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BIO-SCOPE Project 5405

Scoping the Irish fruit and vegetable supply chain for valuable biomass resources for upgrade ……

...... into new fibre ingredients to add texture to different food products.

Why was the project important?

- Tackling food waste is a major issue at a national, European and Global level.
- Minimising food waste in the Irish agricultural sector is a key priority for the EPA.
- Fruit and vegetable supply chains generate a large amount of waste that typically becomes a financial and environmental burden to farmers, processors, distributors and retailers.
- Still relatively little is known about the levels of fruit and vegetable waste that are generated during the pre-consumer stage of the Irish supply chain every year.

What were the key aims?

- To scope the extent to which fruits and vegetables are lost or wasted from the food supply chain in Ireland.
- To identify the current strategies and barriers for disposal and/or reuse.
- To screen targeted resources for potential upgrade into new food fibre ingredients.
- To offer potential solutions to farmers, processors and distributors to minimise waste and to add value.
- To offer recommendations to EPA and stakeholders for the development of waste management and sustainability programmes.

How we went about it

- Four key activities
- Scoping the potential resource.
- Choosing candidate crops for upgrade.
- Evaluating candidate resources for upgrade.
- Dissemination to industry, stakeholders and EPA.

Scoping the resource

- The key crops grown in Ireland in any one year are:
  - Root vegetables: **potato, carrot, swede/turnip*, parsnip**.
  - Alliums: **leeks, onions**.
  - Brassicas: **cabbage, cauliflower, Brussels sprouts, kale, broccoli**.
  - Peas & beans.
  - Salad leaves & other vegetables: **tomato**, cucumber, pepper, celery, lettuce, herbs.
  - Soft fruit/berries: blueberry, raspberry, **strawberry**.
  - Orchard fruit: **apple**, pear, plum.
- Of these **14 candidate crops were identified** (in bold).

* some confusion in local use of "turnip" and "swede" in reference to the yellow turnip/rutabaga. For this study all "turnip" and "swede" data combined and experimental work carried out on swede (yellow turnip/rutabaga).

Choosing candidate resources

Table 1. Decision matrix summary showing 14 key crops chosen for evaluation (highlighted in blue).
NB: ✓ = positive, X = negative, ID = insufficient data. NB: swede & turnip combined.

Crop	Potato	Carrot	Swede	Turnip	Parsnip	Leek	Onion	Cabbage	Cauliflower	Brussels sprout	Kale	Broccoli
Availability	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Processing potential	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Commercial potential	✓	✓	✓	✓	✓		✓	✓	✓			✓
Crop	Tomato	Cucumber	Pepper	Celery	Lettuce & salad	Herbs	Strawberry	Blueberry	Raspberry	Apples	Pear	Plum
Availability	ID	ID	ID	ID	ID	X	✓	ID	ID	✓	ID	ID
Processing potential	✓	ID	✓	✓	ID	✓	✓	✓	✓	✓	✓	✓
Commercial potential		ID		✓	ID		✓	✓	✓	✓	✓	

Scoping the resource - key findings

- Based on average data for 14 key Irish crops in 2018.
- Substantial waste biomass is generated across the fruit and vegetable supply chain in Ireland each year.
- An estimated **300,000 - 360,000 tonnes** of waste was generated at farm, distribution and processing level.
- In **excess of 200,000 tonnes** of this was for **potatoes alone**.
- Between **45% -70%** of the **Irish vegetable crop** is potentially wasted each year.
- Up to **25%** of the **Irish fruit crops** is potentially wasted each year.

Scoping the resource - key findings

- Losses vary substantially between different crops and across years and are dependent on:
  - yields and harvests;
  - storage and transport;
  - processing and packing activities;
  - consumer & market forces.
- At **farm level**, losses of **15%-30% typically** reported for most crops except apples and strawberries (5%-15%).
- At **processing/distribution level** - losses of **40%-60% typically** reported except for apples and strawberries (30%-50%).

