Moisture requirements of wood decay fungi – Review on methods, thresholds and experimental limitations

Christian Brischke[1], Linda Meyer-Veltrup[2], Arved Soetbeer[3]

[1]University Goettingen – Department of Wood Biology & Wood Products

[2]Heinz-Piest-Institute for Craftsmen Techniques, Hannover

[3]Leibniz University Hannover – Faculty of Architecture and Landscape Sciences

Leibniz Universität Hannover

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Background

- Moisture is key parameter for durability of wood
- Critical thresholds of wood MC allowing transport and activity of fungal enzymes into cell walls

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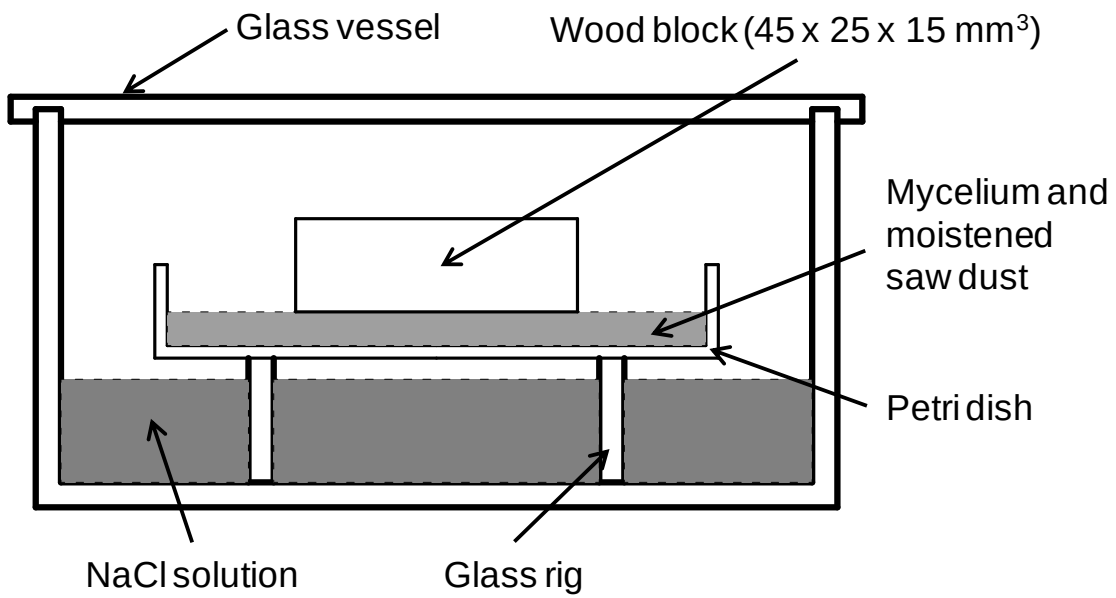
- Moisture is key parameter for durability of wood
- Critical thresholds of wood MC allowing transport and activity of fungal enzymes into cell walls
- Important input factor for:
  - decay modelling
  - simulation in building physics (WUFI)
- Experimental studies since ~100 years

Bavendamm and Reichelt (1938)

- NaCl solutions of different concentrations
- RH = 81.5 – 99 %
- 7 Basidiomycetes
- Scots pine sap & Beech

  >2 % ML at 85.6 % RH

- MC after incubation not determined → no threshold

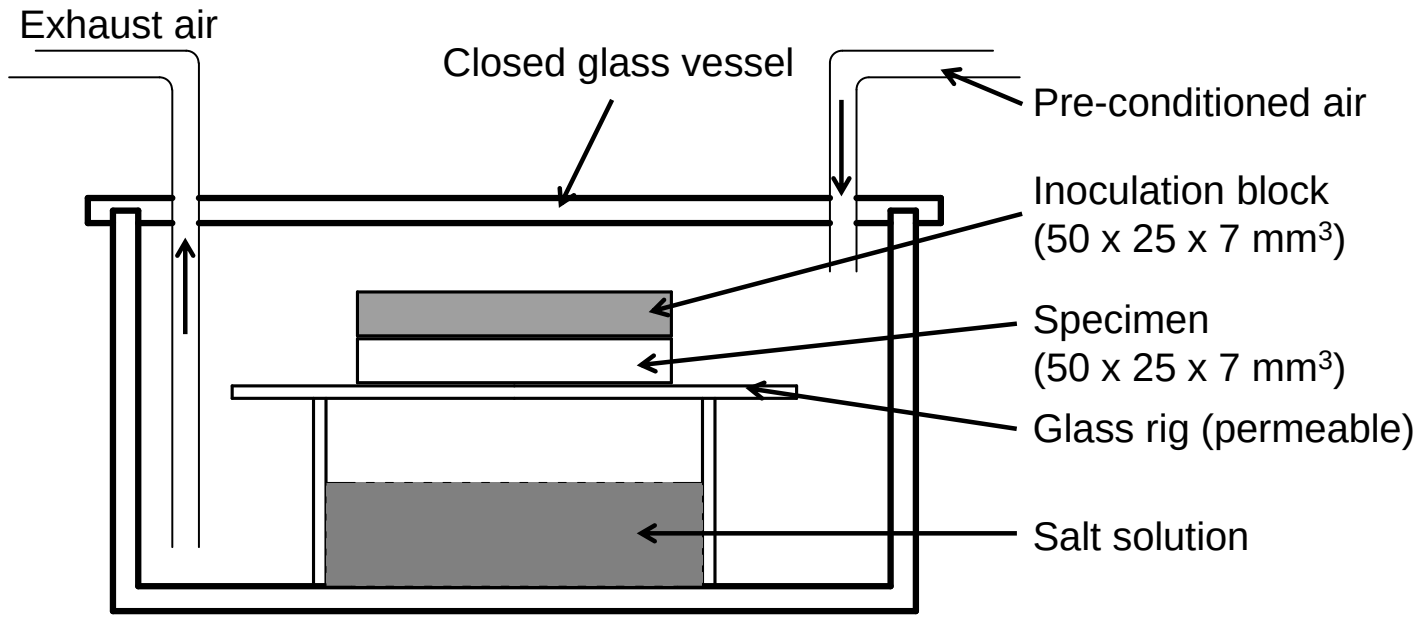


Theden (1941)

