The bio-based polyamide road to sustainability: state-of-the-art & potential developments

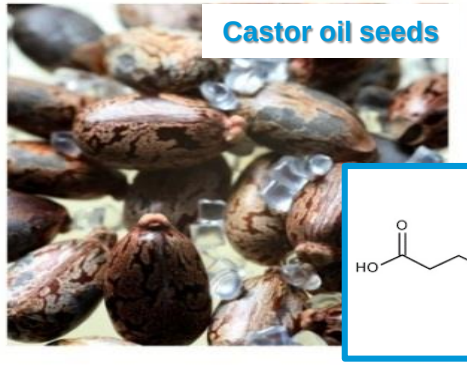
Patrizia Crepaldi (*Project leader of Advanced R&D Programs*)

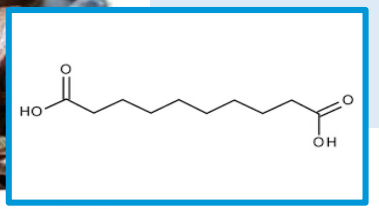
Erico Spini (*Global Marketing Manager)*

15TH March 2023

Agenda

- ❑ RadiciGroup experience with bio-based polyamides (20 min, Patrizia Crepaldi)
- ❑ Confirmed and potential future applications (20 min, Erico Spini)
- ❑ Q&A





RadiciGroup experience with bio-based polyamides

Patrizia Crepaldi, *Project leader of Advanced R&D Programs*

Sustainability in RadiciGroup

- Mechanical recycling
- Chemical recycling
- Bio-based polymers

Sustainability in RadiciGroup

Environmental impact

Feasibility

Applications range

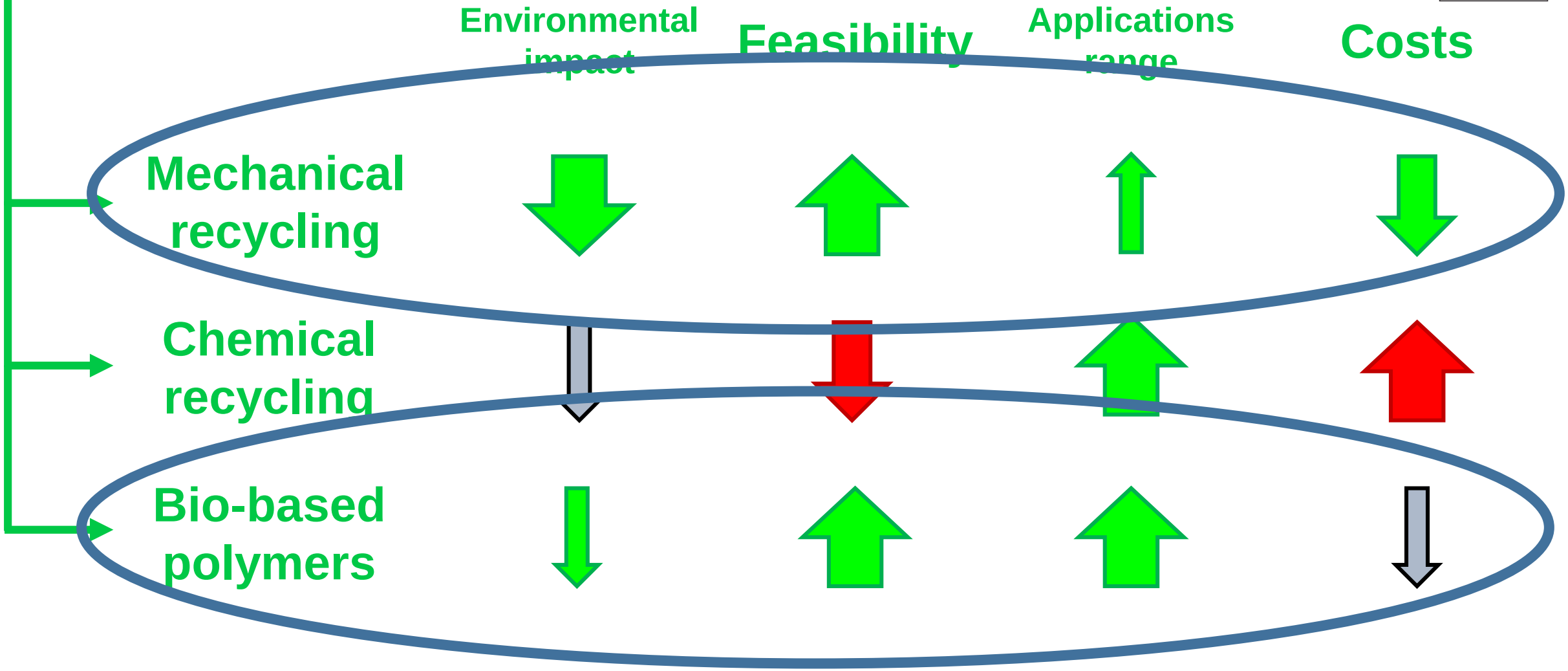
Costs

- Mechanical recycling
- Chemical recycling
- Bio-based polymers

Sustainability in RadiciGroup

	Environmental impact	Feasibility	Applications range	Costs
Mechanical recycling	↓	↑	↑	↓
Chemical recycling	↓	↓	↑	↑
Bio-based polymers	↓	↑	↑	↓

Sustainability in RadiciGroup



Bio-Polyamides properties

Polyamide	Theoretical Bio-content (%)	CH2/NHCO dilution	Melting Point (°C)
PA66	**0**	**5**	**260**
PA 11	100	10	190
PA 610	64	7	220
PA 410	70	6	254
PA 1010	100	9	205
PA 1012	43	10	190
PA 510	100	6,5	215
PA 56	41	4,5	254

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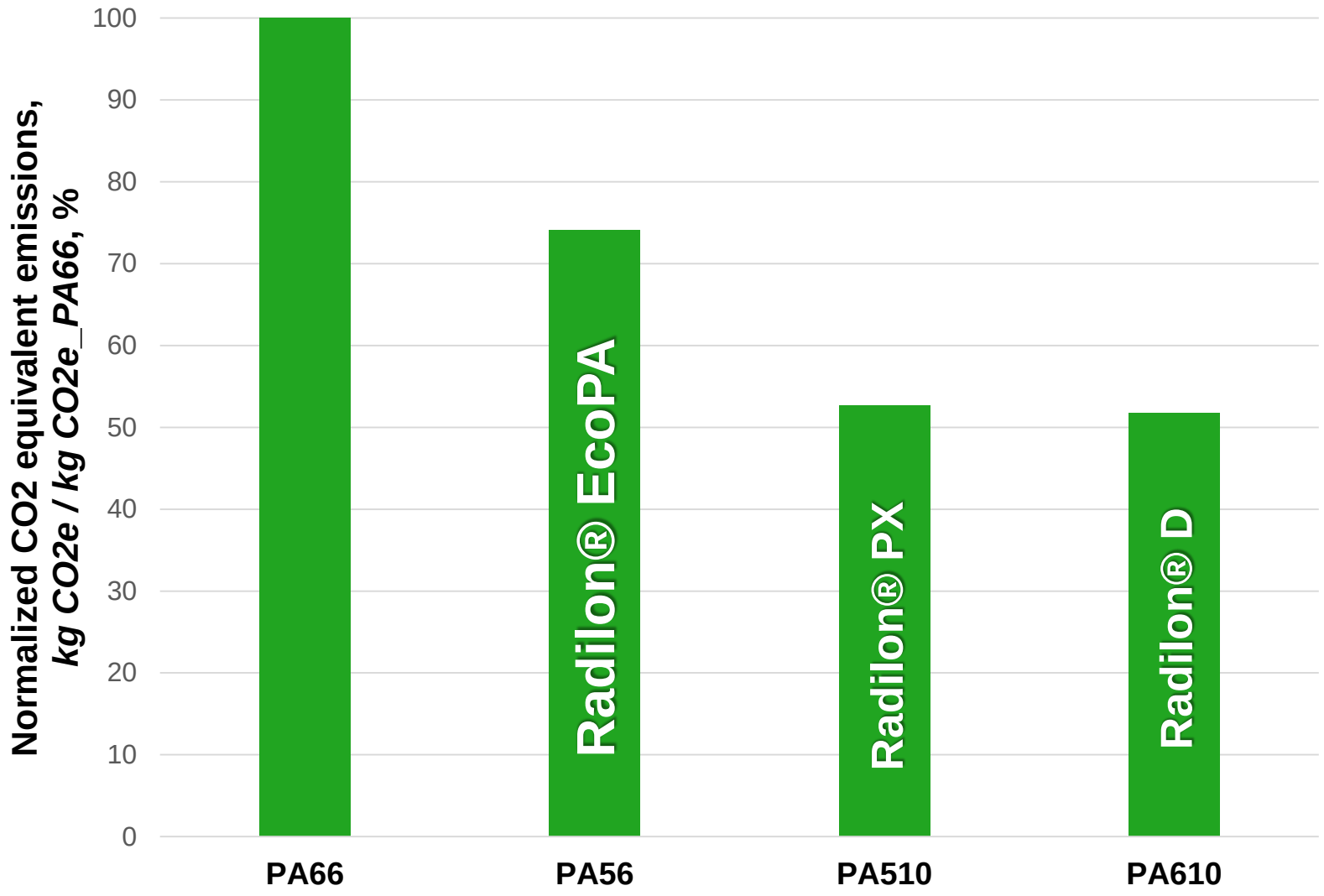
PA 56	41	4,5	254

