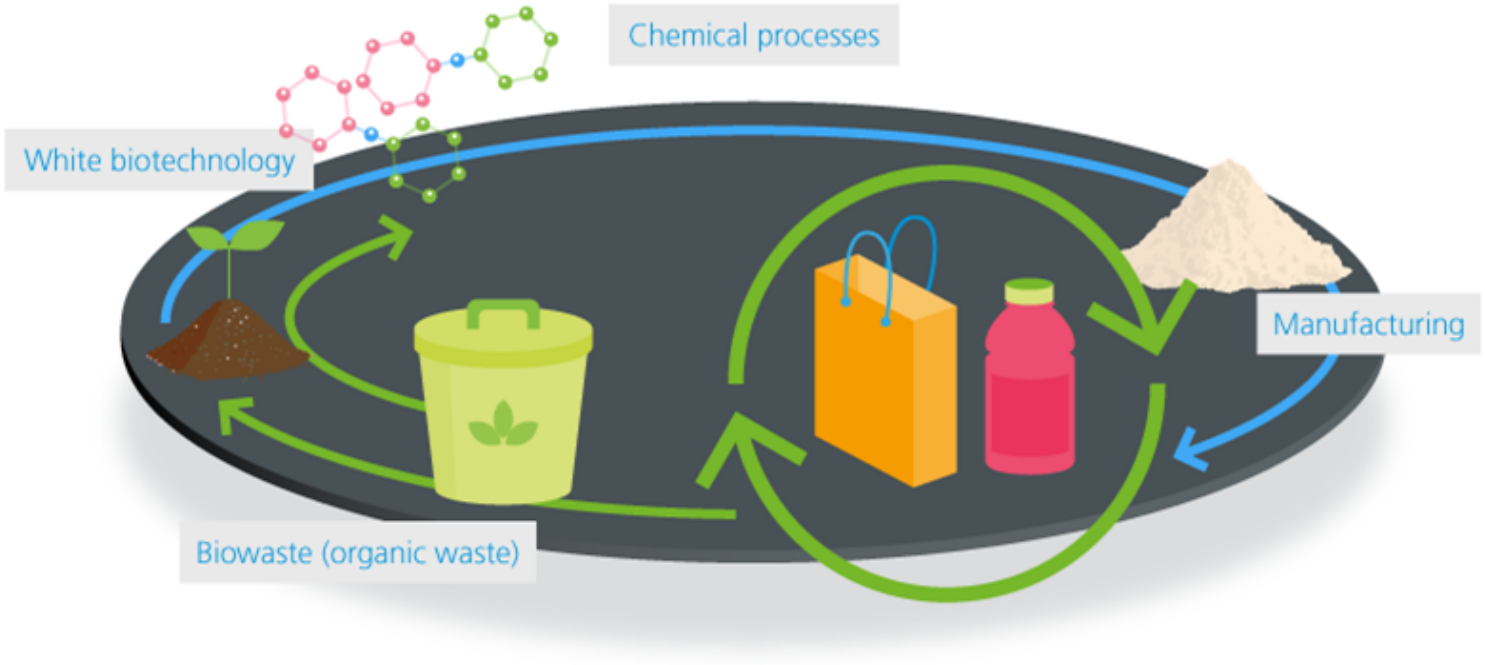
Bioplastics and other alternatives of plastics



