Synthetic polymer coating on biopolymers intended for food packaging applications

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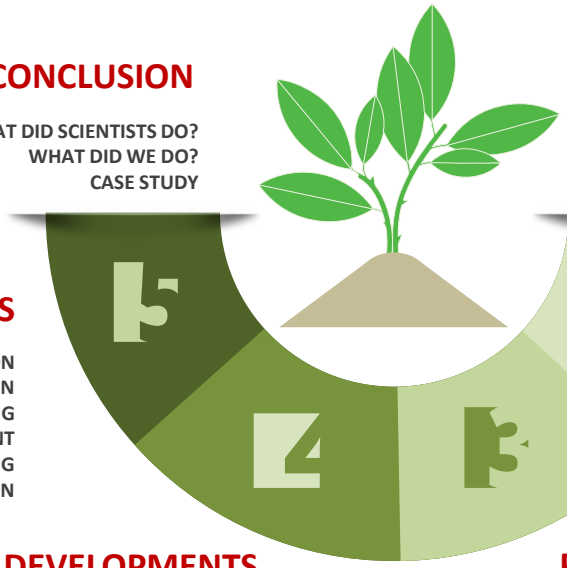
OUTLINE



BIOPLASTICS

AN ALTERNATIVE SOLUTION
REASONS
TERMS

CLASSIFICATION

INDUSTRIAL VIEW
POTENTIAL

PROPERTIES OF BIOPLASTICS

MECHANICAL
BARRIER

DEVELOPMENTS

MARKET SEARCH

ENHANCEMENT STRATEGIES

PLASTICIZATION
CHEMICAL MODIFICATION
CROSS-LINKING
NANOREINFORCEMENT
BLENDING
COATING/LAMINATION

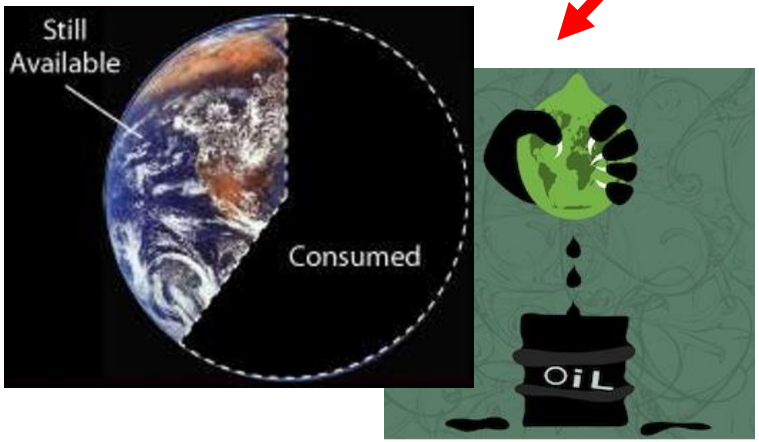
CONCLUSION

WHAT DID SCIENTISTS DO?
WHAT DID WE DO?
CASE STUDY

PACKAGING MATERIALS COMMONLY USED IN FOOD INDUSTRY

1. Polyolefin (PP, PE)
2. PET
3. PS, EPS
4. PVC
5. PC
6. PA
7. Combinations (Co-extrusions, laminates etc)

- Mechanical strength
- Excellent barrier against water, O_2
- Resistant to food constituents
- Elasticity
- Cost and easy process



DEPLETION OF SOURCES

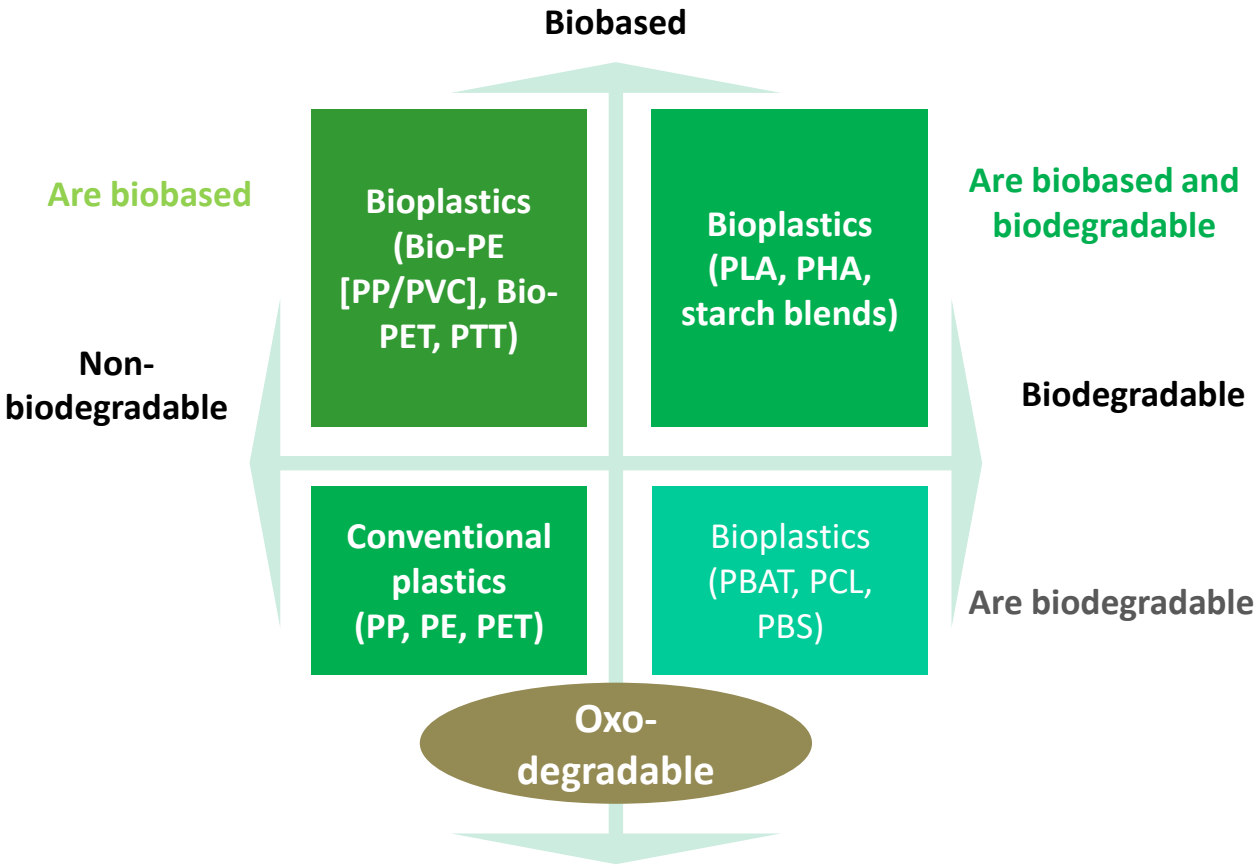
ENVIRONMENTAL POLLUTION

NEED FOR THE SOLUTION?

BIOPLASTICS: *an alternative*

Terms…

Confusion in bioplastics and their definitions…

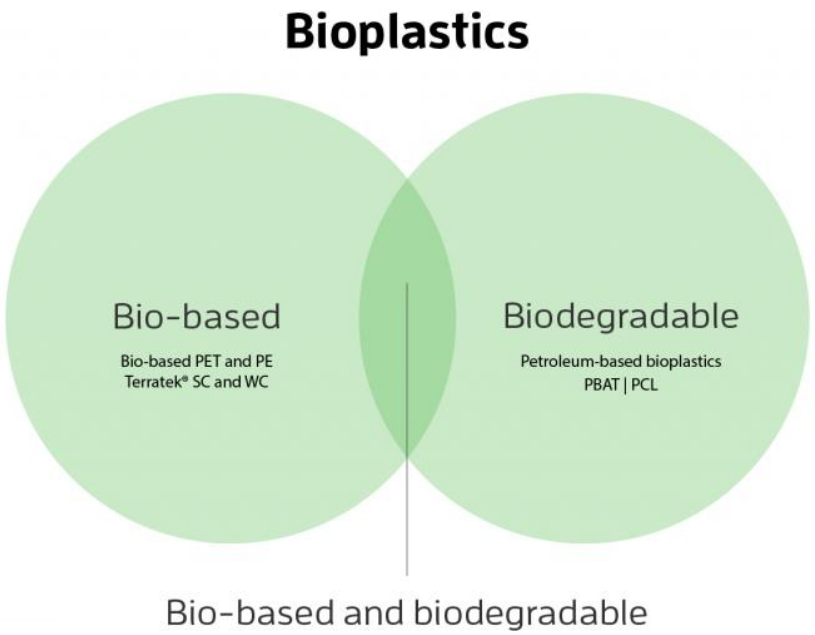


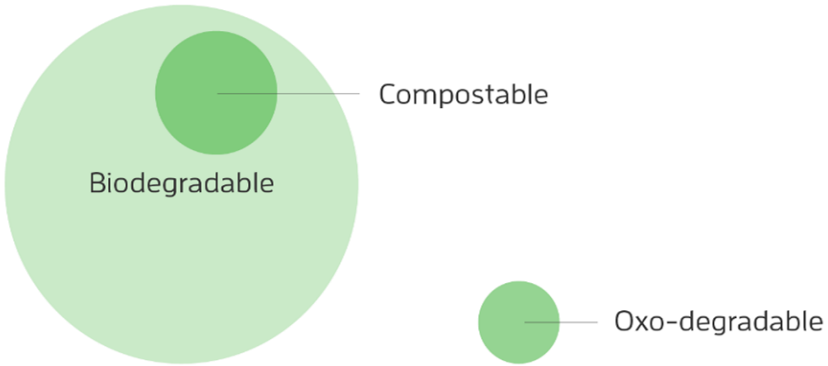
BIO-

PLASTIC

DEGRADABLE

BASED





Not all bio-based plastics are biodegradable,
and not all biodegradable plastics are bio-based.

bio-based plastics
Plastics made at least partly from biological matter

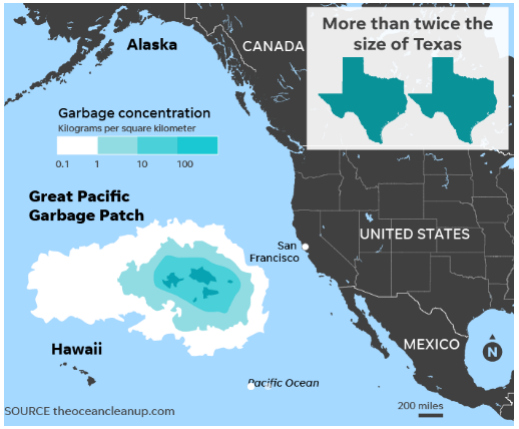
biodegradable plastics
Plastics that can be completely broken down by microbes
in a reasonable timeframe given specific conditions

https://www.greendotbioplastics.com/biodegradable-vs-compostable-vs-oxo-degradable-plastics-a-straightforward-explanation/

WHY BIOPLASTICS?

