Summary

Biopolymers
CHEM-E2155

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Engineering

Schedule

Day	Subject of lecture	Discussion part
08 January	Introduction to the course	
15 January	Biopolymers overview	Reading 1
22 January	Biopolymers for packaging	Reading 2
29 January	Discussion day	Reading 3 & Assignment 1
05 February	Biodegradation 1	Reading 4
12 February	Biodegradation 2	Reading 5
26 February	Discussion day	Reading 6 & Assignment 2
04 March	Chitin, alginates and others	Reading 7
11 March	Proteins	Reading 8
18 March	Discussion day	Reading 9 & Assignment 3
25 March	Summary	Reading 10

Previous lecture

<u>Discussion day:</u>

- Video assignment: *Kitchen chemistry*
- Reading assignment: *Green Polymer Chemistry and Bio-based Plastics: Dreams and Reality*

Learning Outcomes

After today's course you

- know about singe use plastics
- have reflected on the entire course content

Final assignment
Learning Essay

Instructions

Due date: April 11 23:59
(no late submission accepted!)

- Your essay should touch the content of all lectures and summarize them briefly.
- Do not address them one by one. Instead, find a holistic approach in your summary.
- Create connections between the subjects. A connection to at least three reading assignments is also needed (cite those!).
- Write a short final paragraph on your opinion about the future role of biopolymers for our society. Explain your opinion.

Instructions

Due date: April 11 23:59
(no late submission accepted!)

You are encouraged to use AI-tools (e.g., ChatGBT) to support you in this essay. If you do so, highlight the paragraphs that are written with the aid of AI.

Responsible use of AI-tools:

- You are solely and fully responsible for the writing you turn in bearing your name.
- If it's factually inaccurate, that's on you.
- If it's badly organized, that's on you.
- If it's stylistically or logically inconsistent, that's on you.
- If it's partially plagiarized, that means that you have committed plagiarism.

Aalto University Code of Academic Integrity and Handling Violations Thereof | Aalto University
https://www.aalto.fi/en/applications-instructions-and-guidelines/aalto-university-code-of-academic-integrity-and-handling-violations-thereof

Aalto University guidelines and tips for student in using artificial intelligence in learning

Guidelines for the use of artificial intelligence in teaching and learning

What are the general guidelines at Aalto?

What are my responsibilities as a student?

→ Guidance for the use of artificial intelligence in teaching and learning at Aalto University | Aalto University

Tips on using artificial intelligence in learning

How do I use AI responsibly?

How can I take advantage of AI in learning?

→ Tips for using artificial intelligence for students | Aalto University

Single use plastics SUP

Single use plastics SUP

7.6.2021 EN Official Journal of the European Union C 216/1

IV

(Notices)

NOTICES FROM EUROPEAN UNION INSTITUTIONS, BODIES, OFFICES AND AGENCIES

COMMISSION NOTICE

Commission guidelines on single-use plastic products in accordance with Directive (EU) 2019/904 of the European Parliament and of the Council on the reduction of the impact of certain plastic products on the environment

(2021/C 216/01)

Single use plastics SUP

‘a product that is made **wholly or partly** from plastic and that is **not conceived, designed or placed on the market** to accomplish, **within its life span, multiple trips or rotations by being returned to a producer for refill** or **re-used for the same purpose for which it was conceived**’ *[emphasis added]*

- Balloons, balloon sticks
- Beverage containers (up to three litres) including their caps and lids
- Cups for beverages; straws
- Cotton bud sticks;
- Food containers; cutlery (forks, knives, spoons, chopsticks);
- Lightweight plastic carrier bags
- Sanitary towels (pads), tampons and tampon applicators
- Tobacco products with filters and filters marketed for use in combination with tobacco products
- Wet wipes

Single use plastics SUP

'"plastic" means a material consisting of a **polymer as defined in point (5) of Article 3 of Regulation (EC) No 1907/2006 of the European Parliament and of the Council** ([3]), to which additives or other substances may have been added, and which **can function as a main structural component** of final products, with **the exception of natural polymers that have not been chemically modified**' [Emphasis added]

'polymer: means a substance consisting of molecules characterised by the sequence of one or more types of monomer units. Such molecules must be distributed over a range of molecular weights wherein differences in the molecular weight are primarily attributable to differences in the number of monomer units.

Single use plastics SUP

‘**Unmodified natural polymers**, within the meaning of the definition of “**not chemically modified substances**” in **point 40 of Article 3 of Regulation (EC) No 1907/2006**…, should not be covered by this Directive as they **occur naturally in the environment**. Therefore, for the purposes of this Directive, the definition of polymer in point 5 of Article 3 of Regulation (EC) No 1907/2006 should be adapted and a separate definition should be introduced’ *[Emphasis added]*

‘Plastics manufactured with **modified natural polymers**, or plastics manufactured from **bio-based, fossil or synthetic starting substances are not naturally occurring** and should therefore be addressed by this Directive. The adapted definition of plastics should therefore cover **polymer-based rubber items and bio-based and biodegradable plastics** regardless of whether they are derived from biomass or are intended to biodegrade over time’ *[Emphasis added]*

Single use plastics SUP

'Natural polymers are understood as polymers which are the result of a polymerisation process that has **taken place in nature, independently of the extraction process** with which they have been extracted. This means that natural polymers are not necessarily "**substances which occur in nature**" when assessed according to the criteria set out in Article 3(39) of the REACH Regulation.' *[Emphasis added]*

In view of the above, the terms natural polymer and naturally occurring substance are two distinct terms and should not be confused. A key distinction relates to the extraction methods allowed. The scope of the natural polymer refers to a broader group that is independent of the method used to extract the substance from nature. Furthermore, point (39) of Article 3 of the REACH Regulation is not directly referred to in the Directive. A consequence of this distinction and applying the definition from the ECHA Guidance is, for example, that cellulose and lignin extracted from wood and corn starch obtained via wet milling meet the definition of natural polymer.

Another key distinction is whether the polymerisation process has taken place in nature or is the result of an industrial process involving living organisms. Based on the REACH Regulation and the related ECHA Guidance, polymers produced via an industrial fermentation process are not considered natural polymers since polymerisation has not taken place in nature. Therefore, polymers resulting from biosynthesis through man-made cultivation and fermentation processes in industrial settings, e.g. polyhydroxyalkanoates (PHA), are not considered natural polymers as not being the result of a polymerisation process that has taken place in nature. In general, if a polymer is obtained from an industrial process and the same type of polymer happens to exist in nature, the manufactured polymer does not qualify as a natural polymer.

