Biopolymers from food co-products and their properties

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Bioplastics and biopolymers - opportunities and challenges for industry and academia
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Background

Co-products

By-products

Waste

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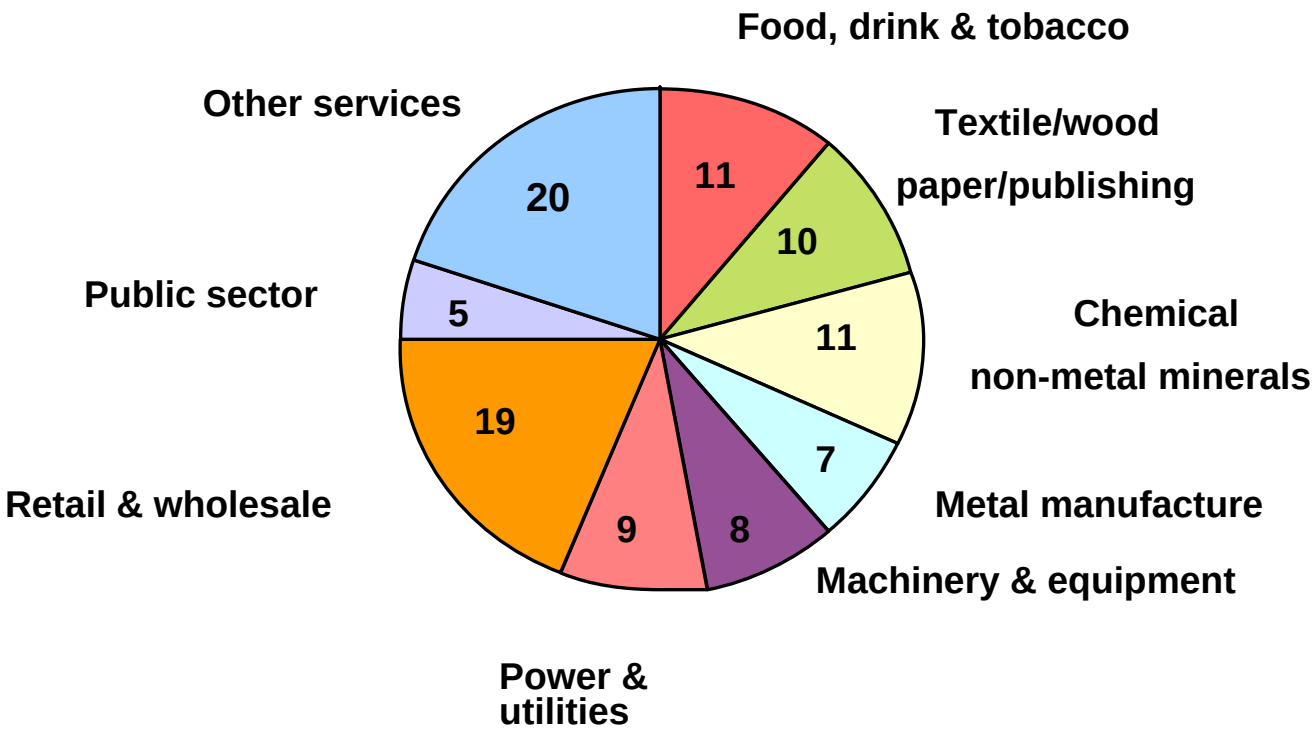
Background

- Industrial food waste?
  - Used for cattle feeding
  - Disposed in landfill
  - Landfill tax: increase by £3/T/year, £35/T which will cost £441 millions
  - 1/5 of UK Greenhouse gases
  - Odours
  - Stability