- RH = 83 – 100 %
- different Basidiomycetes
- Scots pine sap

  >3 % ML at 98.2 % RH

- No decay below FSP
- MC after incubation >> EMC



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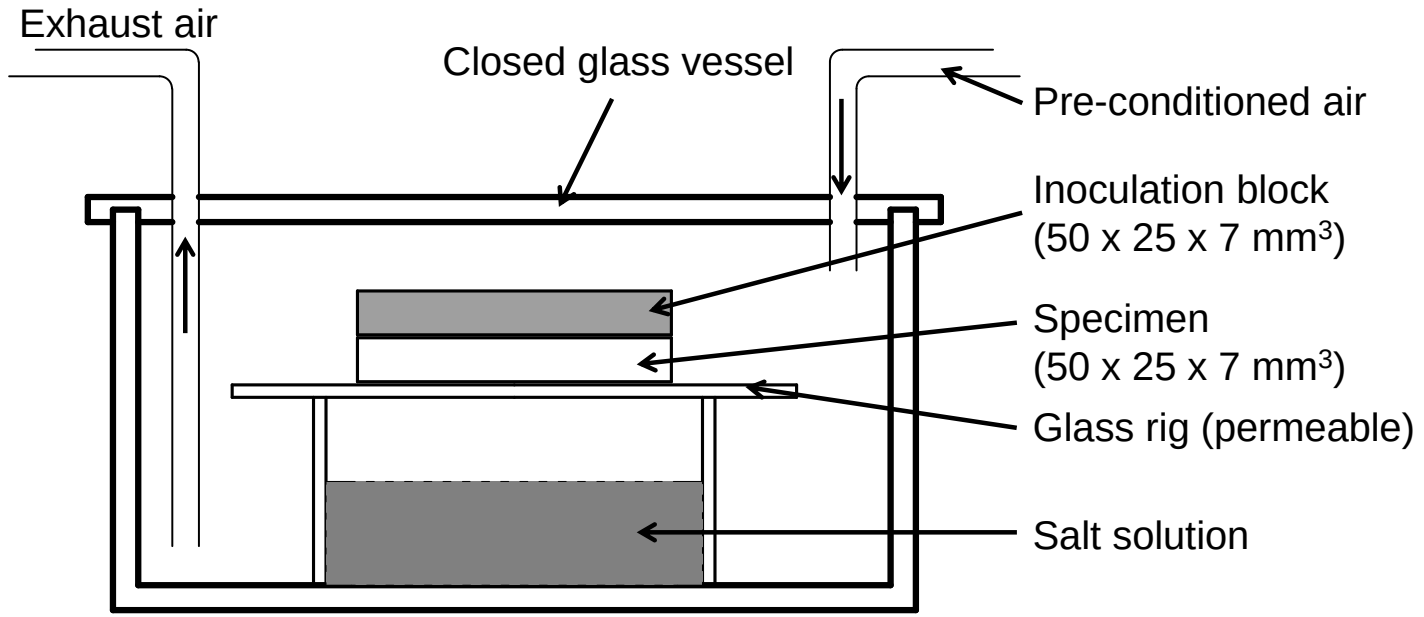
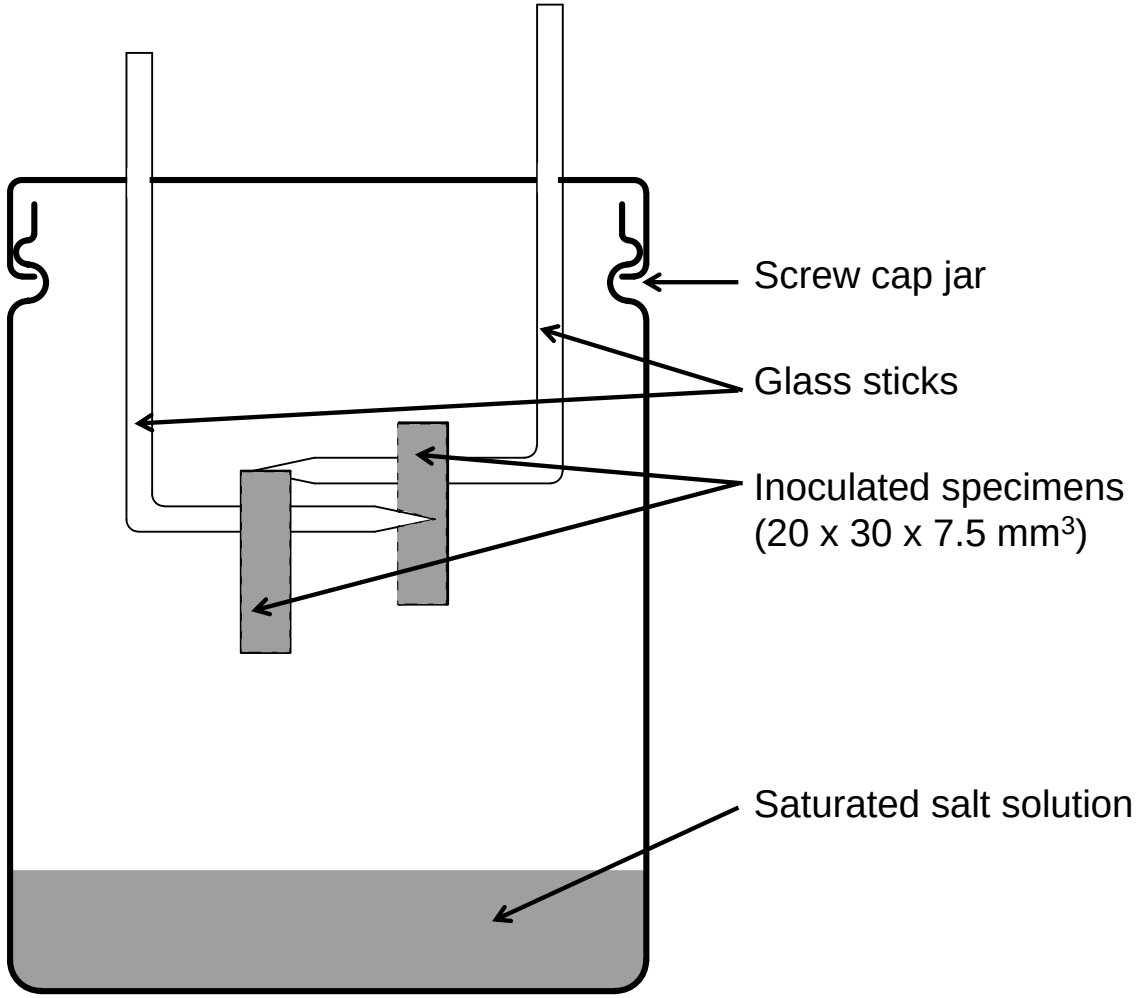


$$(C_6H_{10}O_5)_n + 6 \cdot n \cdot O_2 = 6 \cdot n \cdot CO_2 + 5 \cdot n \cdot H_2O$$

Ammer (1963)

- Different salt solutions
- RH = 22 – 100 %
- Different temperatures
- 7 different Basidiomycetes
- Norway spruce sap

→ ML at 19 % MC (85 % RH)

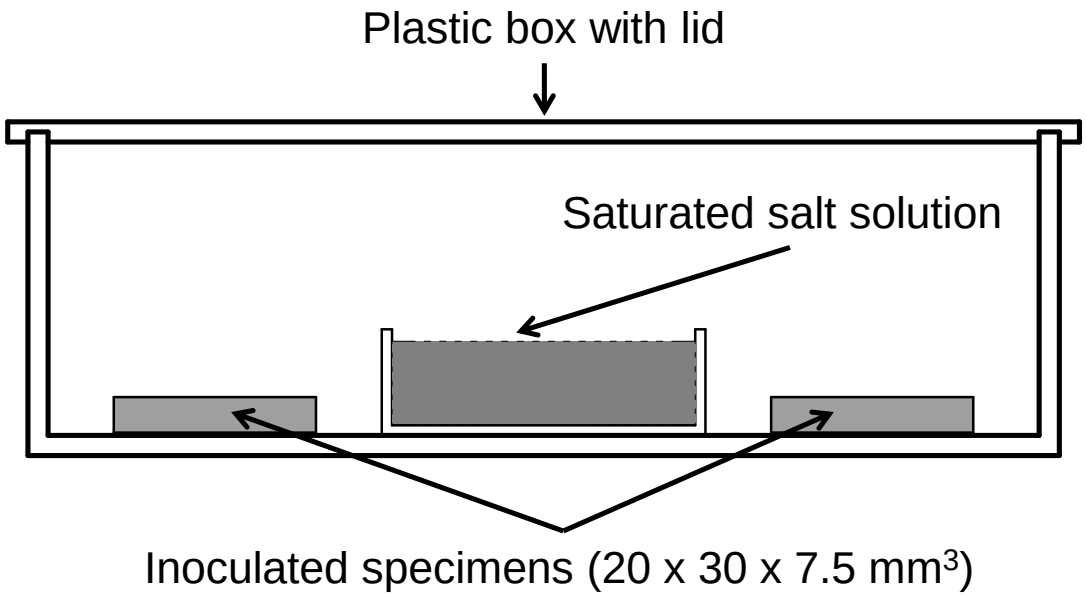


Saito *et al.* (2012)

- Different salt solutions
- RH = 93, 97, 100 %
- *Fomitopsis palustris*
- Japanese red pine sap

