# Packaging in a Circular Bioeconomy

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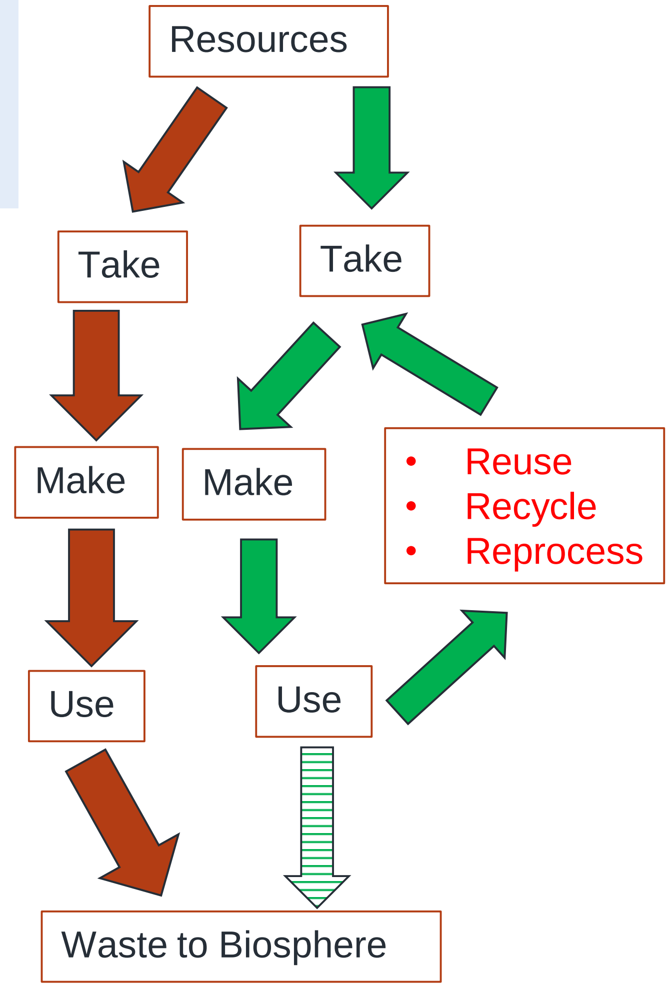
# Circular Economy: Drivers for Change

- **Circular Economy Directive:**
- 70% reduction in packaging waste by 2030
- All biowaste to be collected separately or recycled at source



A PLASTICS STRATEGY TO PROTECT EUROPE'S CITIZENS AND THE ENVIRONMENT



# Progress

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By Tony Corbin · 14 March 2019

## Asda removes 6,500 tonnes of own brand plastic packaging

Asda has announced it has removed 6500 tonnes of plastic from its o brand packaging since February 2018 in accordance with the promise by the retailer last year.


## Retailers adopt new recyclable black PET

By James Ridler
05-Mar-2019 - Last updated on 06-Mar-2019 at 10:55 GMT

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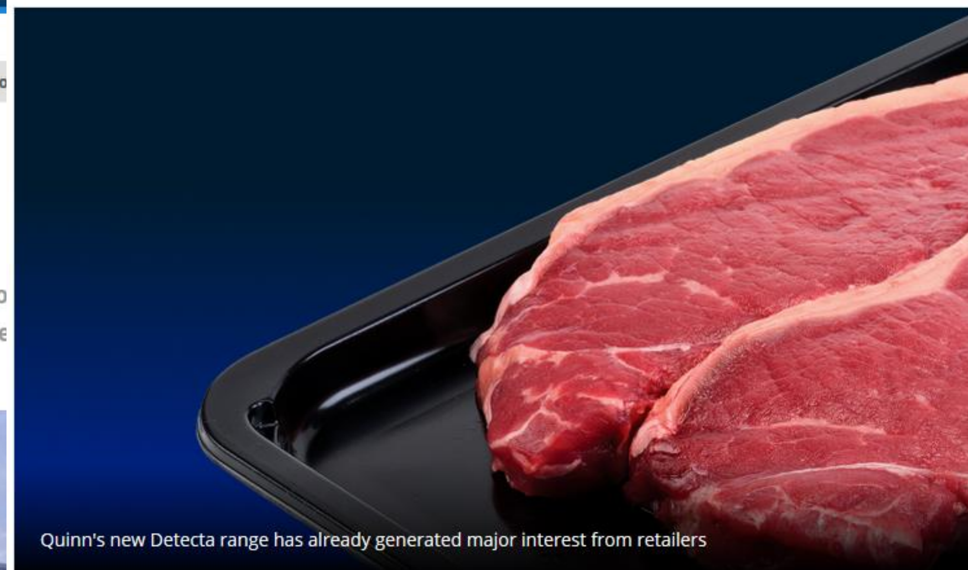

Quinn's new Detecta range has already generated major interest from retailers

**A new black polyethylene terephthalate (PET) food tray that is able to be picked up by recycling equipment will soon to be adopted by UK retailers, according to Ireland-based creator Quinn Packaging.**

The Detecta range launched in mid-February and has garnered a lot of positive engagement from several UK retailers, the manufacturer claimed.