Background

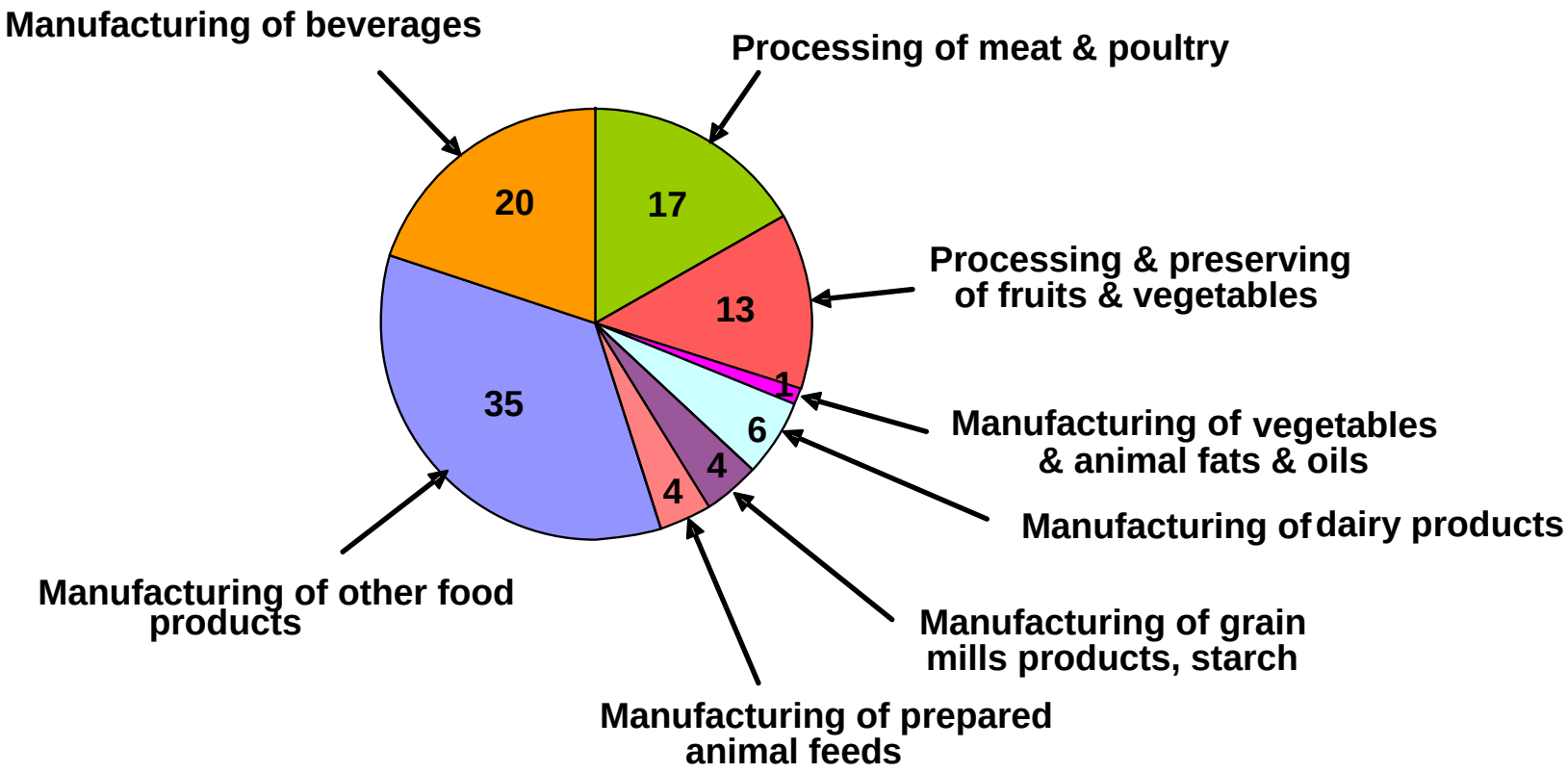
- In the UK: 12.6 millions tonnes/year (envirowise.gov.uk)



(DEFRA, 2007)

Background

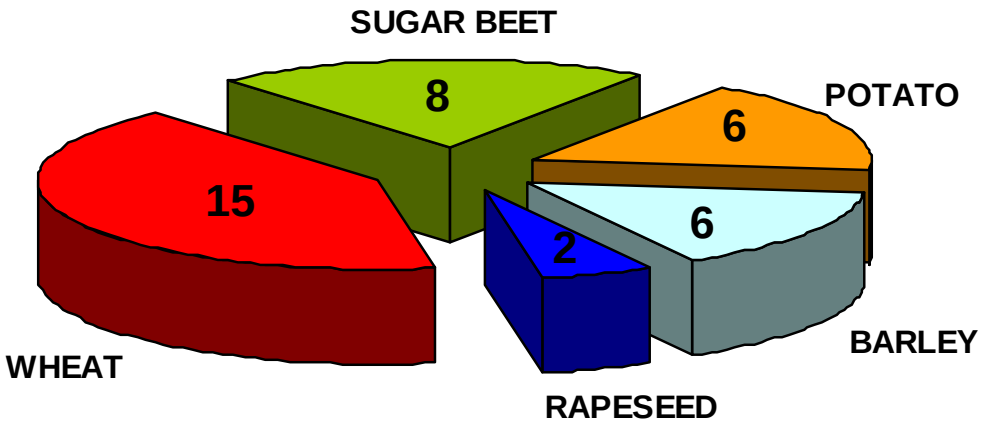
- Waste from food and drink industry by sectors



