Valorization of natural polymers from waste into biocomposites

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In 2016 in Europe
55 Millions tons of vegetable waste

Food biomass valorization

- Composting
  - cheap processing
  - low added value
- Animal feed
  - low income
- Biorefinery
  - biogas
  - chemicals
  - biopolymers (PHAs, PLA)

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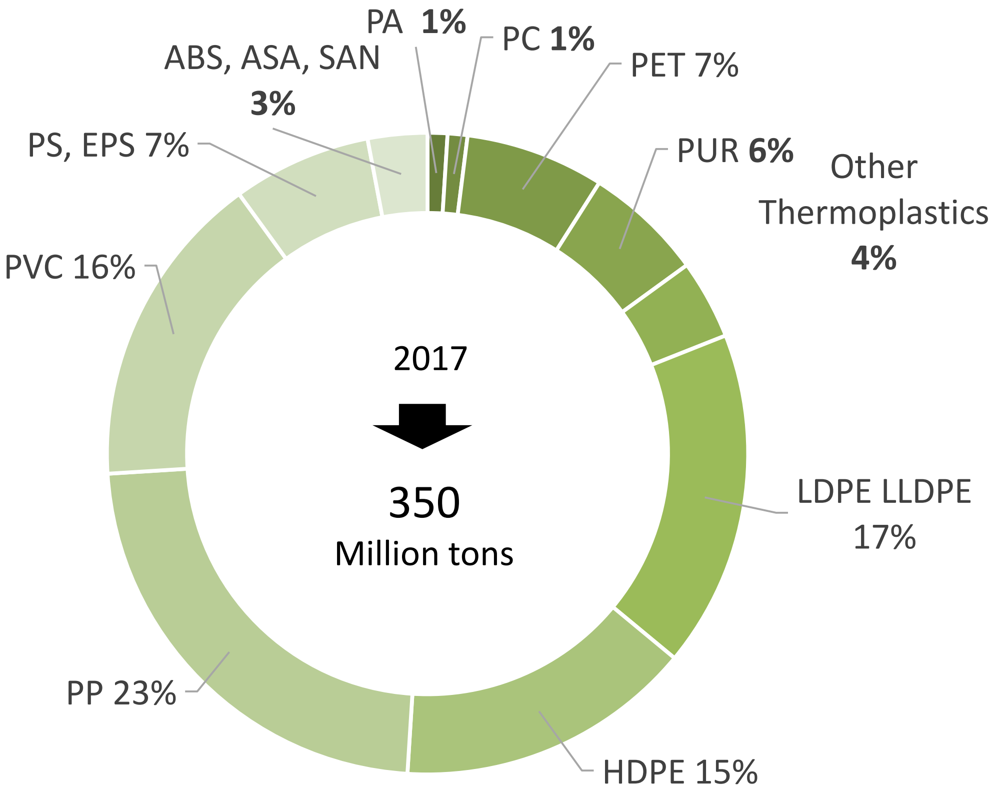
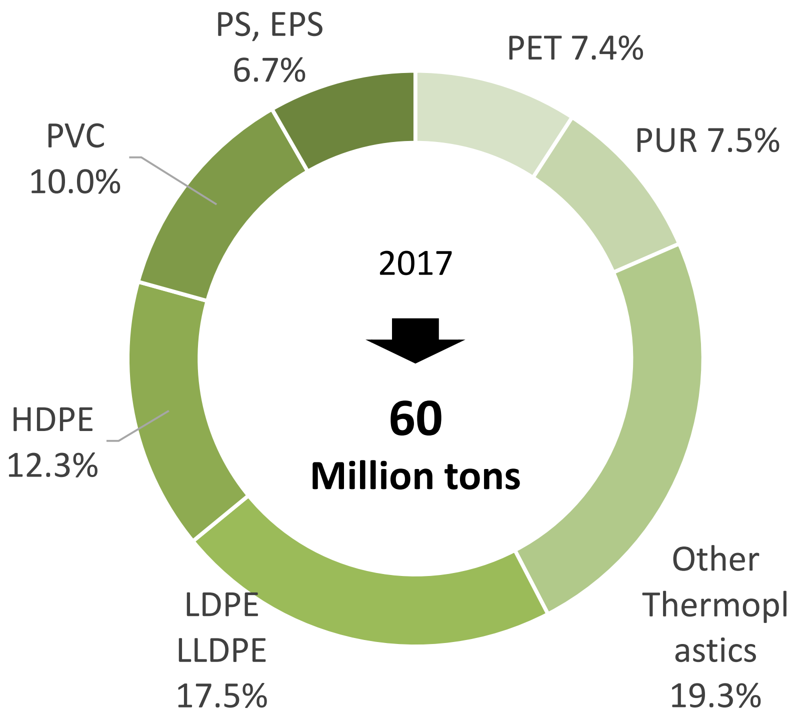
Global Plastics Market

