Development of Injection Mouldable, Durable PBS Compounds

From biodegradable towards biobased

Innoplast New York, May 25th 2017, Karin Molenveld

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Wageningen Food & Biobased Research

- Market oriented R&D approach
- Connection with the university of Wageningen
- Up-scaling: from lab to pilot
- From idea to processes and products
- Research areas:
  - Sustainable Food Chains
  - Healthy & Delicious Food
  - Biobased Products

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Biobased Performance Materials Program

- PPP, coordinating R&D activities in the Netherlands on biobased Performance Materials
- Focus on Products, Materials, Polymers, Monomers
- Initiated by Wageningen UR - Food and Biobased Research
- Unique in its construction: industrial partners participate actively from all parts of the value chain
- Sponsored by the “Topsector” Chemistry
- 9 completed and 8 running projects

biobased performance materials

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BPM2-APPS; Bio-PBS for injection moulded durable applications

- Project objective
  - Develop bio-PBS based compounds suitable for application in durable, injection moulded applications

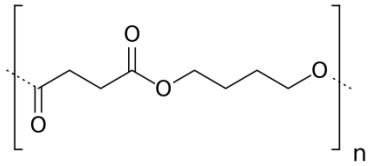
- Project members
  - WFBR Compound development, compounding
  - Reverdia Bio-PBS supply, compound development
  - RPC Promens Reusable transport packaging for agriculture
  - Teamplast Packaging and hinge caps

WAGENINGEN UNIVERSITY & RESEARCH reverdia RPC PROMENS Teamplast opening solutions

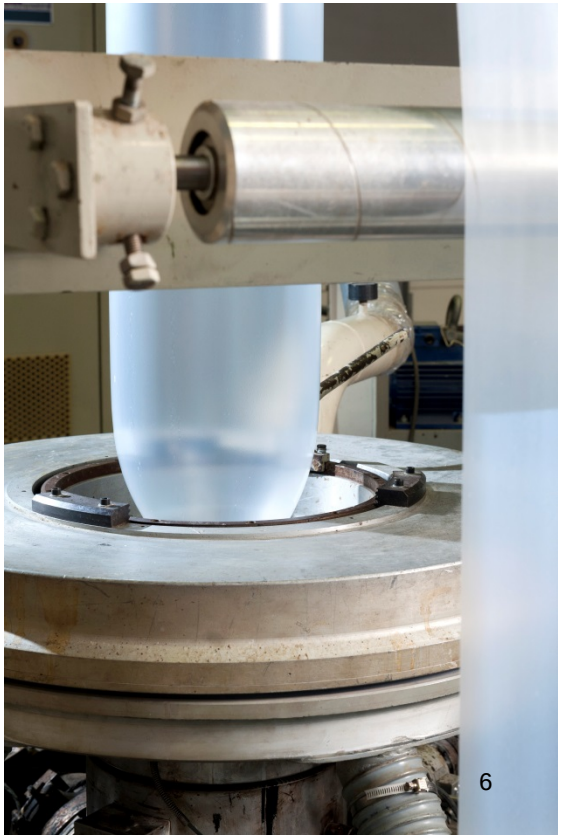
Specific properties needed

- PP replacement
- Excellent processing properties
    - Cycle time
    - Flow length
- Sufficient stiffness
- Durable (> 25 years)
- High toughness (at low temperatures)

PBS, PolyButylene Succinate



- Aliphatic polyester originally fossil based
  - Based on succinic acid and butane diol
- Semi-crystalline, non-transparent
- Niche polymer, small production scale
- Biodegradable products
  - (Mulch) film
  - Disposables
  - Other agricultural applications
  - Blend component (starch, PLA)



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PBS as a PP or HDPE replacement

Property	PP	HDPE	PBS
Tg (°C)	-5	-120	-30
Tm (°C)	163	130	115
HDT (°C)	110	82	97
E-Modulus (MPa)	1300	1000	700
Tensile strength (MPa)	33	28	34
Elongation at break (%)	415	700	560