(DEFRA, 2007)

Background

- Major plant based food (UK)



Millions metric Tonnes

(FAO)

Background

Cereals

Wheat

Bran

15-20%

Barley

Spent grain

15-20%

Maize

Gluten meal

8%

Bran

15-20%

Non -Cereals

Sugar beet

Pulp

4-5%

Rapeseed

Meal

60%

Potato

Peel

2%

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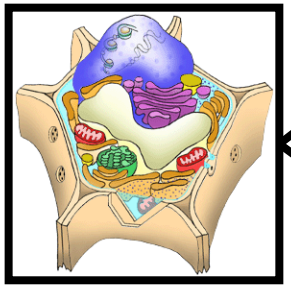
Biopolymers and their origin

Plant based food co-products → **Materials exploitable as packaging components** → **Biopolymers**

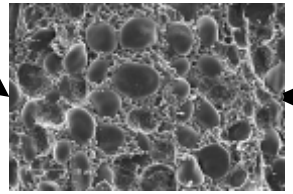
Plant cell



Cell wall

Non starch polysaccharides
- ***cellulose***
- ***hemicellulose***
- ***pectic polysaccharides***

Endosperm



Starch polysaccharides
- ***amylose***
- ***amylopectin***

Proteins

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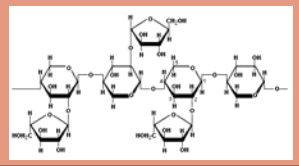
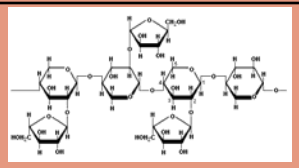
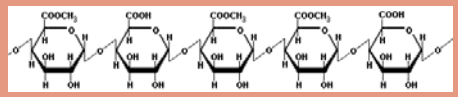
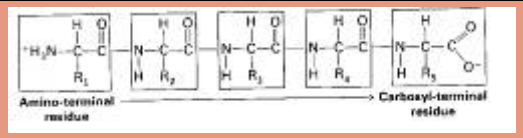
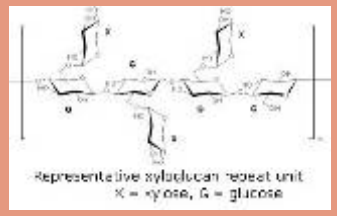
Biopolymers: their structure

Co-products	Biopolymers	%	Structure
Wheat bran	Arabinoxylans	72	
Spent grain	Arabinoxylans	20	
Sugar beet pulp	Pectin	20	
Rapeseed oil meal	Proteins	40	
Potato peel	Xyloglucan Pectin	3	

