

STANDARDIZED TESTS FOR BIODEGRADABLE & COMPOSTABLE PLASTICS

EXISTING PROTOCOLS, RECOMMENDATIONS AND MISCONCEPTIONS



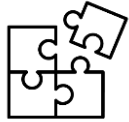
Nordic Bioplastics Conference 13. April 2023

Nicolaj Ma, M.Sc., Teknologisk Institut



DANISH
TECHNOLOGICAL
INSTITUTE

PILOTPLANT AND EQUIPMENT FOR BIOREFINERY



Several processes available in one place

Units can be coupled for a unique process for certain biomass



Food certified

Minimal loss



Stirred tanks

Heat exchanger

Decanter centrifuge

Wet mill

Spray drier

Vibrating sieve

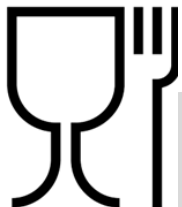
Clarifier centrifuge

Column chromatography

Dry fractionation

Membrane filtration

SANI membran



WHAT DO WE TEST

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



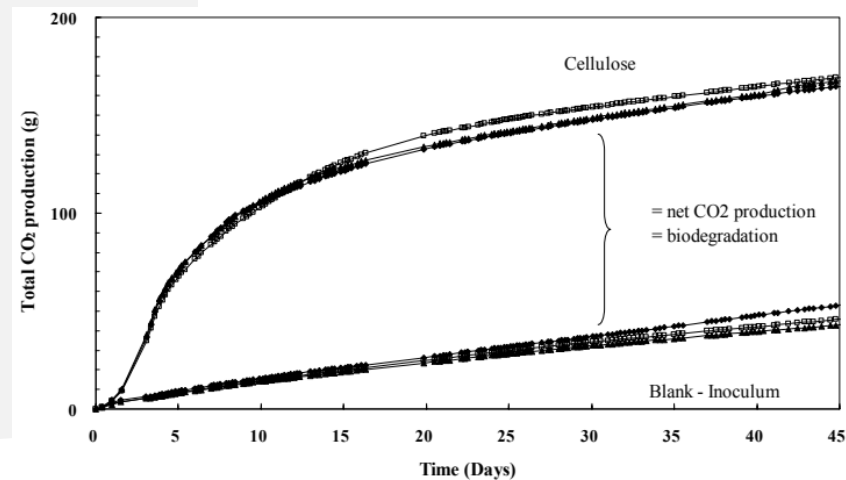
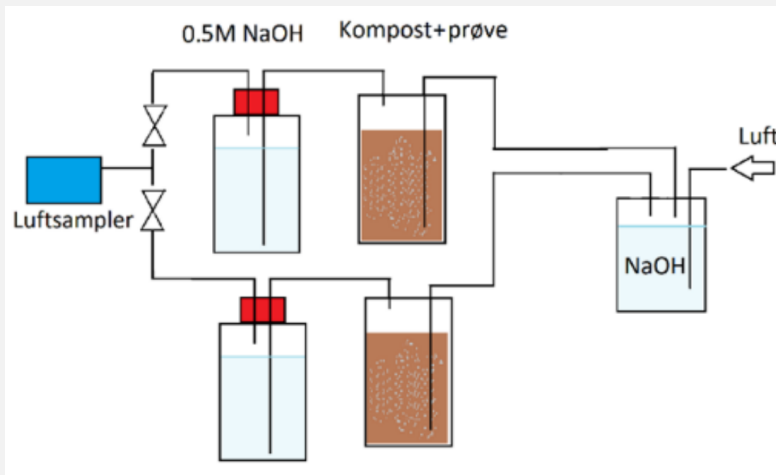


WHY TEST BIODEGRADABILITY?

