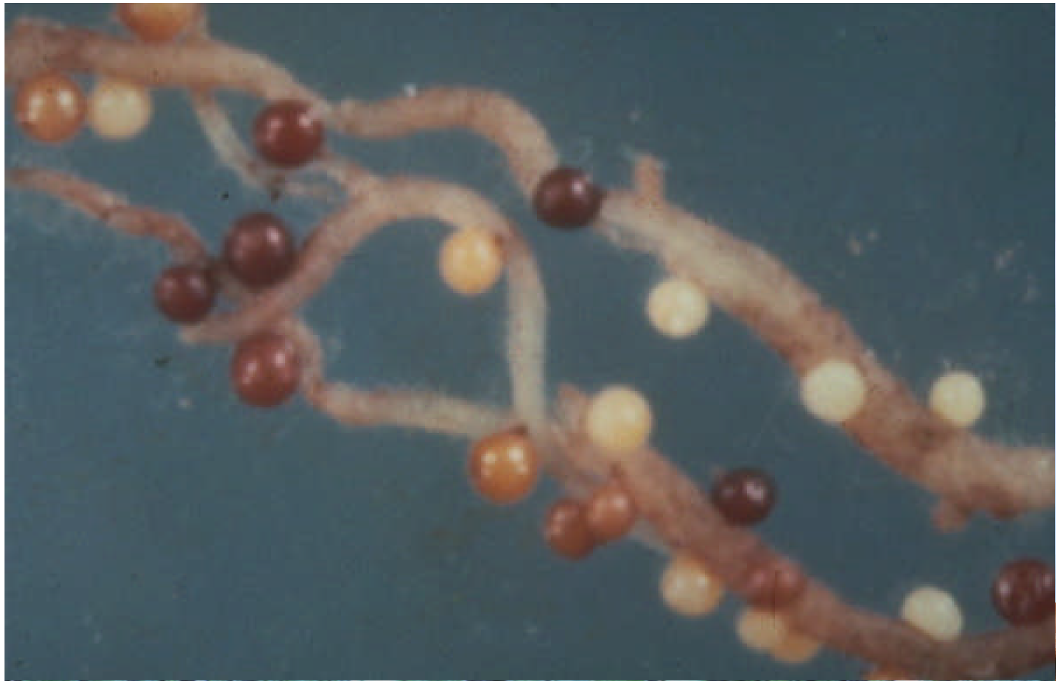
Potato peel as a product for environmentally protective management of potato cyst nematodes

James Hehir & Peter Jones

School of Biological, Earth and Environmental Sciences, UCC

Potato cyst nematodes (PCN)

- Potato: 4th most important crop world wide. Most important non-cereal crop.
- PCN: most important pest of potato (€500 million damage p.a. in EU)
- Two related species: *Globodera pallida*, *G. rostochiensis*
- Microscopic soil-borne eelworms





Conventional PCN control

Control:

- Nematicides
- Resistant potato cultivars
- Crop rotation

Effectiveness:

- Better control of *G. rostochiensis* than *G.pallida*

Result: *G.pallida* is becoming the major pest in Europe

Achilles heel of PCN

- PCN: specialist soil-borne pest
- Hatches in response to hatching factors (HFs) from host only

HFs:

- sesquiterpenoids
- glycoalkaloids (GCAs, present in tuber peel)