A spokesman told *Food Manufacture: "Two retailers in particular have expressed strong interest in the tray and are looking to move products currently packed in clear trays across to Detecta by Quinn black trays."*

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## Coca-Cola produces 3m tonnes of plastic packaging

By James Ridler
14-Mar-2019 - Last updated on 14-Mar-2019 at 15:30 GMT

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Coca-Cola produces 3m tonnes of plastic packaging a year

**Drinks giant The Coca-Cola Company (CCC) has revealed it produces 3m tonnes of plastic packaging a year, the first time the company has ever disclosed this information.**

The figure – equivalent to about 200,000 bottles a minute or 108bn 500ml bottles a year – was supplied to sustainability charity the Ellen Macarthur Foundation as part of its *New Plastics Economy Global Commitment Report*, in the hope to end the secrecy surrounding businesses' plastic footprint.

Coca-Cola Journey™
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## SMARTWATER, RPET, AND CLEAR PLASTIC: HOW COCA-COLA GREAT BRITAIN AND COCA-COLA EUROPEAN PARTNERS ARE MOVING CLOSER TO A WORLD WITHOUT WASTE

17 Jun 2019

SHARE:


As part of The Coca-Cola Company's journey towards a World Without Waste, we're announcing that – in partnership with Coca-Cola European Partners – GLACÉAU Smartwater bottles will be made from 100 per cent recycled plastic (rPET) by the end of the year. And we're on track to double the amount of rPET used in all our other plastic bottles by early next year too.

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COKE, WHY AREN'T YOU COMMITTING TO PUTTING MORE THAN 50% RECYCLED PLASTIC INTO YOUR BOTTLES?

JON WOODS
LET'S TALK ABOUT THE GOVERNMENT'S SOFT DRINKS TAX AND WHAT THAT MEANS FOR OUR DRINKS

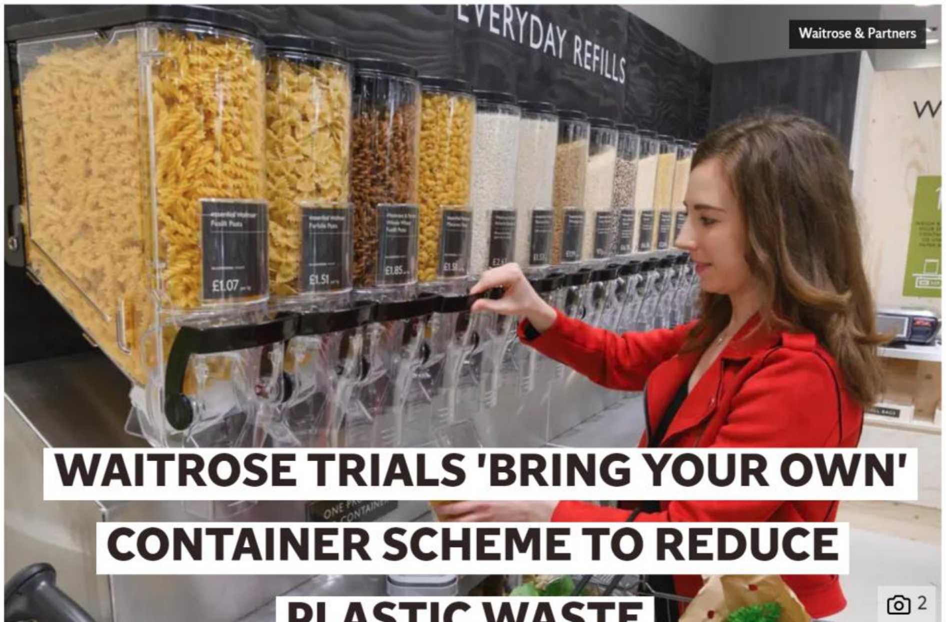
GUIDING PRINCIPLES FOR WELL-BEING SCIENTIFIC RESEARCH AND THIRD PARTY ENGAGEMENT

**REDUCING SUGAR**

PET - EU average recovery rate in 2017 = 58%

# Consumer Pressure

Research by Mintel recently found half of all adults say plastic pollution is a top environmental concern for them, with a similar proportion saying they supported shops going plastic-free.




**WAITROSE TRIALS 'BRING YOUR OWN' CONTAINER SCHEME TO REDUCE PLASTIC WASTE**

'We are determined to build on the work we've already done to reduce packaging'

Olivia Petter | @oliviapetter1 | Tuesday 4 June 2019 07:53 | 14 comments

Click to follow Indy/Life

Waitrose is trialling a "bring your own" container scheme that encourages customers to buy and refill produce.