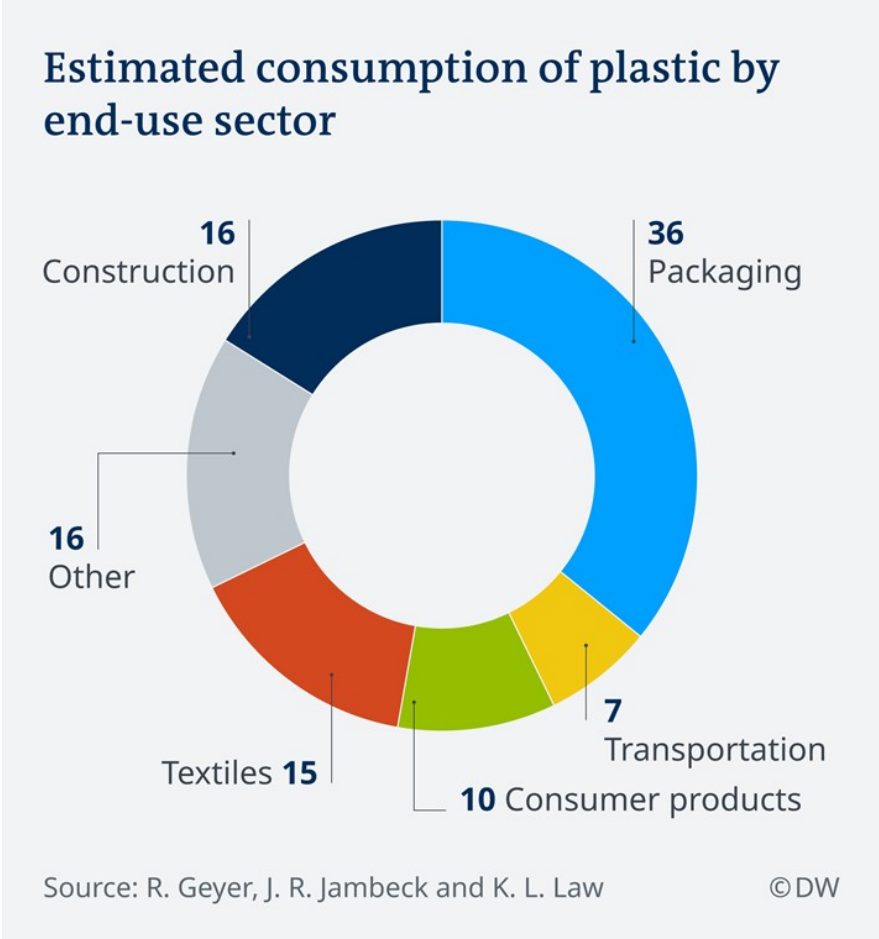
Helena Pokorná
Marie Ptáčková

Brief history of plastics

- Plastics are a wide range of synthetic or semi-synthetic materials that use polymers as a main ingredient

- Organic polymers
- Chemical modification of organic polymers
- Completely synthetic plastics

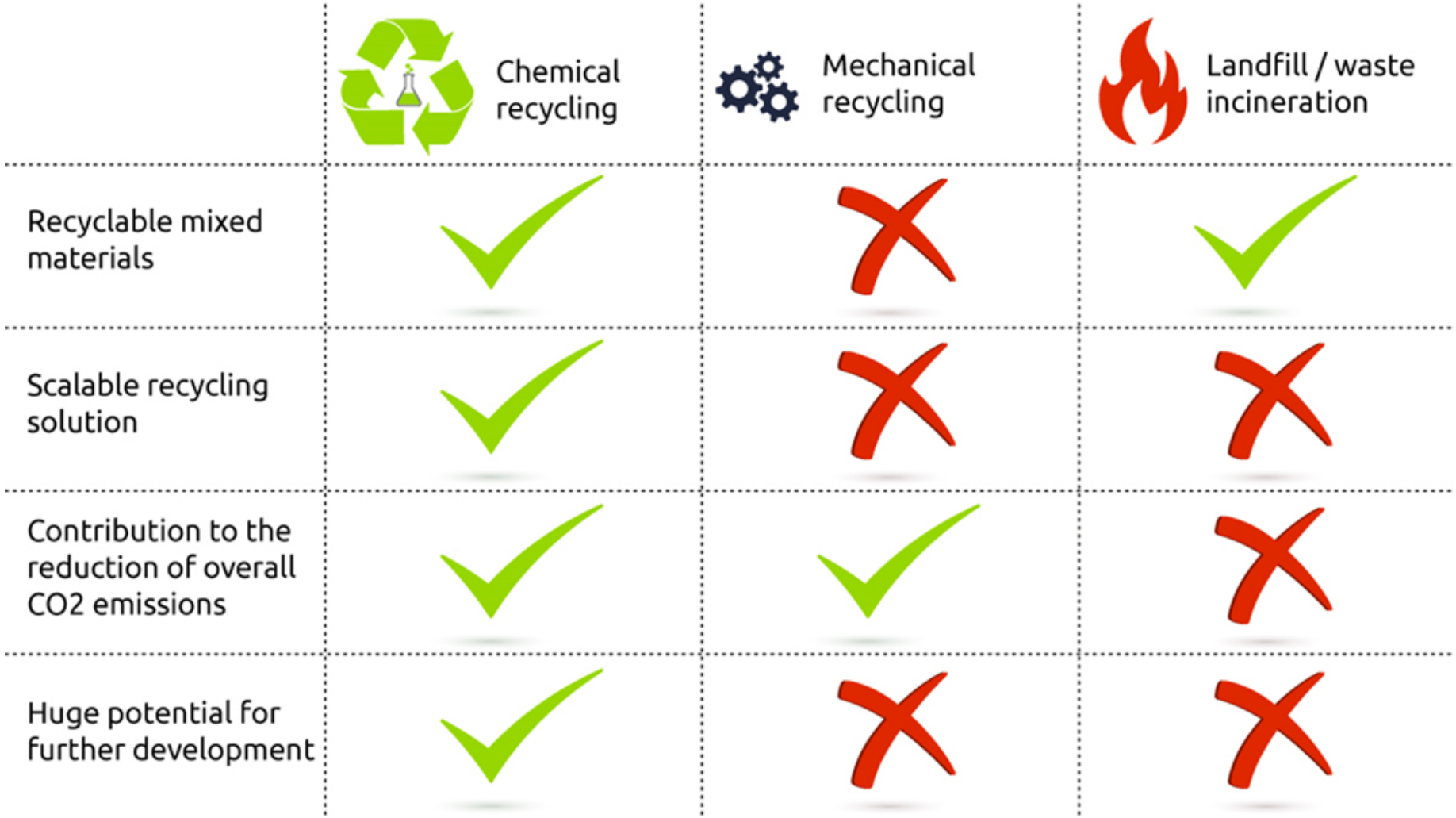
- 1839 - discovery of vulcanization process (Charles Goodyear)
- 1907 - the world's first fully synthetic plastic Bakelite (Leo Baekeland)



Environmental effects of using plastics

- Plastics are resistant to many natural degradation processes
- Problematic of microplastics

Solution of plastics pollution - Recycling



Solution of plastics pollution - Decomposition of plastics

- Photo-oxidation process
- Decomposition of plastics by various types of bacteria, fungi or larvae