Scoping the resource - key findings

Table 2. Estimated annual production and losses **(tonnes)** for key Irish fruit and vegetable crops at farm and distribution/processing level, showing potential biomass for upgrade

Crop	Yield per annum	Min loss at farm level	Max loss at farm level	Min loss at processing & distribution	Max loss at processing & distribution	Max biomass for upgrade
Potato	364050	54608	109215	92833	123777	247392
Carrot	49595	7439	14879	12647	16862	31741
Apple	19964	998	2995	5690	7586	22981
Cabbage	16436	2465	4931	4191	5588	15119
Swede	12650	1898	3795	3226	4301	8096
Onion	7486	1123	2246	1909	2545	14191
Turnip	7335	1100	2201	1871	2494	4694
Parsnip	6342	951	1903	1617	2156	4059
Broccoli	4790	719	1437	1222	1629	3066
Kale	4249	637	1275	1158	1544	2719
Strawberry	4064	203	610	1084	1445	2154
Leek	2806	421	842	700	933	1796
Cauliflower	2405	361	722	590	786	1539
Brussels Sprout	1728	259	518	422	563	1106
Total	**503900**	**73182**	**147566**	**129159**	**172212**	**360653**

Scoping the resource - key findings

- A further **40,000 - 60,000 tonnes** of waste is potentially generated from **imported produce** of the same 14 crops.
- In addition, Ireland imports a wide variety of other fruits & vegetables that are not grown in Ireland but that are upgraded to functionalised fibres elsewhere in Europe and globally.
- For example - citrus waste streams (from juicing & pectin extraction) are utilised, these products are widely used to add texture to different food products and are considered market leaders/benchmarks.

Upgrading the resource – why focus on fibres?

- The potential to upgrade different raw materials into new food fibres with textural functionality was explored – why?
- Food fibres (from different sources) are widely used in the food industry to add texture and nutrition (dietary fibre).
- Including bakery, snacks, meat & fish, soups, dairy, vegetarian/vegan products.
- Fruit & vegetable resources are commonly used to produce fibres, including by products from other processing activities *e.g.* peels & pulp.
- The global market for food fibres is substantial ≈ €5-7 billion.
- The fruit & vegetable fibre sector is reported to ≈ 35% of this.

Upgrading the resource – why focus on fibres?

- The range & quality of fruit & vegetable fibres varies from simple, dried & milled products to more sophisticated products in which particular properties or functionalities have been improved.
- More sophisticated products tend to have wider end use in different foods.
- Food fibres are typically packed in 25kg sacks and sell for €4-10/kg (<€15/kg) – depending on their properties.
- They are sold direct to end use food companies or through ingredients companies/distributors.

Upgrading the resource – what we did

- In this project, 3 different fibre types were produced and evaluated – depending on their compositional makeup:
- **Untreated fibres:** via controlled drying and milling.
- **Water binding fibres:** via additional physical processing to promote the water binding potential of cellulose.
- **Gelling fibres:** via a proprietary process to activate the gelling potential of pectin.
- Note: previous research on potato waste showed upgrade into food fibres to be not very interesting. Therefore, in this project the protein potential of potato has been evaluated.

Why look at water binding & gelling?

- From a texture perspective, fibre **functionality essentially stems from a capacity to hold or bind water** (and sometimes fat) to give structure *i.e.* viscosity and texture.
- Water binding capacity (WBC) is a useful measure of the amount of water (g) that can be bound per g of fibre.
- A general trend exists for market available fibre products - with increasing value/price associated with increasing WBC.
- Gelling provides another means to bind water and to structure food products – albeit to give different textures.
- There are currently very few gelling fibres in the market place and there is plenty of scope to bring new gelling fibres to the market.

Upgrading the resource – what we did

Table 3: Range of fibres produced from the different resources. Note: whole fruit & vegetables used unless stated otherwise.

