Converting potato waste into pre-biotics and other valuable products

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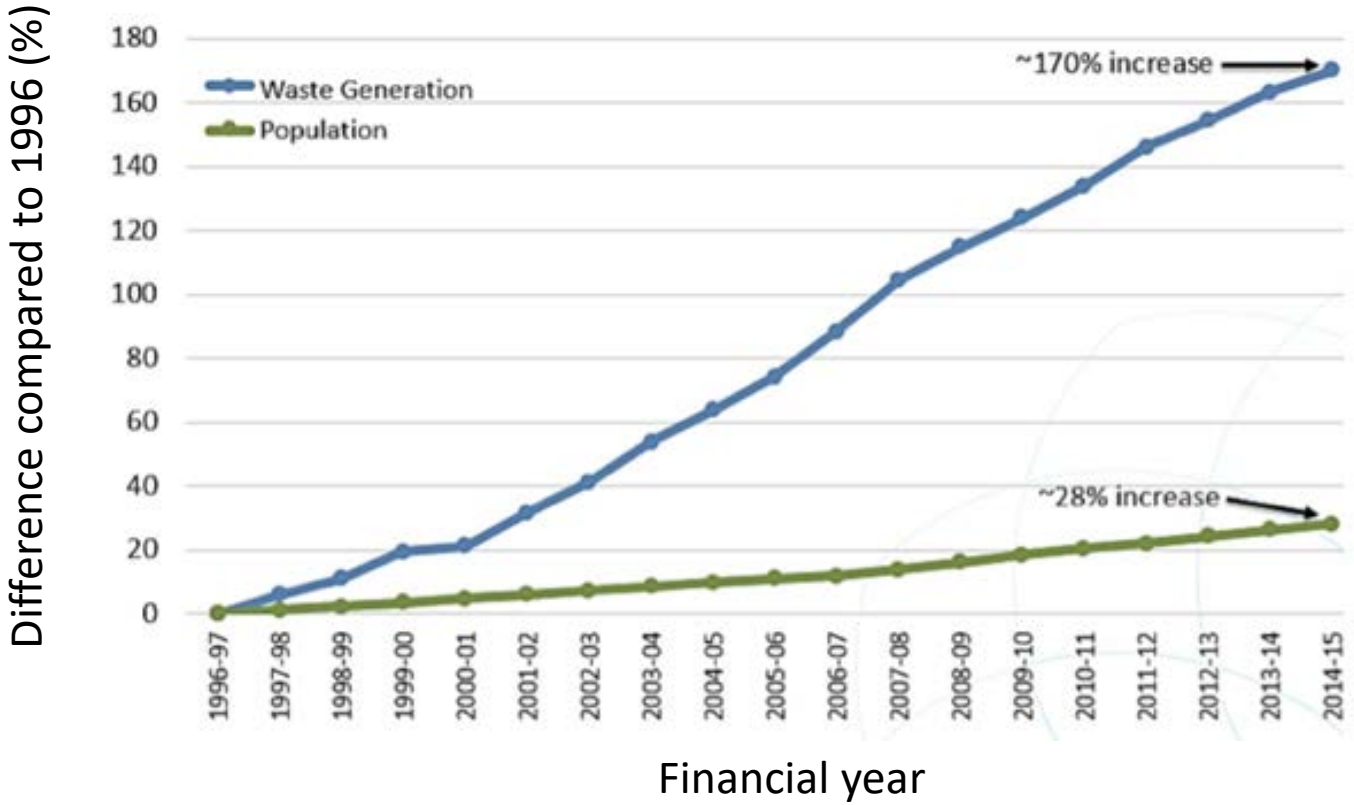
Business Cooperative Research Centres Program

Cost of agricultural waste in Australia

- **$20 billion per annum across the value chain**
- **40% of all food produced for human consumption is lost during primary production**
- **20% primary horticultural production is lost pre-farm gate representing $1.72 billion loss per annum**

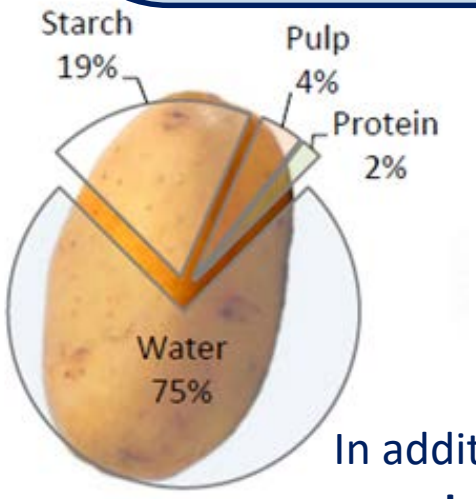


Volumes and value of downgraded potatoes in South Australia

Between 20-40% of the fresh potato harvest falls below supermarket specifications for shape, size and appearance

This represents 100,000 tonnes wasted annually

Current value A$ 0-10/tonne



Paradoxically Australia imports potato starch

Product	Yield	Price/t (USD)
Juice	75%	0
Starch	19%	400–600
Fibre	4%	1500–2200
Protein	2%	1200–1700

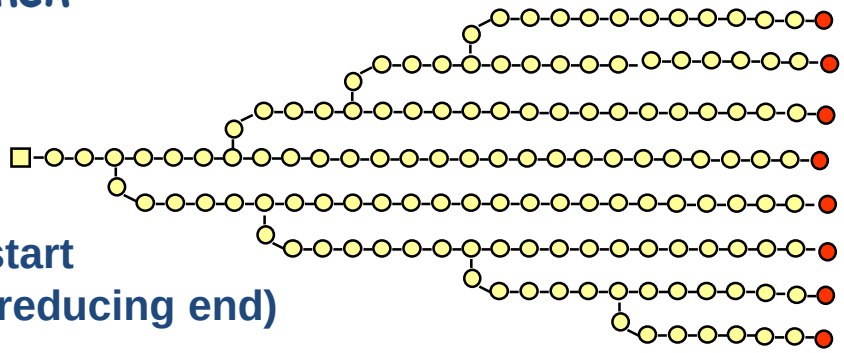
There is clearly potential for import substitution and establishment of a starch industry

In addition, peels are a rich source of phenolics, vitamins and other antioxidants → **nutraceuticals market is expected to surpass $365 billion globally by 2021 – CAGR of 7.3%**

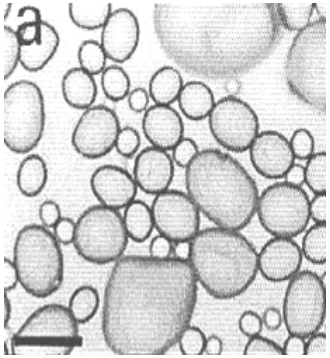
Energy storage: starch in plants (glycogen in animals)

- **Amylopectin**
  - α -1,4 & α -1,6-glucan
  - 10,000 - 100,000 glucose units
  - highly branched, 20 - 25 glucoses/branch

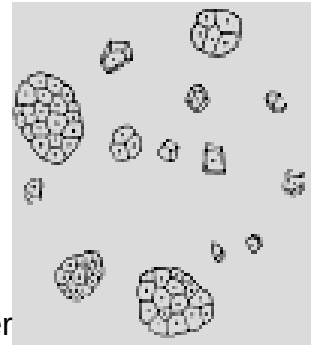
- **Amylose**
  - α -1,4-glucan
  - ~1000 glucose units