Ishioka et al. 2002

Bio-PBS, current interests in IM

- Good injection moulding characteristics
  - Mould shrinkage close to PP
  - Fast crystallisation, similar to PP
  - Short cycle times possible
- Well balanced mechanical properties
  - Good impact resistance (> 9 kJ/m^2)
  - Good elongation (~ 600 %)
  - Rather low stiffness (~ 700 MPa)
- Good thermal properties
  - Heat deflection temperature > 80°C

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Development of bio-PBS

- Bio-succinic acid is an important platform chemical
- Biobased succinic acid has an excellent environmental footprint
- Most efficient production with respect to biomass use
- Other applications for succinic acid as a building block
  - Resins (adhesives, printing inks, paints and coatings)
  - PU foams (insulation, seats)
  - TPU (automotive interior and sealing, construction, footwear)
  - Plasticisers (biopolymers, footwear, food packaging)

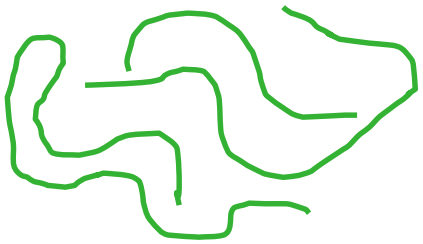
From biodegradable towards biobased PBS

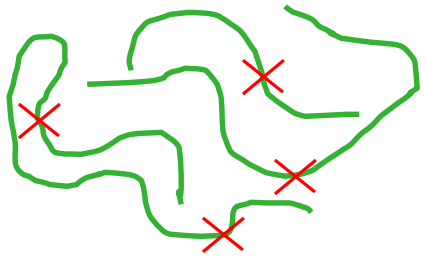
- Biodegradable
  - Biodegradation rate
  - Reducing crystallinity
  - Copolymers (PBSA)
  - Film production
  - Low E-modulus
  - Low to medium MFI

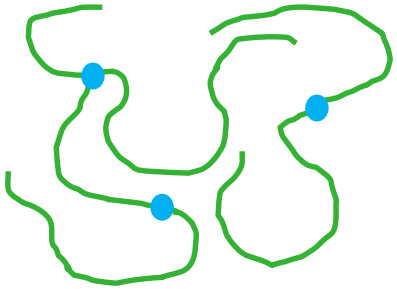
- Biobased
  - Stabilisation
  - Improving performance
  - Additives
  - Injection moulding
  - Moderate E-modulus
  - High MFI

Durability

- Replacing a polyolefin with a polyester
  - Polyesters are susceptible for hydrolysis
  - Largely depending on environmental conditions
  - Effect of end-groups
  - Various options for repair (chain extension)







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Durability approach

- Commercially available IM grade bio-PBS
- Selection of commercial available additives commonly used in polyesters
    - Compounds with various stabiliser loadings
    - Ageing (50°C/50%RH and 70°C/80% RH)
    - Measurement of properties in time
        - Molar mass
        - Mechanical properties
- Comparison with ageing curves of other polyesters