Raw Material	**Untreated fibre**	**Water binding fibre**	**Gelling fibre**
Potato - peelings	✓	✓	✓
Carrot	✓	✓	✓
Swede	✓	✓	✓
Parsnip	✓	✓	✓
Onion - whole	✓	✓	✓
Onion - without skins			✓
Leek	✓	✓	✓
Cabbage	✓	✓	✓
Broccoli	✓	✓	
Cauliflower	✓	✓	
Tomato	✓	✓	✓
Strawberry	✓	✓	✓
Apple - whole	✓	✓	✓
Apple - juiced	✓	✓	✓

Upgrading the resource – key aims

- The aims of this phase of the work were:
- To evaluate the water binding potential of untreated fibres.
- To assess whether physical processing could improve the water binding potential of fibres.
- To assess whether processing could promote gelling potential in fibres containing pectin.
- To evaluate new water binding and gelling fibres against market available products.
- To assess which processing options (or not) have commercial potential.

Upgrading the resource – key findings

Table 4: impact of processing on water binding functionality of fibres. Where improvement of <50% = (+), 50-100% = (++) & >100% = (+++).

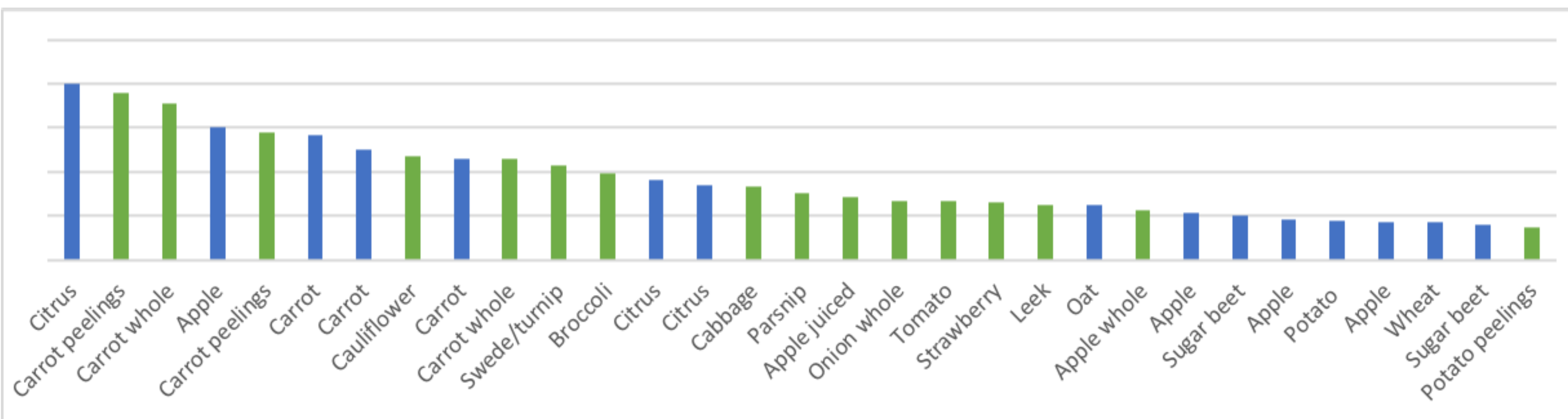
Raw material	**Improved water binding**
Potato peelings	++
Carrot whole	+++
Carrot peelings	+
Swede	+++
Parsnip	+++
Onion whole	+++
Leek	+
Cabbage	+
Broccoli	++
Cauliflower	++
Tomato	++
Strawberry	+++
Apple whole	+
Apple juiced	+

Water binding functionality

- In all cases, physical processing improved the water binding potential of untreated fibres.
- In some cases this was substantial <250%.
- However, **processing is only warranted/economical if the level of water binding becomes commercially interesting** – see over.

Upgrading the resource – key findings

Figure 1. Water binding potential of different fruit & vegetable fibres from this study (green bars) *c.f.* commercially available products (blue bars).



- The majority of water binding fibres produced in this study showed good to very good functionality when comparable to commercially available products.
- Carrot, swede and cauliflower fibres are particularly interesting.

