

# PVC LOOP: RECYCLABILITY STUDY ON FLEXIBLE PVC

## Unlocking recycling potential for flexible PVC from medical applications

**SUMMARY**

The PVC Loop project examined the mechanical recyclability of flexible PVC (PVC-P) from medical applications. The study focused on medical tubing used in IV solutions, blood, and dialysis systems, completing six full recycling cycles, including grinding, extrusion, and injection moulding steps, with no additivation carried out between the cycles.

Findings show that mechanical properties, including tensile strength and plasticiser content, remain stable across six cycles, with only minor degradation observed for the static thermostability after the fourth cycle. The dynamic thermal stability tests confirmed the material's durability under processing conditions. However, slight yellowing was observed after the sixth cycle, indicating aesthetic limitations after many recycling cycles.

A complementary BASF study demonstrated that another PVC-P composition can endure up to 11 extrusion cycles with maintained thermostability, though light yellowing was noticeable after the sixth cycle.

Overall, the study confirms that, as rigid PVC, flexible PVC from medical products retains its functional properties through multiple recycling cycles, supporting its potential for sustainable recycling in the healthcare sector and contributing to a circular economy.

**PVC LOOP AT A GLANCE**

**OBJECTIVES**

Address recyclability with no re-stabilization

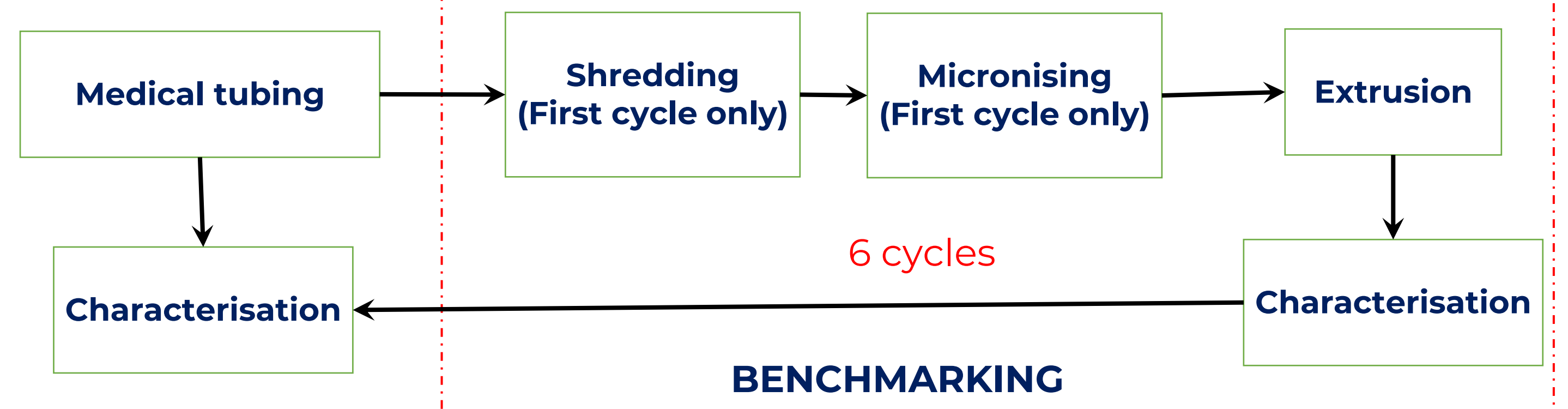
Evaluate mechanical recycling for market suitability

