WOW! CLOSING EVENT – PART 2
FRIDAY SEPTEMBER 8TH – DUBLIN

Interreg North-West Europe WOW!
EUROPEAN UNION
European Regional Development Fund

Products from PHA

Ossi Martikka

LAB University of Applied Sciences

Commercial PHA

- Global plastics production reached 390.7 Mt in 2021
  - Of which, fossil based plastics comprised 352.3 Mt/90.2%, recycled post-consumer plastics 32.5 Mt/8.3% and bioplastics 5.9 Mt/1.5% (PlasticsEurope)
- *Interestingly*, European Bioplastics reports, that global bioplastics production capability in 2022 was 2.2 Mt and was expected to reach 5.8 Mt in 2026
  - Of which, the biobased and biodegradable covers ~52%
- Of all bioplastics, according to European Bioplastics (2023), PHA covered 3.9% off global bioplastics production capacity, while PLA had the highest capacity by margin, 20.7%.

Commercial PHA

- The properties of different PHAs vary, e.g. $T_m \in [115, 175]°C$, TS $\in [14, 36]MPa$, $\varepsilon_b \in [2, 350]\%$ and $\rho \in [1.2, 1.4]kg/m^3$
  - Properties are comparable to those of PE and PP, except for higher density
- The most typical fields of application for PHA (based on the global production capacities) are Packaging (~38 000tn), Agriculture & Horticulture (~19 000tn), Consumer goods (~18 000tn), Coatings & Adhesives and Others with roughly the same volume (~6000tn) (European Bioplastics)
  - As early as in 1996, a PHA Poly(3-hydroxybutyrate-co-3-hydroxyvalerate) received European approval for food contact application (Koller and Mukherjee, 2022)
  - PHAs have been used in shampoo bottles by Wella in 1990's Germany, but the high material cost caused its volume to remain marginal (Chodak, 2008)

PHA fields of application

- Packaging and food industry:
  - Short-time-of-use applications, e.g. wrappings and disposable food utensils
  - Good for compostable food packaging – have high barrier properties towards oxygen permeation providing good shelf-life for products
  - PHA oligomers are usable ketone sources in food supplements
- Coating:
  - with paper materials results in increased gloss, brightness and strength
- Textile:
  - As PHAs are a set of polyester, fibers can be produced from it and used in textiles

(Chen 2009; Koller et al. 2013; Zhang et al. 2018; Amstutz et al. 2019)

PHA fields of application

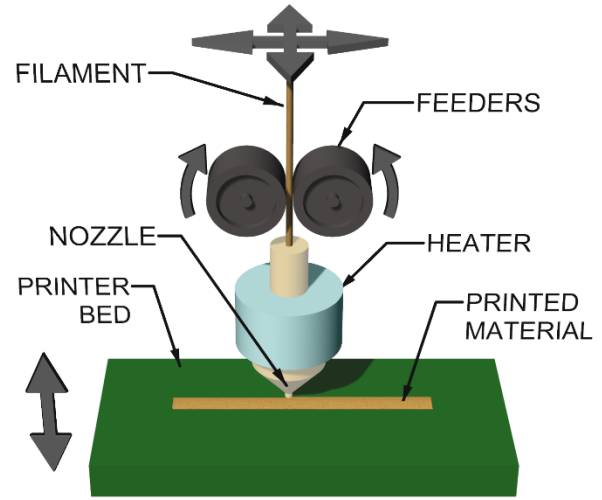
- Construction materials
  - a healing agent in concrete for inducing crack healing thus reducing water permeability in use (Vermeer et al. 2021)
- Cosmetics
  - Use in skin-care products, as PHAs are exfoliants and humectants (Jacoby 2019).
  - Many PHAs also have antioxidant properties and Gluconolactone has been used in multitude of cosmetic preparations. It has been found also suitable for protection against UV induced damage (Bernstein et al. 2004).
- Medical:
  - Biocompatibility enables e.g., PHA in ‘biodegradable surgical staples, screws, plates, pins and cords, bioresorbable suture material and skin staples, wound and burn dressings, membranes for periodontal guided regeneration, surgical mesh endoprostheses, patches for surgical repair of intestinal and pericardial defects, mesh plugs for coloproctological applications and hernioplasty, vascular prosthetic implants, coronary stents, mesh tubes for nerve regeneration, artificial heart valves, and other medical devices’ (Bonartsev et al. 2019)

