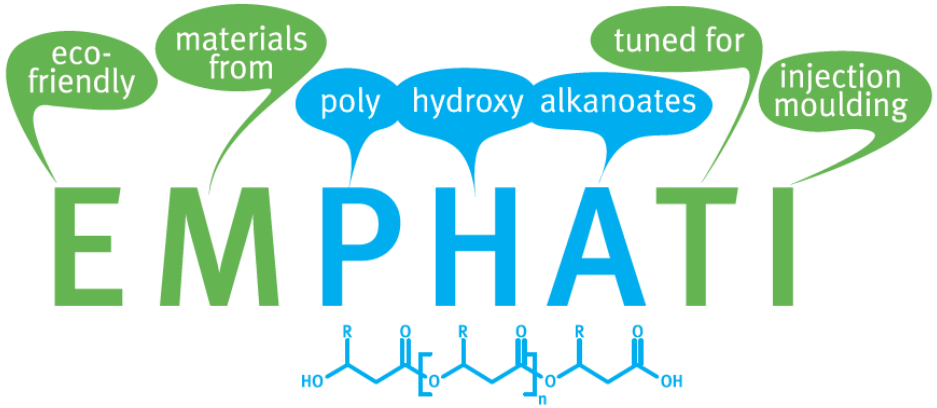
From Raw Material to industry:
Challenges and Optimization Loops in PHA Compounding



Interreg
Deutschland – Nederland
EMPHATI

Interreg
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EMPHATI

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Partner

H&P Moulding Emmen
bekuplast
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HSB
AG Biologische Werkstoffe
Fakultät 5 / Bionik
Hochschule Bremen
NHL STENDEN university of applied sciences
TKT KUNSTSTOFF-TECHNIK
ecoras
Kompetenzzentrum Niedersachsen · Netzwerk Nachwachsende Rohstoffe und Bioökonomie e.V. 3N

Assoziiert

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BINDER|3D
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Projekt 11080 EMPHATI

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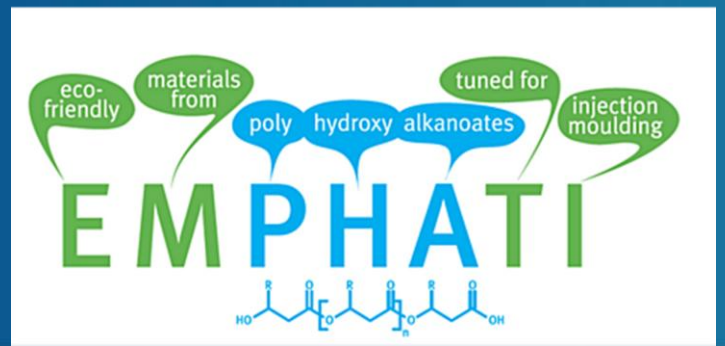
euregio
rhein-maas-nord rijn-maas-noord

From Raw Material to industry: Challenges and Optimization Loops in PHA Compounding

Raja Bade[1] & Andreas Hellmann[2]

[1] The Biological Materials Group, Hochschule Bremen - HSB - City University of Applied Sciences Bremen, Germany

[2] 3N Kompetenzzentrum, Werlte







Aim of EMPHATI Project

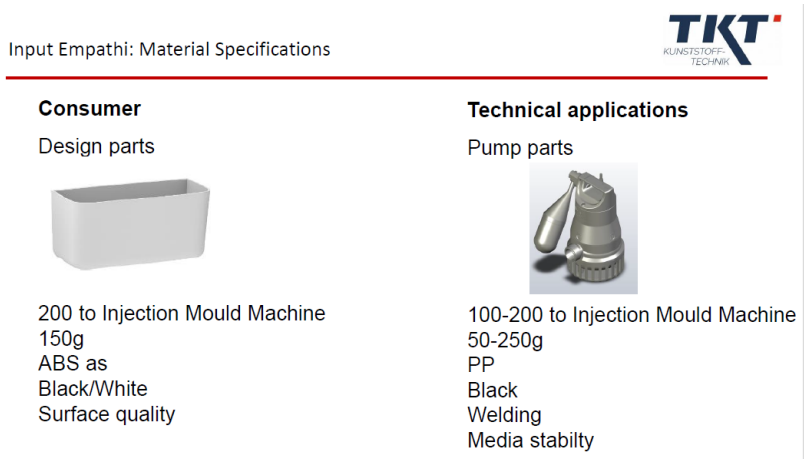
- **Injection mouldable compounds with PHA Polymer**

Bekuplast



(bekuplast, 2026)

TKT



H & P moulding



(Happy cups, 2026)

Aim of EMPHATI Project

Injection mouldable compounds with PHA Polymer

Bekuplast



(bekuplast, 2026)

PP

MFR	≥ 25 g/10 min
Tensile strength	≥ 20 MPa
Elongation at yield	≥ 5 %
Charpy notched	≥ 6 kJ/m²
Charpy unnotched	≥ 60 kJ/m²
Density	≥ 0,9-0,93 g/cm³

TKT





ABS Terluran GP22 | Karilen PP GF 30

MFR	≥ 19 & 3 g/10 min
Tensile strength	≥ 45 & 85 MPa
Elongation at yield	≥ 2,6 & 3,5 %
Charpy notched	≥ 22 & 11 kJ/m²
Charpy unnotched	≥ 180 & 50 kJ/m²

Polymer and fibres/biomass selection

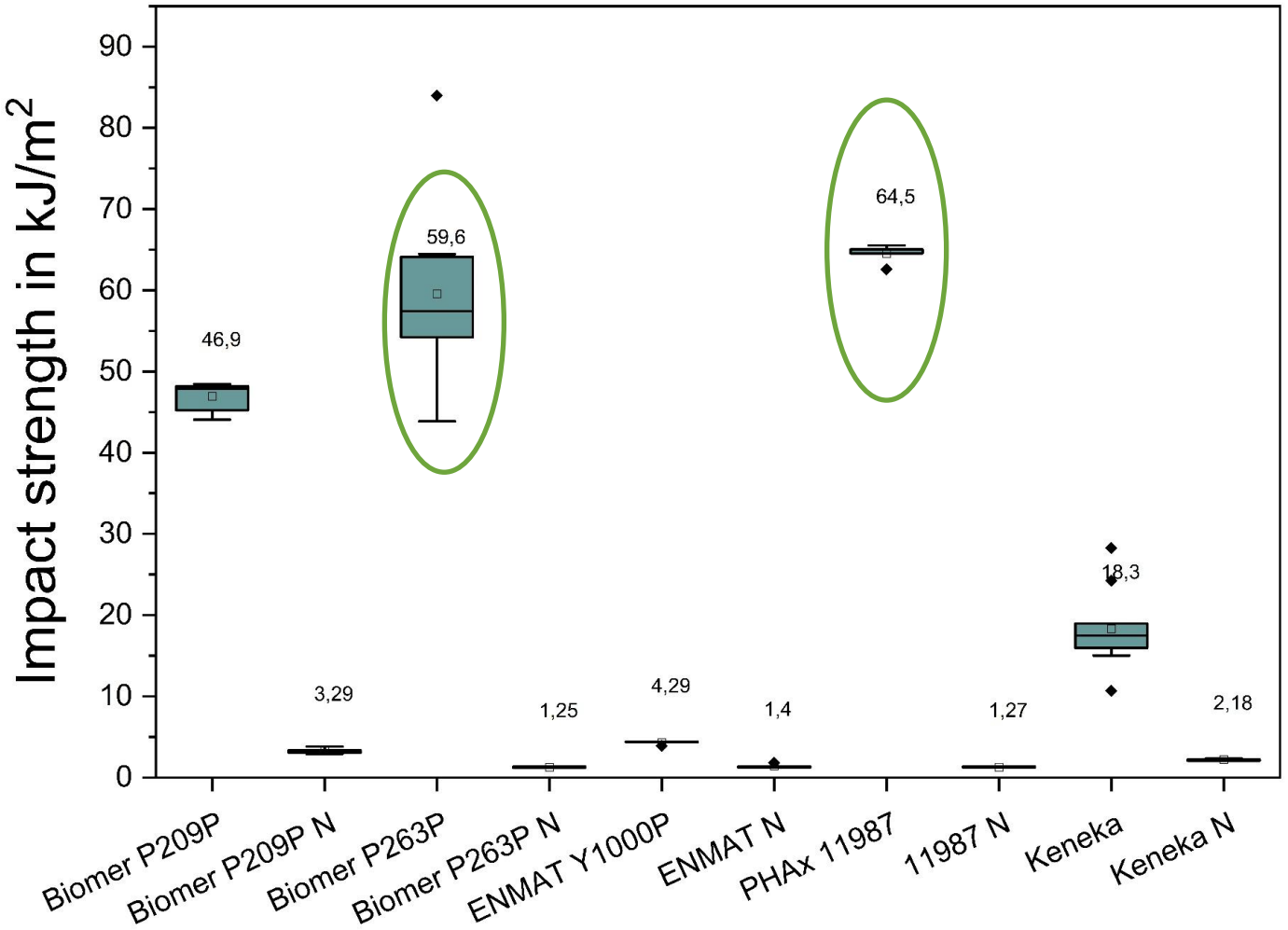
PHAs

- P3HB – Biomer P209P
- P3HB – Biomer P263P
- P3HB4HB – Helian PHAX 11987
- P3HB4HB – Helian PHAX 11284 MFT 10
- PHBV – ENMAT Y 1000P

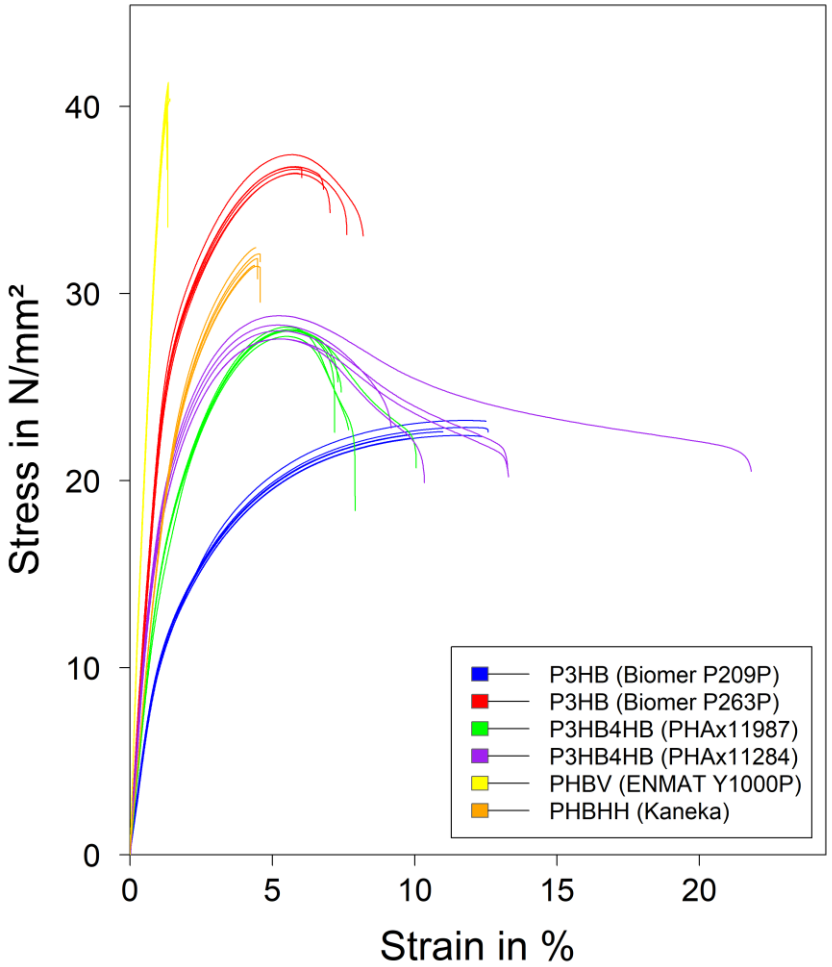
Fibre/biomass

- Cotton Comber Noil
- Comber wool
- German Wool Washed
- Hemp fibre
- Cordenka short fibres
- Arbocel BC200 (Wood fibres)
- Pea shell powder