Effect of stabilisers on properties

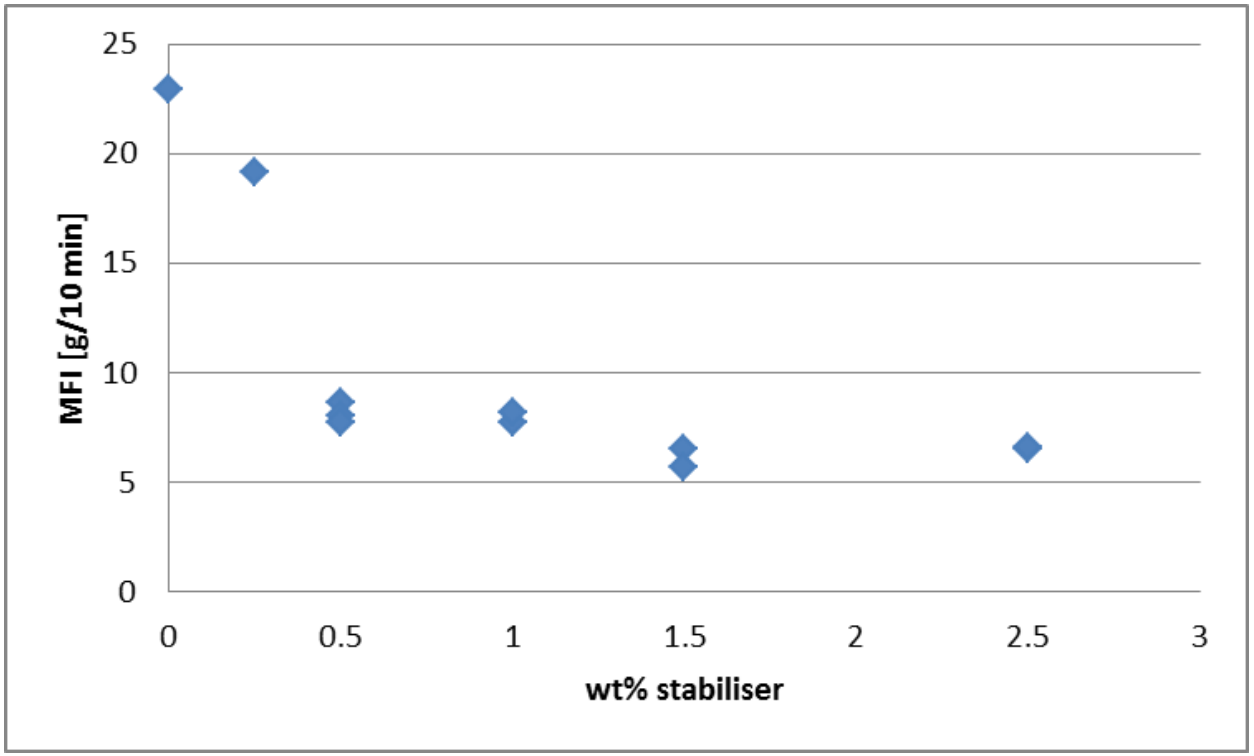
- Stabiliser loading @ 1wt%

Property	Bio-PBS	Stab A	Stab B	Stab C
Mw (kg/mol)*	84	81	111	95
E-modulus (MPa)	697 (10)	691 (7)	668 (11)	705 (19)
Tensile strength (MPa)	38 (0.2)	38 (2.8)	43 (1.1)	40 (1.5)
Elong. at break (%)	450 (93)	526 (99)	547 (52)	454 (34)
Izod Notched (kJ/m^2)	8.2 (3.3)	10.9 (0.7)	12.4 (1.5)	10.8 (1.5)