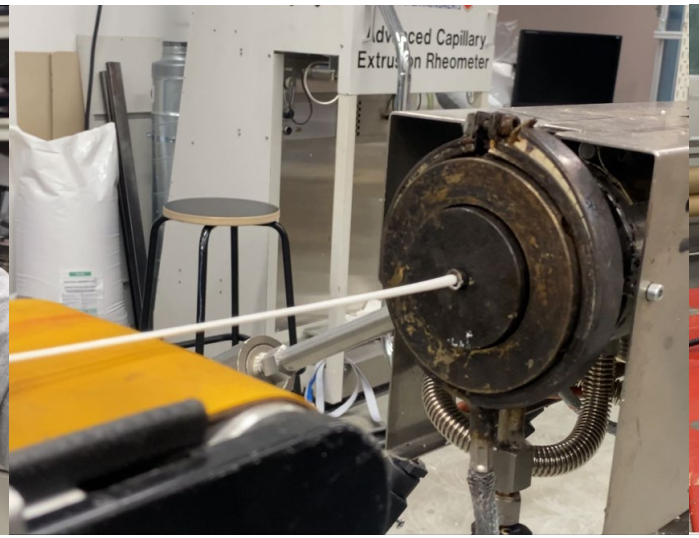
WoW!-PHA ideas for applications

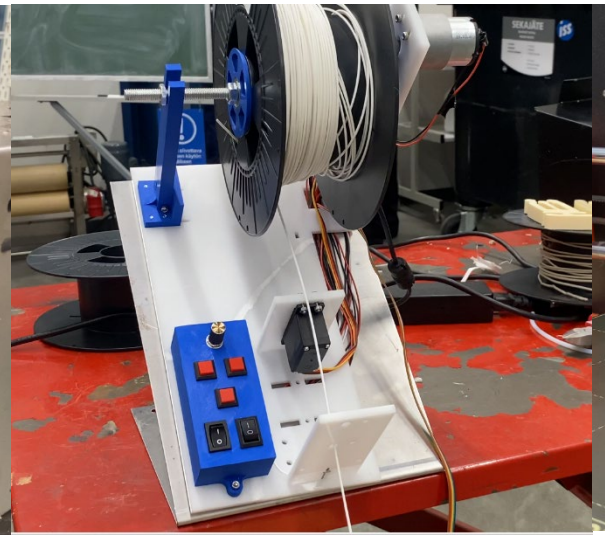
- Demo products:
  - For applications in which unpurified PHA could be utilized while taking advantage of its properties, e.g., compostability and mechanical strength.
  - Therefore, the samples are aimed at outdoor use applications – such with a notable risk of ending up in the nature.
  - The demo products selected were fishing lure, pole holder for x-country skiing, fender for mountain bike (MTB) and golf tee produced using 3D printing.
  - The advantage of 3D printing is that it enables easy personalization of products in small scale production and especially producing novel shapes and functionalities that are difficult or even impossible to achieve with the current volume processing methods (e.g., the fishing lure presented later).

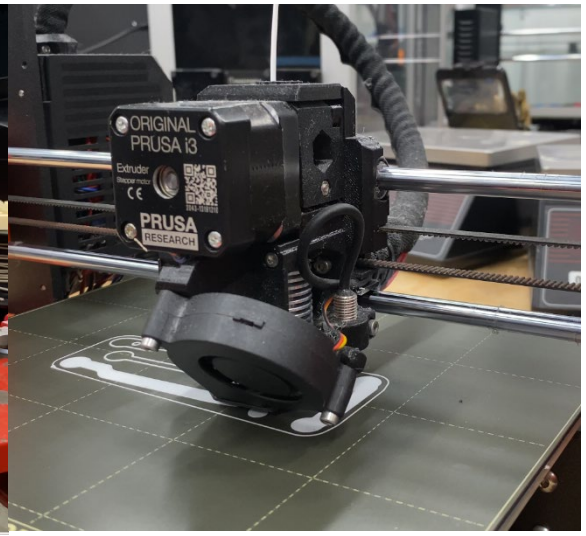
3D-printing of the demos

- The method of demo production was Fused Deposit Modeling (FDM) 3D-printing
- Steps at the LAB were: Filament manufacture -> spooling -> 3D-printing (+ modeling the products)