Single use plastics SUP

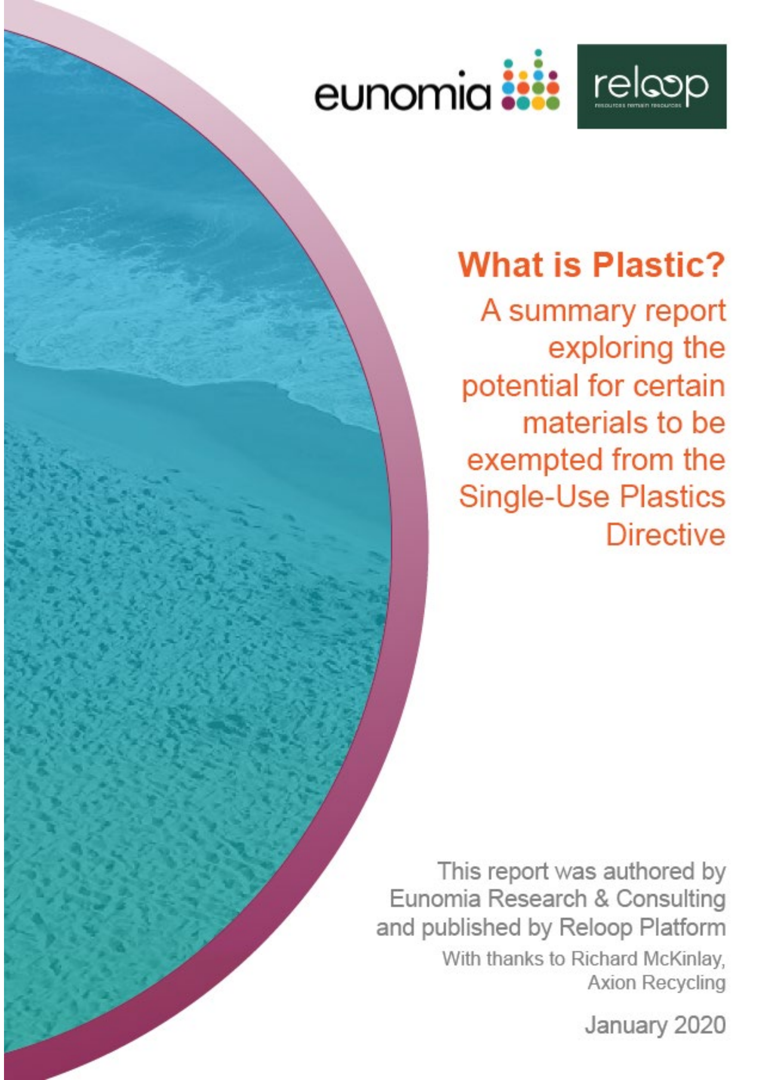
‘not chemically modified substance: means a substance whose **chemical structure remains unchanged**, even if it has undergone a chemical process or treatment, or a physical mineralogical transformation, for instance to remove impurities.’ *[Emphasis added]*

Single use plastics

5.0 Conclusions and Recommendations

A **strong argument can be made that viscose products do fall within the scope** of the SUP Directive provisions, based on the Directive definition of plastic and the scientific evidence relating to viscose production.

Regarding lyocell and viscose, there is a **lack of evidence around the extent to which biodegradation will take place in the marine environment**. There are no currently available specifications or established frameworks for certification of biodegradability in the marine environment. Although some test methods exist, they do not encompass a wide range of marine environments. Flushability standards are primarily focused on sewer blockages and vary in how rigorously this is tested. They also provide a very limited indication of other environmental impacts, including biodegradation in the marine environment. This means that **current standards cannot provide confidence that materials that pass into the marine environment will not have a similarly detrimental impact as a synthetic plastic product**. Based on this, **there appears to be no justification on environmental grounds for an exemption for lyocell or viscose under the SUP Directive.**



eunomia reloop

What is Plastic?

A summary report exploring the potential for certain materials to be exempted from the Single-Use Plastics Directive

This report was authored by Eunomia Research & Consulting and published by Reloop Platform

With thanks to Richard McKinlay, Axion Recycling

January 2020

Aalto University
School of Chemical
Engineering

Single use plastics SUP

FINNISH GOVERNMENT

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Press release of the Ministry of the Environment, Finnish Food and Drink Industries' Federation, Finnish Hospitality Association, Finnish Grocery Trade Association and Finnish Packaging Association

Companies commit to reducing use of single-use plastic portion packs

Ministry of the Environment

Single use plastics SUP

Attention to details – new law already partially in effect

Producers subject to producer responsibility should be careful with the new requirements and guidelines, as they affect company operations and the choices they make. SUP legislation is already partially in effect. In March 2022, the Ministry of the Environment and certain organizations signed a so-called Green Deal agreement, which is voluntary and aims to reduce the consumption of single-use food packages. The enforcement of the directive was supplemented by a government proposal to amend the waste act that was submitted to parliament in September 2022. The parliament approved the amendment on 29.11.2022.

The next steps concerning SUP legislation are:

- Producers responsible for cleaning costs of SUP waste in municipalities in 2024
- Beverage containers must have attached caps as of 1.7.2024
- 77% of plastic bottles should be collected nationwide in 2025
- All PET beverage bottles must contain 25% of recycled plastic in 2025

Recap

Themes

Definitions, methods, tools

Examples for biopolymers

Properties of biopolymers

Definitions, methods, tools

Biopolymers

(or “bioplastic”)

Criteria:

- the source of the raw materials
- the biodegradability of the polymer.

A. Biopolymers made from renewable raw materials (bio-based), and *being biodegradable*

B. Biopolymers made from renewable raw materials (bio-based), and *not being biodegradable*

C. Biopolymers *made from fossil carbon* and being *biodegradable*.

Michael Niaounakis, *Biopolymers: Processing and Products*, PDL Handbook Series, 1st Edition, Elsevier 2015
Chapter-1-Introduction_2015_Biopolymers-Processing-and-Products.pdf

Degradable Polymers

broad term applied to polymers or plastics that disintegrate by a number of processes (physical disintegration, chemical degradation, and biodegradation by biological mechanisms).

A polymer may be degradable but not biodegradable.

Biodegradable Polymers

degrade under the action of microorganisms such as molds, fungi, and bacteria within a specific period of time and environment.

On its own, the term biodegradable has no clear meaning and creates confusion.