Impact properties – Pure PHAs Unnotched & notched



Impact strength of the unnotched and notched selected PHAs



Stress-strain curves of the selected PHAs

Aim of EMPHATI Project

Injection mouldable compounds with PHA Polymer

Bekuplast



(bekuplast, 2026)

PP

MFR	≥ 25 g/10 min
Tensile strength	≥ 20 MPa
Elongation at yield	≥ 5 %
Charpy notched	≥ 6 kJ/m²
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TKT





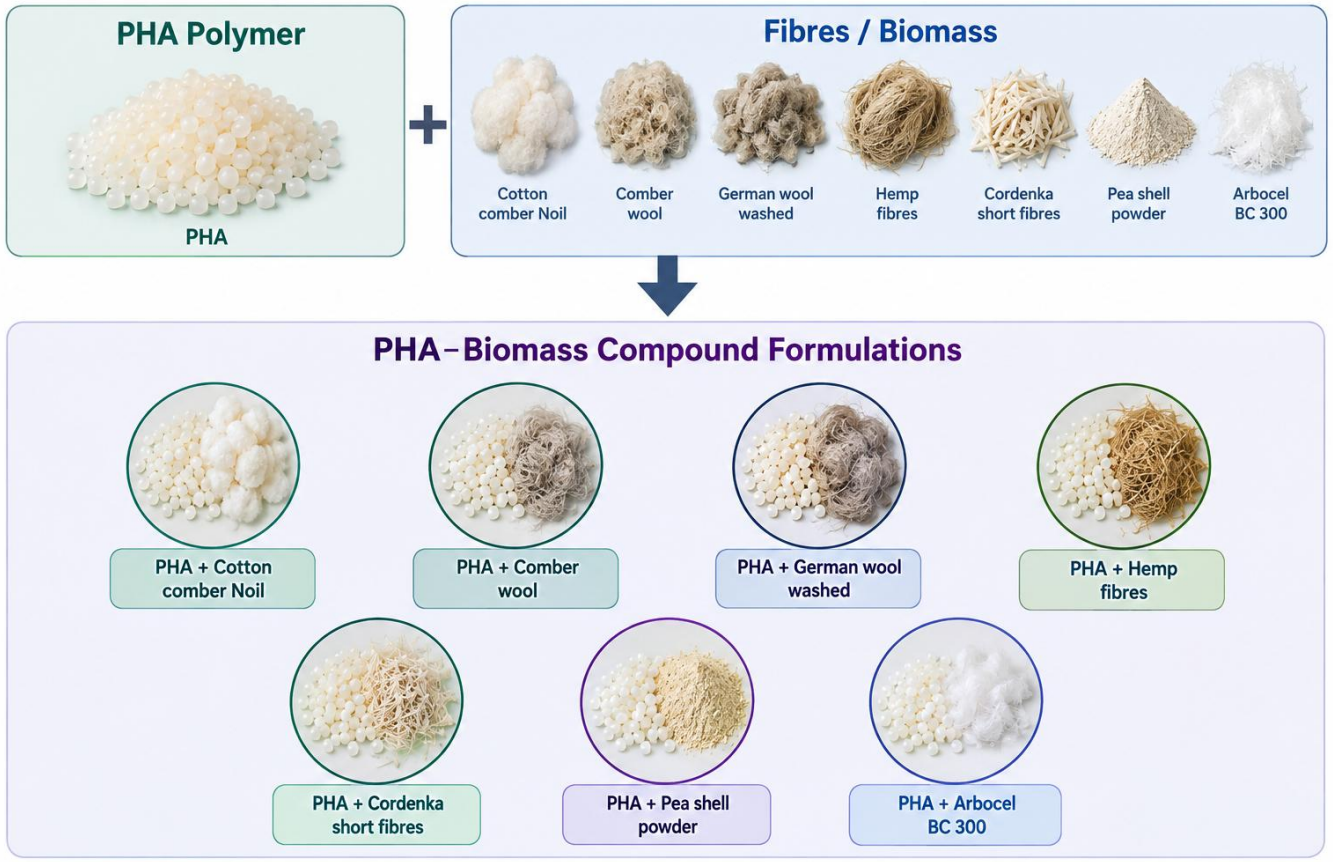
ABS Terluran GP22 — Karilen PP GF 30

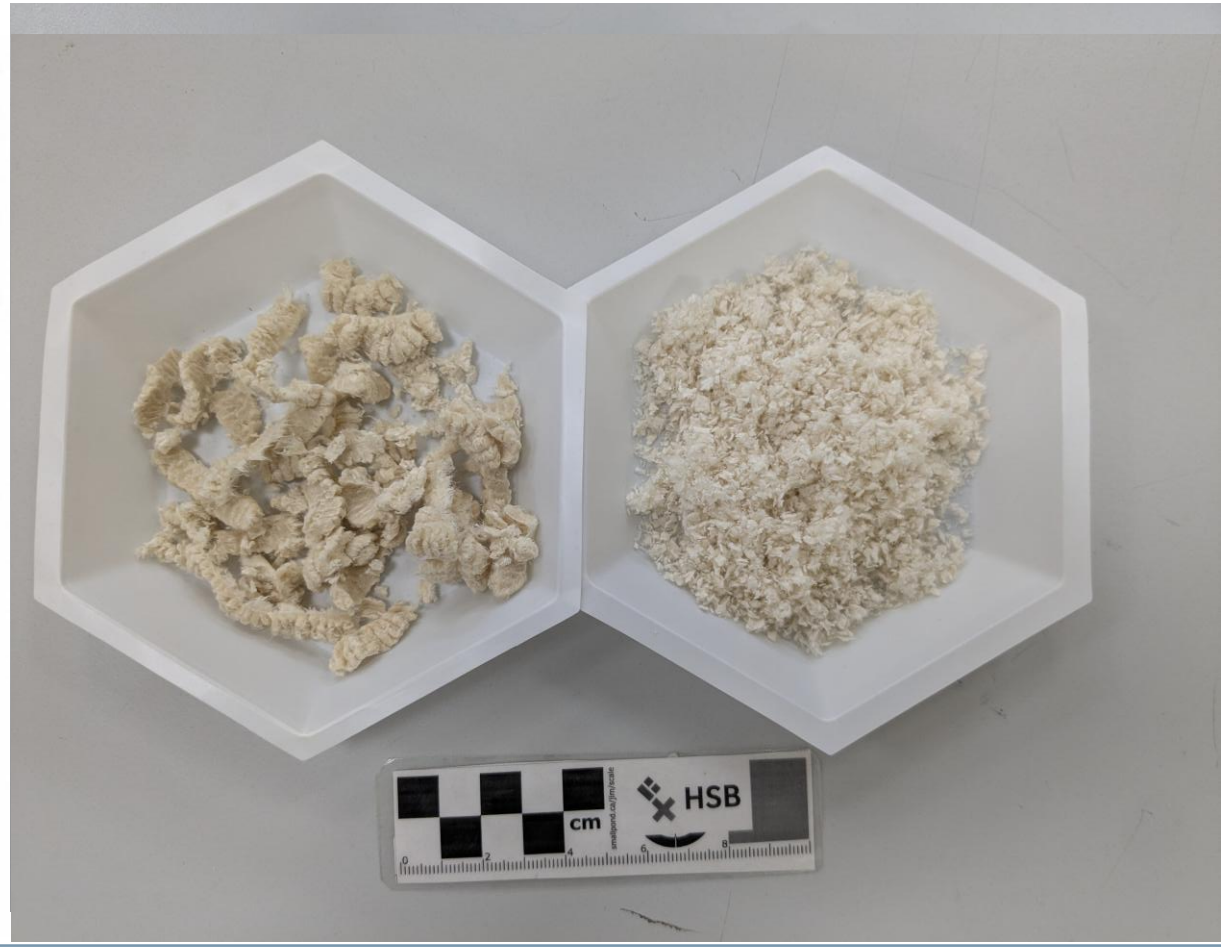
MFR	≥ 19 & 3 g/10 min
Tensile strength	≥ 45 & 85 MPa
Elongation at yield	≥ 2,6 & 3,5 %
Charpy notched	≥ 22 & 11 kJ/m²
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PHA Compound formulations

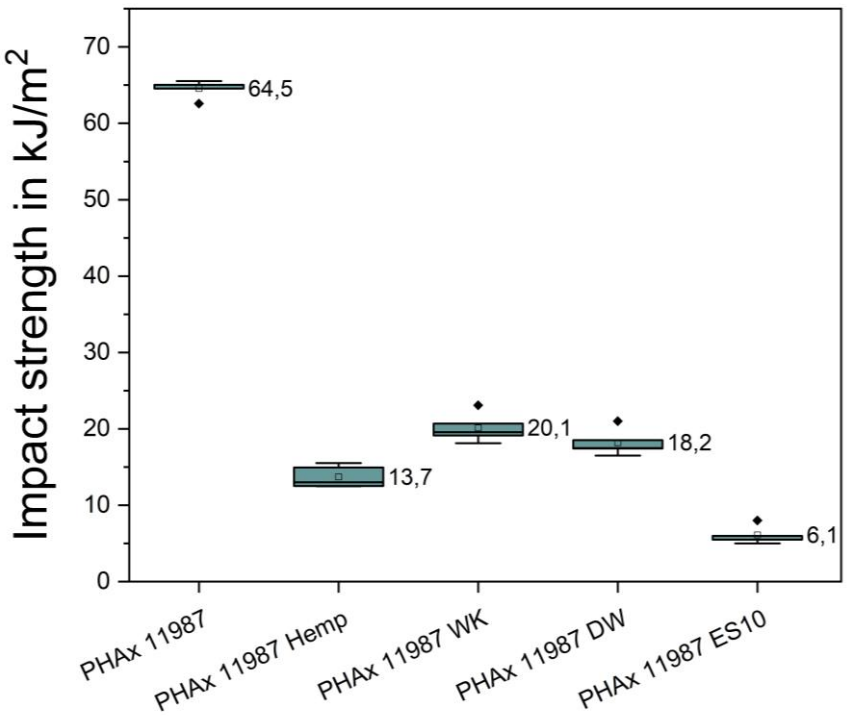
Economical aspect

Formulations were developed with 30 wt % of fibre & bio-mass to reduce price, to improve mechanical properties

