Testing of durability of bio-based non-wood composites

COST Action FP1303, Tallinn 4.-5. Mars 2015

Hannu Viitanen, Elina Sohlberg, Kirsi Immonen

VTT Technical Research Centre of Finland Ltd

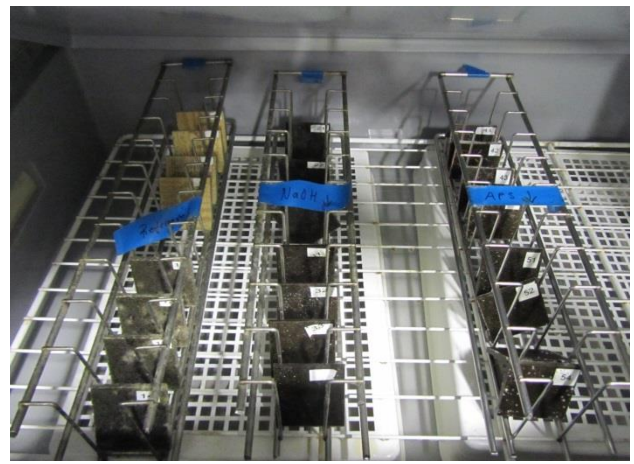
Introduction

- During the last decade there has been increasing research and development activities going on with natural fibre containing sustainable composites.
- Drivers: new environmental laws and regulations, need for CO_2 neutral materials, increasing pollution and increasing demand for bio-based materials.
- Natural fibres from annual crops (e.g. flax, hemp, jute), animal, grasses, leaves or wood are now commonly used as reinforcements or fillers in various applications.

Tasks of the present work

- Biological resistance of the modified flax fibre – bio-epoxy polymer composites was studied using an accelerated laboratory decay test in terrestrial microcosms and mould test in a chamber at high relative humidity.

Terrestrial microcosmos test “TMC”



Mould test in high humidity

Samples

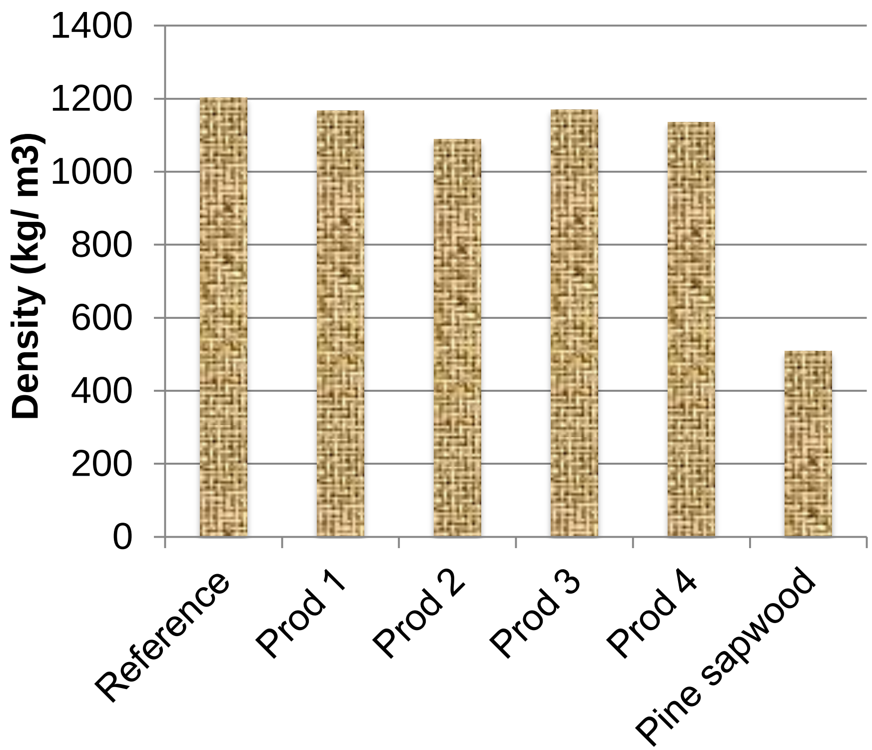
- Modified flax fibre – bio-epoxy polymer composites
  - A bio-based pine-oil derived epoxy resin SuperSap for matrix material
  - Non-woven flax mats with areal weight 600 g/mm^2 (3 mm)
  - Unidirectional fabrics, areal weight 180 g/mm^2 (0.35 mm)
- Chemical modifications on non-woven flax mats placed on both composite surfaces:
  - Prod. 1: butane tetracarboxylic acid treatment to reduce number of hydroxyl groups and restrain swelling properties of fibre,
  - Prod. 2: mercerization with NaOH to increase fibre roughness and improve adhesion between polymer matrix interphase
  - Prod. 3: enzymatic laccase-dodecyl gallate treatment to increase hydrophobic properties of flax fibre
  - Prod. 4: aminopropyl triethoxy silane treatment
- Reference: composite without chemicals and pine sapwood