- **Starch grain**
  - Water insoluble,
  - size & shape is species specific

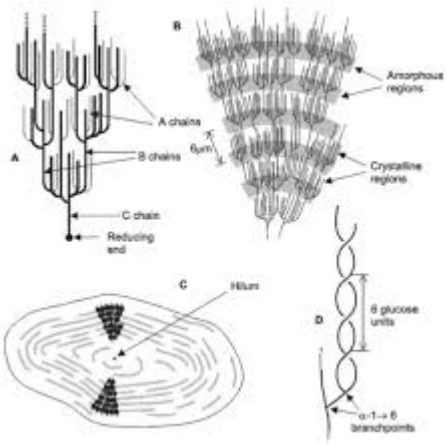


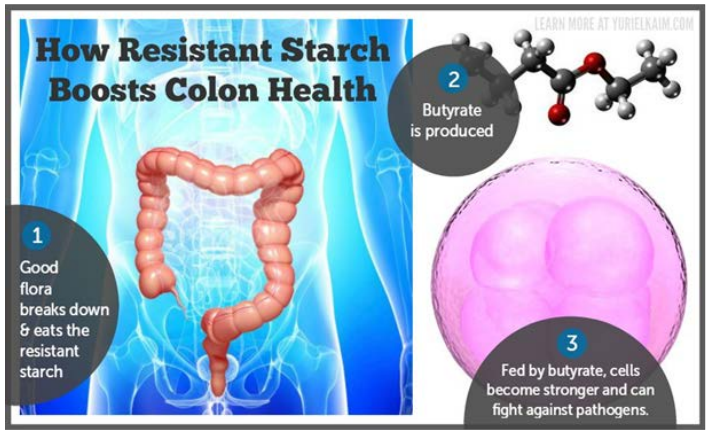
potato: oval,
100 µm in diameter

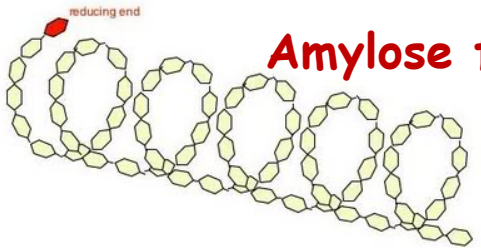


rice: angular,
10 µm in diameter

Exploitation of waste streams from potato primary production







Amylose for Low Glycemic Index

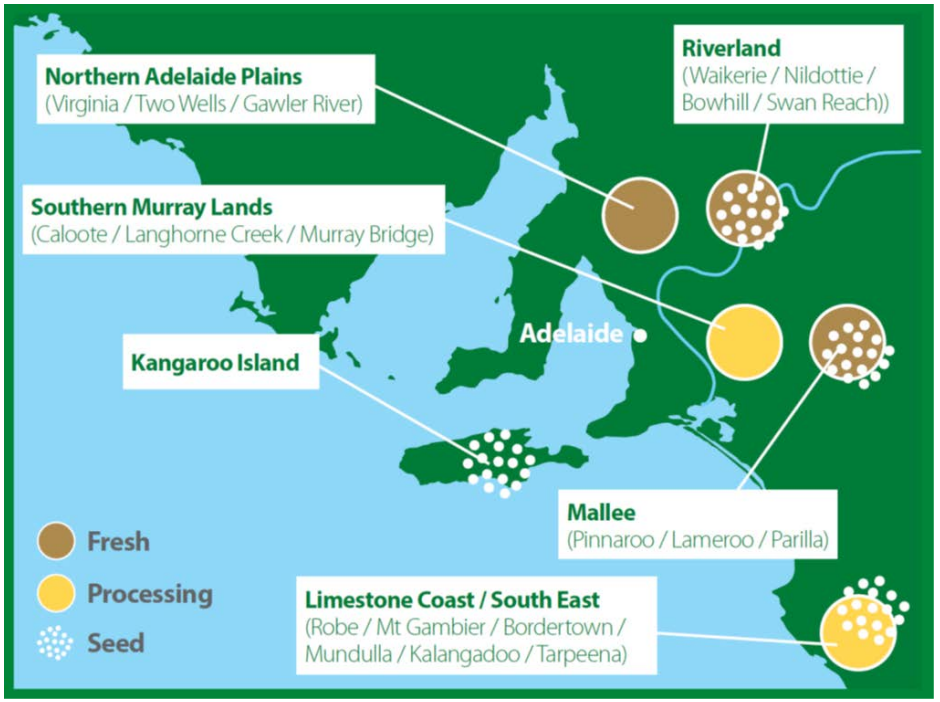
and many more, e.g., non-food fillers, composite materials, textiles, packaging materials, emulsion stabilizers, cosmetics and paints (after modification)

- Potential to establish the first starch industry in Australia taking advantage of the local production

- Potential to amplify 60-200 fold the value of the (current) 100,000 tonnes of annual 'waste'

South Australia: competitive advantages

- Security of supply (year-round production of fresh potatoes)
- Additional land available to increase potato production for starch business
- Range of established potato production districts close to Adelaide markets and suppliers
- Varying climates between production districts allows production over extended periods