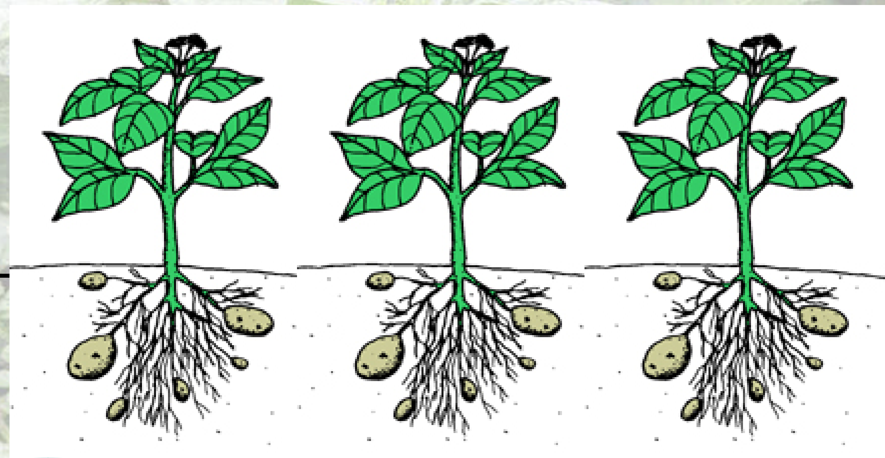
PCN control using induced hatch

HFs in absence of potatoes

Nematodes hatch

No food plant - die

HFs in presence of potatoes



Nematodes hatch early

\+ nematicide

More nematodes die

Evaluation of potato peel in PCN management

1. Does peel affect PCN?

2. Optimising the peel formulation

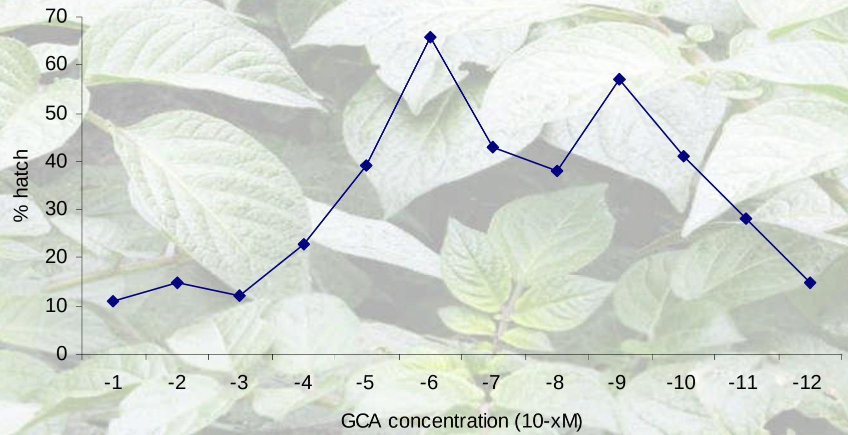
3.Ecotoxicology

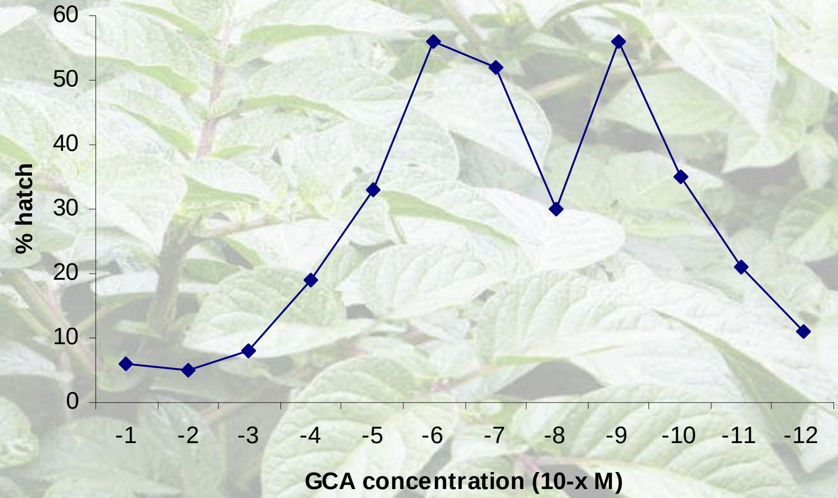
4.Field trials

1. **Does peel affect PCN survival?**

- *In vitro* hatch response of PCN to GCAs
- *In vivo* response of PCN to peel

In vitro hatch of *G. rostochiensis* (left) and *G. pallida* (right) in response to alpha-solanine