Radici Proposals

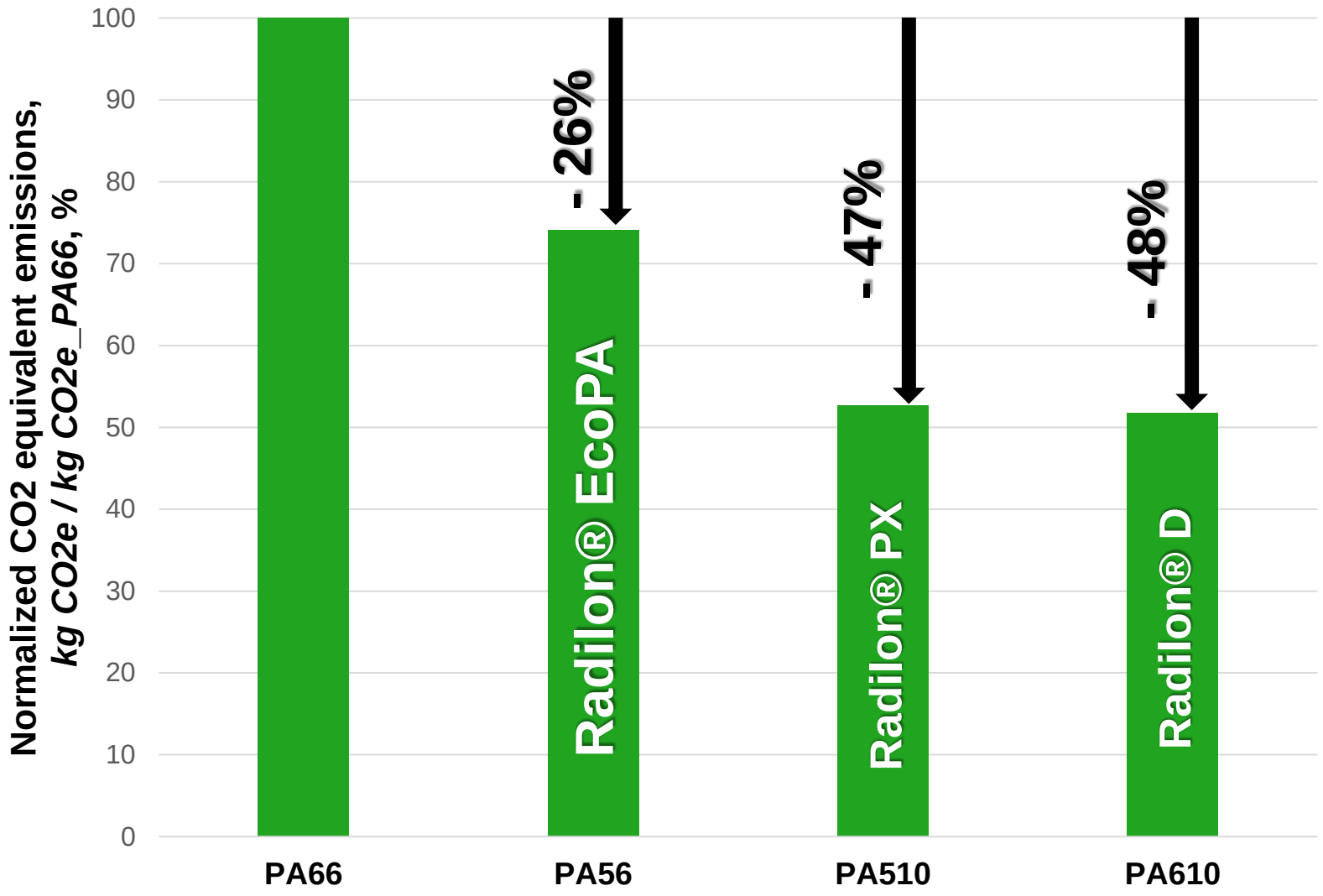
- **Radilon® EcoPA (PA56) - *Experimental***
- **Radilon® PX (PA510)**
- **Radilon® D (PA610)**
- **Radilon® TT (PA1012)**

Radici Proposals: Environmental impact



The calculation was carried out through SimPro v.9.3.0.3, the datase is Ecoinvent 3.5 and the method is based on IPCC 2021 (includ. CO2 uptake). It's a cradle-to-gate study cetified by Certiquality in 2022. Data referred to 2019 productions, kindly provided by Radici Innova.

Radici Proposals: Environmental impact



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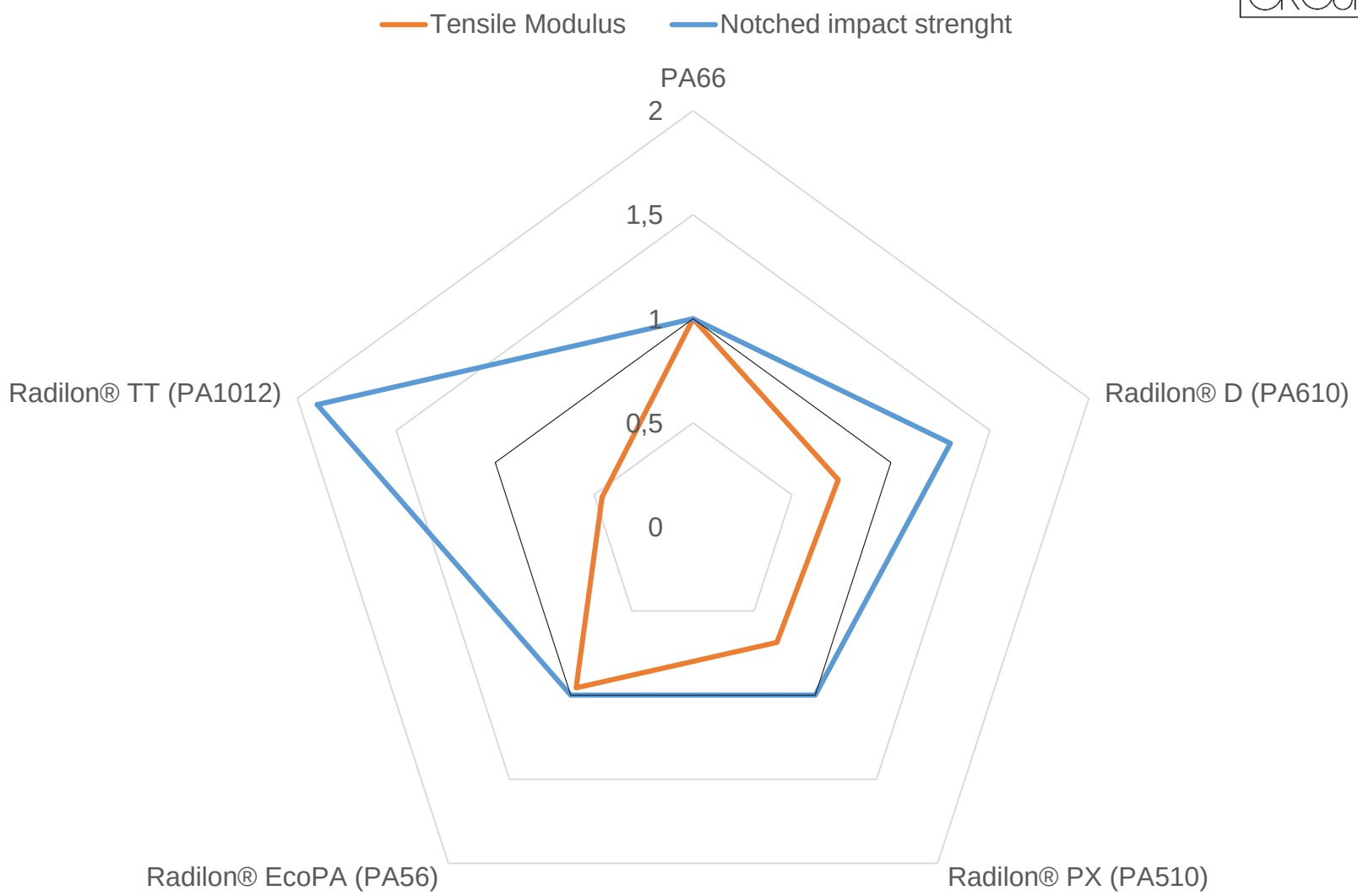
Radici Proposals: Mechanical properties