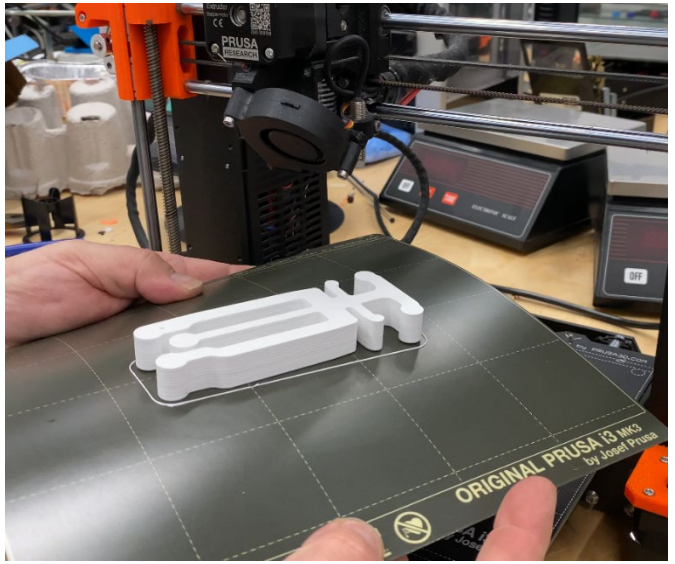


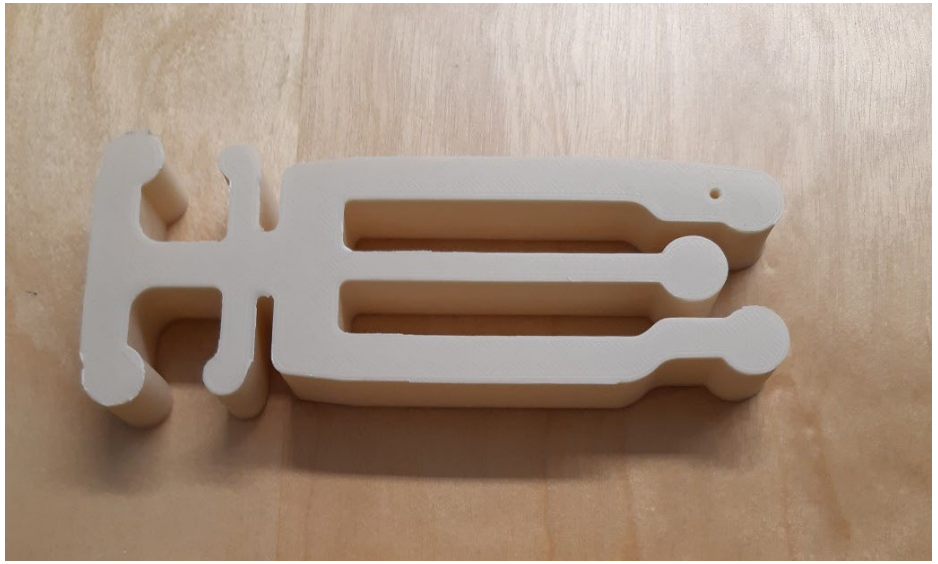




Ski pole holder

- Used to keep skis and poles together for easy transport
- Have tendency of getting lost while carrying the equipment
- The global cross country ski equipment market garnered a market value of US$ 1.7 Billion in 2023 (Fact.MR, 2022). The global ski poles market was valued at USD 127.29 million in 2022 (Polaris Market Research, 2023).



