DANISH
TECHNOLOGICAL
INSTITUTE

Creation to Compost

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Nordic Bioplastic Conference 2025

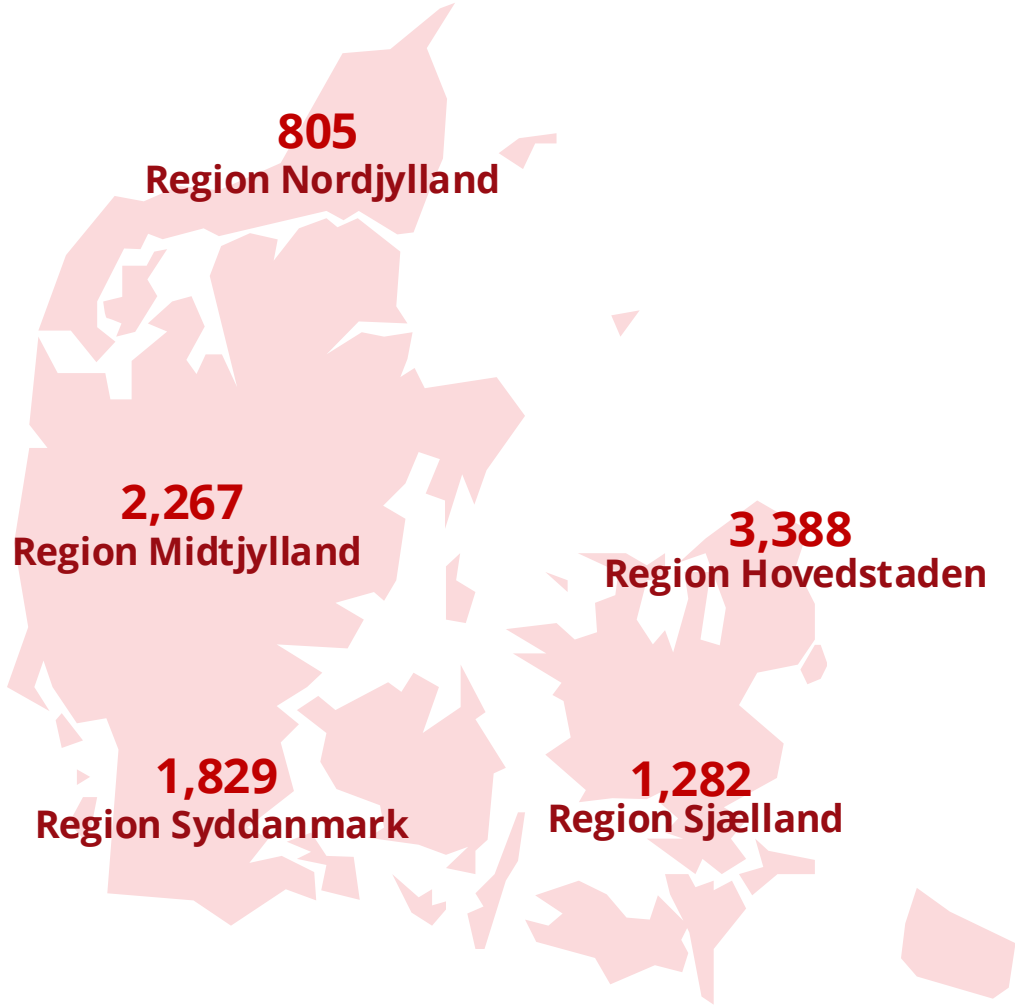
24th April 2025

11,000 satisfied customers

High customer satisfaction*

9,571
Danish customers

1,380
International customers



*Source: The Institute's customer satisfaction evaluation. The assessment is based on 2,428 respondents.

We offer three types of services

Validation

We validate and document technological solutions through tests and trials in our state-of-the art technology infrastructures.

Development

We run extensive research projects and develop pioneering technological solutions.

Integration

We integrate and implement technological solutions aligned with market, organisation, environment and culture.

DANISH TECHNOLOGICAL INSTITUTE

Strategic focus

Global challenges

- Climate crisis
- Geo political crisis
- Growth/recession

The Institute's development focus

- Food
- Materials
- Energy

Center for Bioressources

Biosolution Teknologi Center

- Multifunctional pilot facility
- Industrial infrastructure
- Prototype production and validation
- Process and technology evaluation
- Data treatment

Biorefinery

- Evaluation and utilization of sidestreams
- Procesdevelopment
- Wet and dryfractionation
- Enzyme hydrolysis
- Separation, purification, drying
- Alternative proteins

Fermentation

- Precision fermentation
- New ingredients and functional products
- Biomass cultivation incl. mikroalgae, fungi, bacateria, macrophages
- Cell harvest, cleaning, drying

Microalgae

- Design of microalgae production
- Stable productionfacilities
- Upscaling for pilotscale photobioreactors
- Optimization of growth conditions

Biomaterials

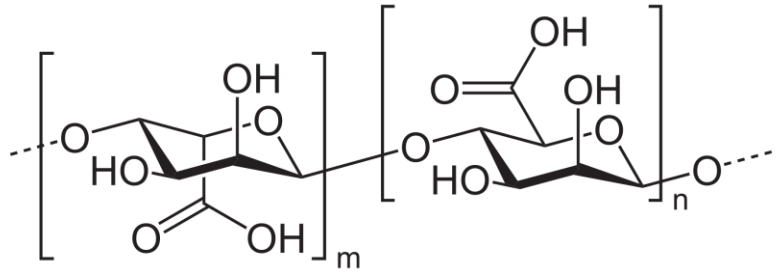
- Biomaterials and product development
- Fibre for pulp and packaging
- "End-of-life" evaluations
- LCA
- TEA (Tekno-economic analysis

Case 1:

Bioplastics from algae

Alginate Extraction and Processing

- **What is Alginate?**
  - A natural polysaccharide extracted from brown algae (seaweed).
  - Composed of two uronic acids: mannuronic acid (M) and guluronic acid (G).
  - Biodegradable, biocompatible, and non-toxic.



Alginic acid consisting of guluronic acid and manuronic acid

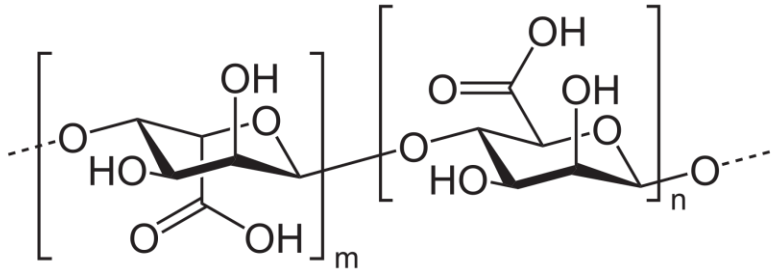
- **Harvesting**:
  - Seaweed is harvested from the ocean, either wild or cultivated.

- **Extraction:**
  - Washing and drying the seaweed.
  - Alkaline extraction using a solution like sodium carbonate.
  - Filtration to remove impurities.
  - Precipitation of alginate as alginic acid or sodium alginate.

Seaweed (Saccharina latissima) harvested at Faroe Islands

Conversion to bioplastic

- **Conversion to Bioplastic:**
  - Alginate can be processed into films, beads, and other forms by techniques like solution casting, extrusion, and 3D printing.
  - Often cross-linked with calcium ions (Ca2+Ca2+) or other divalent cations to improve strength and water resistance.



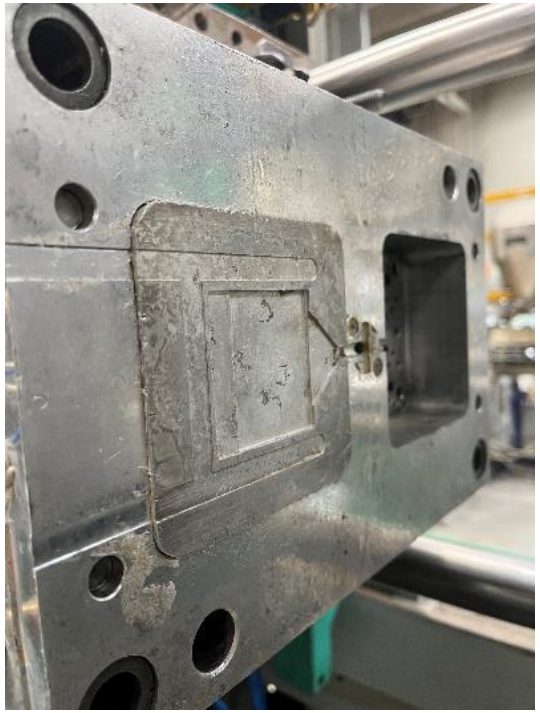
Alginic acid consisting of guluronic acid and manuronic acid

