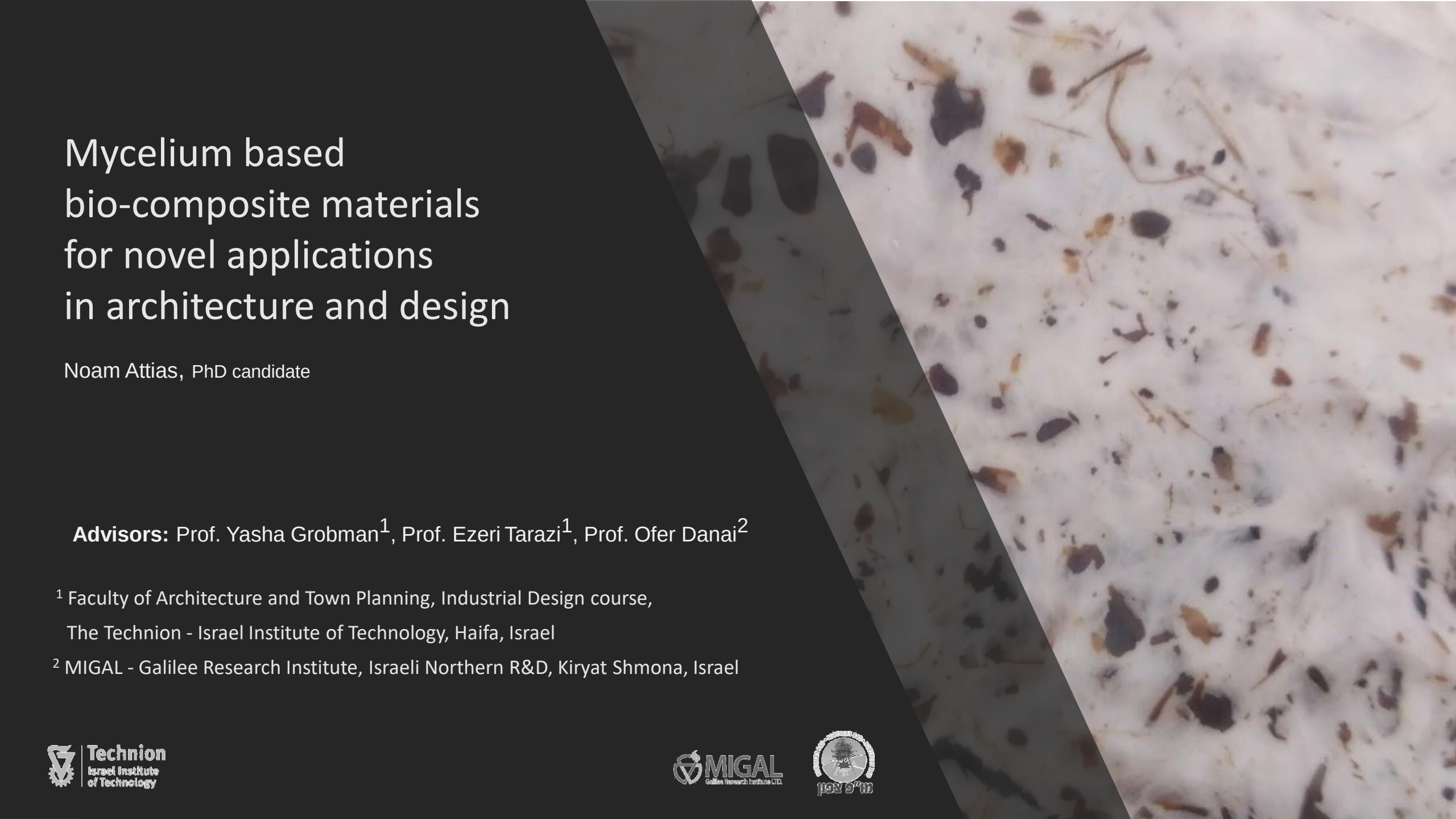
Mycelium based bio-composite materials for novel applications in architecture and design

Noam Attias, PhD candidate

Advisors: Prof. Yasha Grobman[1], Prof. Ezeri Tarazi[1], Prof. Ofer Danai[2]

[1] Faculty of Architecture and Town Planning, Industrial Design course,
The Technion - Israel Institute of Technology, Haifa, Israel