The supermarket chain, which is part of John Lewis & Partners, will start selling items such as cereals, pasta, coffee and rice in large dispensers as



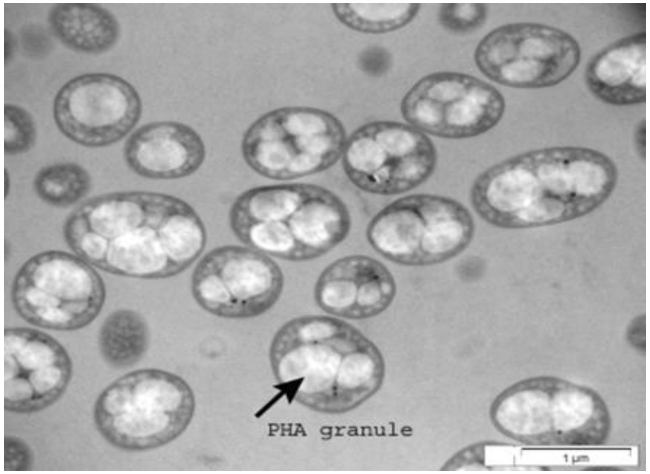
*Category insight*


**PACKING TOMATOES IN TOMATOES**

*Waitrose is trialling new technology that it says could save 3.5 million plastic trays from being recycled every year. Michael Barker reports*

# Bioplastics for Packaging

1. Polymers produced from renewable bio-based monomers often obtained by microbial fermentation e.g. bioPET, polylactic acid (PLA) from fermentation of corn starch or sugar beet
2. Polymers directly extracted or removed from biomass (biopolymers) e.g. alginate from seaweed.
3. Polymers synthesized by microorganisms including bacterial fermentation of sugars or lipids e.g. polyhydroxyalkanoates

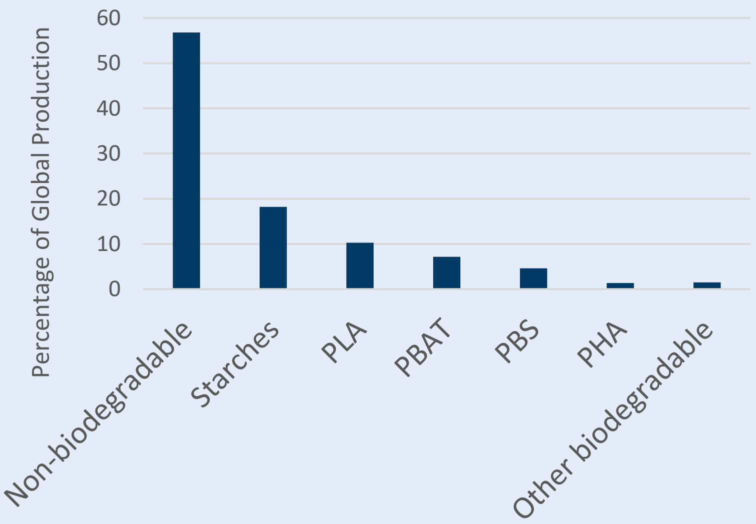



**PHA inclusion in Pseudomonas putida CA-3**
Ward, P.G. de Roo, G. & O'Connor, K.E. (2005)
**DOI:** 10.1128/AEM.71.4.2046-2052.2005

# Bioplastics: Increasing Market Share

- An attractive alternative to fossil carbon-based polymers because they are derived from sustainable sources and may be biodegradable or compostable

- ➢ Global bioplastic production 2018 = 2.112 million tonnes (biodegradable and non-biodegradable)
- ➢ Projected 41.2% growth by 2023
- ➢ Biodegradable materials – 0.912 million tonnes
- ➢ Food Packaging applications – 0.516 million tonnes
- ➢ Increase in poly lactic acid (PLA) usage by 2023 >60%




- Use is anticipated to rise significantly in response to consumer pressure, manufacturer demand and increased levels of industrial production.

**Source: Nova Institute, 2018**

# Circular Bioeconomy

Agri-food by-products / waste

Added value biomaterials with food, feed, pharma and packaging applications

Bioreactors/ Composting / AD

Biomass Bioproducts

**Packaging must be biodegradable to be compatible with a circular bioeconomy**

# Insects as Biomass Converters

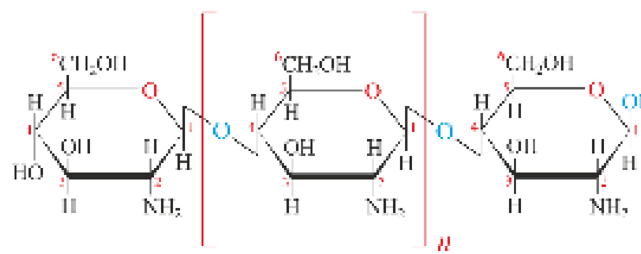



(Eawag – Swiss Federal Institute of Aquatic Science & Technology)