Assess impact of multicycle recycling on the performance of flexible PVC



**TARGET: MEDICAL TUBING**

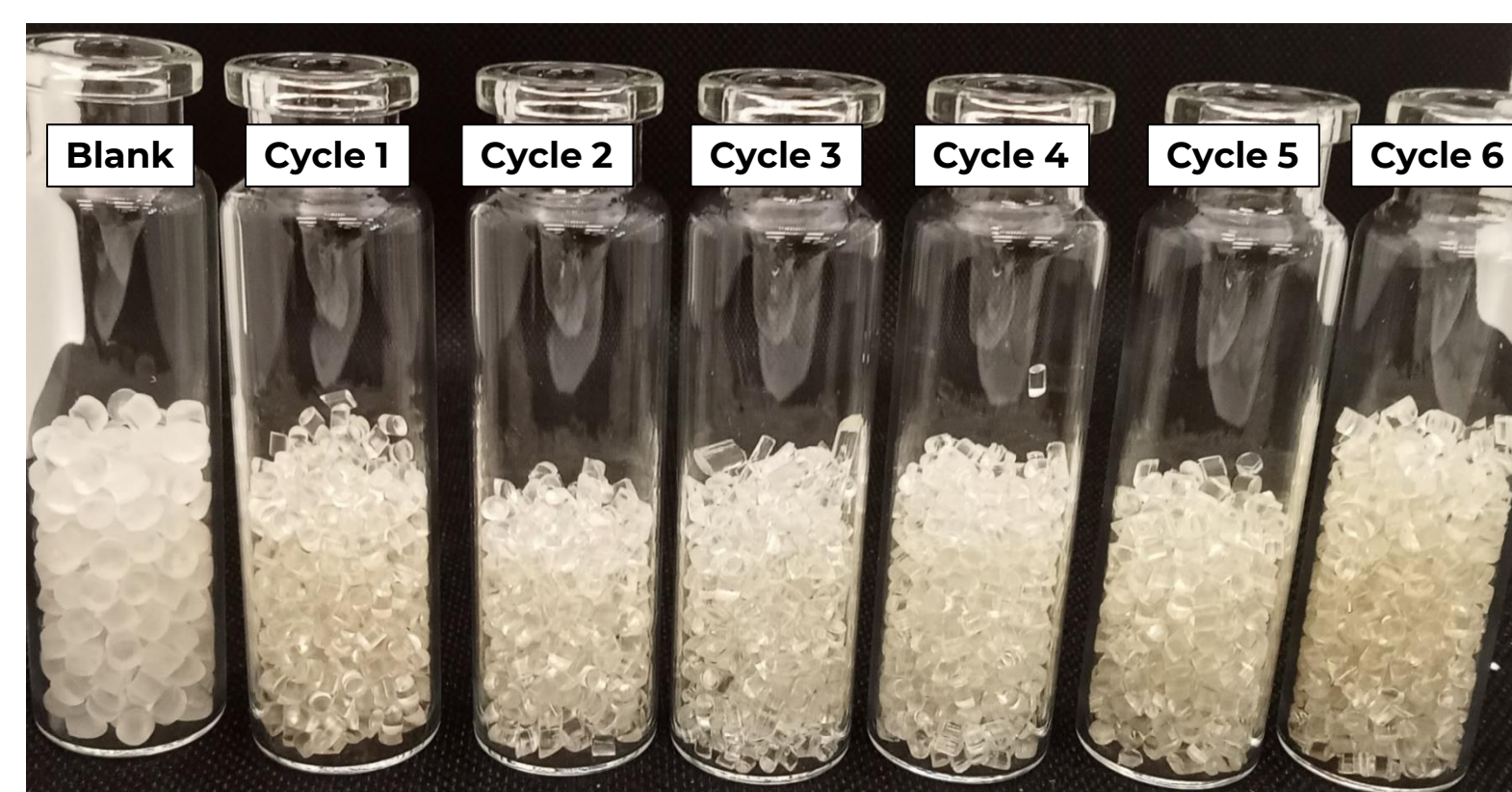
- Application: IV solutions, blood and dialysis systems
- European Pharmacopoeia grade
- 6 complete recycling cycles: grinding, extrusion, injection moulding