ISO 17088:2012 / EN 13432:2000, EN 14995:2006 / ASTM D6400-12

Michael Niaounakis, *Biopolymers: Processing and Products*, PDL Handbook Series, 1st Edition, Elsevier 2015
Chapter-1-Introduction_2015_Biopolymers-Processing-and-Products.pdf

Bio-based

Term focused on the raw materials basis (polymers **derived from renewable resources**).
Raw materials are **renewable if they are replenished by natural procedures** at rates comparable or faster than their rate of consumption

ASTM bio-based materials: "an organic material in which carbon is derived from a renewable resource via biological processes. Bio-based materials include all plant and animal mass derived from carbon dioxide (CO_2) *recently* fixed via photosynthesis, per definition of a renewable resource."

A bio-based polymer is not *per-se* a **sustainable polymer**; this depends on a variety of issues, including the source material, production process, and how the material is managed at the end of its useful life.

- Not every bio-based polymer is biodegradable
  (bio-based polyethylene or polyamide 11)
- Not every biodegradable polymer is bio-based
  (poly(ε-caprolactone) or poly(glycolic acid)
- Some fall into both categories
  (polyhydroxyalkanoates, PHAs)

Michael Niaounakis, *Biopolymers: Processing and Products*, PDL Handbook Series, 1st Edition, Elsevier 2015
Chapter-1-Introduction_2015_Biopolymers-Processing-and-Products.pdf

Biomaterial

"Synthetic material used to replace part of a living system, or to function in intimate contact with living system"

" A material intended to interface with biological systems to evaluate, treat, augment or replace any tissue, organ or function of the body"

" A substance which is used to direct the course of any therapeutic or diagnostic procedure in medicine"

Lumbar disc prosthesis PRODISC® L

Synthetic biomaterials:

- Metals
- Alloys and ceramics
- Polymers
- Composites

Joint replacements, bone plates and screws, dental root implants, pacer and suture wires, orthopedic implants, sutures, blood vessels, implantable ocular lenses, heart valves, surgical packaging, cannulaes etc.

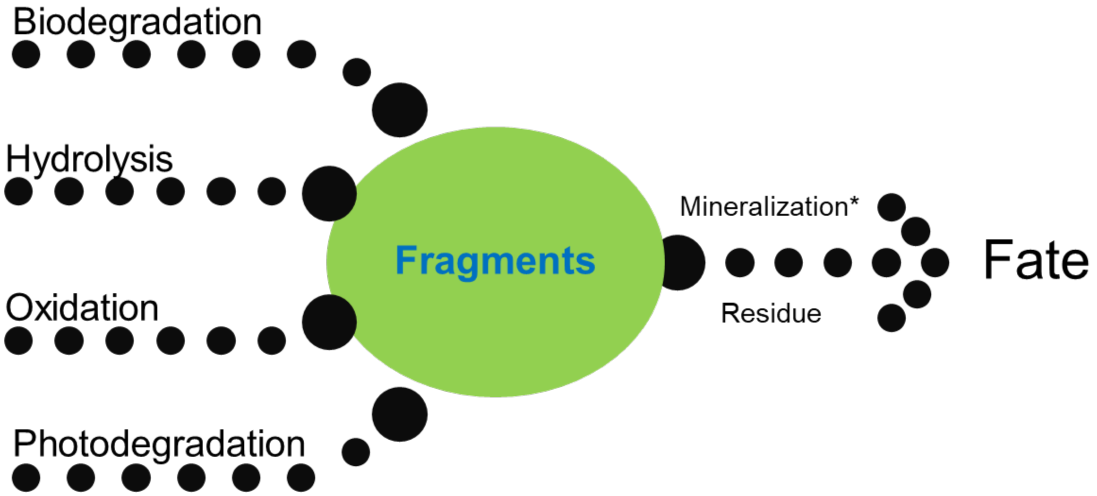
Williams D.F., On the nature of biomaterials, *Biomaterials* 30 (2009), 5897-5909

Definitions used in relation to biodegradable plastics

DIN FNK 103.2	Biodegradable plastics(1): if all its organic compounds undergo a complete biodegradation process. Environmental conditions and rates of biodegradation are to be determined by standardized test methods.
	Biodegradation(3): process, caused by biological activity, which leads under change of the chemical structure to naturally occurring metabolic products.
ASTM sub-committee D20-96	Biodegradable plastics(1): A degradable plastic in which the degradation results from the action of naturally occurring microorganisms such as bacteria, fungi and algae.
Japanese Bio-degradable Plastics Society	Biodegradable plastics (1): Polymeric materials which are changed into lower molecular weight compounds where at least one step in the degradation process is though metabolism in the presence of naturally occurring organisms.
ISO 472	Biodegradable plastics(1): A plastic designed to undergo a significant change in its chemical structure under specific environmental conditions resulting in a loss of some properties that may vary as measured by standard test methods appropriate to the plastic and the application in a period of time that determines its classification. The change in the chemical structure results from the action of naturally occurring microorganisms.
CEN	Biodegradable plastics(1): A degradable material in which the degradation results from the action of micro-organisms and ultimately the material is converted to water, carbon dioxide and/or methane and a new cell biomass.
	Biodegradation(2): Biodegradation is a degradation caused by biological activity, especially by enzymatic action, leading to a significant change in the chemical structure of a material
	Inherent biodegradability (2): The potential of a material to be biodegraded, established under laboratory conditions.
	Ultimate biodegradability(2): The breakdown of an organic chemical compound by microorganisms in the presence of oxygen to biodegradability carbon dioxide, water and mineral salts of any other elements present (mineralization) and new biomass or in the absence of oxygen to carbon dioxide, methane, mineral salts and new biomass.
	Compostability(2): Compostability is a property of a packaging to be biodegraded in a composting process. To claim compostability it must have been demonstrated that a packaging can be biodegraded in a composting system as can be shown by standard methods. The end product must meet the relevant compost quality criteria.

Müller, R-J, **Biodegradability of Polymers: Regulations and Methods for Testing** in **Biopolymers Online,** Online ISBN: 9783527600038, DOI: 10.1002/3527600035, pp. 365-388

Biodegradation, hydrolysis, oxidation, and photodegradation, initially give intermediate products (fragments) that may biodegrade further to some other residue, biodegrade completely and be removed from the environment entirely and ultimately mineralized, or remain unchanged in the environment.