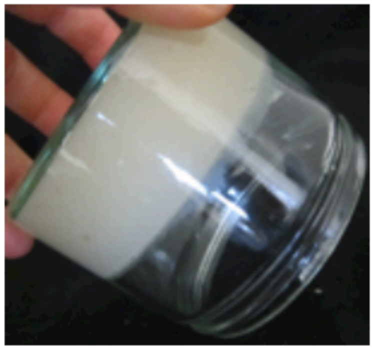
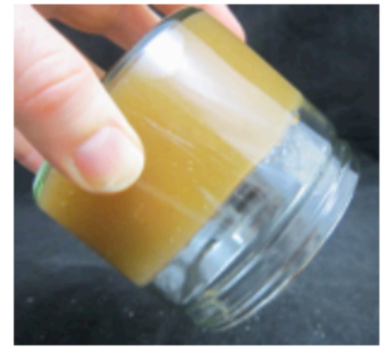
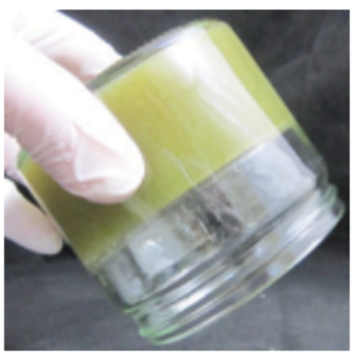
Upgrading the resource – key findings

Table 5: impact of processing on gelling functionality of different fibres. Note: (+++) = very high, (++) = high, (+) = low, (-) = very low gelling capacity.	
Raw material	**Gelling capacity**
Carrot whole	**+++**
Carrot peelings	**++**
Swede	**++**
Parsnip	-
Onion whole	+
Onion – no skin	-
Leek	+
Cabbage	-
Tomato	**+++**
Strawberry	**++**
Apple whole	+
Apple juiced	**++**

Gelling functionality

- The gelling potential of different raw materials was variable across.
- Gelling capacity was assessed by measuring the gel strength relative to commercially available comparators.
- Also, using a simple inversion test to assess whether gels are strong enough to be self supporting – see over.

Upgrading the resource – key findings

Figure 2. Inversion test for gels made with a range of different fruit and vegetable fibres.		
		
Swede/turnip	Whole carrot	Juiced apple
		
Leek	Onion – no skins	Tomato

Upgrading the resource - application in food

- Evaluating the physical properties of new fibre ingredients gives an indication of their functionality and is a useful screening tool, however assessing performance in food formulations is essential.

- We evaluated the functionality of swede and apple fibres in a simplified mayonnaise formulation.

- Swede fibres – neutral sensory profile, excellent water-binding properties and produced thick and creamy dispersions.

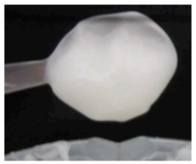
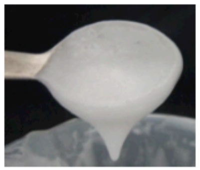
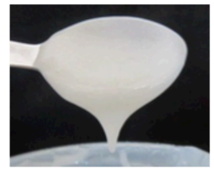
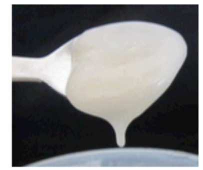
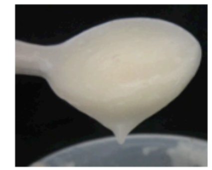
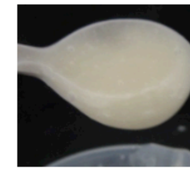
- Apple fibres – neutral sensory profile and good viscosity.
- Fibre was added at 0.8%. For the water binding swede fibres, a 1.6% fibre dose was also assessed.

Application in mayonnaise – key findings

- The key criteria for a good mayonnaise are:
- Viscosity – thick & creamy consistency.
- Appearance – smooth & glossy, for low fat versions important to give the impression that the "indulgence factor" has not been removed by reducing the fat content.
- Cling – important for sticking/coating in salads and dressings.
- It is essential to benchmark performance against appropriate commercial comparators, for this study we used citrus fibres (typically used in market available mayonnaise products).