**PROCESSING**

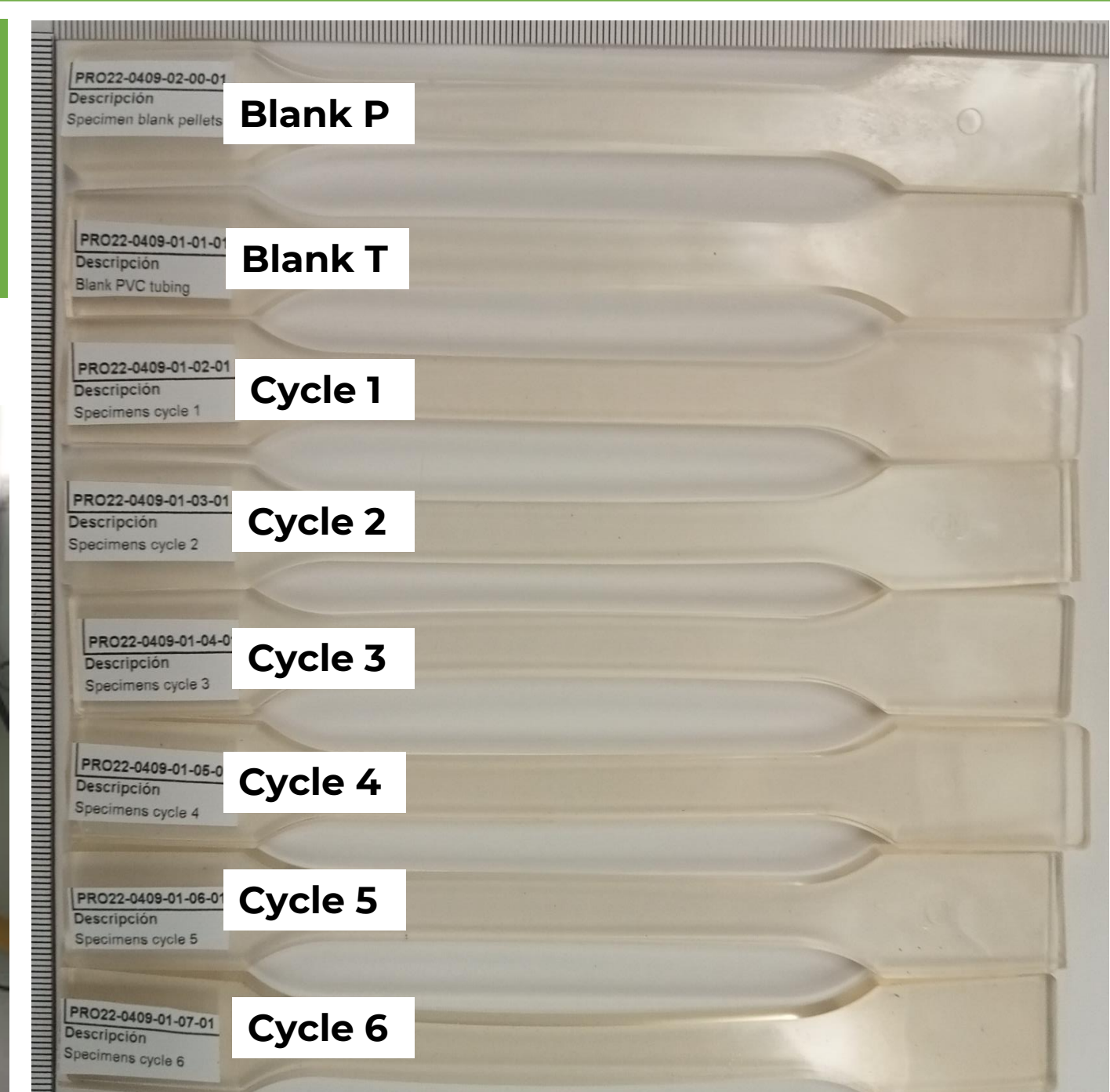
**Extrusion**

Pellets production in a pilot-plant Bausano D30 counter-rotating twin-screw extruder was used, aimed at a maximum melt temperature of 175 °C.