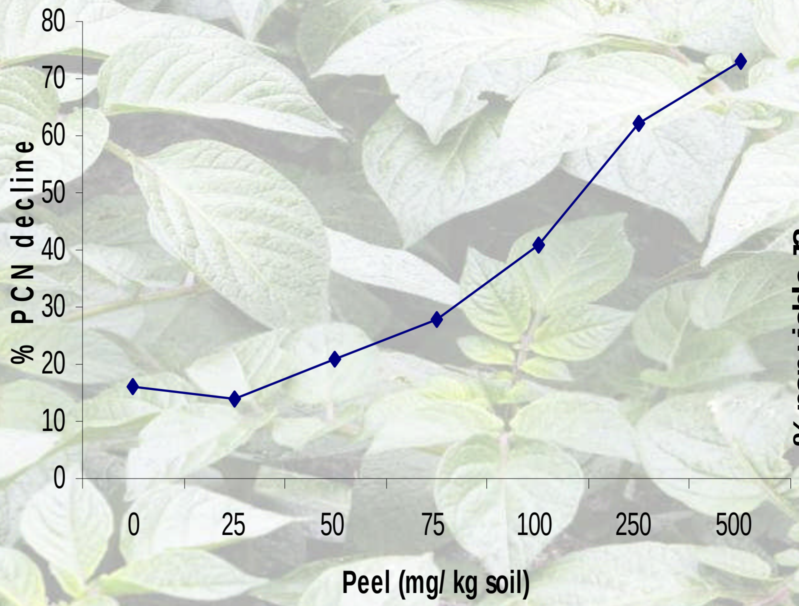
Main points:

• both PCN species produced bimodal hatch response to both major glycoalkaloids (solanine >chaconine)

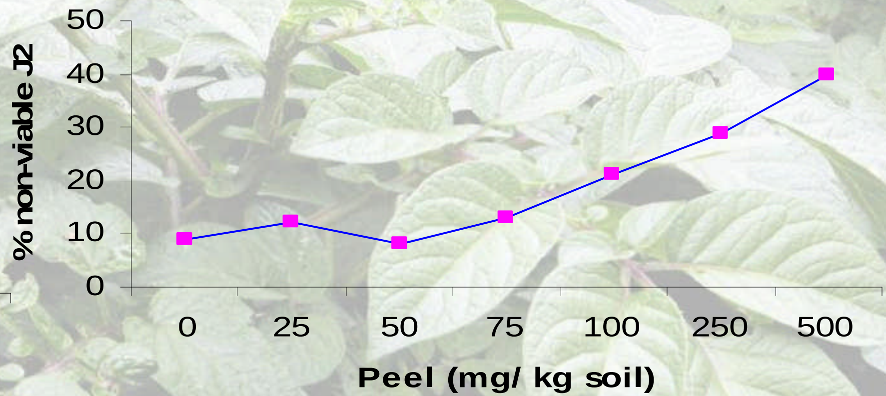
• *G. rostochiensis* responded better to GCAs than *G. pallida*

• Maximum hatch was 92% of that achieved by potato root leachate

In vivo effect of potato peel incorporation into soil on *Globodera rostochiensis* population