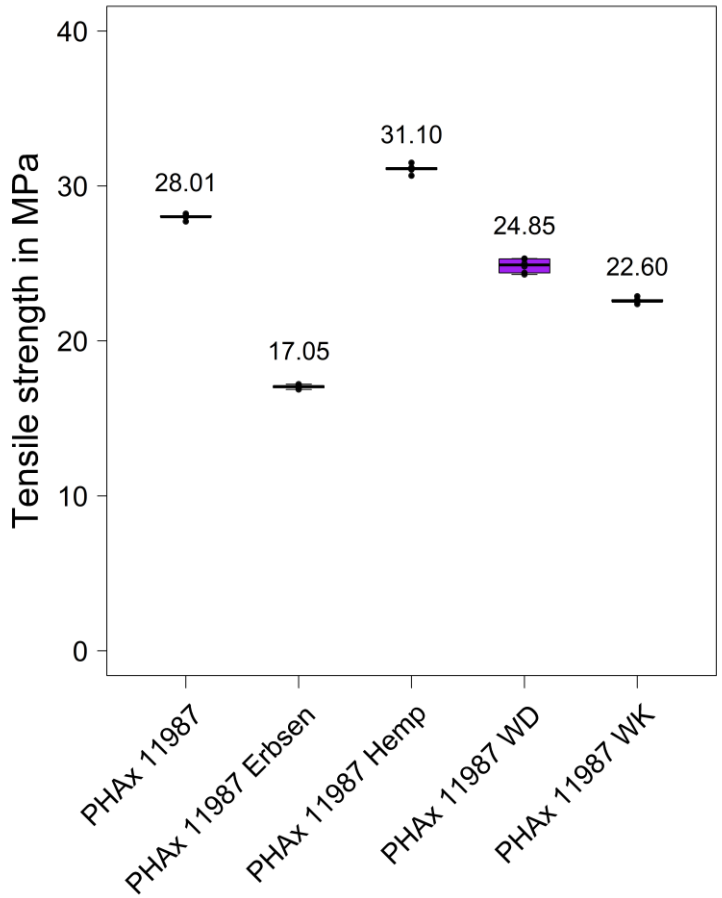




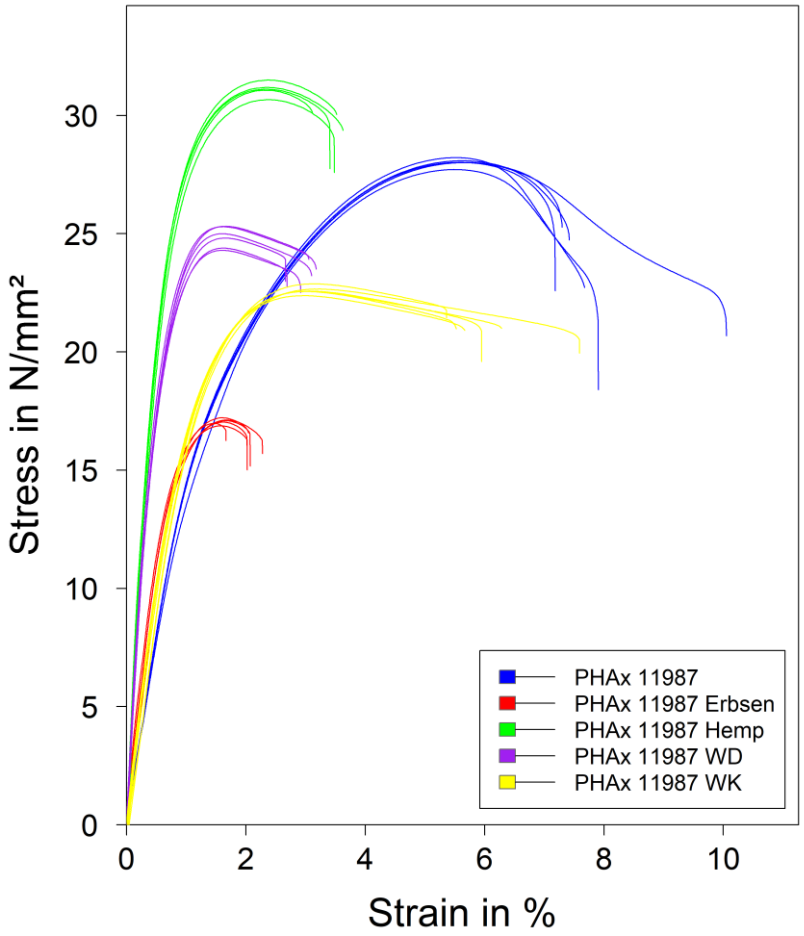
Impact properties – Pure PHAs Unnotched & notched



Impact strength of the unnotched PHA/blends



Tensile strength of the PHA/blends



Stress-strain curves of the PHA/blends

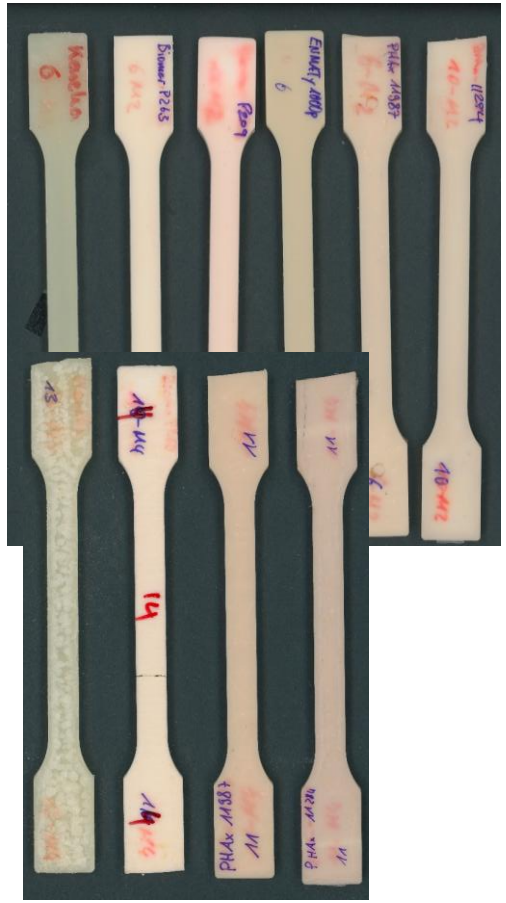
Outcomes of the initial Investigations

- Hemp & Pea shell compounds; better processability but brittle in nature.
- Cotton, Reg.Cellulose & wool fibre based compounds; poor processability.

Water ageing and UV weathering tests

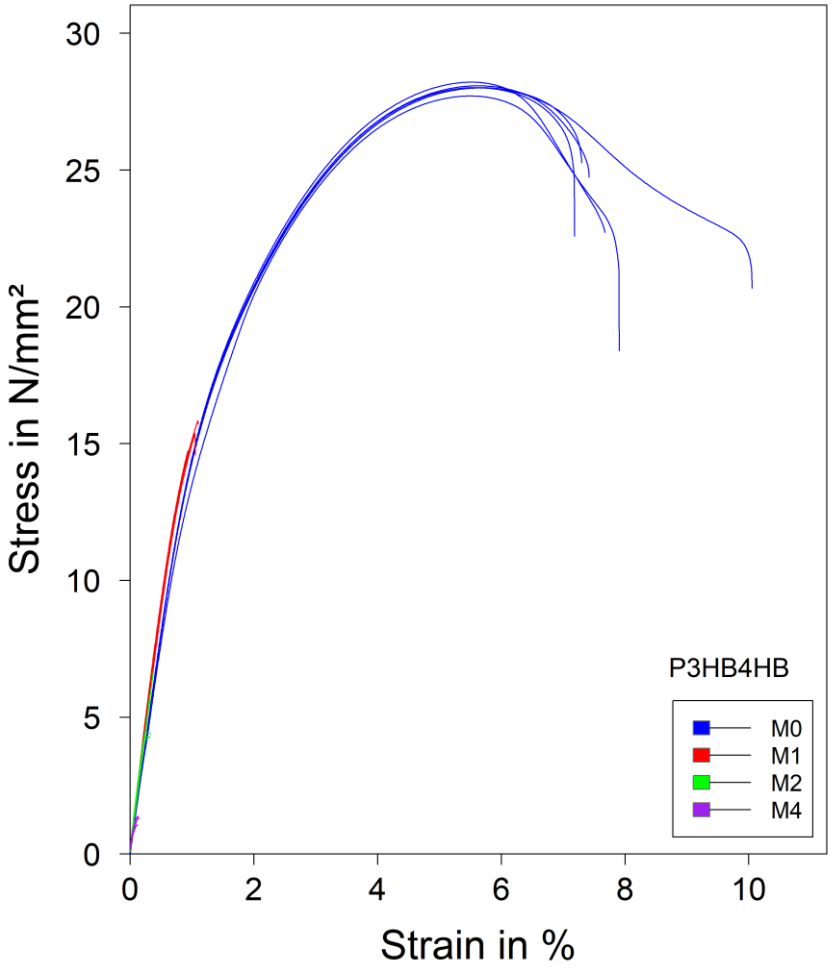
- Water ageing in distilled water at 50 °C - 1, 2, 3, 4, 6, and 12 months