** Absolute molar mass via tri-sec GPC, HFIP solvent*

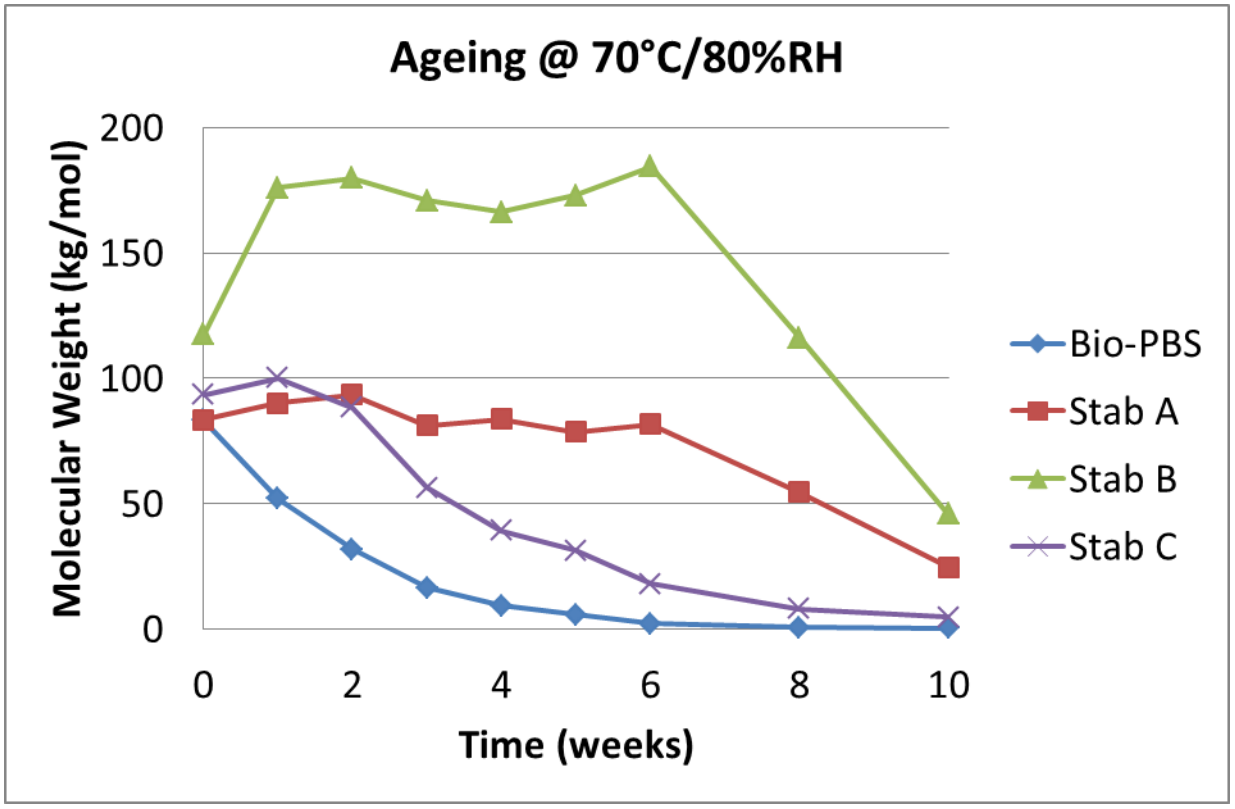
Effect of stabilisers on MFI

- Stabiliser inducing crosslinking with available end-groups