PLASTIC POLLUTION

Annually, 300 million tons of plastic are produced, of which a high percentage ends up in rivers and oceans. Many scientists believe that is a more serious problem than climate change.



PLASTIC ISLANDS

In the ocean are plastic islands, the biggest being twice the size of Texas! It is estimated that by 2050 there will be more plastic than fish in the sea. Plastic fibers have been found both in the North pole and in the South pole.

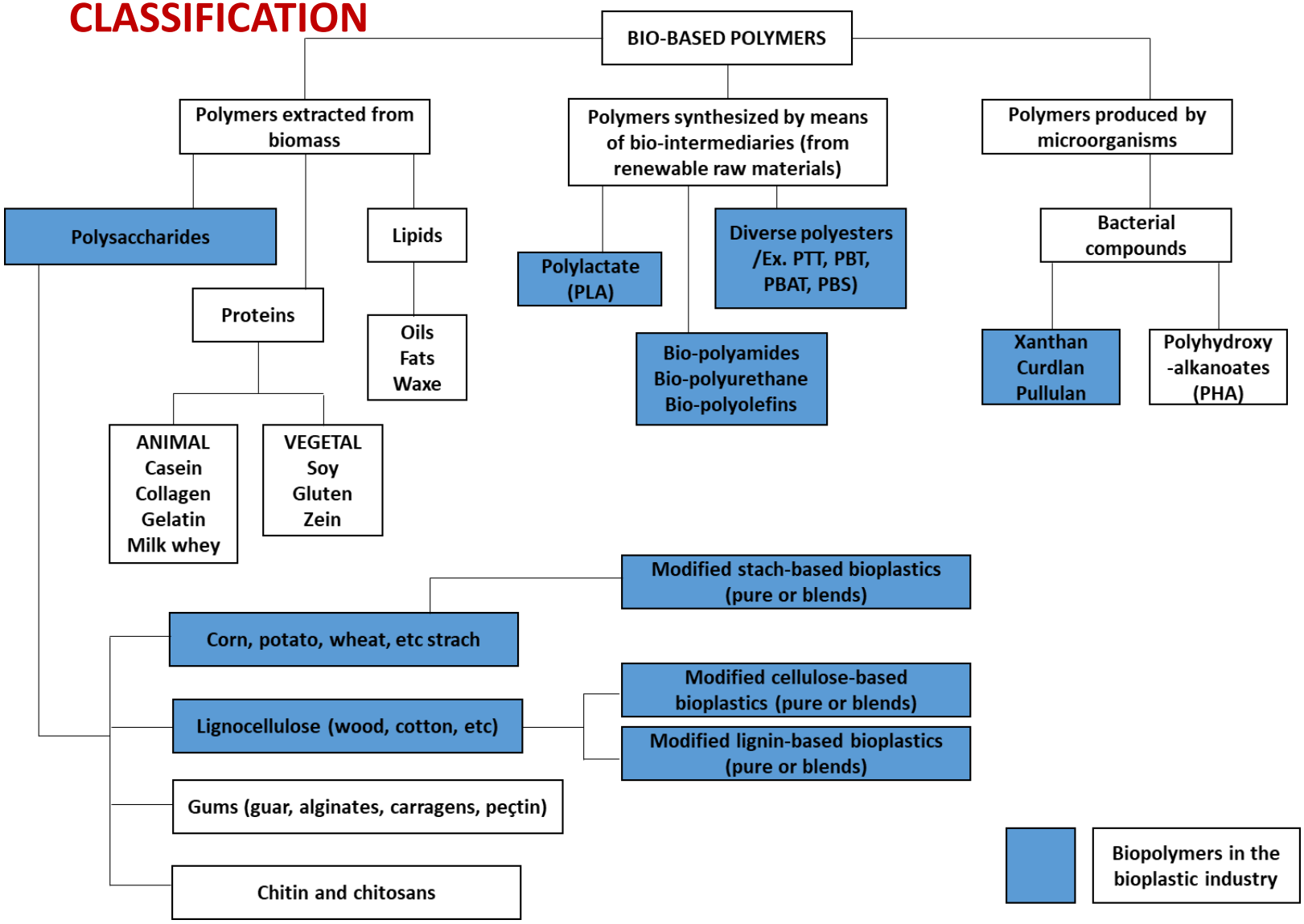
BIOPLASTICS ARE COMPOSTABLE

Bioplastics decay into natural materials that blend harmlessly with soil when they are met with the right level of heat, water, and oxygen.

BIOPLASTIC USE REDUCES GREEN HOUSE EMISSIONS

Substituting the annual global demand for fossil-based polyethylene (PE) with bio-based PE would save more than 42 million tones of CO_2

CLASSIFICATION



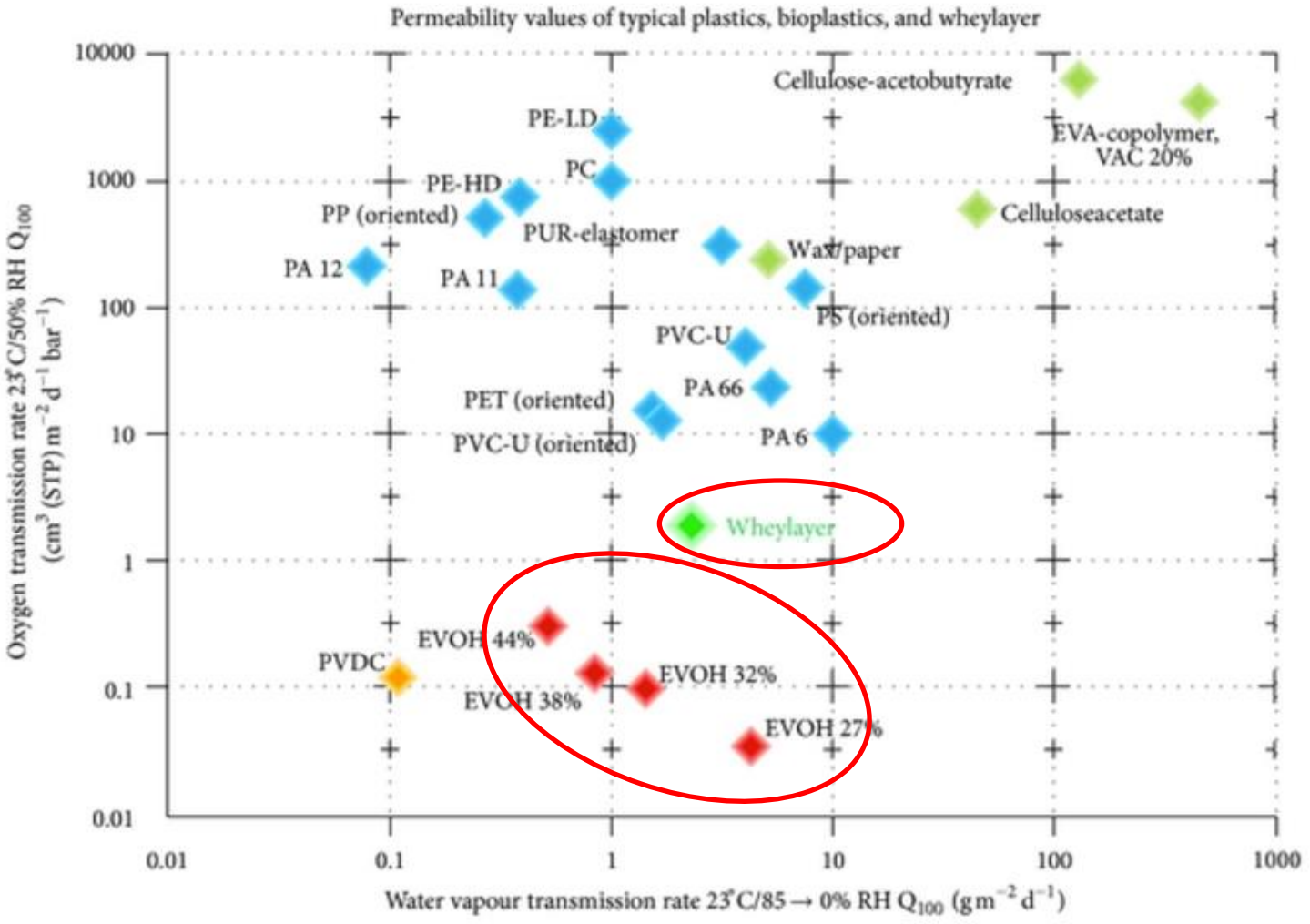
PROPERTIES OF BIOPLASTICS

Mechanical properties

ITEM	CONVENTIONAL POLYMER	PHA TYPE	PROPERTIES
PACKAGING FILM	3 PVC	P4HB PBHH	▪ Flexible ▪ Good moisture and oxygen barriers ▪ Ductile
PLASTIC BAGS	4 LDPE	P(3HB-co-4HB) PBHH	▪ Flexible ▪ Tough ▪ Ductile
FOOD CONTAINERS	5 PP	PHBV	▪ Stiff ▪ High operating temperature ▪ Tough
DISPOSABLE CUTLERY	6 PS	PH3B PHBV	▪ Strong ▪ Stiff ▪ High softening temperature
MEDICAL SUTURES	7 PLA	P(3HB-co-4HB)	▪ Biocompatible ▪ Resorbable ▪ Strong