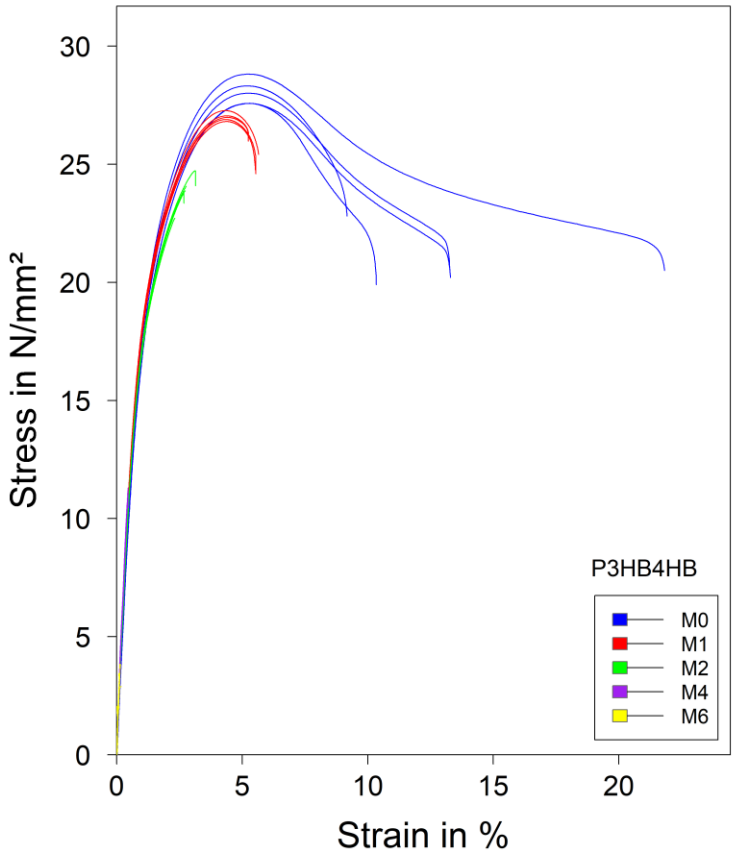




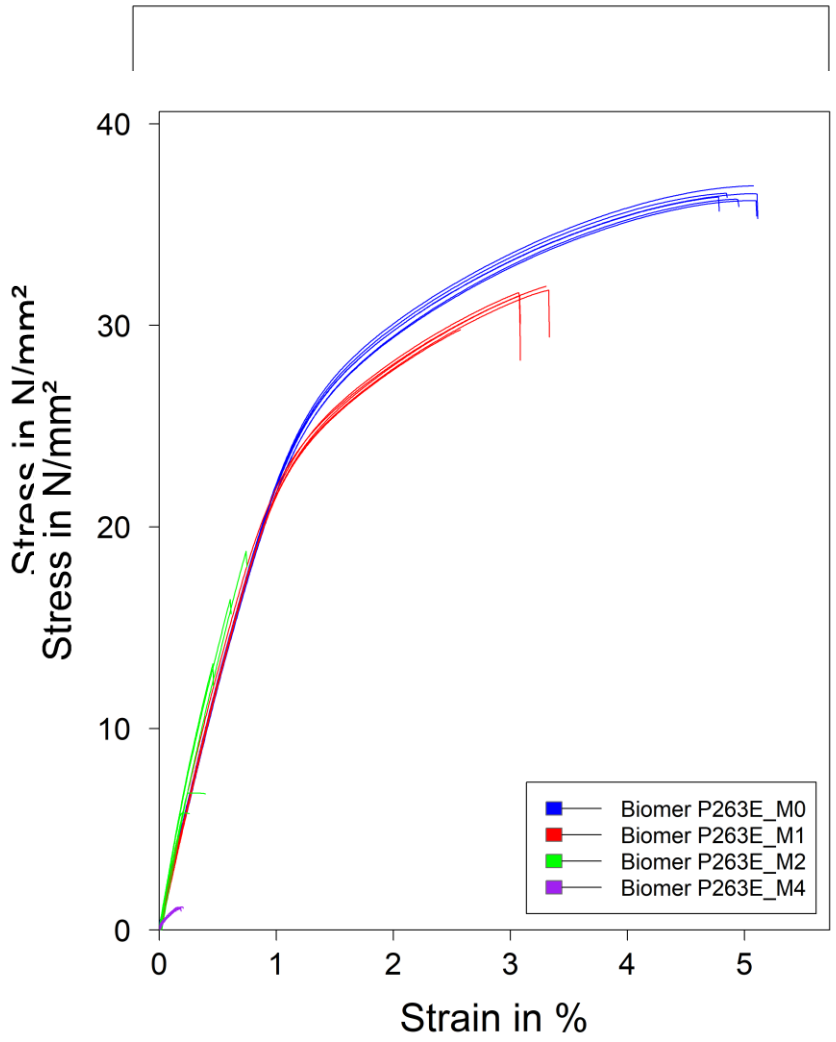
Water aged PHA



Stress-strain curves of the P3HB4HB

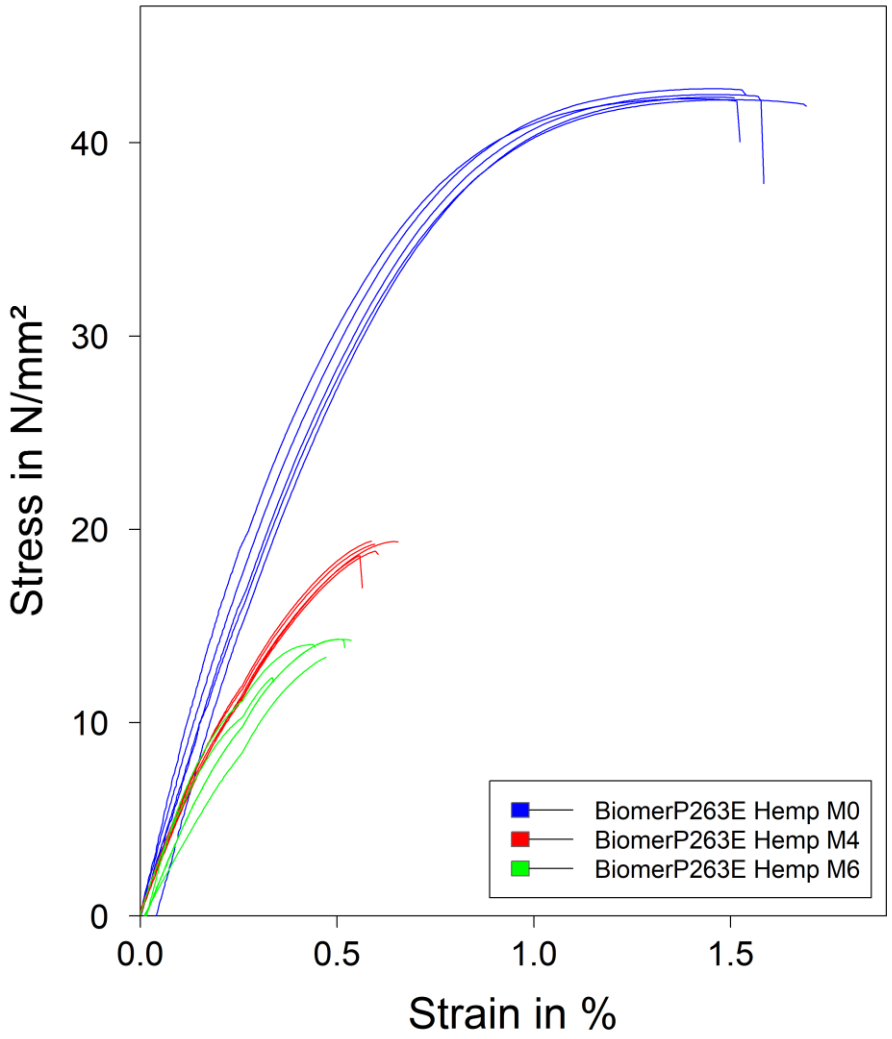


Stress-strain curves of the P3HB4HB with Mineral filler

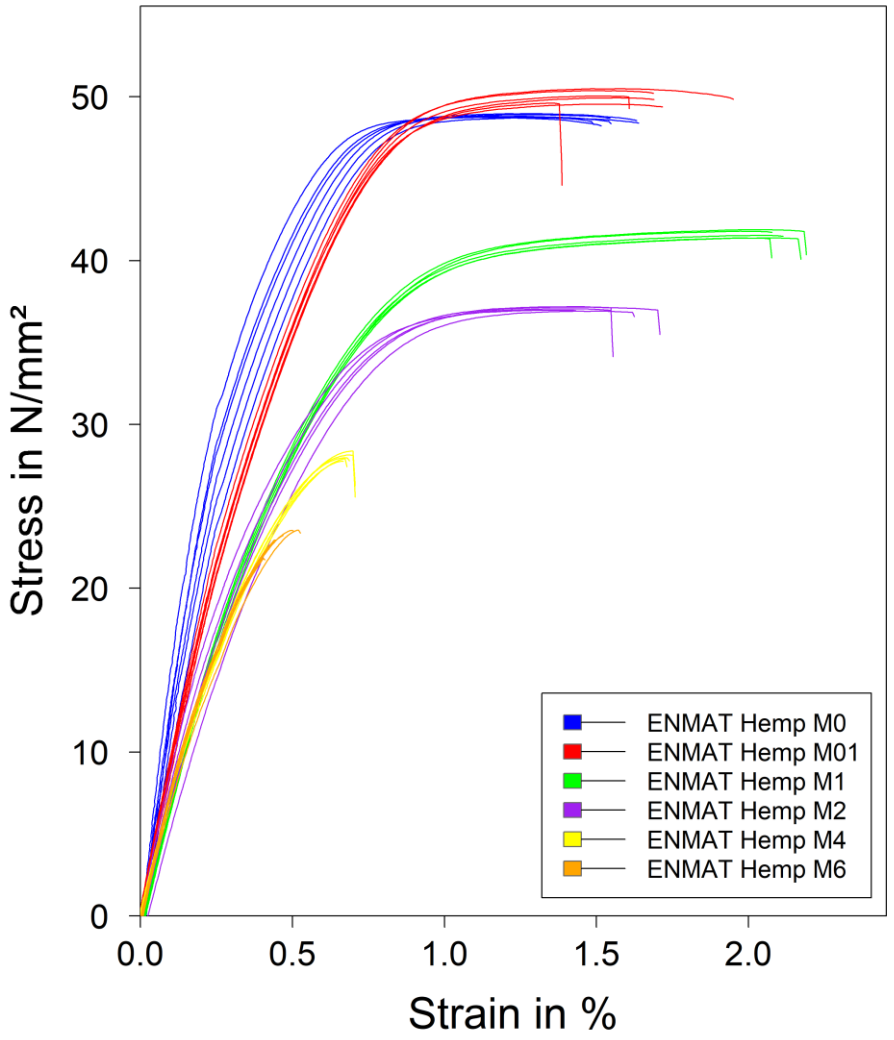


Stress-strain curves of the P3HB

Water aged PHA/hemp



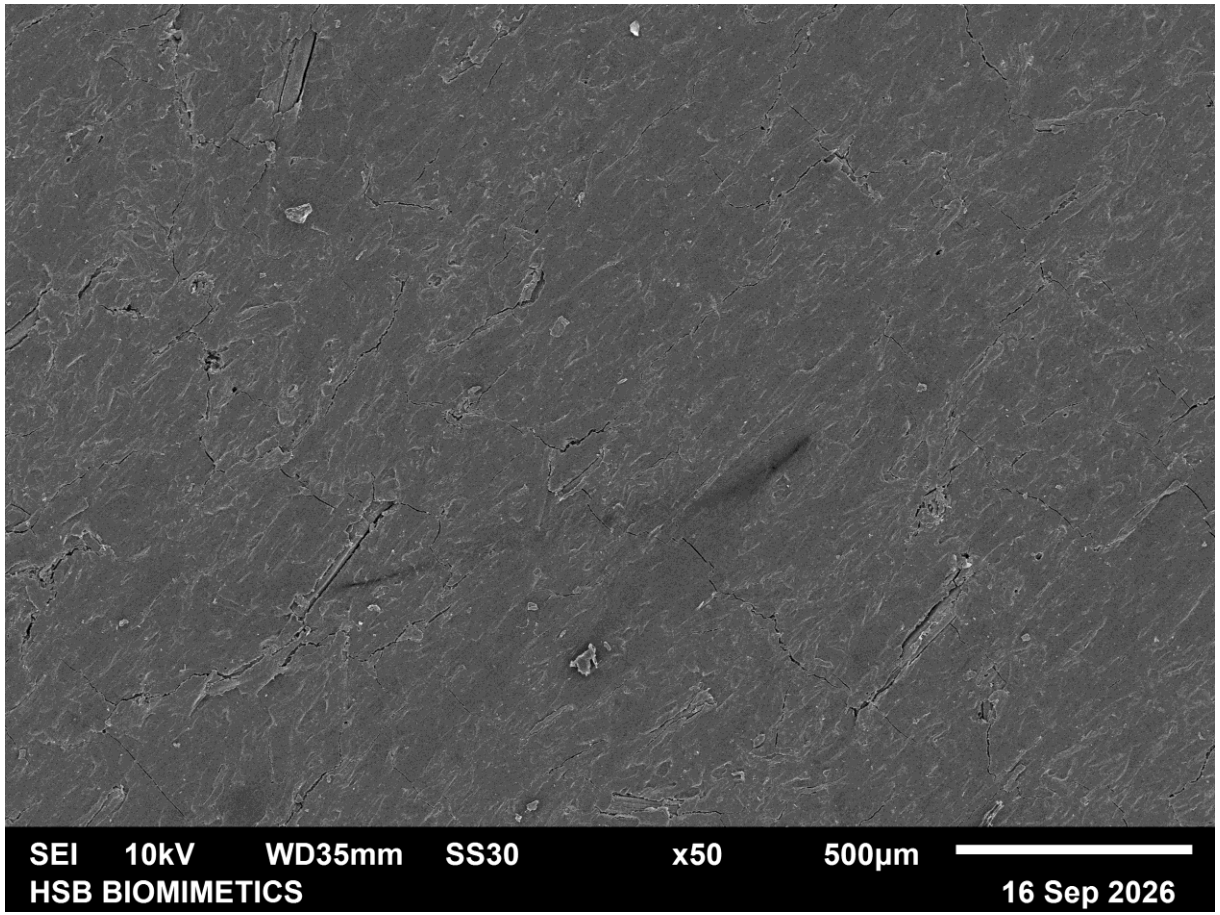
Stress-strain curves of the P3HB/hemp



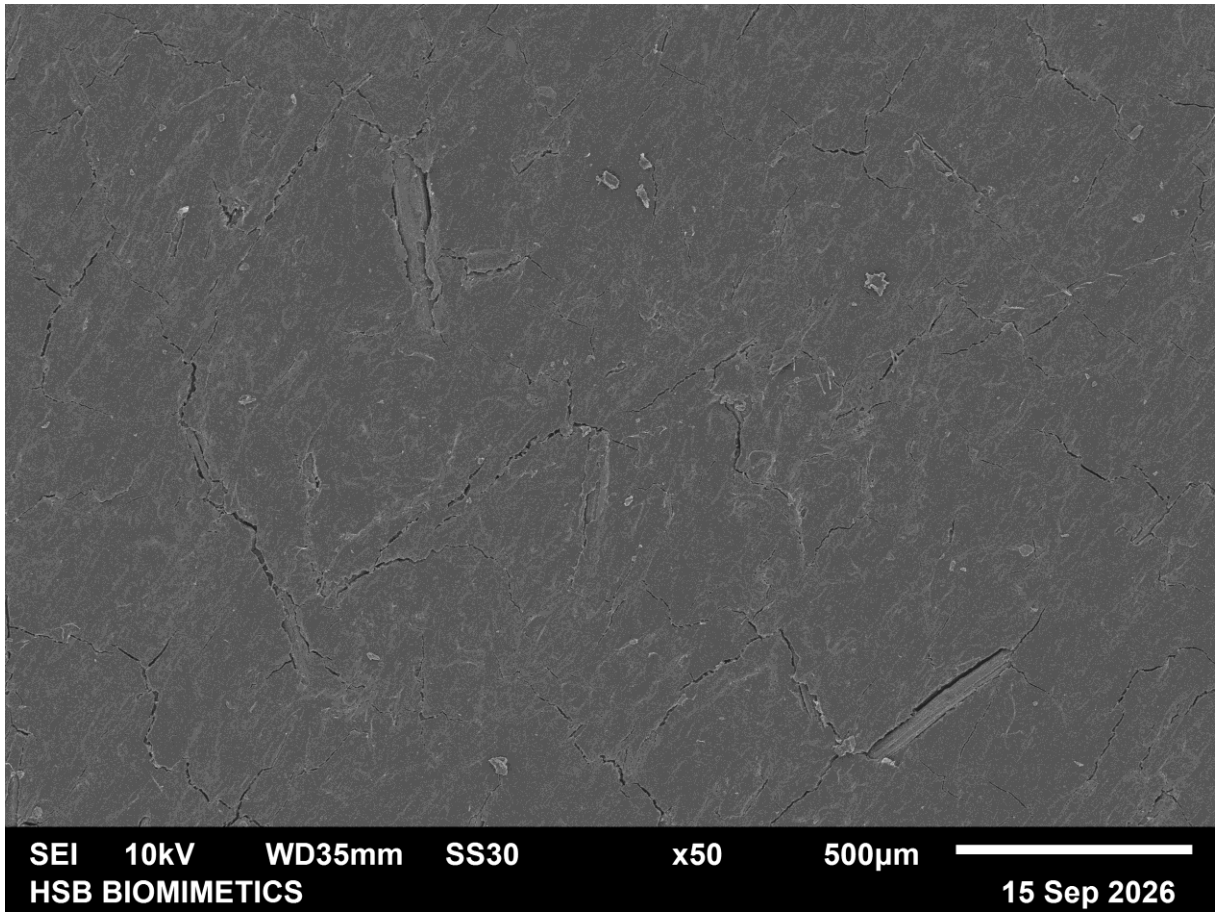
Stress-strain curves of the PHBV/hemp

UV weathering of PHA/hemp blends