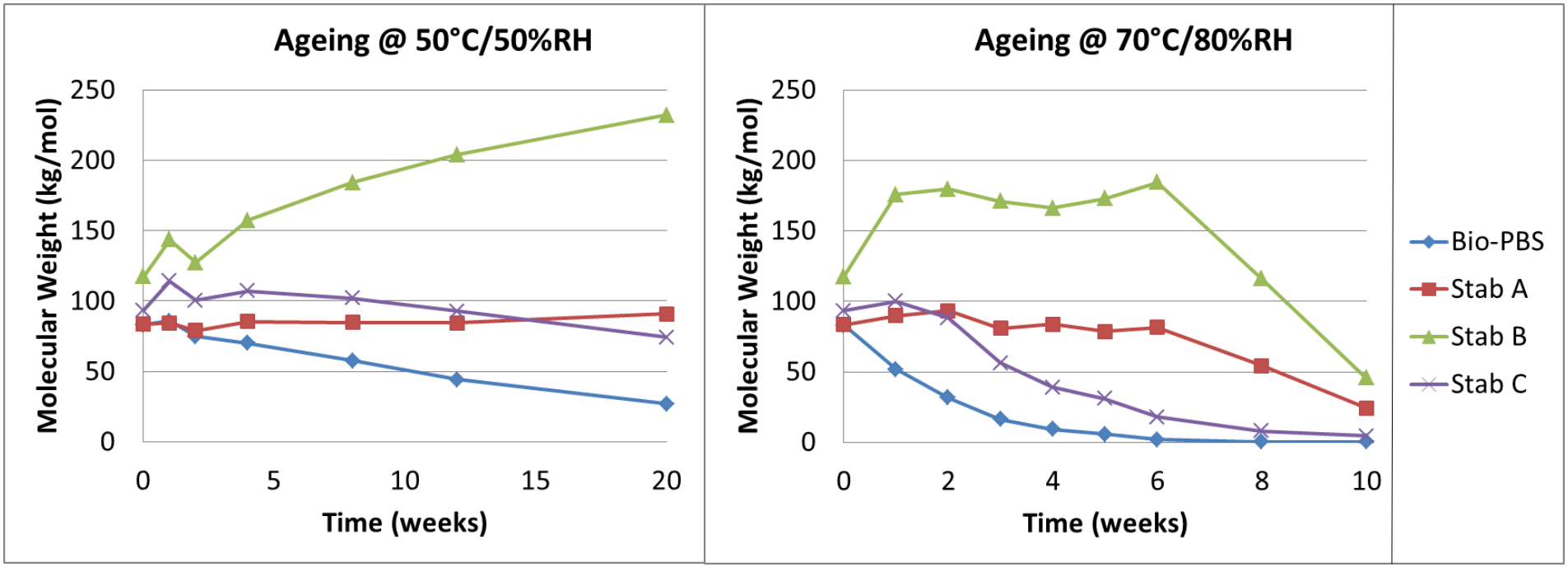


MFI @ 190°C, 2,16 kg

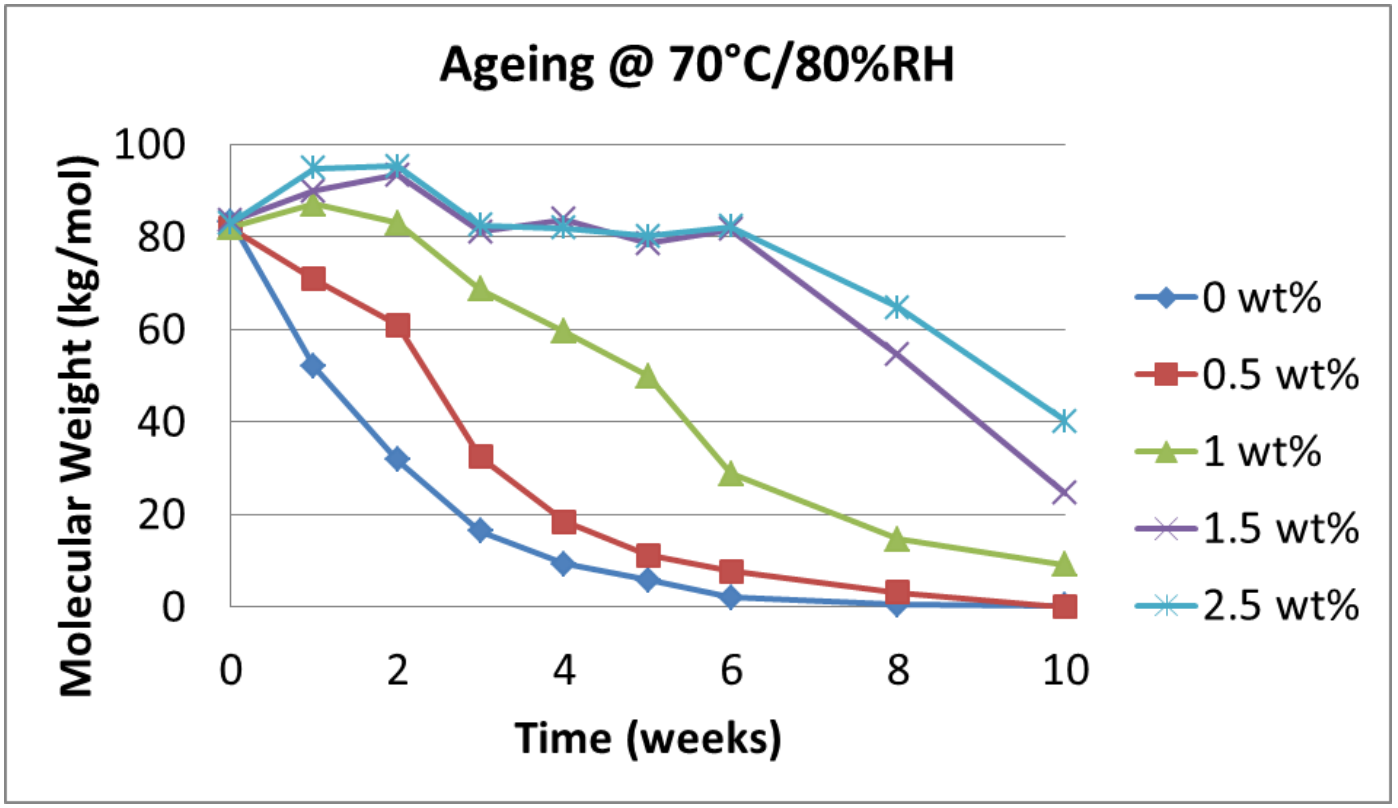
Ageing comparing 3 different stabilisers