GLOBAL PLASTICS DEMAND 2015 by type



Source: Nòva-Sole24Ore

EUROPE PLASTICS DEMAND 2017 by type



Source: PlasticsEurope Market Research Group (PEMRG) and Conversio Market & Strategy GmbH

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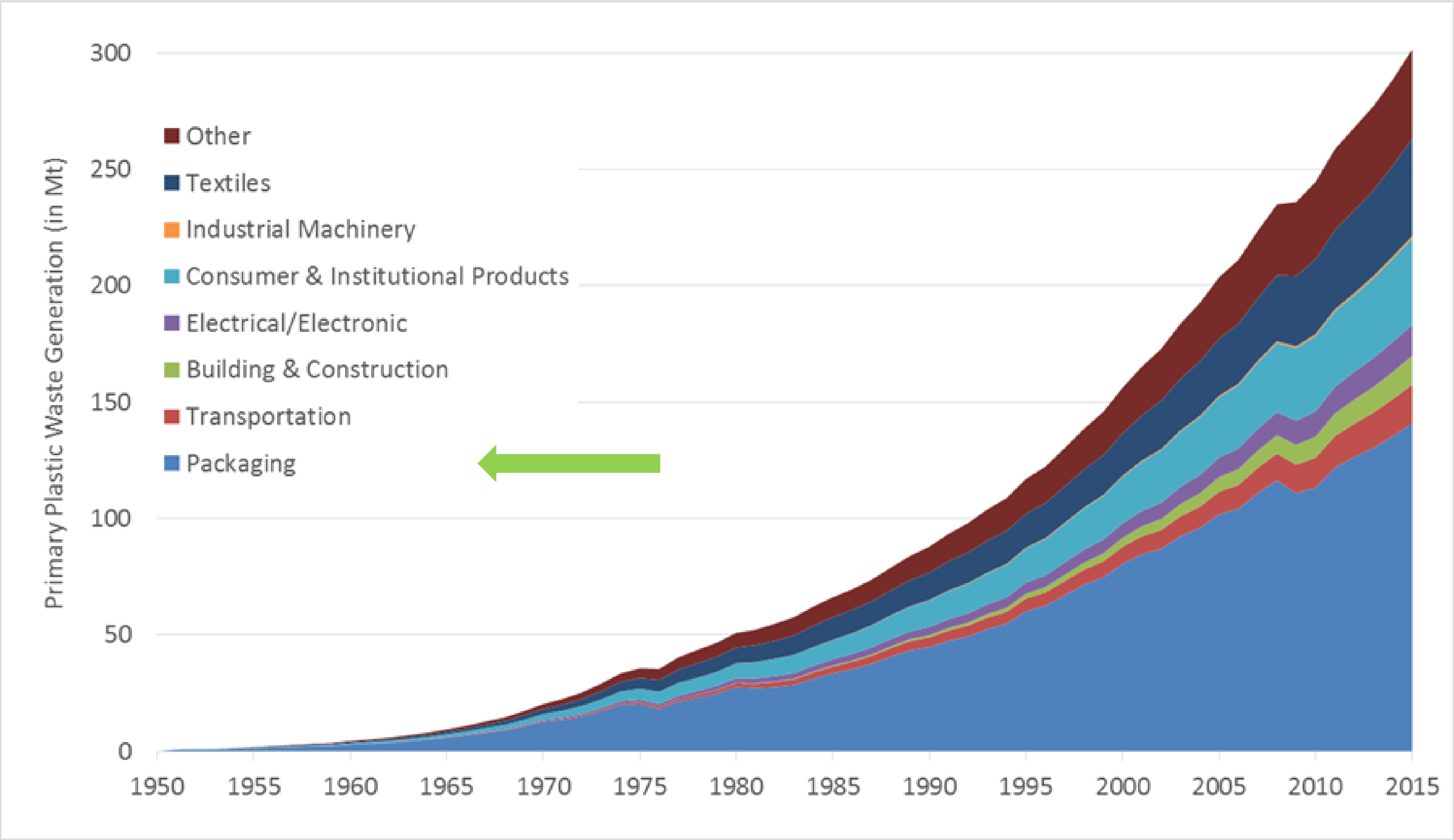
Global Plastic Waste production

Packaging represents 40% of the plastic consumption



Geyer, Jambeck, **Law,** Production, use, and fate of all plastics ever made**,** *Science Advances,* 2017