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Appl Environ Microbiol. 2011 Sep; 77(17): 6076–6084.
doi: 10.1128/AEM.00521-11
PMCID: PMC3165411
PMID: 21764951

Biodegradation of Polyester Polyurethane by Endophytic Fungi

Jonathan R. Russell,[1,#] Jeffrey Huang,[1,#] Pria Anand,[1,#] Kaury Kucera,[1] Amanda G. Sandoval,[1] Kathleen W. Dantzler,[1] DaShawn Hickman,[1] Justin Jee,[1] Farrah M. Kimovec,[1] David Koppstein,[1] Daniel H. Marks,[1] Paul A. Mittermiller,[1] Salvador Joel Núñez,[1] Marina Santiago,[1] Maria A. Townes,[1] Michael Vishnevetsky,[1] Neely E. Williams,[1] Mario Percy Núñez Vargas,[2] Lori-Ann Boulanger,[1] Carol Bascom-Slack,[1] and Scott A. Strobel[1,*]

ELSEVIER

Environment International
Volume 145, December 2020, 106106

Biodegradation of Polyvinyl Chloride (PVC) in *Tenebrio molitor* (Coleoptera: Tenebrionidae) larvae

Bo-Yu Peng [a], Zhibin Chen [a], Jiabin Chen [a], Huarong Yu [b], Xuefei Zhou [a], Craig S. Criddle [b], Wei-Min Wu [b] ✉, Yalei Zhang [a] ✉

International Journal of *Molecular Sciences*

MDPI

Review

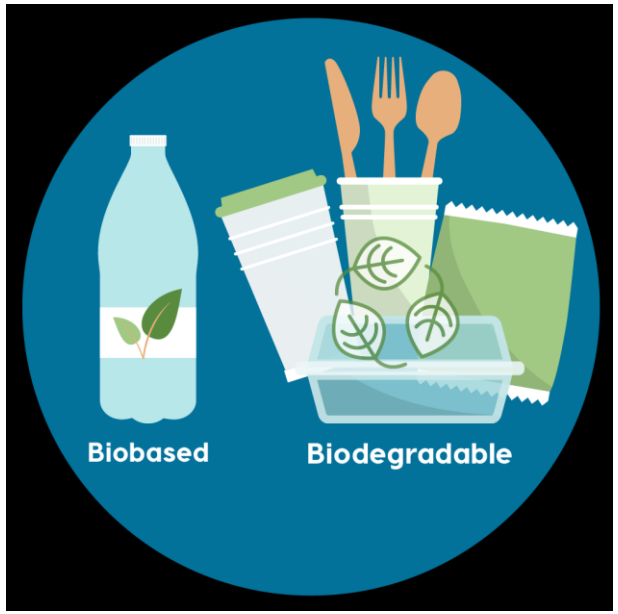
Plastic Degradation by Extremophilic Bacteria

Nikolina Atanasova, Stoyanka Stoitsova, Tsvetelina Paunova-Krasteva and Margarita Kambourova *

Stephan Angeloff Institute of Microbiology, Bulgarian Academy of Sciences, Acad. G. Bonchev str. Bl. 26, 1113 Sofia, Bulgaria; nikolina@microbio.bas.bg (N.A.); stoitsova_microbiobas@yahoo.com (S.S.); pauny@abv.bg (T.P.-K.)
* Correspondence: margikam@microbio.bas.bg

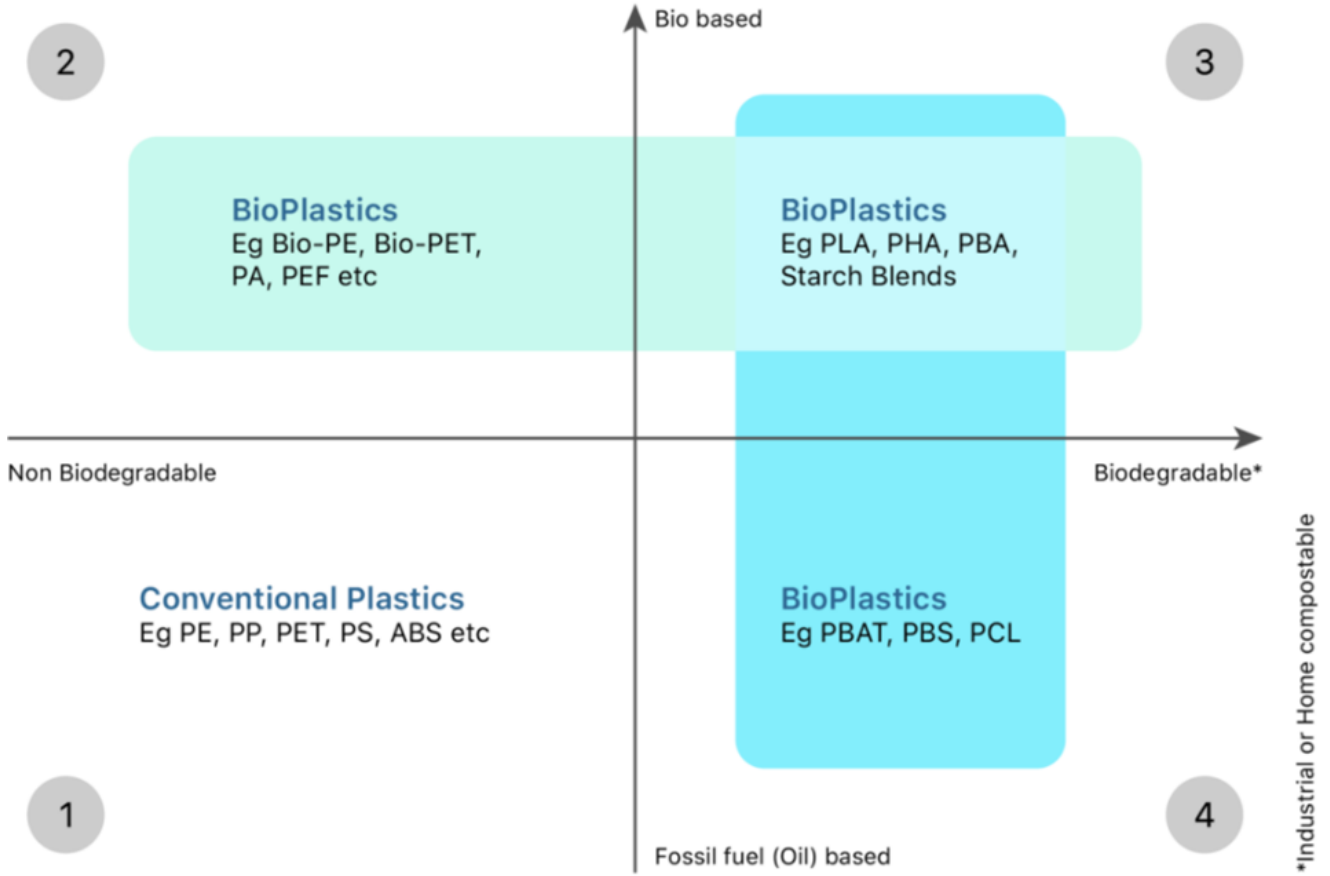
Solution of plastics pollution – Alternative materials