Mechanical properties of bio-PA normalized over PA66 properties



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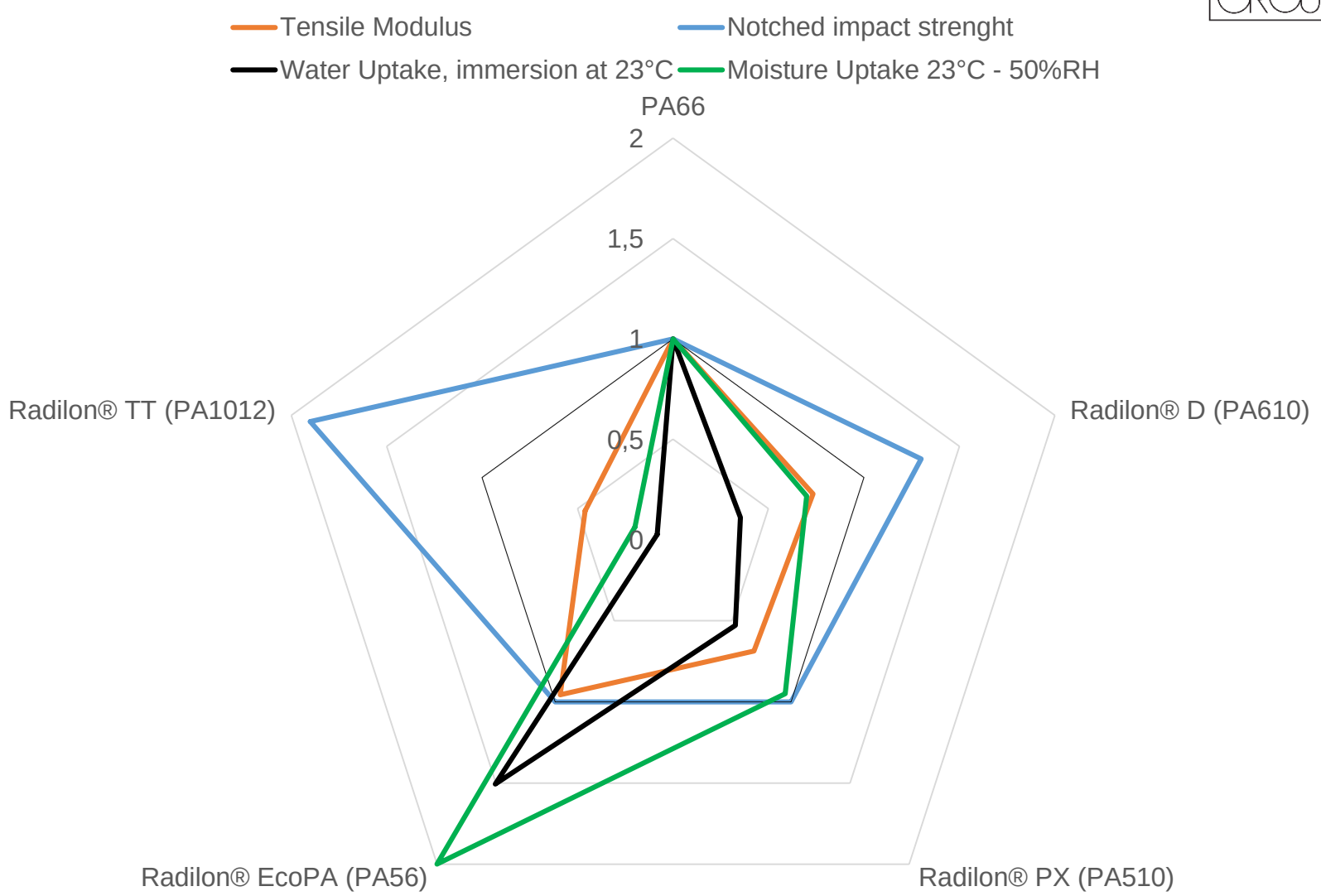
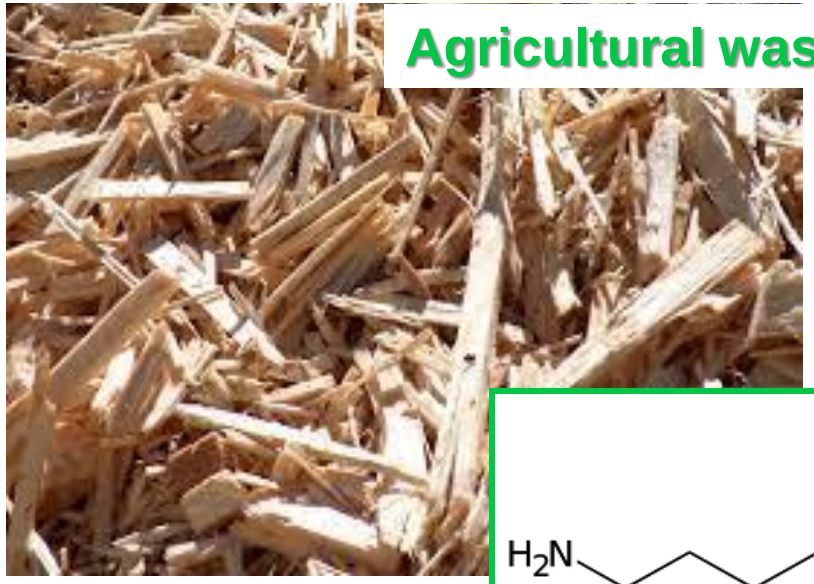


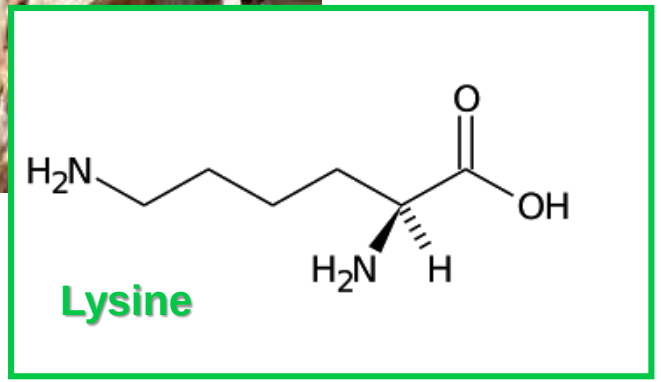
Radici Proposal: Radilon® EcoPA

- Ease of processing
- High melting point
- High level of cristallinity
- Good LOI

PA 5.6 with *41%* of bio-content



Agricultural waste



Lysine

Radici Proposal: Radilon® TT

- High flexibility
- Transparency
- Low water and moisture uptakes
- Superior chemical resistance

PA 10.12 with *43%* of bio-content

Castor oil seeds

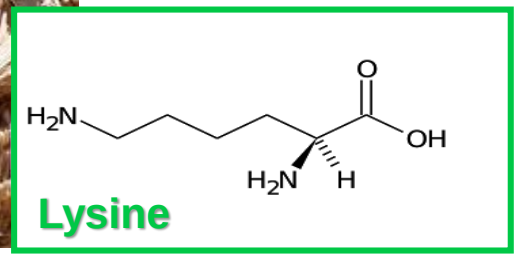
1,10 - diaminodecane

Radici Proposal: Radilon® PX

- Easy flow & processing
- Lower shrinkage
- High melting point
- Good mechanical properties
- Excellent surface aspect
- Easy & good uniform dye in textile products

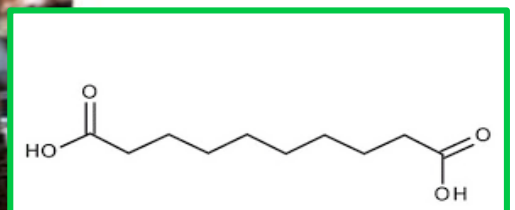
PA 5.10 with *100%* of bio-content

Agricultural waste



Lysine

Castor oil seeds



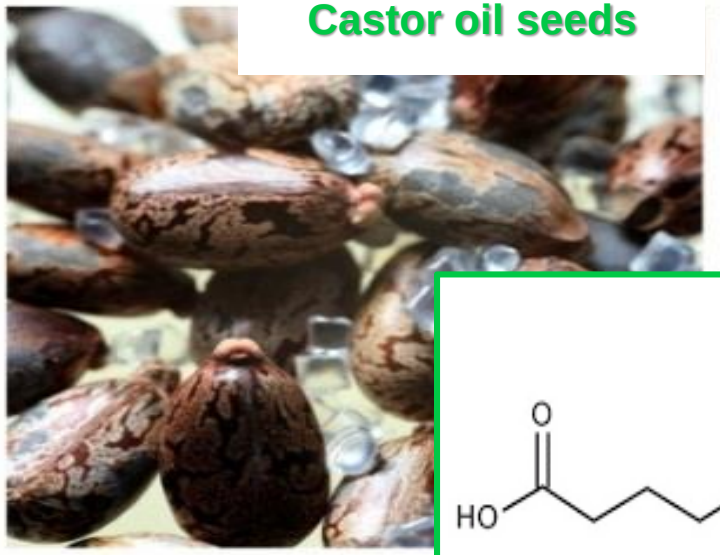
Sebacic acid

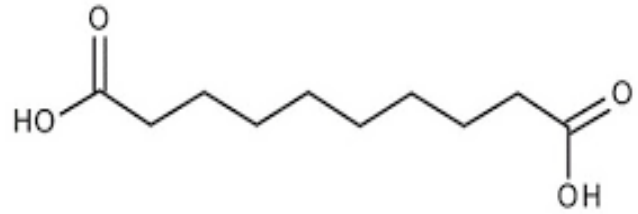
Radici Proposal: Radilon® D

- Bend recovery (monofilaments)
- Easy processing by injection molding extrusion
- Low moisture and water uptakes
- High chemical resistance
- High dimensional stability
- Good spinnability and textile properties