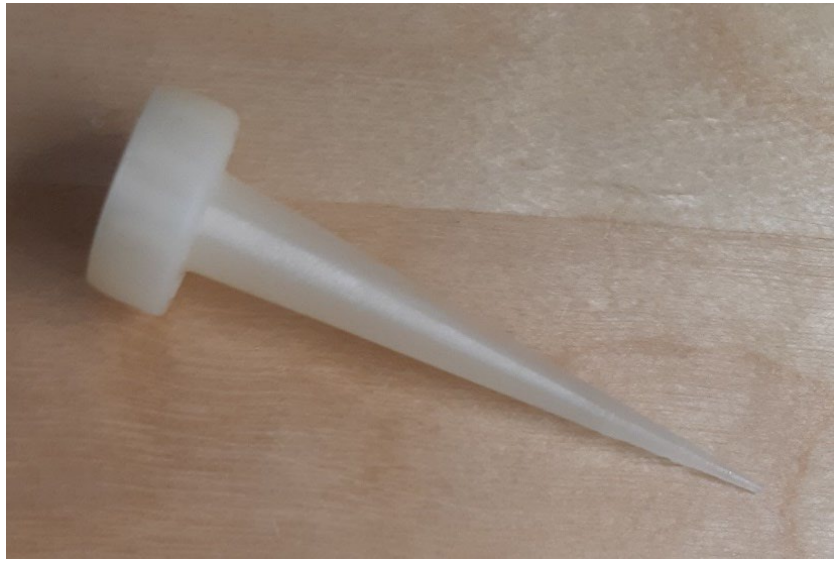


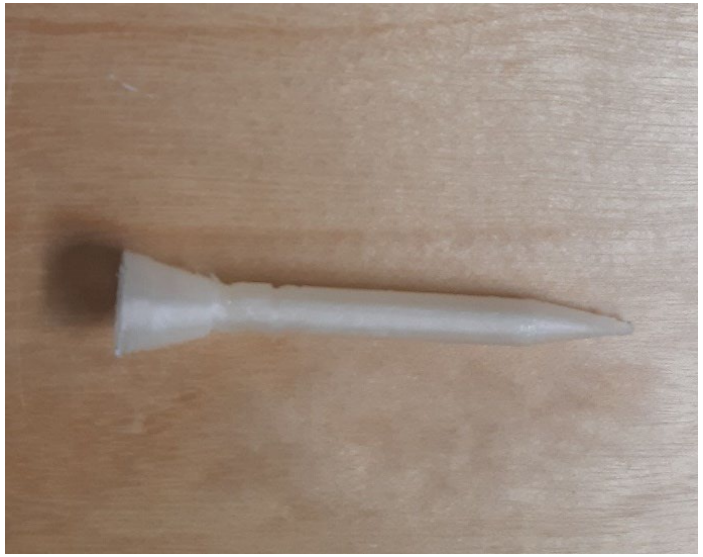
Fender/Mud guard for MTB

- Rear fender for mountain bikes, also have tendency of getting lost while biking it the wilds
- The global mountain bike market size was valued at USD 9.27 Billion in the 2022 (Growth Market Reports 2023). In the year 2020 the global mountain bike (MTB) market was estimated to be ***44.2 million units*** (GlobeNewswire, 2020).

Golf tee

- It has been estimated that approx. 5 million golf tees are used annually in golf games (The Bigger Ball, 2023). Tees made of biodegradable plastics appear the least common in the market.
- Can get lost or break ending up in the nature.
- 3D-printing enables personalization of small series with e.g., name