- Testing materials or products ability to degrade with microbial activity
- To help evaluation and decision making during product development
- To achieve product claims
- To help create customer acceptance of a product
- Law requirements (e.g. rule out oxo-degradability)

HOW BIODEGRADABILITY IS TESTED

- Organic carbon is determined
- Experimental setup uses glass vessels supplied with CO₂ free air.
- CO₂ is captured and measured in the output flow



MISCONCEPTION 1:

BIODEGRADABLE MEANS ECO-FRIENDLY

Reality: Although biodegradable materials can break down, they may still release harmful substances during degradation or require specific conditions, making them not inherently eco-friendly.



MISCONCEPTION 2:

BIODEGRADABLE AND COMPOSTABLE ARE THE SAME THING

Reality: They may be part of the same testing scheme, but the words mean different things: Compostable items are biodegradable by definition, but not necessarily the other way around!





Compostability

European standard EN 13432

1. Material characterization

2. Biodegradability

3. Disintegration

4. Ecotoxicity

5. Compost quality

A guideline for compostable materials that is valid for plastic and packaging products.

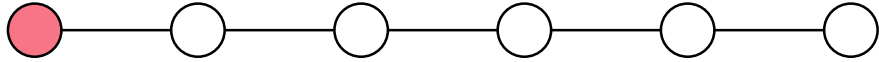
The standard is also being used for certain textile polymers such as lyocell, modal.

The standard involves a series of tests each with pass/fail criteria in 5 different areas.

It must pass all five areas to be considered compostable



PART 1: MATERIAL CHARACTERIZATION



- Measure thickness or mass:surface
- Heavy metal analysis
- Total solids/Volatile solids
- Total organic carbon (TOC)

- Pass/fail criteria:
 - Permitted amounts of elements in material (Table 1)
 - Levels of volatile solids

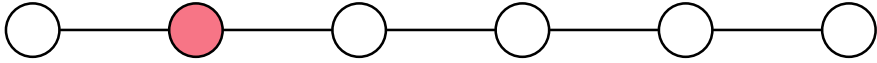
Table 1: Maximum permitted amounts of elements in material (EU)

Element	mg/kg DW
Zn	150
Cu	50
Ni	25
Cd	0.5
Pb	50
Hg	0.5
Cr	50
Mo	1
Se	0.75
As	5
F	100





PART 2: BIODEGRADABILITY



- Laboratory biodegradation of granular/powdered material in medium
- Compost soil at 58 °C (ISO 14855-1).
- Constant supply of CO₂-free air.
- Emitted CO₂ compared to TOC measured in Part 1

- Sample in medium (3 replicates)
- Cellulose in medium (3 replicates)
- Blank medium (3 replicates)

- Pass/fail criteria: ≥90% carbon release (relative to TOC or reference) in timeframe

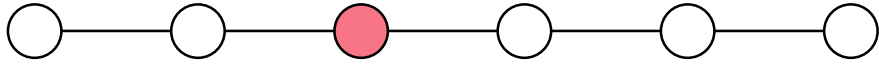
Mediums

- Compost at 58 °C (ISO 14855)
- Soil 20-25 °C (ISO 17556)
- Water 20-25 °C (EN14987/OECD 301B)
- Marine 30 °C (ISO 22403)