Application in mayonnaise – key findings

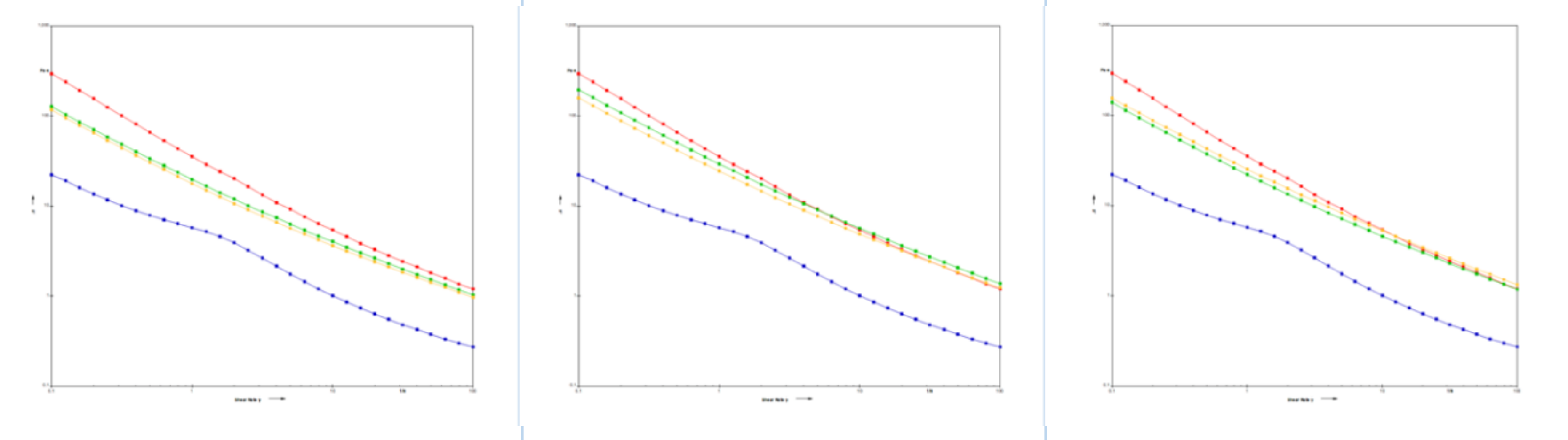
Table 6. Summary of properties of mayonnaise made with swede and apple fibres *c.f.* commercial comparator.

Commercial citrus fibre	Untreated swede	Water binding swede	Untreated whole apple	Water binding whole apple	Untreated juiced apple	Water binding juiced apple
						
Appearance						
Smooth & shiny, neutral colour	Slight pink colour.	Smooth and shiny texture, slight yellow colour.	Slight pink colour.	Stronger colour than untreated.	Smooth shiny surface, slight orange colour.	Smooth appearance, less coloured than untreated.
Cling						
Excellent cling and consistency.	Less body & thinner consistency than benchmark fibres.	Texture resembled benchmarks, especially when double dose used.	Least body of all mayonnaises produced.	More body than untreated whole apple fibre.	More body than whole apple fibres.	More body than whole apple fibre.
Viscosity						
See following slide						

Application in mayonnaise – key findings

Figure 3. Viscosity curves for swede and apple fibres *c.f.* two commercial citrus fibres (red & blue lines). Showing in all cases that the swede and apple fibres had commercially relevant viscosity

(a) untreated fibres	(b) water binding fibres	(c) juiced apple fibres



- **(a) untreated** and **(b) water binding fibres from swede (green) and whole apple (yellow)** had very similar viscosities to each other, they had comparable viscosity to the red commercial fibre and were better than the blue commercial fibre.
- **(c) untreated (green) and water binding (yellow) fibres made from apple pulp** had very similar viscosity to one another and to the red commercial fibre, both out performed the blue commercial fibre.