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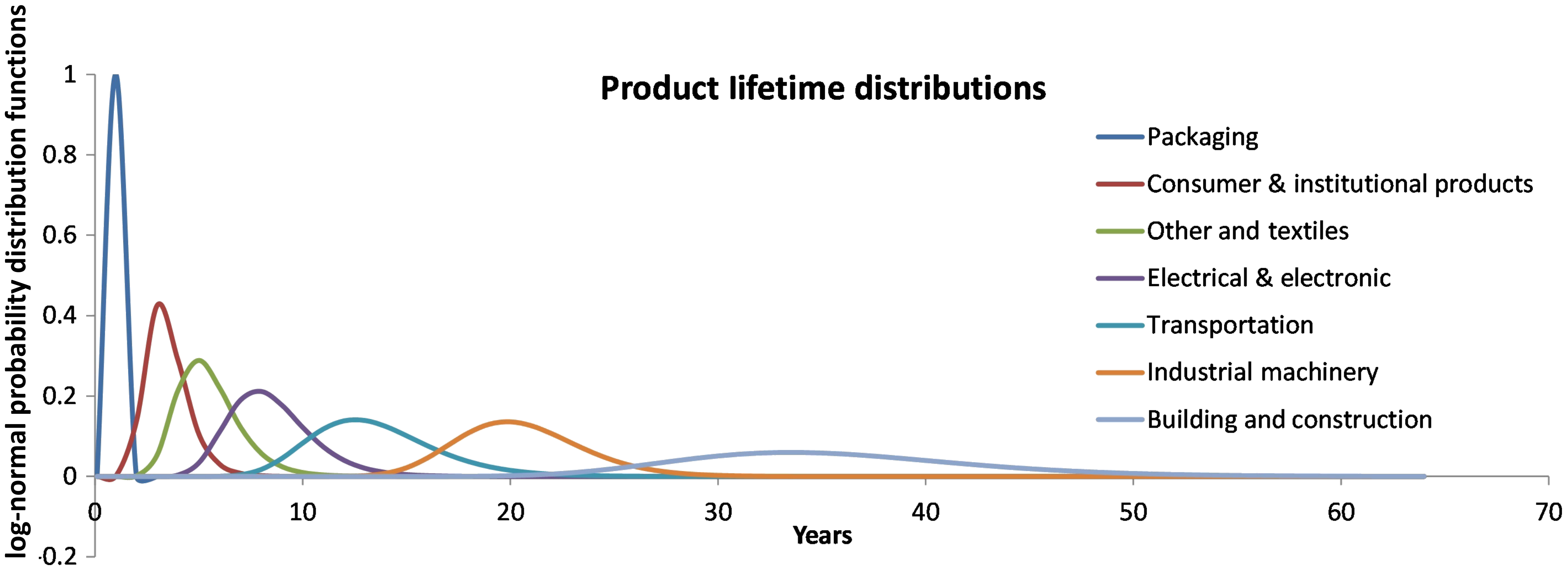
Lifetime of plastic products



Geyer, Jambeck, **Law,** Production, use, and fate of all plastics ever made**,** *Science Advances,* 2017

Bioplastics

- Natural polymers
  - Thermoplastic starch
  - Cellulose (acetate, nitrocellulose)

Use of "noble" resources
Reduced biodegradability

- Polymers from renewable resources
  - PolyLacticAcid
  - PHAs

Require complicated processing
Expensive

- Synthetic biodegradable
  - Polyadipate
  - PCL

Fossil fuel raw materials

Desiderata

- Use of waste instead of the edible portion
- Minimal processing
- No harsh chemicals
- High waste to bioplastic conversion efficiency
- Useful final properties

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100 % VEGETABLE-BIOCOMPOSITE FILMS

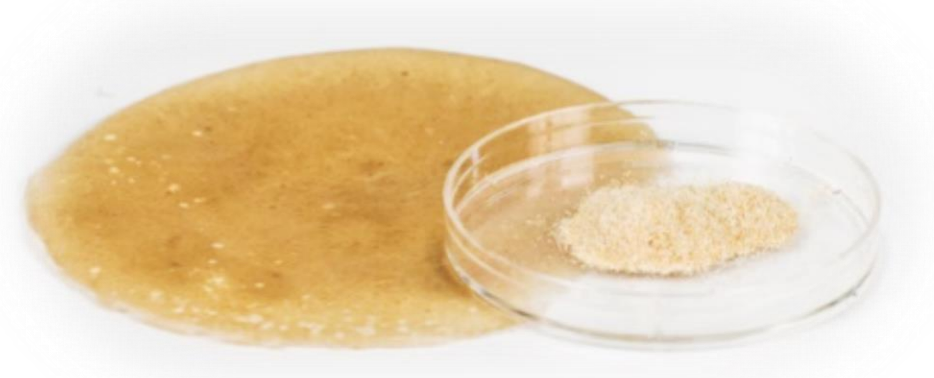
Trust The Process

Acidic pH

40 °C, 12 hours

Neutralization
- dialysis
- NaOH
- CO_3^{2-}
- evaporation

Casting
& overnight drying



Perotto et al, Bioplastics from vegetable waste via an eco-friendly water-based process; *Green Chemistry,* 2018