- UV aged for 500 h using Xenon lamp

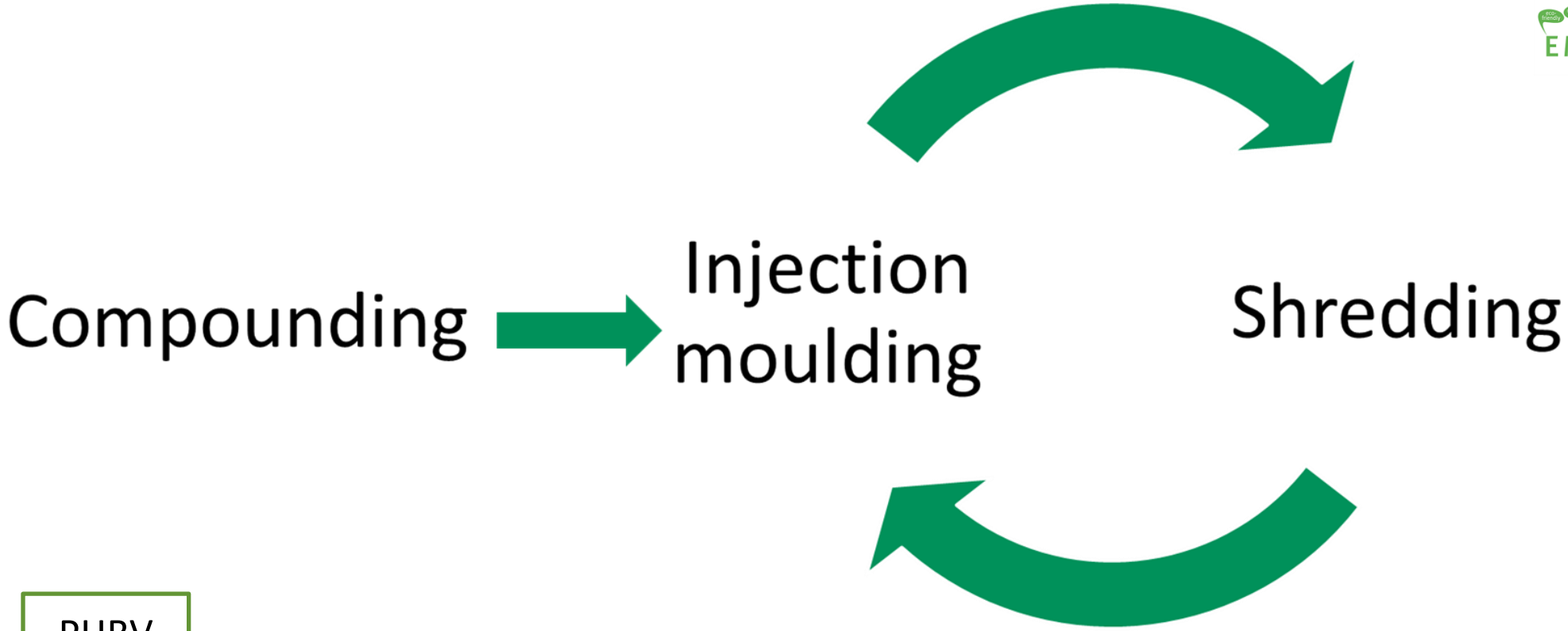


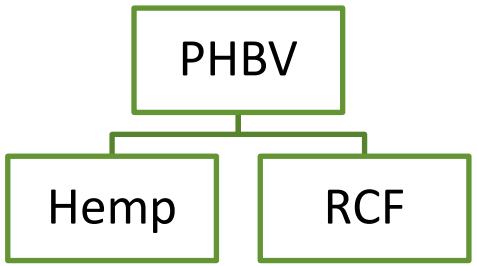
PHBV/hemp



P3HB4HB/hemp

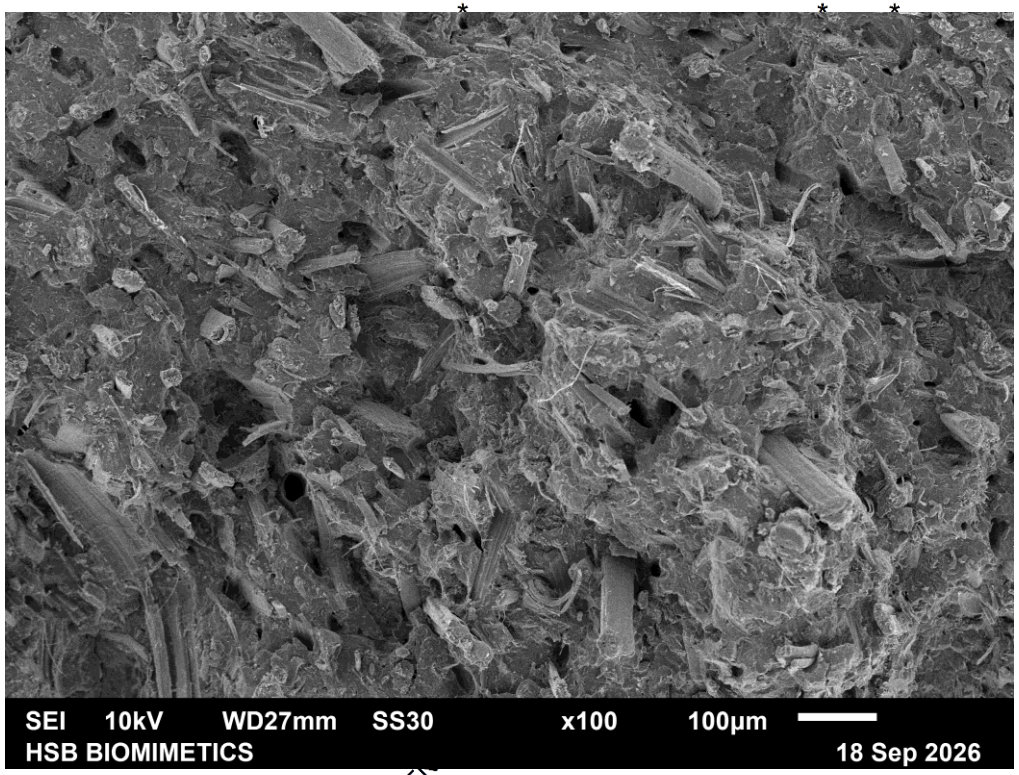
Reprocessing of PHBV composites



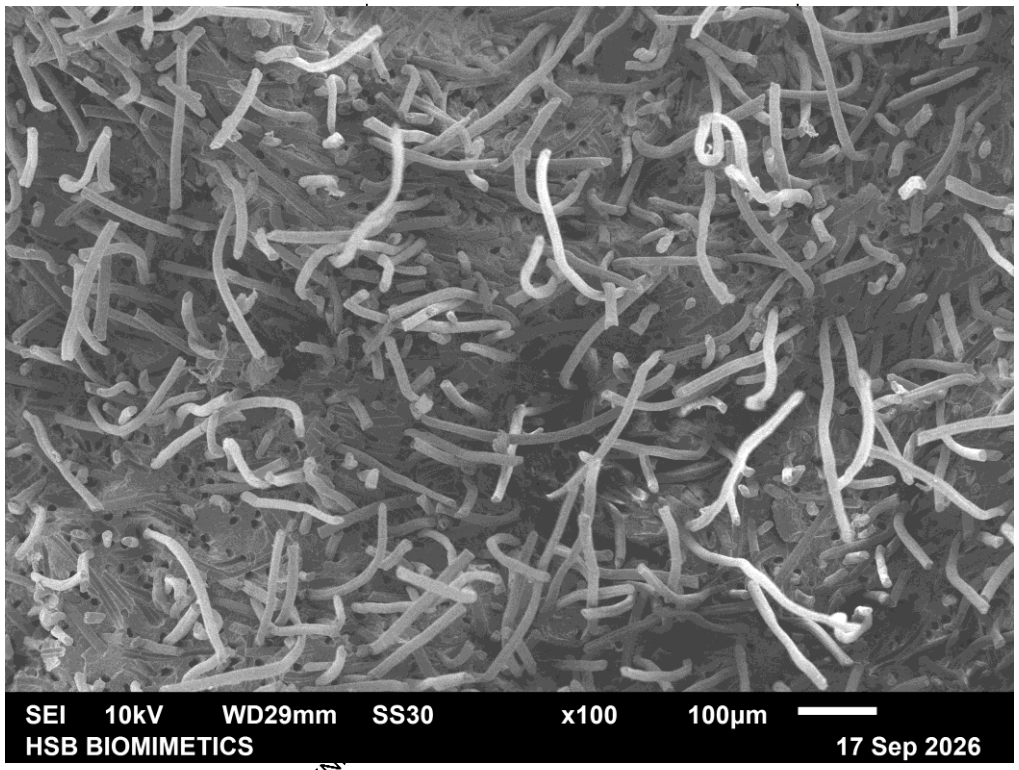


Reprocessing of PHBV composites

Impact test results - Unnotched



Impact strength of virgin PHBV (ENMAT Y 1000P) and PHBV/Hemp composites after multiple reprocessing cycles.



Impact strength of virgin PHBV (ENMAT Y 1000P) and PHBV/RCF composites after multiple reprocessing cycles.