- Black Soldier Fly larvae reduce the volume by 50-80% and convert up to 20% into larval biomass within 14 days
- A biomass source for protein, oils and chitin/chitosan


Enterra

Chitosan




β-(1,4)-D-glucosamine

# Agri-Food By-Products for Bio-based Packaging: Are there enough to meet demand?

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Food waste – Typically 35-40% of total production

Mushroom waste -25 kT/year

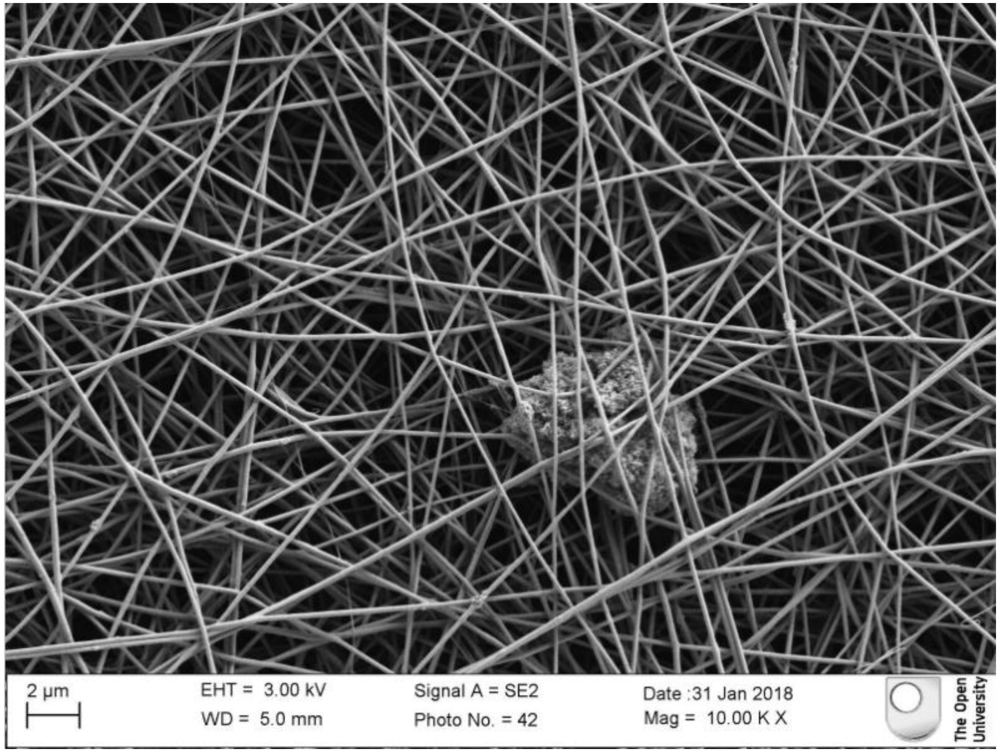
Sugar beet pulp -14 MT/year

Bio-waste represents around half of Europe's municipal waste streams but only about a quarter are currently collected separately and organically recycled. Around 100 million tonnes annually are 'wasted' across the EU and lost as a valuable resource

# Proof of Concept: Active Packaging From Agri-food Waste

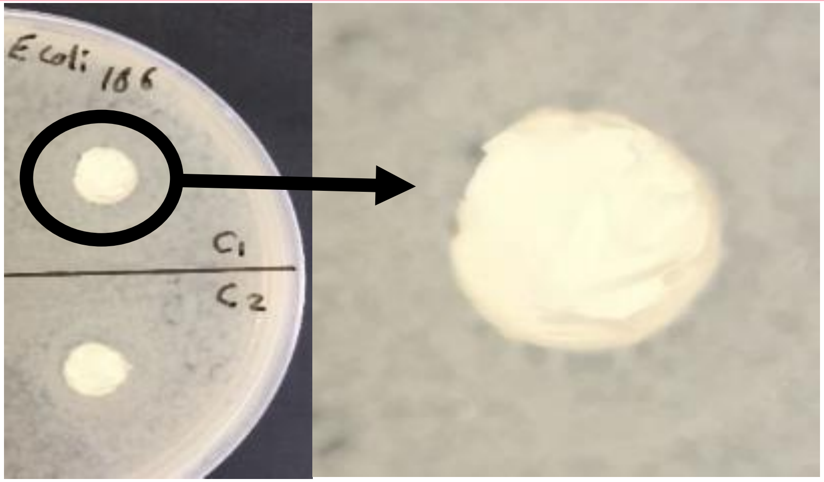
1. Production of composite biopolymer nanofibre films by electrospinning which incorporated micronized agri-food by-products (cereals, tomato)
2. Chemical and enzymatic processing of micronized agri-food by-products to increase porosity and enhance the incorporation and/or controlled release of added antioxidant or antimicrobial substances.
3. Investigation of the antimicrobial activity of nanofibre films
4. Evaluate the release of antioxidants from the nanofibre films