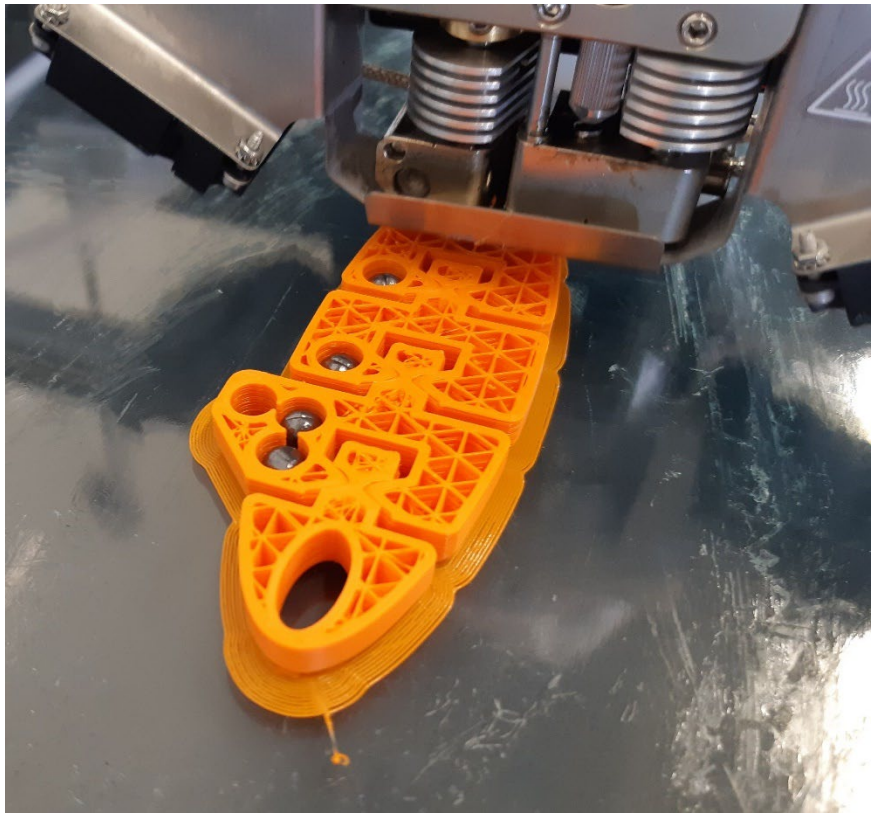


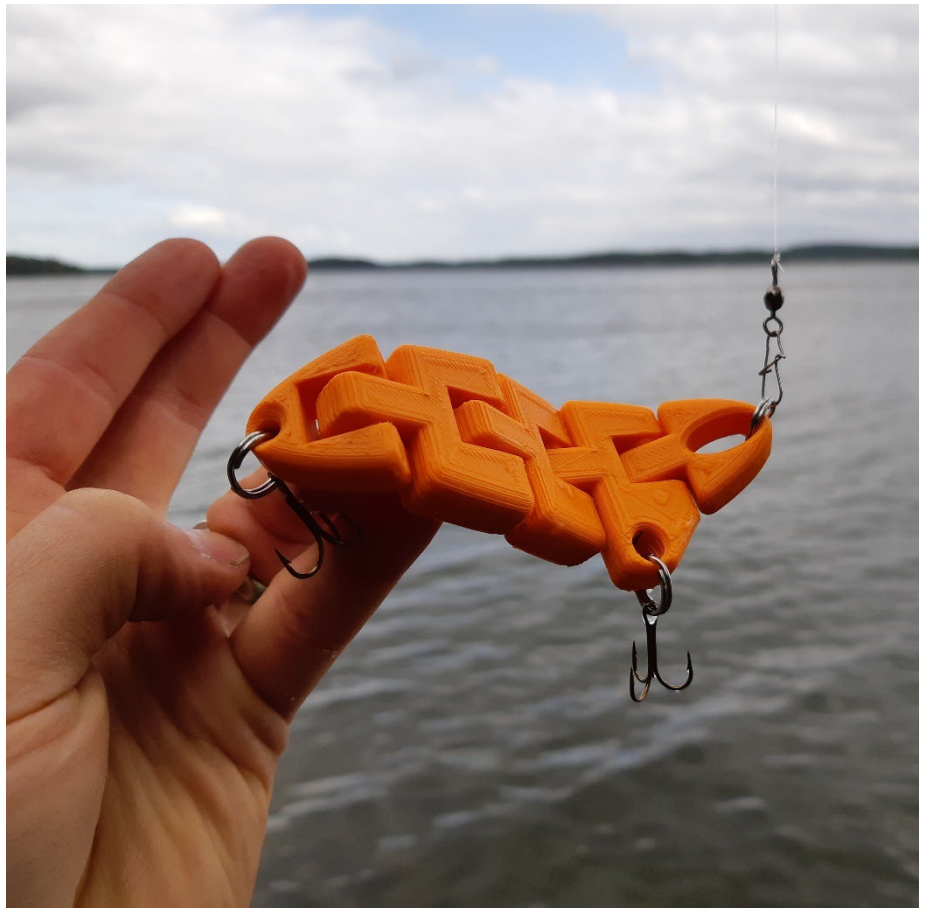
Fishing lure

- Global fishing lure market has been estimated to US$ 3.96 bn in 2023 (Fact.MR, 2023). In addition, it has been estimated that approximately 1 billion fishing lures are sold globally p.a. (Branson, W. 2023).
- Lures are known to get stuck and lost in rapids, lakes, and seas – lure waste culminates if it does not degrade rapidly -> ***use PHA***
- Misplaced fishing equipment is more dangerous to the nature than just the amount of plastic it contains, as it is capable of ensnaring several types of creatures living in aquanautic environment, e.g., fish, birds, seals, otters, snakes, and multitude of other piscivore animals. (Straits Research, 2023)