- Using degradable materials
- Bioplastics



What is bioplastic?

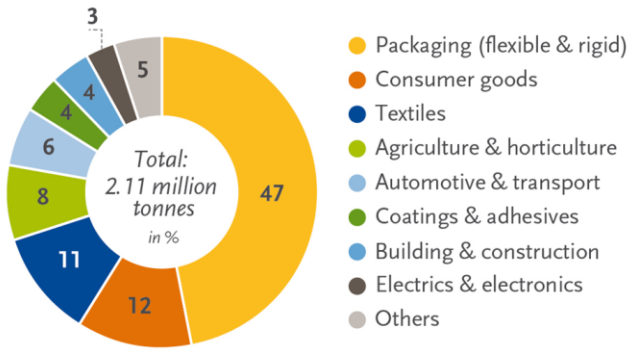
- Biodegradable, biobased, or both



What is bioplastic?

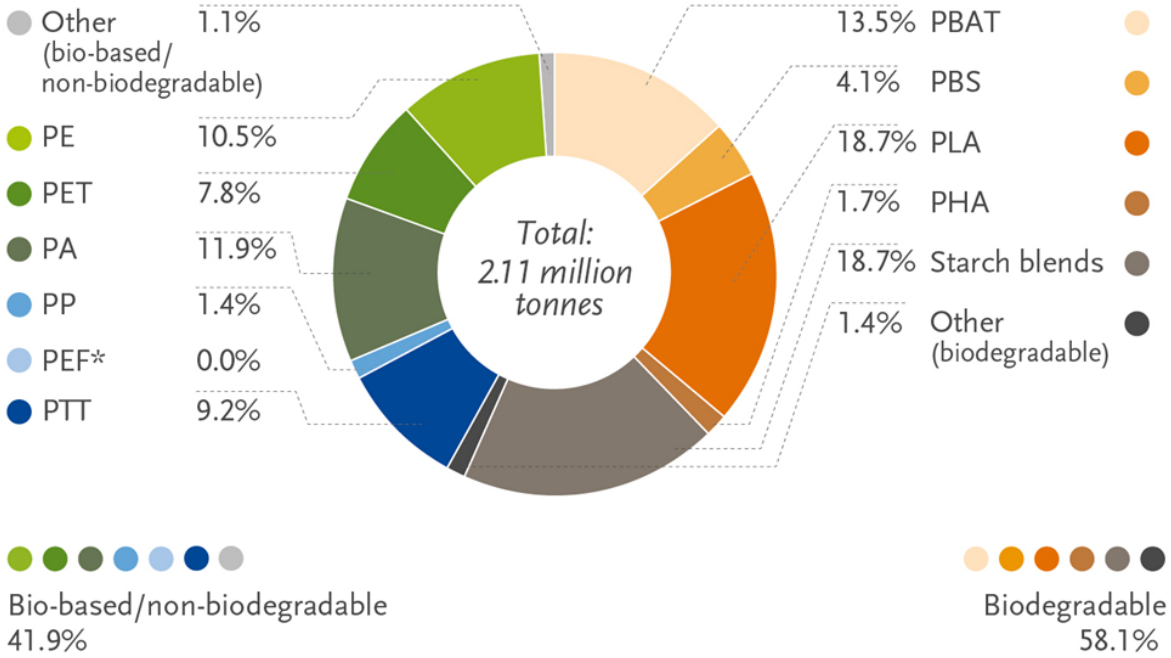
- Biodegradable, biobased, or both
- Bioplastics represents 1% of world plastic production