# Agri-Food Waste for Nanofibre Films

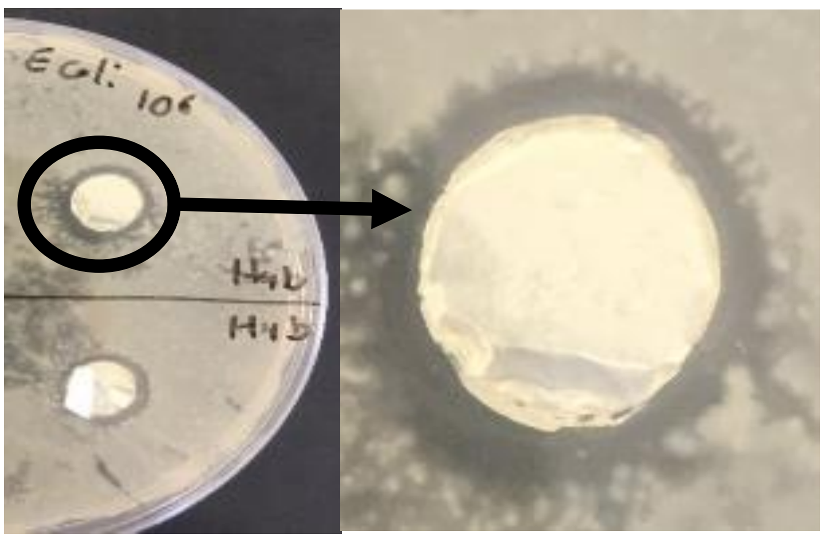



- Scanning electron micrograph of materials obtained from electrospinning of a Polyethylene Oxide (PEO)/Chitosan/oat husk mixture
- Smooth fibres, irregular object potentially oat husk.
- Overall, PEO/Chitosan polymer blends appeared to be most compatible with electrospinning of vegetable food waste.

# Agri-Food Waste for Nanofibre Films



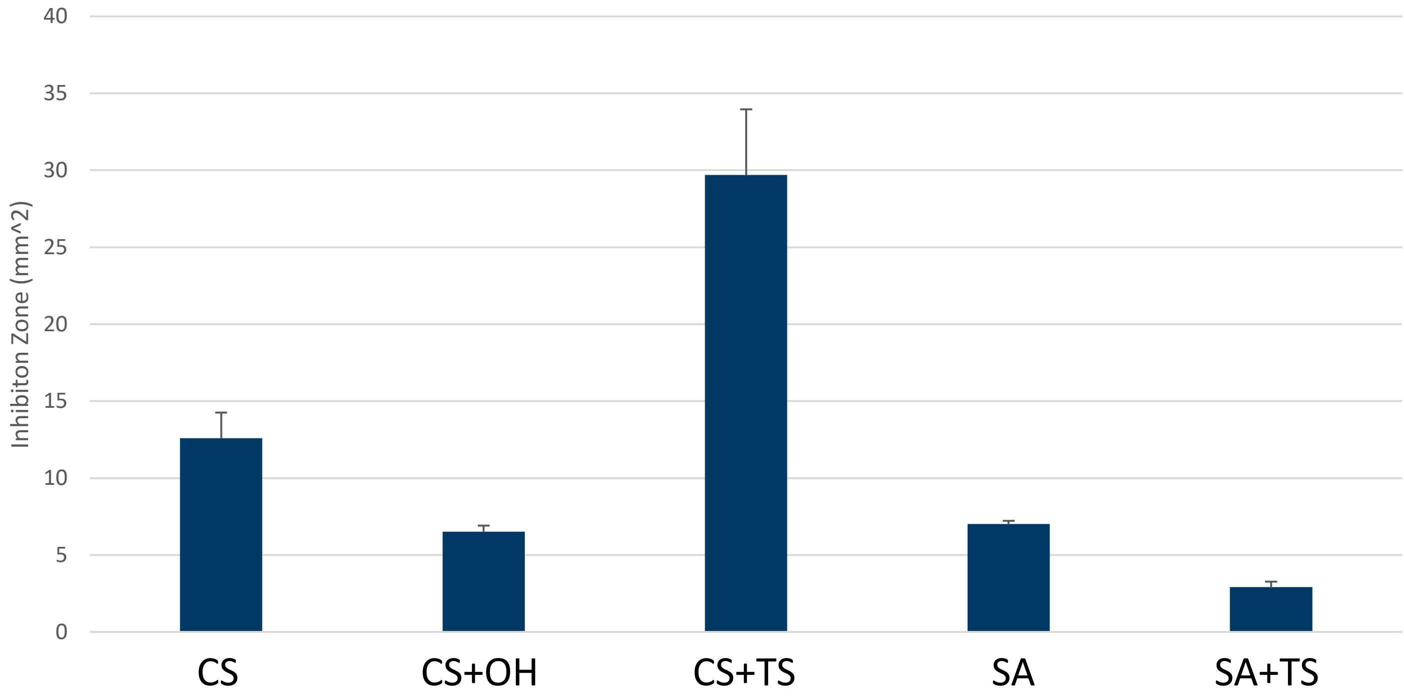
**Control – uncoated Al foil disk**
No inhibition of *E. coli* growth