**Injection moulding**

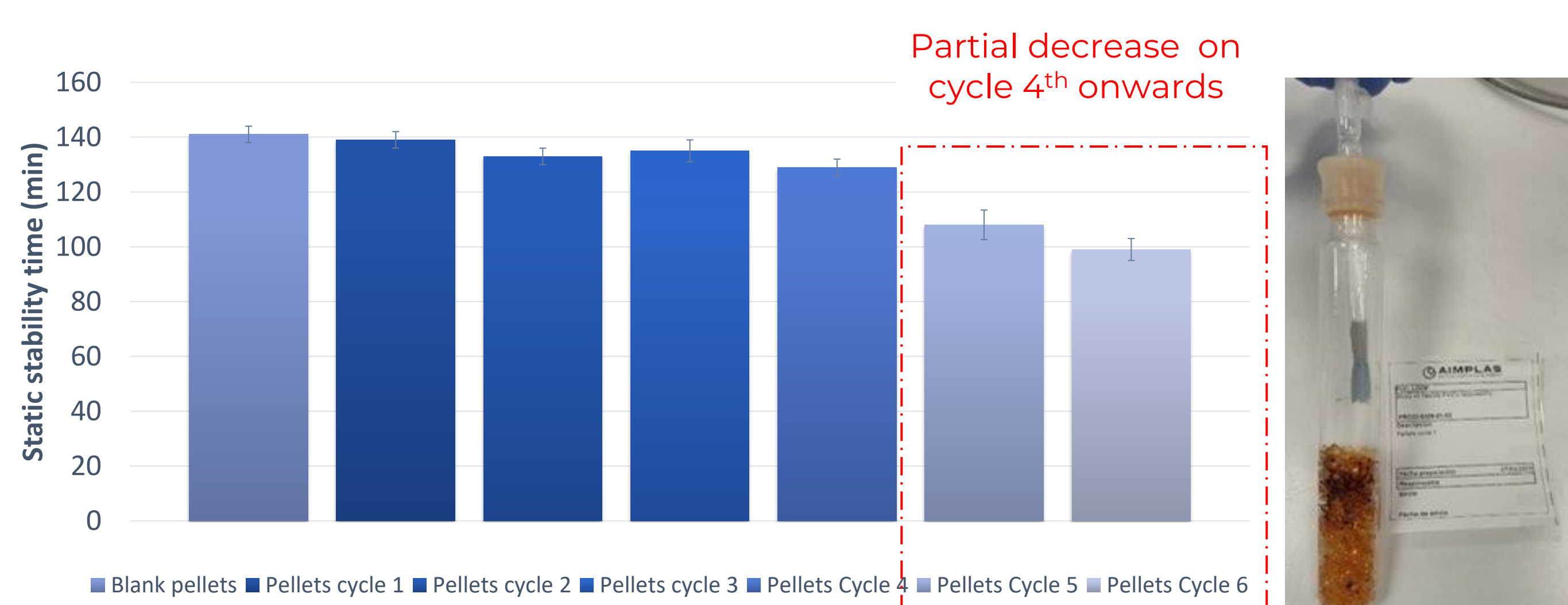
Test bars injected in an Engel VC 200/50 Tech injection moulding machine, into ISO 1A test specimens (dog-bone).



**THERMOSTABILITY**

**Static stability**

Congo red test at 180 °C, in accordance with S/N ISO 182-1



**Dynamic stability**

Continuous stress in plastograph at a given temperature: 180°C, 185 °C and 190 °C