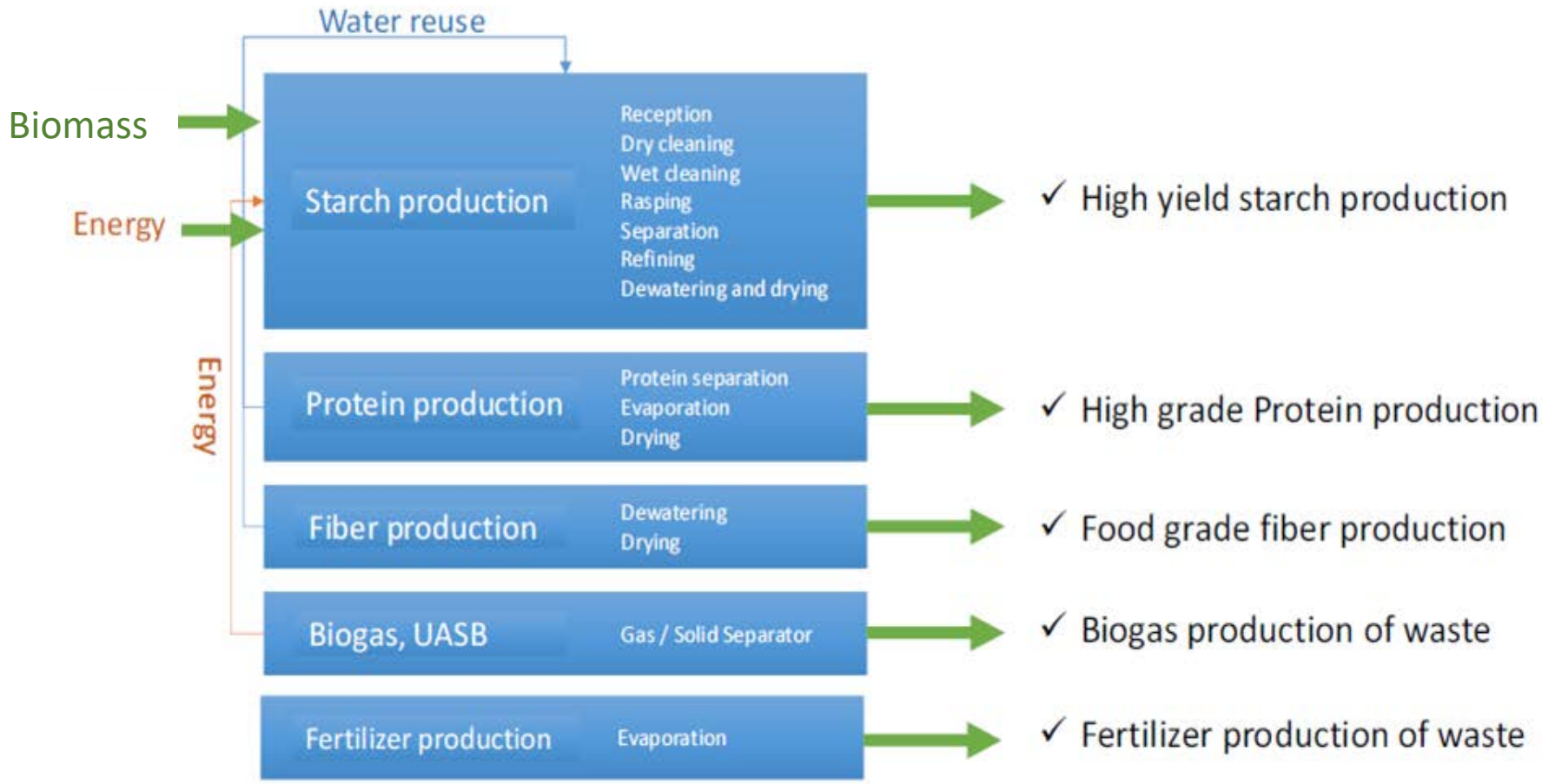


Harvesting Periods

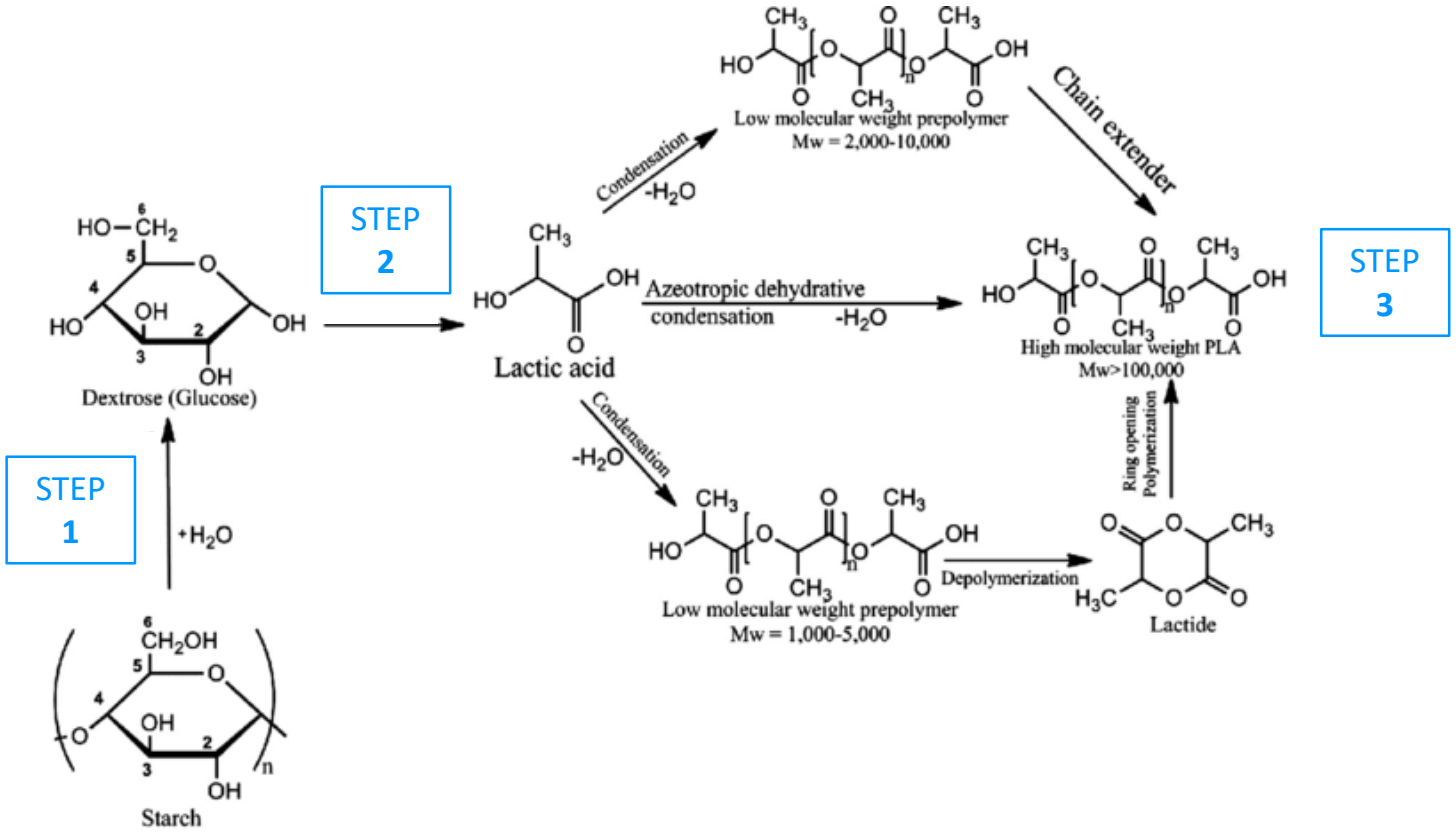
Potato harvest periods in South Australia

		Summer			Autumn			Winter			Spring		
District	Location	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
Adelaide Hills	Woodside, Mt Baker				✓	✓	✓						
Lake Alexandrina	Langhorne Creek	✓	✓	✓				✓	✓	✓			✓
Adelaide Plains	Virginia, Angle Vale	✓	✓	✓				✓	✓	✓			✓
Lower South East	Mt Gambier, Penola		✓	✓	✓								
Upper South East & Mallee	Pinnaroo, Lameroo, Bordertown	✓	✓			✓	✓	✓	✓	✓	✓		✓
Port Pirie	Port Pirie					✓	✓	✓	✓	✓			
Lower Murray	Murray Bridge	✓	✓					✓	✓	✓			
Upper Murray	Waikerie, Loxton	✓	✓					✓	✓	✓	✓		✓

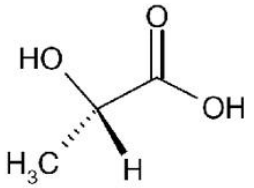
Integrated extraction process



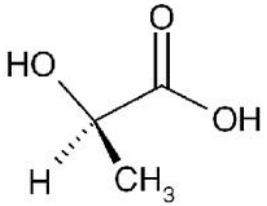
From starch to lactic acid (LA) and poly-lactic acid (PLA)