MOR and MOE analyses

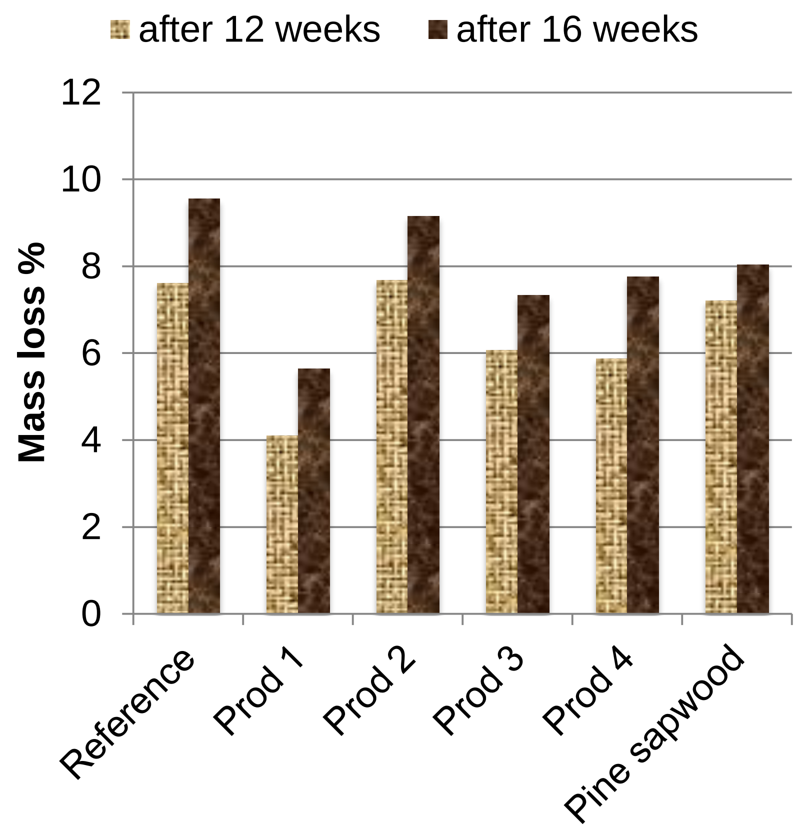
- The strength properties of the samples prior and after the microcosm test were measured according to ISO 178 for specimens with dimension 2.6x12x154 mm.
- ISO 178:2010 specifies a method for determining the flexural properties of rigid and semi-rigid plastics under defined conditions.
  - The flexural strength and flexural modulus under the conditions defined.

Original Density of the products and mass loss of the products after 12 and 16 weeks TMC tests