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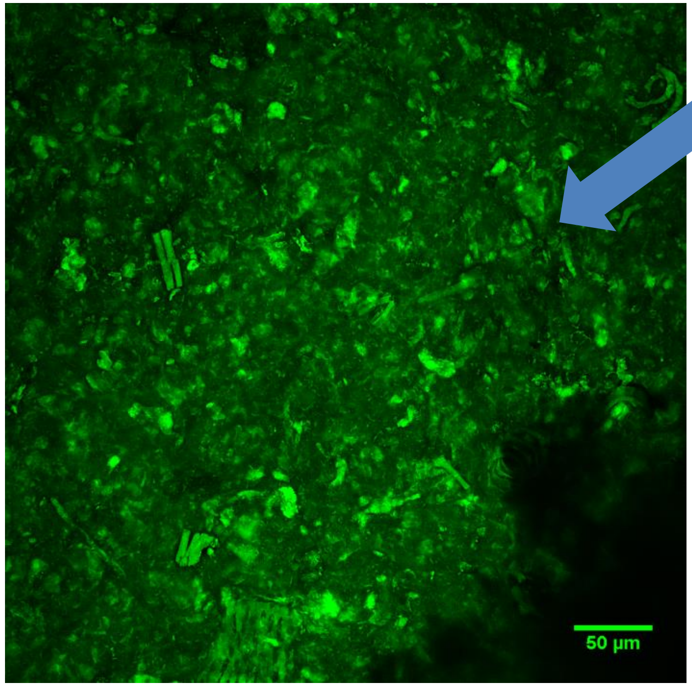
We made it!

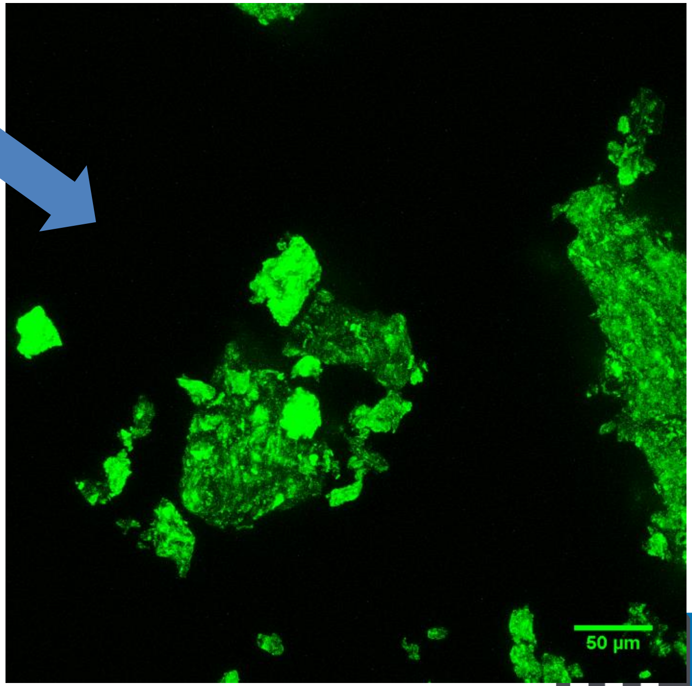
Perotto et al, *Green Chemistry,* 2018

Bioplastic film structure

Carrot bioplastic



Carrot waste powder



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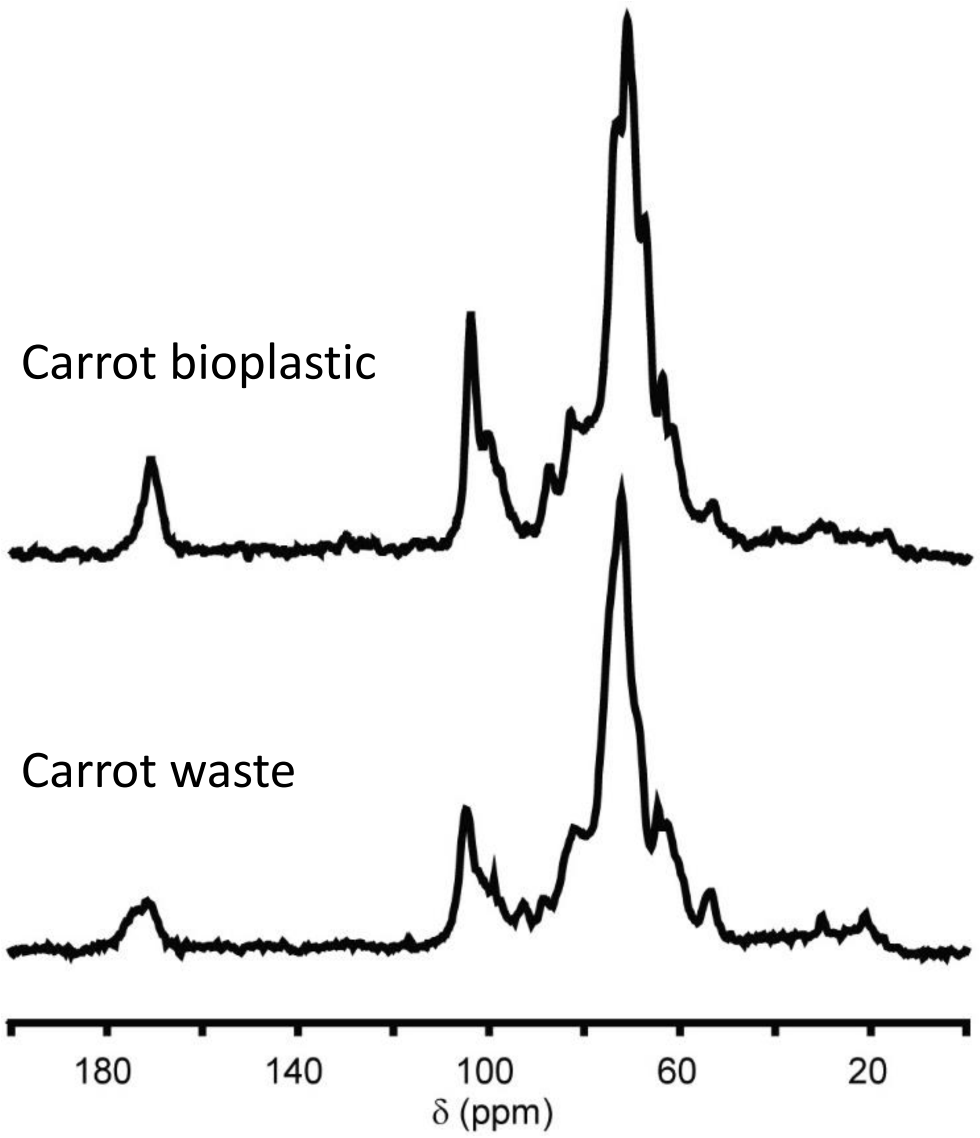
^{13}C CP-MAS NMR