- **We have worked with additives to improve**
  - ✓Increase tensile strength
  - ✓Improve barrier properties for thin films
  - ✓Makes material shelf stable when moisture present
  - ✓Identified suitable mold release agent
  - ✓Tested additives effect on dewatering
  - ✓Adjusted plasticizer for use in films or pelletizing

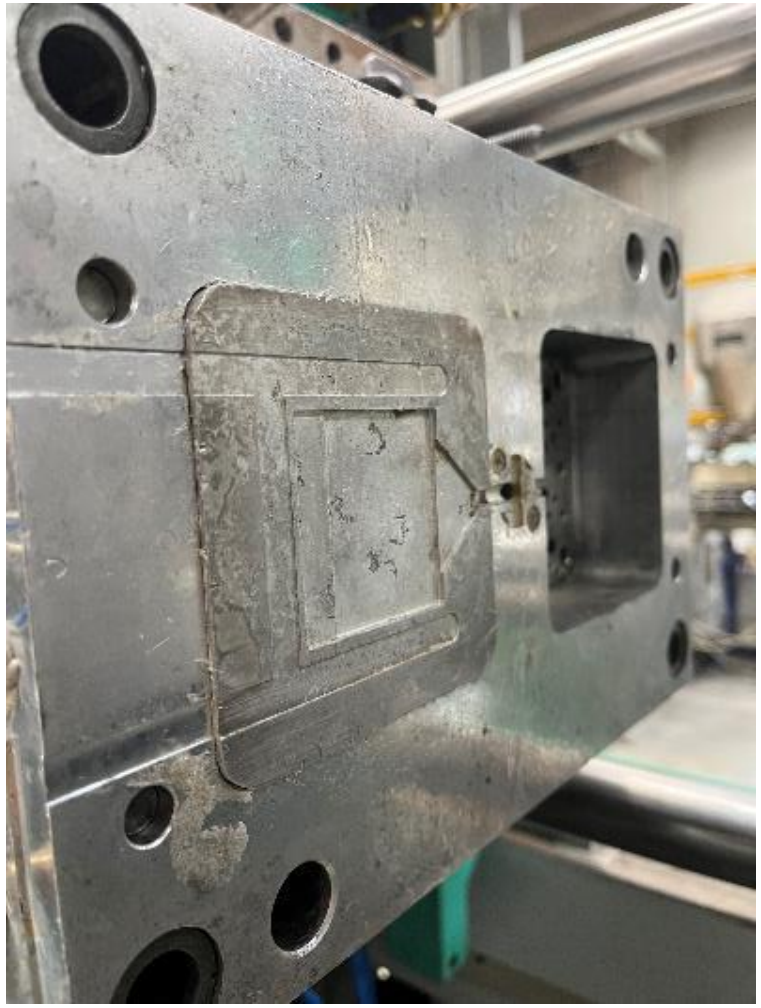
Compounding (good extrusion)

Injection molding

- Injection molding with alginate is possible
- Requires precise fine tuning.
- Challenges include mold filling, drying, and deformation at temperatures up to 130 °C and injection pressures of 1300 bar. Optimal conditions require external drying, and the dried material resembles bendable plastic.



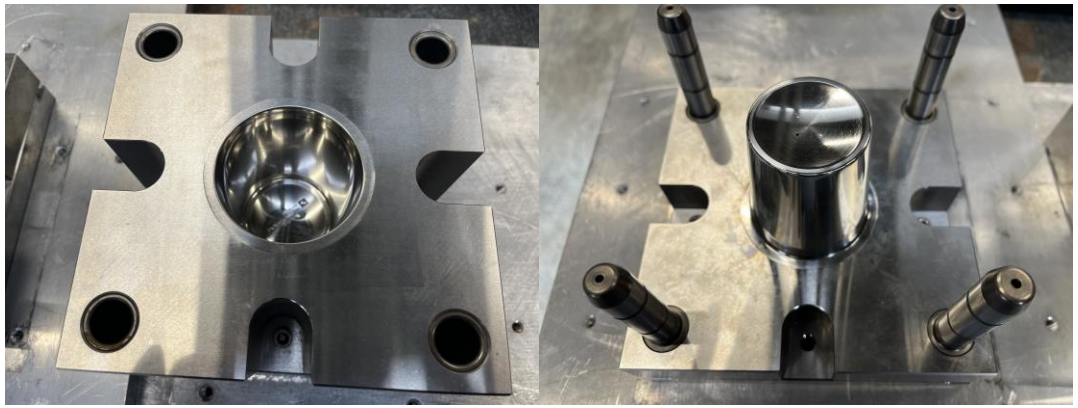
Injection molding



Injection molded AlgaePlast

Hot pressing (cups)

Laser cut blanks



Polished mold

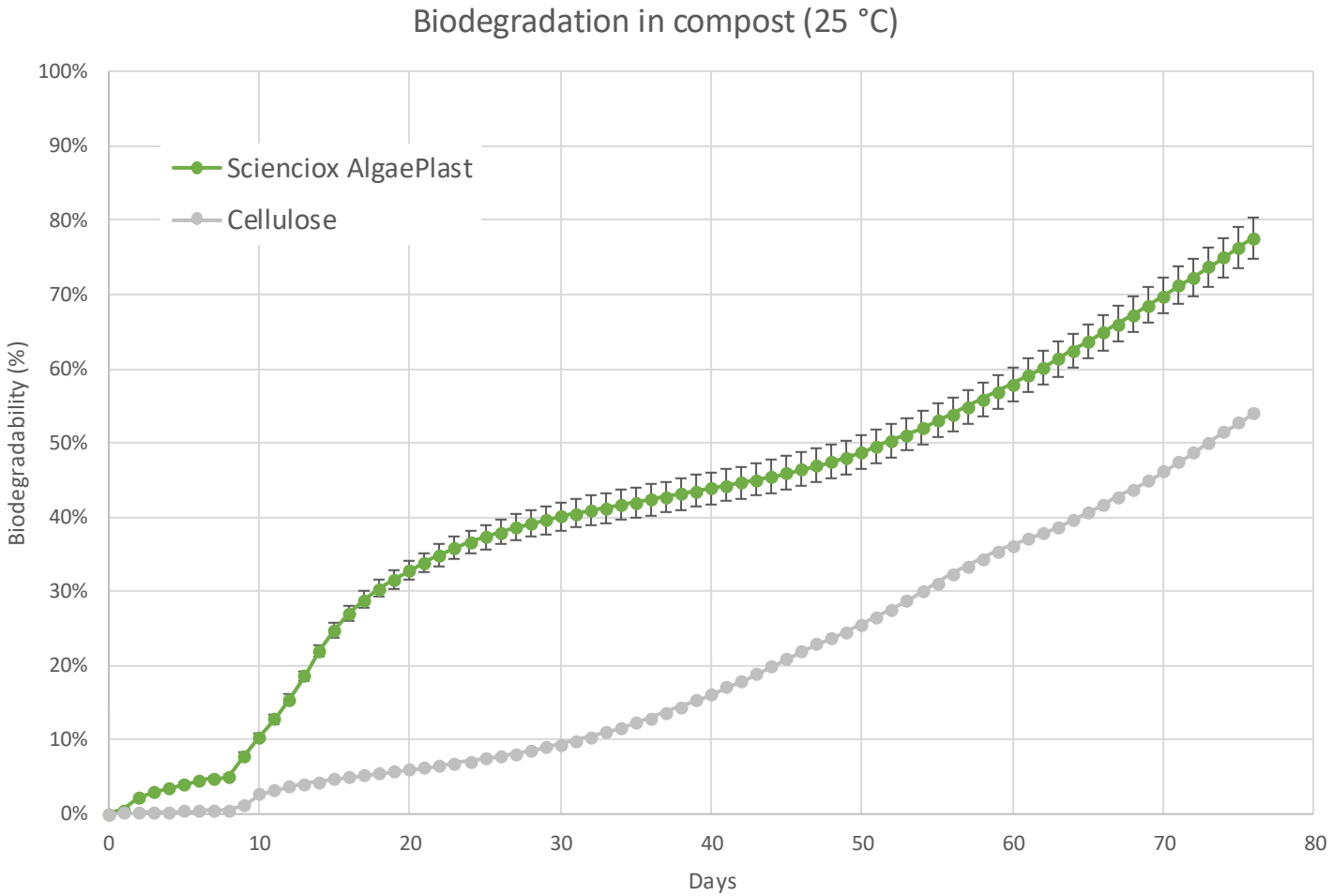
Hot pressing at elevated pressure and temperature