→ No decay below FSP

→ No decay below 100 % RH

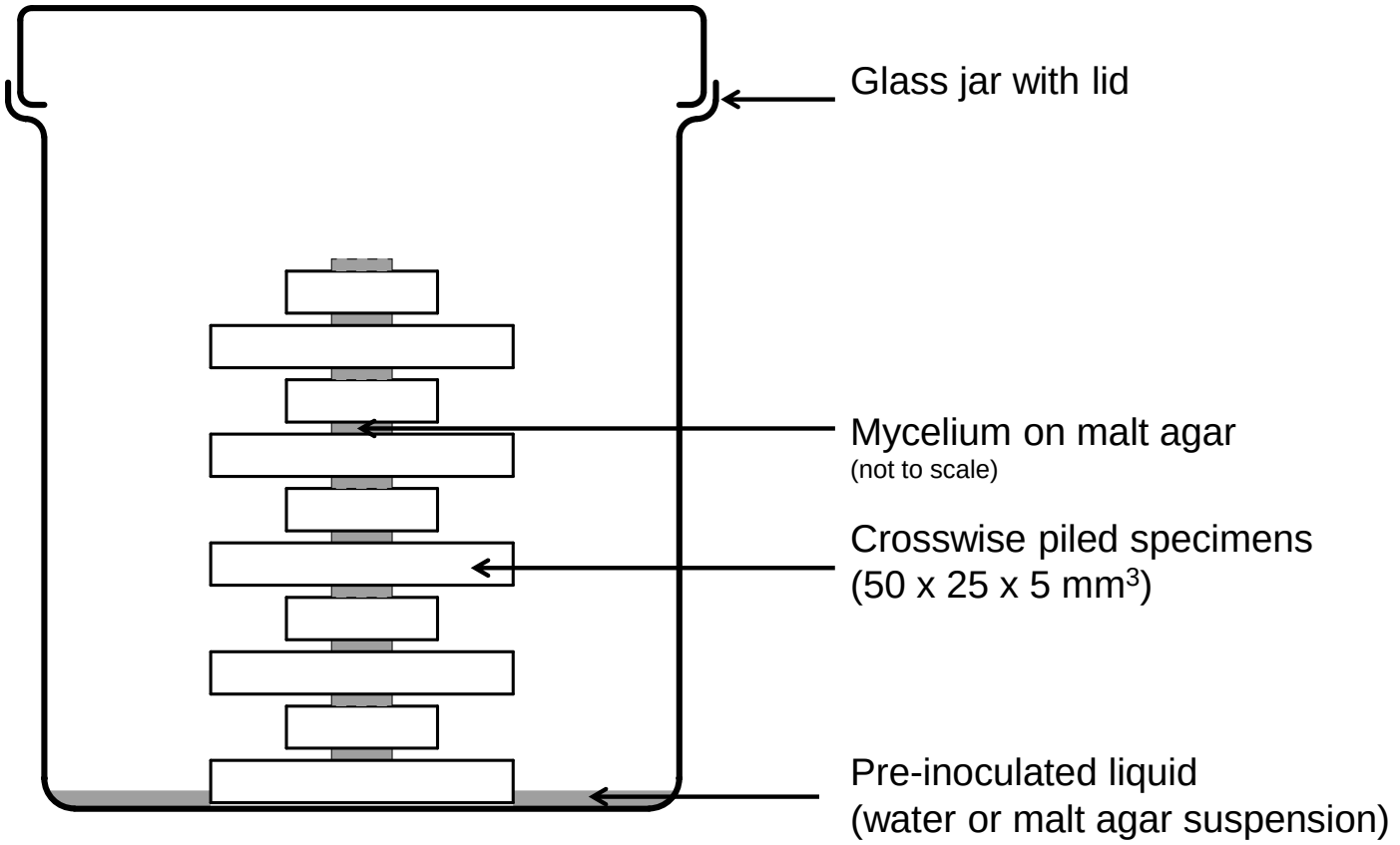


Schmidt *et al.* (1996)

- Pile tests
- 3 different basidiomycetes
- Scots pine sap

→ MC gradient: 31- 205 %

→ ML = 2 – 12 % (*Ph. vitreus*)

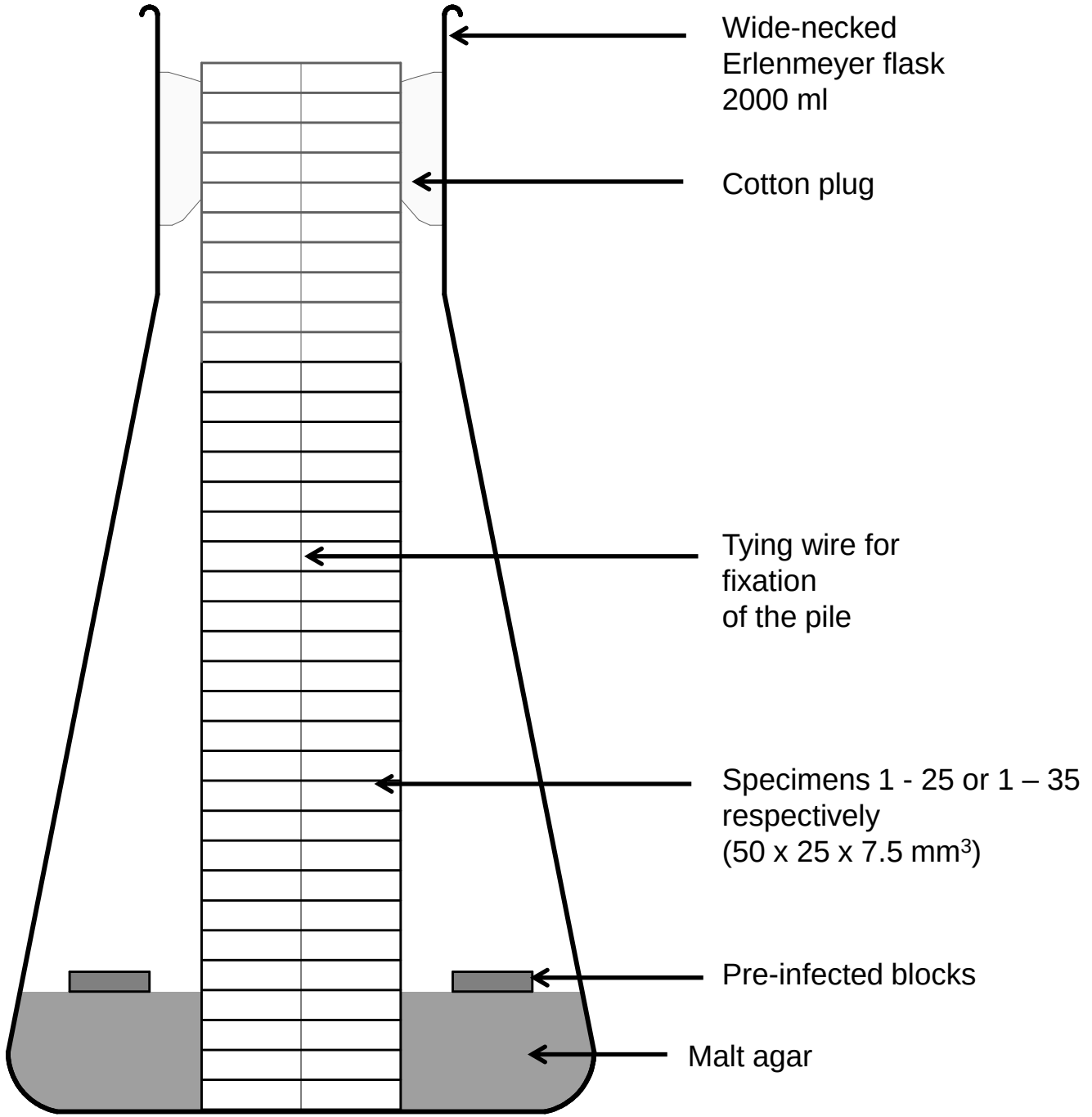


Huckfeldt *et al.* (2005)

- Pile tests
- Different indoor decay fungi
- Scots pine sap

→Decay at **26.2 % MC**
(min. range 27.1 – 35.5 % MC)