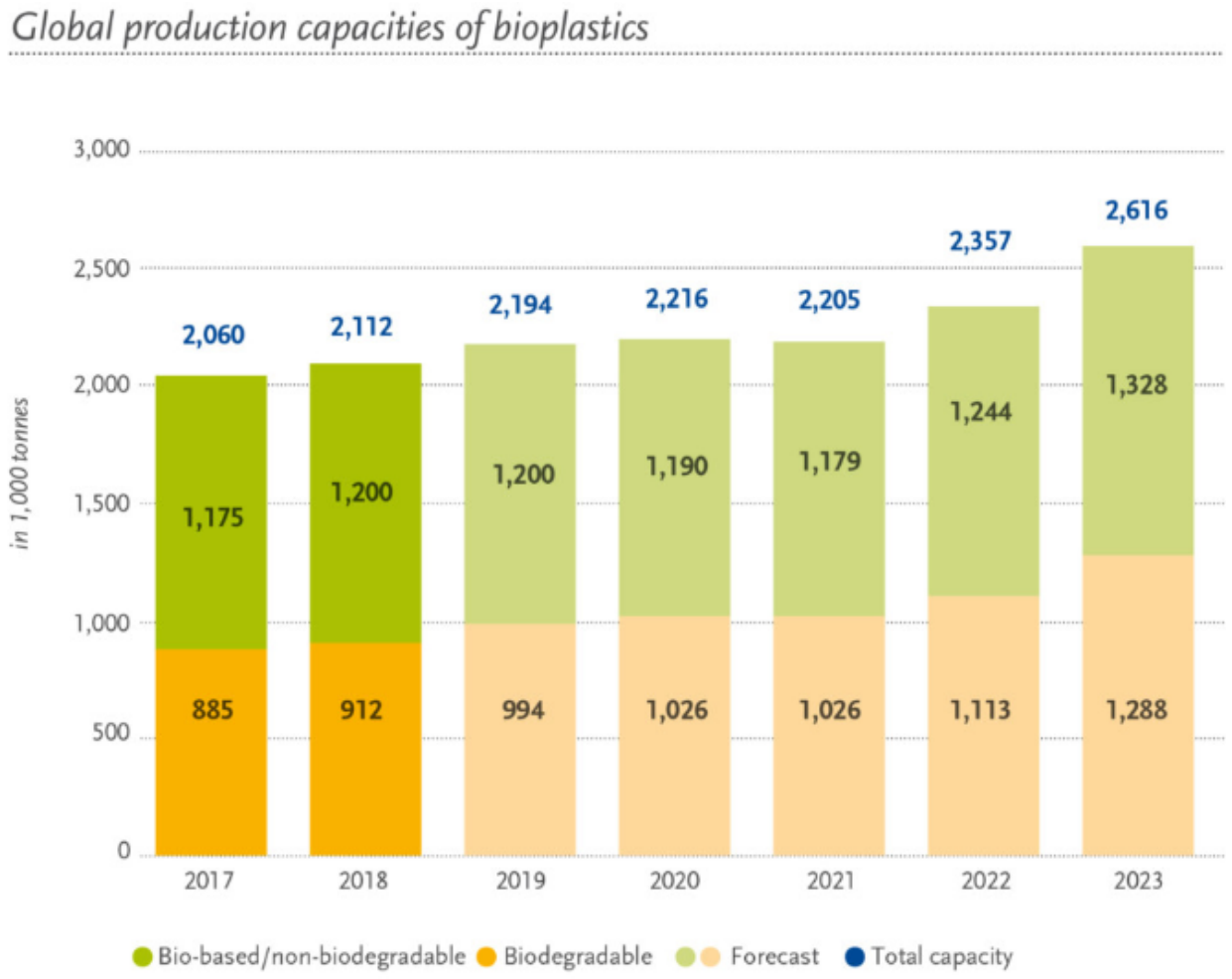
Kirk-Othmer Encyclopedia of Chemical Technology. Copyright # 2015 John Wiley & Sons, Inc. All rights reserved.
DOI: 10.1002/0471238961.koe00006

Barrier properties



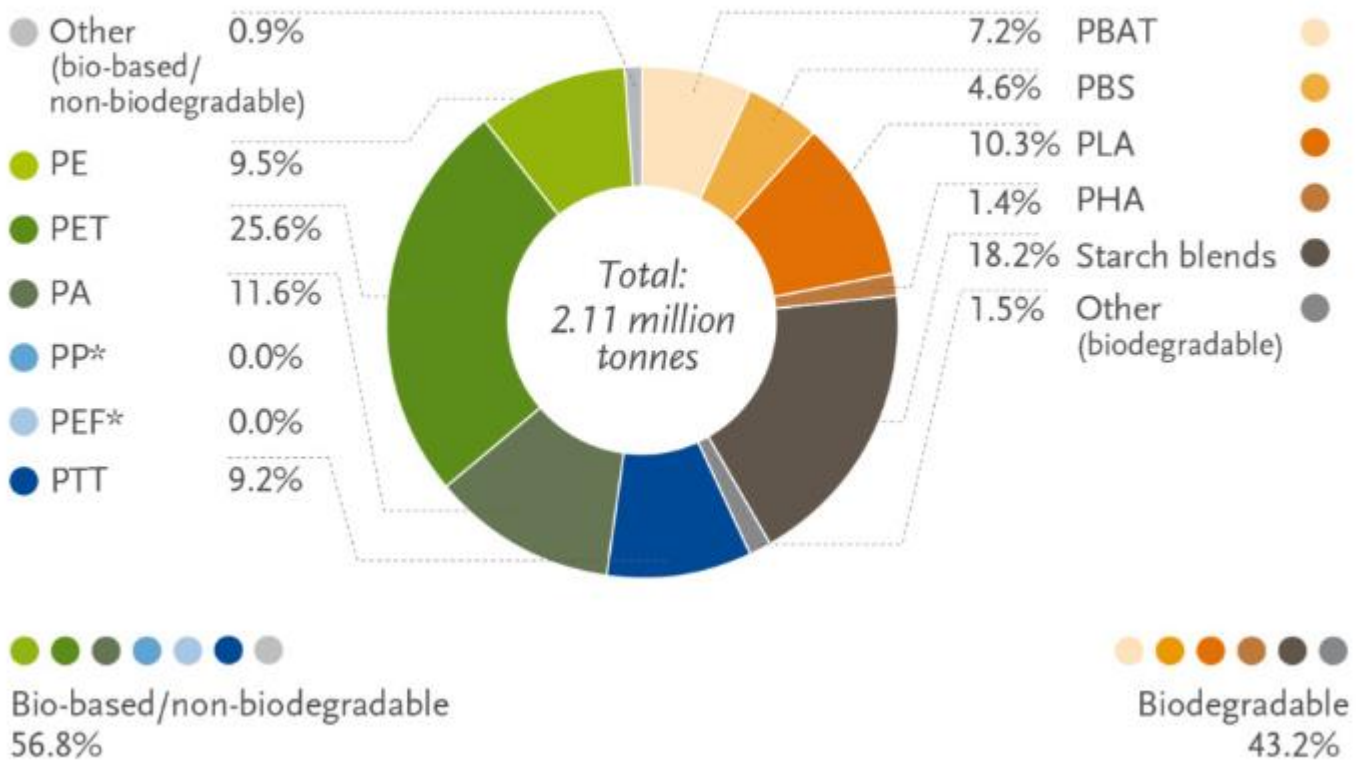
https://www.hindawi.com/journals/amse/2013/496207/

DEVELOPMENTS IN BIOPLASTIC INDUSTRY



European Bioplastics, nova-Institute (2018).
www.bio-based.eu/markets ve www.european-bioplastics.org/market

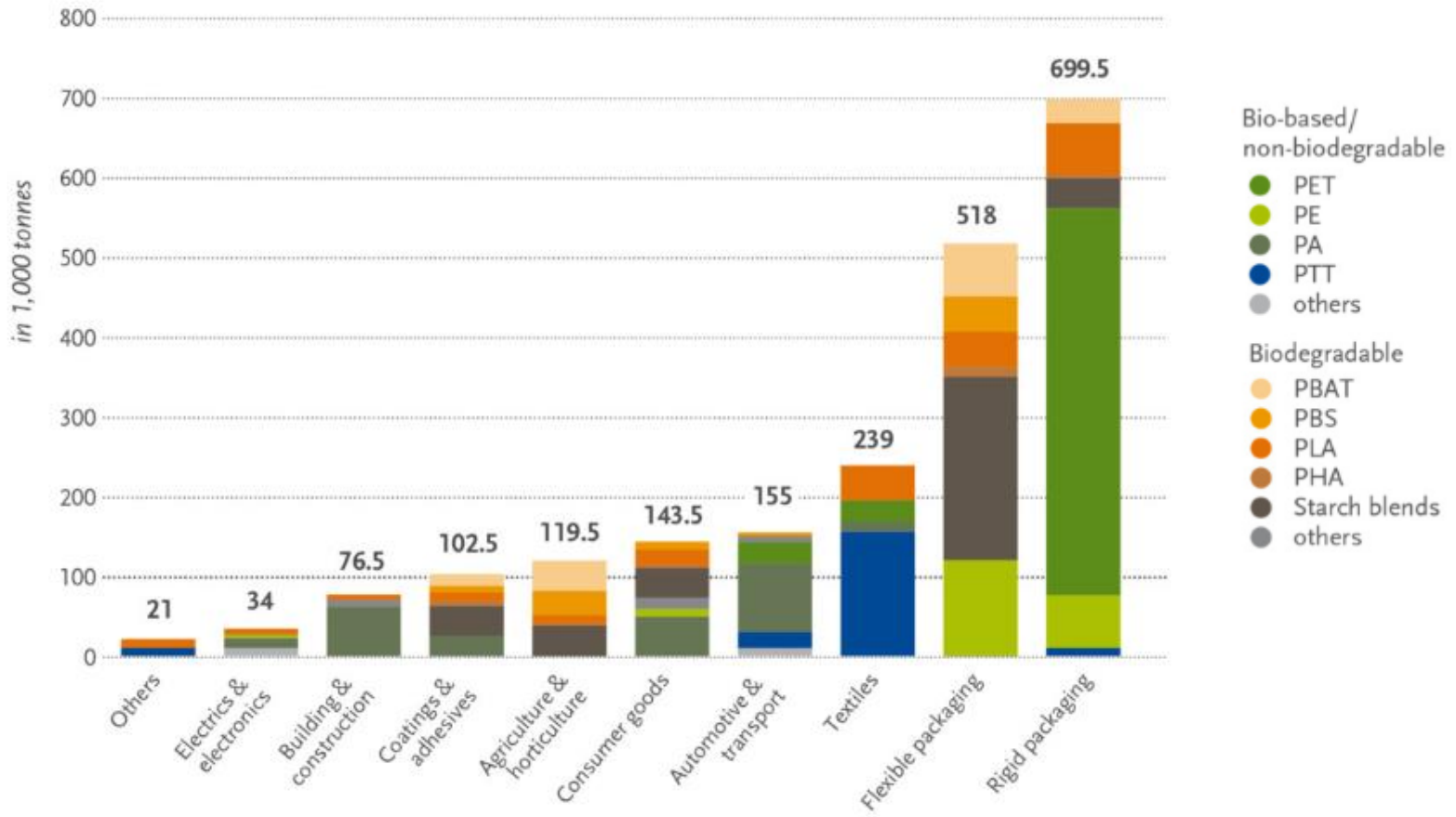
Global production capacities of bioplastics 2018 (by material type)



*Bio-based PP and PEF are currently in development and predicted to be available at commercial scale in 2023

European Bioplastics, nova-Institute (2018).
www.bio-based.eu/markets ve www.european-bioplastics.org/market