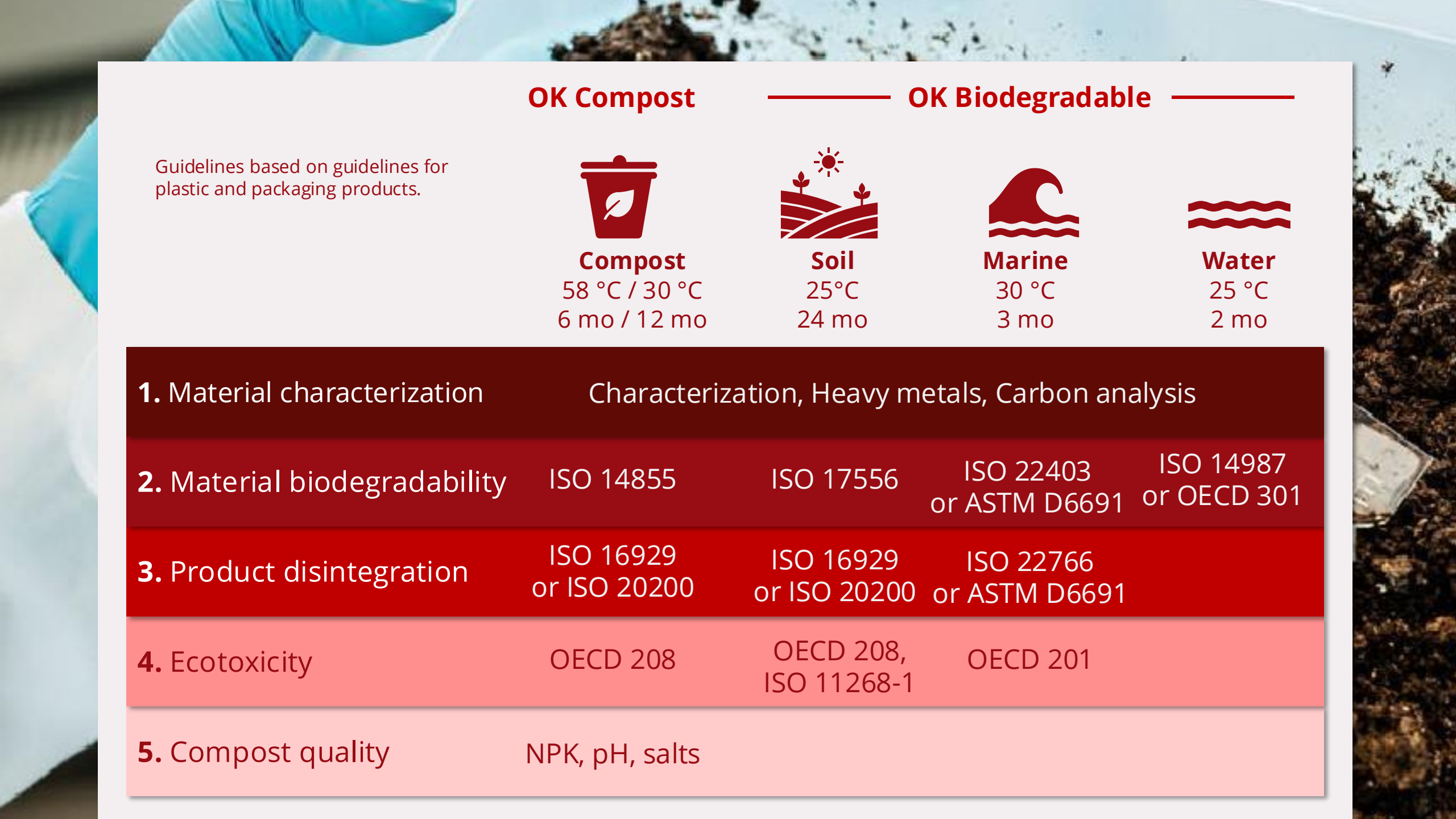
Hot pressing

Prototype cups and trays

Biodegradability

- Material passes home biodegradability tests, surpassing cellulose in degradation speed





Guidelines based on guidelines for plastic and packaging products.

	OK Compost	OK Biodegradable		
	Compost 58 °C / 30 °C 6 mo / 12 mo	**Soil** 25°C 24 mo	**Marine** 30 °C 3 mo	**Water** 25 °C 2 mo
1. Material characterization	Characterization, Heavy metals, Carbon analysis			
2. Material biodegradability	ISO 14855	ISO 17556	ISO 22403 or ASTM D6691	ISO 14987 or OECD 301
3. Product disintegration	ISO 16929 or ISO 20200	ISO 16929 or ISO 20200	ISO 22766 or ASTM D6691	
4. Ecotoxicity	OECD 208	OECD 208, ISO 11268-1	OECD 201	
5. Compost quality	NPK, pH, salts			

Biodegradability and compostability

Does the material really disappear?

- **Ability to degrade with microbial activity**
- **Evaluation and decision making for product development**
- **To achieve product claims**
- **Increase branding value (certification)**
- **Customer acceptance of a product**
- **Law requirements (e.g. rule out oxo-degradability)**

What do we test?

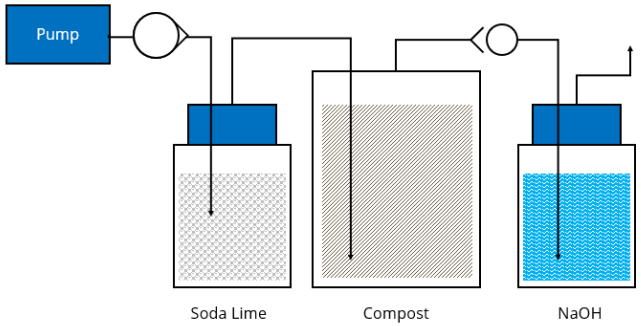
- Raw plastics
- Textile fibers (Clothes, Carpets)
- Foils
- Trays
- Cups
- Coffee pods
- Coatings
- Plastic ammunition and shells
- Chewing gum
- Plant pots
- etc

Biodegradability

How Biodegradability is analyzed (ISO 14855)

- Organic carbon is determined in the sample
- Experimental setup uses glass vessels supplied with CO2-free air.
- CO_2 is captured and measured in the output flow (titrimetric/NDIR)
- Temperature, pH and moisture controlled

Titrimetric setup



NDIR measurement

$$Biodegradation(t) \quad [\%] = \frac{m_{CO_2,sample}\,(t) - m_{CO_2,blank}\,(t)}{ThCO_2}$$

Case 2:

Hunting wads

Ministry of Environment of Denmark
Environmental Protection Agency

Hunting wads case study

Challenge

- Each year 20-30 tones hunting wads in the Danish environment
- Hunting wads are made of conventional plastics
- Several knowledge gaps
  - Market/ product analysis
  - Functionality
  - Potential biodegradability

Solution

- Selecting representative products (4 products)
- Development of protocol to test under Danish conditions
  - Adjustment of standard (ISO 14855)
  - AVR summer (21°C) and winter 5° C
  - Compost/soil

Effect

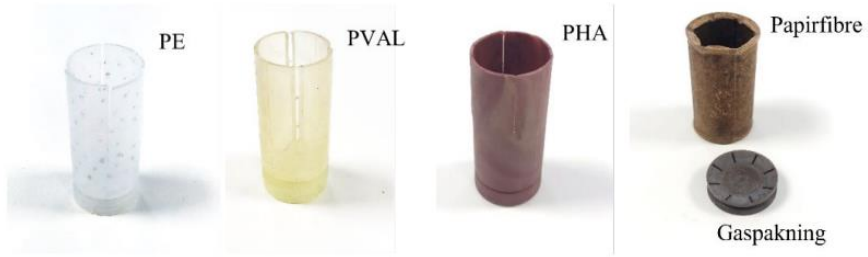
- Closing knowledge gaps
- Identification of real biodegradable material
- Supporting product development
- Advising for future political decisions