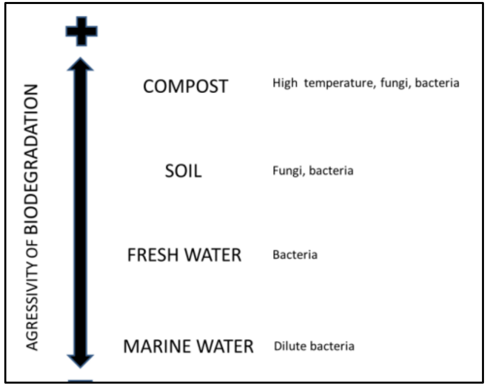
*slow process for polymeric materials and fragments: complete conversion to CO_2 or CH_4, water, and salts.
In the cases where residues remain in the environment, they must be established as harmless by suitably rigorous fate and effect evaluations.

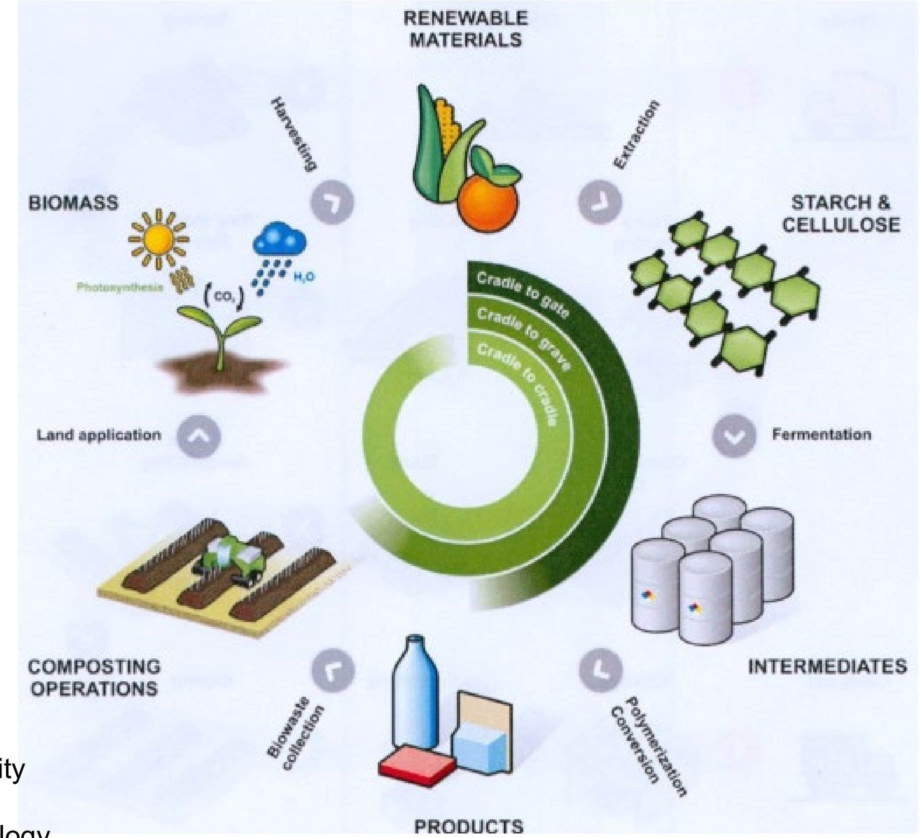
Adapted from: Swift, G. 2000. Polymers, Environmentally Degradable. Kirk-Othmer Encyclopedia of Chemical Technology

Compositing

In landfills moisture and oxygen are minimized or absent, thus the materials are not readily decomposed.

In a compost operation biodegradable plastics can be converted by microbes into CO_2, water and humus in a matter of months.





- Moisture content
- Oxygen availability
- Temperature
- Type of microbiology
- Density of microbiology
- Salt concentration.

A biodegradable plastic is not automatically biodegradable in all environments

Kijchavengkul, T. and Auras, R., Perspective compostability of polymers, Polymer International 57 (2008) 793-804.

Factors affecting biodegradation

- **Exposure conditions**
  - **Abiotic**
    - Temperature
    - Moisture
    - pH
    - UV radiation
    - Salts
    - Metal ions
    - Nutrient content
  - **Biotic**
    - Extracellular enzymes
    - Hydrophobicity
    - Biosurfactants
- **Polymer characteristics**
  - Flexibility
  - Crystallinity
  - Morphology
  - Functional Groups
  - Crosslinking
  - MW
  - Copolymers
  - Blend
  - Tacticity
  - Additives

Kijchavengkul, T. and Auras, R., Perspective compostability of polymers. Polymer International 57 (2008) 793-804.

Reading assignment 4

Title: Biopolymers Reuse, Recycling, and Disposal. Chapter 3: Reuse

Recuperation

Restabilization

Blending Recycled Biopolymers with other Polymers

Modification of the Chemical Structure

Multiple Processing

LCA – shopping bags

Table 34. Gross Energy by Activity (MJ)					
	Fuel prod'n (total)	Fuel use (total)	Transport (total)	Feedstock (total)	Total
Paper Bag (1000 bags)	493	1105	34	991	2622
Compostable Plastic Bag (1000 bags)	265	659	38	418	1380
Compostable Plastic Bag (1500 bags)	398	988	57	627	2070
Polyethylene Plastic Bag (1000 bags)	106	114	11	279	509
Polyethylene Plastic Bag (1500 bags)	159	171	16	418	763

Table 37. Global Warming Potential (CO2 Equivalents in tons)				
	Paper bag with "sequestered scenario" of carbon dioxide emissions (1000 bags)	Compostable plastic bag With 100% aerobic decomposition in landfill (1500 bags)	Compostable plastic bag with 50% aerobic & 50% anaerobic decomposition in landfill (1500 bags)	Polyethylene Plastic Bag (1500 bags)
Production	0.03	0.15	0.15	0.03
Disposal	0.05	0.03	0.22	0.00
Total	0.08	0.18	0.37	0.04

Life Cycle Assessment for Three Types of Grocery Bags - Recyclable Plastic; Compostable, Biodegradable Plastic; and Recycled, Recyclable Paper.
Chet Chaffee and Bernard R. Yaros; Boustead Consulting & Associates Ltd. 2014

Comparison of shopping bags

Type of carrier	HDPE bag (No secondary reuse)	HDPE bag (40.3% reused as bin liners)	HDPE bag (100% reused as bin liners)	HDPE bag (Used 3 times)
Paper bag	3	4	7	9
LDPE bag	4	5	9	12
Non-woven PP bag	11	14	26	33
Cotton bag	131	173	327	393

UK Environment Agency:
Life cycle assessment of supermarket carrier bags: a review of the bags available in 2006
Report: SC030148