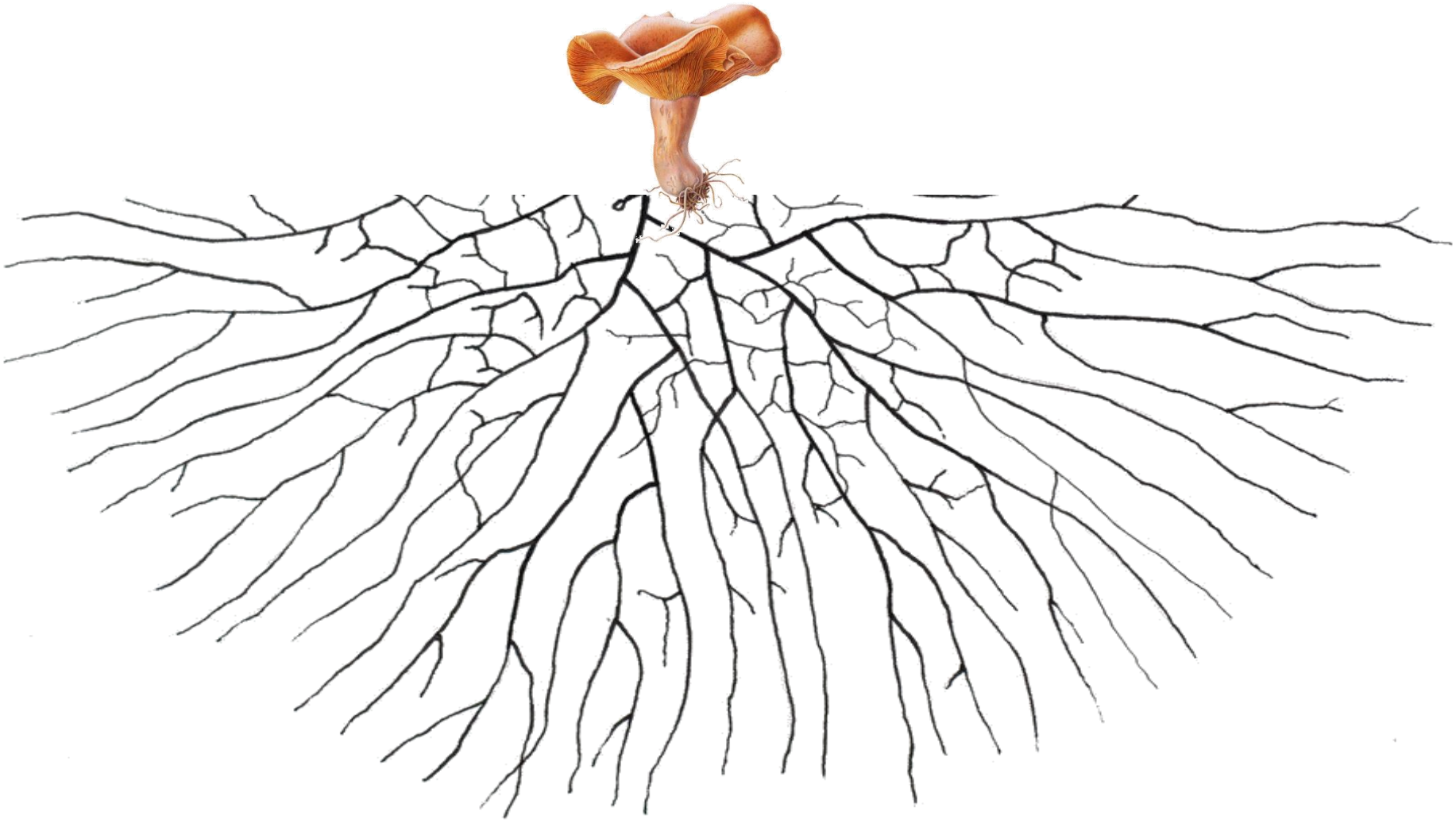
[2] MIGAL - Galilee Research Institute, Israeli Northern R&D, Kiryat Shmona, Israel