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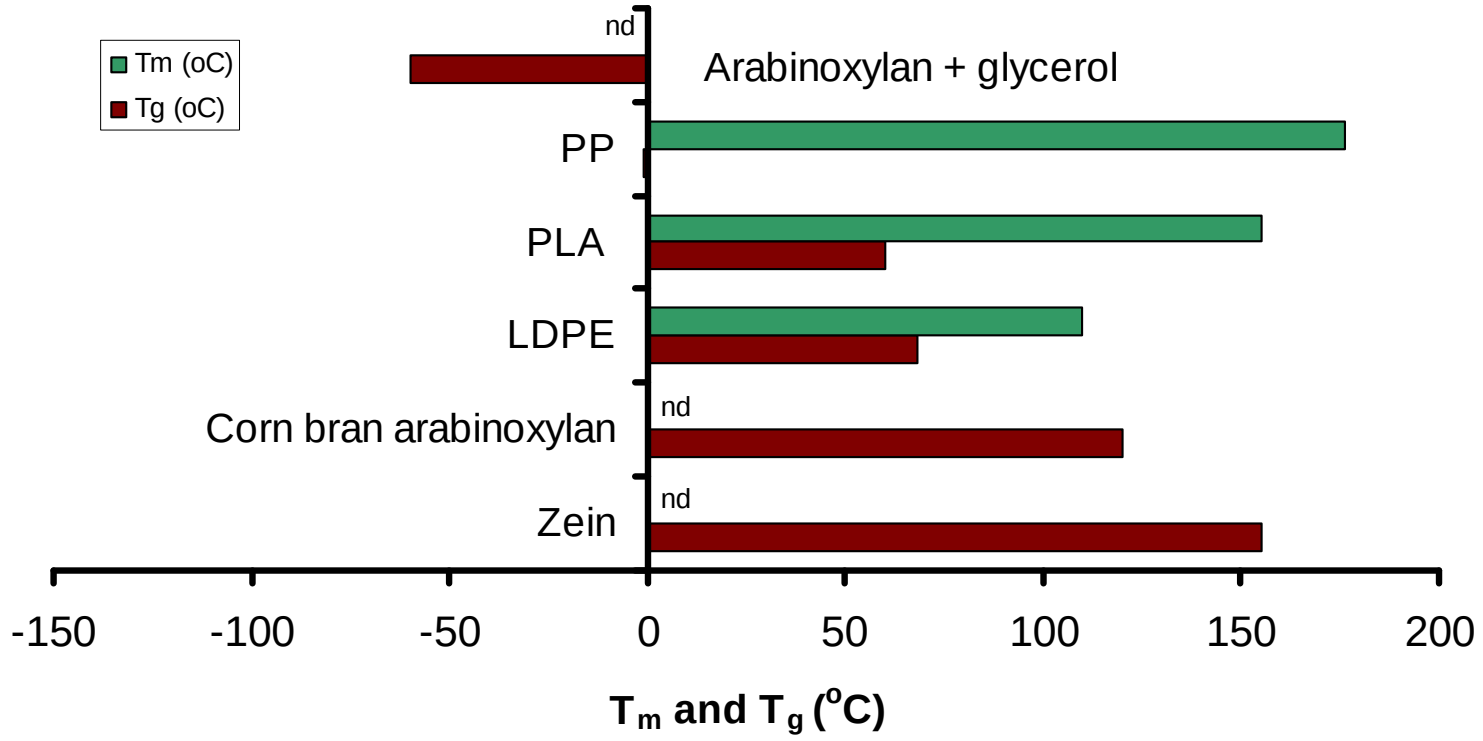
Biopolymers: their physical properties



Melting temperature (T_m) and glass transition temperature (T_g) of biobased and synthetic polymers