Reading assignment 6

Title: Disposable Paper-based Food Packaging

From: Profundo Research & advice

Impact of paper and board production and products thereof

Examples for biopolymers

Biopolymers

Animal based

Polysaccharides
- Chitin
- Alginates
- Xanthum gum

Proteins
- Collagen
- Gelatin
- α/β-Keratin

Plant based

Polysaccharides
- Starch
- Cellulose
- Hemicelullose
- Pectine

Proteins
- Soy protein
- Gluten

Vegetable fats and oils

Natural rubber

Lignin

From microorganisms

- Polyhydroxyalkanoates
- Pullulan
- Bacterial cellulose

Synthetic

Bio-derived
- Polylactic acid

Oil-based
- Poly(alkylene dicarboxylate)s
- Polycaprolactone

TABLE 1.1 Biodegradable versus Bio-Based Polymers

Origin	Biodegradable	Nonbiodegradable
Bio-based	CA, CAB, CAP, CN, P3HB, PHBHV, PLA, starch, chitosan	PE (LDPE), PA 11, PA 12, PET, PTT
Partially bio-based	PBS, PBAT, PLA blends, starch blends	PBT, PET, PTT, PVC, SBR, ABS, PU, epoxy resin
Fossil fuel-based	PBS, PBSA, PBSL, PBST, PCL, PGA, PTMAT, PVOH	PE (LDPE, HDPE), PP, PS, PVC, ABS, PBT, PET, PS, PA 6, PA 6.6, PU, epoxy resin, synthetic rubber

ABS, acrylonitrile-butadiene-styrene; CA, cellulose acetate; CAB, cellulose acetate butyrate; CAP, cellulose acetate propionate; CN, cellulose nitrate; HDPE, high density polyethylene; LDPE, low density polyethylene; PA 6, polyamide 6; PA 6.6, polyamide 6.6; PA 11, aminoundecanoic acid-derived polyamide; PA 12, laurolactam-derived polyamide; PBAT, poly(butylene adipate-*co*-terephthalate); PBS, poly(butylene succinate); PBSA, poly(butylene succinate-*co*-adipate); PBSL, poly(butylene succinate-*co*-lactide); PBST, poly(butylene succinate-*co*-terephthalate); PBT, poly(butylene terephthalate); PCL, poly(ε-caprolactone); PE, polyethylene; PET, poly(ethylene terephthalate); PGA, poly(glycolic acid), polyglycolide; P3HB, poly(3-ydroxybutyrate); PHBHV, poly(3-hydroxybutyrate-*co*-3-hydroxyvalerate); PLA, poly(lactic acid), polylactide; PP, polypropylene; PS, polystyrene; PTMAT, poly(methylene adipate-*co*-terephthalate); PTT, poly(trimethylene terephthalate); PVOH, poly(vinyl alcohol); PVC, poly(vinyl chloride); PU, polyurethane; SBR, styrene-butadiene rubber.

Michael Niaounakis, *Biopolymers: Processing and Products*, PDL Handbook Series, 1st Edition, Elsevier 2015
Chapter-1-Introduction_2015_Biopolymers-Processing-and-Products.pdf

TABLE 1.2 Classification of Biopolymers

Biodegradable				Nonbiodegradable
Bio-Based			Fossil-Based	Bio-Based
Plants	Microorganisms	Animals		
Cellulose and its derivatives[1] (polysaccharide)	PHAs (e.g., P3HB, P4HB, PHBHV, $P3HBHH_x$)	Chitin (polysaccharide)	Poly(alkylene dicarboxylate)s (e.g., PBA, PBS, PBSA, PBSE, PEA, PES, PESE, PESA, PPF, PPS, PTA, PTMS, PTSE, PTT)	PE (LDPE, HDPE), PP, PVC
Lignin	PHF	Chitosan (polysaccharide)	PGA	PET, PPT
Starch and its derivatives (monosaccharide)	Bacterial cellulose	Hyaluronan (polysaccharide)	PCL	PU
Alginate (polysaccharide)	Hyaluronan (polysaccharide)	Casein (protein)	PVOH	PC
Lipids (triglycerides)	Xanthan (polysaccharide)	Whey (protein)	POE	Poly(ether-ester)s
Wheat, corn, pea, potato, soy, potato (protein)	Curdlan (polysaccharide)	Collagen (protein)	Polyanhydrides	Polyamides (PA 11, PA 410, PA 610, PA 1010, PA 1012)
Gums (e.g. *cis*-1, 4-polyisoprene)	Pullulan (polysaccharide)	Albumin (protein)	PPHOS	Polyester amides
Carrageenan	Silk (protein)	Keratin, PFF (protein)		Unsaturated polyesters
PLA (from starch or sugar cane)		Leather (protein)		Epoxy
				Phenolic resins


Chitosan

Medicine

(Because bioactivity, antimicrobial, immunostimulation, chemotactic action, enzymatic biodegradability, mucoadhesion…)

Pharmacy

(formation of polyelectrolyte complexes, easy formation of capsules, low swelling in water, pH-sensitivity)

Agriculture

(fungicidal, antiviral, antibacterial, plant growth and regulation, plant protection…)

Food

(Chitosan is not FDA approved nor EU regulated, lots of attention as flocculant for the recovery of proteins, antimicrobial, emulsion stabilizer)

Cosmetics

(cationic character interacts with negatively charged biological surfaces – skin and hair - , metal ion complexing capacity, water retention)

Alginate

- Food industry (thickening agent, gelling agent, emulsifier, stabilizer, texture-improver)… It is FDA approved
- Textile printing (substrate of color paste)
- Animal food (binder and thickening agent)
- Pharmaceutical (wound dressing, dental impression material, tablet binder, controllable drug release, immobilization)
- Cosmetics (thickener, moisture retainer)