PART 3: DISINTEGRATION



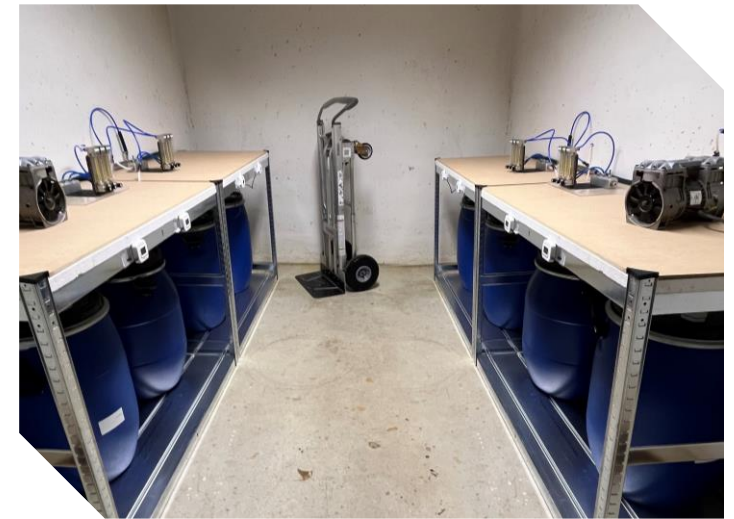
- Samples are added to 30 kg aerobic composting bins for 12 weeks
 - 27 kg compost (municipal compost, rabbit feed, vegetable waste, 10-50 mm bark or wood chips.)
 - 0,3 kg of sample with a surface:volume equal or lower to the tested product
 - 2,7 kg of powdered sample (< 0.5 mm)
- Constant air supply and re-watering
- Temperature, pH, RH% and O₂ monitoring

- Whole sample: (2 replicates)
- Blank (2 replicates)

- Pass/fail criteria: <10% remains >2 mm in screened compost after 12 weeks
- Maturity is evaluated based on temperature and Rottegrad level (Table 2)



ISO 20200 laboratory scale disintegration

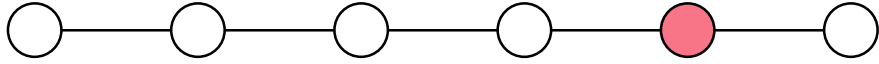


ISO 16929 Pilot scale disintegration (under development)





Part 4b: Compost quality (sprouting test)



- Ecotoxicity test (modified OECD 208)
- 2 species plant species tested in reference compost soil and composted sample soil (from part 3).
- 100 seeds + 200 g mixed soil per replicate
- 70-100 %RH
- >16 hr light (300-400 $\mu\text{E}/\text{m}^2/\text{s}$) per day

- Mixed soils:
 - Reference soil + 25% sample compost from Part 3 (3 replicates)
 - Reference soil + 50% sample compost from Part 3 (3 replicates)

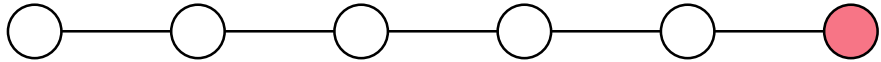
 - Reference soil + 25% reference compost from Part 3 (3 replicates)
 - Reference soil + 50% reference compost from Part 3 (3 replicates)

- Pass/fail criteria: Evaluation on seedling emergence, dry shoot weight, visual assessment.





Part 5: Combined evaluation



- The final evaluation concludes results from Part 1-4, which are summarized in a checklist (EN 13432 Annex C) in a final report with any remarks.
- Final evaluation.
- Pass/fail criteria: Part 1-4 and final evaluation pass.



MISCONCEPTION 3:

ALL PRODUCTS LABELED AS BIODEGRADABLE WILL FULLY DEGRADE

Reality: The pass/fail criteria are dependant on surpassing a threshold.
Any amount above this threshold may not be accounted for.

Some plastics labeled as biodegradable only partially break down or require specific conditions, leaving microplastics or toxic residues behind.



MISCONCEPTION 4:

BIODEGRADABLE PRODUCTS WILL BREAK DOWN QUICKLY IN ANY ENVIRONMENT

Reality: The rate of biodegradation depends on factors like **temperature, moisture, and oxygen levels**. Biodegradable products may not break down quickly in landfills due to lack of oxygen or ideal conditions.