PA 6.10 with *64%* of bio-content

Castor oil seeds

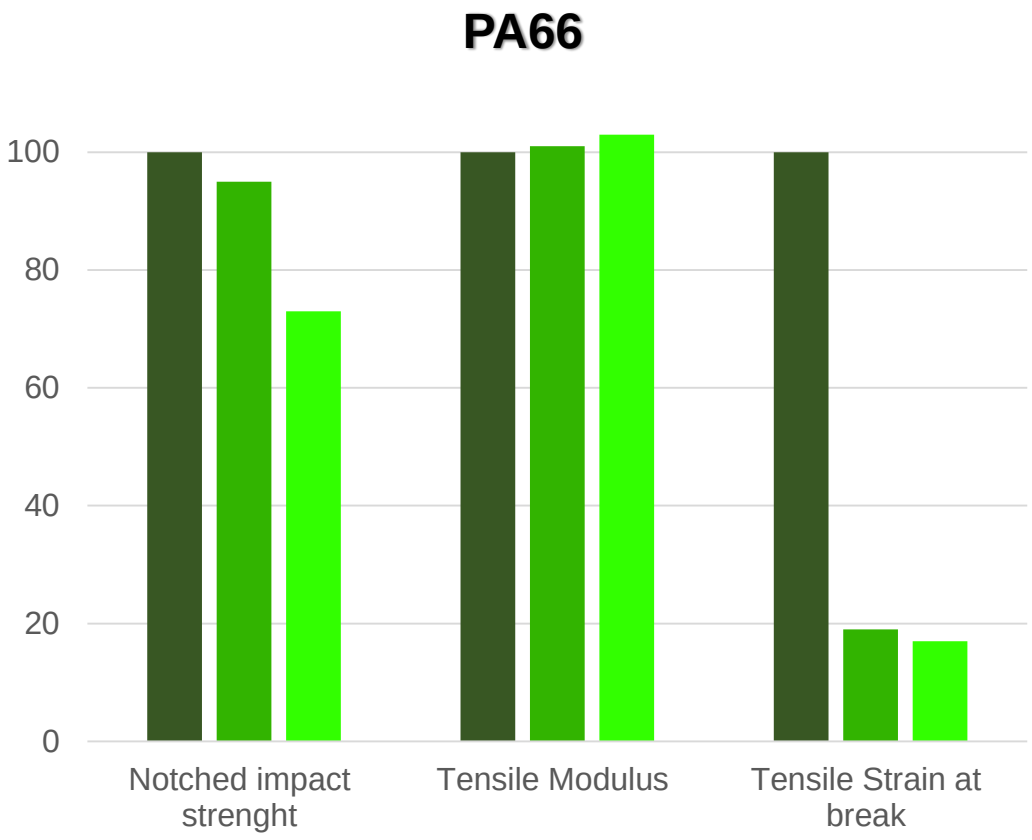


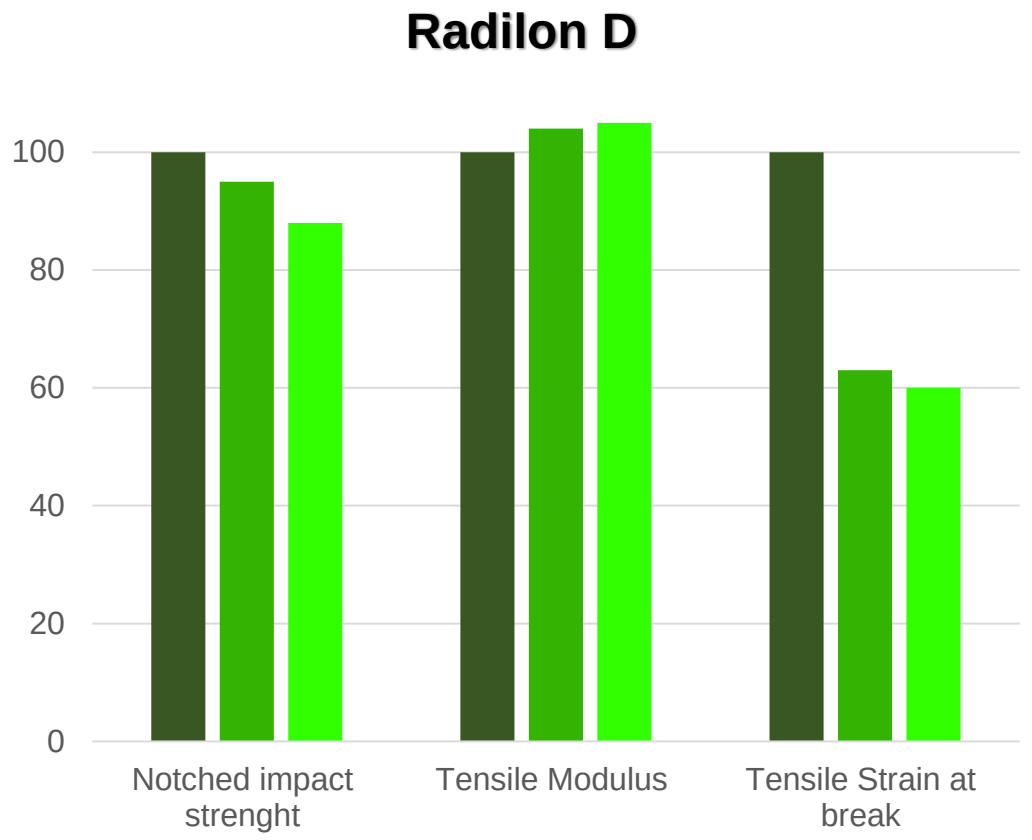


Sebacic acid

RadiciGroup cutting-edge research project: Mechanical recycling of bio-based Radilon D

Normalized mechanical properties of PAs (Radilon D & PA66) with recycled content from primary recycle of: 0 % 50 % 100 %





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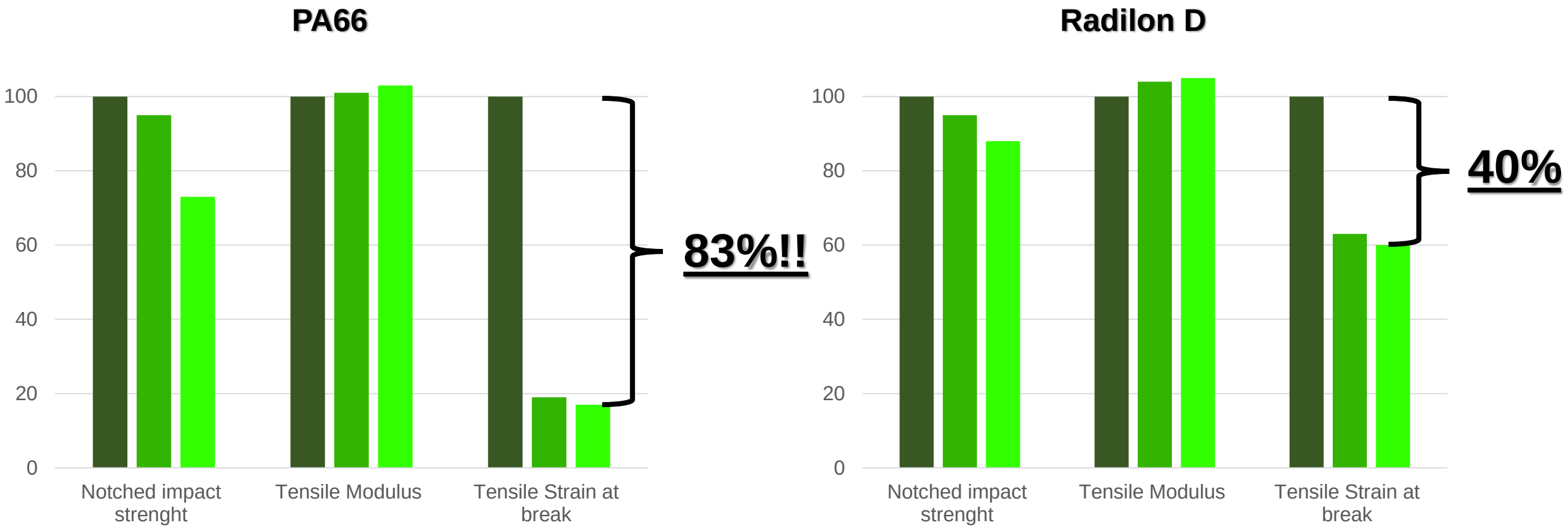
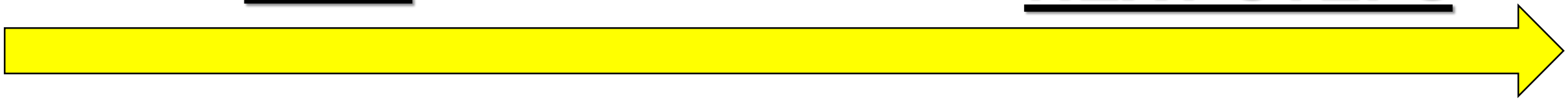


✓ **Provide eco-friendly products based on bio-sources (Radilon® D, TT, PX, EcoPA)**