Global production capacities of bioplastics 2018 (by market segment)

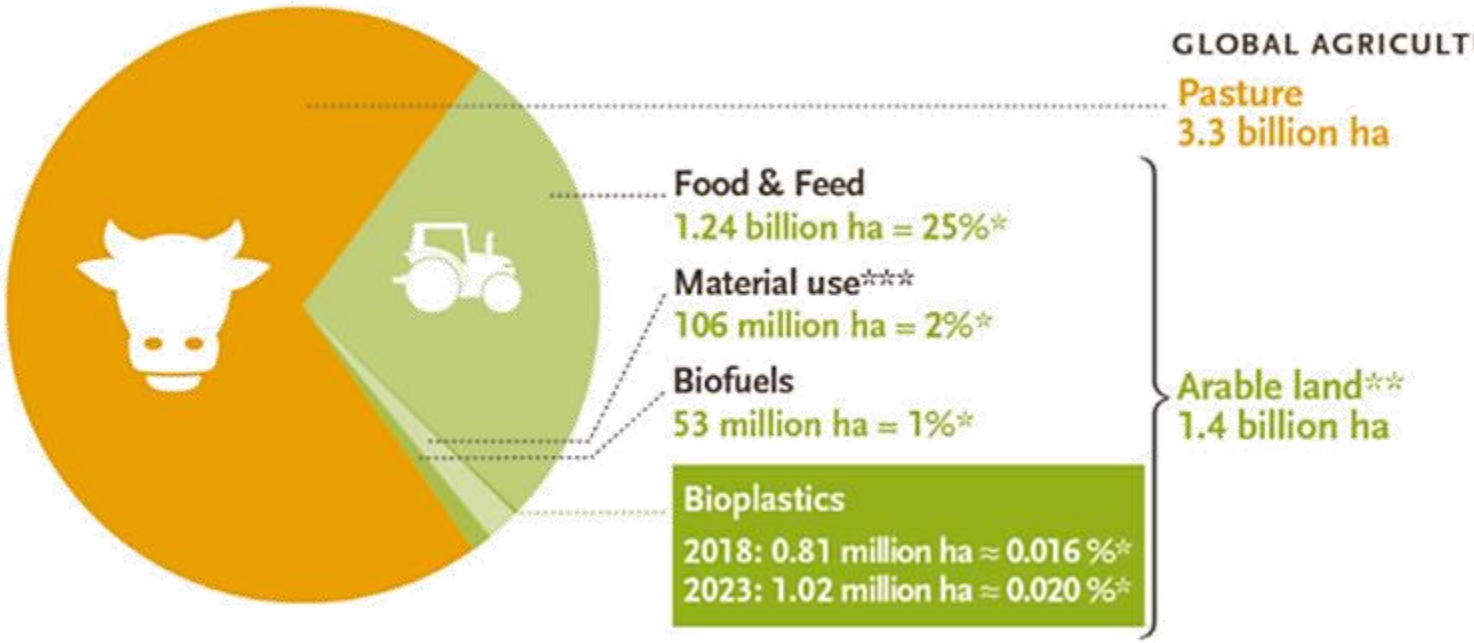


European Bioplastics, nova-Institute (2018).
www.bio-based.eu/markets ve www.european-bioplastics.org/market

Global production capacities of bioplastics in 2018 (by region)

European Bioplastics, nova-Institute (2018).
www.bio-based.eu/markets ve www.european-bioplastics.org/market

Land use estimation for bioplastics 2018 and 2023



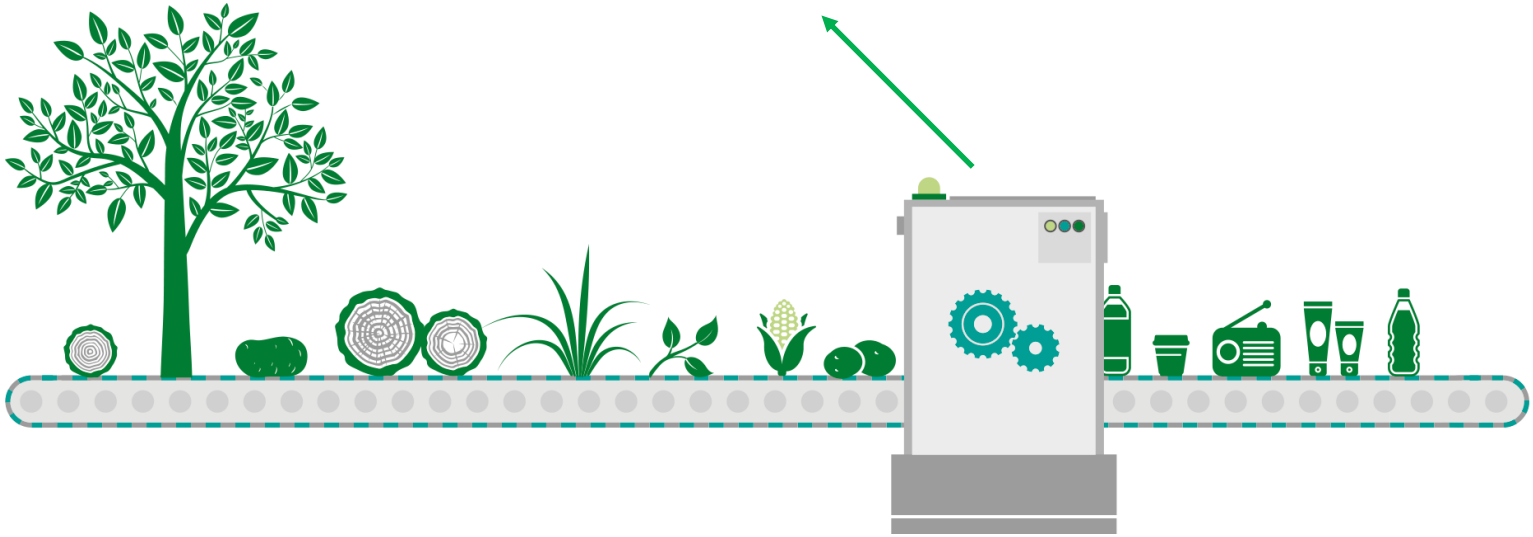
* In relation to global agricultural area
** Including approx. 1% fallow land
*** Land-use for bioplastics is part of the 2% material use

European Bioplastics, nova-Institute (2018).
www.bio-based.eu/markets ve www.european-bioplastics.org/market

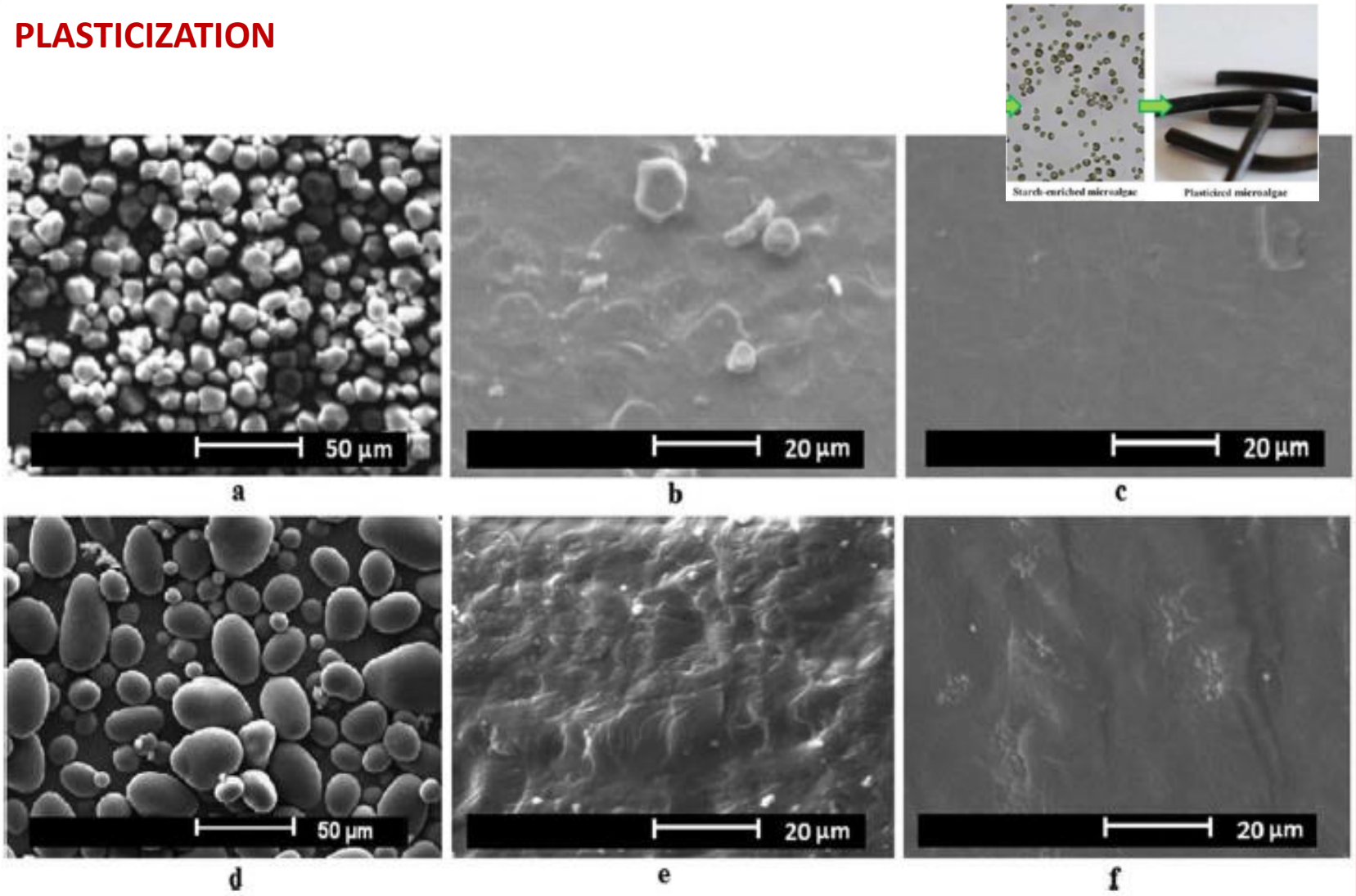
	ADVANTAGES	DISADVANTAGES
CONVENTIONAL PLASTICS	Low cost	Based on petrochemicals
	Good and excellent technical properties	Difficult to recycle
	Easy processability	Mostly not biodegradable
	Can save energy and resources compared with other materials, depending on application	Uncontrolled combustion can release toxic substances
	Thermal recycling possible (cascade use)	Ecotoxixicty, particularly microplastics in the marine environment
		Partly toxic raw materials and additives
BIOPLASTICS	(partly) biodegradable	Costly
	(partly) based on natural feedstock, hence reducing the emission of GHG and the dependence on crude oil	(partly) use of genetically modified organisms
	Interesting properties	Use of land, fertilizers, and pesticides for crops, potential food competition
	Generally standard manufacturing processes and plants can be used for biobased feedstock, and standard processing machines can be used for biobased plastics	Narrow processing window (lower melting temperature)
	Positive image among consumers	Brittleness
		Thermal degradation