**Active packaging film** –
*E. coli* growth inhibition by micronized oat husk embedded in a food grade nanofibre film.

H4b: (PEO 6.8% w/w, chitosan 0.8% w/w and oat husk)

# Nanofibre Film *E. coli* growth inhibition

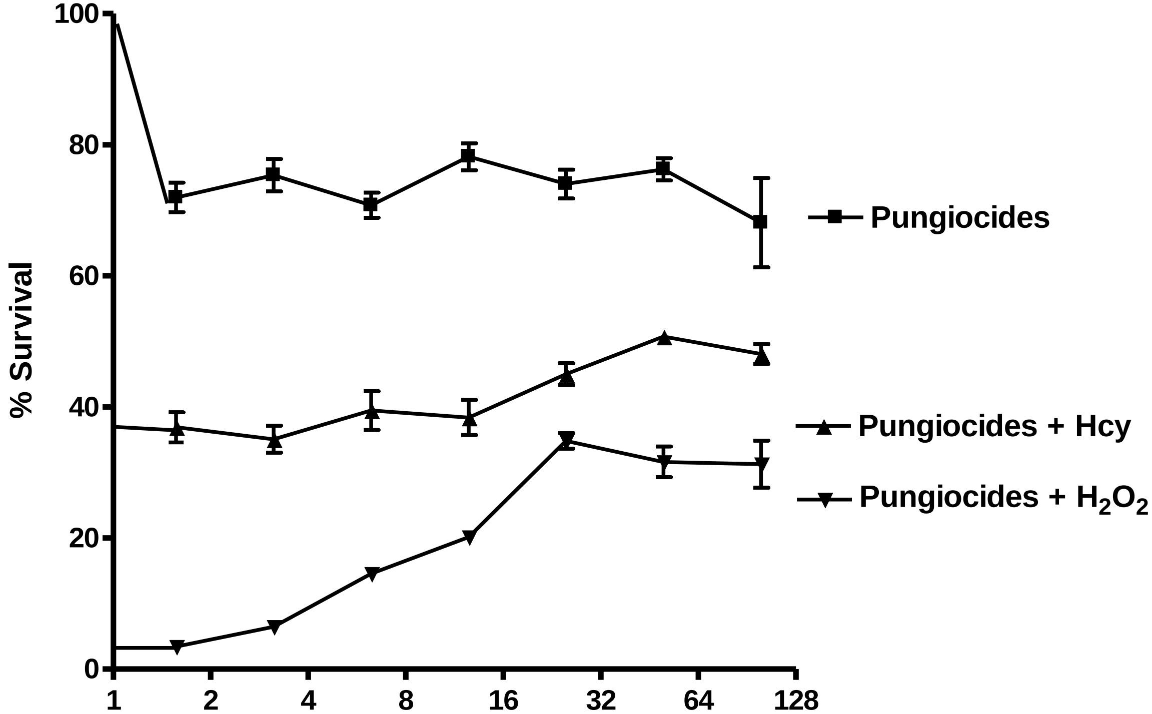


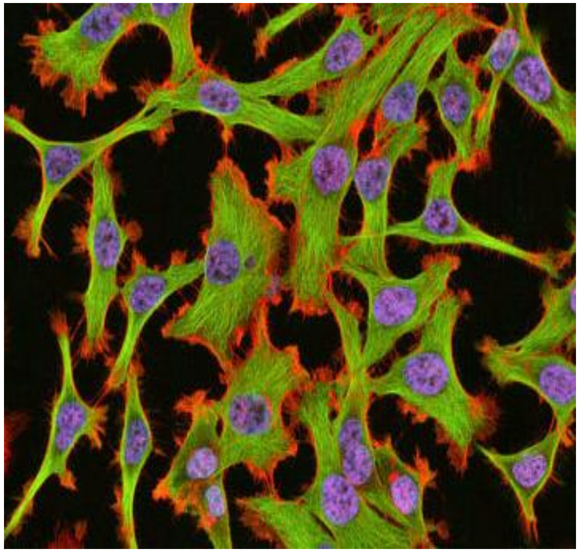

Gram -ve

**Inhibition of *E.coli* K12 growth on Mueller-Hinton agar inoculated at $10^6$ CFU/ml by nanofibre films with added tomato skin or oat husk.**

CS: (PEO 6.8%, chitosan 0.8% and distilled water); CS+OH: (PEO 6.8% w/w, chitosan 0.8% w/w and oat husk); CS+TS: (PEO 6.8% w/w, chitosan 0.8% w/w and tomato skin); SA: (PEO 6% w/w, alginate 1.5% w/w); SA+TS: (PEO 6% w/w, alginate 1.5% w/w and tomato skin). Values are means ± s.d., n=4.