→Decay below FSP

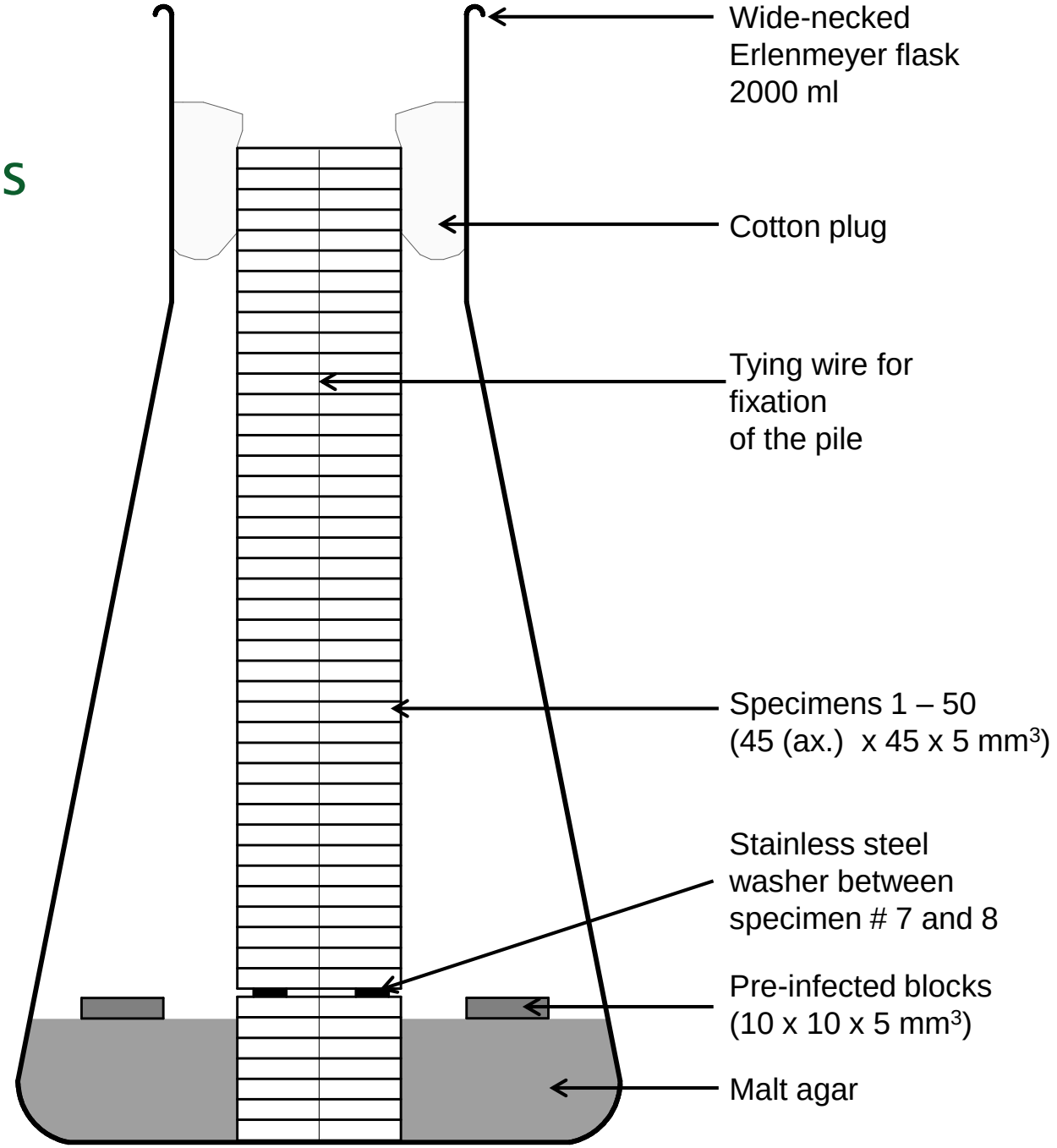


Stienen *et al.* (2014)

- Pile tests with diff. temperatures
- 4 different basidiomycetes
- Scots pine sap
- Metal washer

→Decay below FSP

→No clear effect of temperature on MC thresholds



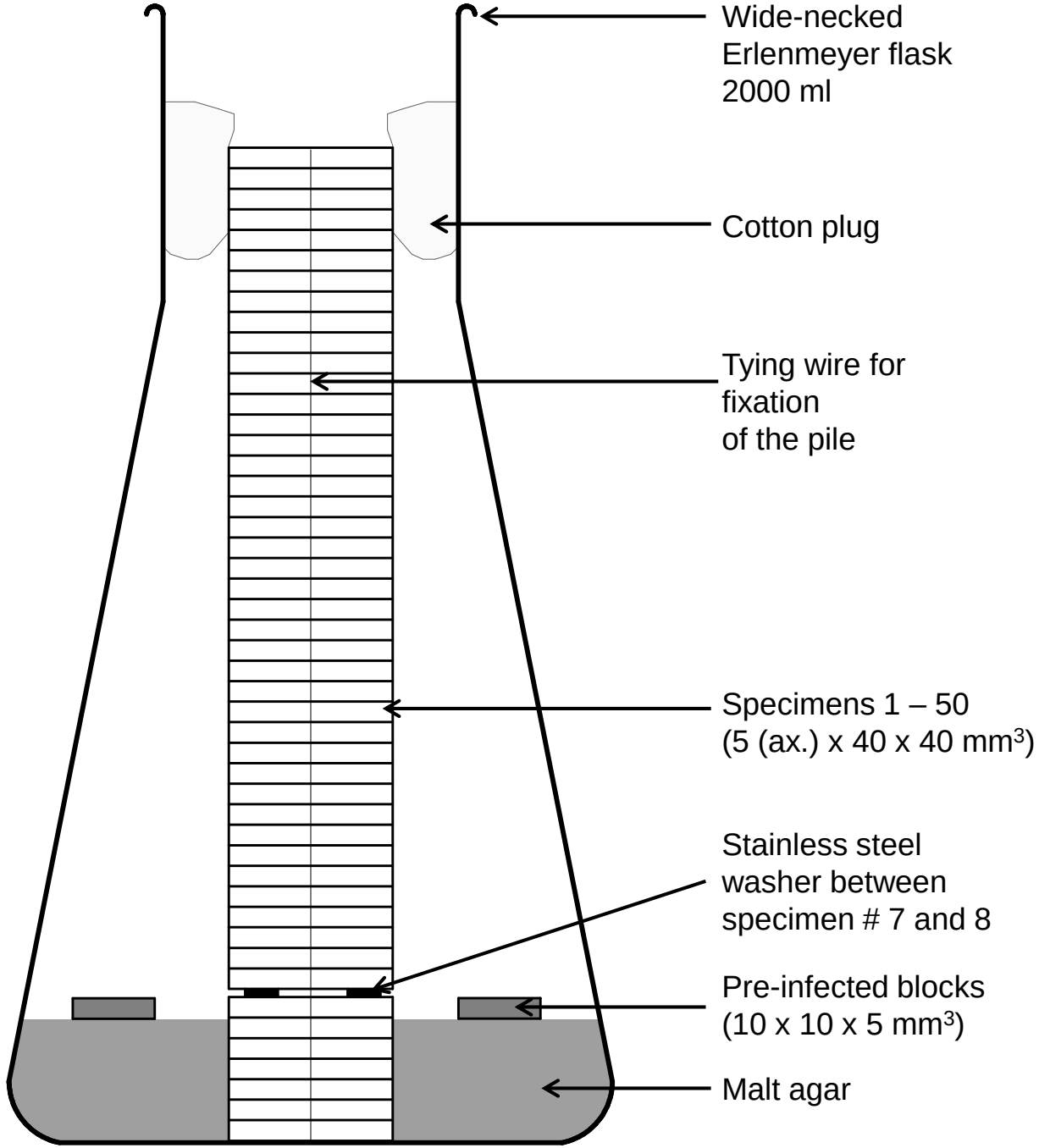
Meyer *et al.* (2015)

- Pile tests with modified wood
- TMT, Furfurylation, Acetylation
- Scots pine sap & Beech