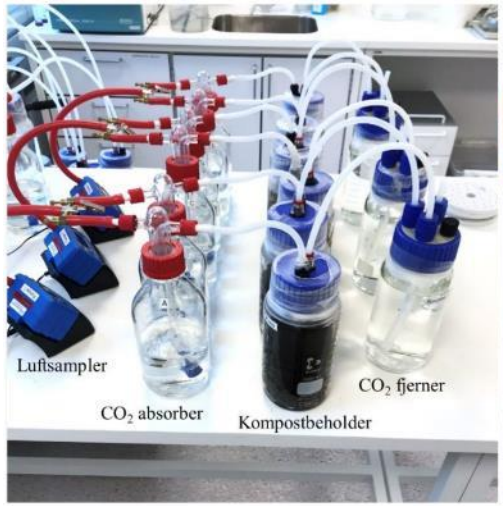
Hunting wads case study

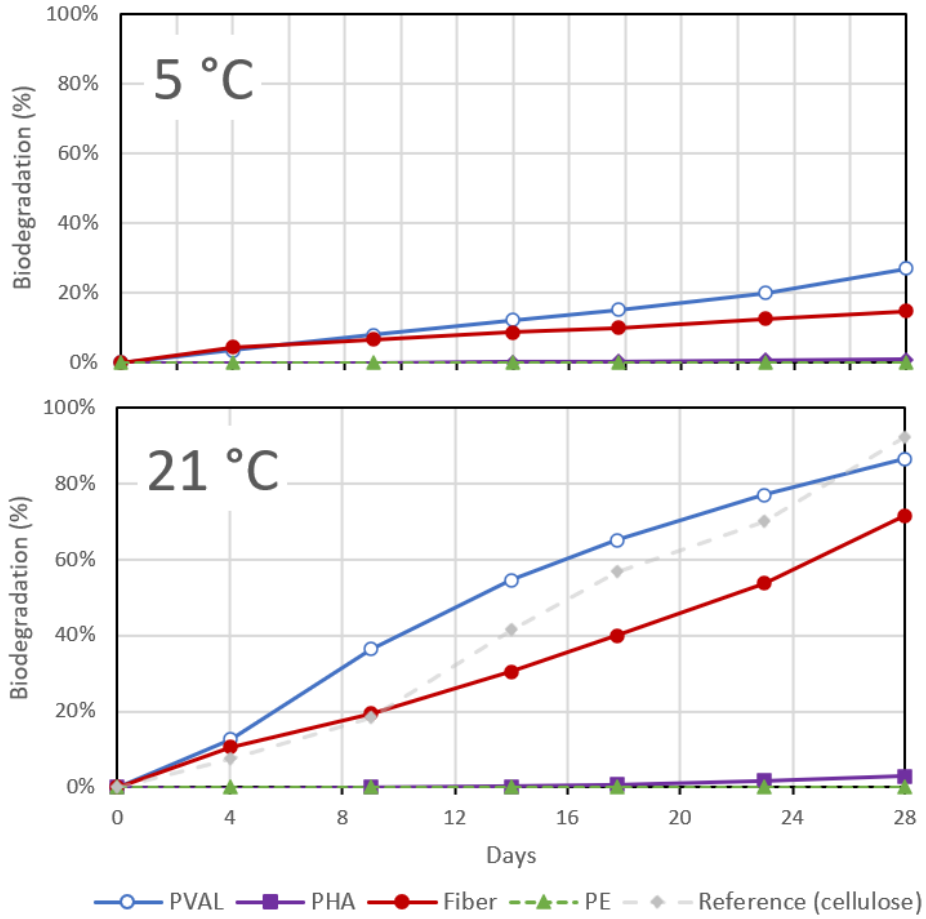
Ministry of Environment of Denmark
Environmental Protection Agency

Hunting wads

Scan to read report







Disintegration (laboratory scale)

How Disintegration is analyzed (ISO 20200)

Sample preparation

- Samples are cut to 35x35 mm and vacuum dried

Compost preparation

- Synthetic compost prepared

Test setup

- Boxes with 1 kg compost + samples
- Adjustment of moisture level, mixing and visual assessment

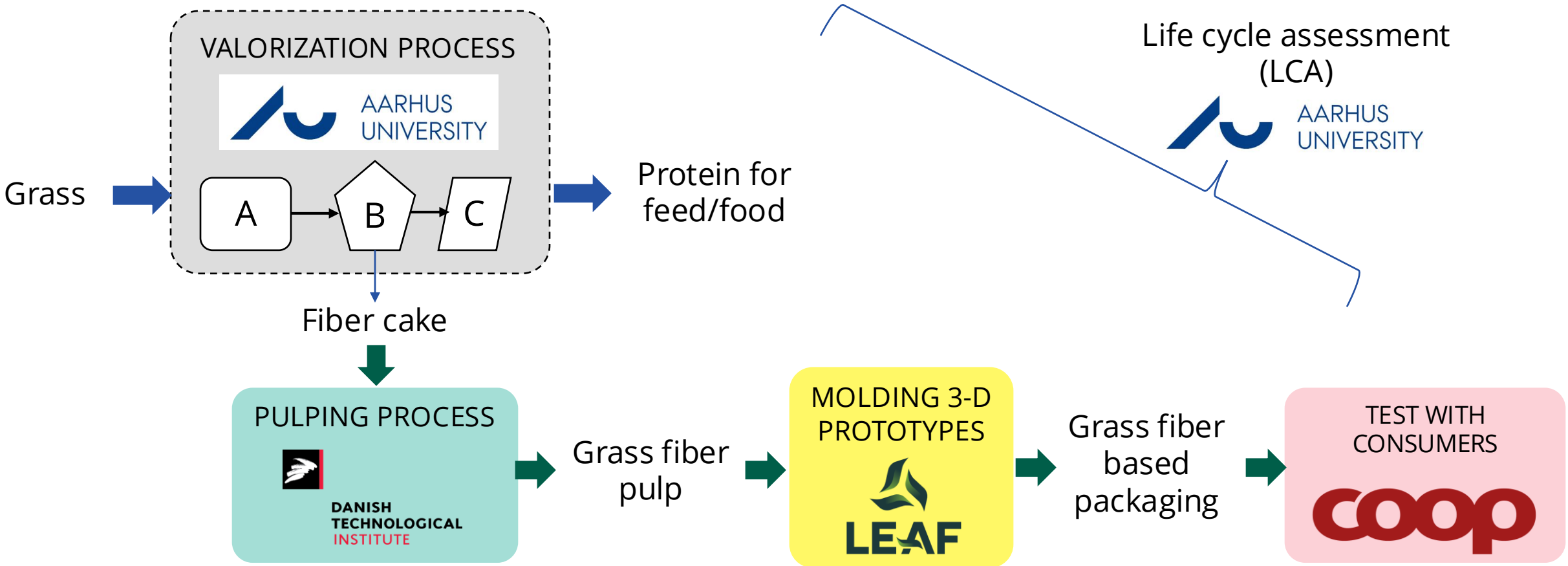
Evaluation

- Sieving to <2mm should retain less than 10% of the original material

Case 3: Grass fiber-based paper for sustainable “to-go” packaging products GUDP

SinProPack

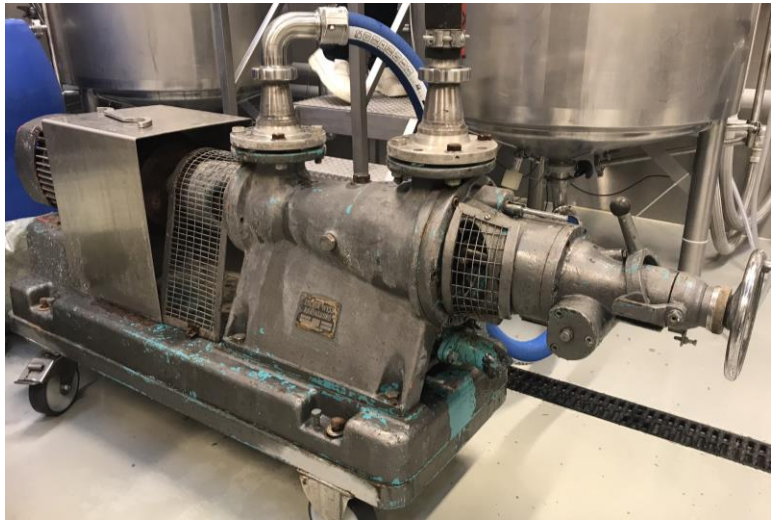
Case: SinProPack



PULPING PROCESS

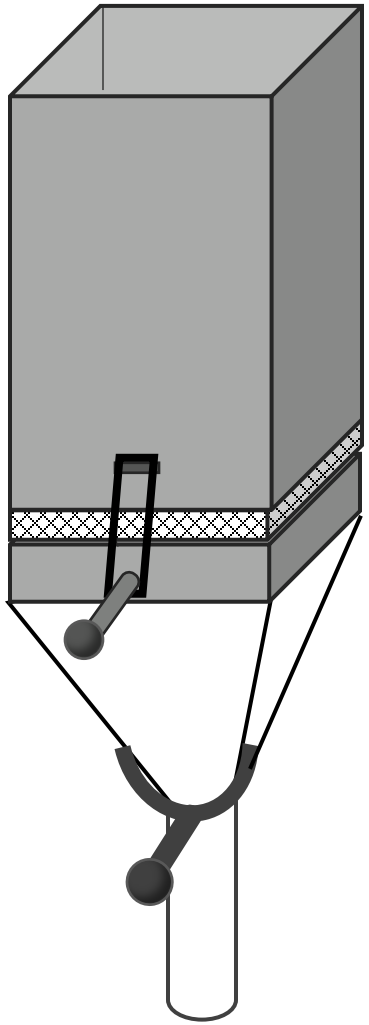
Mechanical refining

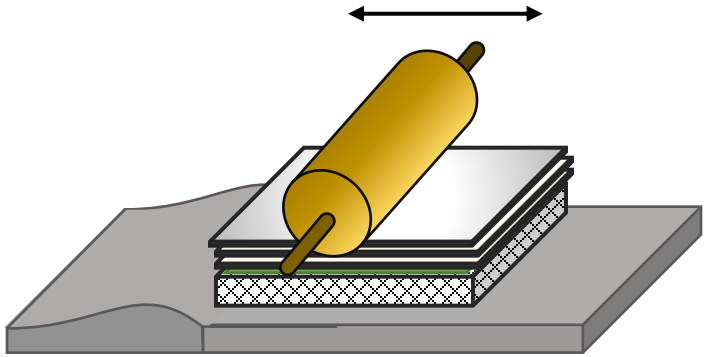
- Thermomechanical pulping: high pressure and high temperature
- Chemo-mechanical pulping: chemical treatment before mechanical refining
- Chemo-thermomechanical pulping: combination of temperature, pressure and chemical treatments
- Bleaching: pre-treatment with hydrogen peroxide
- Enzymatic treatment