TYPICAL BIODEGRADABILITY STANDARDS

Environment	Teststandard	Temperature	>90% time limit	Typical Danish conditions
Industrial composting	EN 13432 /ISO 14855	50-70 °C	6 months	50-70 °C
Home composting	EN 13432 /ISO 14855	20-30 °C	12 months	8.5 °C
Soil	ISO 17556	20-25 °C	2 years	3-20 °C
Water	EN 14987 / OECD 301B	20-25 °C	56 days	5-20 °C
Marine	ISO 22403	28-32 °C	6 months	10 °C

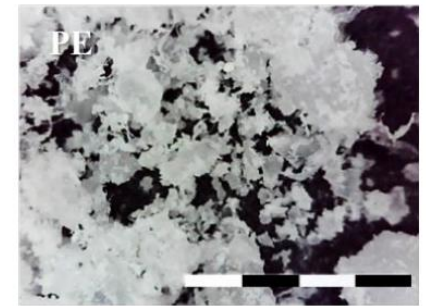
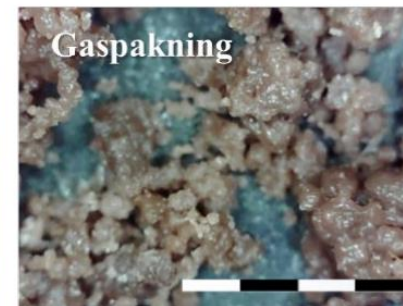
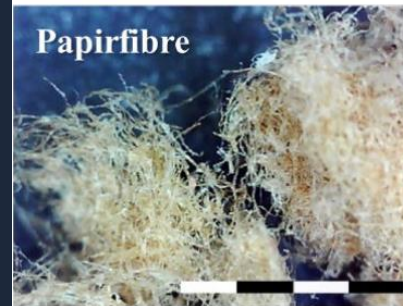
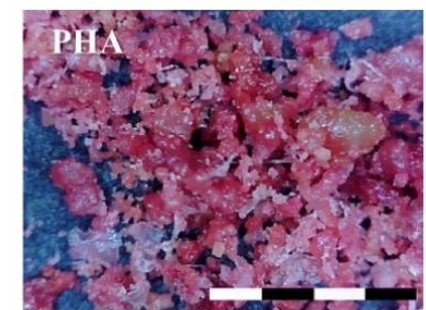
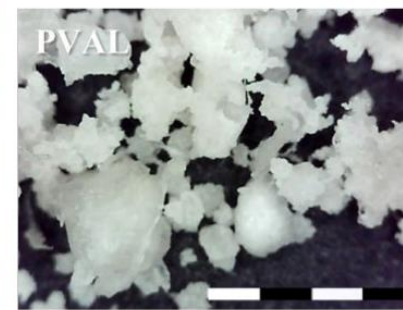
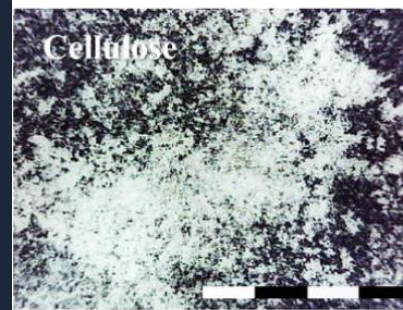


Standard	Titel
EN 13432:2006	Packaging – Requirements for packaging recoverable through composting and biodegradation – Test scheme and evaluation criteria for the final acceptance of packaging
EN 14987:2007	Plastics - Evaluation of disposability in waste water treatment plants - Test scheme for final acceptance and specifications
EN 17427	(Under udvikling) Packaging - Requirements and test scheme for carrier bags suitable for treatment in well-managed home composting installations
ISO 10210:2012	Plastics — Methods for the preparation of samples for biodegradation testing of plastic materials
ISO 13975:2019	Plastics — Determination of the ultimate anaerobic biodegradation of plastic materials in controlled slurry digestion systems — Method by measurement of biogas production
ISO 14851:2019	Determination of the ultimate aerobic biodegradability of plastic materials in an aqueous medium — Method by measuring the oxygen demand in a closed respirometer
ISO 20200:2015	Plastics — Determination of the degree of disintegration of plastic materials under simulated composting conditions in a laboratory-scale test
ISO 22403:2020	Plastics — Assessment of the intrinsic biodegradability of materials exposed to marine inocula under mesophilic aerobic laboratory conditions — Test methods and requirements
ISO 22404:2019	Plastics — Determination of the aerobic biodegradation of non-floating materials exposed to marine sediment — Method by analysis of evolved carbon dioxide
ISO 22766:2020	Plastics — Determination of the degree of disintegration of plastic materials in marine habitats under real field conditions