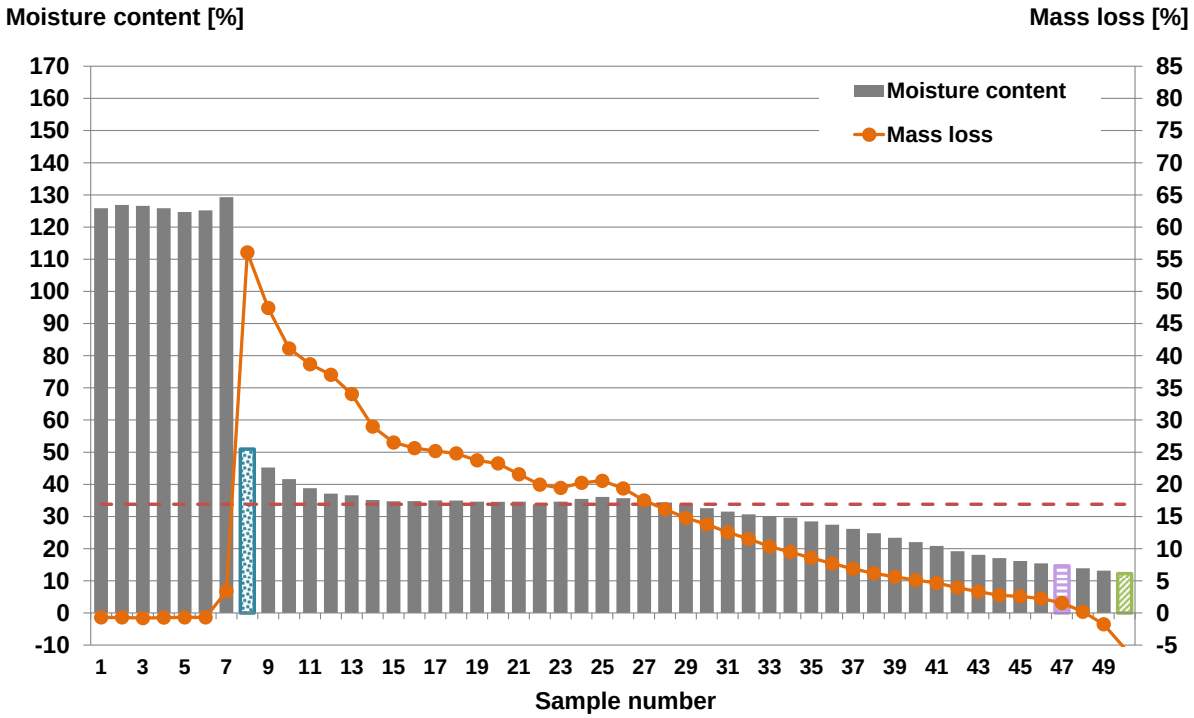
→Decay below FSP

– also in modified wood

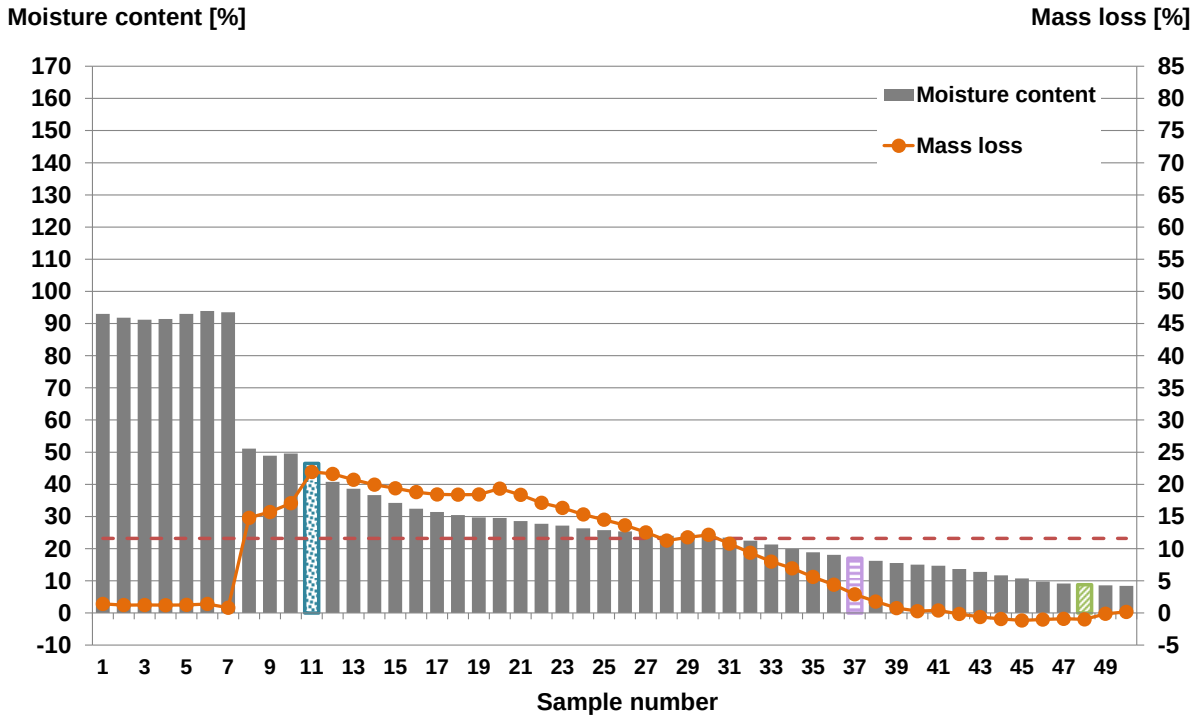
→Extreme: 15.4 % (*T.v.*/beech)



Meyer *et al.* (2015)

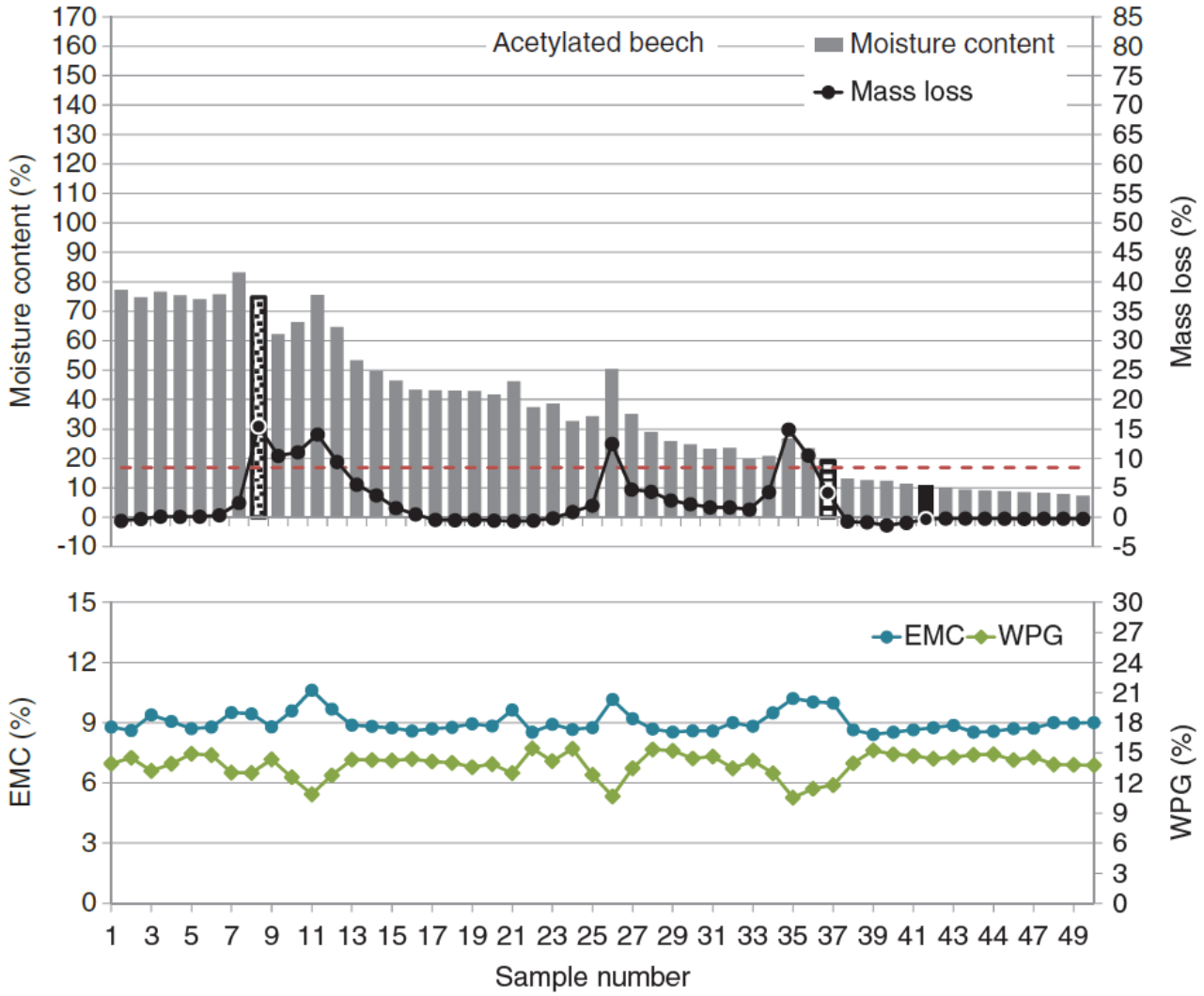


- Beech untreated (*Trametes versicolor*)
- FSP = 33.8 %
- MC threshold = 14.64 %



- Beech TMT (*Trametes versicolor*)
- FSP = 23.2 %
- MC threshold = 17.04 %

Meyer *et al.* (2015)