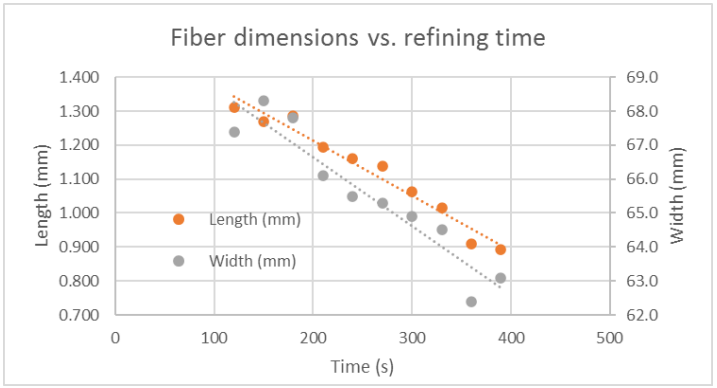
REFINED FIBERS

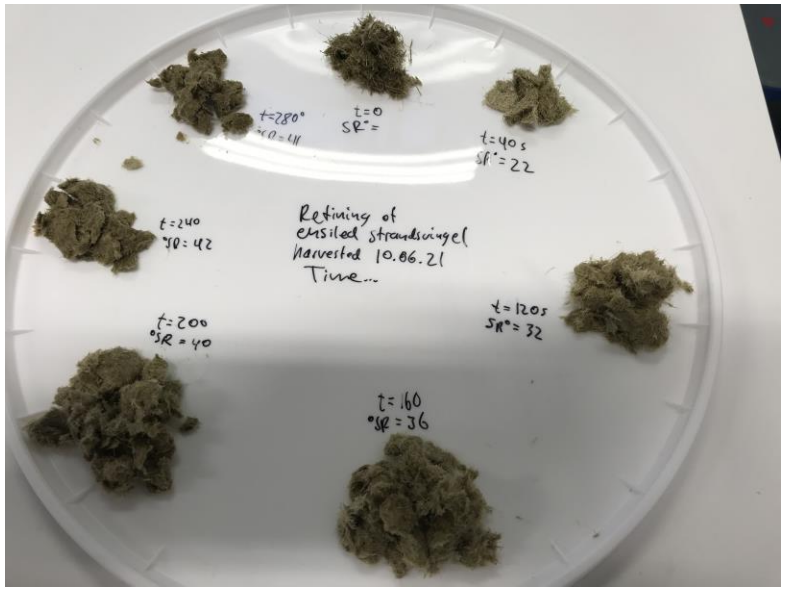
Handsheet

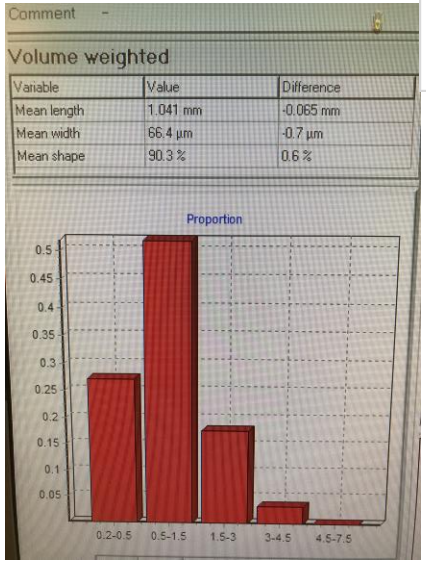


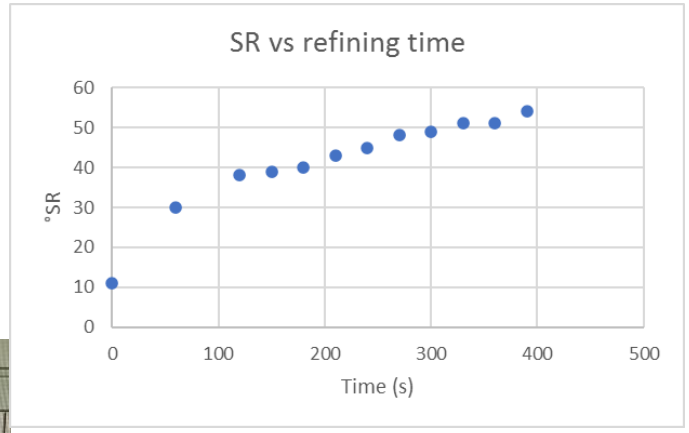


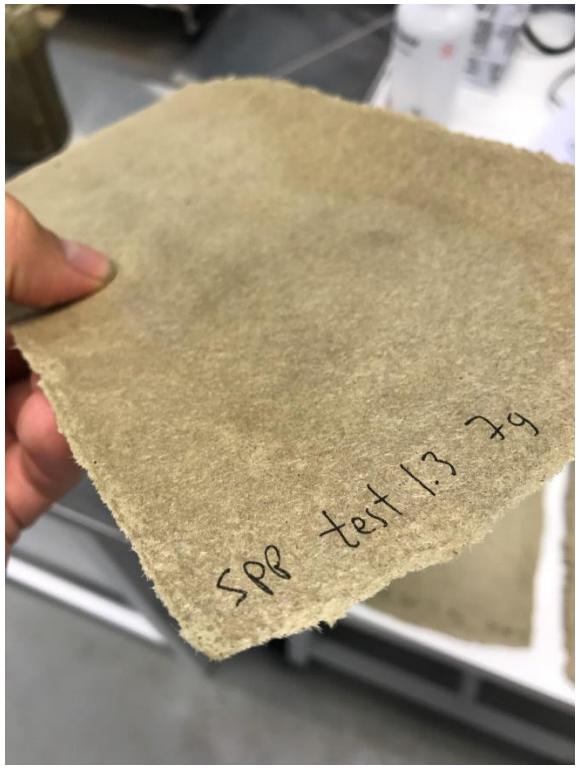
PROCESS DEVELOPMENT



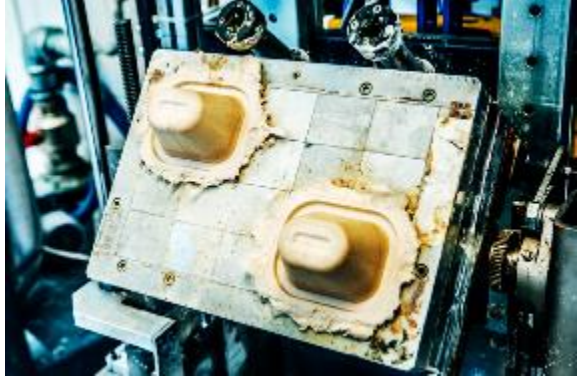








MINI-PAPER FACTORY (MPF)



- ✓ MPF is a compact paper molding machine designed at Danish Technological Institute
- ✓ Primary application area is prototyping and pilot manufacturing of customer-specific fibre-based packaging – flat sheets, trays, cups, bowls, plates etc.