Stable up to 6 cycles

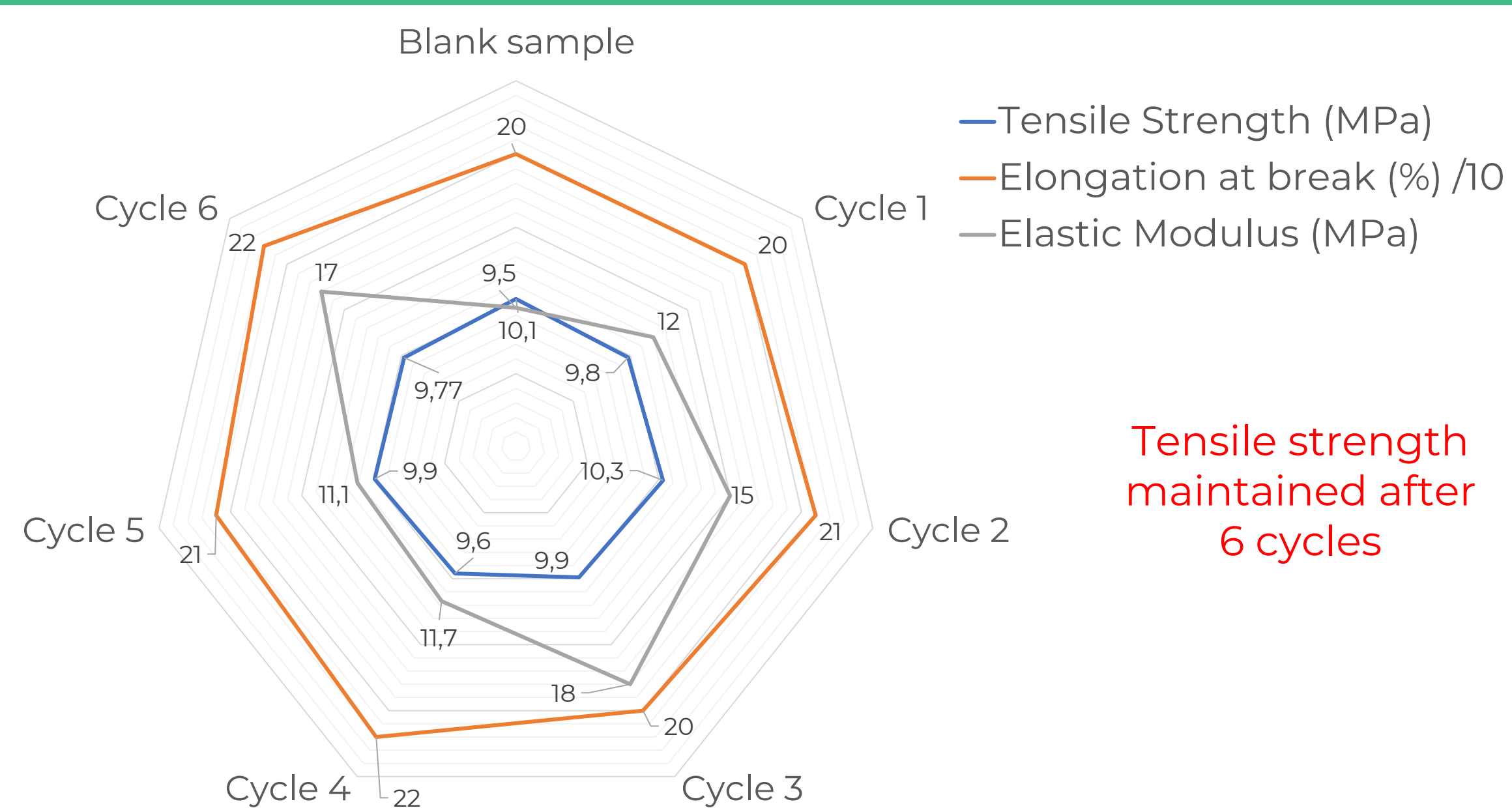
Description	Heat & shear stability time (minutes)			Heat & shear stability time (minutes) – Fusion time omitted		
	180 °C	185 °C	190 °C	180 °C	185 °C	190 °C
<b>Blank</b>	47 ± 2	44 ± 2	36 ± 2	37 ± 2	36 ± 2	27 ± 2
<b>Cycle 1</b>	46 ± 2	38 ± 2	26 ± 2	36 ± 2	32 ± 2	21 ± 2
<b>Cycle 2</b>	45 ± 2	33 ± 2	31 ± 2	29 ± 2	28 ± 2	26 ± 2
<b>Cycle 3</b>	46 ± 2	40 ± 2	34 ± 2	34 ± 2	29 ± 2	26 ± 2
<b>Cycle 4</b>	45 ± 2	39 ± 2	35 ± 2	35 ± 2	28 ± 2	26 ± 2
<b>Cycle 5</b>	44 ± 2	38 ± 2	36 ± 2	31 ± 2	27 ± 2	26 ± 2
<b>Cycle 6</b>	43 ± 2	36 ± 2	29 ± 2	33 ± 2	26 ± 2	24 ± 2