ENHANCEMENT STRATEGIES

- Plasticization
- Chemical modification
- Cross-linking
- Nano-reinforcement
- Blending with synthetic polymers
- Lamination/Coating with synthetic polymers

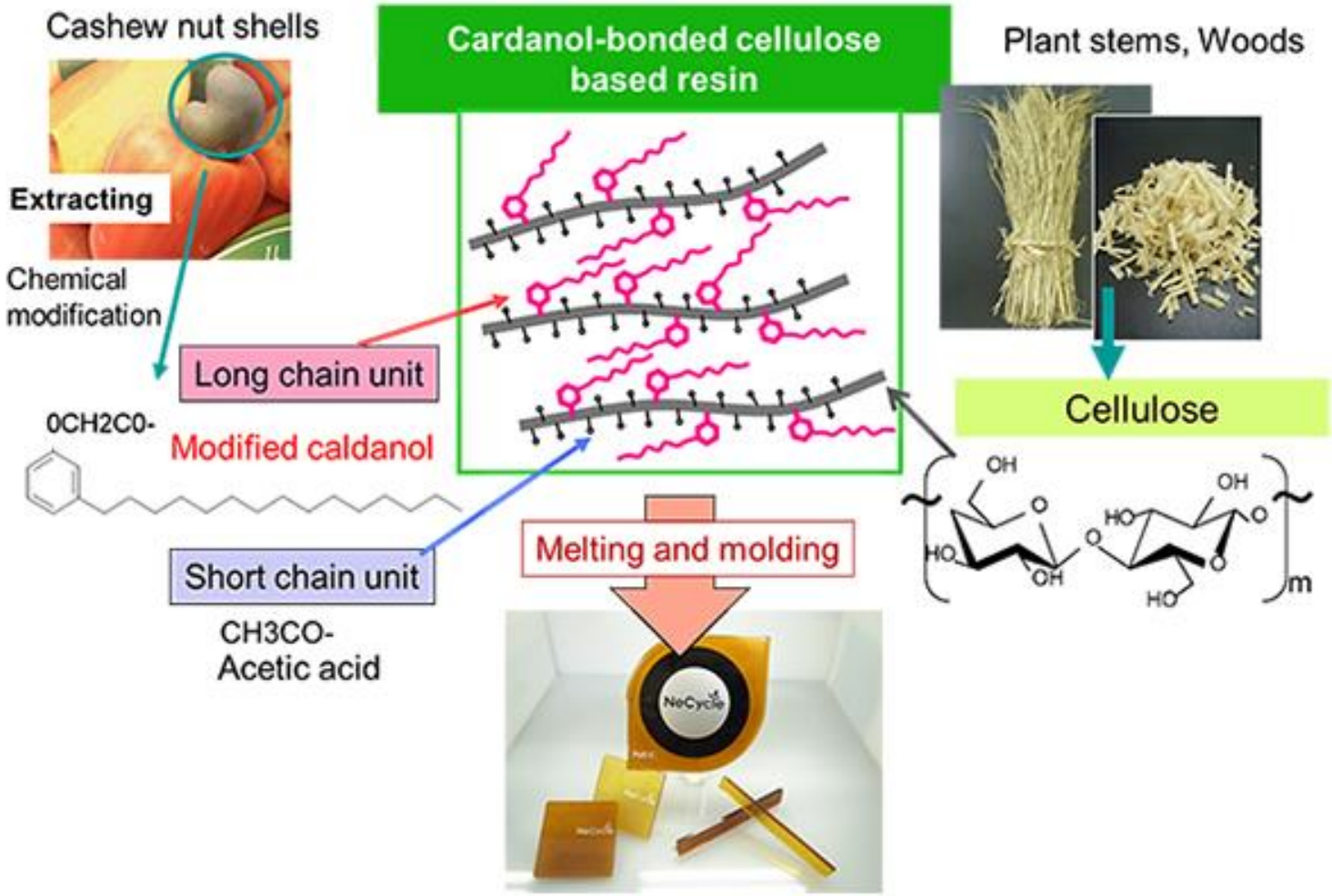


PLASTICIZATION



Scanning electron microscopy micrograph of (a) native corn starch granules, (b) ethylenebisformamide (25%) plasticized TPS, (c) ethylenebisformamide (30%) plasticized TPS (adapted from: ref. 126 John Wiley & Sons, copyright ª 2006) and (d) native potato starch.

CHEMICAL MODIFICATION



https://www.jst.go.jp/pr/announce/20140508-2/index_e.html

CROSSLINKING

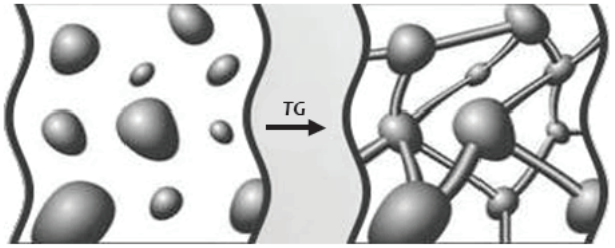
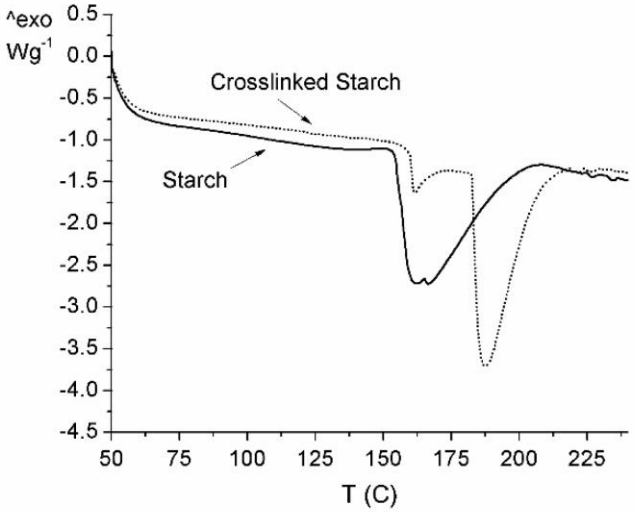
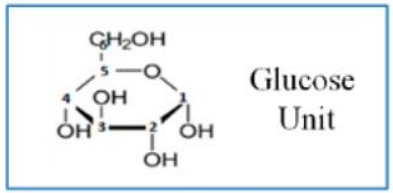
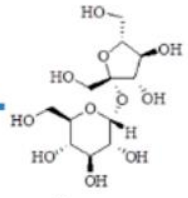


Figure1: TG-crosslinked bioplastics.