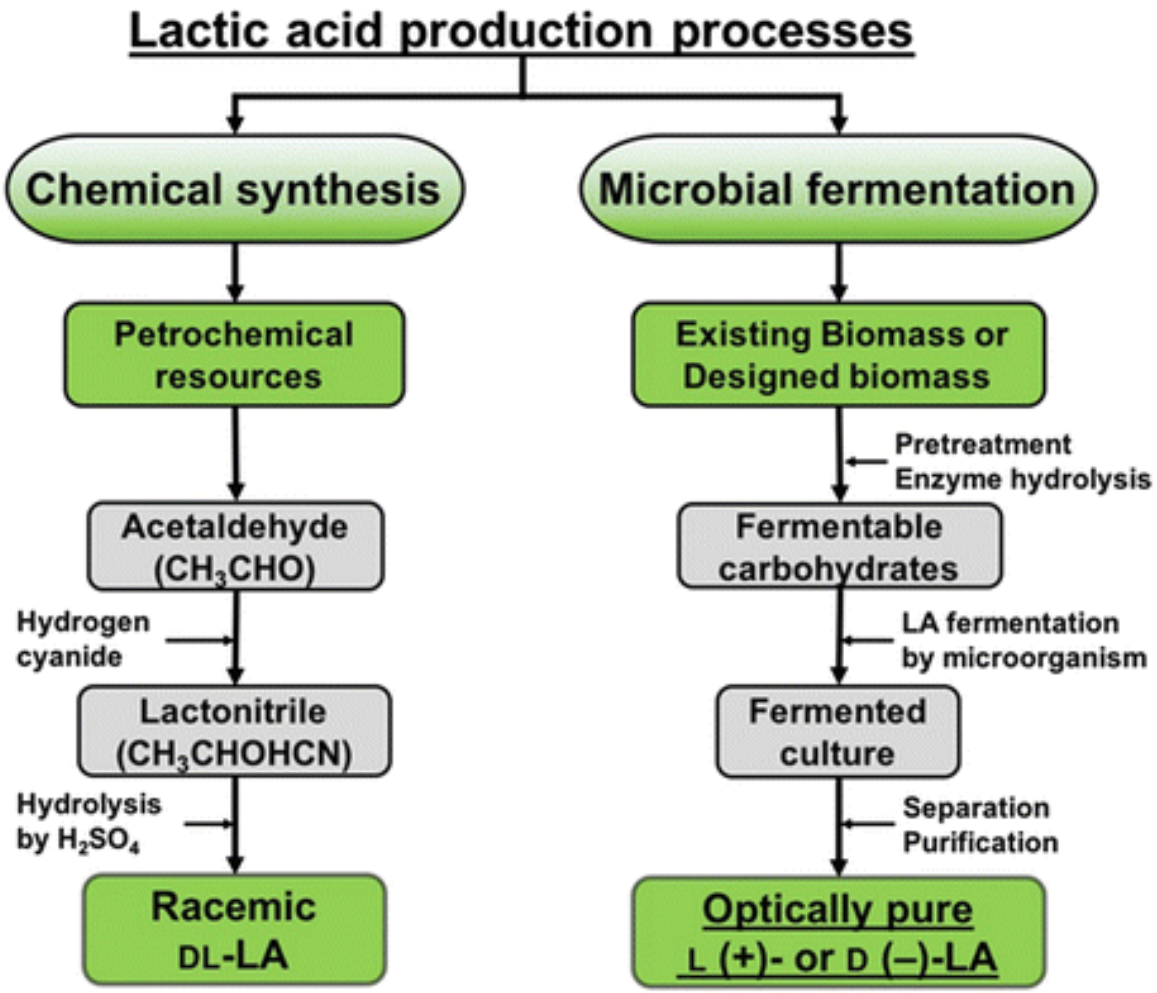
Production of lactic acid (LA) production from glucose



D - Lactic acid



L - Lactic acid



Lactic Acid uses

Pharmaceutical & cosmetic industry:

Extensively used in over-the-counter skin products and cosmeceutical products to:

- Moisturize
- Improve signs of aging (fine lines and wrinkles)
- Fade hyperpigmentation (sun spots or age spots)
- Treat “chicken skin” and calluses
- Topical treatment of acne, eczema, psoriasis, rosacea, warts
- Controlled drug delivery system

Medical sector:

- Treat calcium deficiencies (calcium lactate)
- Treat dry skin disorders (ammonium lactate)
- Treat anaemia, hypertension, osteoporosis (mineral lactate)

Household:

- Descaling agent in cleaning products
- As antibacterial in dish detergent and hand soap

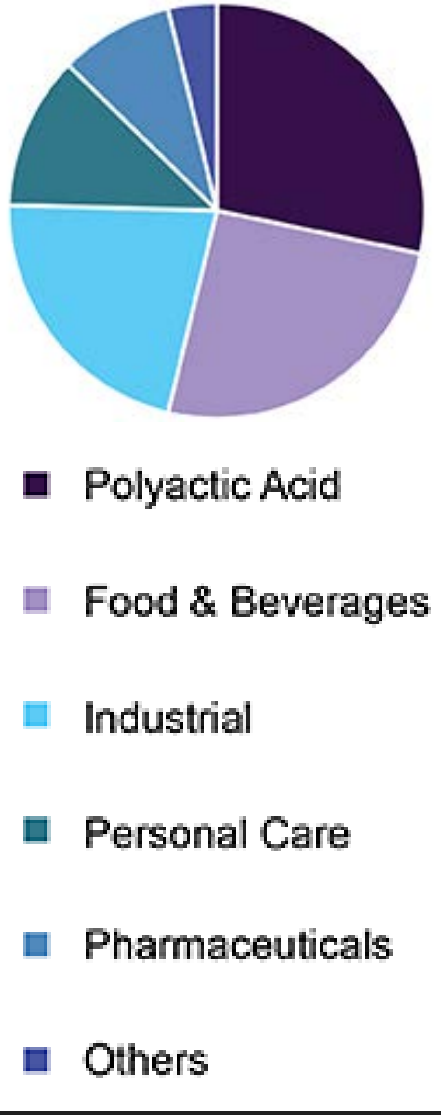
Food industry:

- Emulsifying agent (lactic acid esters)
- Good preservative, curing agent, flavouring agent, pickling agent, pH buffering
- Increase of poultry and fish shelf life (aqueous solution)
- Bread additive in baking industry

Generally, the food and pharmaceutical industries prefer L-Lactic acid, however other industries may require racemic mixtures.

Global Lactic Acid markets

- The global lactic acid market size was valued at USD 3.7 billion in 2020.
- It is expected to grow at a compound annual growth rate (CAGR) of 18.7% from 2019 to 2025 to reach USD 8.7 billion by 2025.
- Key factors that are driving the market growth include the possibility to use lactic acid as a monomer for the manufacturing of biodegradable polylactic acid



Poly-Lactic Acid uses

Medical field:

Because of its biocompatibility, it is used for:

- Surgical sutures
- Medical implants (tissue growth, bone grafting)
- Medical devices

Fibres & textiles:

- Single-use antimicrobial wipes
- car interior parts (carpets, floor mats)
- Replaces major synthetic polymers (e.g. nylon) in textile industry
- Suitable for sports apparel

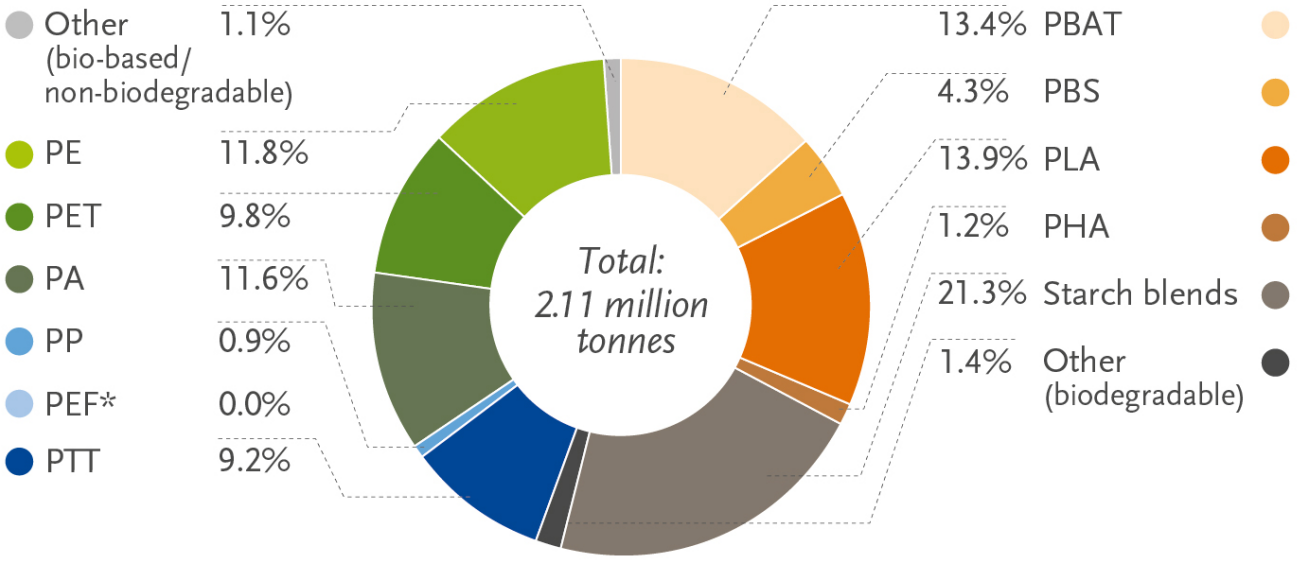
Packaging & serviceware:

- Clamshells to package fresh products (fruit, veg, bakery)
- Yogurt cups, water/juice bottles
- Shrink labels/films
- Potato chip bags
- Shopping bags
- Microwaveable containers, disposable drinking cups

PLA has some limitations (e.g. poor toughness), so PLA products with particular characteristics are obtained by blending PLA with other resins, fillers, fibres, micro- or nanoparticles

Global PLA markets

Global production capacities of bioplastics 2019 (by material type)



Bio-based/non-biodegradable
44.5%

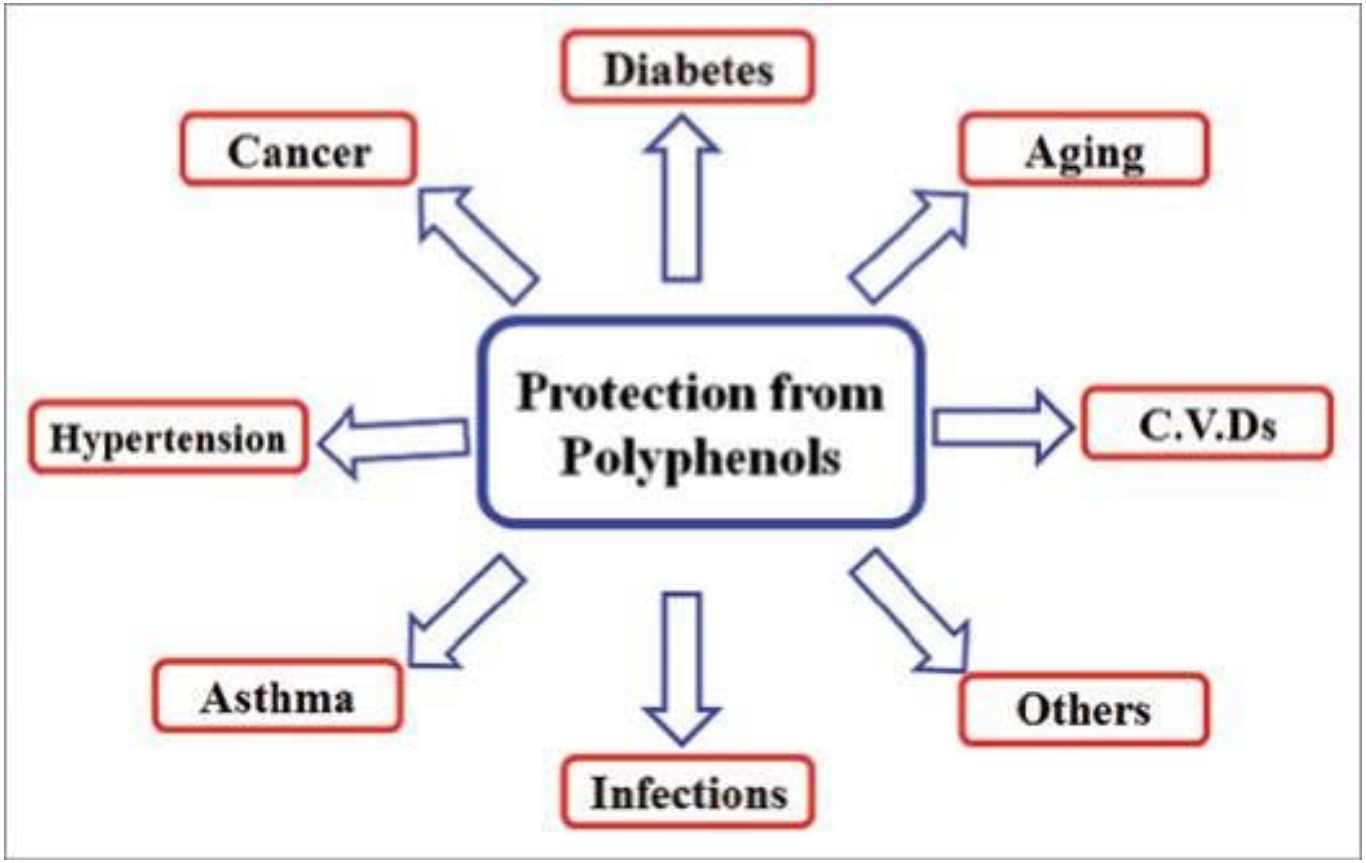
Biodegradable
55.5%

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

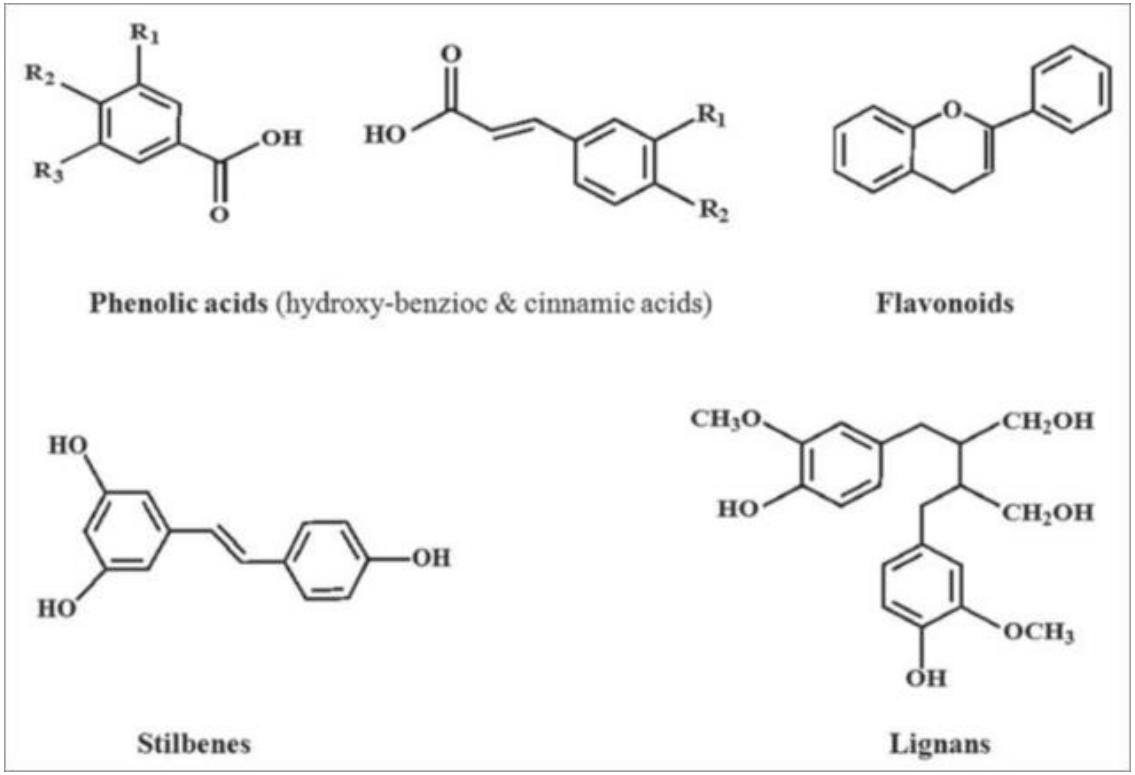
Source: European Bioplastics, nova-Institute (2019)
More information: ***www.european-bioplastics.org/market*** *and* ***www.bio-based.eu/markets***