Hatch + parasitism



Parasitism

Hatching	Parasitism	Total control
59%	15%	74%

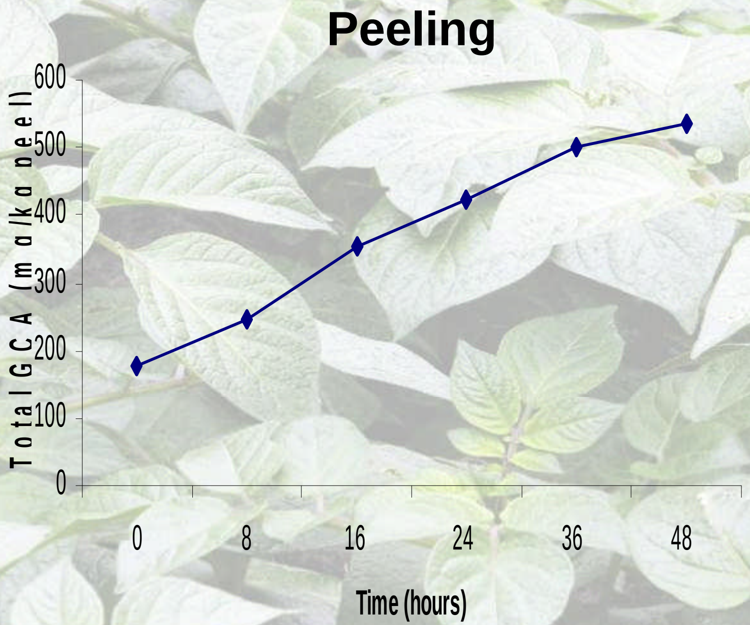
2. Optimisation of peel formulation

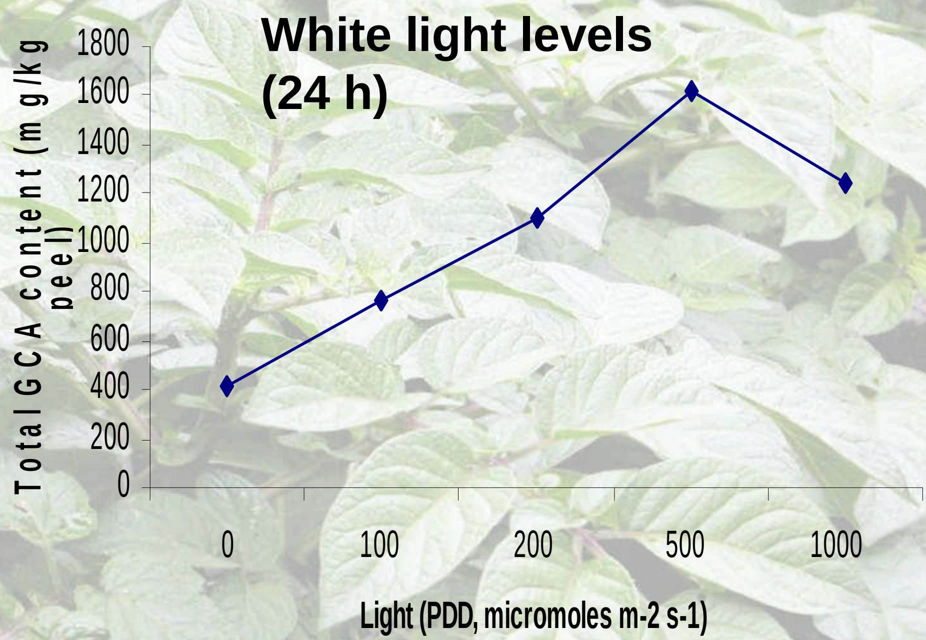
a. Maximise GCA content of peel

b. Optimise GCA release from peel

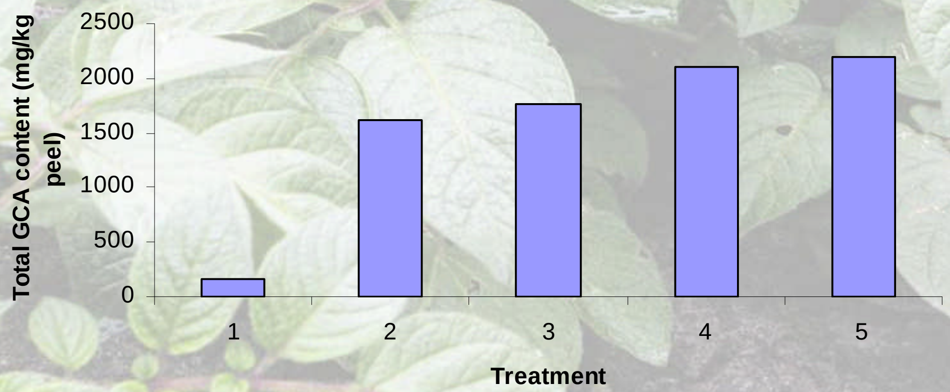
c. Optimise peel application method

a. Maximise GCA content of peel



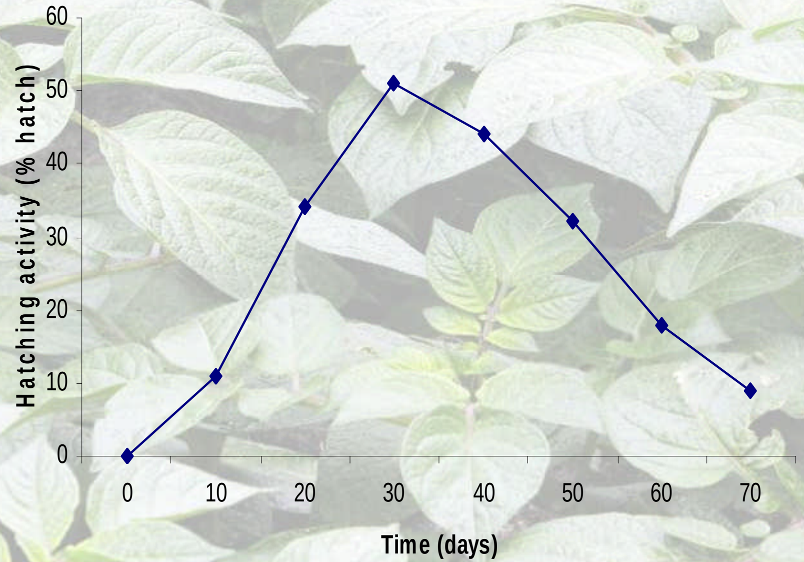


Light quality (24 h)