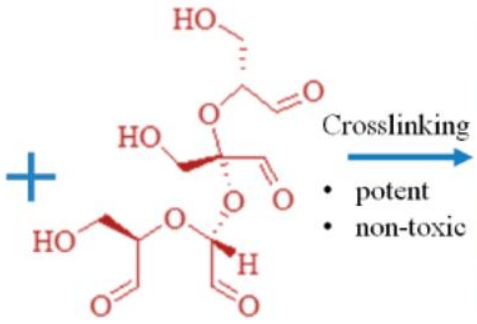




Oxidation



Sucrose

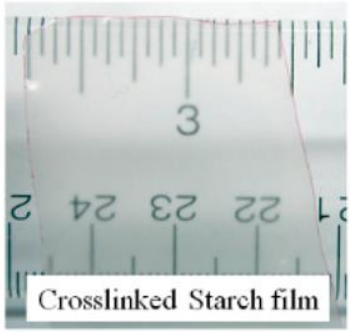


Oxidized Sucrose

Crosslinking

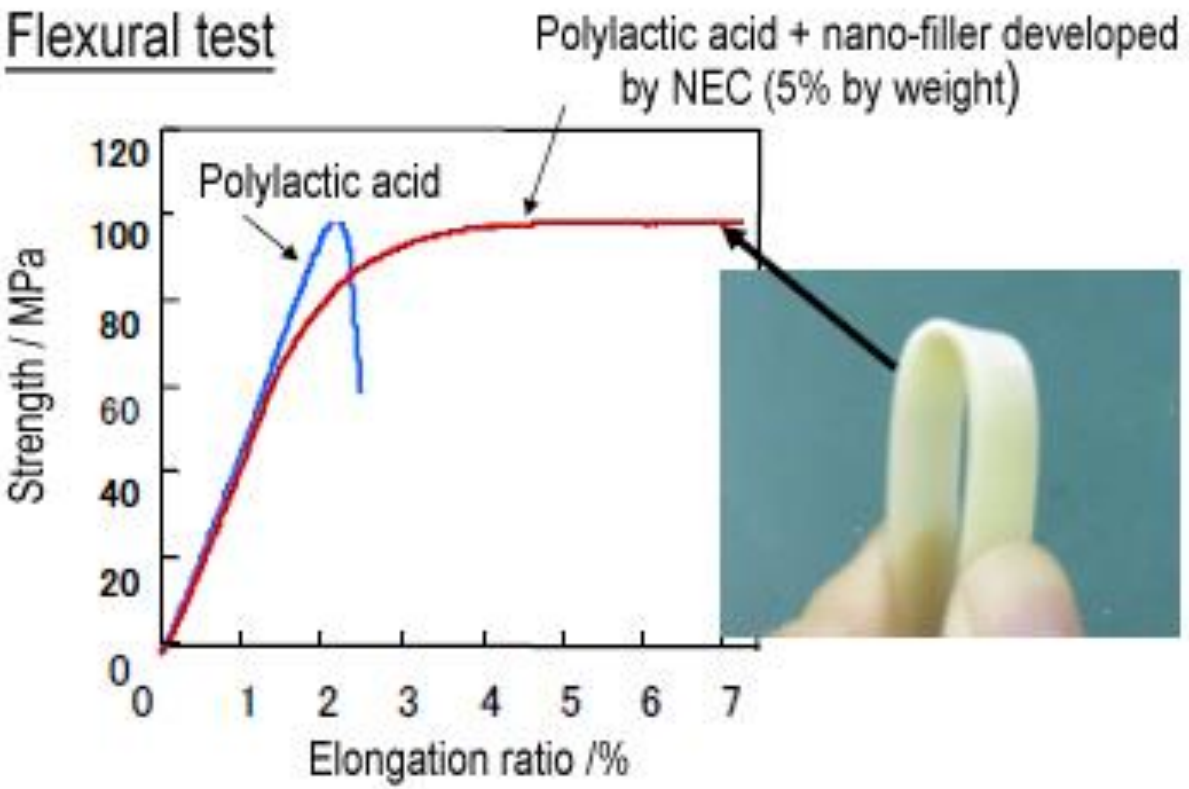
- potent
- non-toxic

- Water stable
- Mechanically robust



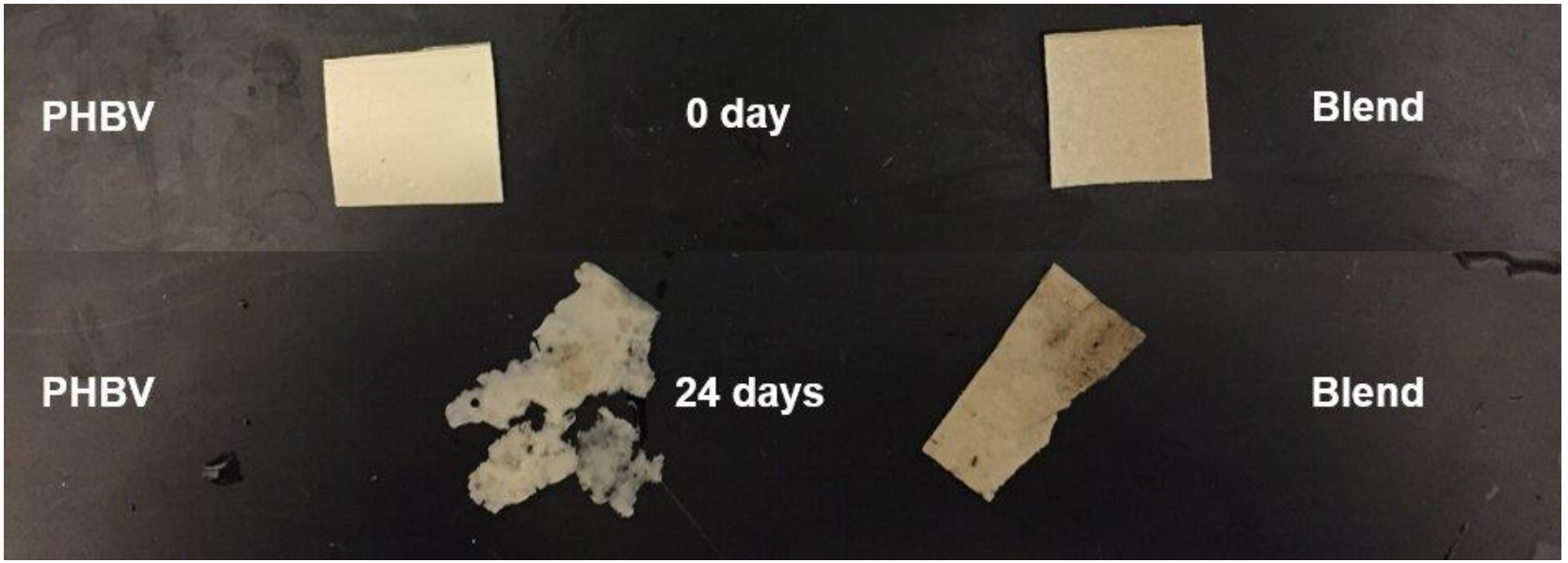
https://www.omicsonline.org/promising-perspectives-for-transglutaminase-in-bioplastics-production-2155-952X.1000e102.php?aid=1477

NANOREINFORCEMENT



https://www.nec.com/en/global/rd/technologies/bioplastics/bioplastics2.html

BLENDING

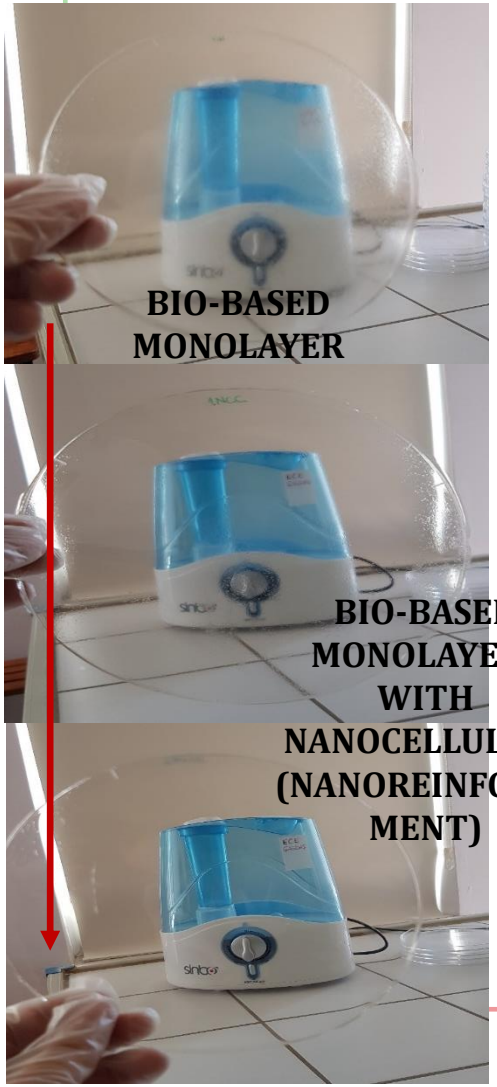


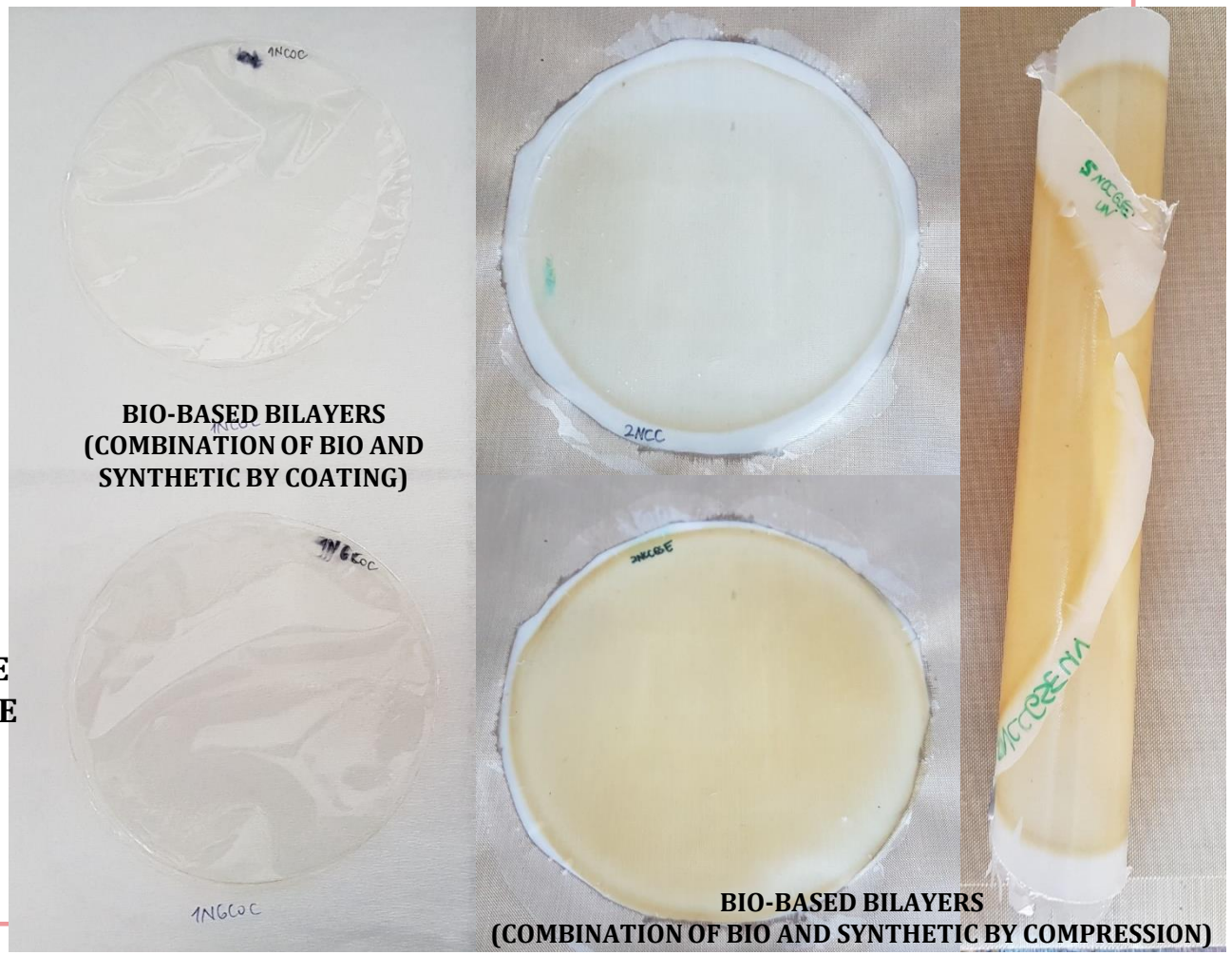
Injected TPS

- To obtain more flexible materials
- To soften the stiffness
- To improve the processability (blown film extrusion)

https://phys.org/news/2019-04-potential-earth-friendly-plastic.html

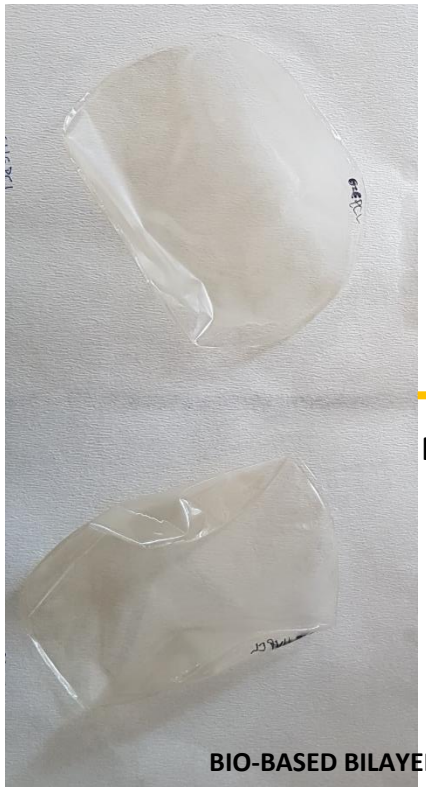
SYNTHETIC POLYMER COATING ON BIOPOLYMERS-CASE STUDY-I