ISO 14852:2019	Determination of the ultimate aerobic biodegradability of plastic materials in an aqueous medium — Method by analysis of evolved carbon dioxide
ISO 14855:1999	Determination of the ultimate aerobic biodegradability and disintegration of plastic materials under controlled composting conditions – Method by analysis of evolved carbon dioxide
ISO 14855-1:2012	Part 1: General method
ISO 14855-2:2018	Part 2: Gravimetric measurement of carbon dioxide evolved in a laboratory-scale test
ISO 15985:2014	Plastics — Determination of the ultimate anaerobic biodegradation under high-solids anaerobic-digestion conditions — Method by analysis of released biogas
ISO 16929:2020	Plastics — Determination of the degree of disintegration of plastic materials under defined composting conditions in a pilot-scale test
ISO 17088:2012	Specifications for compostable plastics
ISO 17556:2019	Plastics - Determination of the ultimate aerobic biodegradability of plastic materials in soil by measuring the oxygen demand in a respirometer or the amount of carbon dioxide evolved
ISO 18830:2016	Plastics — Determination of aerobic biodegradation of non-floating plastic materials in a seawater/sandy sediment interface — Method by measuring the oxygen demand in closed respirometer
ISO 19679:2020	Plastics — Determination of the aerobic biodegradation of non-floating materials exposed to marine sediment — Method by analysis of evolved carbon dioxide
ISO 23977-1:2020	Plastics — Determination of the aerobic biodegradation of plastic materials exposed to seawater — Part 1: Method by analysis of evolved carbon dioxide
ISO 23977-2:2020	Plastics — Determination of the aerobic biodegradation of plastic materials exposed to seawater — Part 2: Method by measuring the oxygen demand in closed respirometer