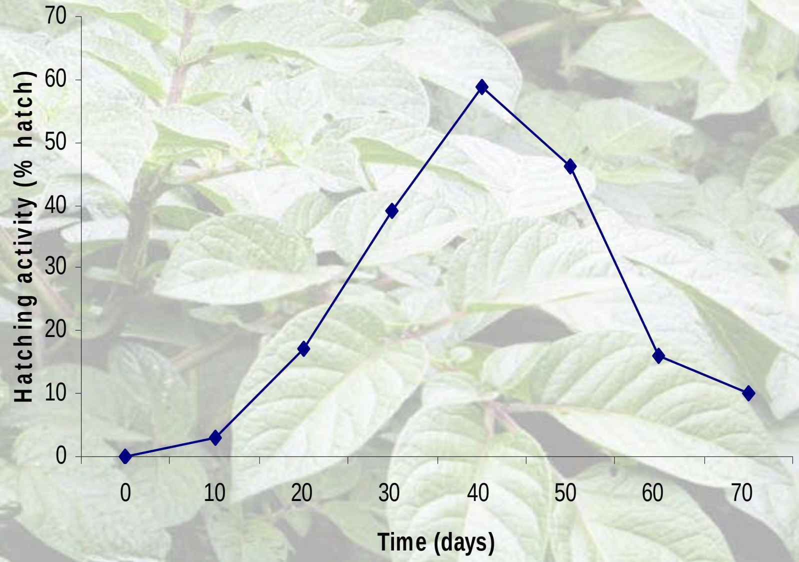


1. Dark
2. White light
3. Red light
4. Blue light
5. UVB light

b. Optimise GCA release from peel



Globodera rostochiensis

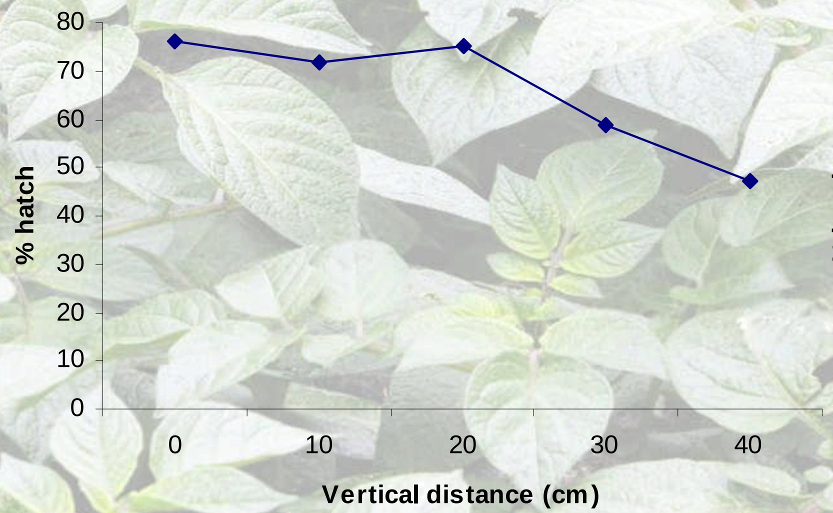


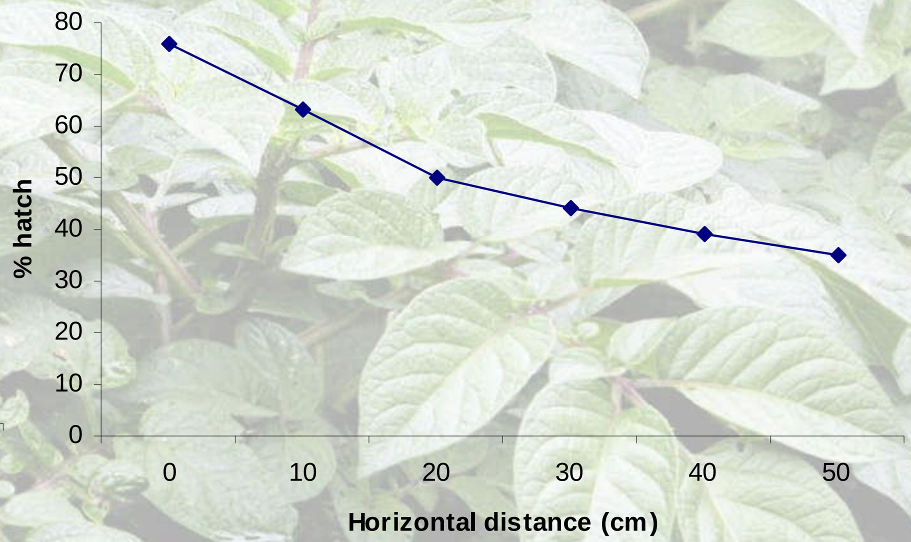
Globodera pallida

c. Optimise peel application method

- Aim: peel to be incorporated (0.5 t/ha) into planting furrow – inter-ridge distance is approximately 60-80 cm
- Needed – some mobility (>70% hatch at 30 cm horizontal, >70% hatch at 20 cm vertical) to ensure contact with most of PCN population
- Needed - not enough mobility to pose a threat to groundwater

In-soil movement of hatching activity from peel (after 2 weeks) at 12ºC





Greater vertical than horizontal mobility of hatching activity

72% hatch at 20 cm (vertical)

32% hatch at 30 cm (horizontal)