Density

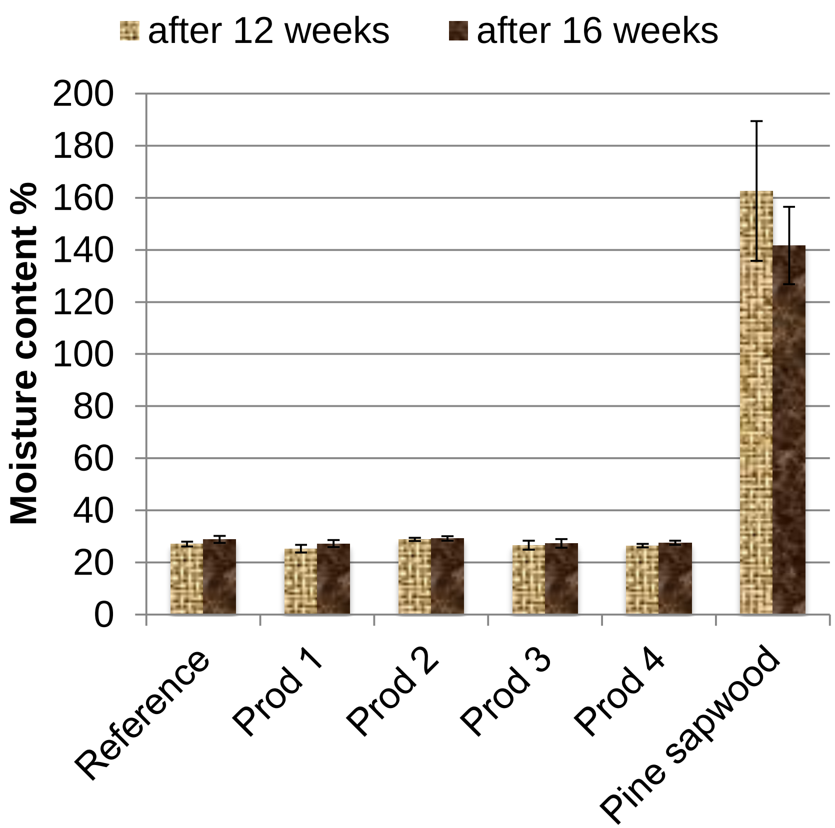


Mass loss

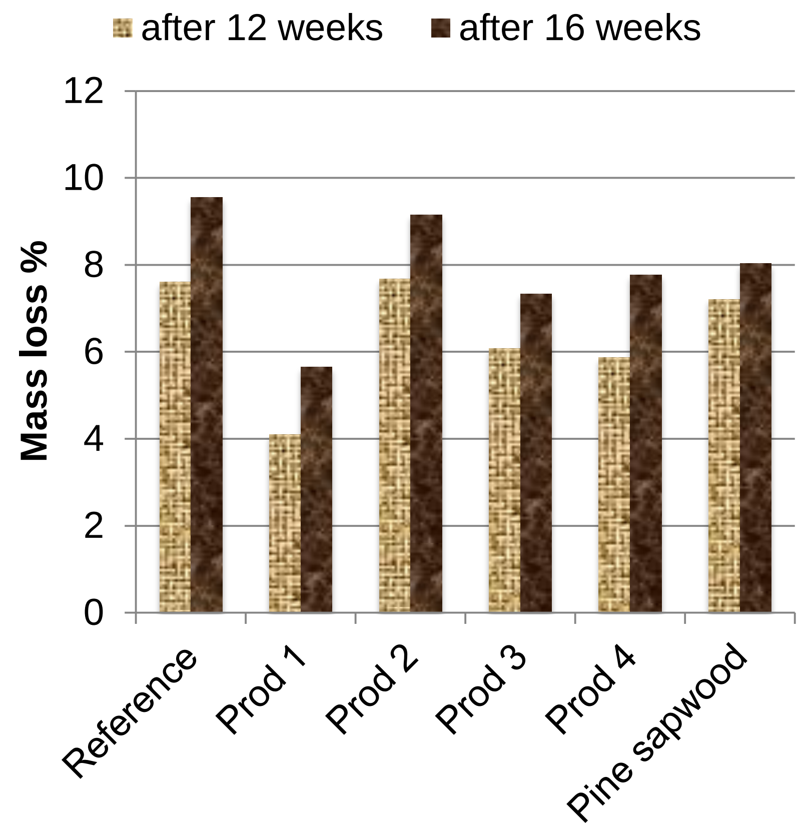


Moisture content and mass loss of the products after 12 and 16 weeks TMC tests

Moisture content

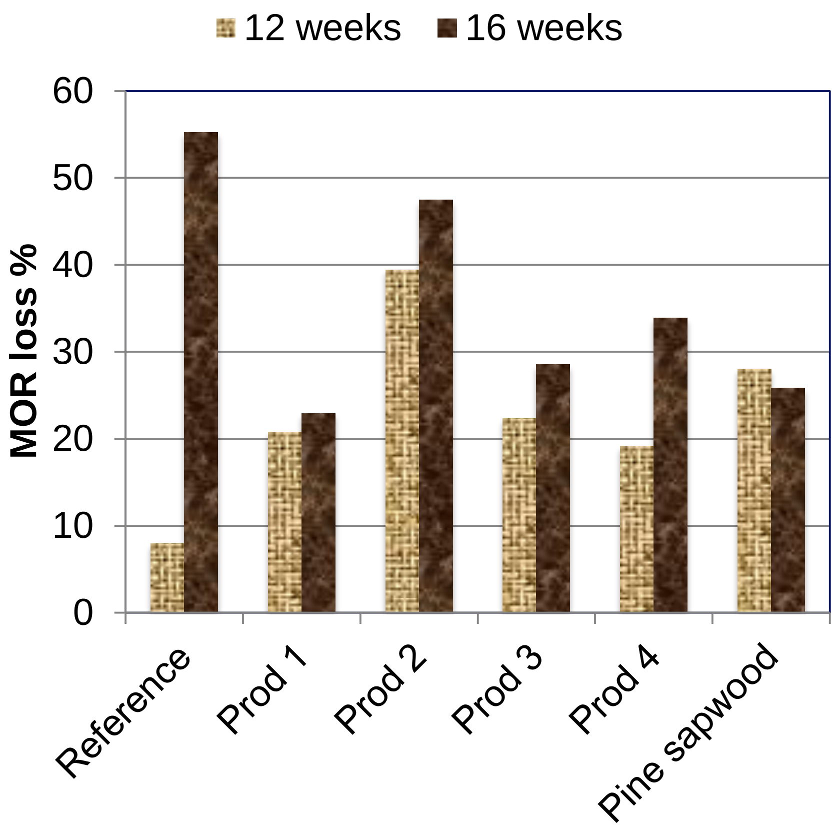


Mass loss