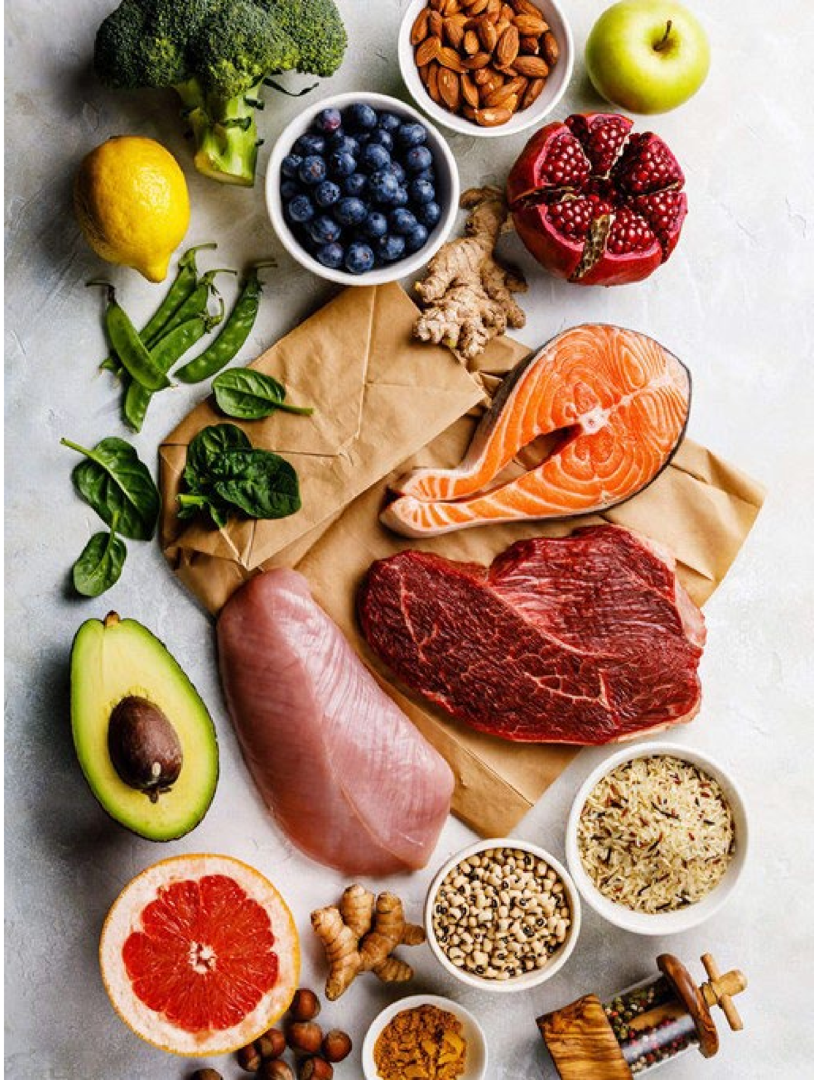
Sodium alginate, water, calcium lactate

Sodium alginate, fruit juice and calcium solution expunged through a syringe

Proteins (Polypeptides)

- **Keratin**
- **Silk proteins**
- **Wheat protein**
- **Soyprotein**

- **Casein**



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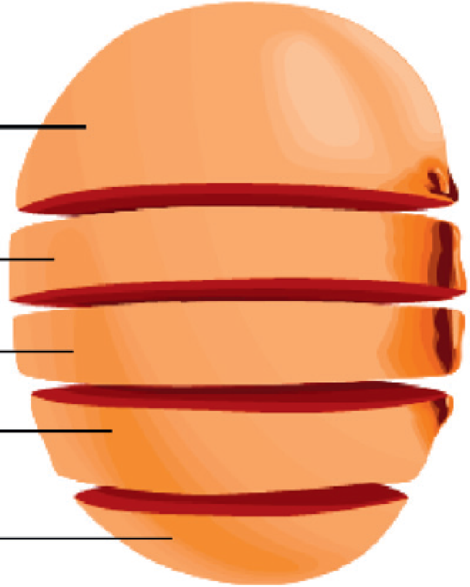
Soy protein

Soybean production in 2022

Brazil	121 Mt
USA	116 Mt
Argentine	44 Mt

= 80% of global production



M. Thrane, P.V. Paulsen, M.W. Orcutt, T.M. Krieger, Chapter 2 - Soy Protein: Impacts, Production, and Applications, Sustainable Protein Sources, 2017, 23-45.

Wheat protein

Wheat grain proteins

Non-gluten proteins
(15-20%)

Albumins
(water soluble)

Globulins
(water insoluble or soluble in salt solutions)

Mostly monomeric with MW<25 kDa

Gluten proteins
(80-85%)

Monomeric gliadins
(soluble in alcohols MW 20-80 kDa)

Polymeric glutenins
(MW 80-10^3 kDa)

- High-molcular-weight glutenin subunits (HMW-GS)
- Low-molcular-weight glutenin subunits (LMW-GS)

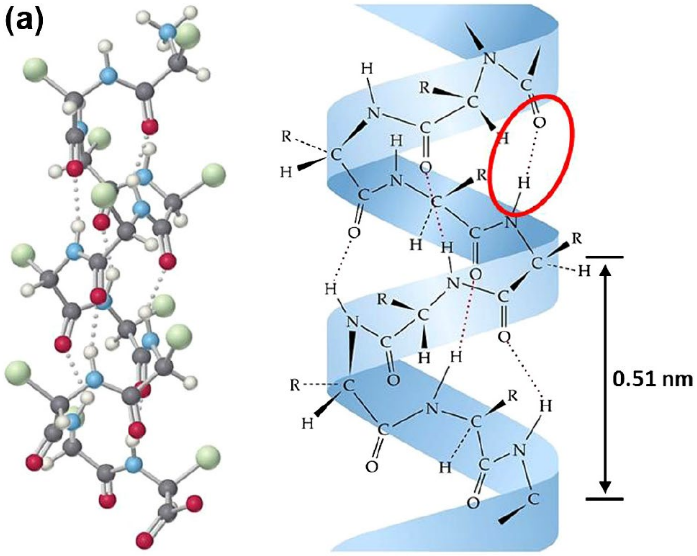
Wim S. Veraverbeke & Jan A. Delcour, Wheat Protein Composition and Properties of Wheat Glutenin in Relation to Breadmaking Functionality, Critical Reviews in Food Science and Nutrition, 2002, 42, 179-208.

Keratin

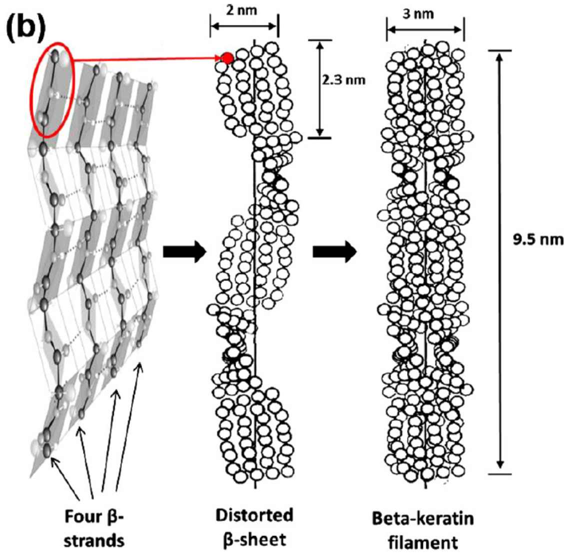
Distribution of α- and β-keratin.