Global Bioplastics Market

Antioxidants and Polyphenols



Antioxidants and Polyphenols in Potato Skins

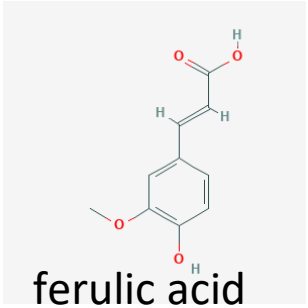


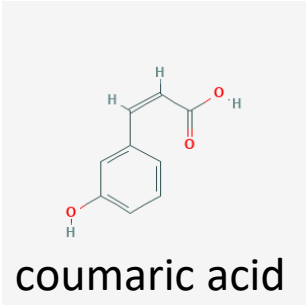
Types of Polyphenols include

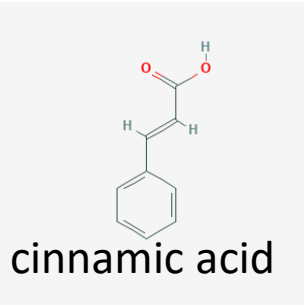
- Phenolic acids:
  - Examples are ferulic, coumaric, cinnamic, chlorogenic acids (hydroxyl cinnamic acids HCA and amides HCAA)
- Flavonoids
  - Examples includes quercetin, catechins and anthocyanins (red colour)
- Lignans and Stilbenes

Hydroxycinnamic acids (HCA) and Hydroxycinnamic acid amides (HCAAs)

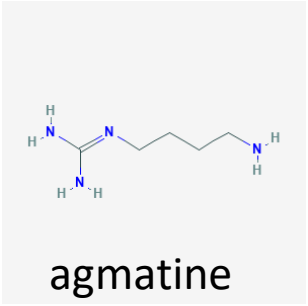
Hydroxycinnamic acids

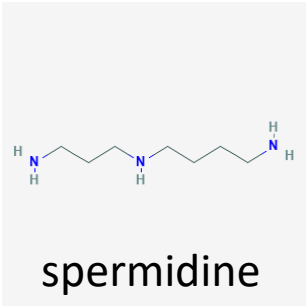

ferulic acid

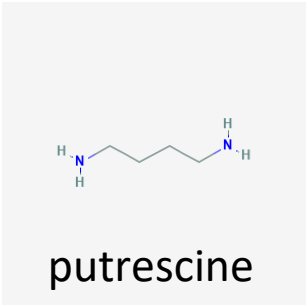

coumaric acid


cinnamic acid

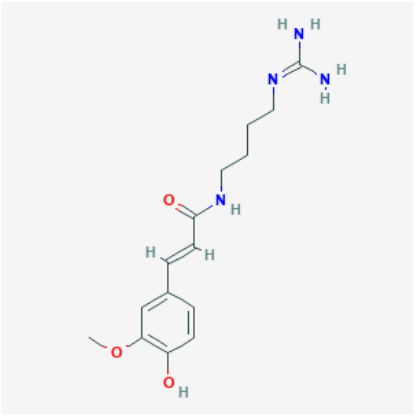
Amines


agmatine


spermidine


putrescine

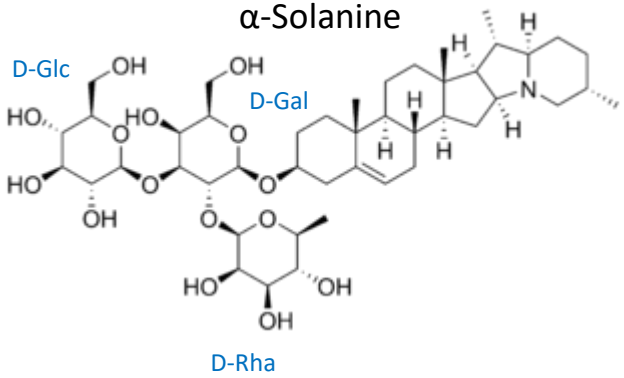
Hydroxycinnamic acids amides
Phenolamides


feruloylagmatine

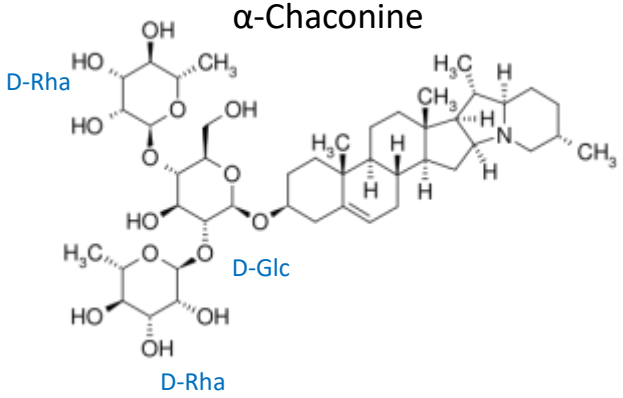
Glycoalkaloids in potato skins

- Produced in nightshade plants, *Solanaceae:* potatoes, tomatoes, peppers, capsicum
- Main two in potatoes are α-solanine and α-chaconine
- High in shoots, leaves and flowers. Higher towards the outside of the tuber, i.e. skins
- Produced in response to light. The green colour is chlorophyll but it indicates the potato is likely to also be producing alkaloids
- Poisonous to animals and humans
- Potential as natural anti-fungal, insecticide and antimicrobial agents (Bakkar and Brunton, 2019)

α-Solanine



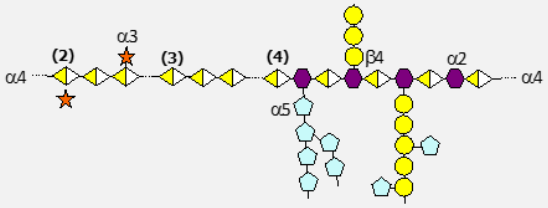
α-Chaconine



A South Australian facility for glycan analysis

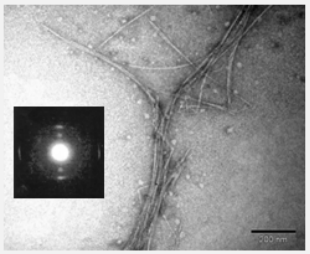
'Adelaide Glycomics' Partnership with Agilent Technologies

THE UNIVERSITY of ADELAIDE



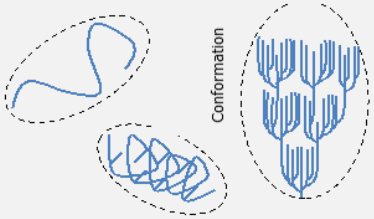
Fine detailed structure of complex glycans (e.g. sugar composition, linkages, etc)

GC; GC-MS; HPLC; CE-MS; LC & LC-MS; MS; NMR



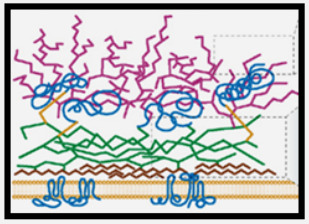
Carbohydrates in the solid state (e.g. cellulose, chitin)

(Cryo-)TEM & SEM; solid-state NMR; X-ray diff.