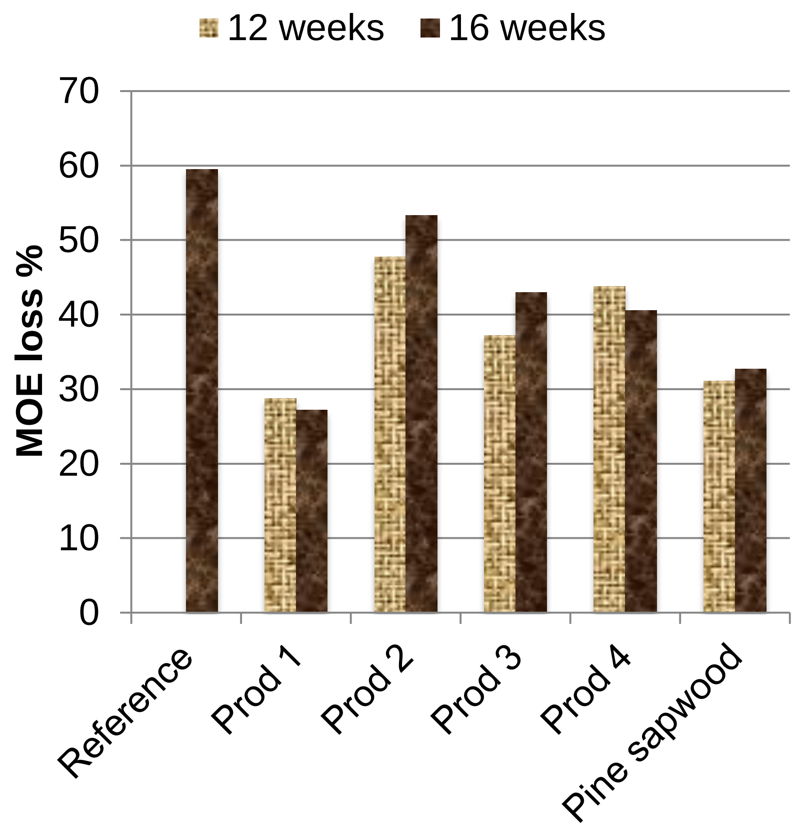


Loss of MOR and MOE the products after 12 and 16 weeks TMC tests

MOR loss

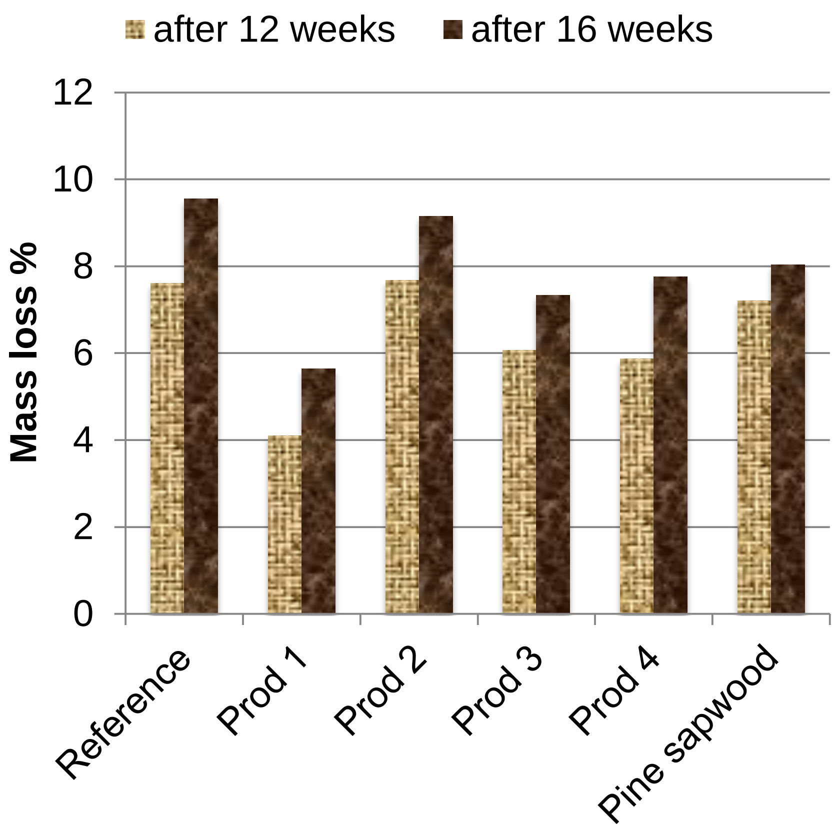


MOE loss

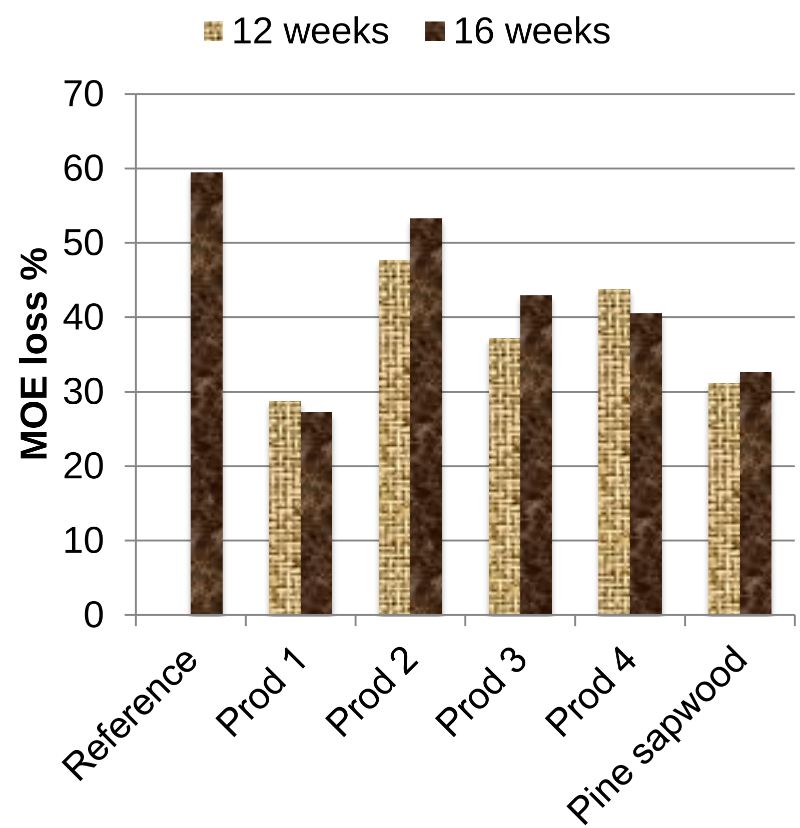


Mass loss and MOE loss of the products after 12 and 16 weeks TMC tests