## Pomegranate skin – source of potent antioxidants



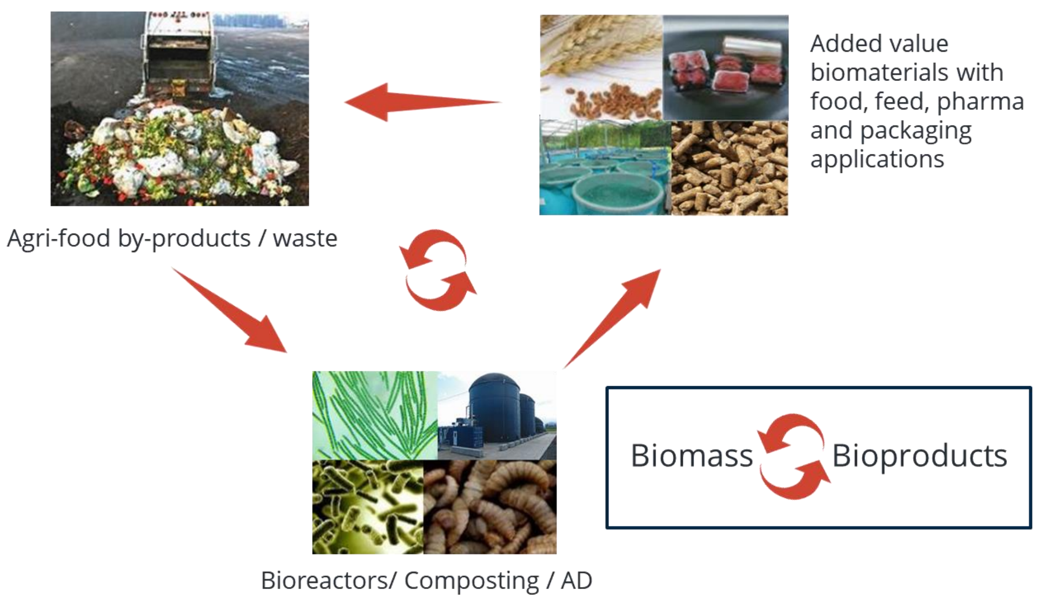



Sk-Hep-1 cells

Sk-Hep-1 cells were treated with increasing concentrations of mixed pungiocides (0 -120.0µM). Cells were then exposed to $H_2O_2$ (25.0µM) or Hcy (30.0µM) for a further 2hr. Extracellular $H_2O_2$ activity was terminated with 100,000U/L catalase at the end of the test period. Cell viability was determined by MTS assay. Data are presented as means ± SEM, n = 6. * P > 0.01; Test statistics one-way ANOVA with Bonferroni test *post hoc.*

# Circular Bioeconomy Benefits

- Waste stream exploitation and valorisation – reduced wastage to the biosphere / littering / landfill
- New sources of food or feed ingredients / bioactives
- De-fossilisation of packaging through use of ‘drop ins’ (e.g. BioPET) or bio-based materials
- Reduced use of fossil carbon for energy production



# Potential Risks?

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- Bioplastics often fail to perform as well as oil-based polymers in primary packaging roles– *lack flexibility, water soluble, poor barrier performance*, more expensive
- Recent work to improve performance - production of composites and supplementation with nanomaterials
- What are the risks of using Bio-based Food Contact Materials (BBFCMs)?

- Heavy metals and trace elements
- Persistent organic pollutants
- Pesticide residues
- Natural toxins
- Process contaminants
- Nanomaterials
- Endocrine active compounds (EACs)
- GM materials
- Allergens
- Poor performance – shelf life

**Desk Study Results:**

- >1100 publications since 2013
- No data were obtained regarding the presence or transfer to food for:
  - Persistent Organic Pollutants (POPs)
  - Pesticide or veterinary medicines residues
  - Natural toxins
  - Process contaminants
  - GM materials

# BBFCM Safety

**Heavy Metals and Metalloids:**

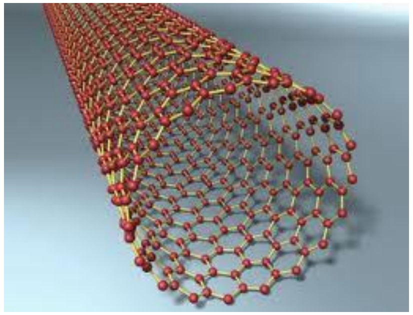
- Polylactide (PLA) articles (n = 211) were tested for migration of lead (Pb), cadmium (Cd) and arsenic (As) into the food simulant (4% v/v acetic acid).
- Migration was low (1% of the migration limit for Pb at 100$^{o}$C, 30 min). (Kim et al., 2018)
- Evidence of heavy metal migration has primarily been reported in relation to the inclusion of metallic nanoparticles (zinc and silver) within composite BBFCMs.