Fishing lure

- 3D-printing enabled the creation of flexible lure with joints made as one piece. Can also be customized.





The fishing lure in action

WoW!-PHA processing

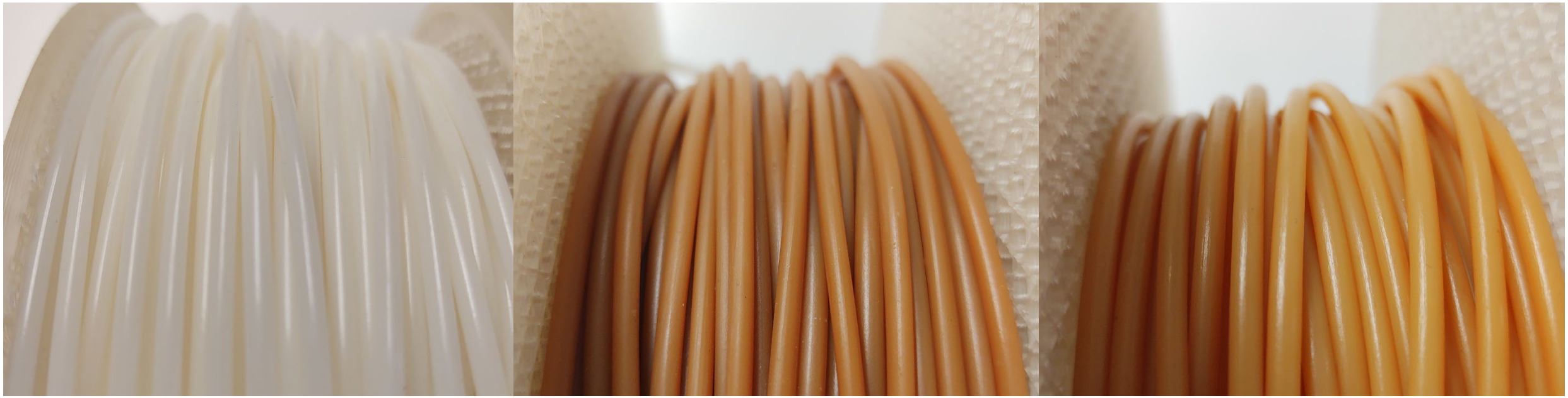
- Tests revealed that processing of PHA into 3D-printing filament is challenging:
  - All tested materials have narrow processing temperature window – they turn from solid into liquid within a few degrees
  - DSC analysis suggested that waste-derived PHA would perform more like amorphous material, but it did not
  - Soft, nearly molten material is challenging to pull into spool – this required extensive attention into material temperature, cooling and processing speed
  - The unpurified PHA turned quite brittle – challenge in the printing
- The brewery-PHA appeared to be more heterogeneous and more rubbery than the one made from juice processing water, that also appeared to be closer to commercial PHA grades in terms of physical properties
- The wastewater derived PHA has **strong** stench –needs purification!
- Blending the PHA with also biobased and biodegradable polybutylene succinate (PBS) formed material decently suitable for filament production