NOW **NEXT STEPS**



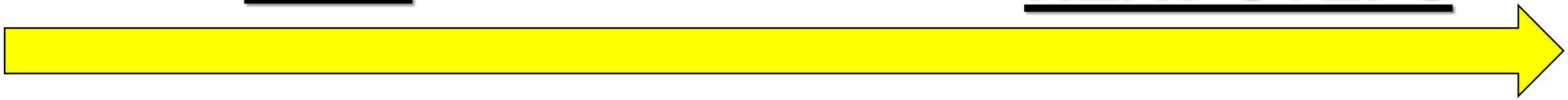
✓ **Provide eco-friendly products based on bio-sources (Radilon® D, TT, PX, EcoPA)**

➢ **Widening range of bio-based PA products**

➢ **Provide recycled bio-based PA**

NOW

NEXT STEPS



Confirmed & potential future applications

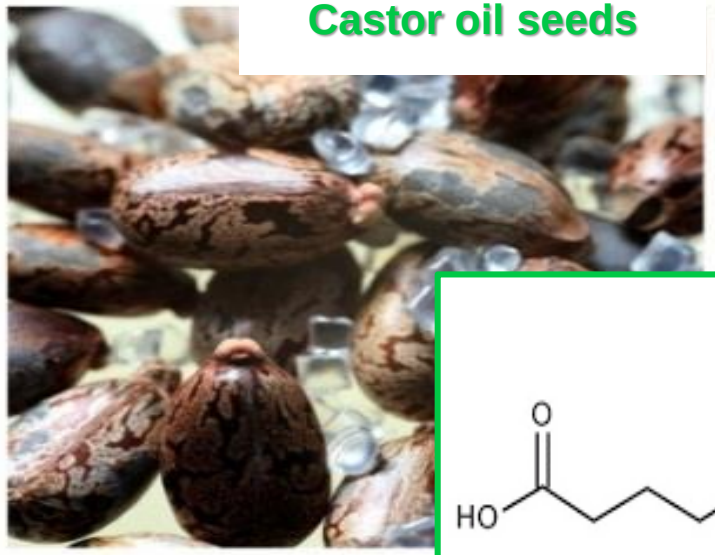
Erico Spini, *Global Marketing Manager*

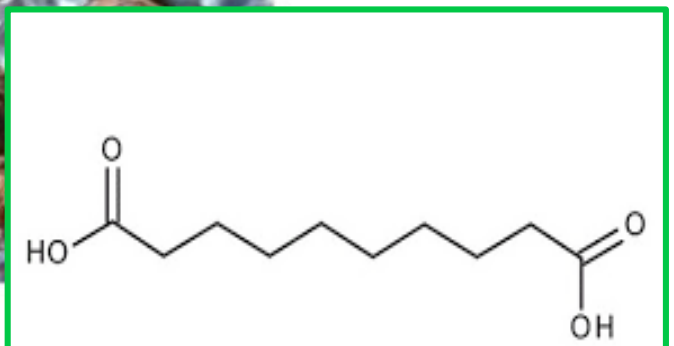
Radici Proposal: Radilon® D

- Enhanced Chemical resistance
- Stress cracking resistance
- Dimensional stability
- Low fuel permeation
- Limited moisture sensitivity
- Hydrolysis resistance

PA 6.10 with *64%* of bio-content

Castor oil seeds





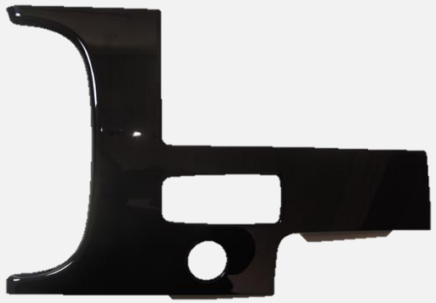
Sebacic acid

PA610 applications

High gloss trims

Main requirements :

High gloss
Excellent surface aspect
Excellent UV resistance (SAE J 2412)
Low moisture sensitivity
Partially bio (64%)
Abrasion and scratch resistance
Good impact resistance even at low temperature



Materials:

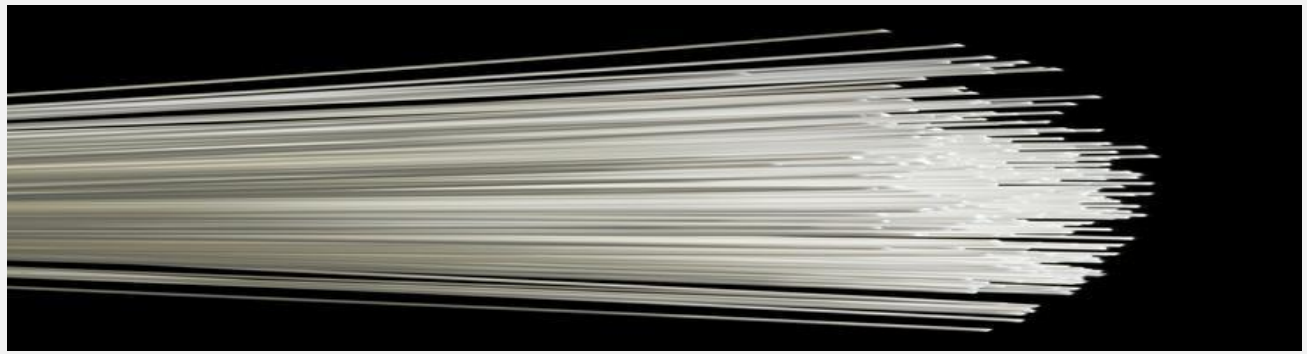
Radilon® D HSUK 3010 BK (PA610, UV stabilized, high gloss black colour)

PA610 applications

Monofilaments

Main requirements :

Excellent chemical resistance
Easy processing
Low moisture sensitivity
Bio content (64%)



Materials:

Radilon® D 24D 1000 NT (PA610, low viscosity)

PA610 applications

In tank fuel line

Main requirements :

Resistance to different fuels (diesel & gasoline)
Conductivity retention after prolonged fuel immersion for two layers solution
Excellent processability

Materials:

Radilon® D 40P50K (PA610, flexible)

Radilon® D 40EP50XK1C 333 BK (conductive and flexible PA610 for internal layer)

PA610 applications

Cooling lines connectors

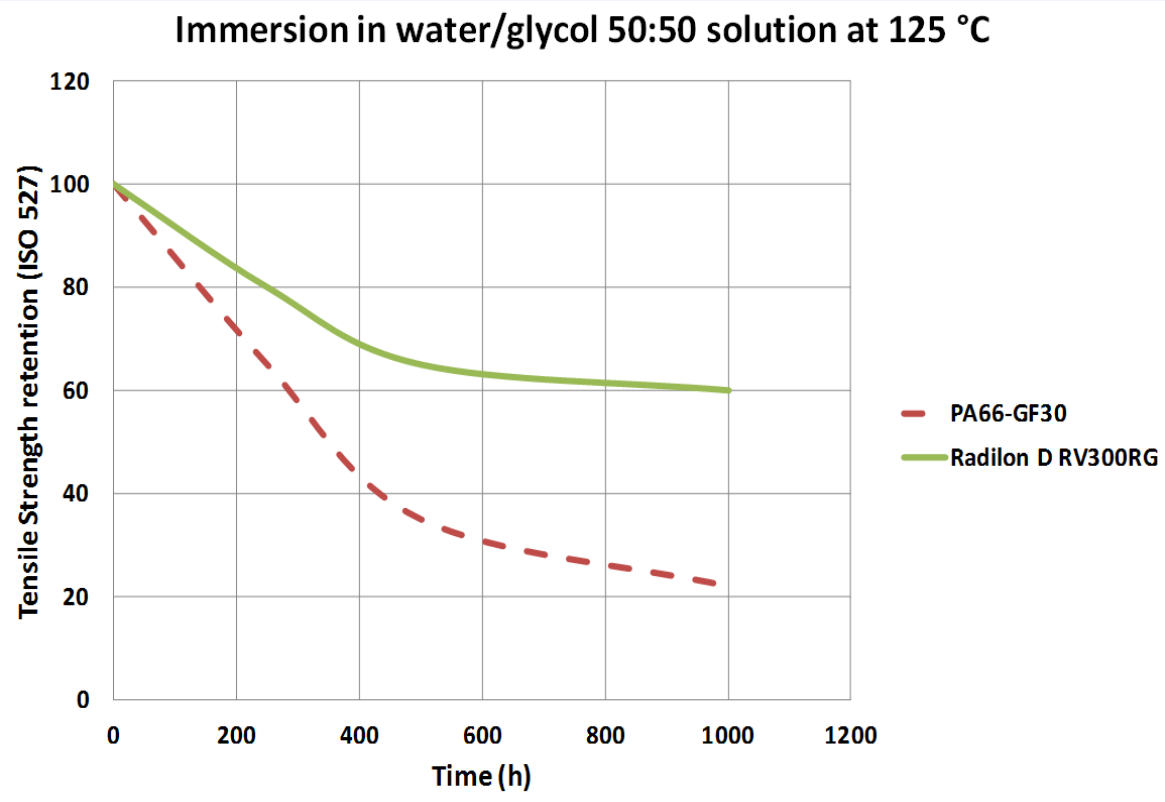
Main requirements :

Resistance to cooling liquid
Resistance to road salts solutions contact
Dimensional stability