Comparing carrot powder and carrot bioplastic

- Bioplastic film has the C-peaks related to cellulose more pronounced and sharp
  - *Cellulose is "more crystalline"*
- The C-peaks related to pectin are in their de-esterified form
  - *Production of low methoxyl pectin*

- Partial hydrolysis of the non-crystalline part of cellulose and de-methoxylation of pectin
- **Amorphous polysaccharides will become the soft matrix, isolated crystalline cellulose will be the hard filler**

Perotto et al, Bioplastics from vegetable waste via an eco-friendly water-based process; *Green Chemistry,* 2018

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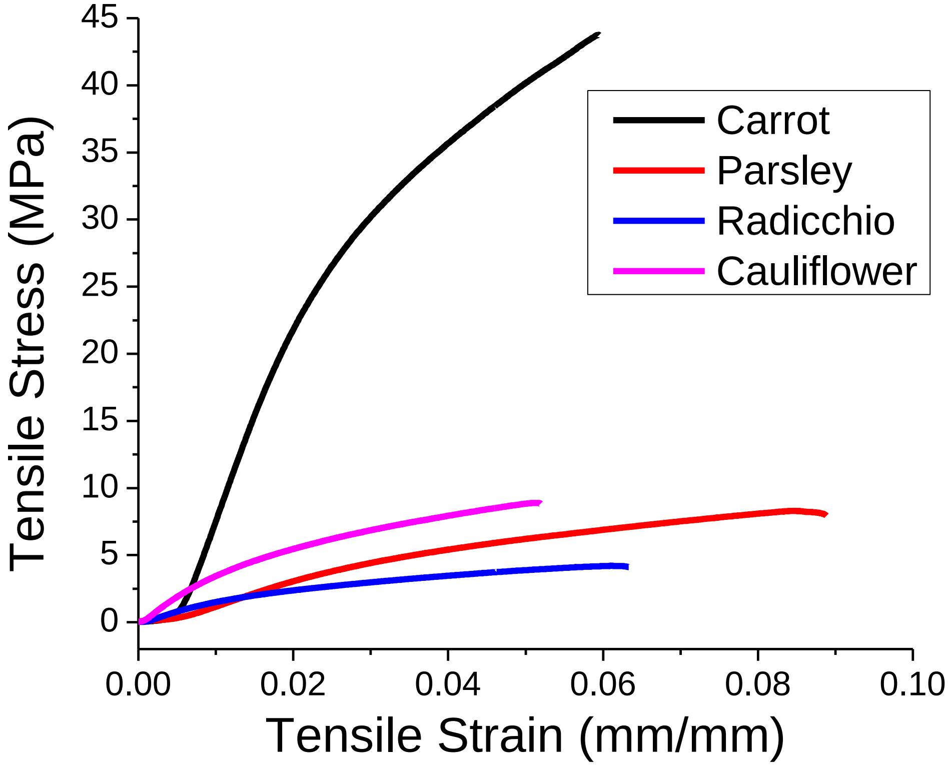
Is it good for something?