HUNTING WADS TEMPERATURE CASE STUDY

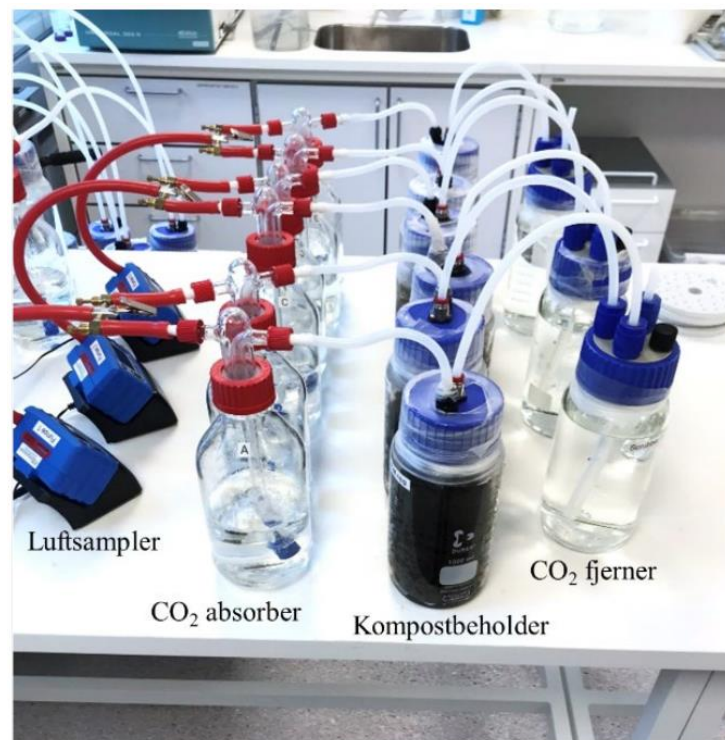
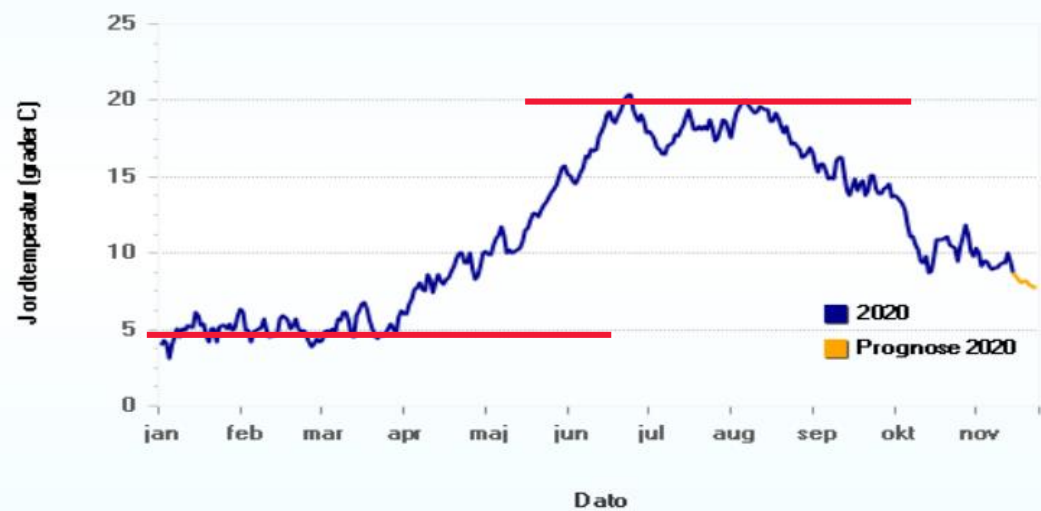


Link to report (Danish)