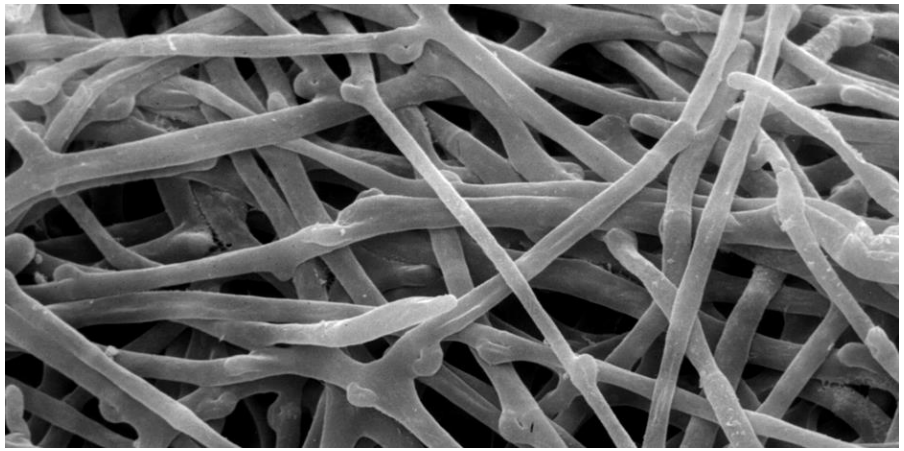
Fungi

Susannah Blaxill - Botanical Artist - Pine Cap Mushroom - Science and Nature

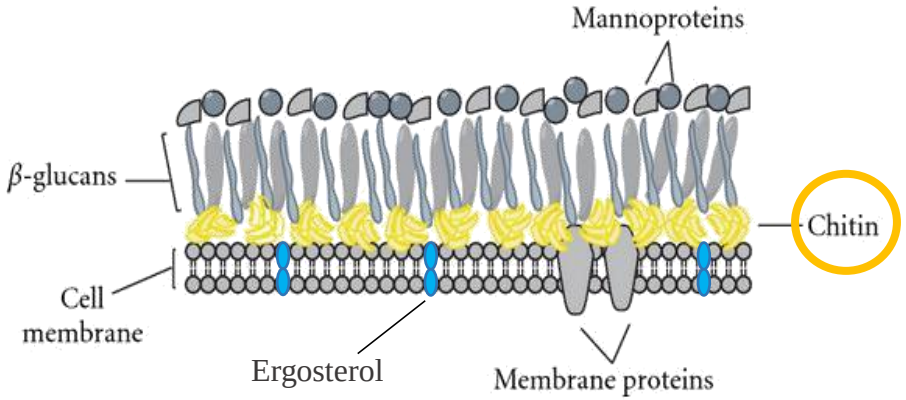
Mycelium



Mycelium



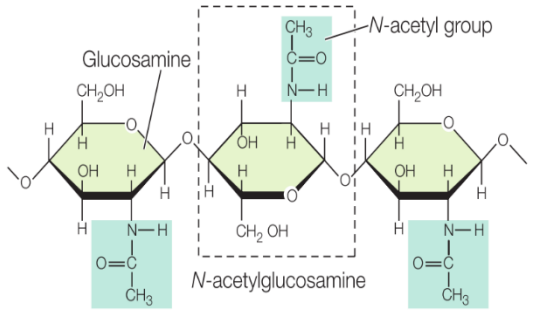
Fungal cell wall structure

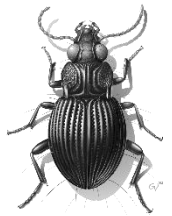


Main Functions:

- Organic matter degradation
- Absorption and transfer of nutrients
- Vegetative reproduction
- Structural properties

Chitin- A highly rigid carbohydrate





Fungi - Division by feeding method

Fruiting body

Mycelium

Saprophytic

nonliving organic matter

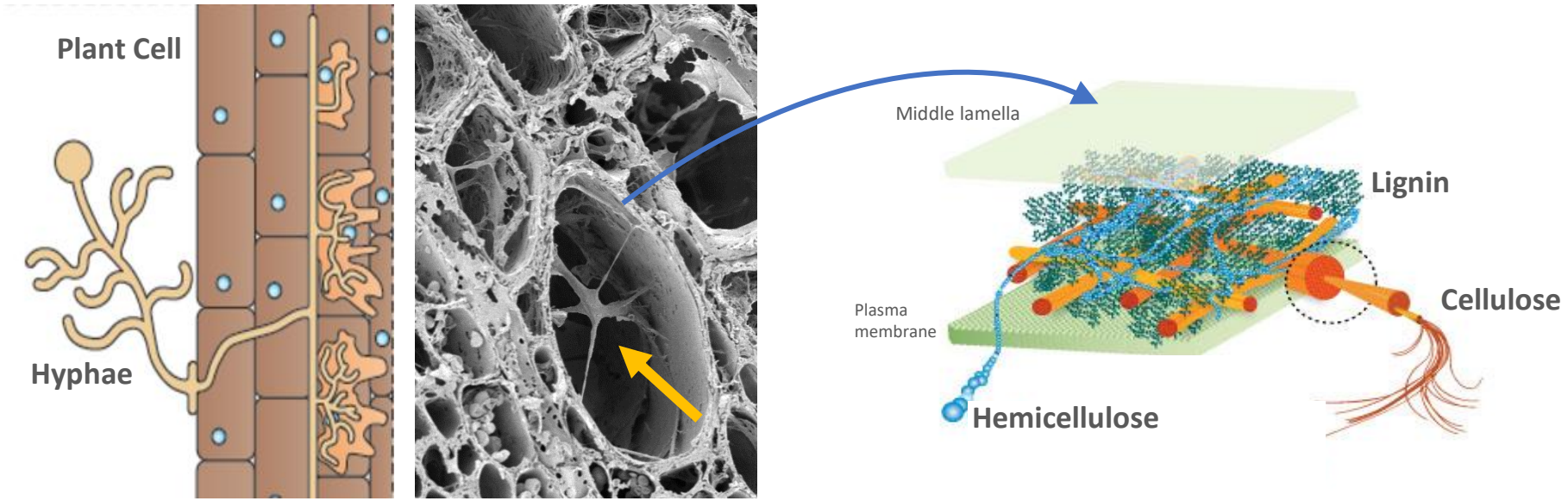
Parasitic

Living Organisms

Mycorrhizae

Beneficial relationship with plants

Selective digestion of plant by fungi



A complex enzymatic process enables the white rot fungi with a unique ability to digest highly stable molecules such as the structural polysaccharides of plants

While mycelium digest and develop, its also binds the plant fibers together

The Problem

WASTE

The Opportunity

Current applications

Ecovative Eben Bayer & Gavin McIntyre

MycoWorks Philip Ross

Officina Corpuscoli Maurizio Montalti

Mycelium + Plant waste = A natural bio-composite

Gaps

- **Biology:** A systematic test of all significant variables affecting material properties
- **Design:** Using nano-biological mechanisms to achieve desirable shapes and functions

Hypothesis

The initial chemical composition of the substrate affects the rate and structural development of the fungal mycelium.