Materials:

Radilon® D RV300RG (PA610-GF30, hydrolysis resistant)

PA610 resistance to hydrolysis



- 60 % retention with Radilon® D RV300RG (PA610-GF30-hydrolysis resistant)
- 22% retention with standard PA66-GF30

PA610 applications

Vacuum brake booster hose

Main requirements :

Stress cracking resistance
UV resistance
Respect norms requirements: ISO 7628, DIN 74324, SAE J844, FMVSS106
Excellent processability by extrusion

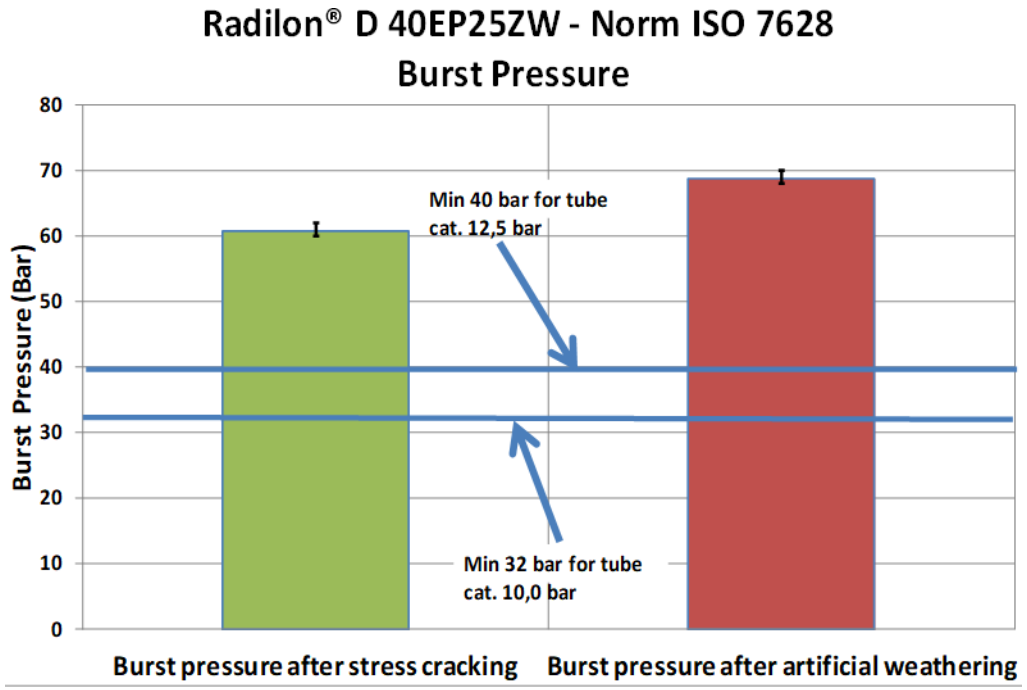
Materials:

Radilon® D 40EP25ZW (PA610, flexible)

PA610 applications

APPLICATIONS : Vacuum brake booster hose

To examine the stress cracking resistance, the installed lines were first exposed at 60 °C to an increased air humidity of 85 %, then bent by a given diameter and dipped at regular intervals into a corrosive solution. No cracks are allowed to develop. Furthermore, the value for the burst pressure must be at least 80 % of the original value. The corrosive solution is made up of 50 % water, copper chloride, sodium chloride, potassium chloride and zinc chloride. For aging in artificial light, the hose was irradiated with xenon lamps for 750 hours at 65 °C. In this case, too, the burst pressure must be at least 80 % of the original value.

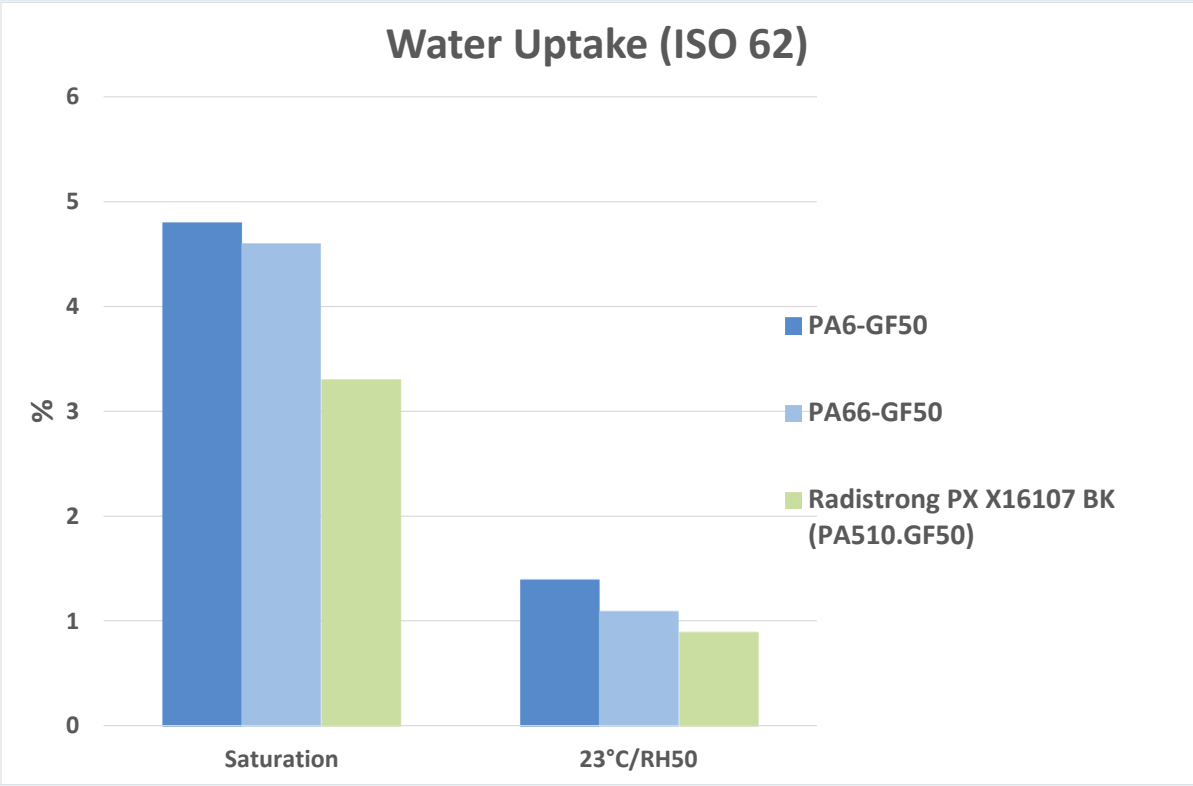


PA510 (experimental grade) key properties vs PA6&PA66

	PA510	PA6&PA66
Bio Content	**100%**	**0%**
Easy flow	**+**	**=**
Easier to add high fillers	**+**	**=**
Lower moisture absorption	**+**	**=**
Lower density	**+**	**=**
Dimensional stability due to moisture absortion	**=**	**–**
Change of mech properties due to moisture absorption	**=**	**–**
Price	**–**	**=/+**

+ good **= fair** **– weakness**

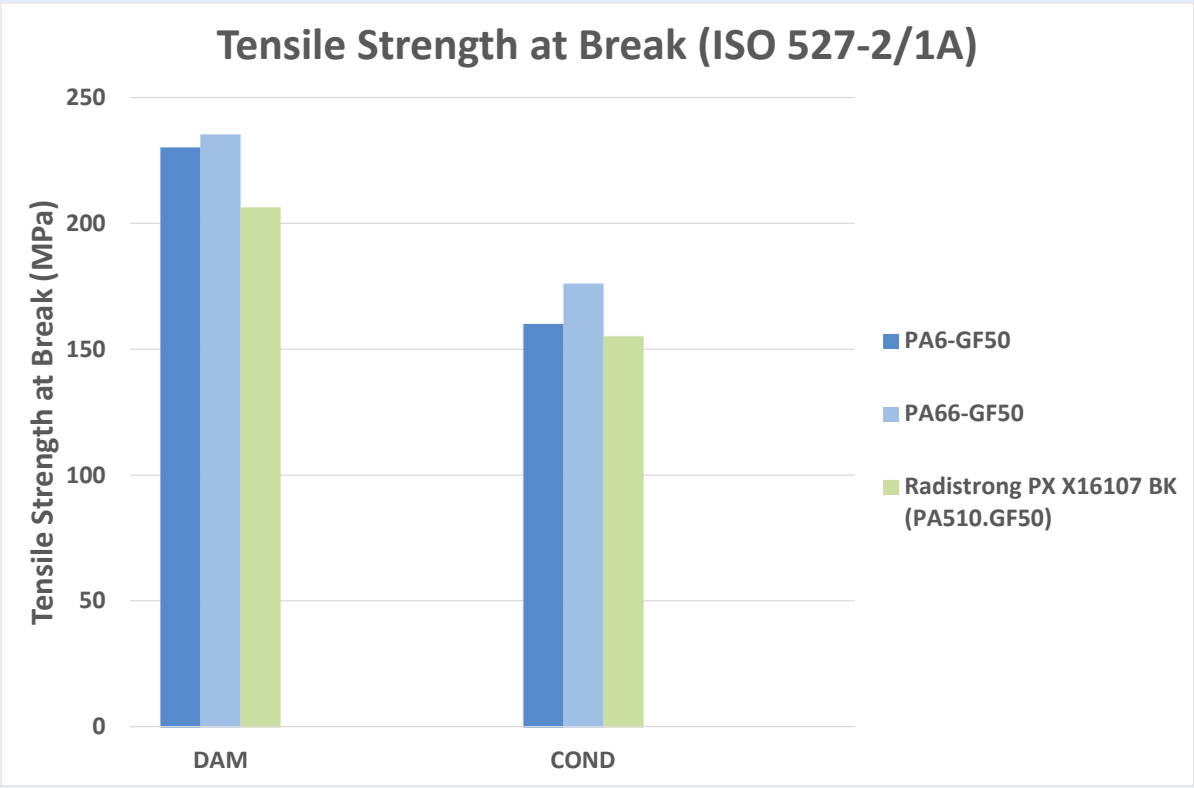
PA510 key properties



Radistrong PX 50% GF

- Significant reduction of water uptake versus PA6-GF50 & PA66-GF50
- Better dimensional stability + lower mechanical property sensitivity due to lower moisture absorption