Main features

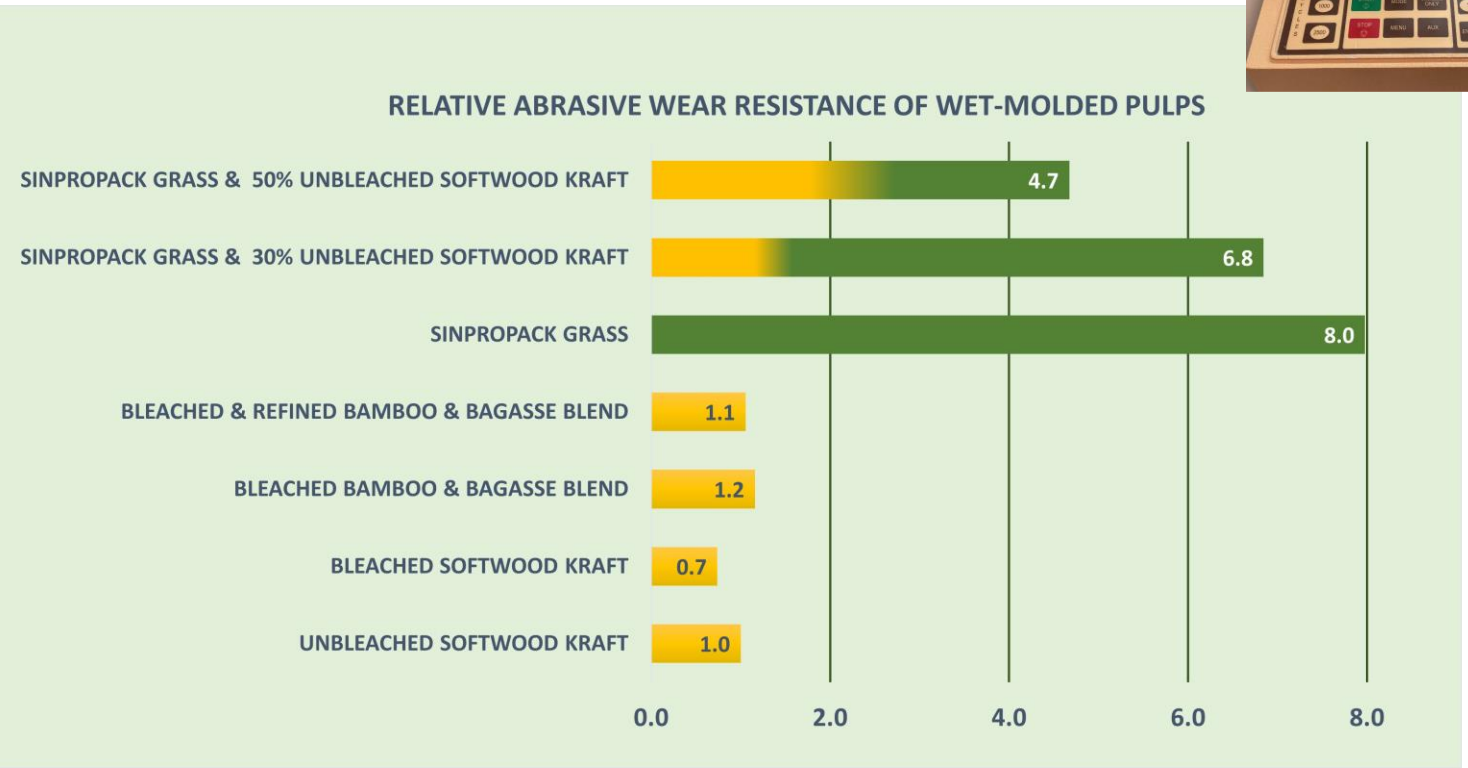
- ✓ Fast and convenient mold interchange
- ✓ Full controllability of process parameters
- ✓ Ideal for research or piloting
- ✓ Easy to upscale
- ✓ Extremely low initial pulp volume of only 50 L

Technical specifications

- ✓ Overall dimensions: 1600 (H)×1500 (W)×1200 (L) mm
- ✓ Footprint: 1.8 m^2
- ✓ Power consumption: 14 kW
- ✓ Maximum overall dimensions of a molded object: 150 (H)×200 (W)×300 (L) mm
- ✓ Average capacity: 30 molded objects per hour

EXCEPTIONAL ABRASIVE STRENGTH OF GRASS-DERIVED CELLULOSE FIBERS

ISO 9352:2012 test



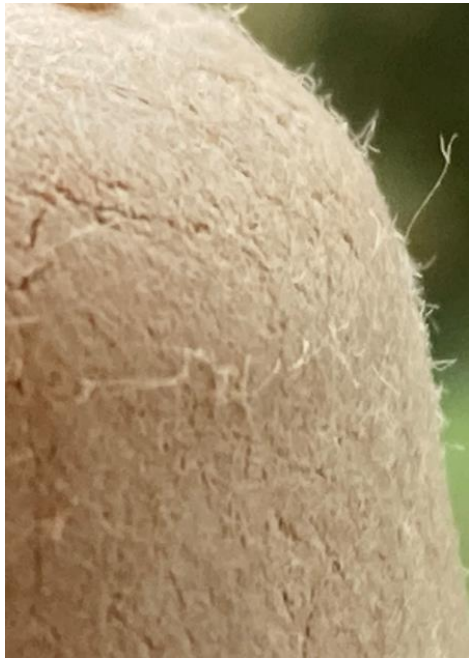
Bleached softwood Kraft

Unbleached softwood Kraft

Pure SinProPack grass fibers

FIBER DETACHMENT (DUSTING) AND SURFACE POROSITY OF THE MOLDED PULP

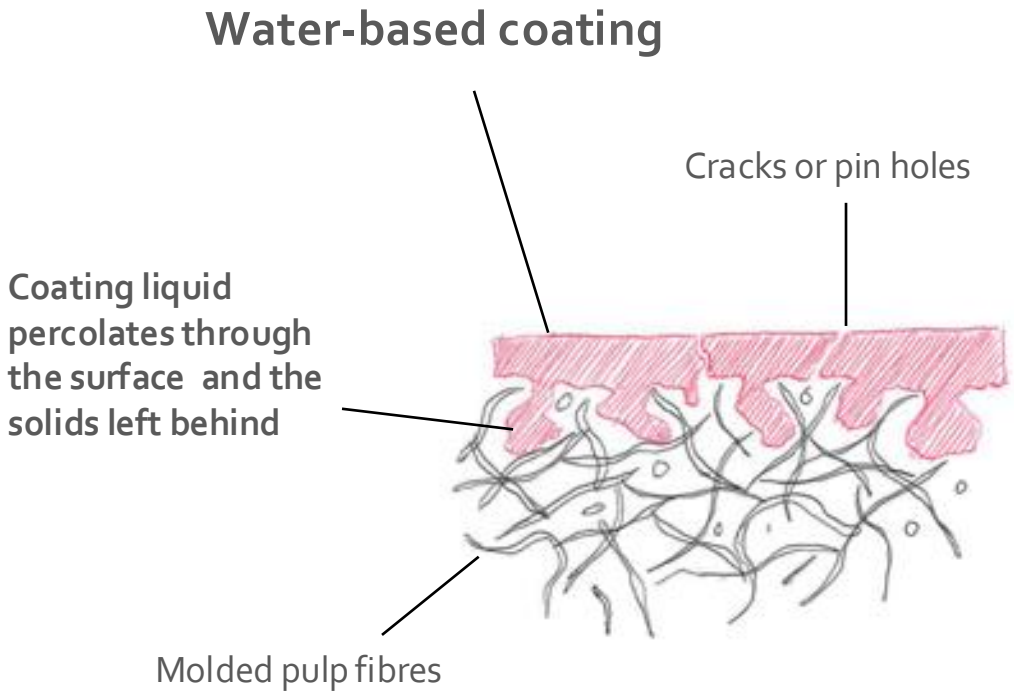
100%
Unbleached Kraft pulp (UKP)



50% UKP and
50% SinProPack grass fiber pulp

PECULIARITIES OF WET MOLDED PULP THAT TYPICALLY AFFECT PERFORMANCE OF WATER-BASED BARRIER COATINGS

- Surface roughness
- Detachment (uplift) and dusting of fibers - fibers protrude from the coating layer of a regular thickness
- Pulp porosity
- Hydrophilicity and water absorption of Kraft fibers



- **Molded pulp with SPP fibers does not have all these shortcomings and would be an excellent substrate for water-based barrier coatings**

Disintegration results

Testing Period: 60 days under controlled composting at 21°C

Findings:

- **10% Grass Fiber Paper**: 90.8% ± 2.6 disintegration
- **20% Grass Fiber Paper**: 90.1% ± 0.2 disintegration

Implication:

- ✔ Both results meet the ≥90% pass level required by ISO 20200:2023

Observations:

- Material was very fragile and barely distinguishable from compost upon sieving.
- Test validated by reduction in volatile solids and minimal variance.