Changes in chemical composition of both plant/fungi cell wall during mycelium development affect on material properties of the final bio-composite

Objectives

Fungi species	<> **Substrate** type & processing	**Composition** Chemical	**Material** properties	**Fabrication** methods	**Applications** Material driven

Fungi-Substrate Experiment

Goals:

1. locate the most suitable **fungi-substrate combination** for further exploration and development.

2. understand which **quantitative parameters** can assist to **evaluate mycelium** quality and efficiency.

Materials and Methods:

- **Incubation** of 4 white rot fungi species with 5 types of grinded agriculture and forest pruning wastes
- **Test changes in chemical parameters:** Water capacity, pH level, Nitrogen content, Organic matter content
- **Qualitative characterization of mycelium development:** Rate, thickness, density

Aegerita agrocybe

Pleurotus pulmonarius

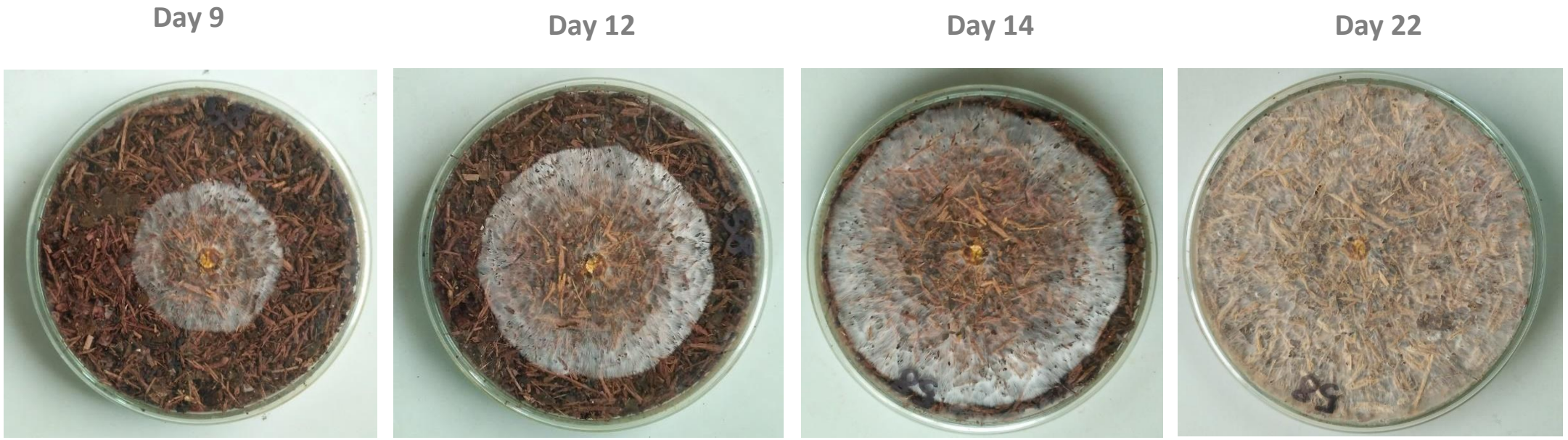
Pleurotus ostreatus

Pleurotus salmoneo

+

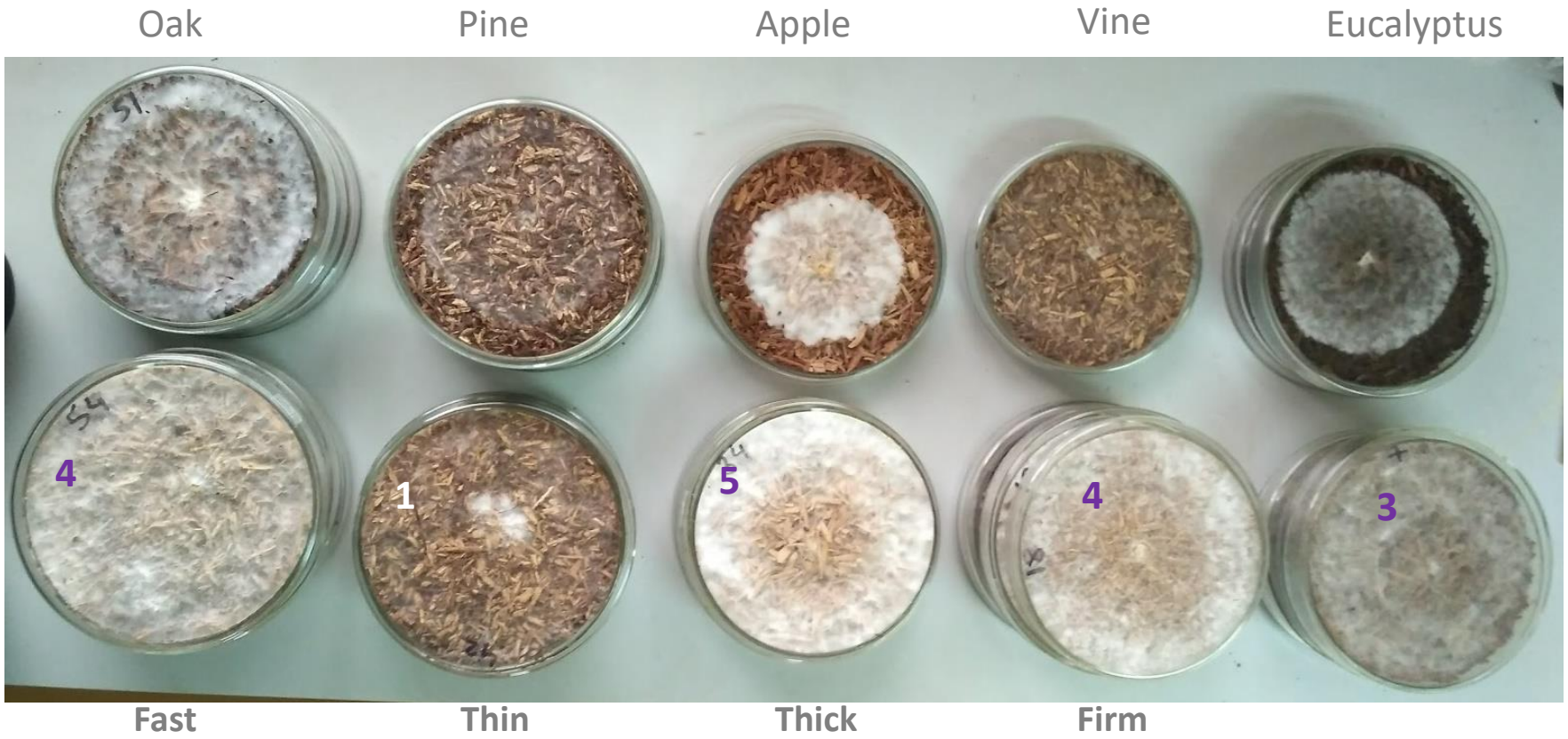
Eucalyptus, Vine, Apple, Pine, Oak

Results Qualitative characterization of mycelium development: Rate, thickness, density



Oak wood chips + *P. pulmonarius* – fastest growth – full plate in 16 days

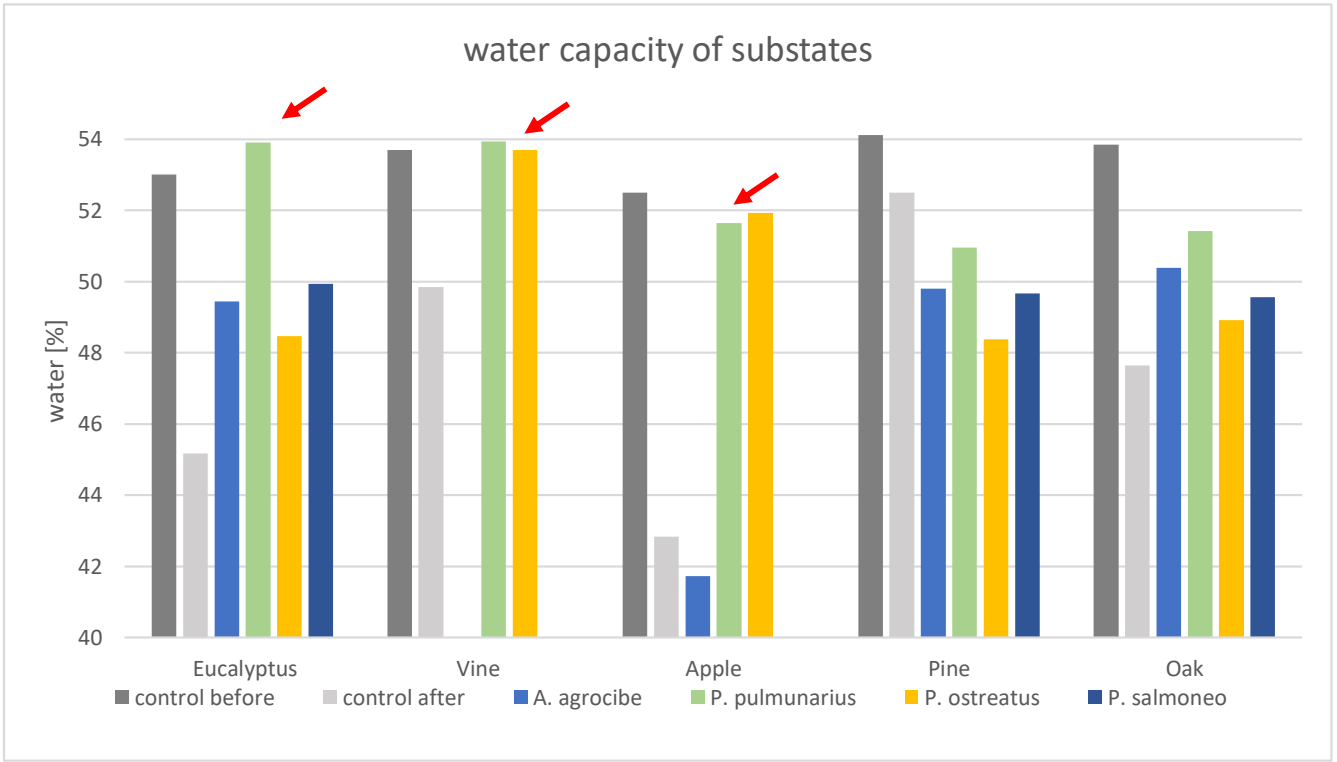
Results Day 28



>> The initial chemical composition of the substrate affects the rate and structural development of the fungal mycelium