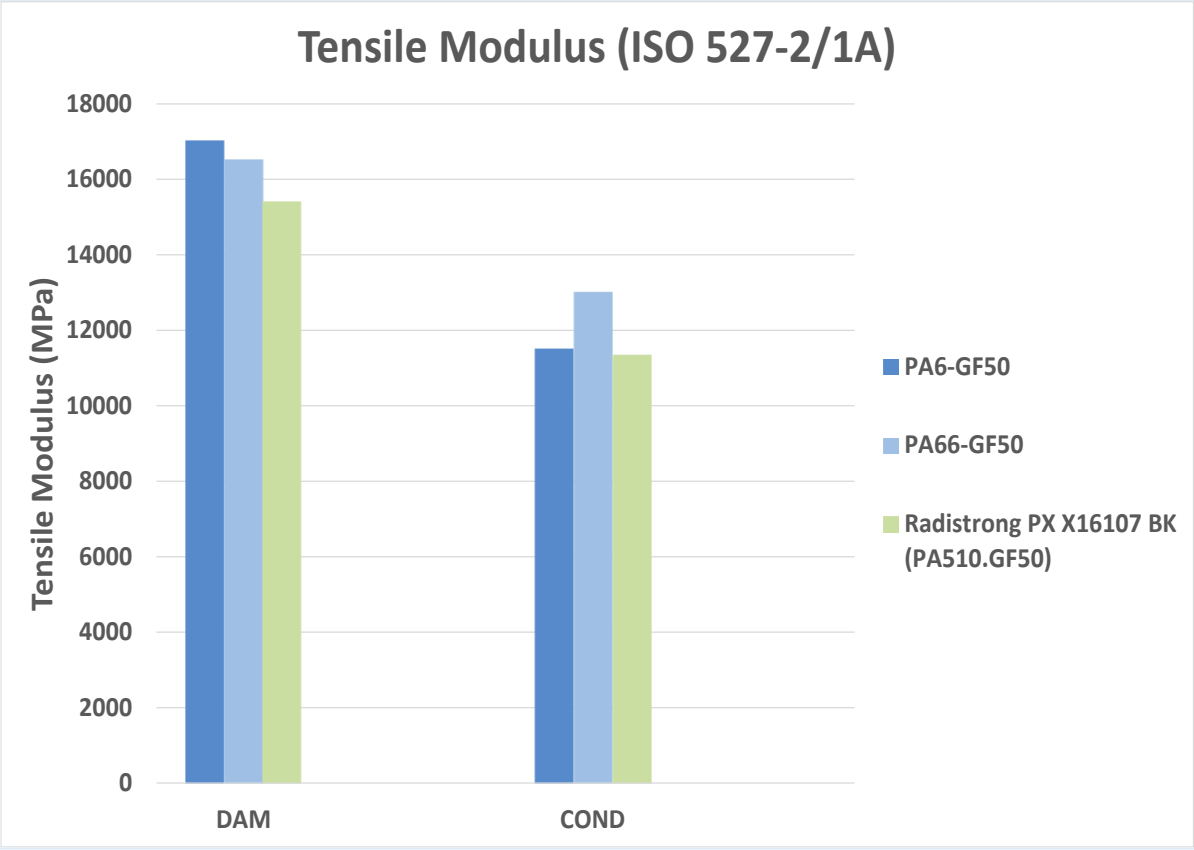
PA510 key properties



Radistrong PX 50% GF

- TS at break lower than PA6-GF50 & PA66-GF50 in DAM status. Test done on few experimental lots. To be confirmed.
- TS at break close to PA6-GF50 in conditioned state.

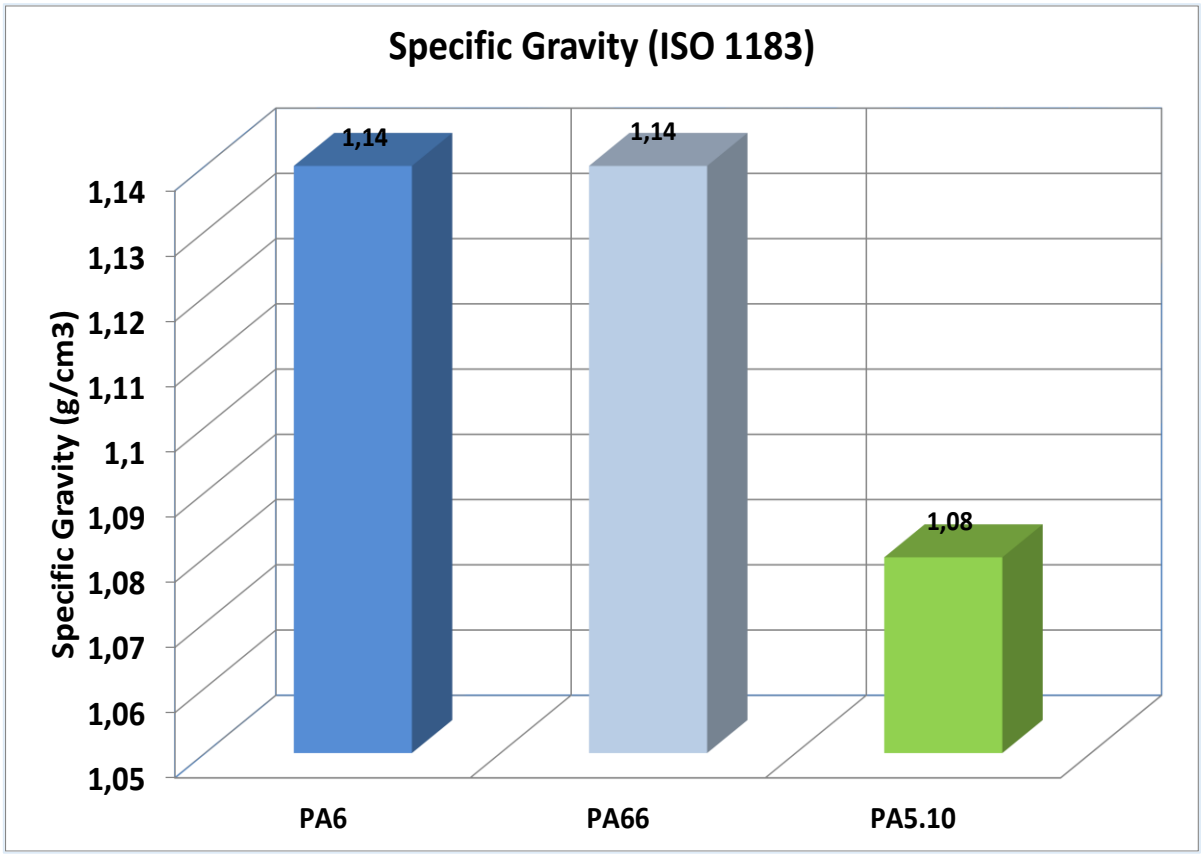
PA510 key properties



Radistrong PX 50% GF

- TM lower than PA6-GF50 & PA66-GF50 in DAM status. Test done on few experimental lots. To be confirmed.
- TM equal to PA6-GF50 in conditioned state.