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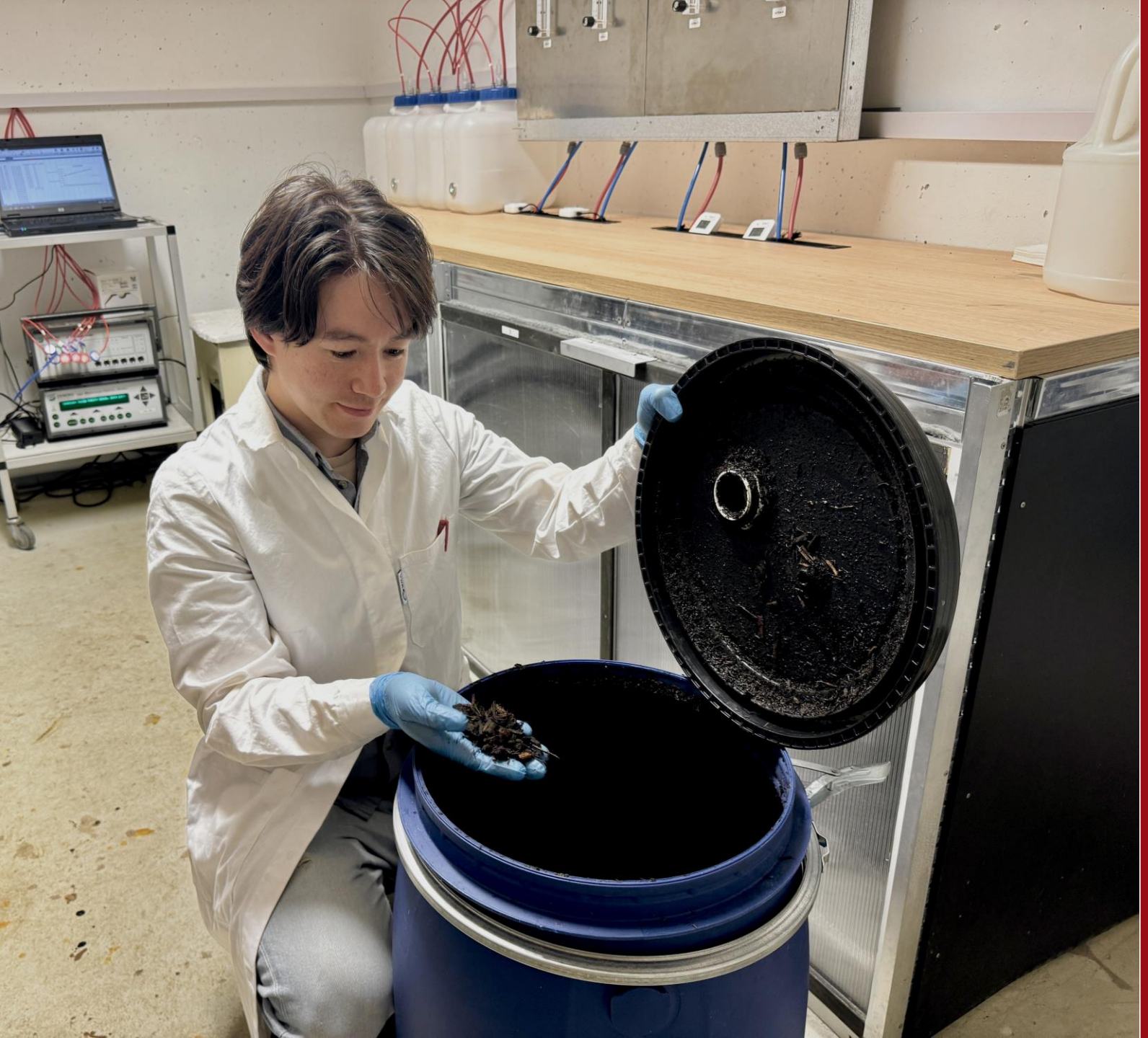
SinProPack 10% grass fiber

SinProPack 20% grass fiber

60 day timelapse



Disintegration (pilot scale)

Disintegration (pilot scale)

Sample preparation

- Samples are cut to 50x50 mm and vacuum dried

Compost preparation

- A biowaste is mixed with the biopolymer in 60L barrels

Temperature

- Temperature and oxygen is monitored within the compost to closely follow a specific temperature profile (45-70°C)

Evaluation

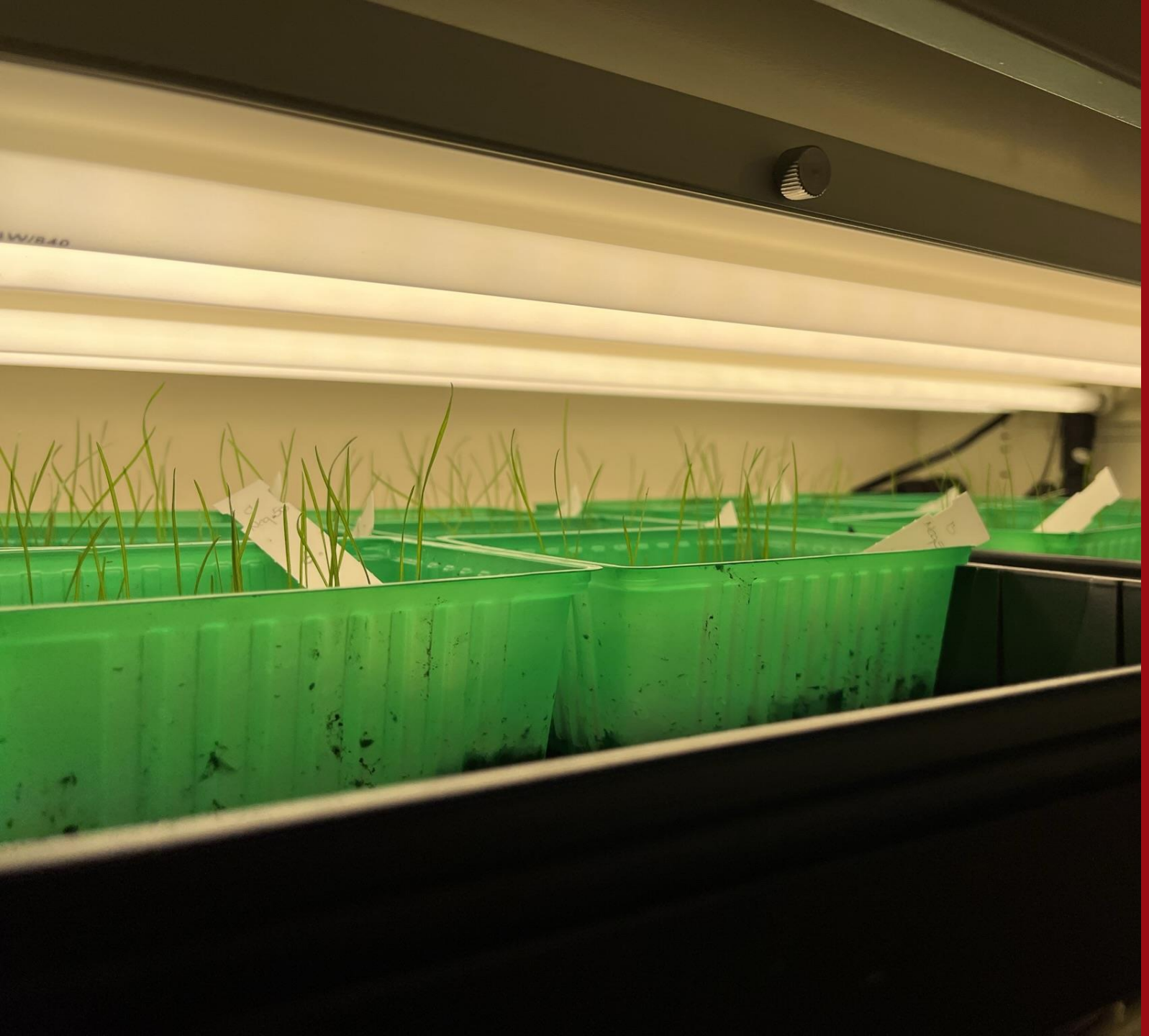
- Sieving to <2mm should retain less than 10% of the original material

Custom built pilot scale composting

Pilot scale industrial composting (45-70 °C)