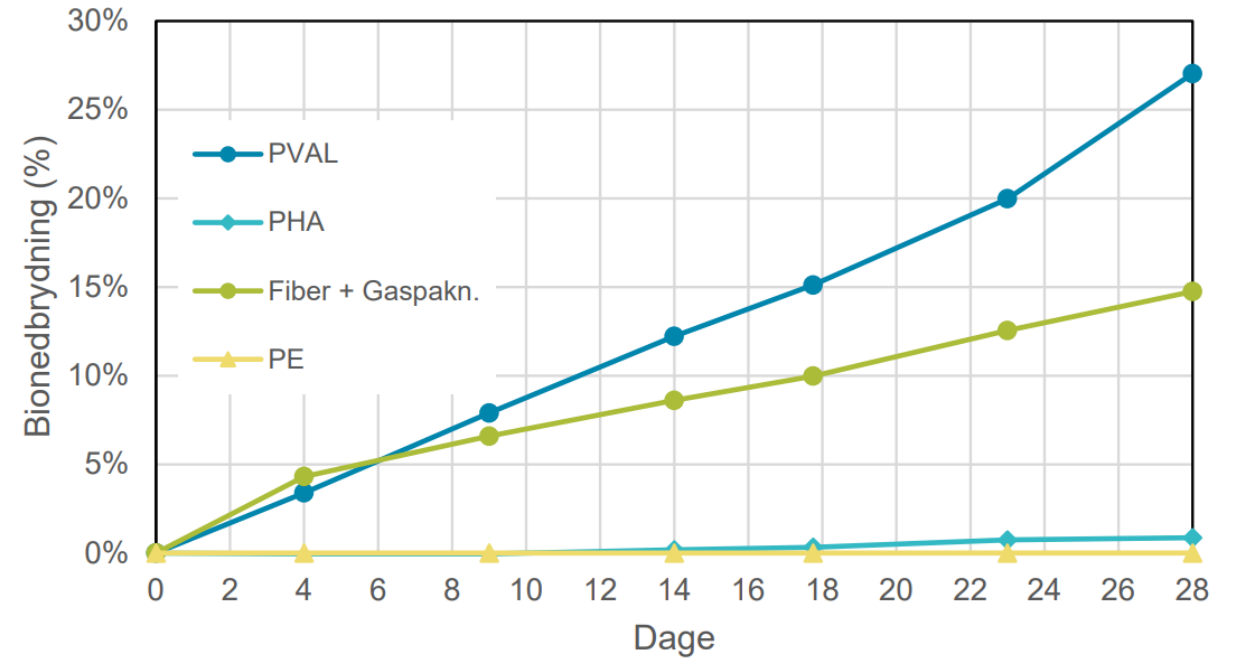
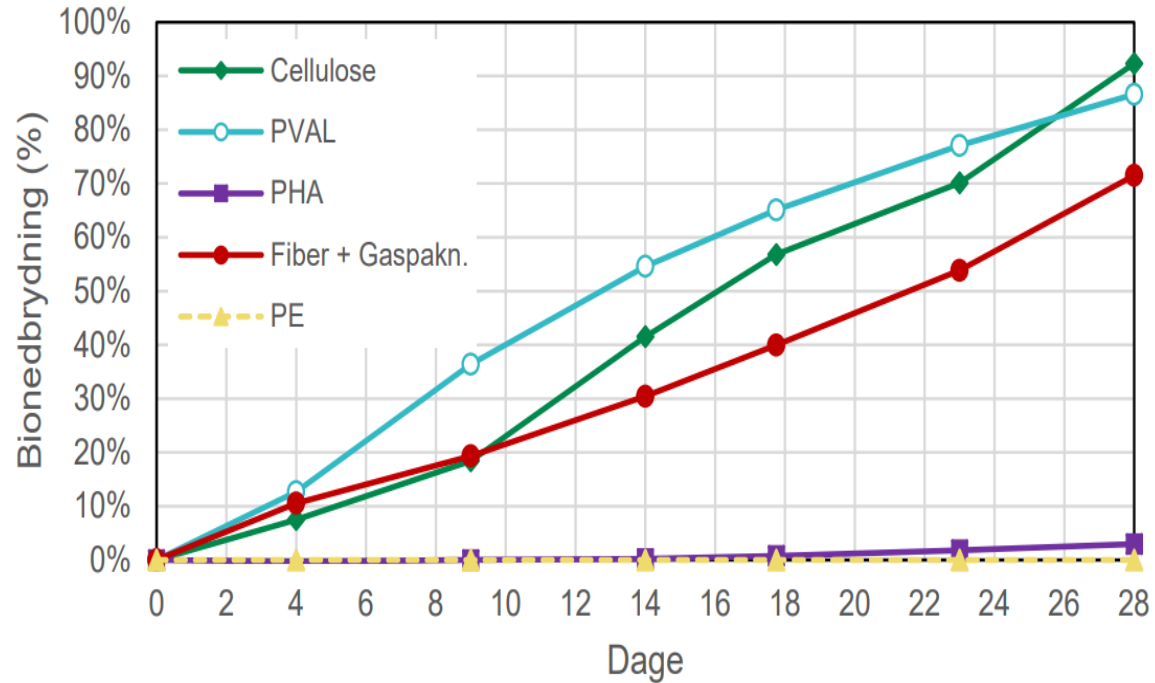
<https://mst.dk/service/publikationer/publikationsarkiv/2021/mar/kortlaegning-af-markedet-for-bionedbrydelige-haglskaale/>



Jordtemperatur - Ballerup (2750)



REDUCED BIODEGRADABILITY AT LOWER TEMPERATURE





TEKNOLOGISK
INSTITUT

QUESTIONS AND INQUIRIES CAN BE DIRECTED TO



Nicolaj Ma, MSc
nima@teknologisk.dk
+45 72202396
Bioresources



Anna-Catharina Röper, PhD
annr@teknologisk.dk
+45 72203421
Bioresources