HSB
Hochschule Bremen
City University of Applied Sciences

The Biological Materials Group
Fakulty 5 / Biomimetics
Hochschule Bremen

Thank You for Your Attention



M.Sc.
Raja BADE



Dr.-Ing.
Nina GRAUPNER

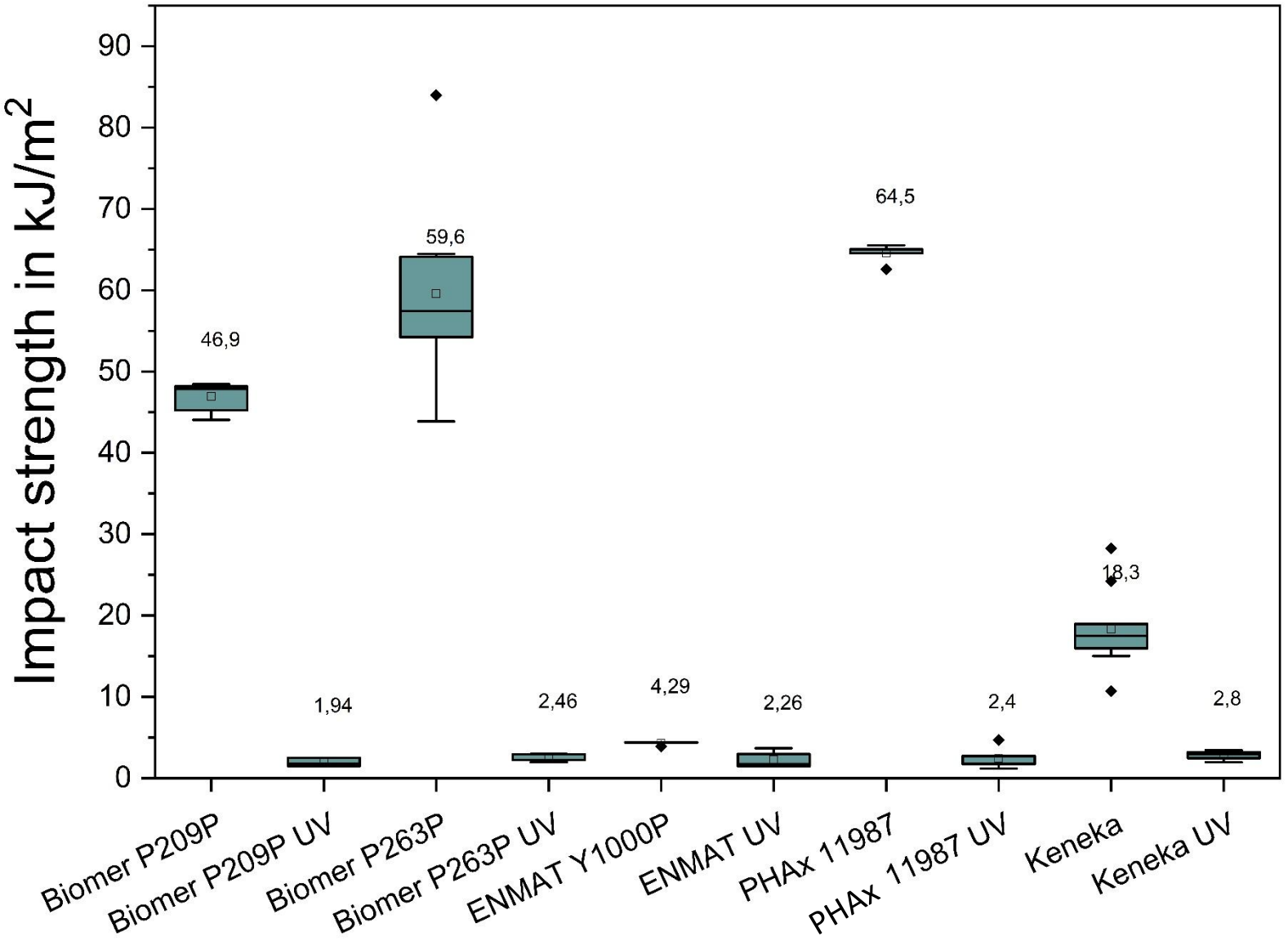


Prof. Dr.-Ing.
Jörg MÜSSIG



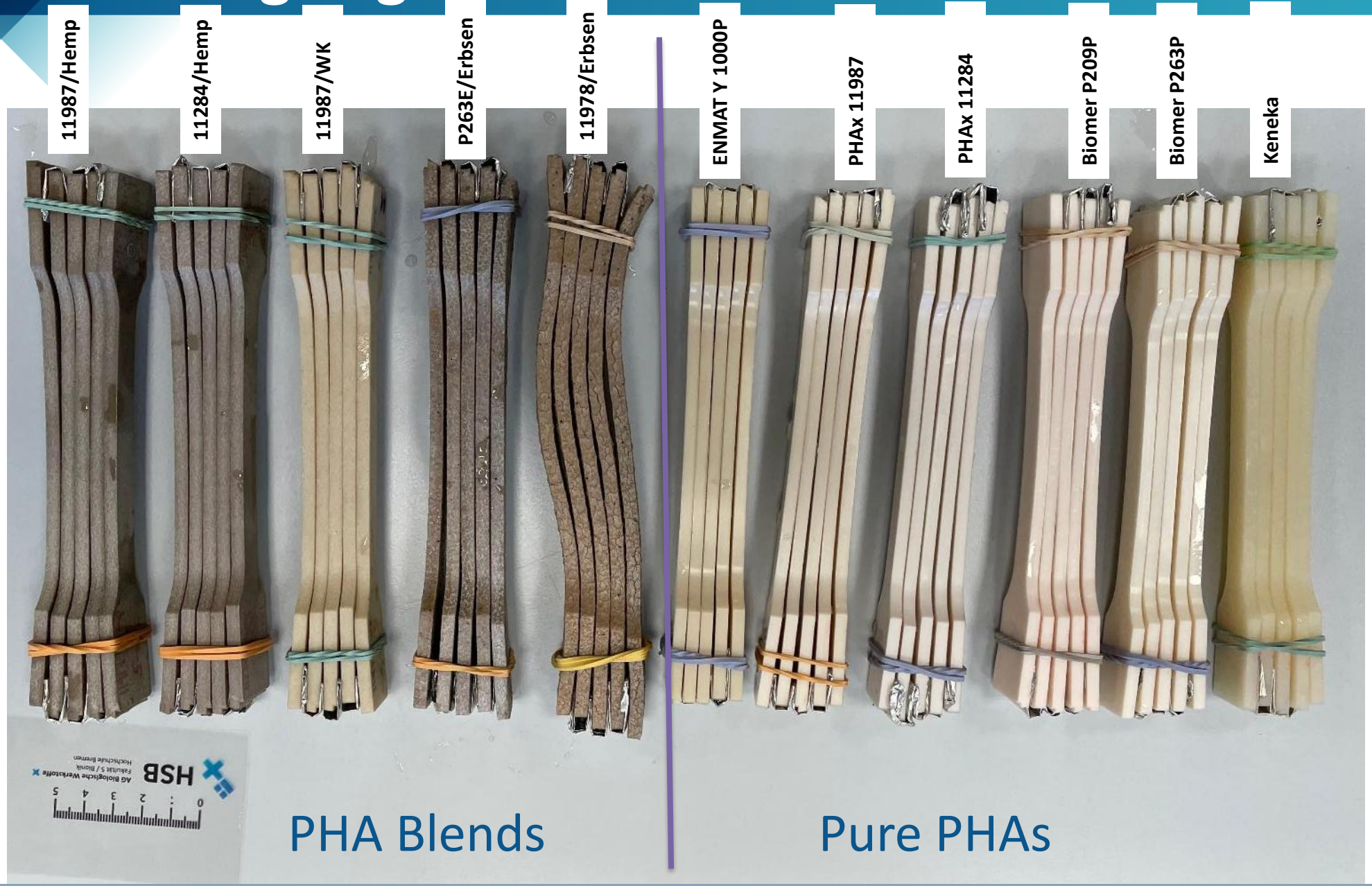
The Biological Materials Group
Department of Biomimetics
HSB – City University of Applied Sciences Bremen
Bremen, Germany
Internet: www.bionik-bremen.de