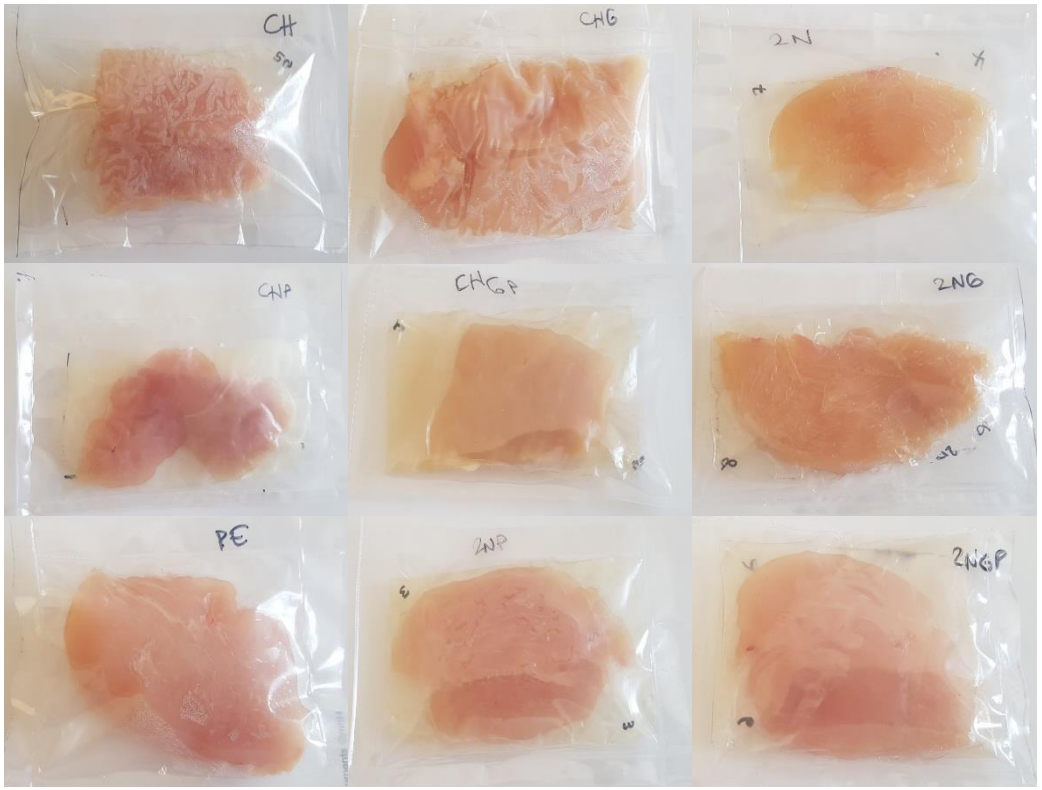
These studies were performed by Ece Söğüt and Atıf Can Seydim

SYNTHETIC POLYMER COATING ON BIOPOLYMERS-CASE STUDY-II

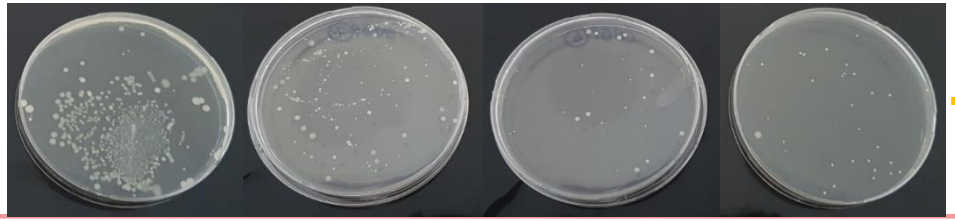


BIO-BASED BILAYERS

PACKAGING CHICKEN FILLETS



TOTAL MESOPHILIC AEROBIC BACTERIA

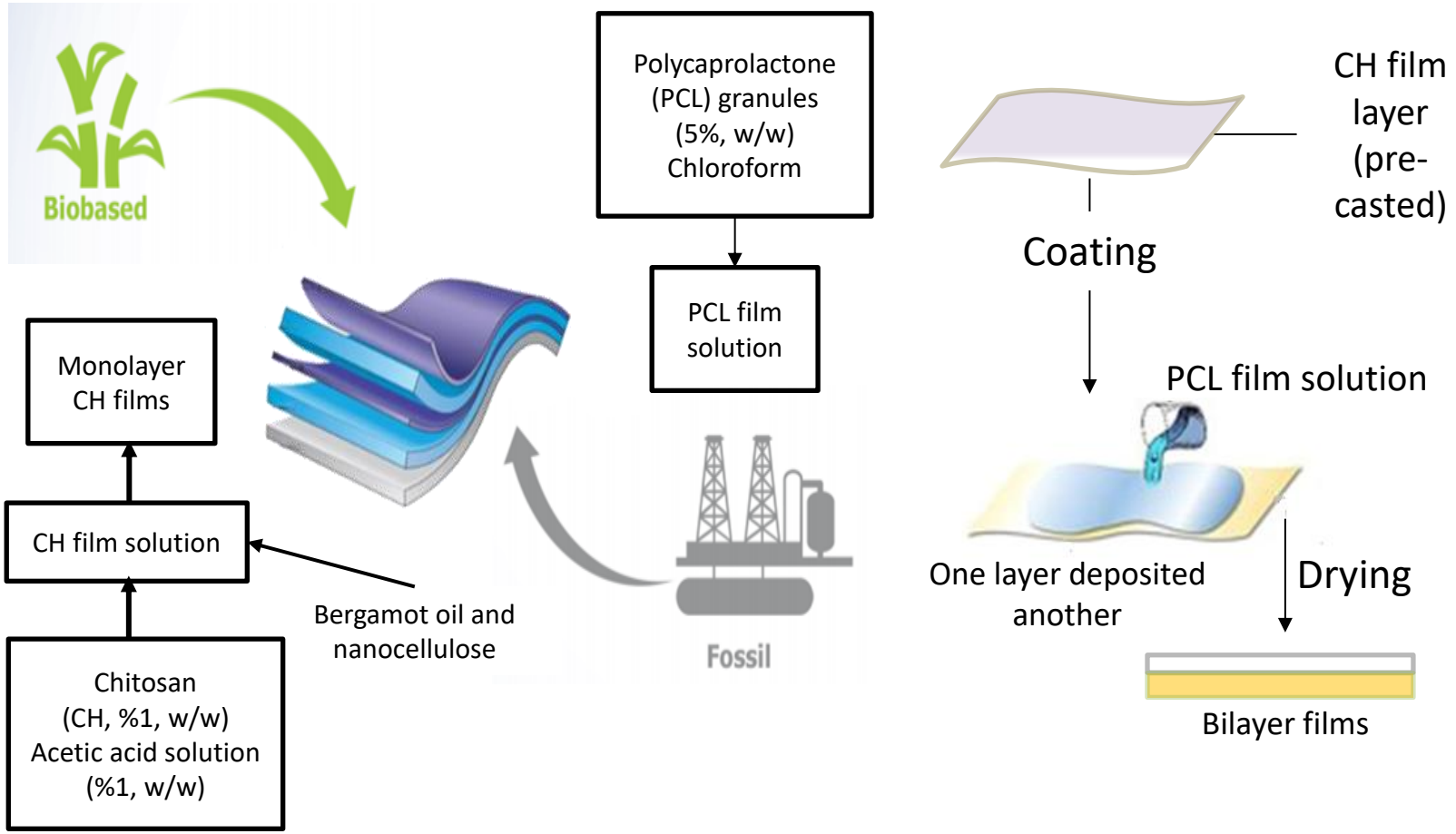


DAY 15

PE | **BIO-BASED MONOLAYER** | **BIO-BASED BILAYER** | **BIO-BASED REINFORCED BILAYER**

by Söğüt and Seydim, 2018

SYNTHETIC POLYMER COATING ON BIOPOLYMERS-CASE STUDY-III

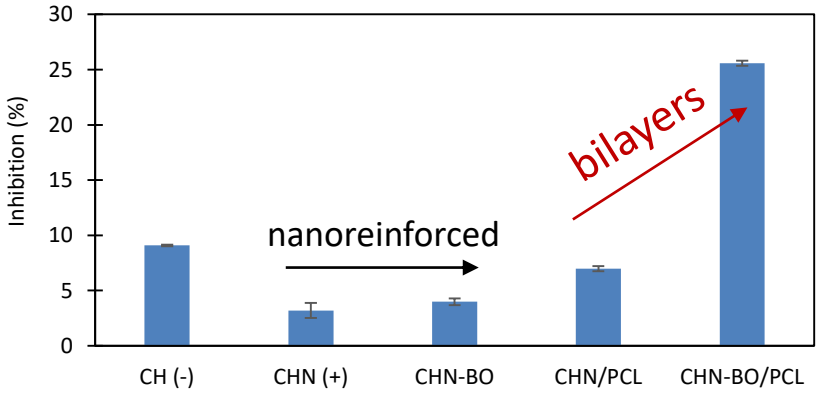


Combination of bio-based polymer layers with fossil based polymer by coating process to prepare active bilayer films.

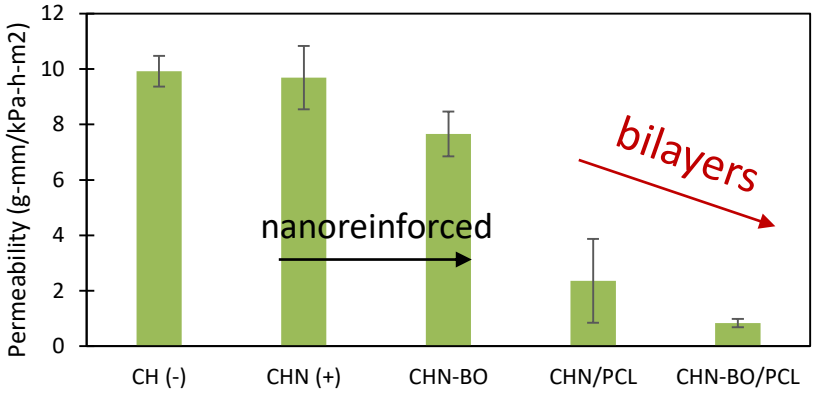
by Söğüt, Kaymaz, and Seydim, 2018

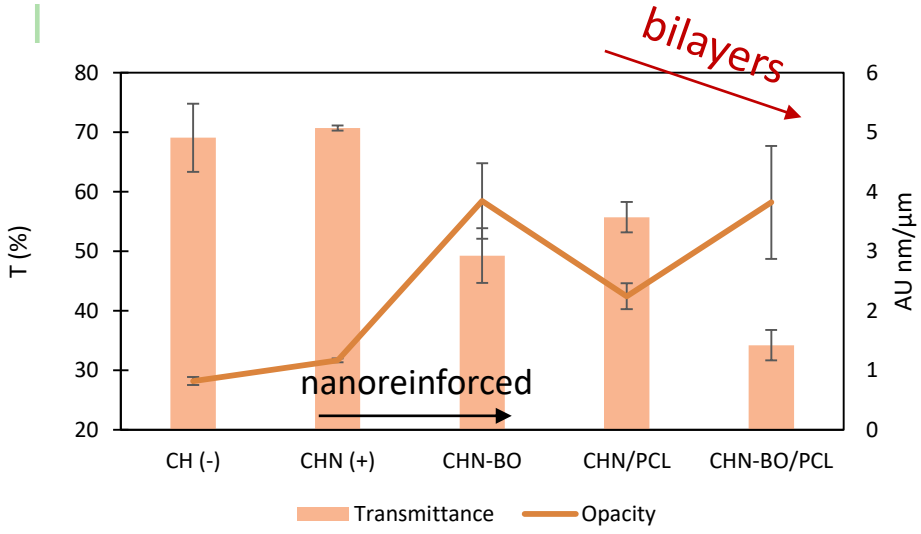
CASE STUDY-III cont.