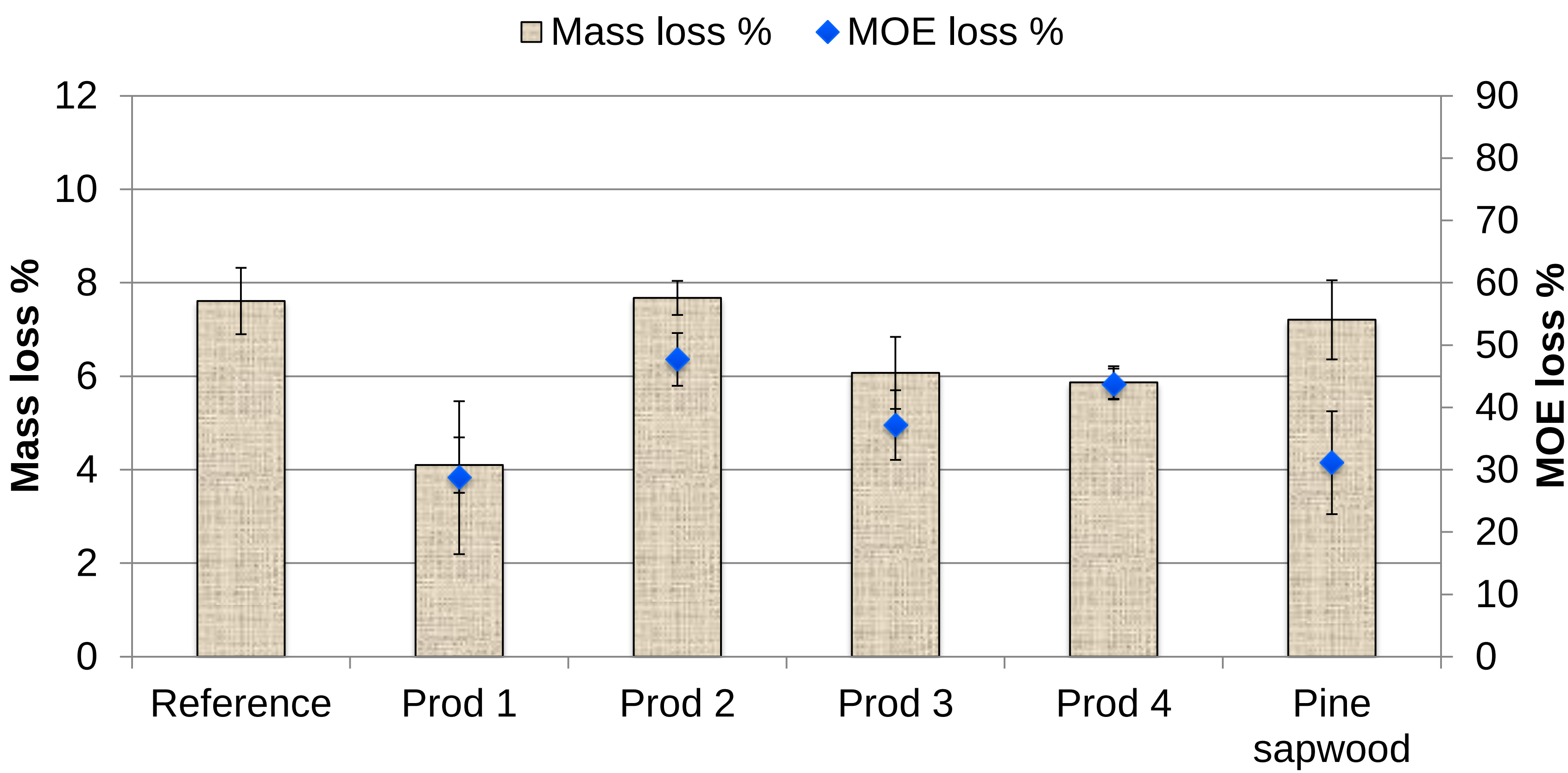
Mass loss



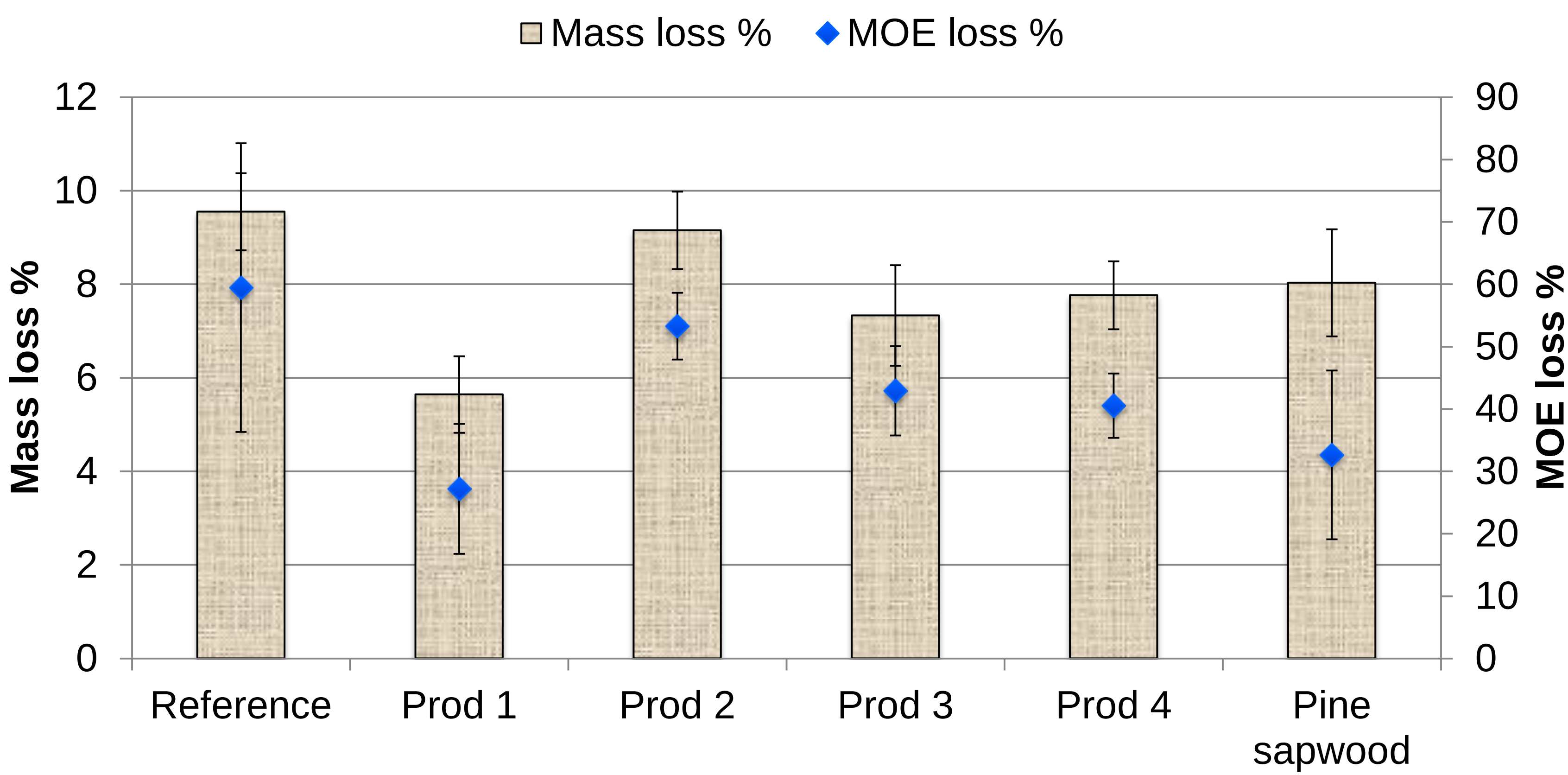
MOE loss



Mass loss and MOE loss of the products after 12 weeks TMC tests

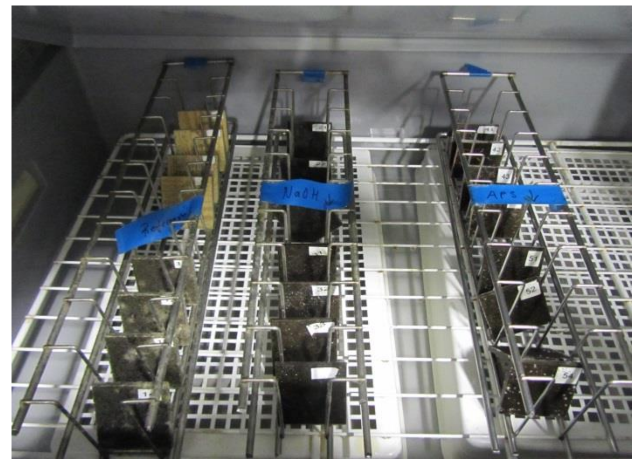