Impact properties – Pure PHAs: UV aged for 1000 Hours



- UV aged for 1000 h using Xenon lamp
- Probably no UV stabilisers in PHAs

Water ageing – PHAs & PHA Blends



Experimental Design II: Starting Point

- Previous industrial moulding trials were unsuccessful. The selected formulations did not meet the processing requirements of the injection moulding tools used by the industrial partners
- The main issue was insufficient demoulding performance
- Therefore, the objective was to improve the impact resistance of the formulations in order to support more reliable demoulding
- A new formulation screening plan was developed, including components with the potential to improve impact performance
- Biomer GmbH contributed its material and formulation expertise

Experimental Design II: Selection Criteria

- The total filler content was limited to 20 wt.% in order to avoid excessive stiffness and melt viscosity
- Performance-enhancing fillers were combined with commercially attractive, cost-efficient filler options
- Potential impact modifiers were selected and evaluated in a targeted manner
- The formulation window was designed to balance stiffness, processability, cost and impact performance.

Experimental Design: Raw Materials

Polymer

Biomer P263E

Suitable baseline properties
and
good compoundability

Filler

Talc
Chalk (Calcium Carbonate)
Pea fibre

Commercial relevance
and
processability

Modifier

Viscose fibre
Vinyl Acetate
Finely ground birch bark

Target:
Improved impact strength

Experimental Design Matrix and Test Procedure

Fifteen PHA compound formulations were prepared and evaluated

No.	Polymer Biomer P263E	Filler			Impact Modifier		
		Pea fibre	Talc	Chalk	Birch bark	Viscose fibre	Vinyl acetate
1	80	-	15	-	-	5	-
2	75	-	15	-	-	5	5
3	80	-	20	-	-	-	-
4	75	-	-	20	-	-	-
5	80	-	20	-	-	-	5
6	75	-	10	10	-	-	-
7	80	-	-	15	5	-	-
8	75	15	-	-	-	5	5
9	80	-	10	10	-	-	5
10	75	-	-	20	-	-	5
11	75	15	-	-	5	-	-
12	75	20	-	-	-	-	5
13	80	15	-	-	5	-	5
14	75	5	15	-	-	-	5
15	80	5	15	-	-	-	-

Pea fibre: Empet ES B10, Emsland Group

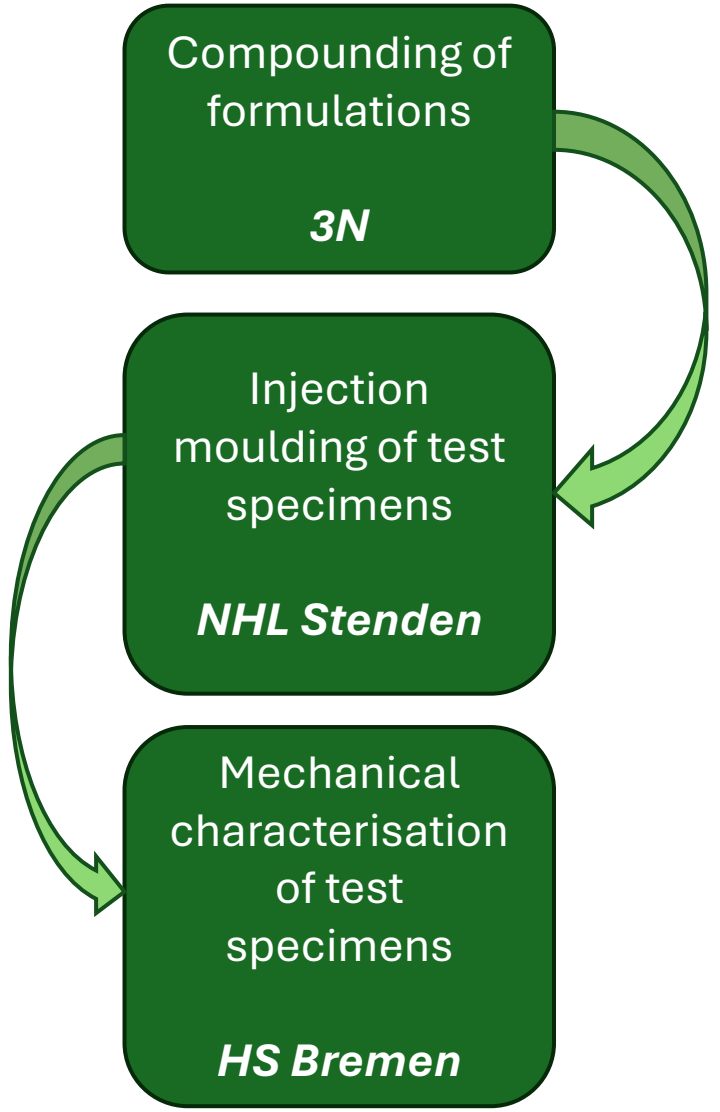
Talc: HB M10B, Prechel GmbH

Chalk: Calcit SH easyflow, SH Minerals

Birch bark: Finely ground birch bark, Holzmühle Westerkamp

Viscose fibre: Rayon staple fibre, 2mm

Vinyl acetate copolymer: Vinnex 2504, Wacker Chemie



Mechanical Properties of the Screened Formulations

No.	Polymer Biomer P263E	Filler			Impact modifier			Mechanical properties			
		Pea fibre	Talc	Chalk	Birch bark	Viscose fibre	Vinyl acetate	Tensile modulus (MPa)	Tensile strength (MPa)	Elongation at break (%)	Unnotched impact strength (kJ/m^2)
1	80	-	15	-	-	5	-	4.030	35,7	4,3	17,7
2	75	-	15	-	-	5	5	3.750	34,9	4,5	17,9
3	80	-	20	-	-	-	-	3.450	34,6	3,1	20,6
4	75	-	-	20	-	-	-	2.870	28,6	4,0	15,9
5	80	-	20	-	-	-	5	3.400	32,3	3,3	19,9
6	75	-	10	10	-	-	-	3.200	31,6	4,1	15,5
7	80	-	-	15	5	-	-	2.300	26,1	3,4	13,7
8	75	15	-	-	-	5	5	2.800	27,8	2,3	9,1
9	80	-	10	10	-	-	5	2.950	30	4,5	14,7
10	75	-	-	20	-	-	5	2.650	28	3,1	13,1
11	75	15	-	-	5	-	-	2.500	23,5	1,5	6,7
12	75	20	-	-	-	-	5	2.630	26,9	1,8	6,1
13	80	15	-	-	5	-	5	2.200	24,3	2,1	8,7
14	75	5	15	-	-	-	5	3.140	31,1	2,4	8,4
15	80	5	15	-	-	-	-	3.700	32,6	2,2	7,7

Analysis: Effect of Talc-Containing Formulations

Filtered by Tensile strength

Filler			Impact modifier			Mechanical properties			
pea fibre	Talc	Chalk	Birch bark	Viscose fibre	Vinyl acetate	Tensile Modulus (MPa)	Tensile Strength (MPa)	Elongation at break (%)	Impact Strength (kJ/m^2)
-	15	-	-	5	-	4.030	35,7	4,3	17,7
-	15	-	-	5	5	3.750	34,9	4,5	17,9
-	20	-	-	-	-	3.450	34,6	3,1	20,6
5	15	-	-	-	-	3.700	32,6	2,2	7,7

Filtered by Elongation at break

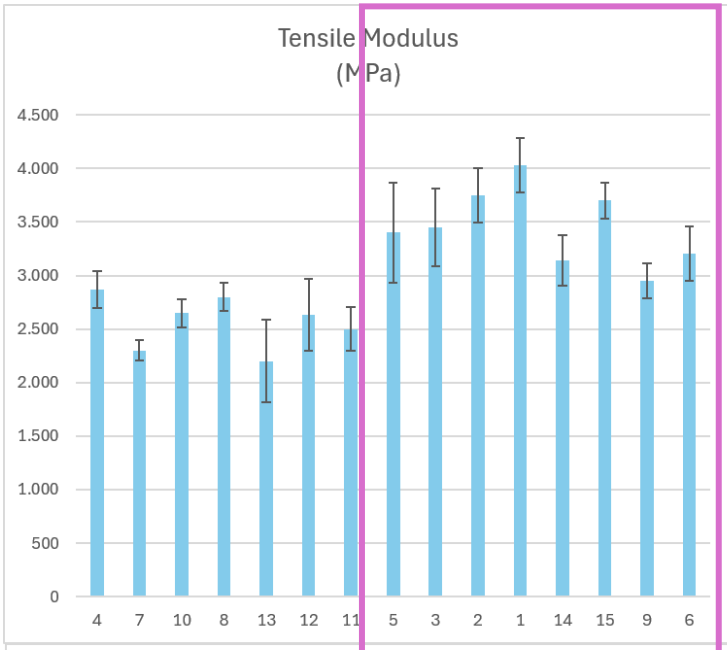
Filler			Impact modifier			Mechanical properties			
pea fibre	Talc	Chalk	Birch bark	Viscose fibre	Vinyl acetate	Tensile Modulus (MPa)	Tensile Strength (MPa)	Elongation at break (%)	Impact Strength (kJ/m^2)
-	15	-	-	5	5	3.750	34,9	4,5	17,9
-	10	10	-	-	5	2.950	30	4,5	14,7
-	15	-	-	5	-	4.030	35,7	4,3	17,7
-	10	10	-	-	-	3.200	31,6	4,1	15,5