**Allergens**

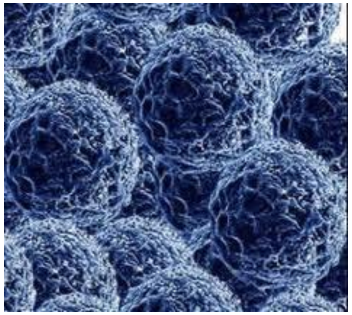
- Materials used for packaging may include substances that are known or suspected allergens or are extracted from matrices that contain allergens.
- The effects of processing to produce packaging materials may alter allergenicity in unpredictable ways
- Very limited information is available on the allergenicity of BBFCMs as well as the potential for transfer of allergens to food.

# Performance: Shelf Life

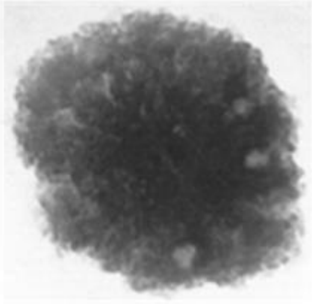
- Many diverse composite bio-based materials have been reported – very active area of research >50% of all publications since 2013.
- Food packaging performance equal to or greater than fossil-carbon based packaging demonstrated by addition of materials to enhance barrier properties and anti-microbial activity.
- Metallic nanoparticles (nanosilver, nanocopper), Montmorillonite (nanoclay) platelets, graphene.
- 'Natural' antimicrobials frequently used e.g. chitosan and nanosized essential oil droplets.
- In general – anti-microbial activity increases as particle/droplet size decreases.



Carbon nanotubes / graphene



Nanoparticulate metals



Chitosan nanoparticles

# Safety: Composites and Nanomaterials

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- Natural/soft nanomaterials are very diverse and included essential oils, cellulose nanocrystals, chitosan particles and electrospun nanofibers.
- Hard/engineered nanomaterials most frequently used were such heavy metals (zinc, siver) or Montmorillonite nanoclay platelets.
- Limited evidence of migration of the nanomaterials, although Kumar et al. (2014) *demonstrated high cytotoxicity due to nanoclay migration from PLA*.
- Limited data on the effect of processing on migration – HHP considered to present little risk when applied to PVA/chitosan/ nano-$TiO_2$ films.
- Complexity of BBFCMs (especially with nanosized or nanostructured components) **suggests that *in vitro* toxicology methods may also be required to establish safety**.

Kumar, S., Mishra, A., & Chatterjee, K. (2014). Effect of organically modified clay on mechanical properties, cytotoxicity and bactericidal properties of poly(epsilon-caprolactone) nanocomposites. Materials Research Express, 1(4). doi:10.1088/2053-1591/1/4/045302

# Fraud – A Future Risk?

- Essential oils used in packaging to extend shelf life
- Attractive ‘natural’ anti-oxidant / anti-microbial properties
- Price inflation due to resource limitations - growing reports of fraud
- Will bioplastic fraud be next?

# Packaging in a Circular Bioeconomy: Future Requirements

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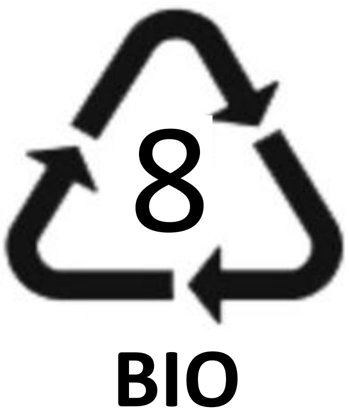
- Seasonal variations in biomass availability, effects on biopolymer characteristics and packaging performance.
- Characterisation and authenticity of bio-based food contact materials
- Safety – contaminant presence and transfer, *in vitro* assays of cytotoxicity (especially if nanostructured components present)
- Shelf life of biodegradable biopackaging?
- Biodegradability standards and symbols – separation of recyclable plastics from biodegradable bioplastics
- Waste handling – put bioplastics in the food waste stream
- Bioreactor performance – impact of waste stream composition, microorganism engineering / tailored culture blends
- Local solutions – avoid biomass transport / $CO_2$ emissions
- Consumer acceptance and education –’treat as food waste’



# Acknowledgements

Newcastle University UK | Malaysia | Singapore

**SAgE ISCF Pump Prime Fund Project #555**
Othman Qadir

The Open University
Simon Collinson, Nicholas Chatterton, George Bryant, Jo Handford

**Biopower Technologies Ltd**

M&S EST. 1884

BBSRC bioscience for the future FoodWasteNet

FUTURE PACK

FuturePack CIC – a 'not-for-profit' community interest company established to promote understanding and awareness of packaging. Stakeholder liaison, communication and dissemination.
**futurepackuk@gmail.com**

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# Thank you for your attention

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