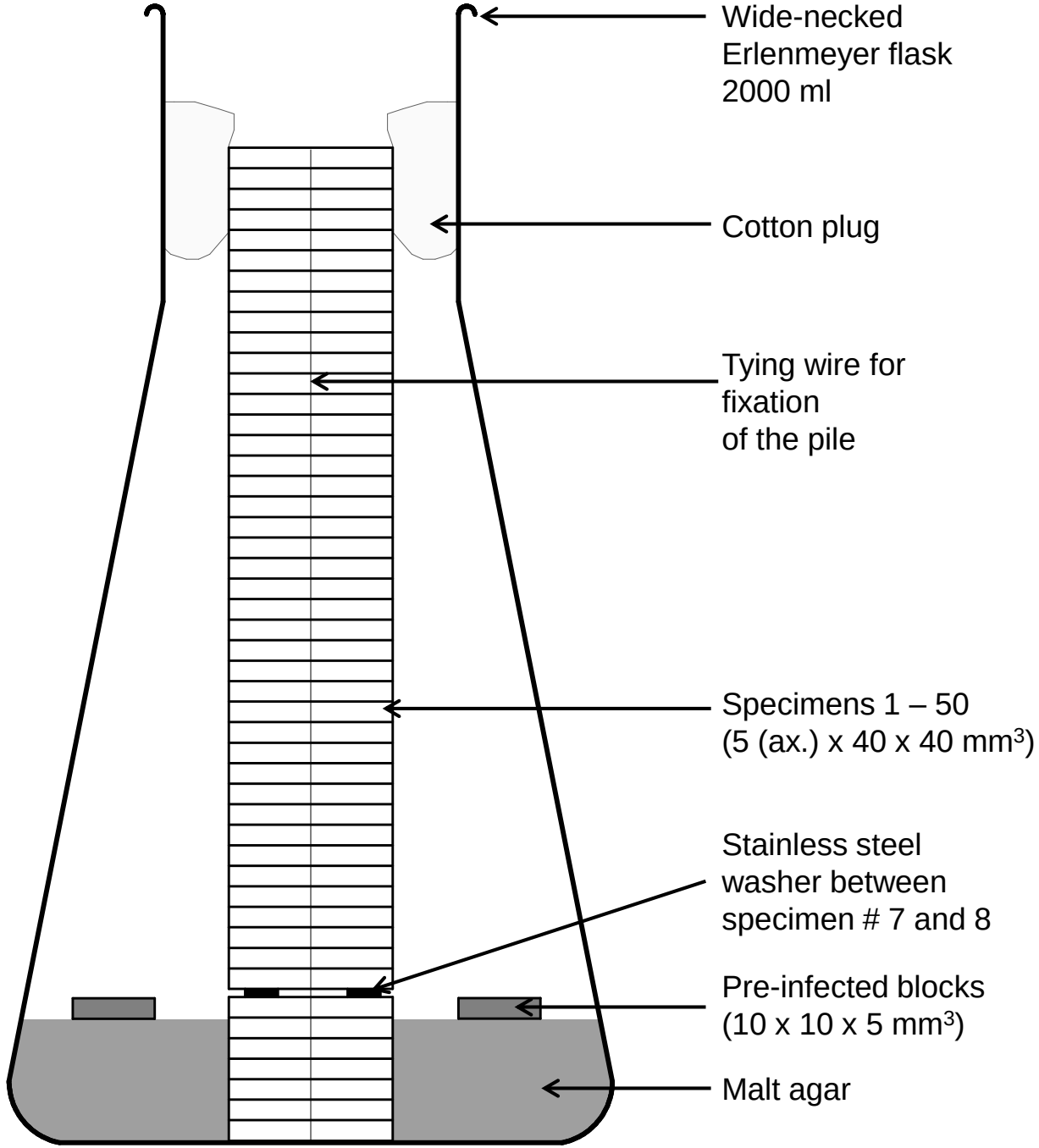
- Acetylated beech / *C. puteana*
- Fungus is able to find weak points!

Meyer and Brischke (2015)

- Pile tests with Pine sap, Pine heart, Spruce, Larch, Douglas fir, Oak, Robinia

→Decay below FSP

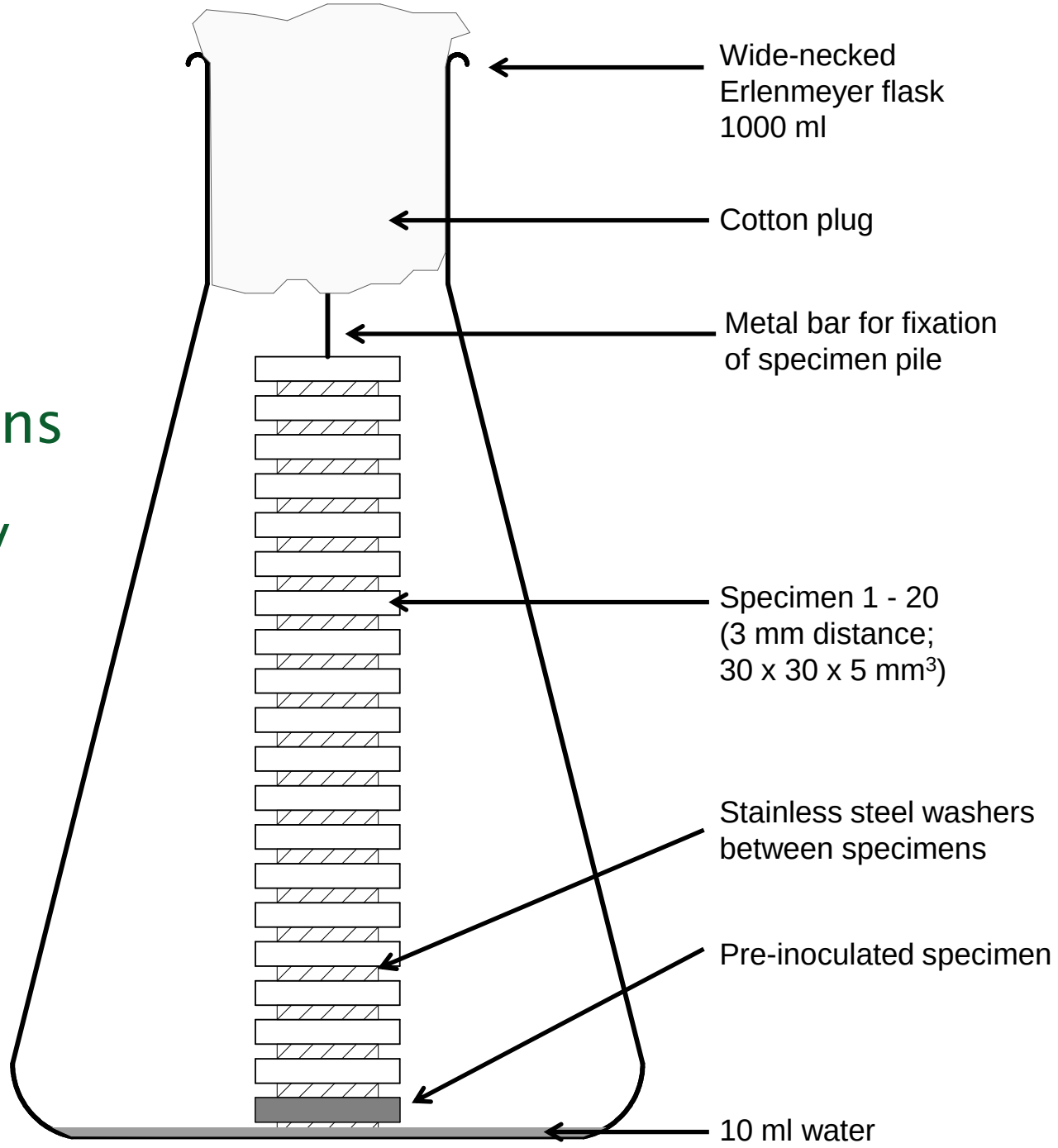
– largest difference between threshold and FSP for wood species with lowest durability



Höpken (2015)

- Pile tests without malt agar
- Pine sap and Oak
- Spacer between wood specimens