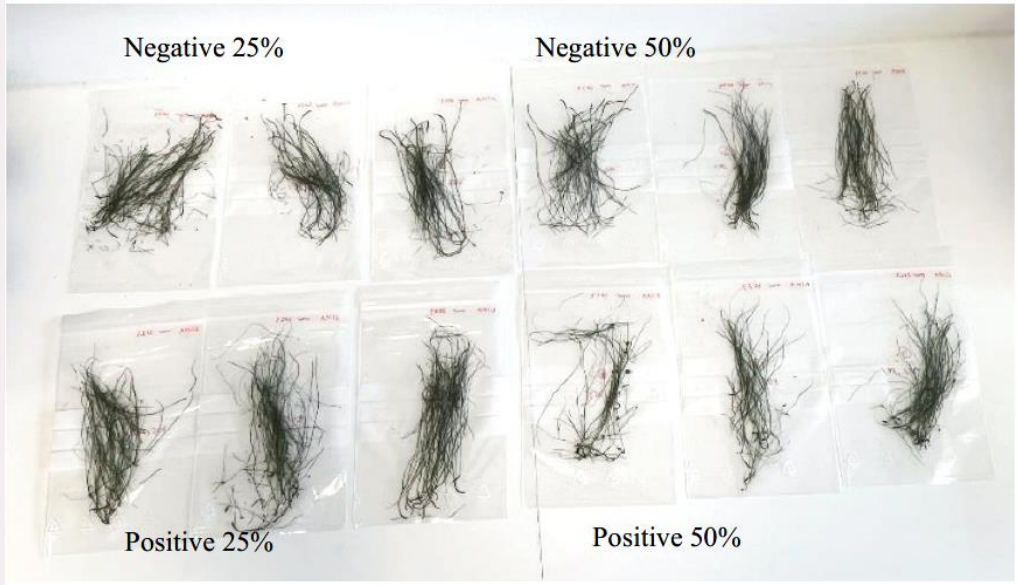
Pilot scale industrial composting (45-70 °C)

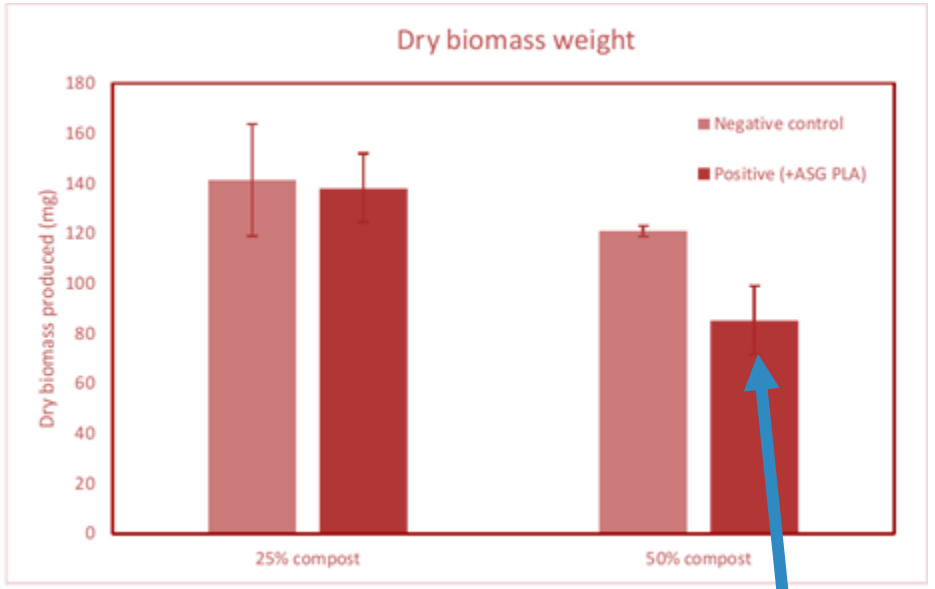
Compost mixing with bioplastic cups made from coffee grounds



Ecotoxicity

Ecotoxicity test





OECD 208 - Ecotoxicity

Sample preparation

- Chosen seeds are sprouted in the compost from pilot disintegration

Compost preparation

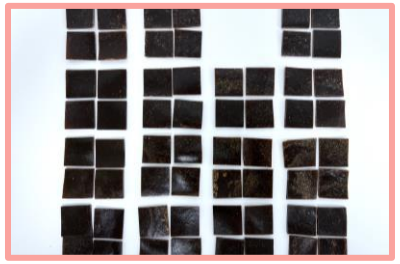
- Controlled light, relative humidity, temperature and watering

Evaluation

- Dry weight and emergence of harvested should be at least 90% that of control

Difference shows ecotoxic effect

Biomaterials

	Production	Characterisation	Biodegradation and composting tests	Certification
Value Chain	➢ Optimized bio fermentation ➢ Pulp treatments ➢ Enzymatic hydrolysis	➢ Strength testing ➢ Humidity tolerance ➢ Phase chance ➢ Melting	➢ Material characterisation ➢ Material biodegradation ➢ Product disintegration ➢ Ecotoxicity test ➢ Compost quality	➢ Material characterisation ➢ Material biodegradation ➢ Product disintegration ➢ Ecotoxicity test ➢ Compost quality
Customer services				TÜV AUSTRIA
Focus	• Bio fermentation • Fiber-based • Side streams	• FTIR • Tensile strength	• Compost, soil, marine and water • Ecotoxicity tests • Compost quality • Micro plastic screening	• (in audit) • OK Compost HOME and INDUSTRIAL • REAL (UK)
R&D projects	• TRACE, DK • FBCD • Plan Danmark, DK	• FBCD, Dk • MADE Demonstration	• FBCD, DK • Closing Loop • HE, EU	

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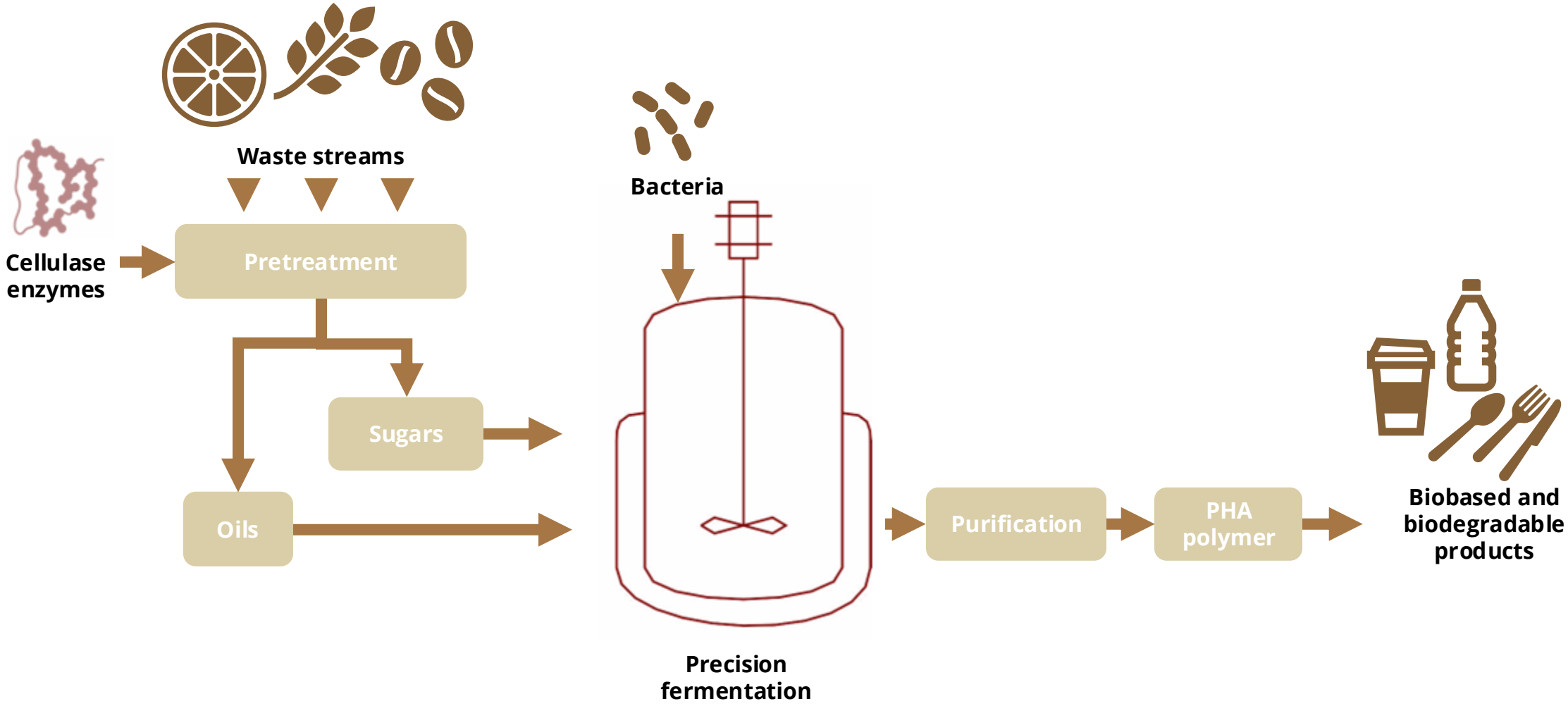
Fermentation of biomaterials



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Medfinansieret af Den Europæiske Union
Danmarks Erhvervsfremmebestyrelse
Food & Bio Cluster Denmark

Thank you!

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