WoW!-PHA 3D-printing filament

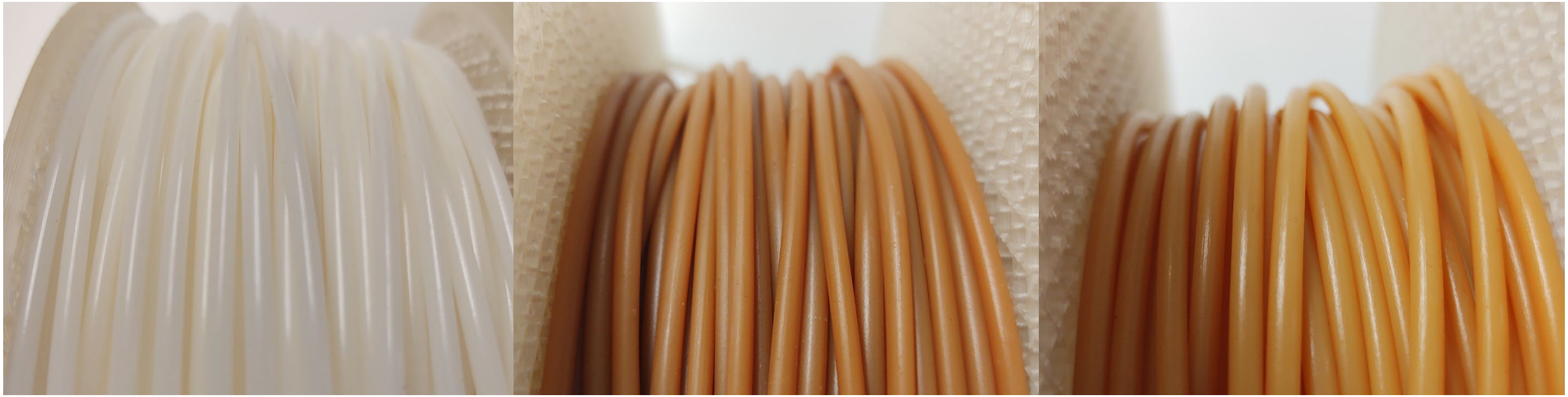
	PBS (reference)	Brewery PHA 20% in PBS	Juice PHA 20% in PBS
Modulus of elasticity [MPa]	467,2	411,0	392,6
Tensile strength [MPa]	51,8	36,0	34,4
Tensile strain at break [%]	439,0	86,7	28,0
Tensile strain at tensile strength [%]	32,8	28,0	25,8
Tensile strain at yield [%]	7,9	2,9	3,0
Tensile strength at yield [MPa]	19,0	10,2	9,6

WoW!-PHA 3D-printing filament

- Spooled filaments of PBS and WoW!-PHA blend
- To do: Pure PHA, additives to improve properties and processability, fillers for decreasing cost, colorants… Another project? ☺



Interreg
EUROPEAN UNION
North-West Europe
WOW!
European Regional Development Fund



Questions, comments?

- A big thanks to Interreg North-West Europe for enabling the whole WoW! Project.
- Also, many thanks for the whole consortium – thanks for having LAB from Finland as a partner and thanks for all support.
- Thanks to the audience for interest!

- Please feel free to contact me:
  - Ossi Martikka, D.Sc.(Tech.), Chief Specialist, LAB University of Applied Sciences
  - ossi.martikka@lab.fi Tel: +358 50 516 2757


Trinity
College
Dublin
The University of Dublin


UNIVERSITÉ DU
LUXEMBOURG


avans
hogeschool


Interreg
EUROPEAN UNION
North-West Europe
WOW!
European Regional Development Fund


LAB University of
Applied Sciences


TECHNISCHE UNIVERSITÄT
KAISERSLAUTERN


VLARIO
OVERLEGPLATFORM


CIRTEC


WUPPERVERBAND
für Wasser, Mensch und Umwelt


REMONDIS®
IM AUFTRAG DER ZUKUNFT


NaturePlast
Bioplastics Expert


waterschap
vallei en
veluwe


WiW
Wupperverbandsgesellschaft für
integrale Wasserwirtschaft mbH


vito


SEVERN
TRENT

Ossi Martikka

LAB University of Applied Sciences

Ossi Martikka (D.Sc.(Tech.), M.Sc.(Tech.) works as a Chief Specialist at LAB University of Applied Sciences in Finland.

His activities are related to sustainability and mechanical material cycles areas. Ossi is also co-leader of Textile and Plastics recycling research team.

The main fields of research and development he is working on are related to bioplastics, biocomposites and plastics recycling.

Other relevant fields of expertise he is involved in are material processing and processing technology, material science, recycling, upcycling and circular economy.