Conformational analysis of complex glycans

Laser light scattering/SEC; NMR



Relationship between structure, chemical reactivity & physico-chemical properties

AFM; Mechanical testing; TEM &SEM

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Food sustainability
Nutrition
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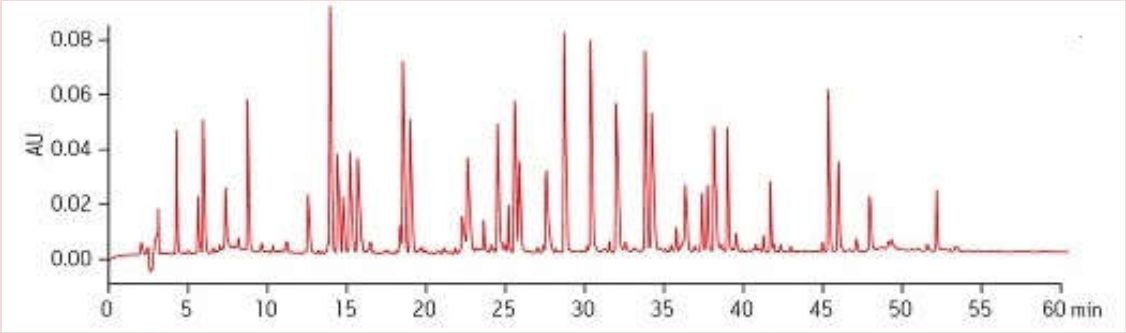
Adelaide Glycomics: equipment & main applications

Type of analysis	Instrument used
Qualitative Proteomics	LC-QTOF
Quantitative Proteomics (semi quantitative by spectral counting/quantitative by iTRAQ)	LC-QTOF
Targeted Proteomics	LC-QQQ
Targeted metabolomics	LC-QQQ
Quantitative Metabolomics	LC-QQQ
Qualitative Metabolomics	LC-QQQ
Determination of monosaccharide composition (neutral & amino sugars)	GC-MS-FID #1
Determination of monosaccharide composition (uronic acids)	GC-MS-FID #1
Determination of glycosidic linkages (neutral sugars only)	GC-MS-FID #1
Determination of glycosidic linkages (uronic acids – this requires a different type of chemical derivatisation as neutral sugars)	GC-MS-FID #1
Glycosidic linkage (uronic acids & amino sugars)	GC-MS-FID #1 & #2
Glycosidic linkage (amino sugar, chitin)	GC-MS-FID #1 & #2
Glycosidic linkage (amino sugar, chitin & chitosan)	GC-MS-FID #1 & #2
Degree of N-acetylation of chitosan	FTIR
Molecular weight and size determination of polysaccharides	HPSEC-Triple Detection (MALLS, viscosimetry and refractometry)
Oligosaccharide composition	HPAEC-PAD (Dionex)
Monosaccharide composition (PMP derivatisation method)	HPLC
Chemical imaging and fingerprinting	FTIR microscope
Separation and analysis of isobaric compounds	IM-MS-QTOF
Analysis of protein conformation and structural features	IM-MS-QTOF
Structural determination of carbohydrates by 1D-1H, 1D-13C, and 2D NMR spectroscopy (COSY, TOCSY, HMBC, HMQC, ROESY)	600 MHz NMR

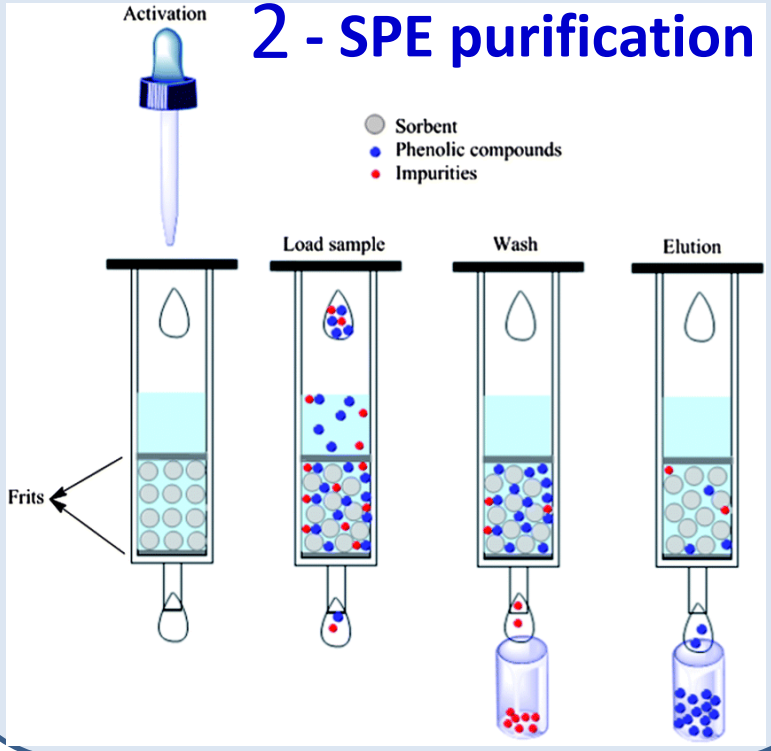
Solid-Phase Extraction (SPE) for the preparation of phenolic compounds

1 – Complex starting material

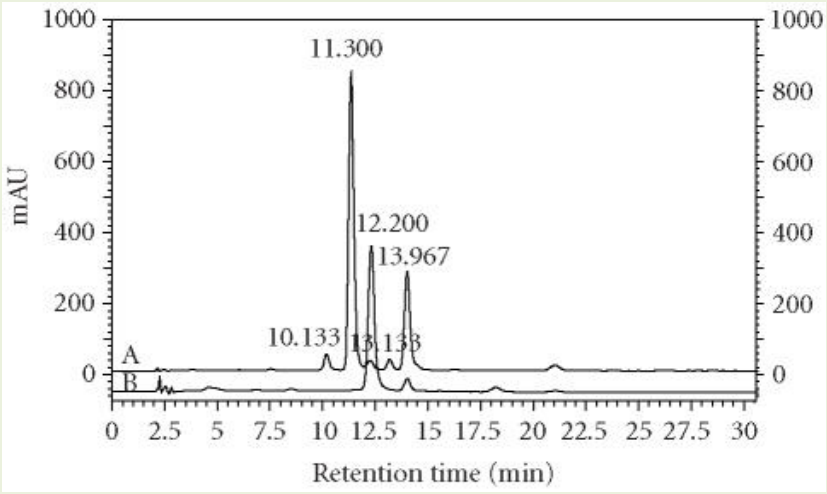


Each peak represents a different compound – Up to 2000 compounds are present in an extract, most of which are not of interest