Results Changes in water content

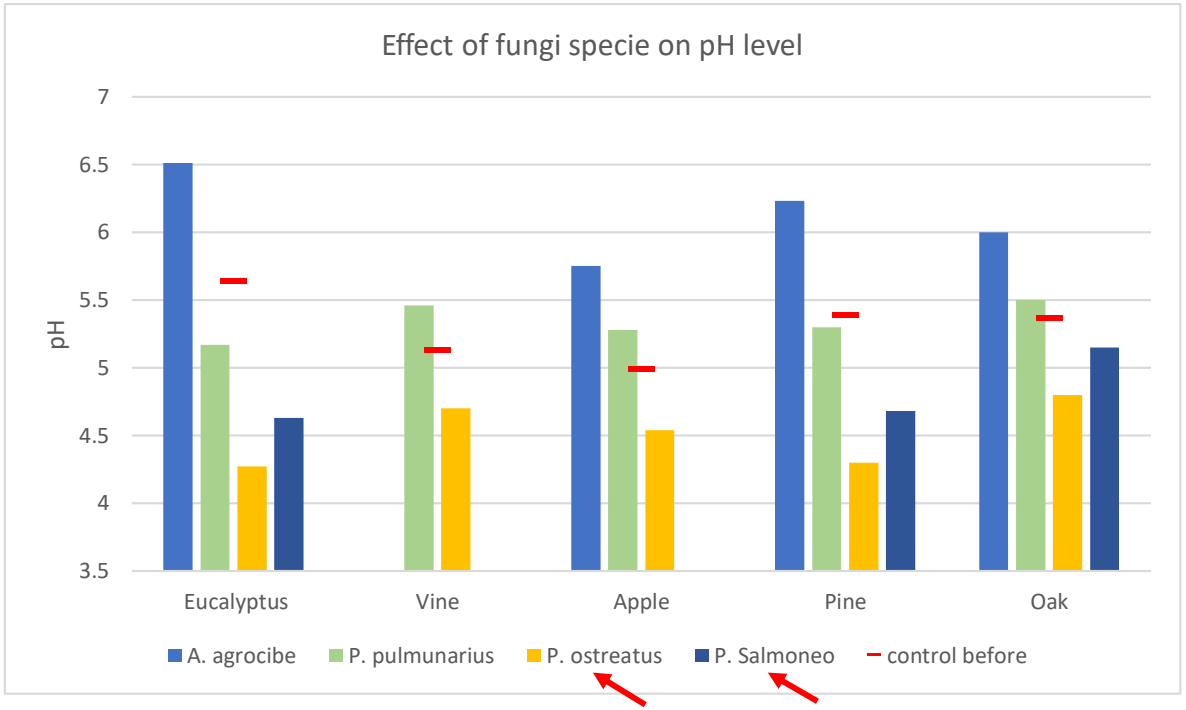
about 65% water is essential for fungal growth and development



Due to the release of metabolic water during enzymatic digestion process, where mycelium develops, water content is expected to rise or remain stable.

During the experiment, the control samples (without fungi) have generally lost a significant amount of water compared with mycelium containing samples.