Global production capacities of bioplastics in 2020 (by market segment)



Source: European Bioplastics, nova-Institute (2020). More information: **www.european-bioplastics.org/market** and **www.bio-based.eu/markets**

Global production capacities of bioplastics 2020 (by material type)

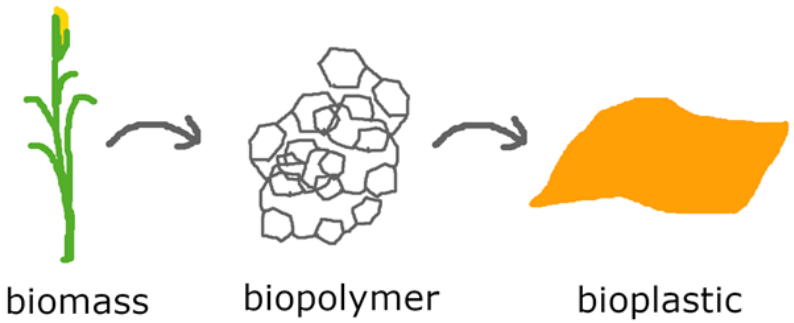


*PEF is currently in development and predicted to be available in commercial scale in 2023.

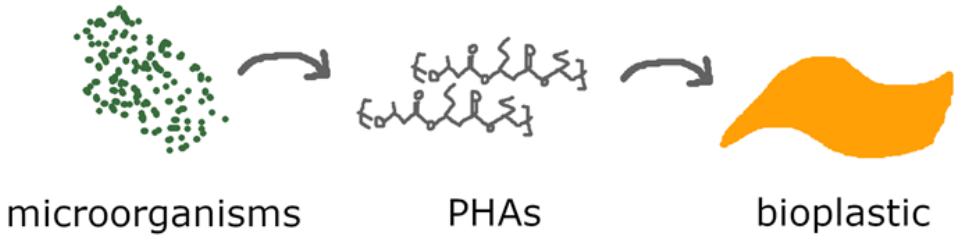
Source: European Bioplastics, nova-Institute (2020)
More information: **www.european-bioplastics.org/market** and **www.bio-based.eu/markets**

Biobased and biodegradable bioplastics - two ways of production

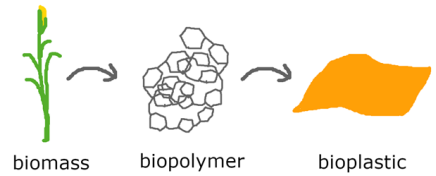
- Polymers are extracted from biomass



- Polymers are produced by microorganisms

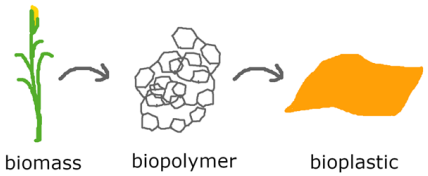


Polymers extracted from biomass



- polymers
  - starch, cellulose, lignin, chitin, carrageenan, agar, …
  - casein, keratin
- biomass resources
  - land crops (corn, potato, rice), seaweed, cotton
  - wood industry byproducts (wood chips, sawdust)
  - food waste (corn husks, fruit peels and seeds, spent coffee grounds)

From biomass to bioplastic



- polymer is extracted from biomass

- polymer is dissolved in water

- additional biopolymers, plasticizers, fillers are added

- melt-processing – gelatinization

- a film is made

Currently on the market

- Starch blends (TPS - thermoplastic starch)
  - food packaging
  - poor water resistance

- Polymers from algin and carrageenan extracted from seaweeds
  - edible food packaging

- Casein protein polymers
  - adhesives, edible food packaging
  - controlled release drug delivery systems