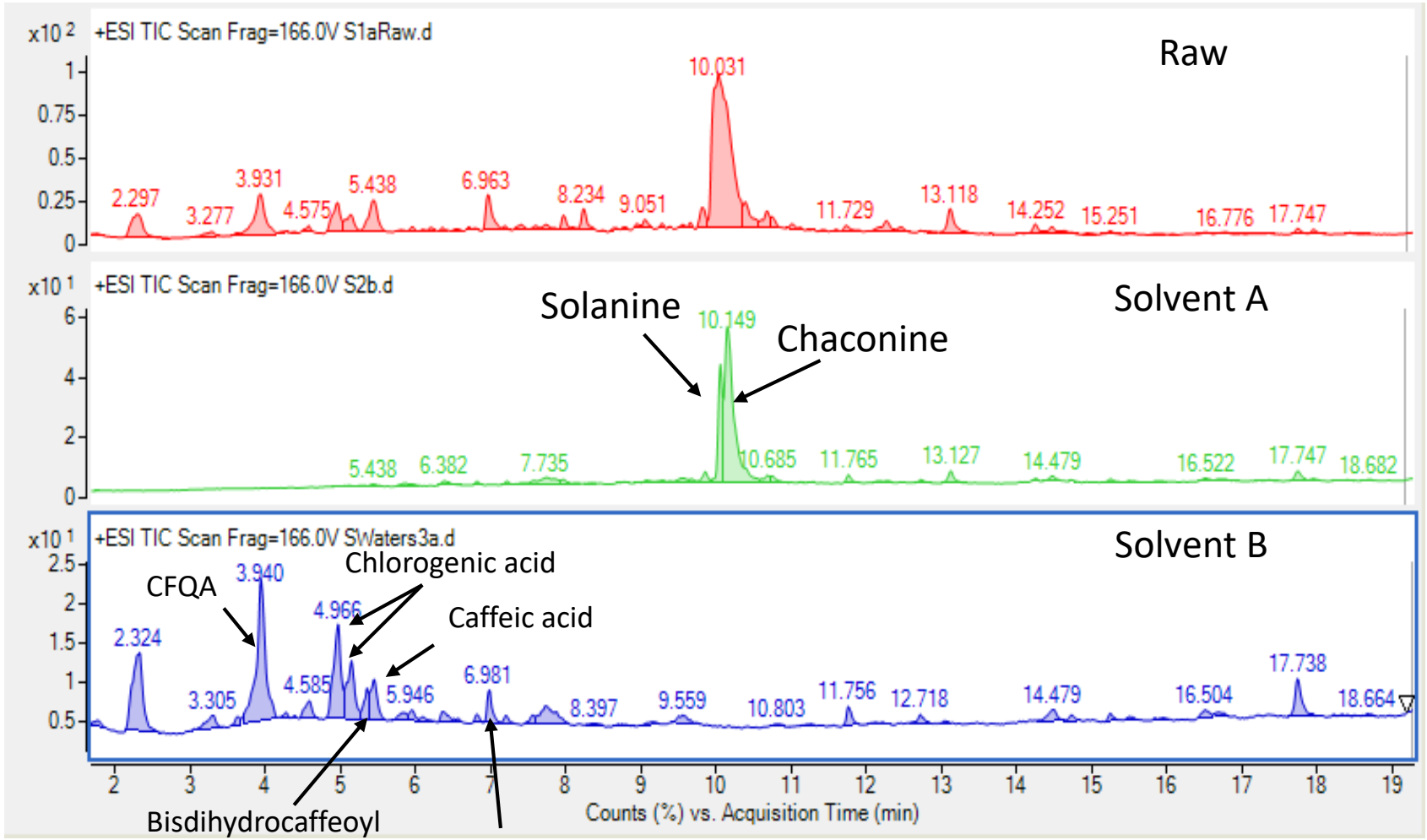
2 - SPE purification



3 - Quality control at Adelaide Glycomics



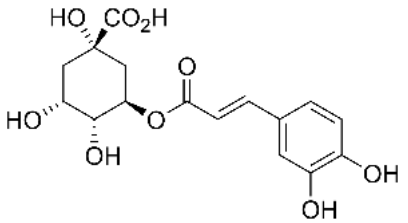
Chromatographic separation after solvent extraction



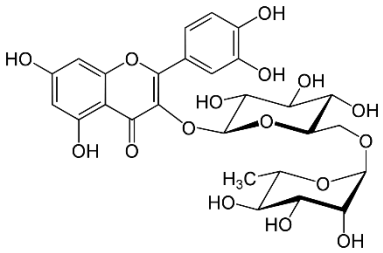
Bisdihydrocaffeoyl spermidine

N1,N4,N12-Trisdihydrocaffeoyl spermine

Polyphenolic compounds

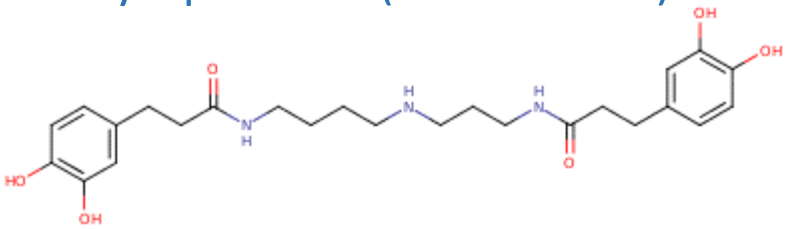


- Chlorogenic acid:
  - High in coffee beans,
  - potential as antioxidant, may reduce blood pressure, cardioprotective, anti-inflammatory



- Quercetine-3-rutinoside (rutin):
  - High in citrus
  - Potentially lowers cholesterol, reduces arthritis pain

- Bishydro caffeoyl spermine and trishydrocaffeoyl spermine (Kukoamines):
  - Found in box thorn (goji berries)
  - Potentially prevents blood hypertension



- Caffeoyl putrescine and feruoyl putrescine:
  - High antioxidant activity and possibly chemopreventive

HCAs and HCAAs in waste streams

HCAs

Free

- Cinnamic acid
- Ferulic acid

Bound in cell walls

- Ferulic acid
- Coumaric acid
    - Released by acid hydrolysis or enzymes

- Antioxidant
- Anti-inflammatory
- Implicated in diabetes, hyperlipidemia and obesity treatment

HCAAs

- Coumaroyl, Feruloyl, Sinapoyl, Caffeoyl Agmatines, Spermidines and Putrescines

- Strong antifungal activity
- Defence against pathogen attack in the plant
- Implicated in gastrointestinal motility

Other polyphenols

Flavanols

- Catechin, epicatechin, gallocatechin (found in green tea extracts)

Flavanoids

- Isorhamnetin, Apigenin, Isovitexin, Isoscoparin, Isoorientin

Assessment of potential of these compounds

Develop extraction methods

Evaluate properties

Functional Packaging Materials

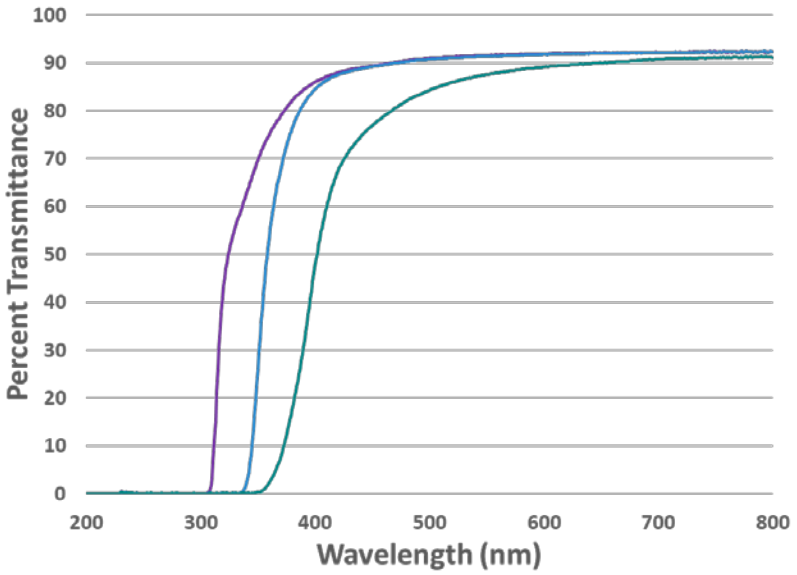
Intrinsic properties

- Preserve freshness (antioxidant)
- Antimicrobial
- Good transparency & flexibility (tunable)
- All food-based materials and reagents.
- Potentially edible
- Are 100 % biodegradable

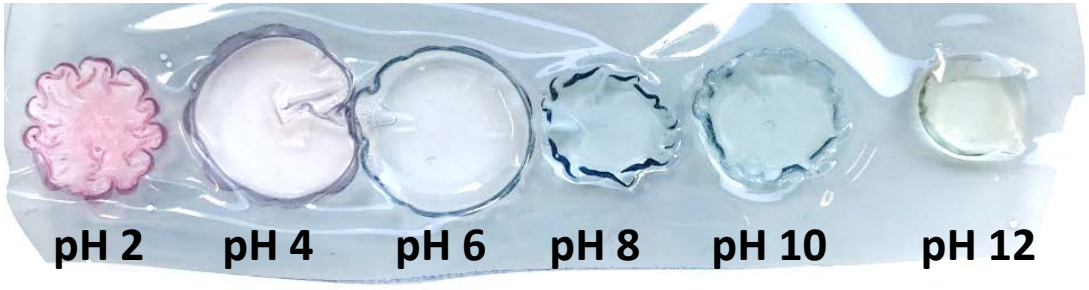
New technologies

- Improve water repellence with ultra-thin deposited coatings

UV blocking



pH indicating



Participants involved & impact

Production of different forms of starch and bioactives for:

- Functional foods
- Nutraceuticals
- Packaging materials
- Non-food fillers
- Composite materials
- Emulsion stabilizers
- Cosmetics and paints (after modification)