RESULTS

Mechanical properties of bioplastics



Sample	Young Modulus (MPa)	Elongation at break (mm/mm)	UTS (MPa)
Carrot	1300 ± 200	0.058 ± 0.008	38 ± 5
Parsley	180 ± 50	0.10 ±0.02	8.0 ± 0.4
Radicchio	230 ± 40	0.05 ±0.01	4.4 ± 0.4
Cauliflower	470 ± 80	0.04 ± 0.01	10.0 ± 0.9

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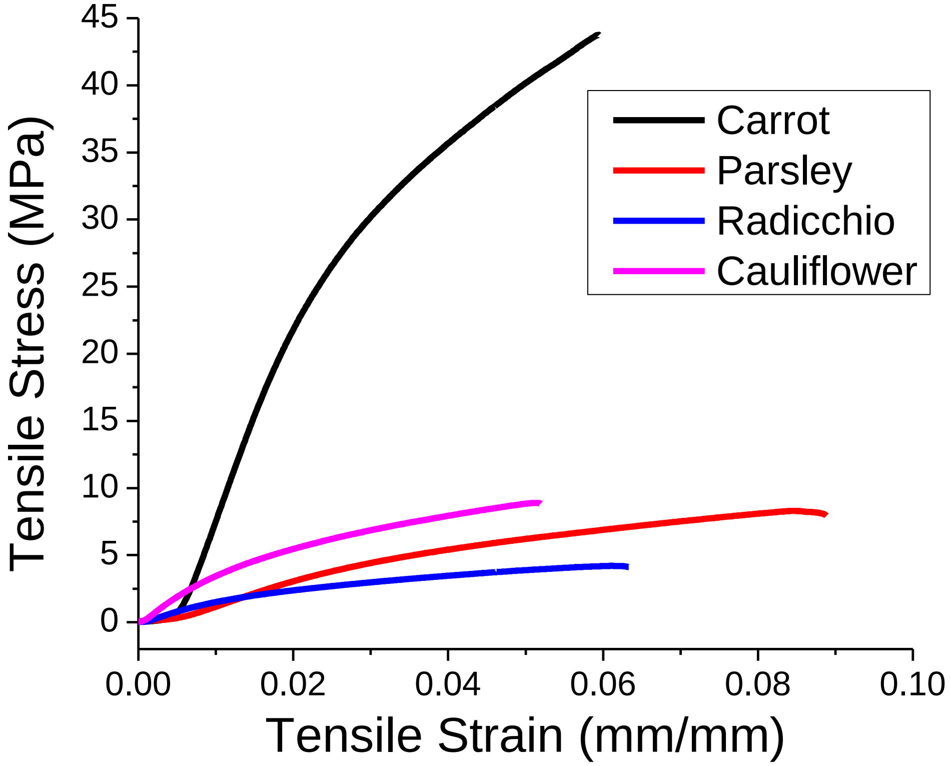
Mechanical properties of bioplastics



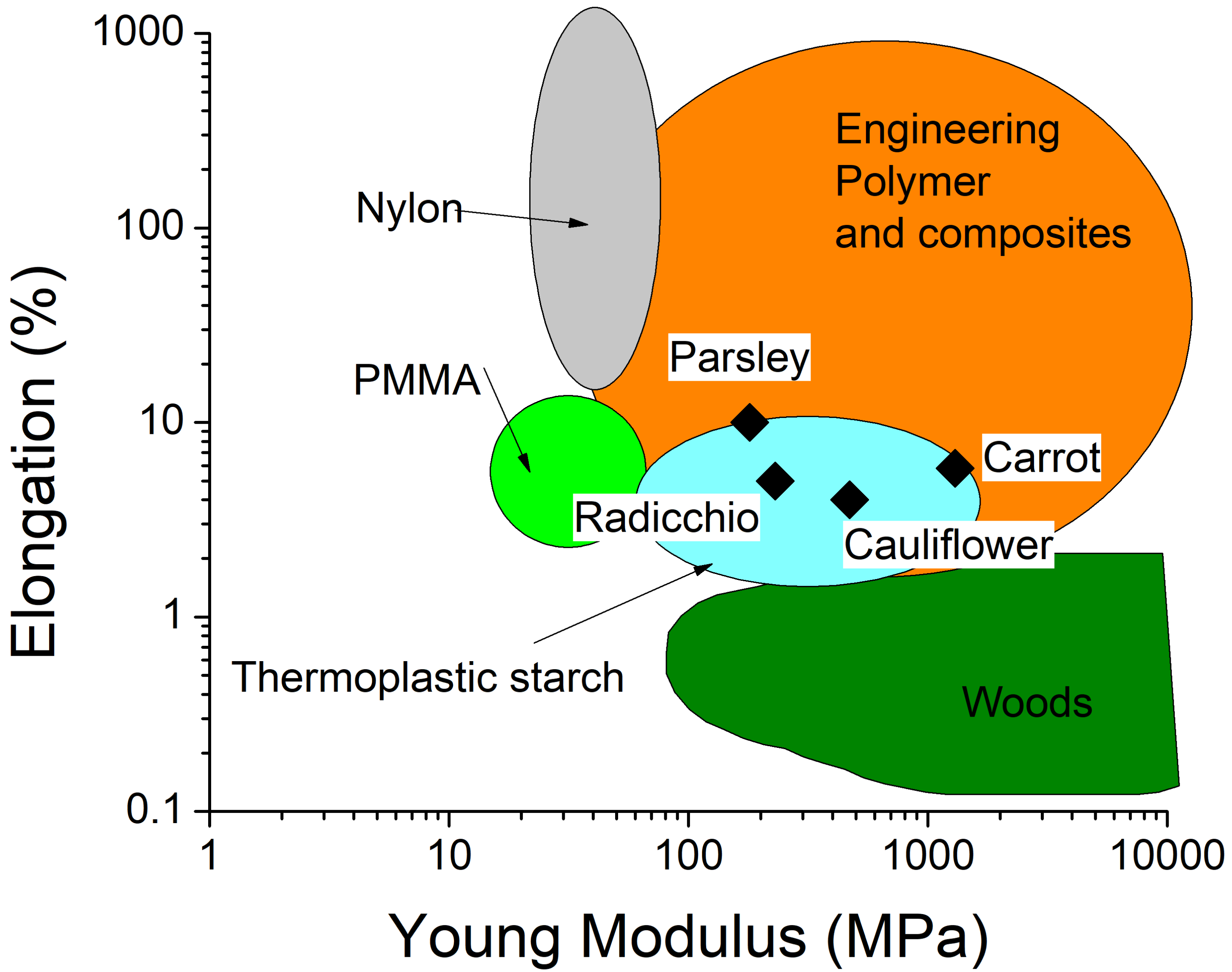
Sample	Young Modulus (MPa)	Elongation at break (mm/mm)	UTS (MPa)
Carrot	1300 ± 200	0.058 ± 0.008	38 ± 5
Parsley	180 ± 50	0.10 ±0.02	8.0 ± 0.4
Radicchio	230 ± 40	0.05 ±0.01	4.4 ± 0.4
Cauliflower	470 ± 80	0.04 ± 0.01	10.0 ± 0.9