Upgrading potato waste - potato protein

- Potatoes represent the largest source of waste biomass from the Irish fruit & vegetable supply chain
- 150,000 - 250,000 tonnes potentially available in any one year.
- Finding potential solutions to utilise this biomass is therefore of key importance.
- Our previous research has shown that untreated potato fibres performed well in targeted food applications.
- However, additional processing did not promote functionality enough to warrant the additional cost/effort.
- In this project therefore, we focused on the potential to upgrade potato into a protein ingredients

Potato protein – market demand

- There is real market demand for potato protein.
- Potato proteins have higher market value than other plant derived proteins and are comparable in price to animal derived proteins such as casein, egg & whey.
- Potato protein has excellent technical functionality – gelling, foaming, emulsifying.
- It is used in a wide range of food products including gluten-free, egg-free, meat and meat analogues, dairy-free milks, cheese & ice creams, high-protein snacks & bars.
- It is nutritionally superior to many other plant derived proteins – contains 19/22 of the amino acids, including lysine.
- Potato protein also has a strong marketing message, being non-GMO, sustainable, clean label, plant derived and non-allergenic.

Proof of concept – protein extraction

- A simple, cold extraction process was devised for use with Irish Rooster potatoes.
- The process makes use of standard protein extraction techniques in combination with membrane filtration.
- The process was developed with the following in mind:
  1. suitable for use with whole or part-potato waste;
  2. suitable for incorporation into a multi-stream approach in which potato fibres and starch could also be valorised;
  3. ease of transfer to potential scaled up production;
  4. cold processing more economical;
  5. no pH adjustment *i.e.* simple processing with no chemical use or chemical waste.

Potato protein – key findings

- Total protein recovery was excellent for a preliminary study – 1.6% (as % of starting material) *c.f.* 1.5%-2% as reported in the literature.
- The colour of the end product was comparable with market available products.
- Gelling behaviour promising although not as good as egg or market available potato proteins.
- Plenty of scope for optimisation of the process:
  - colour could be improved;
  - use of different membrane sizes and filtration cycles needs to be evaluated.

Conclusions & recommendations

- Ireland generates sufficient fruit and vegetable waste that could feed into one (or a few) central processing facilities to produce new food ingredients.
- It makes sense to locate such facilities in key growing regions/clusters.
- Simple processing technology can be applied to produce new food ingredients with market appeal.
- Potatoes, carrots, swedes (turnips) and apples are of particular interest.
- Other crops of potential interest in a centralised, mixed processing facility.

Conclusions & recommendations

- **Potatoes –** protein story is commercially interesting and warrants further investigation.
- **Carrots -** we have previously demonstrated the technical and market potential of carrot. This study has further confirmed that carrot is a very interesting material with real commercial potential. More carrot fibres have entered the market in 2019/20.
- **Swede -** arguably the most interesting finding of this study. Untreated & water binding swede fibres perform very well, easy to process, good yields, relatively neutral sensory profile. Good “Irish appeal”. Further evaluation recommended.
- **Apple pulp from juicing -** lower functionality than swede but relatively neutral colour and sweet odour. Untreated and water binding fibres worthy of investigation in application, possibly bakery.

Conclusions & recommendations

- **Parsnip -** lower functionality than swede but relatively neutral colour and sweet odour. Untreated and water binding fibres worthy of investigation in application, possibly bakery.
- **Tomato -** good gelling potential and worthy of further testing in application. Possibilities to prevent syneresis in frozen/ready meals, prevent boil-out in sweet and savoury pies/tarts, pasta bakes etc.
- **Onions & leeks -** despite issues with strong odours during processing, end products have very savoury profiles. Recommended further evaluation in savoury products *e.g.* stock cubes, gravy.
- **Brassicas –** sensory and processing issues limit potential, cauliflower an exception, may have potential in a mixed processing facility.
- **Strawberry -** functionally interesting and pleasant sensory profile but very poor yields. Not commercially interesting.

Available for download on our website

- This work has built on previous EPA funded research that has focused on Irish carrot & potato.
- The outputs of this study (BIOSCOPE) can be downloaded at http://www.cybercolloids.net/information/bioscope
- A series of recommendations for industry & stakeholders will also be available for download on the CyberColloids website http://www.cybercolloids.net/information/bioscope
- All other research summaries relating to our work on different biomass resources can be downloaded at http://www.cybercolloids.net/food-fibres-research

For more information

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