Results Changes in pH level

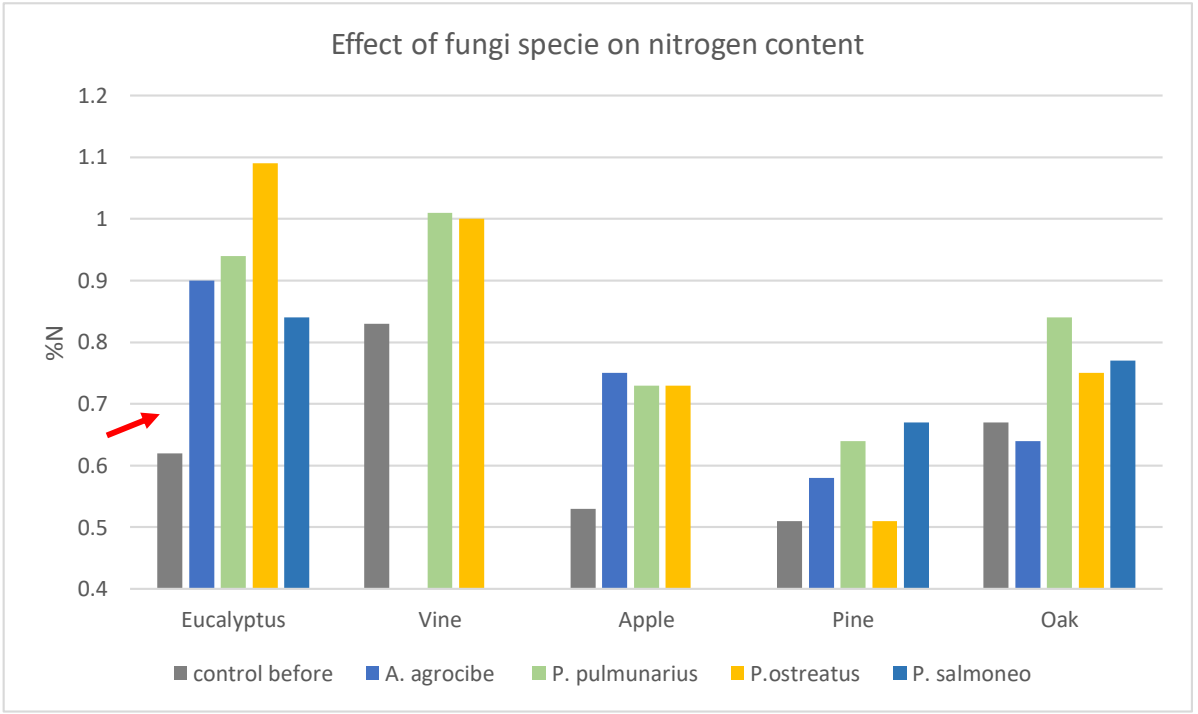


The initial pH level of all substrates was not optimal for mycelium development.
This might have influenced mycelium growth and properties

Due to enzymatic digestion process , the pH level of the substrate is expected to drop where fungal mycelium have developed.

A relatively high initial pH level (around 8) can donate to the selectivity of a substrate, since Pleurotus mushrooms can manage to grow on higher pH levels than other, unwanted fungi types.

Results Changes in nitrogen content

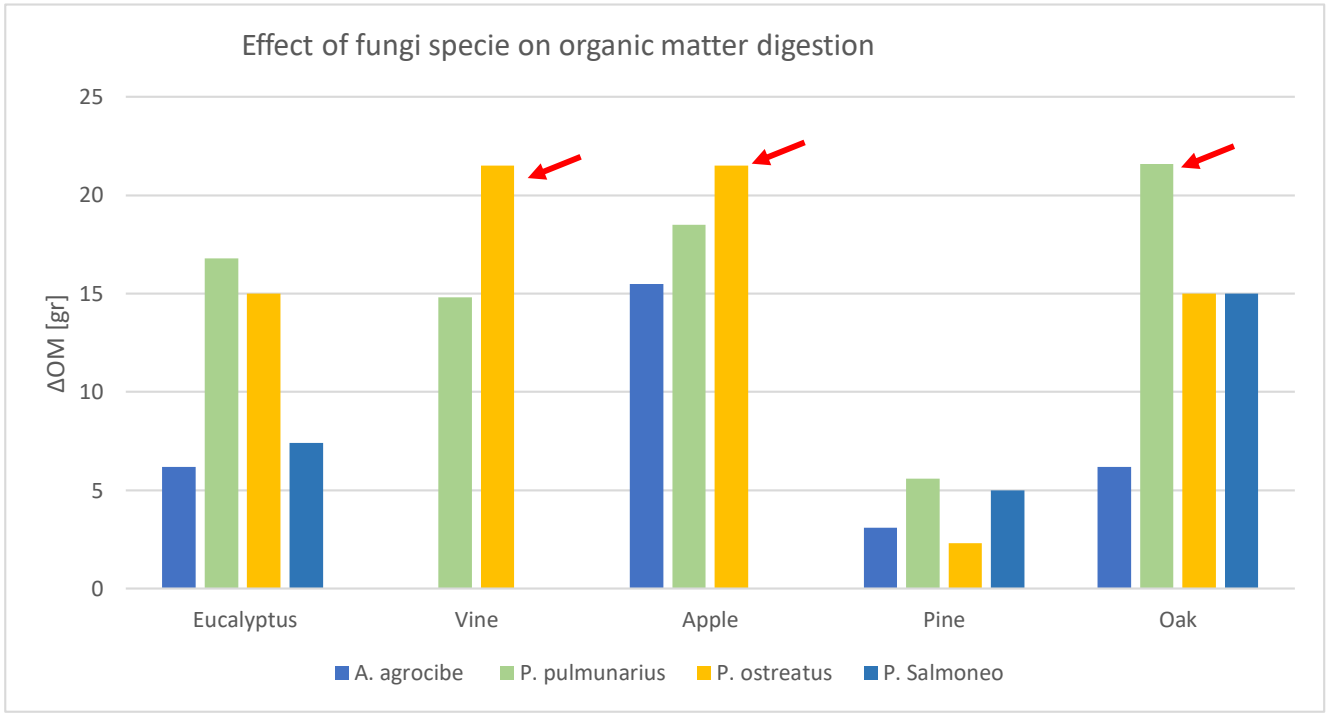


The optimum nitrogen content range for Pleurotus mushroom growth is about 0.6-1%. The organic matter composing wood contains about 50% carbon and around 1% nitrogen.

Due to enzymatic digestion process, the relative nitrogen content is expected to increase in comparison with the control.

In all sets (accept the *A. agrocibe* on oak), the nitrogen level increased during mycelium development.

Results Organic matter digestion



A high correlation between the change in organic matter content and mycelium development indicate that this test is a reliable quantitative index to evaluate mycelium quality.