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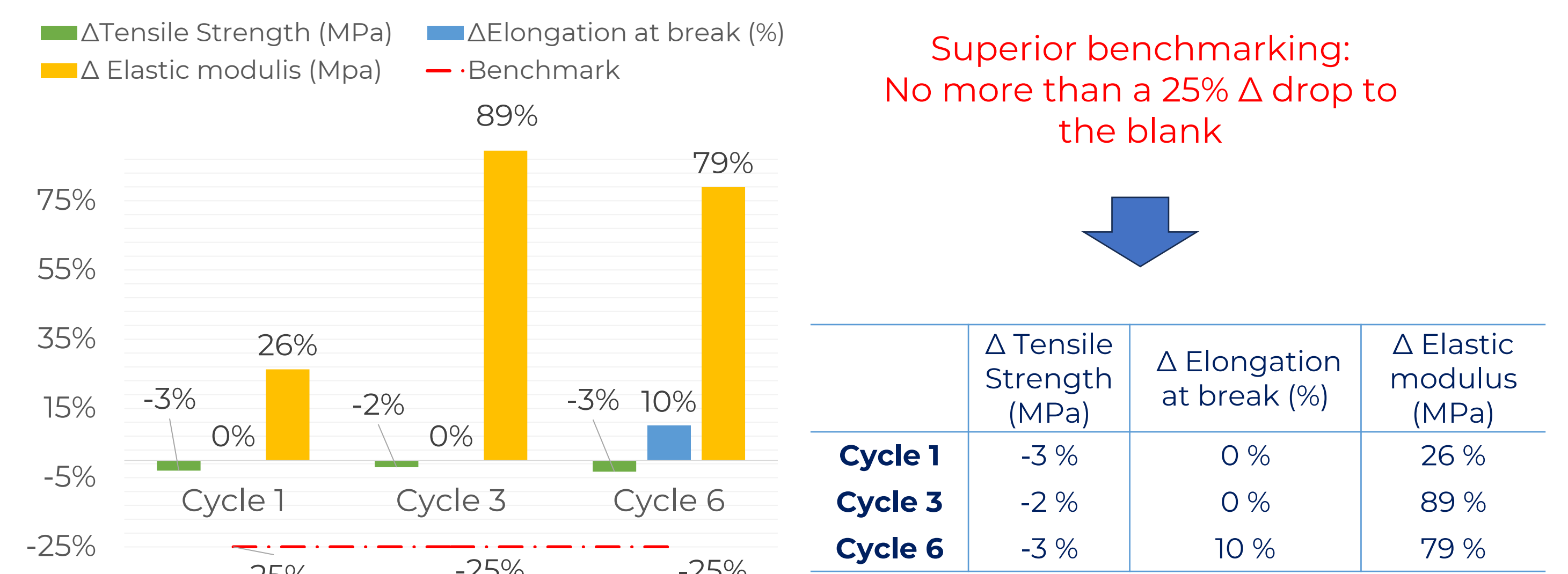
Unlocking recycling potential for flexible PVC from medical applications

PERFORMANCE

Mechanical properties  
Tensile properties according to UNE:EN ISO 527



Mechanical properties  
Tensile properties benchmarking



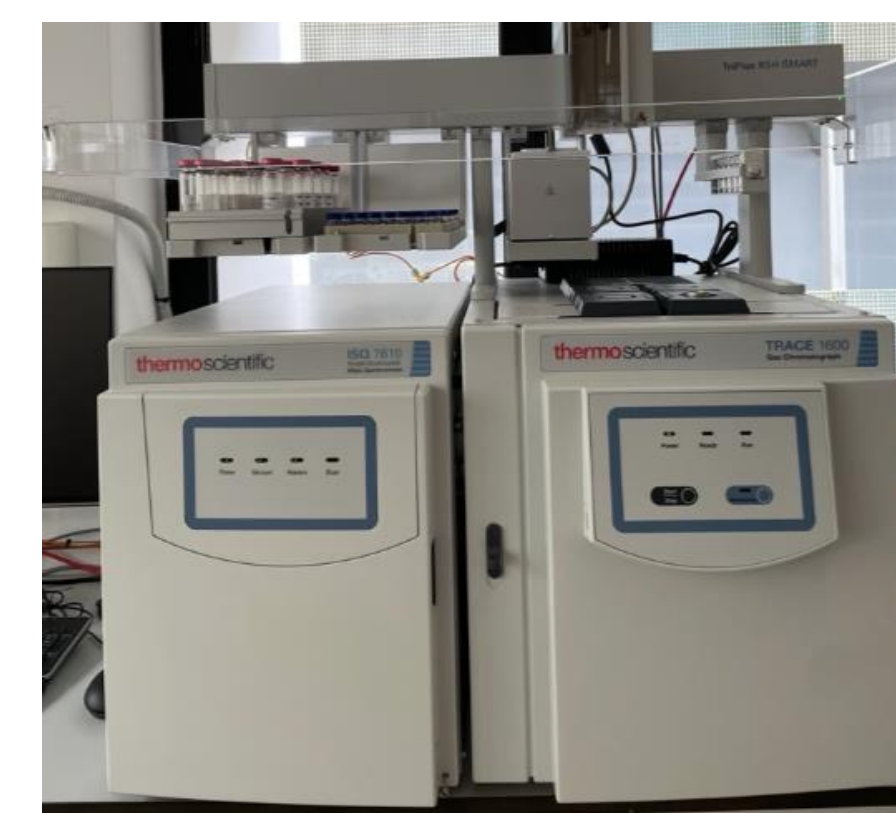
Colour evaluation  
Determination of L\*, a\* & b\* coordinates according to UNE-EN ISO 11664-4:2020