→ Active moistening of wood by the fungus

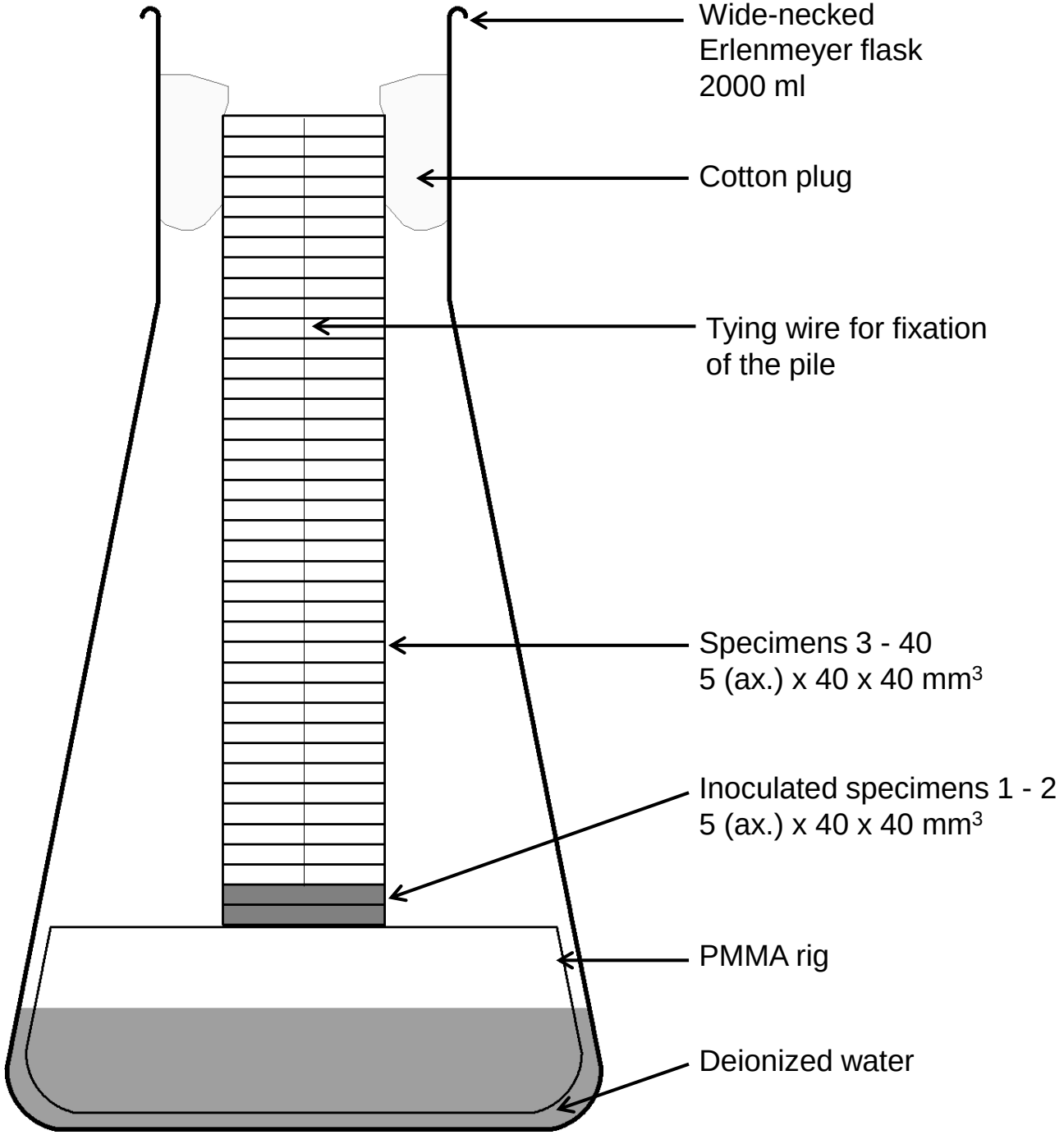


Brischke *et al.* (2017)

- Pile tests without malt agar
- Norway spruce and Beech
- Pile on rigs above water

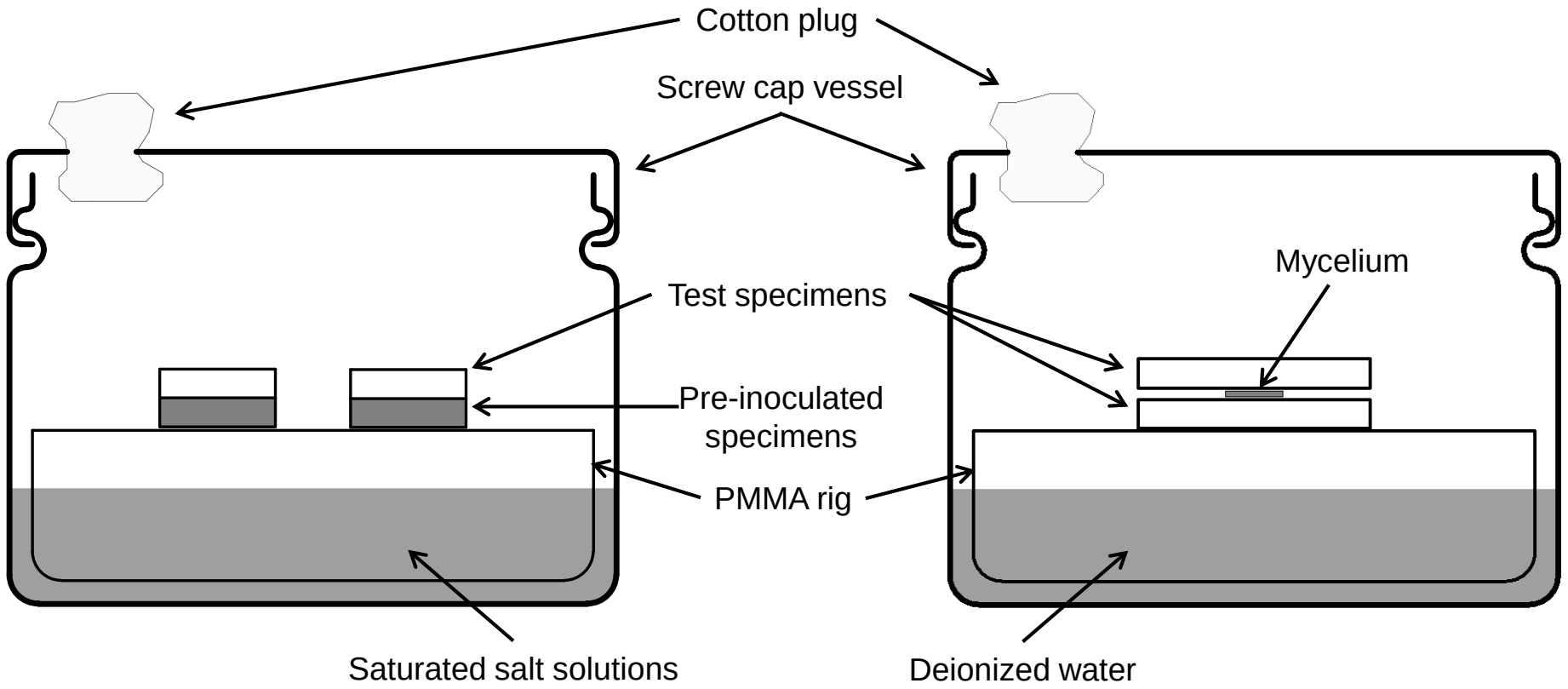
→ Threshold (Spruce / *T.v.*)

MC = 16.3 %



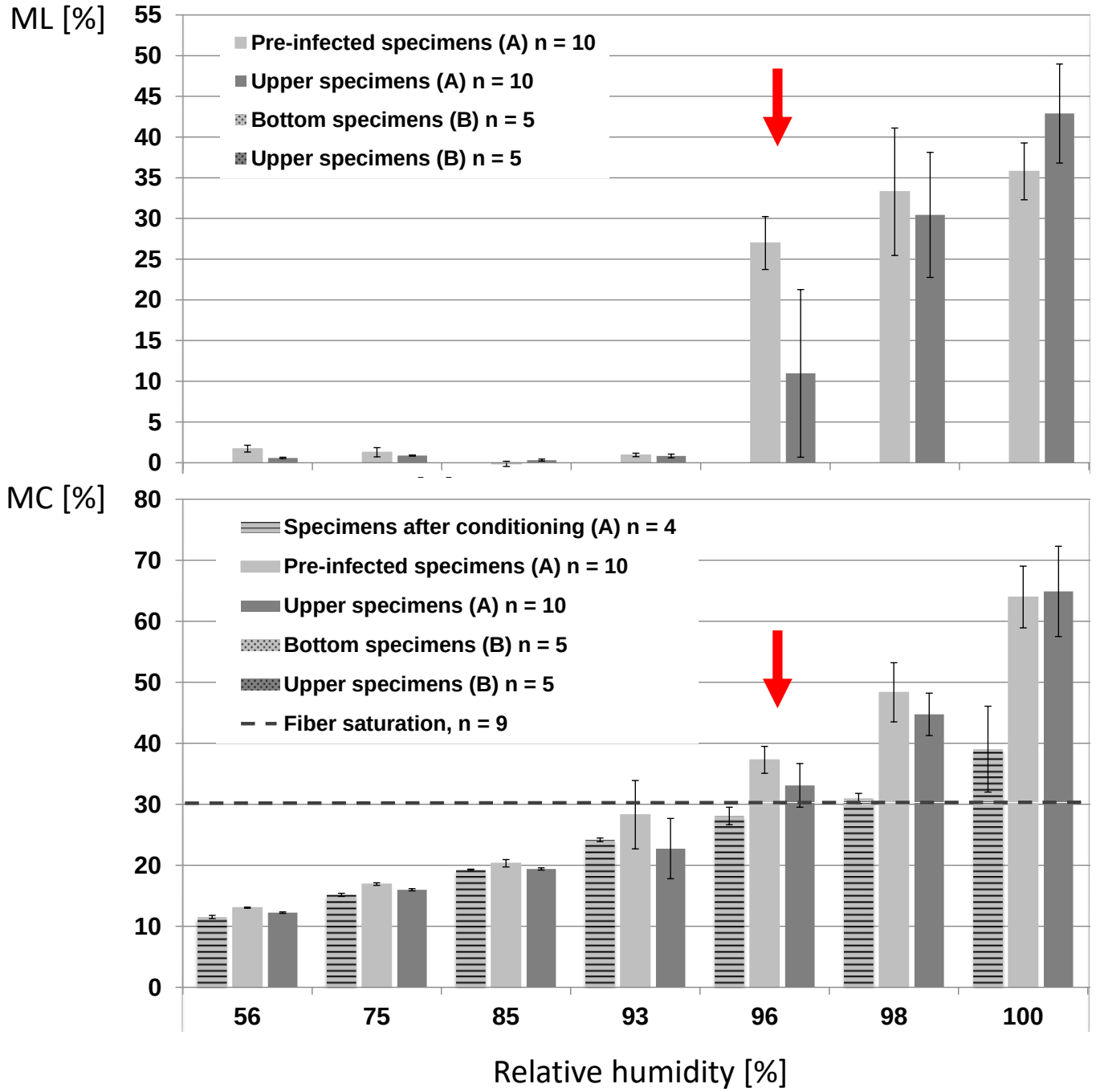
Brischke *et al.* (2017)