Bioplastic composition

	Cellulose % (mol)	Pectin % (mol)	Hemicellulose % (mol)	Aliphatic polyesters % (mol)
Carrot	61	28	8	3
Parsley	48	31	15	6
Radicchio	44	34	4	18
Cauliflower	46	24	9	21

Perotto et al, Bioplastics from

Mechanical properties



Perotto et al, Bioplasti

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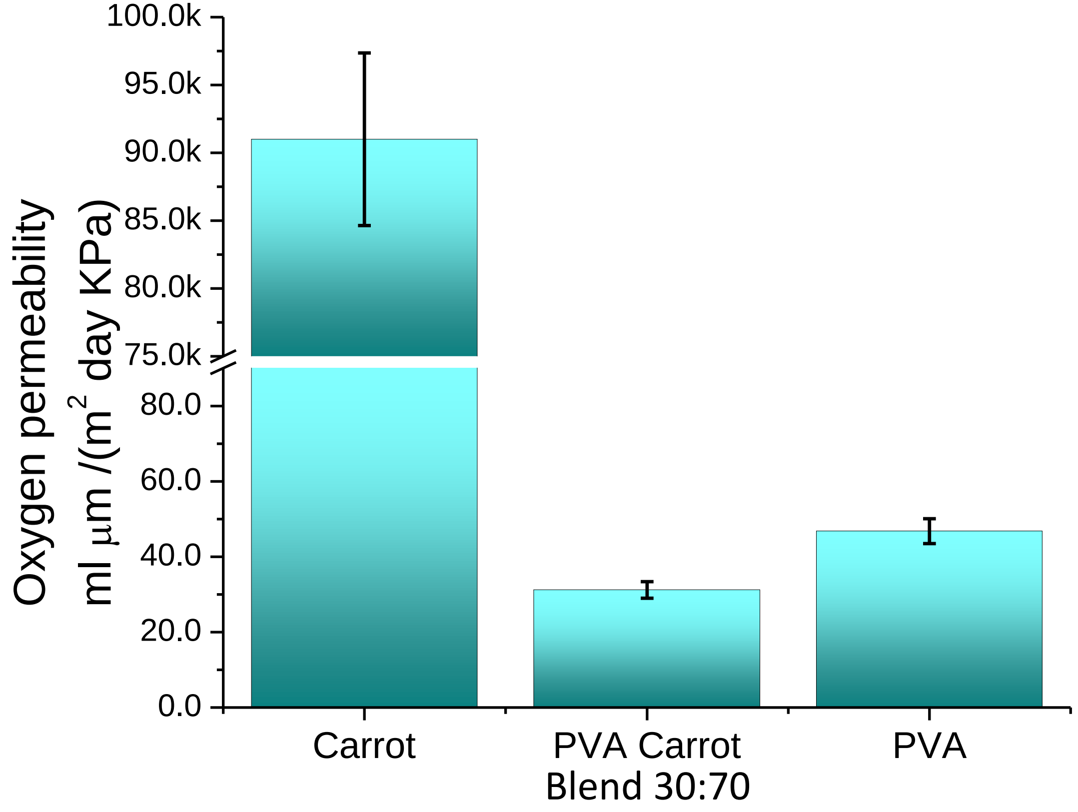
Packaging

Oxygen Permeability

Blending with PVA greatly helps!