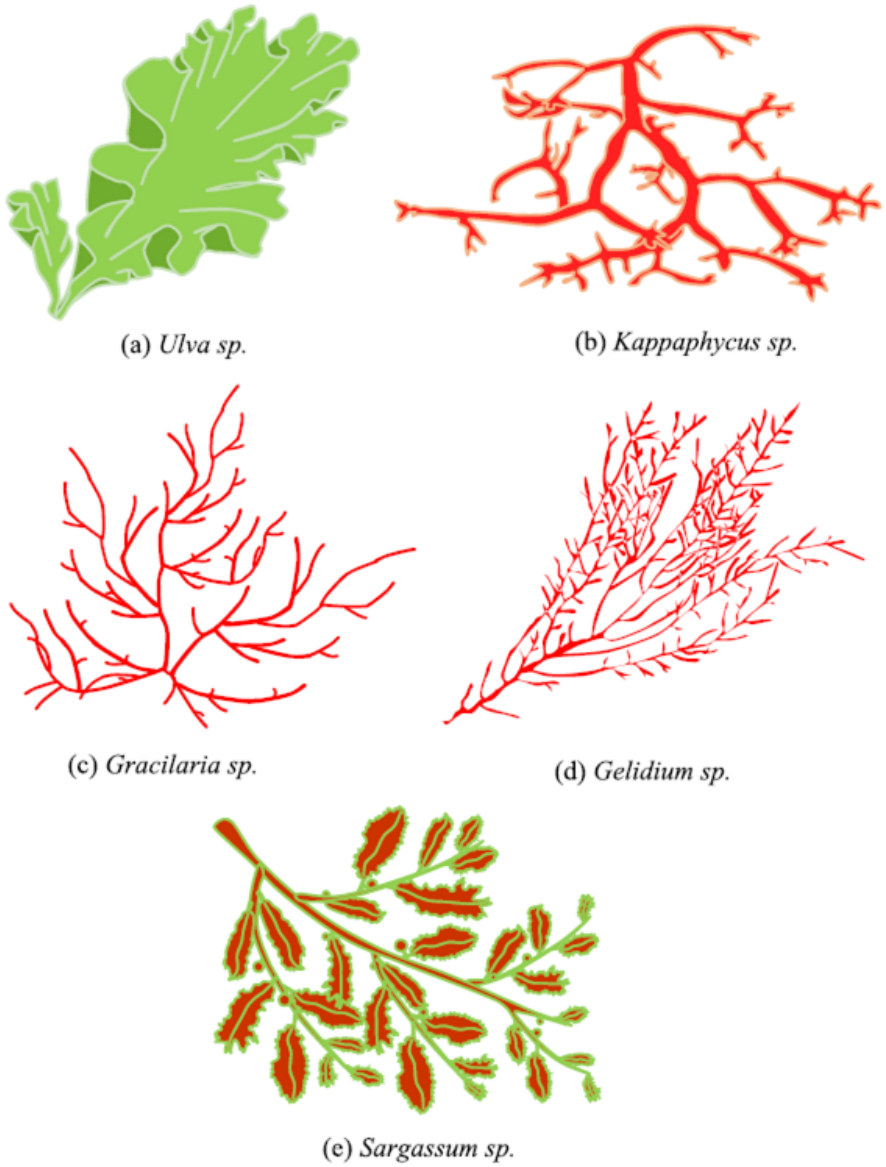


Fig. 1. Popular seaweeds used in bioplastics production.

Currently on the market

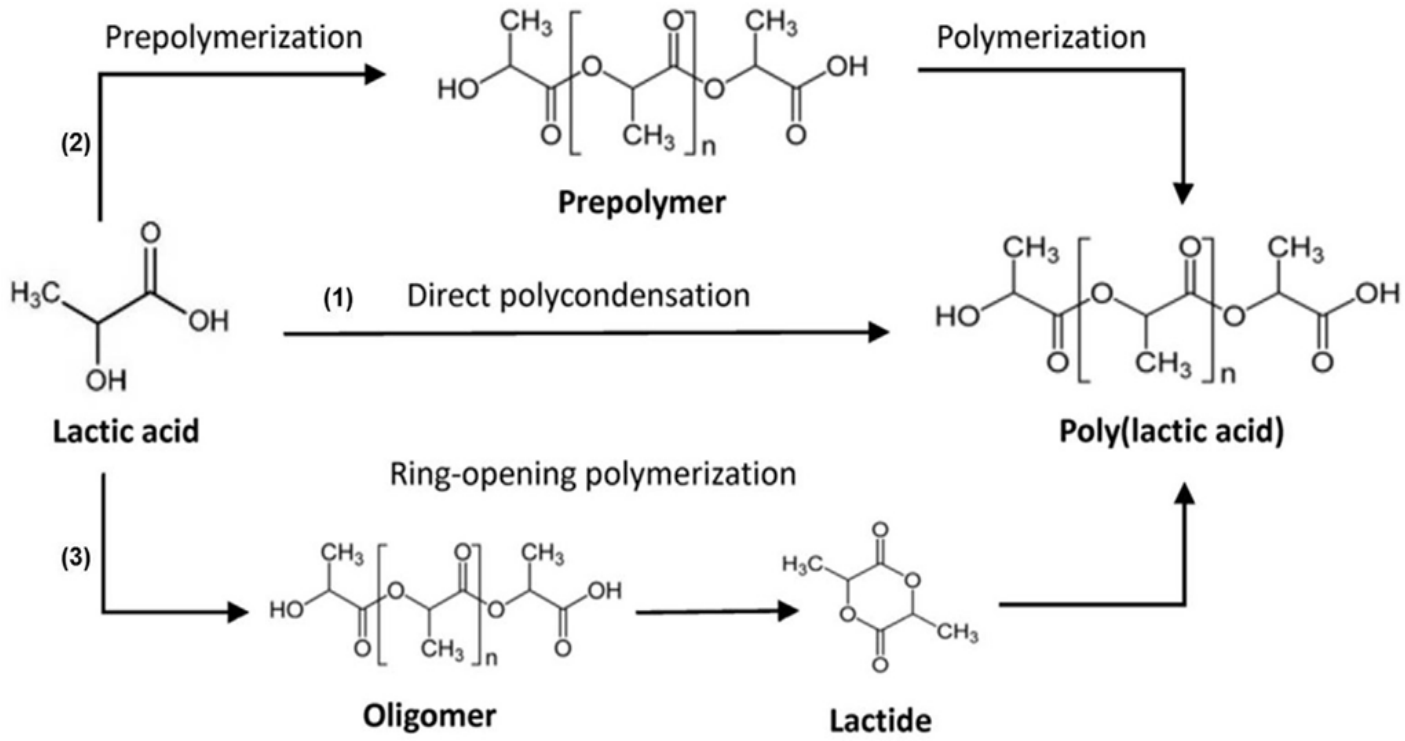
- Chitin based polymers
  - marine crustaceans (crab, lobster)
  - hazardous substances used for extraction