Mass loss and MOE loss of the products after 16 weeks TMC tests



Mould test in high humidity

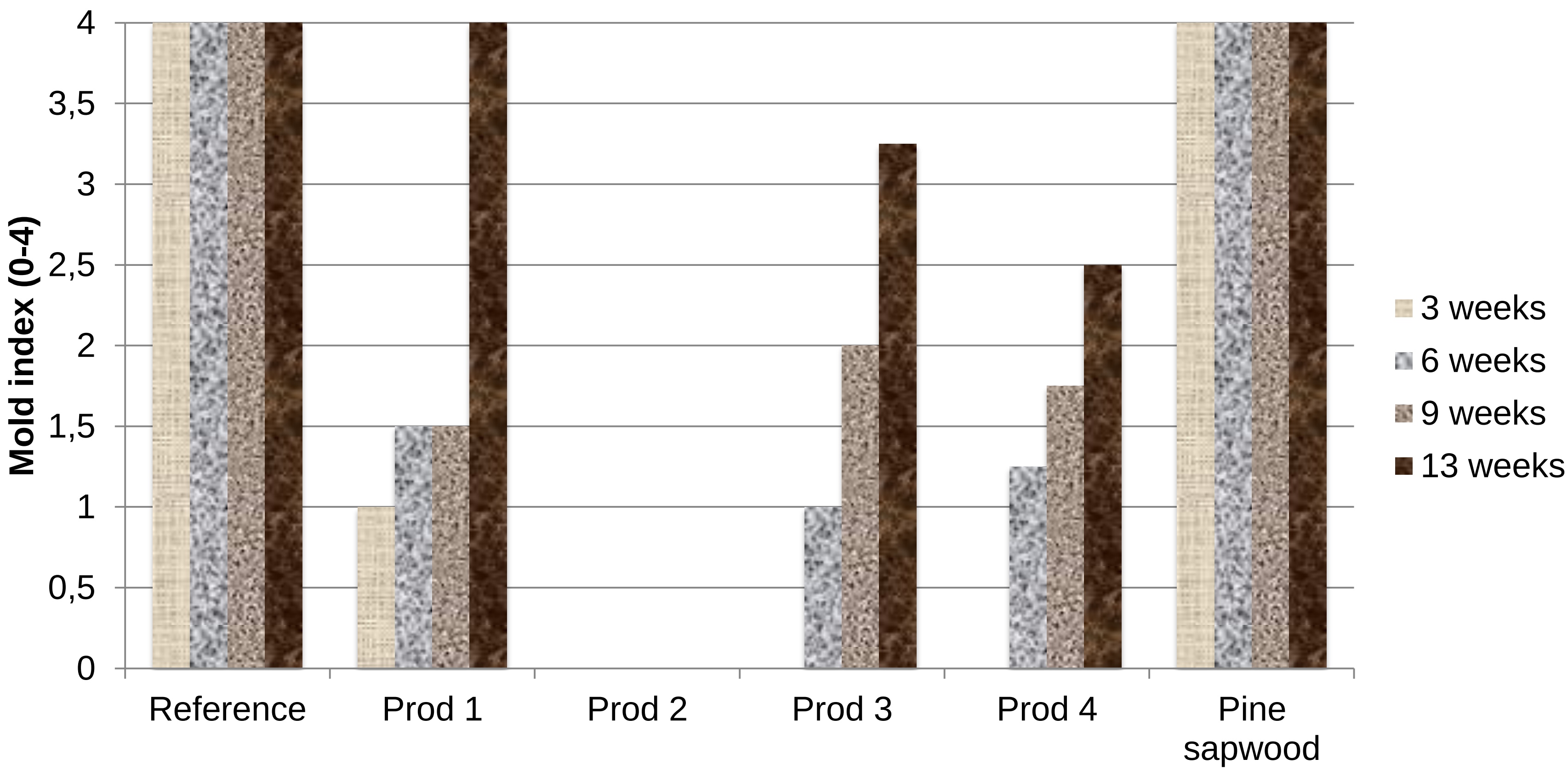
- Chamber test was carried out according to the principles of ASTM D3273-00: (2005) standards method with some modifications.
- Incubation in a plastic chamber with a 30 mm layer of water on the bottom.
- The ambient temperature 23 ^{o}C
- Relative humidity in the chamber RH 98 % ± 2%
- The condition of the samples was examined after 3, 6, 9 and 13 weeks using mould index evaluation method.