Migration in food

Tenax® used as dry food simulant
2 hours @ 70 °C

	Overall Migration (mg/dm^2)
Carrot	3.5 ± 0.7
Parsley	2.8 ± 0.7
Radicchio	1.7 ± 0.5
Cauliflower	1.8 ± 0.4

EU limit: 10 mg/dm^2

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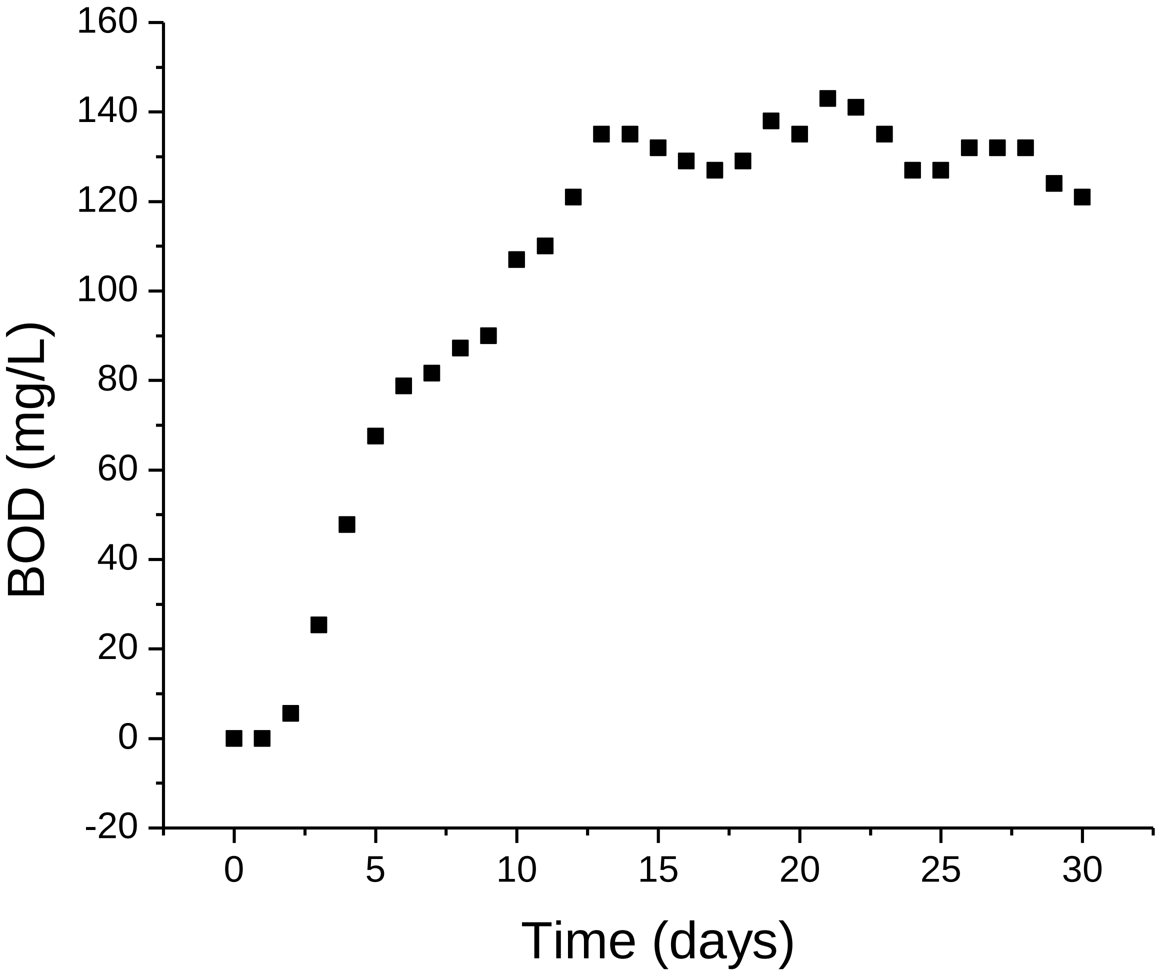
Biodegradability



Conclusion

- Simple processing
- Non vegetable-specific
- Mechanical properties similar to other biosource-derived plastics
- Structure is homocomposite of pectin-hemicellulose-cellulose
- Can be easily combined with other polymers to produce blends
- Safe for dry food contact
- Interesting for packaging applications
- Biodegradability is preserved

Aknowledgements

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MARS deutschland

SGM società gestione mercato

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THANK YOU!