α-Keratin	**Wool**, hair, quills, fingernails, horns, hooves; stratum corneum
β-Keratin	**Feathers**, avian beaks and claws, reptilian claws and scales
α- and β-Keratin	Reptilian epidermis, pangolin scales

α-keratin structure



β-keratin structure



A?

Wang et al. Progress in Materials Science 2016, 76, 229-318

Reading assignment 1

Title: Biopolymers: overview of several properties and consequences on their applications
Authors: K. Van de Velde & P. Kiekens
Polymer Testing **2002**, 21, 433–442

PLA, PGA, PCL, PHB

Reading assignment 3

Title: Starch-based biodegradable materials: Challenges and opportunities
From: Jiang et al. *Advanced Industrial and Engineering Polymer Research* 2020, 3, 8-18

Properties of starch and use in biobased materials such as composites, foams, etc.

Reading assignment 7

Title: Chapter 3 - Bioplastics, Biocomposites, and Biocoatings from Natural Oils

Isolation of carbonic acids with olefinic moieties from triglycerides

Polymerization via various techniques

Polymer properties and application fields

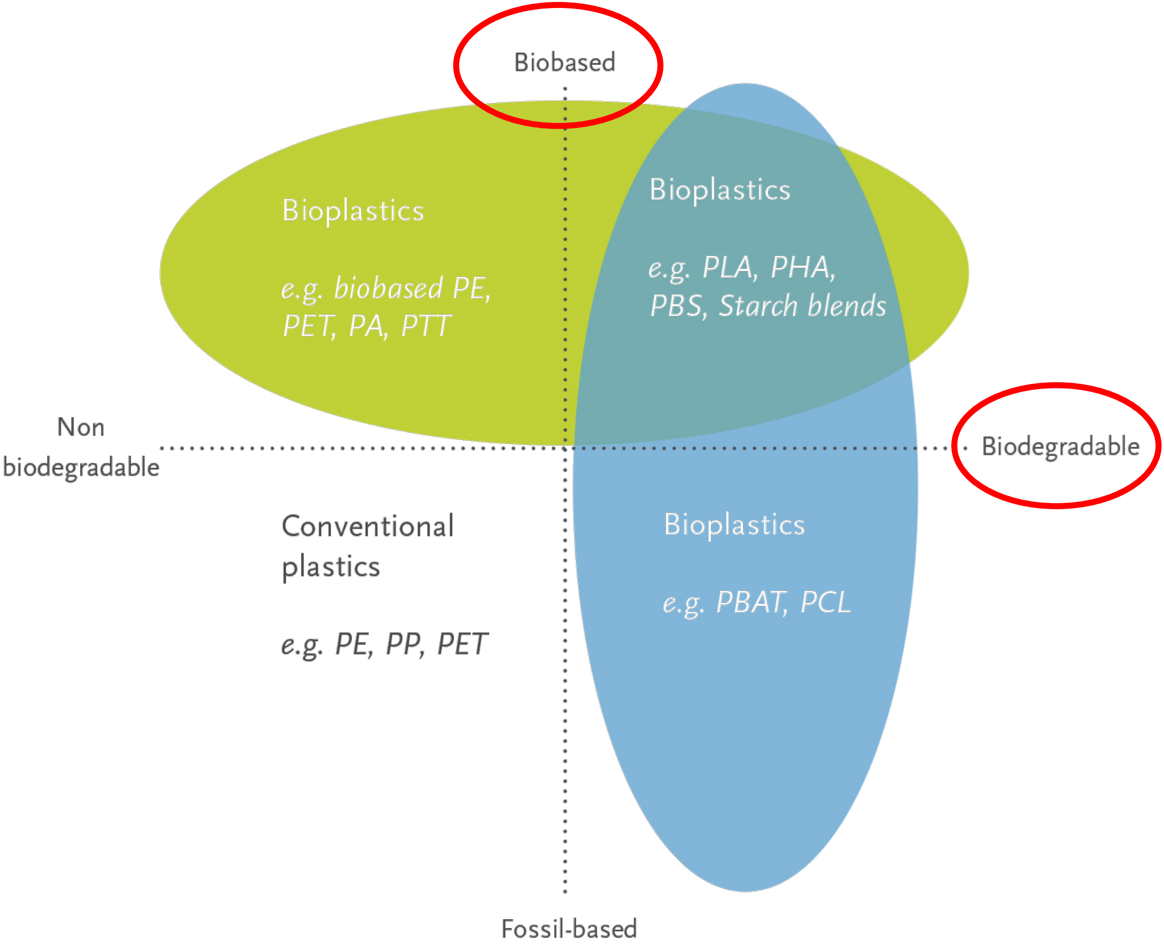
Reading assignment 8

Title: The Myth of Cultured Meat: A Review
From: Chriki, S. and Hocquette, J.-F. *Frontiers in Nutrition* 2020

- Discussion on issues associated to i*n vitro* meat
- Biased view of authors noticable