Similar behaviour in most soils, except organic soils (less movement). Similar response from both PCN species

In-soil mobility of % hatch from directed and broadcast application

	Directed	Broadcast
% hatch at 30 cm horizontal spread	32	53
% hatch at 20 cm vertical spread	72	77

Effect of encasement of pulverised peel in alginate beads on PCN hatch

- Produce alginate beads 2 mm diameter
- Mill to produce 1 and 0.5 mm diameter beads
- Smallest beads – more rapid disintegration
- Optimum size profile for maximum hatch:

  3 small: 4 medium: 1 large
- % hatch at 20 cm depth: 78%
- % hatch at 30 cm spread: 60%
- But: beads reduced parasitism of PCN

3. Ecotoxicology: effects of peel soil amendment on non-target organisms

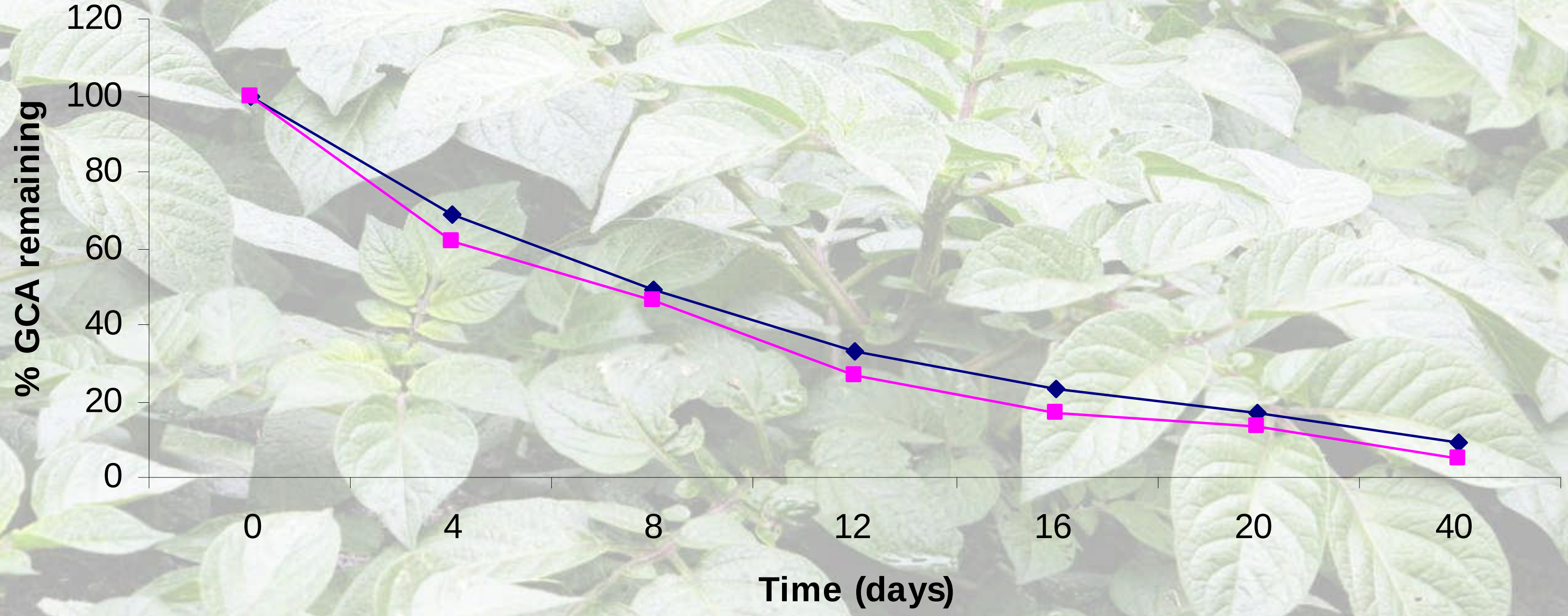
Behaviour of GCAs in soil:

- Persistence
- Mobility

Effect on non-target organisms:

- Crop plants
- Soil microbiota (bacteria, fungi)

Recovery of GCA from soil

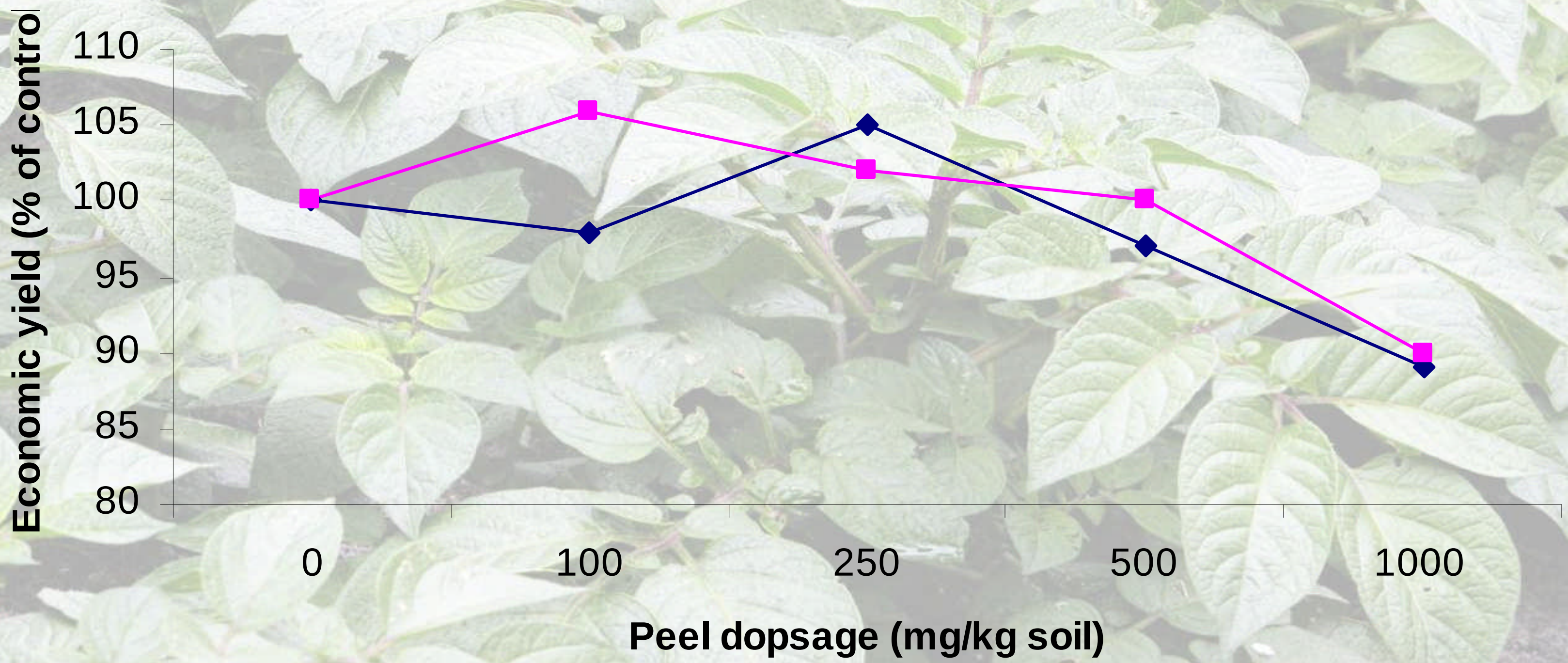


Red: alpha-solanine **Blue**: alpha-chaconine

GCA half-life

- Very short: 6.2 days for solanine, 7.7 days for chaconine at $12^{o}C$
- **Causes of loss**:
  - microbial degradation
  - irreversible binding to soil particles
- **Effect of soil type**
  - shortest half-life on organic soils