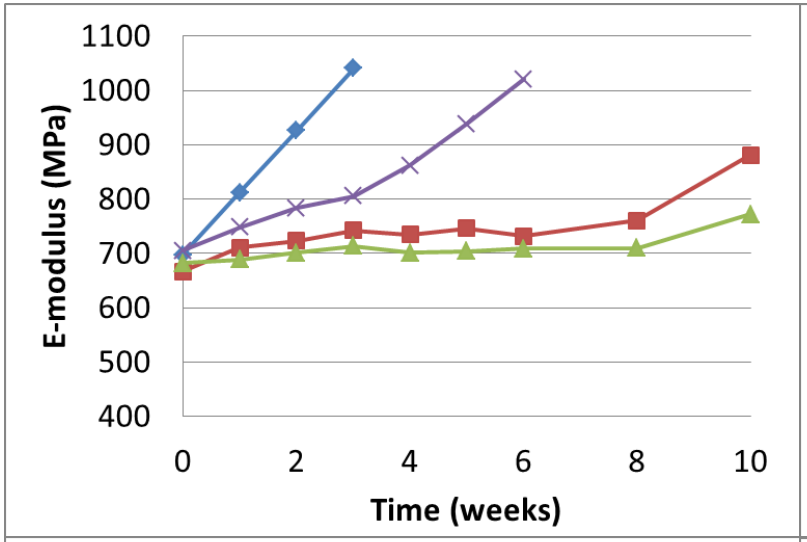
Effect of ageing conditions

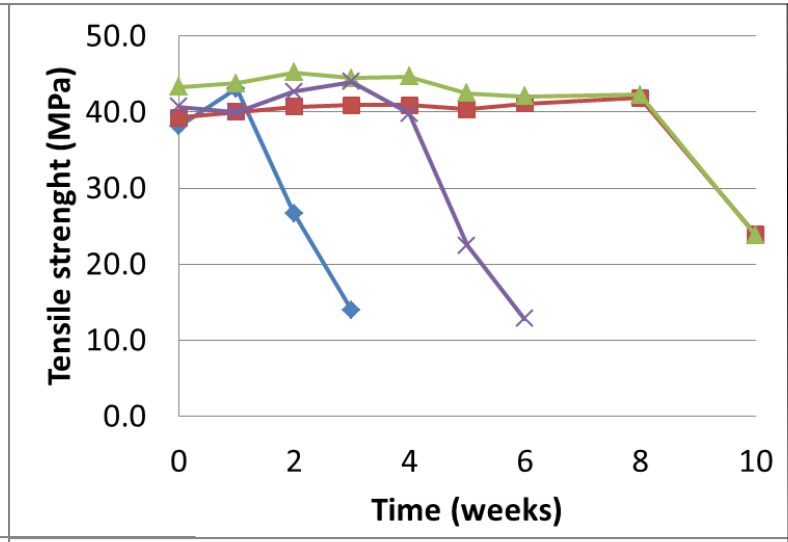


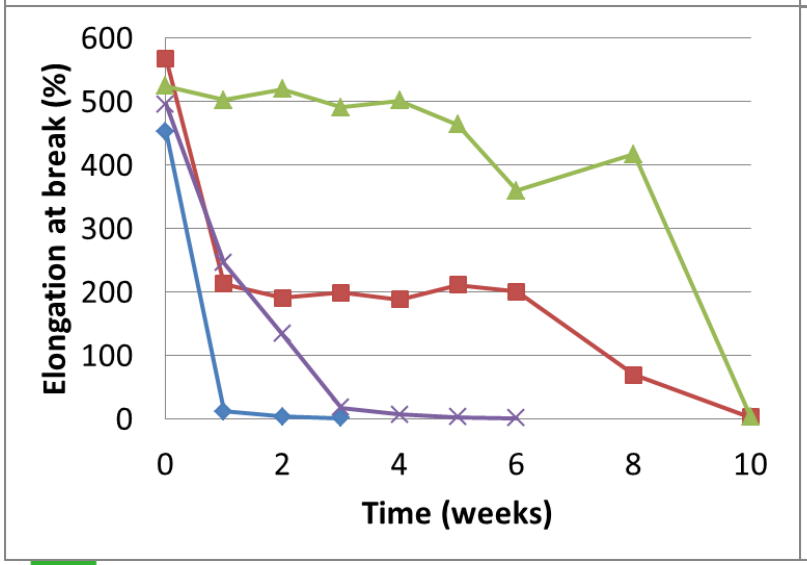
Effect of stabiliser loading

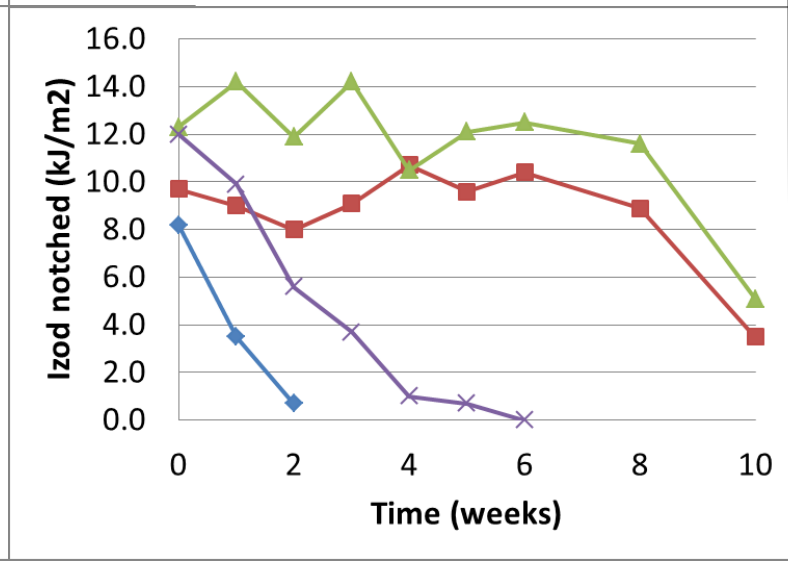


Effect on mechanical properties









Results & Conclusions

- Bio-PBS can be stabilised using commercially available additives
- Stabiliser selection can depend on application (influence on MFI)
- Comparing with databases durability > 25 years at ambient conditions is achieved
- In combination with other favourable properties replacement of PP and HDPE by bio-PBS is feasible

Thank you for your attention

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