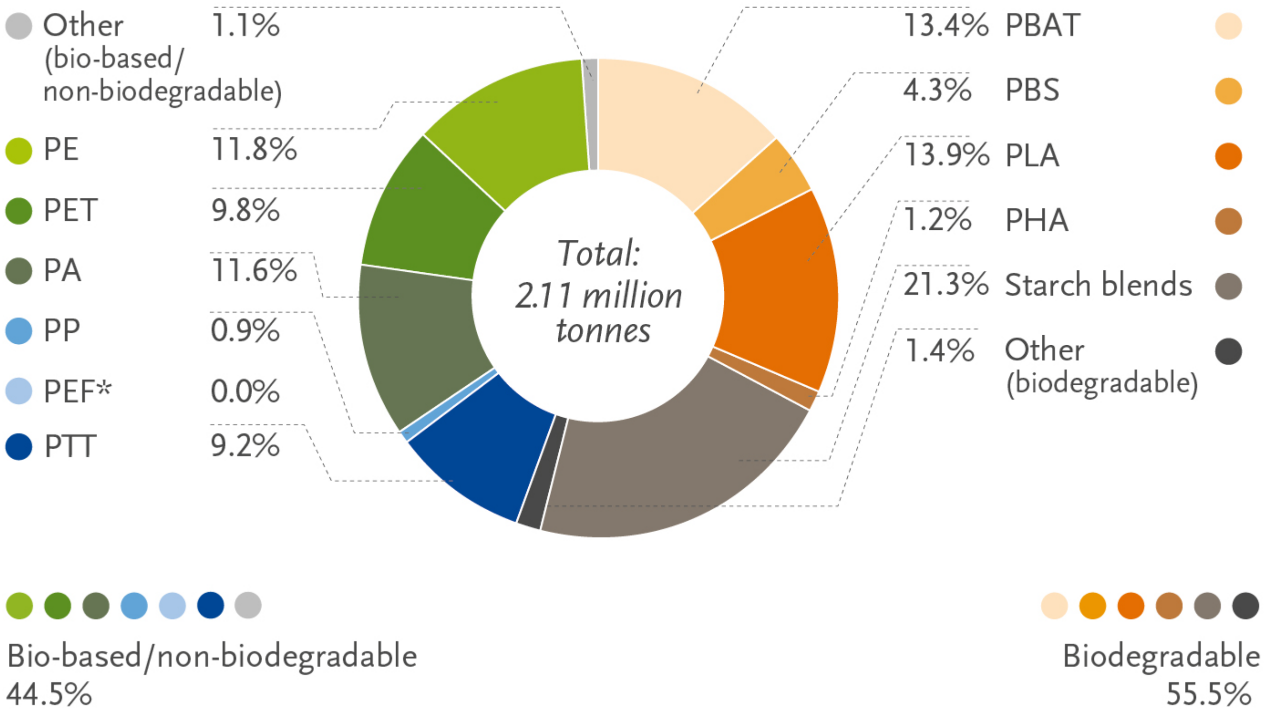
Bioplastics

- Bioplastics are biobased, biodegradable or both
- The term biobased describes the part of a material or product that stems from biomass
- *When making a biobased claim, the unit (biobased carbon content or biobased mass content), a percentage, and the method of measurement should be clearly stated*



Source: European bioplastics

Global production capacity of bioplastics 2019



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

Source: European Bioplastics, nova-Institute (2019)
*More information: **www.european-bioplastics.org/market** and **www.bio-based.eu/markets***

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Properties of biopolymers

Properties through assignments

Assignment 1: Lego: thermal and mechanical properties

Assignment 2: Tetrapak: barrier properties

Assignment 3: Kitchen chemistry

Reading assignment 2

Chapter title: Biopolymer-Based Sustainable Food Packaging Materials: Challenges, Solutions, and Applications
By Perera *et al.*
From: *Foods* 2023, 12, 2422

Overview of a wide range of biopolymers and their properties relevant for applications for food packaging.

Reading assignment 5

Title: US Patent: Polymer compositions
US 4121025, 17.10.1978

How to induce oxodegradability in polymeric scaffolds.

What next?

Definition: Biopolymers

Potential for production of sustainable goods
- products made from natural renewable resources
- products that decompose into environmentally friendly constituents

…but they need to provide same results with products made from synthetic materials

Possible challenges:
- costs
- inferior properties

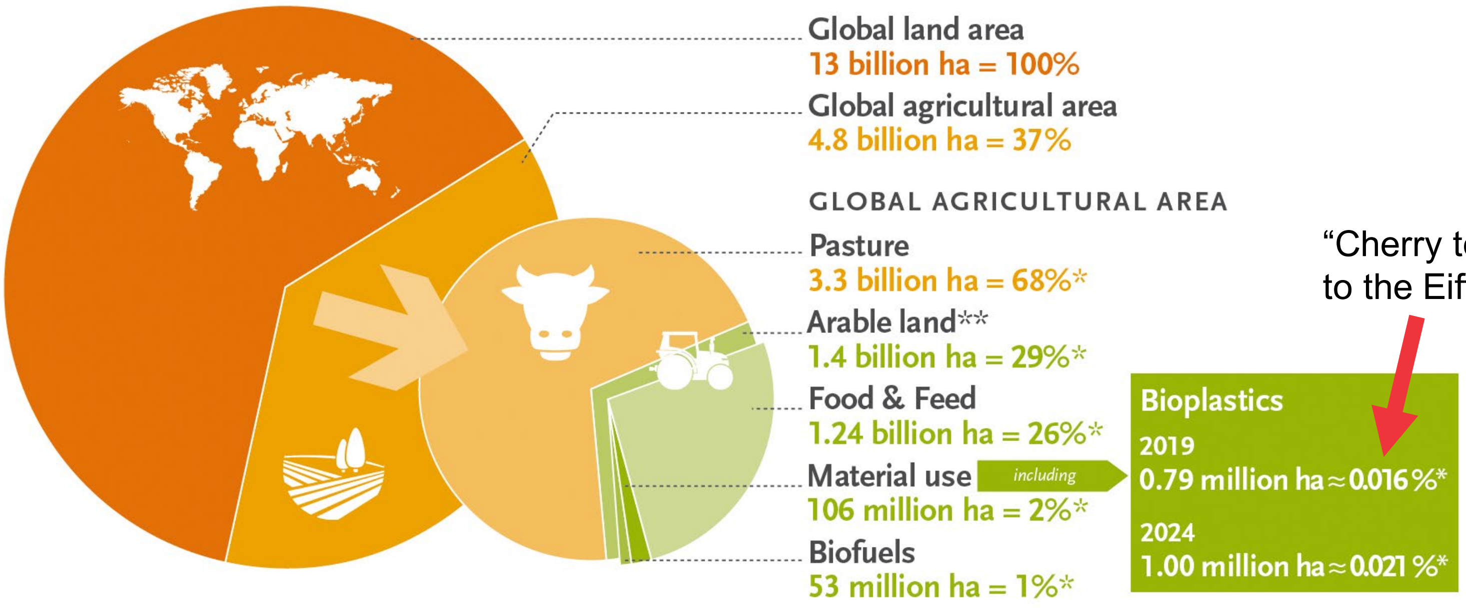
Reading assignment 9

Title: Green Polymer Chemistry and Bio-based Plastics: Dreams and Reality

Possible pitfalls of large-scale implementation of biopolymers

Outcry of synthetic polymer chemist

Land use estimation for bioplastics 2019 and 2024



Source: European Bioplastics (2019), FAO Stats (2017), nova-Institute (2019), and Institute for Bioplastics and Biocomposites (2019). More information: ***www.european-bioplastics.org***

** In relation to global agricultural area*
*** Including approx. 1% fallow land*

"Cherry tomato next to the Eiffel Tower"

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Learning Outcomes

After the course the student

- knows the most common natural and synthetic biodegradable polymers.
- can define what is biodegradation and how it is measured.
- can describe the synthesis methods of synthetic biodegradable polymers.
- knows the application areas and particular requirements of biodegradable polymers.

“Reading 10”

Instructions:

Upload your meme to the Padlet page:

https://padlet.com/michaelhummel/CHEME2155_2024

Feedback time

Please fill in the feedback questionnaire that has been sent to you.