- Cellulose acetate
  - fibers, films
  - hazardous substances

- Polylactic acid

Polylactic acid PLA

- Starch cleavage by heat or acids/enzymaticaly to glucose
- Fermentation of glucose to lactic acid
- Polymerization of lactic acid to PLA



Polylactic acid PLA

- Starch source: corn, cassava, …
- Properties:
  - biodegradable?
  - degradation rate between 3-5 years
  - specific conditions (60 °C, moisture, soil or compost)

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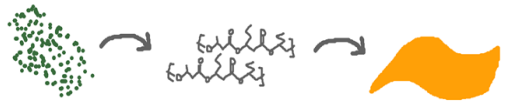
pubs.acs.org/journal/ascecg

Perspective

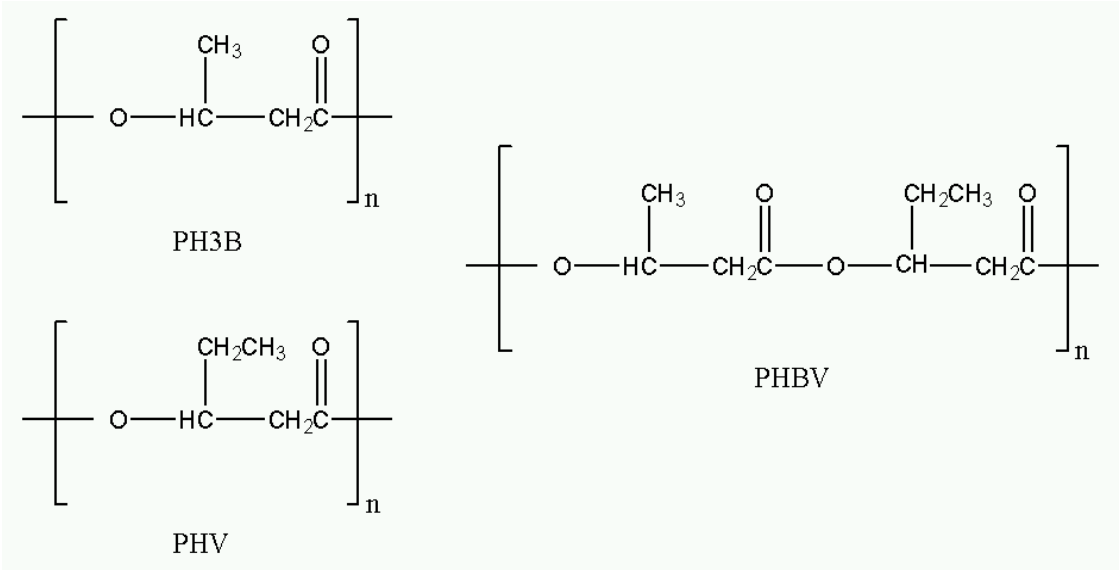
Degradation Rates of Plastics in the Environment

Ali Chamas, Hyunjin Moon, Jiajia Zheng, Yang Qiu, Tarnuma Tabassum, Jun Hee Jang, Mahdi Abu-Omar, Susannah L. Scott,* and Sangwon Suh*