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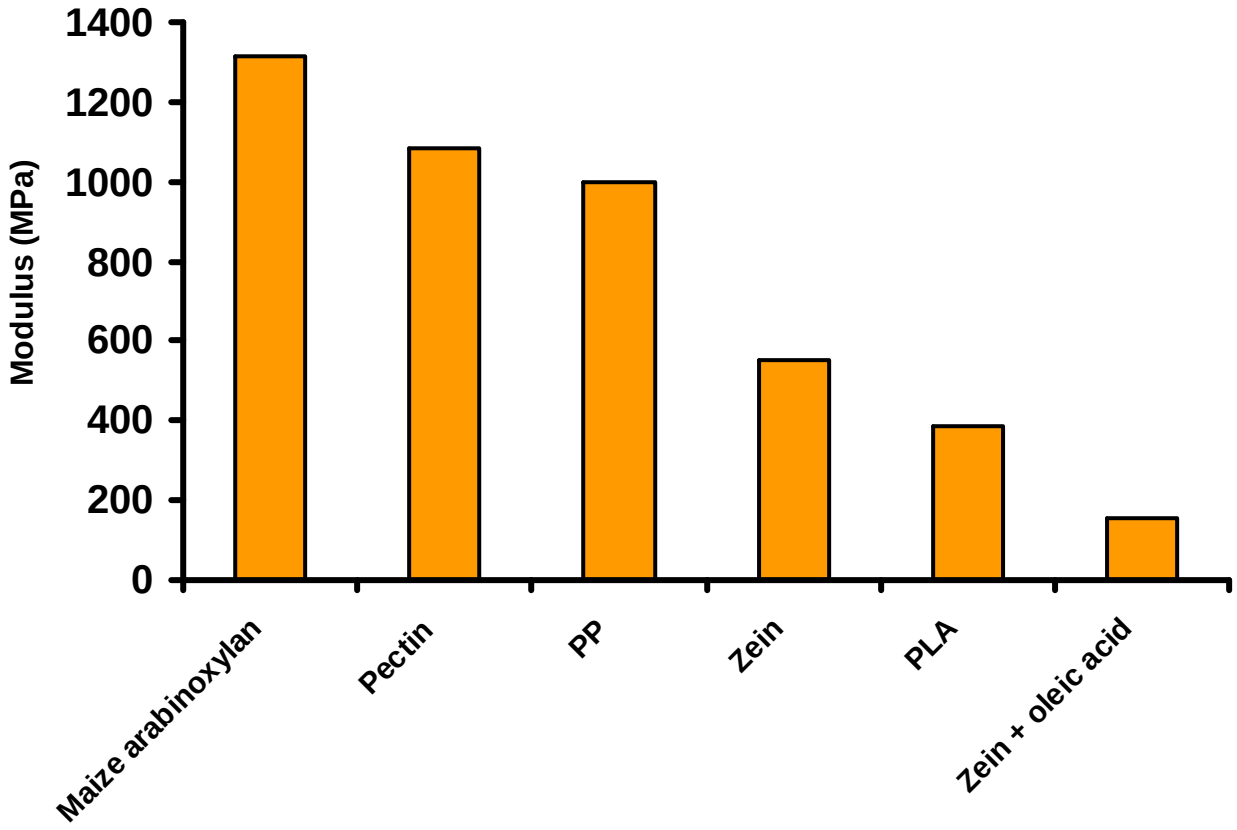
Biopolymers: their physical properties



Mechanical properties of biobased and synthetic polymers

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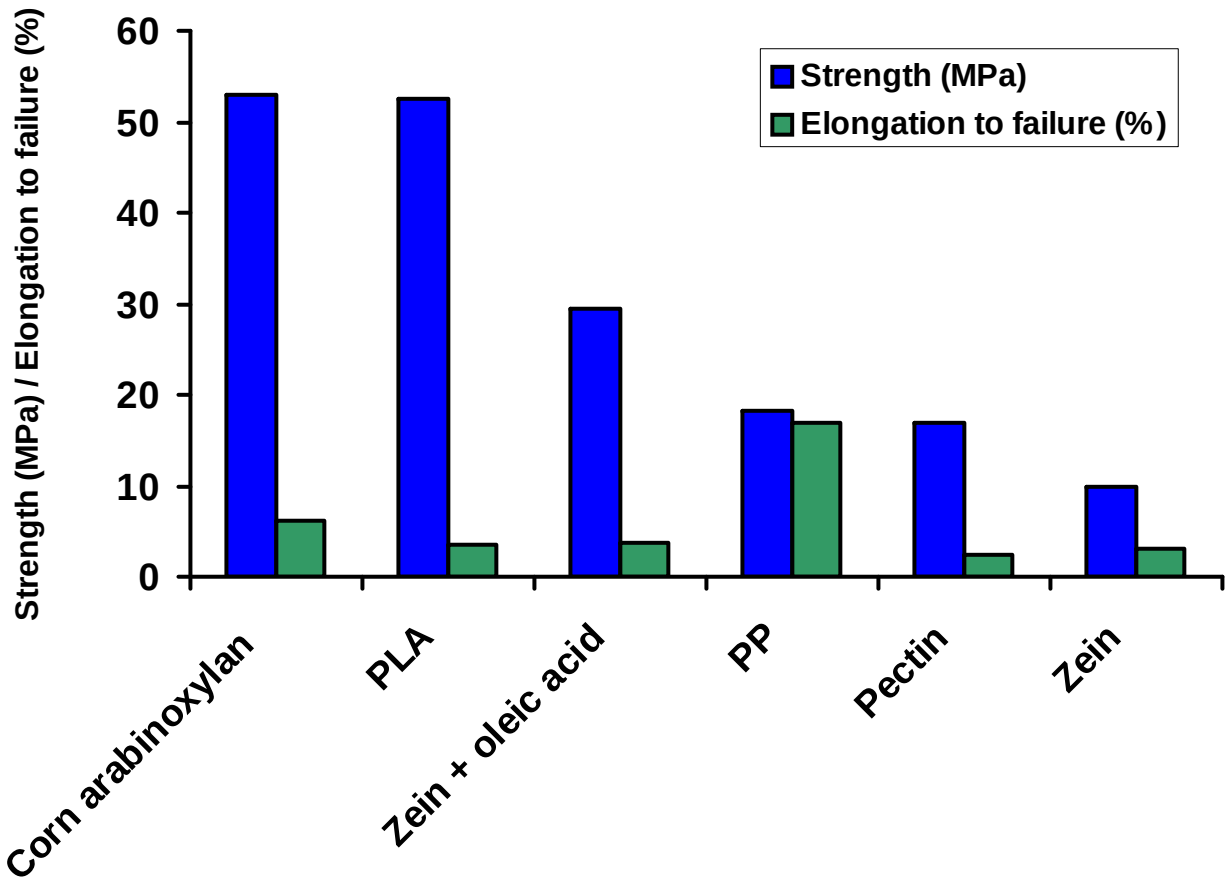
Biopolymers: their physical properties