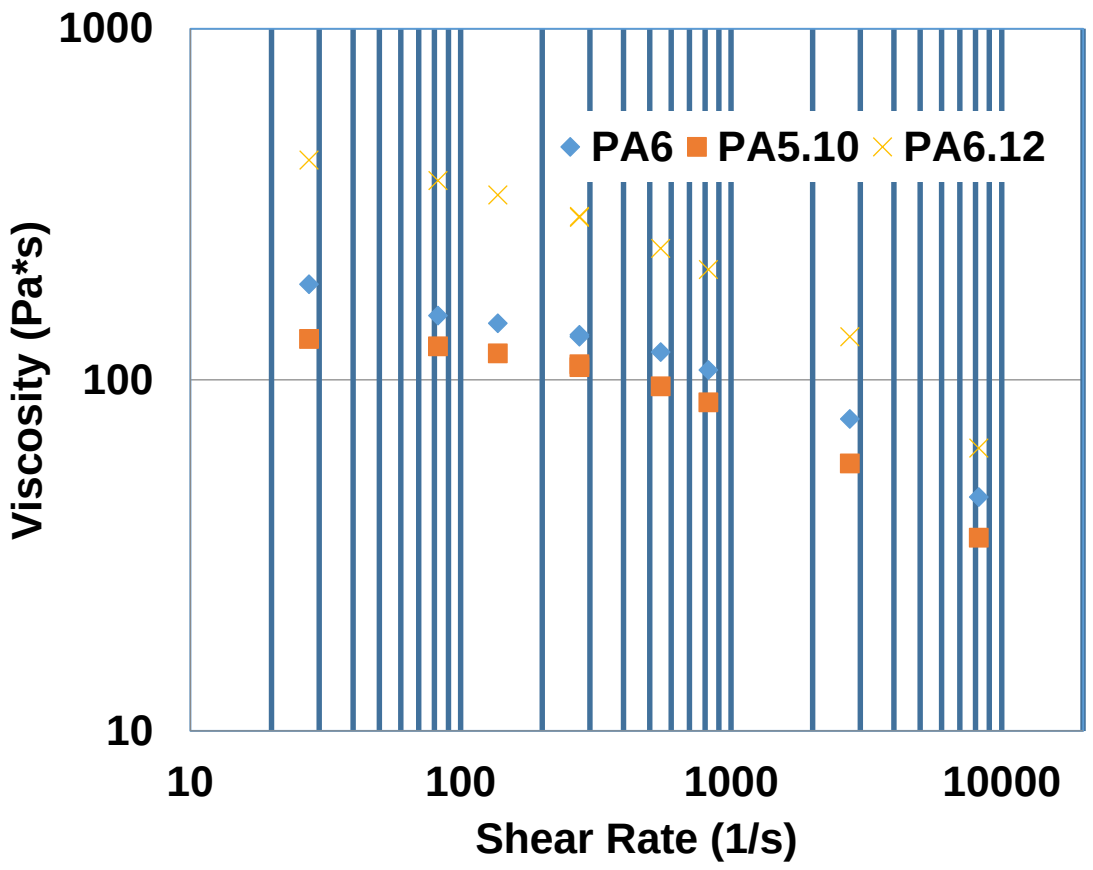
PA510 key properties



Radistrong PX (raw material)

- Lower specific gravity versus PA6 & PA66.
- 5% saving on parts weight

PA510 key properties



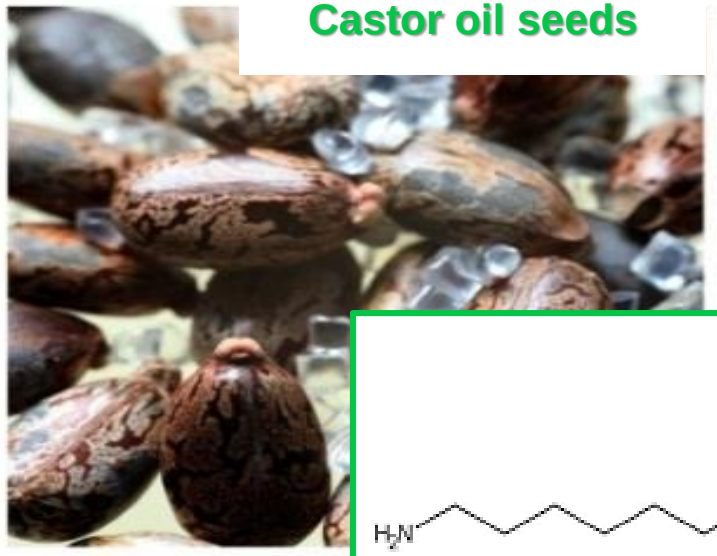
Radistrong PX

- Higher fluidity than PA6
- Potential advantages on processing
- Lower fibers breakage on moulded parts is possible

Radici Proposal: Radilon® EcoTT

- Excellent chemical resistance
- High flexibility
- Dimensional stability
- Transparency
- Very low moisture sensitivity
- Easy flow

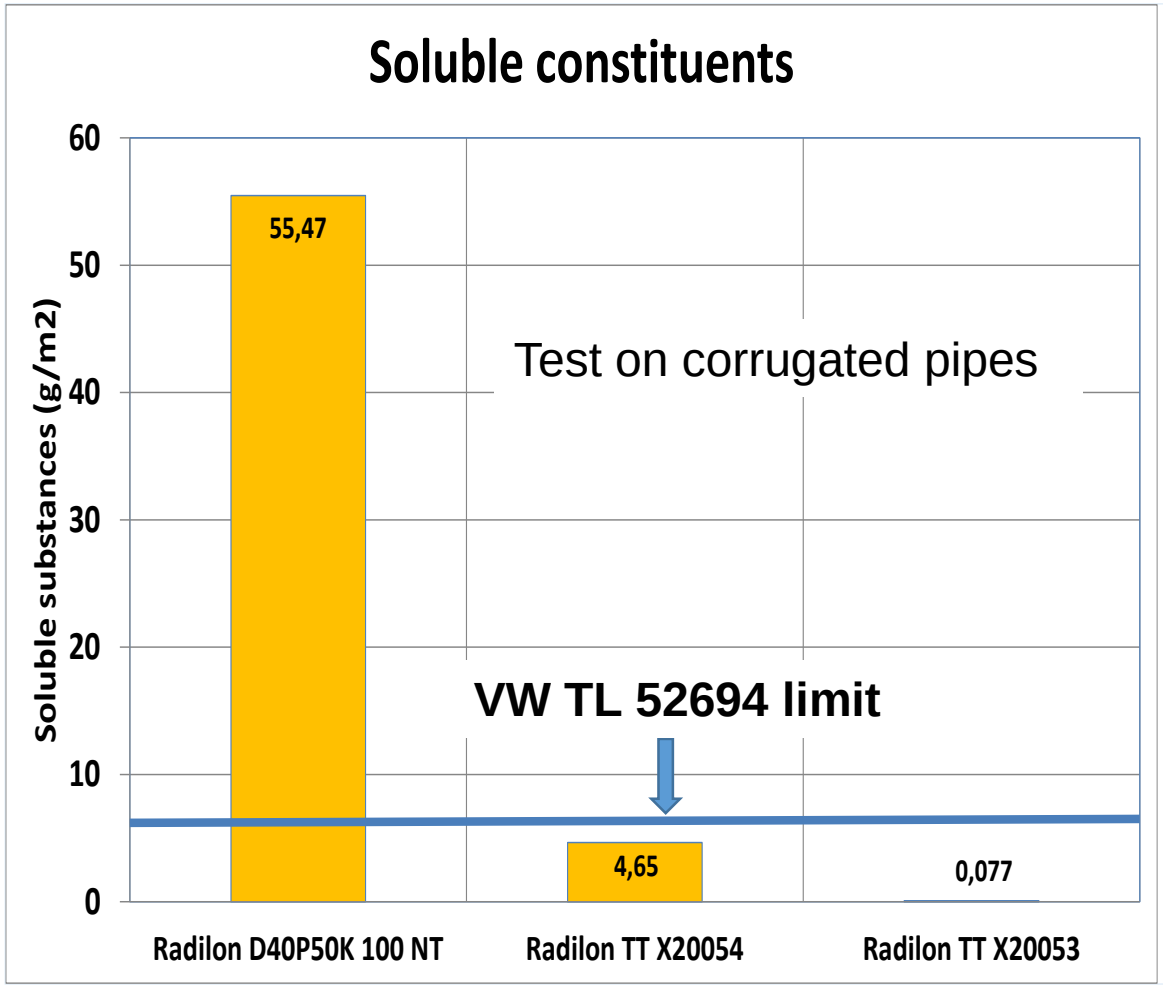
PA 10.12 with *43%* of bio-content



Castor oil seeds

1,10 - diaminodecane

PA10.12 key properties (in tank corrugated pipes)



Radilon EcoTT

- High flexibility (no plasticizers)
- Low extractable in gasoline
- Easy processing

PA1012 applications

Transparent sport soles

Main requirements :

Transparency
Flexural fatigue resistance in a cold environment
Hydrolysis resistance
Excellent flexibility at different temperatures
Colour stability

Material:

Radilon® EcoTT (PA10.12, experimental grade)

Key takeaways
Market drivers and possible opportunities with bio-polyamides

DRIVER	REQUIREMENTS	PREFERRED BIO SOLUTIONS
Sustainability	Low environmental impact vs fossil alternative that must be declared	All bio and partially bio PA
Metal replacement	Grades with high properties (mechanical & other)	PA510, PA610, PA56, other
Metal replacement in water management	Grades with excellent mechanical properties including creep, hydrolysis resistance, suitable for potable water contact	PA610, PA510
E-mobility specialties (battery enclosure, power electronics)	Grades with good electrical properties. FR properties may be requested in many cases	All bio and partially bio grades could be candidate. PA56 as PA66 alternative?
Thermal management components for EV	Excellent road salt resistance, long term hydrolysis resistance	PA610
Special grades for various industry	Transparency (air pipes, sport soles), low extractable (intank fuel lines), high flexibility without plasticizer	PA10.12

The bio-based polyamide road to sustainability: state-of-the-art & potential developments

Q&A

RADICI GROUP

HIGH PERFORMANCE POLYMERS

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THANK YOU