- Threshold (Beech / *T.v.*) MC = 25.3 % (at 96% RH)



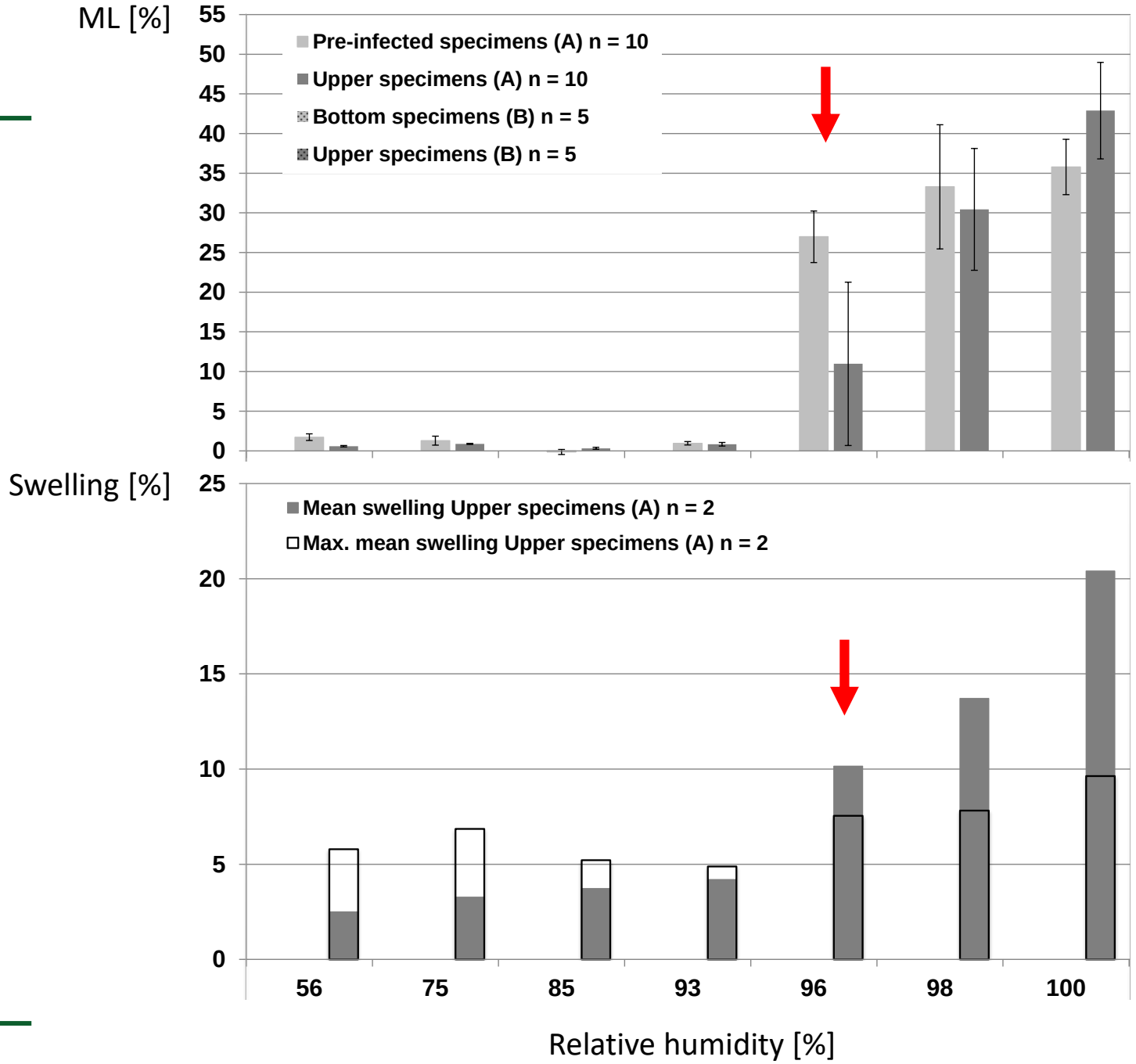
Brischke *et al.* (2017)

- Norway spruce / *Coniophora puteana*



Brischke *et al.* (2017)

- Norway spruce / *Coniophora puteana*
- Swelling required for decay



Summary – Conditioning above salt solutions

Inoculation of specimens	Moisture source	Threshold	Reference
Sawdust, pre-inoculated with mycelium	Humidity, sawdust	85.6 % RH	Bavendamm & Reichelt (1938)
dito	Humidity, mycelium was allowed to grow into liquid	98.2 % RH **28.0 % MC_i**	Theden (1941)
Specimens, pre-inoculated with mycelium	Humidity, increased MC of specimens due to pre-infection on malt agar	85.0 % RH **19.0 % MC_i**	Ammer (1963)
dito	*dito*	n.a.	Saito *et al.* (2012)
dito	Humidity, mycelium was allowed to grow into liquid	96 % RH **25.3 % MC_i**	Brischke *et al.* (2017)

Summary – Pile tests

Inoculation of specimens	Moisture source	Threshold	Reference
Mycelium	Contact to water or liquid agar, humidity	**31.0 % MC_i**	Schmidt *et al.* (1996)
Mycelium on malt agar	Contact to agar, humidity	**26.2 % MC_i**	Huckfeldt *et al.* (2005)
dito	*dito*	**15.4 % MC_i**	Stienen *et al.* (2014)
Pre-inoculated specimens at bottom	Presence of malt agar, humidity	**25.5 % MC_i**	Höpken (2015)
dito	Presence of water, humidity	**24.9 % MC_i**	Höpken (2015)
dito	Humidity	**16.3 % MC_i**	Brischke *et al.* (2017)

Conclusions 1 - Findings

- Decay fungi are able to degrade at high RH
  - also without external moisture source!
- Decay starts below FSP
- Strong influence of experimental set up on thresholds
- Potential impact factors (in the focus of future research):
  - Moisture source
  - Temperature
  - Species (wood and fungi)
  - Incubation time

Conclusions 2 – Transferability to the real world

- **Scenario1:**

  Decay already established, but further ingress of moisture limited or fully restricted

  → Conditioning specimens above salt solutions allows fungus to take up adsorbed moisture in equilibrium with the humidity of the air and to some extent from pre-infected specimens

- **Scenario 2:**

  After damage (e. g. leakage) fungi infested the material and decay expands from an area with extremely high humidity (i. e. approx. 100 % RH) to drier areas

  → Pile test experiments (fungus transports water & produces some extra water)

- **Scenario 3:**

  Absence of developed fungal mycelium, but presence of spores

  → only few studies available (vague summary: FSP needed for germination)

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Thanks for listening!

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