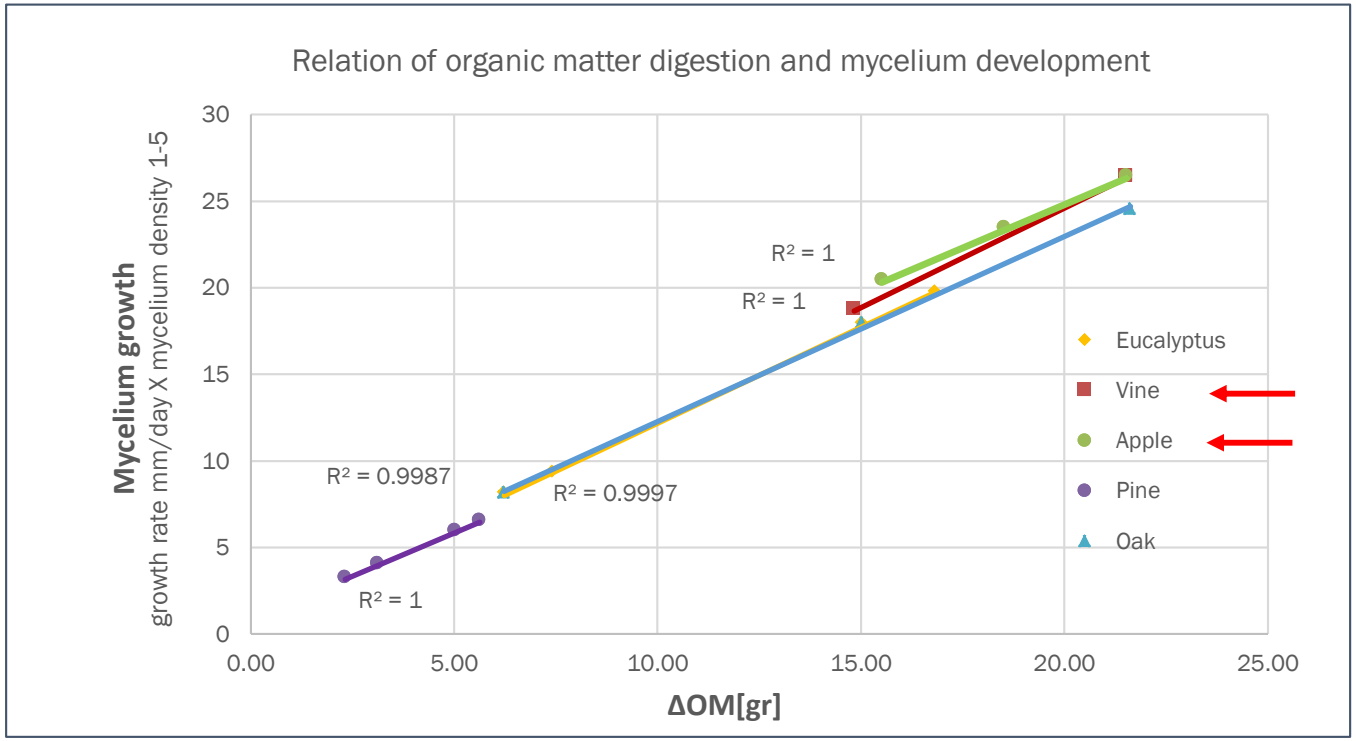
Due to enzymatic digestion, the relative organic matter content is expected to decrease in comparison with the control

The largest change in organic matter is expected where fungal growth is most developed.

Results Quantitative to qualitative evaluation of mycelium growth

Mycelium growth parameters:

Growth rate mm/day **X** **Mycelium density 1-5:** **1**-Thin, almost transparent **5**- Thick and firm, white



A clear correlation between the quantitative change in organic matter content (ΔOM[gr]) during mushroom growth, compared with the parameters of rate, density and thickness tested.

Currently the most reliable index to evaluate mycelium development and suitability for further exploration.

Summary

Chemical parameters: Increase initial water capacity, pH level and Nitrogen content

- ✓ **Match sets** of regional agriculture/forestry waste with available fungal species
- ✓ **Mycelium characterization:** The relation of organic matter digestion (ΔOM) and mycelium development is a reliable index to evaluate mycelium development and suitability for further exploration.

To better evaluate the suitability of each substrate-fungi set for more particular applications, additional analytical and mechanical methods should be used.

P. ostreatus grown in ⌀ 14cm petri dishes with Apple/Vine woodchips

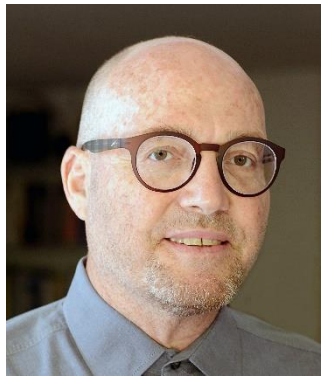
Next steps

- Understand how the development of a Saprophytic fungi mycelium in a plant substrate affects the amount and composition of structural materials in both plant and fungal cell walls
- Evaluate how changes in chemical composition (plant/fungi) during mycelium development affects the final material properties (chemical, physical, mechanical and aesthetic) of the bio-composite
- Use acquired knowledge to deliberately manipulated material properties of a mycelium-plant bio-composite
- Establish international collaborations



Thanks ;)







Noam Attias[1,2], Ofer Danai[2], Nirit Ezov[2], Tom Levi[2], Ezri Tarazi[1], Yasha J. Grobman[1]

[1] The Faculty of Architecture and Town Planning, Industrial Design course, The Technion - Israel Institute of Technology, Haifa, Israel

[2] MIGAL - Galilee Research Institute, Israeli Northern R&D, Kiryat Shmona, Israel