Antioxidant activity



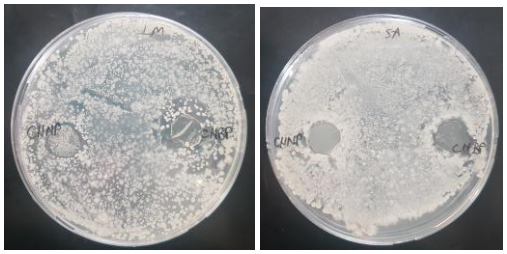
Water vapor permeability





Antimicrobial activity

	Gram (-)		Gram (+)	
	EC	PSA	LM	SA
nanoreinforced	2.1±0.1	1.9±0.1	2.0±0.4	1.7±0.1
bilayer	-	1.7±0.1	1.9±0.3	1.8±0.2



Bilayers: bio-based polymer coated with synthetic polymer
Nanoreinforced: bio*based polymer enhanced with nanofiller
By Söğüt, Kaymaz, and Seydim, 2019

WHAT DID SCIENTISTS DO?

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ASD Ambalaj Kongresi 2019
Uluslararası Ambalaj Sanayi Kongresi

WHAT DID WE DO?

LWT - Food Science and Technology 101 (2019) 799–805

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

The effects of chitosan- and polycaprolactone-based bilayer films incorporated with grape seed extract and nanocellulose on the quality of chicken breast fillets

Ece Sogut*, Atif Can Seydim

Department of Food Engineering, Faculty of Engineering, Süleyman Demirel University,

RESEARCH ARTICLE

ARTICLE INFO

Keywords:
Chitosan
Polycaprolactone
Active bilayer film
Nanocellulose
Chicken breast fillet

ABSTRACT

Chitosan (CH)-and po
extract (GSE) (15% w
Chicken breast fillets
thiobarbituric acid re
bacteria (TMAB) and
films with GSE kept t
(ΔE) was higher for t
films including GSE s
films with GSE and N
with GSE and NC led

Food Packaging and Shelf Life 18 (2018) 13–20

Contents lists available at ScienceDirect

Food Packaging and Shelf Life

journal homepage: www.elsevier.com/locate/fpsl

The effects of Chitosan and grape seed extract-based edible films on the quality of vacuum packaged chicken breast fillets

Ece Sogut*, Atif Can Seydim

Department of Food Engineering, Faculty of Engineering, Süleyman Demirel University, 32200 Isparta, Turkey

ARTICLE INFO

Keywords:
Chitosan
Grape seed extract
Antioxidant activity
Antimicrobial activity
Chicken breast fillets

ABSTRACT

The effect of grape seed extract (GSE) (at 5, 10 and 15%) incorporated into chitosan (CH) film was evaluated by considering its physico-mechanical properties, antioxidant and antimicrobial activities in order to show improved shelf life for vacuum-packed food under refrigerated conditions. GSE-incorporated films showed higher water vapor permeability, elastic modulus, opacity, and a^* and b^* values ($p < 0.05$). Increasing the GSE concentration lowered the transmittance and L^* values. The addition of GSE provided antioxidant activity to the CH films and the addition of 15% GSE into CH films inhibited the oxidation of chicken breast fillets during refrigerated storage ($p < 0.05$). GSE-incorporated CH films inhibited *Escherichia coli*, *Listeria monocytogenes*, *Staphylococcus aureus* and *Pseudomonas aeruginosa* more efficiently than CH films alone. CH films incorporating 15% GSE inhibited total mesophilic aerobic bacteria (TMAB) and coliforms in chicken breast fillets ($p < 0.05$) and provided a 1.50–2.33 log reduction in TMAB and coliforms, respectively, during storage. These results reveal that the inclusion of GSE into CH films has the potential to help develop antioxidant/antimicrobial packaging for food products.

Polymer Testing 77 (2019) 105886

Contents lists available at ScienceDirect

Polymer Testing

journal homepage: www.elsevier.com/locate/polytest

operties of κ-carrageenan and whey protein isolate blended films ning pomegranate seed oil

ıt[a,*], A.M. Ili Balqis[b], Z.A. Nur Hanani[b], Atif Can Seydim[a]

f Food Engineering, Faculty of Engineering, Süleyman Demirel University, 32200, Isparta, Turkey
f Food Technology, Faculty of Food Science and Technology, Universiti Putra Malaysia, 43400, Serdang, Selangor, Malaysia

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whey protein isolate (W), κ-carrageenan (C), and a mixture of both (W–C, 1:1, w/w) containing seed oil (PSO) was developed and characterized by scanning electron microscopy (SEM), water ıbility (WVP), solubility, mechanical, optical properties, release tests and antimicrobial activity. containing PSO showed higher elongation capacity, and lower WVP, solubility and transparency .05). The WVP, solubility and elongation capacity of C films were improved when blended with W, ensile strength of C films was reduced ($p < 0.05$). SEM analysis revealed that there is an inter- n PSO with films with a combination of W and C. In the release tests, the faster release of PSO in all erved with simulant A (10% v/v ethanol) compared to simulant B (3% v/v acetic acid). A limited he film samples containing PSO was seen to inhibit *Escherichia coli* and *Listeria monocytogenes*.

Characterization of cyclic olefin copolymer-coated chitosan bilayer films containing nanocellulose and grape seed extract

Ece Söğüt | Atif Can Seydim

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This study evaluated the effect of applying cyclic olefin copolymer (COC) on the operties of chitosan (CH) he CH film solutions to (NC) (0% to 2%, w/w) to on was carried out by c EM), optical analysis, and hat there was a functiona chment occurred for bilay surface with the addition dition of GSE had an adve NC into the CH films redu owed lower contact angl for CH film surfaces wit d elastic modulus and a d timicrobial activity ag ver, film samples with ad enyl-1-picrylhydrazyl s ± 0.07%. The bilayer film unds as an active packag n, cyclic olefin copolymer, g

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Development of Chitosan and Polycaprolactone based active bilayer films enhanced with nanocellulose and grape seed extract

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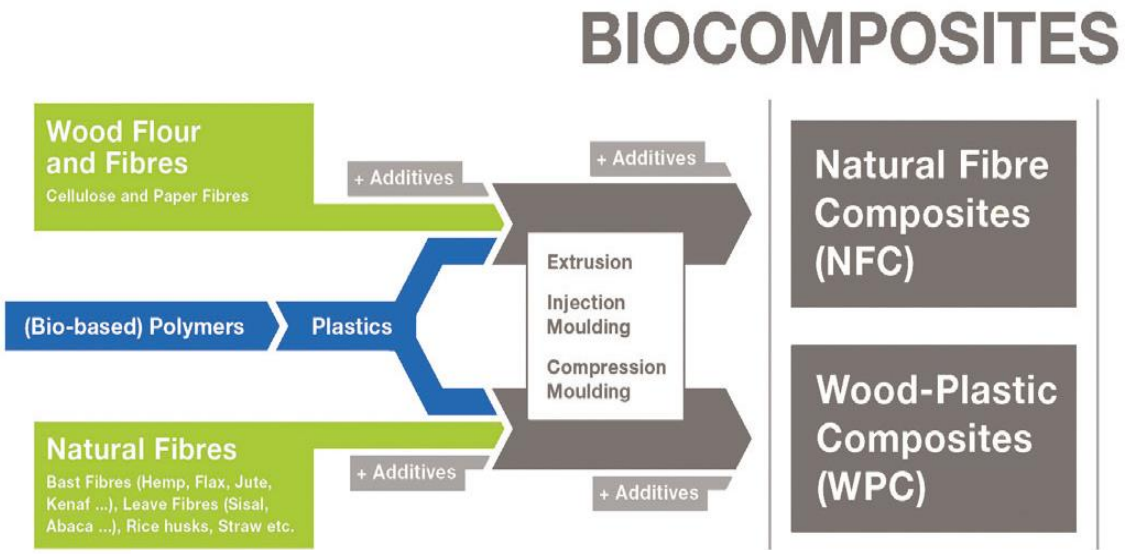
ABSTRACT

In this study, nanocellulose (NC) (2–5%, w/w) and grape seed extract (GSE) (15%, w/w) added chitosan (CH) and polycaprolactone (PCL) based active bilayer films were prepared by either coating with PCL in the form of chloroform solution (C-PCL) or compression of PCL and CH layers (P-PCL). Films were tested by means of scanning electron microscopy (SEM), water vapor permeability (WVP), tensile tests, optical and active properties (antimicrobial, and antioxidant activities), and release studies. The incorporation of NC significantly reduced WVP and opacity of films while GSE addition had an adverse effect. P-PCL films showed higher elastic modulus, tensile strength and WVP values and lower elasticity when compared to C-PCL films ($p < 0.05$). All film samples showed antimicrobial activity, and GSE retained its antioxidant capacity within CH matrix. The formation of the CH and PCL based bilayer films with NC and GSE improved the suitability of CH films for food packaging applications.

CONCLUSION

Because of depletion of petroleum resources and environmental problems, bioplastics arouse much interest in both academic and industrial areas. As a result, about 50% of bioplastics are currently in use. However, due to the poor/inadequate properties of bioplastics derived from biomass, their use are restricted in many industrial areas.

To deal with these problems, physical and chemical methods were used such as blending with synthetic polymers, incorporation of nanoscale fillers, chemical modification, etc. Coating with synthetic plastics are one of these solutions and can be considered as the first step.



A route for production of bioplastics (by Nova-Institute)

ANY QUESTION…