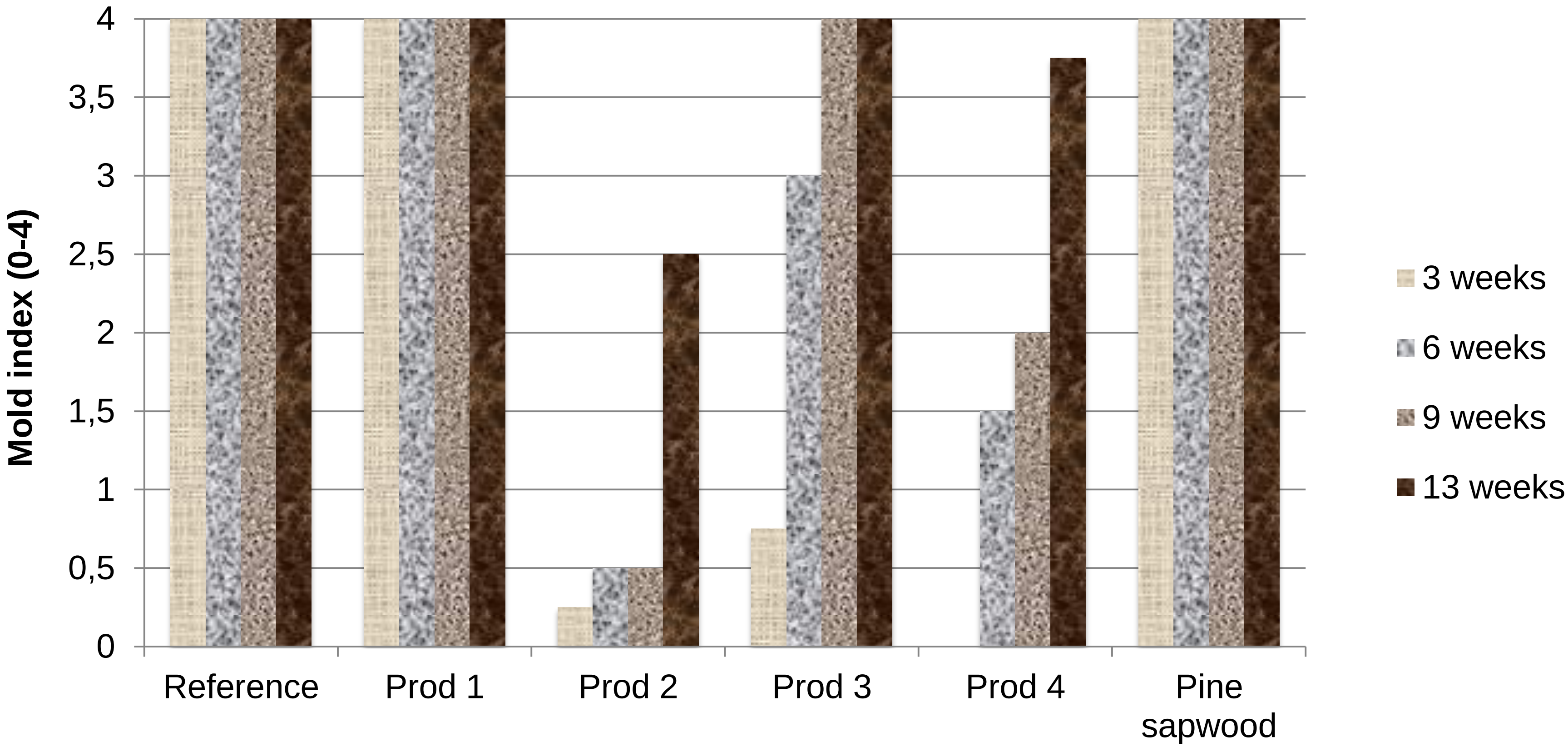
Mould index used in this study

Index	Growth level, visual detection	Growth level, microscopical detection
0	No growth	No growth
1	First sign of visual growth	First sign of growth, area < 10%
2	Clearly detected growth	Growth area 10 – 30%
3	Moderate growth	Growth area 30 – 50%
4	Heavy growth	Growth area 50 – 100%

Visual mould growth on the samples after 3, 6, 9 and 13 weeks exposure at high humidity (RH > 95 %)



Mould growth detected with stereo microscopy after 3, 6, 9 and 13 weeks exposure at high humidity (RH > 95 %)



Conclusions (1)

- Original density and moisture content of the composites did not reflect with the resistance and decay of the materials
- Mass loss of composites reflected with MOR and MOE loss of the composites
  - 8% of mass loss in untreated Scots pine sapwood after 16 weeks' incubation and presence of soft rot was observed
  - Mass loss of 5.6% to 9.2% in modified composites and 9.6% in unmodified composites after 16 weeks.
  - Average modulus of elasticity (MOE) varied between 29% and 53% in modified composites and 59% in unmodified composites.
- Pine sapwood showed 33% MOE loss percentage in average.
- Modified wood-plastic composites showed 5-8% mass loss after 16 weeks in soil block test (Segerholm and Ibach 2013)

Conclusions (2)

- After six weeks' exposure in high humidity conditions, highest visual mould growth was observed in the unmodified composite and pine sapwood specimens.
- In the prod. 2, no visual mould growth was found
  - Using stereo microscopy, slight mould growth was found -> microscopical evaluation is needed for the exact evaluation of mould growth on the composites
- The results of decay test did not reflect with the results of mould test:
  - Prod 1 showed better resistance against decay and lowest resistance against mould fungi
  - Prod. 2 showed best resistance against mould but lowest against decay

TECHNOLOGY FOR BUSINESS

ACKNOWLEDGEMENTS

Financial support from the European Commission and the FP7 ECOSHELL Project (Project Reference No. 265838)