Light yellowing observed after 6 cycles

Sample	Colour coordinate			Delta values			
	L*	a*	b*	DL	Da	Db	DE
Blank	95,61	-0,39	3,72	-	-	-	-
Cycle 1	94,49	-0,72	5,81	-1,12	-0,33	2,09	2,39
Cycle 2	94,94	-0,92	5,97	-0,67	-0,53	2,25	2,41
Cycle 3	94,56	-0,67	5,72	-1,05	-0,28	2,00	2,28
Cycle 4	94,33	-1,14	6,99	-1,28	-0,75	3,27	3,59
Cycle 5	93,15	-0,77	7,42	-2,46	-0,38	3,70	4,46
Cycle 6	92,74	-0,90	10,33	-2,87	-0,51	6,61	7,22

Plasticiser content  
Determination of plasticiser content by solvent extraction and GC(-MS)

Plasticiser content remains stable across 6 recycling cycles



Sample	Plasticiser content %
Blank	36
Cycle 1	36
Cycle 3	36
Cycle 6	36

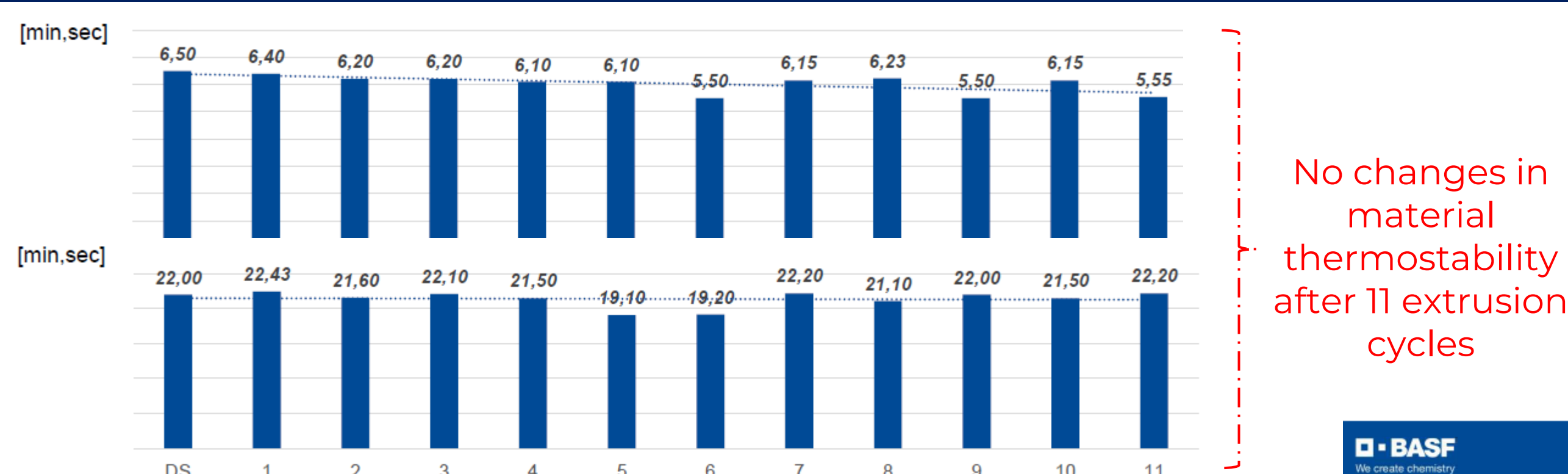
COMPLEMENTARY STUDY: BASF

Recyclability assessment on PVC-P  
Performed up to 11 extrusion cycles

- Transparent formulation
  - 100 phr PVC Inovyn 271 PC
  - 60 phr Palatino® 10-P DPHP
  - 1,2 phr Ca-Stearate
  - 0,6 phr Zn-Stearate
- Compounding on double screw extruder
- 11 extrusion cycles single screw extruder