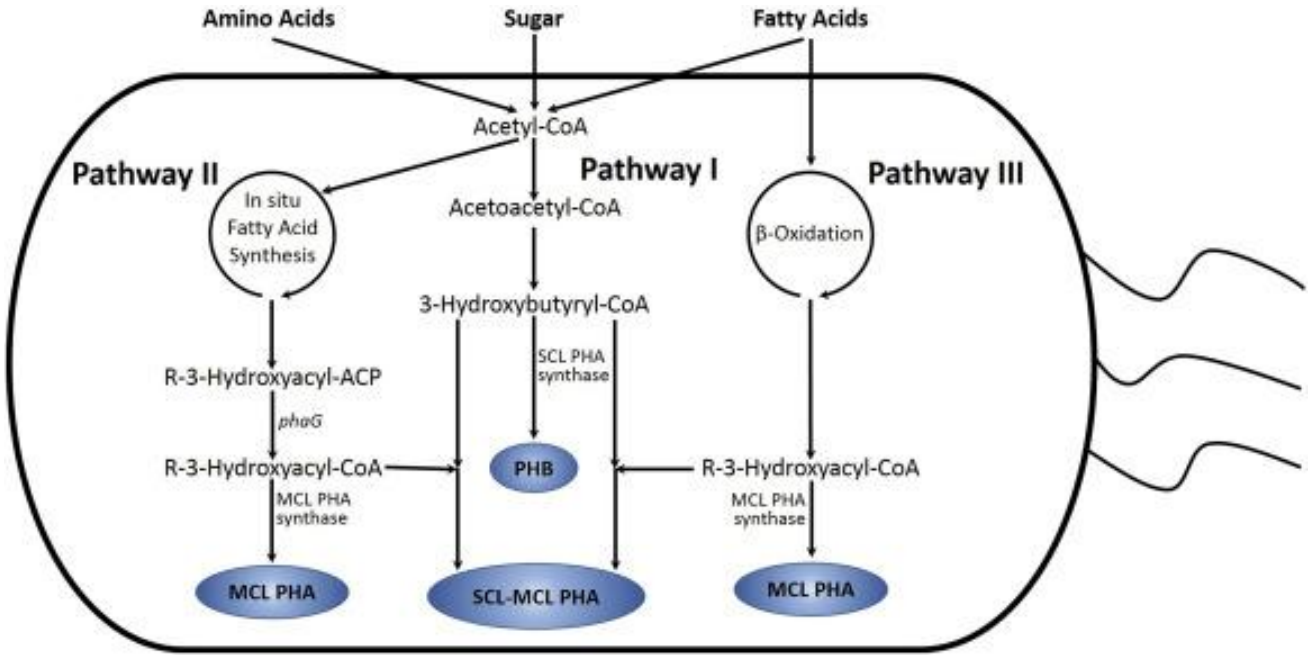


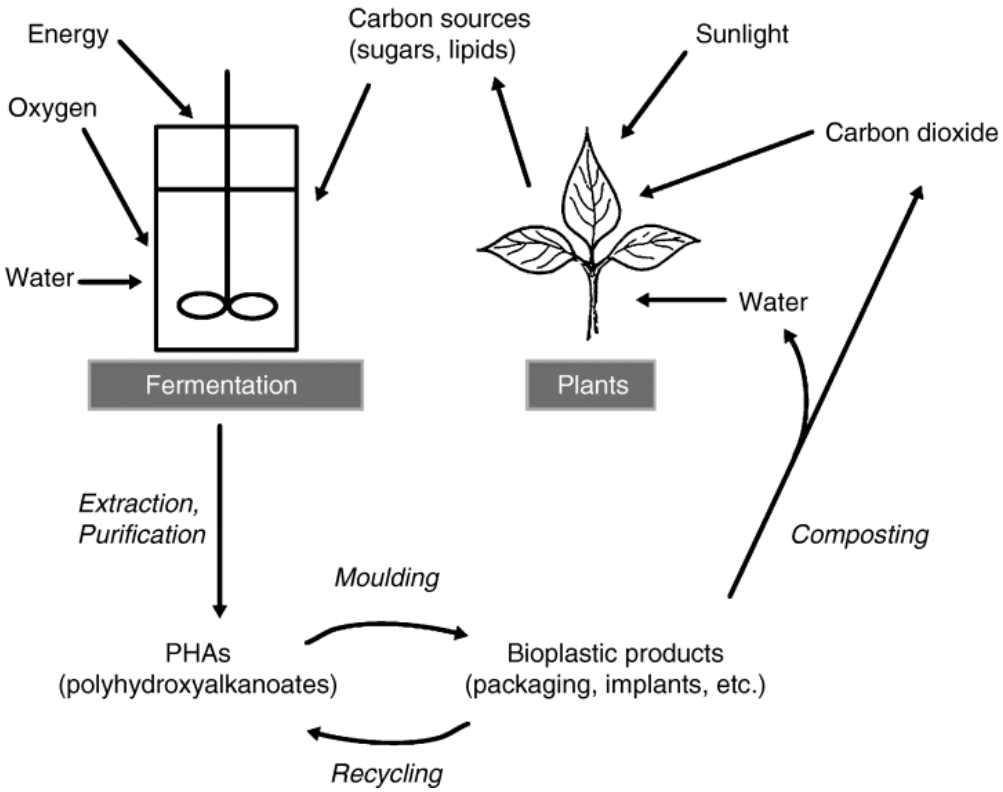
Polymers produced by microorganisms

- PHA (Polyhydroxyalkanoates) are the only biopolyesters completely synthesized by biological means



Polyhydroxyalkanoates PHA





Packaging film

PVC/LDPE

P(4HB)
P(3HB-*co*-3HHx)

- Flexible
- Good moisture and oxygen barriers
- Ductile

Plastic bags

LDPE

P(3HB-*co*-4HB)
P(3HB-*co*-3HHx)

- Flexible
- Tough
- Ductile

Food containers

PP

P(3HB-*co*-3HV)

- Stiff
- High operating temperature
- Tough

Disposable cutlery

PS

P(3HB)
P(3HB-*co*-3HV)

- Strong
- Stiff
- High softening temperature

Medical suture

PGLA

P(3HB-*co*-4HB)

- Biocompatible
- Resorbable
- Strong

Other alternatives

Published: 22 May 2011

Metabolic engineering of *Escherichia coli* for direct production of 1,4-butanediol

Harry Yim, Robert Haselbeck, Wei Niu, Catherine Pujol-Baxley, Anthony Burgard, Jeff Boldt, Julia Khandurina, John D Trawick, Robin E Osterhout, Rosary Stephen, Jazell Estadilla, Sy Teisan, H Brett Schreyer, Stefan Andrae, Tae Hoon Yang, Sang Yup Lee, Mark J Burk & Stephen Van Dien

Nature Chemical Biology **7**, 445–452 (2011) | Cite this article

Summary

Type of polymer	Production	Biodegradable	+	-
PLA polylactic acid	microbial and chemical	Slowly and only under specific conditions (60 °C)	• suitable for wide variety of applications • less energy for production	• problematic degradation • occupation of land • may decrease microbial diversity
Starch blends	chemical	Yes	• availabilty and low cost of starch	Poor gas barrier properties and water resistance
Seaweed polymers	chemical	Easily	• easy cultivation • chemical-independent production	Low thermal stability
PHA polyhydroxyalkanoates	microbial	Yes	• independence from the agricultural sector (cyanobacteria, microalgae) • may increase microbial diversity in area of its degradation	High production price

Thank you
for your attention :)