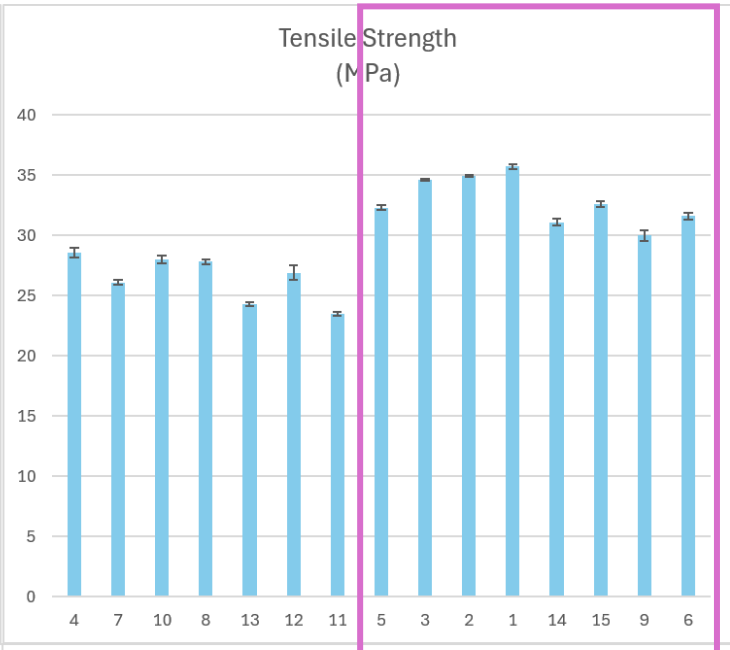
Filtered by Impact strength

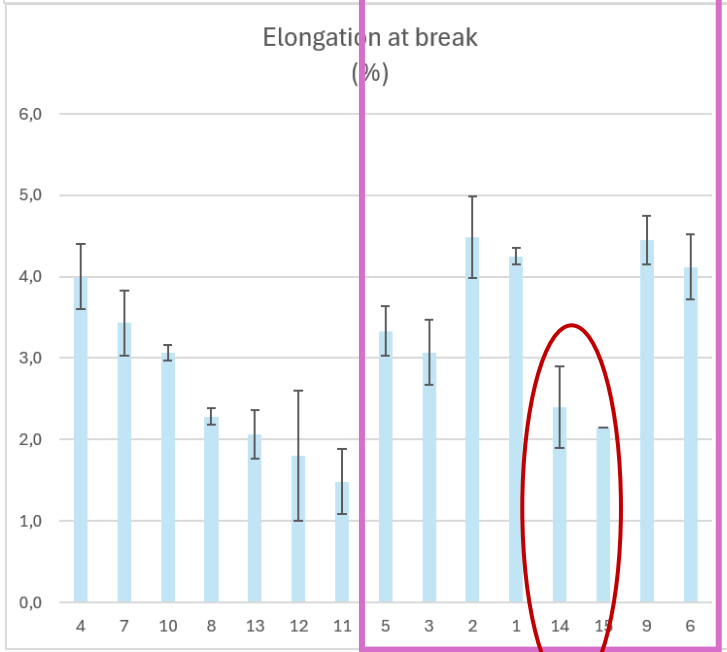
Filler			Impact modifier			Mechanical properties			
pea fibre	Talc	Chalk	Birch bark	Viscose fibre	Vinyl acetate	Tensile Modulus (MPa)	Tensile Strength (MPa)	Elongation at break (%)	Impact Strength (kJ/m^2)
-	20	-	-	-	-	3.450	34,6	3,1	20,6
-	20	-	-	-	5	3.400	32,3	3,3	19,9
-	15	-	-	5	5	3.750	34,9	4,5	17,9
-	15	-	-	5	-	4.030	35,7	4,3	17,7

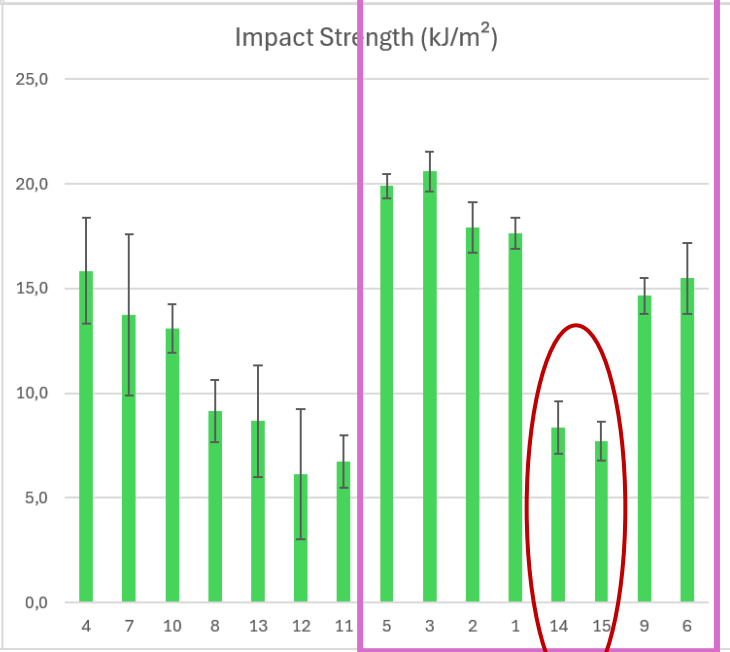
Across the screened formulations, talc-containing compounds showed the most favourable overall balance of tensile strength, elongation at break and impact strength.

No.	Polymer Biomer P263E	Filler			Impact modifier		
		Pea fibre	Talcum	Chalk	Birch bark	Viscose	Vinyl acetate
4	75	-	-	20	-	-	-
7	80	-	-	15	5	-	-
10	75	-	-	20	-	-	5
8	75	15	-	-	-	5	5
13	80	15	-	-	5	-	5
12	75	20	-	-	-	-	5
11	75	15	-	-	5	-	-
5	80	-	20	-	-	-	5
3	80	-	20	-	-	-	-
2	75	-	15	-	-	5	5
1	80	-	15	-	-	5	-
14	75	5	15	-	-	-	5
15	80	5	15	-	-	-	-
9	80	-	10	10	-	-	5
6	75	-	10	10	-	-	-









Analysis: Effects of Fibre Fillers and Modifiers

Filtered by Impact strength

lowest first

Filler			Impact modifier			Mechanical properties			
pea fibre	Talc	Chalk	Birch bark	viscose fibre	Vinyl acetate	Tensile Modulus (MPa)	Tensile Strength (MPa)	Elongation at break (%)	Impact Strength (kJ/m^2)
20	-	-	-	-	5	2.630	26,9	1,8	6,1
15	-	-	5	-	-	2.500	23,5	1,5	6,7
5	15	-	-	-	-	3.700	32,6	2,2	7,7
5	15	-	-	-	5	3.140	31,1	2,4	8,4
15	-	-	5	-	5	2.200	24,3	2,1	8,7
15	-	-	-	5	5	2.800	27,8	2,3	9,1

- ➢ Pea-fibre-containing formulations showed low impact strength and low elongation at break
- ➢ Increasing the talc content did not restore impact performance to the level of talc-only formulations
- ✓ Pea fibre may still be relevant for applications where stiffness, natural-fibre content or cost are prioritised over impact resistance

Calcium carbonate had a measurable effect; however, its overall performance was substantially lower than that of talc.

Under the conditions investigated, vinyl acetate copolymer, birch bark and viscose fibre showed no clear positive effect on the measured mechanical properties.

Conclusion: Selection for Industrial Trials

Based on the mechanical test results, the formulation containing 20%$_{wt.}$ talc was selected for industrial moulding trials at TKT Kunststofftechnik and Bekuplast.

This formulation provided the most favourable balance of impact strength, tensile strength and processability for the requirements of the investigated applications.

Following technical advice from Biomer GmbH, the polymer grade was changed from Biomer P263**E** to Biomer P263**P**. In addition, the talc grade was changed for the industrial trials.

Final formulation selected for industrial trials:
Biomer P263P with 20%$_{wt.}$ Luzenac A3 talc

The other formulations were not rejected in general. They showed different property profiles and may be suitable for applications with different requirements.

Industrial moulding trials

Bekuplast

50 kg Biomer P263P

50 kg Biomer P263P compounded with 20%$_{wt.}$ talc
Compound produced by I.S.T. Ficotex

50 kg Biomer P263P compounded with 20%$_{wt.}$ talc and an impact modifier
Developed by I.S.T. Ficotex

Sampling TKT Kunststofftechnik

10 kg Biomer P263P

10 kg Biomer P263P compounded with 20%$_{wt.}$ Talc
Compound manufactured by 3N

Industrial Trial Strategy

Bekuplast

Material	Experiment					
	V0	V1	V2	V3	V4	V5
PP-C 9642 Reference material	100%					
Biomer P263P		100%				
Biomer P263P + 20%$_{wt.}$ talc			100%	95%	90%	
Bio 500 impact modifier				5%	10%	
Biomer with 20%$_{wt.}$ talc Impact modified by ficotex						100%

Biomer P263P with 20%$_{wt.}$ talc and improved impact strength

If V1 can be moulded successfully, proceed with V2.
If V2 can be moulded successfully, the sampling trial is considered successful.
If V2 cannot be moulded successfully, evaluate V3.
If V3 can be moulded successfully, the sampling trial is considered successful.
If V3 cannot be moulded successfully, evaluate V4

Results of the Industrial Moulding Trials:
Bekuplast

- V1 and V2 were moulded successfully after optimisation of the processing parameters
- As V2 could be moulded successfully, V3 and V4 were not evaluated
- V5 could not be moulded successfully. The trial was stopped because the material stuck to the mould surface

The dimensions and part weight did not meet the required quality standards when compared with the reference material.



PHA crates did not pass the ball-drop test.

Results of the Industrial Moulding Trials:

TKT Kunststofftechnik

Moulding trials with unfilled and 20%$_{wt.}$ talc-filled Biomer P263P

- The injection process was stable
- Parts could be manufactured successfully
- The melt viscosity was not optimal for the 4 mm wall thickness.







Key lessons learned

- The development work focused too strongly on reproducing the material properties of the serial production polymer
- Attempting to replicate the behaviour of a fundamentally different polymer on an existing production tool proved to be unrealistic
- A more effective approach would be to prioritise mouldability in the existing tool and then compare the resulting part properties with those of the reference product
- Based on this comparison, the required adaptations to part design can be identified
- The tool can then be modified where appropriate, or a new tool can be designed specifically for the PHA material
- A polymer compound cannot generally be engineered to behave identically to a fundamentally different polymer in an existing serial-production mould. This may be possible only in exceptional cases.

For PHA-based injection-moulded products, material selection, part design and mould design must be optimised as an integrated system.

The non-selected formulations remain potential candidates for other applications. Their suitability depends on the required balance between stiffness, strength, impact resistance, processability, cost and bio-based content.