- Characterization
  - Thermostability (Congo Red, PVC Thermomat)
  - Colour
  - Mechanical data (Elongation at break, 100% Modulus, etc.)
  - Plasticiser extraction

Thermostability (Congo red, PVC Thermomat HCl-Stability [min, sec]  
VDE 0473 Part 811-3-2 and Metrohm Thermomat stability time at 200°C with 50μS as endpoint

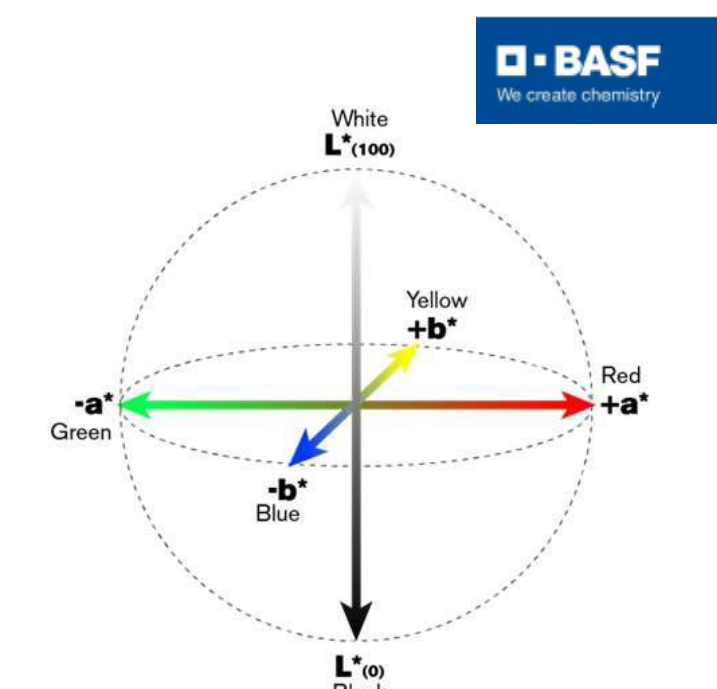


Colour evaluation – Pressed plates at 170 °C  
Determination of colour coordinates L\*, a\* and b\* according to UNE-EN ISO 11664-4:2020  
Yellowness Index is a number calculated from spectrophotometric

Light yellowing observed after 6 extrusions; constant up to 11 extrusions

Sample	L	a	b	Yellowness index	DL	Da	Db	DE
1 X (DS)	88,97	-0,36	3,89	7,80	0,00	0,00	<b>0,00</b>	<b>0,00</b>
6 X (ES)	88,36	-0,66	4,78	9,50	-0,61	-0,30	<b>-0,89</b>	<b>1,12</b>
11 X (ES)	88,40	-0,72	4,93	9,54	-0,57	0,36	<b>1,04</b>	<b>1,24</b>

DS = Double screw extrusion; ES = Single screw extrusion



Mechanical properties  
Tensile properties after 6 and 11 extrusions (11 samples)

Mechanical performance maintained after 11 extrusions

Run	Breaking strength (MPa)	Elongation at break (%)	100% Modulus (MPa)
0 (DS)	18,2 / 18,7	310 / 332	8,9 / 8,7
6 (ES)	18,3 / 18,2	314 / 326	9,0 / 8,6
11 (ES)	20,2 / 18,4	350 / 317	9,0 / 8,9

DS = Double screw extrusion; ES = Single screw extrusion

Plasticiser content %  
Theoretical value 37 %

Plasticiser content stable

Run	Plasticiser content (%)
0 (DS)	37
6 (ES)	37
11 (ES)	37