Mechanical properties of biobased and synthetic polymers

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Biopolymers: their physical properties

Material	O_2 permeability ($cm^3.\mu m.m^{-2}.d^{-1}.kPa^{-1}$)	Source
LDPE	7900 (23°C, 50% RH)	Hansen and Plackett, 2008
PLA	160 (23°C, 50% RH)	Hansen and Plackett, 2008
Arabinoxylan + plasticizer	1-2 (20°C, 50-70% RH)	Tenkanen et al, 2009 Totalfood 2009
Zein + 20% glycerol	3	Gillgren and Stading, 2008

Oxygen permeability of biobased and synthetic polymers

Biopolymers: their physical properties

Material	MVP.10^{-10} ($g.m^{-1}.s^{-1}.Pa^{-1}$)	Source
LDPE	0.019 (25°C, 22% RH)	Peroval et al, 2002
PLA	0.18 (25°C, 50 % RH)	Rhim et al, 2009
Arabinoxylan +plasticiser	1.8	Hansen and Plackett, 2008
Zein	53.3 (23°C, 15 % RH)	Ghanbarzadeh et al, 2007

Moisture vapor permeability of biobased and synthetic polymers

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Potential for packaging

- Historically
  - 1st generation of biobased plastics (LDPE + starch 5-15%)
  - 2nd generation of biobased plastics (LDPE +40-75% starch + copolymer)
  - 3rd generation: completely biodegradable packaging
    - Polymer directly extracted from biomass
    - Polymers produced by chemical synthesis from biomass monomer
    - Polymers produced by nature / genetically modified microorganisms

(Chiellini, Environmental compatible food packaging, CRC, Cambridge, 2008)

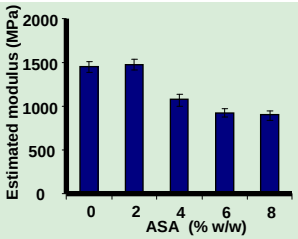
Potential for packaging

Cereal polymers

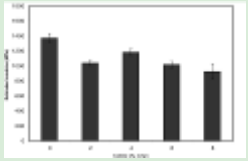
Arabinoxylan films (www.totalfood2009.com)

Cereal proteins

Zein films



(Georget et al, 2009)



(Singh et al, 2009)

Sugar beet pulp

Films (Rouilly et al, 2009, Bioresource Technology, 100, 3076)

Rapeseed oil cake **Films based on proteins** (www.biomatnet.org)

Potato peel **Exploitable material ?** **Hemicellulose films ...**

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Concluding remarks

- Great potential for short shelf life products
- High MVP, desirable to avoid water condensation
- O_2 permeability can be tailored
- Thermally and mechanically comparable to synthetic polymers
- Biodegradable
- Cost: Synthetic <£1/kg Biobased >£5/kg
- Global plastics 250 million T £ 50bn, bioplastics represent 1-4% (£ 1bn)
- Predicted increase 20-30%

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Concluding remarks

- **Improve the performance of biopolymer based packaging**
  - Chemical modification (better functionality)
  - Coating with clay or PLA
  - Processing (extrusion, hot melting…) to increase potential applications

- **Future for biobased polymers**
  - Increase of biobased polymers due to improved technology
  - Demand from consumers

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Thank you