Effects of peel on economic yield of barley (blue) and oilseed rape (red)

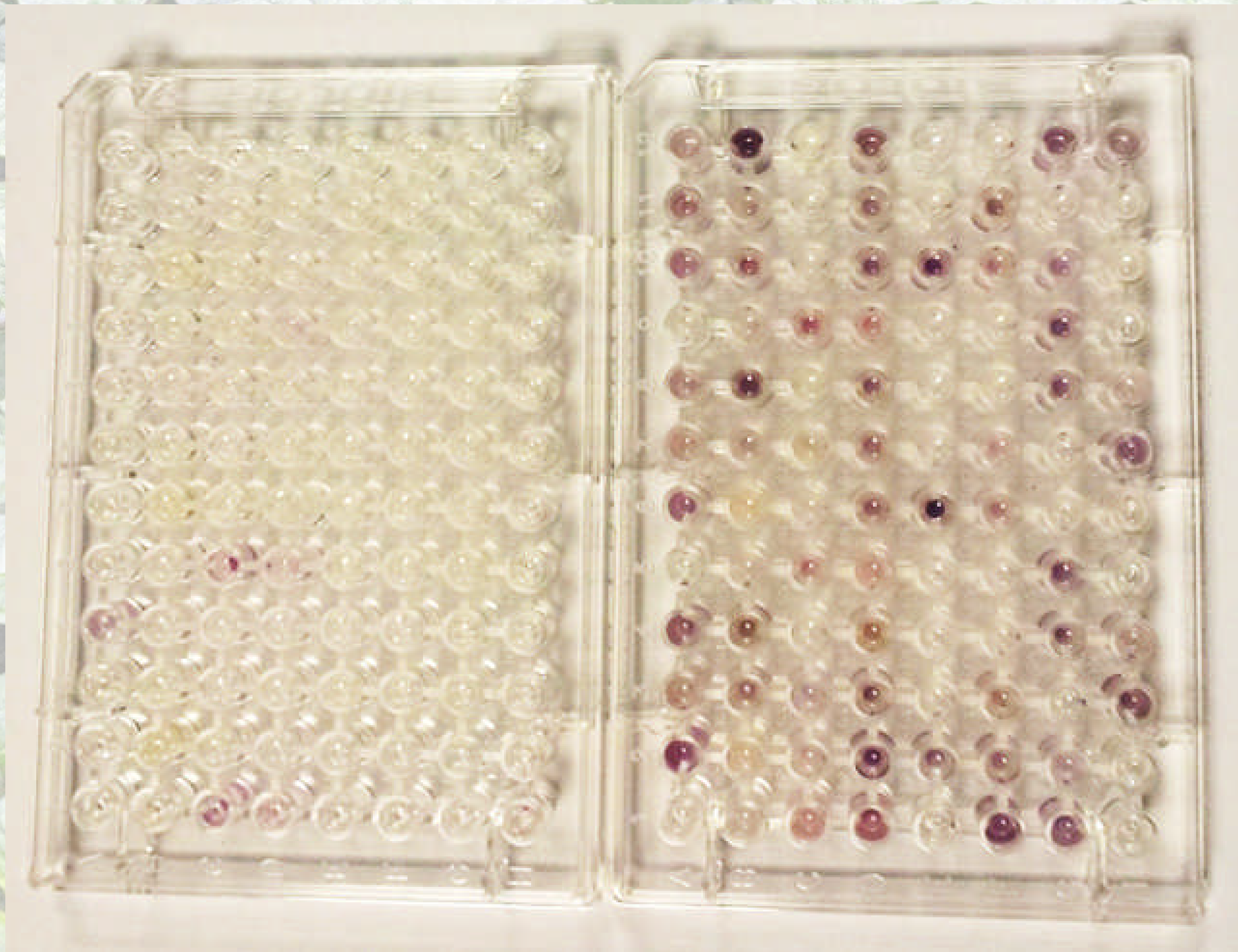


Effects on soil microbiota

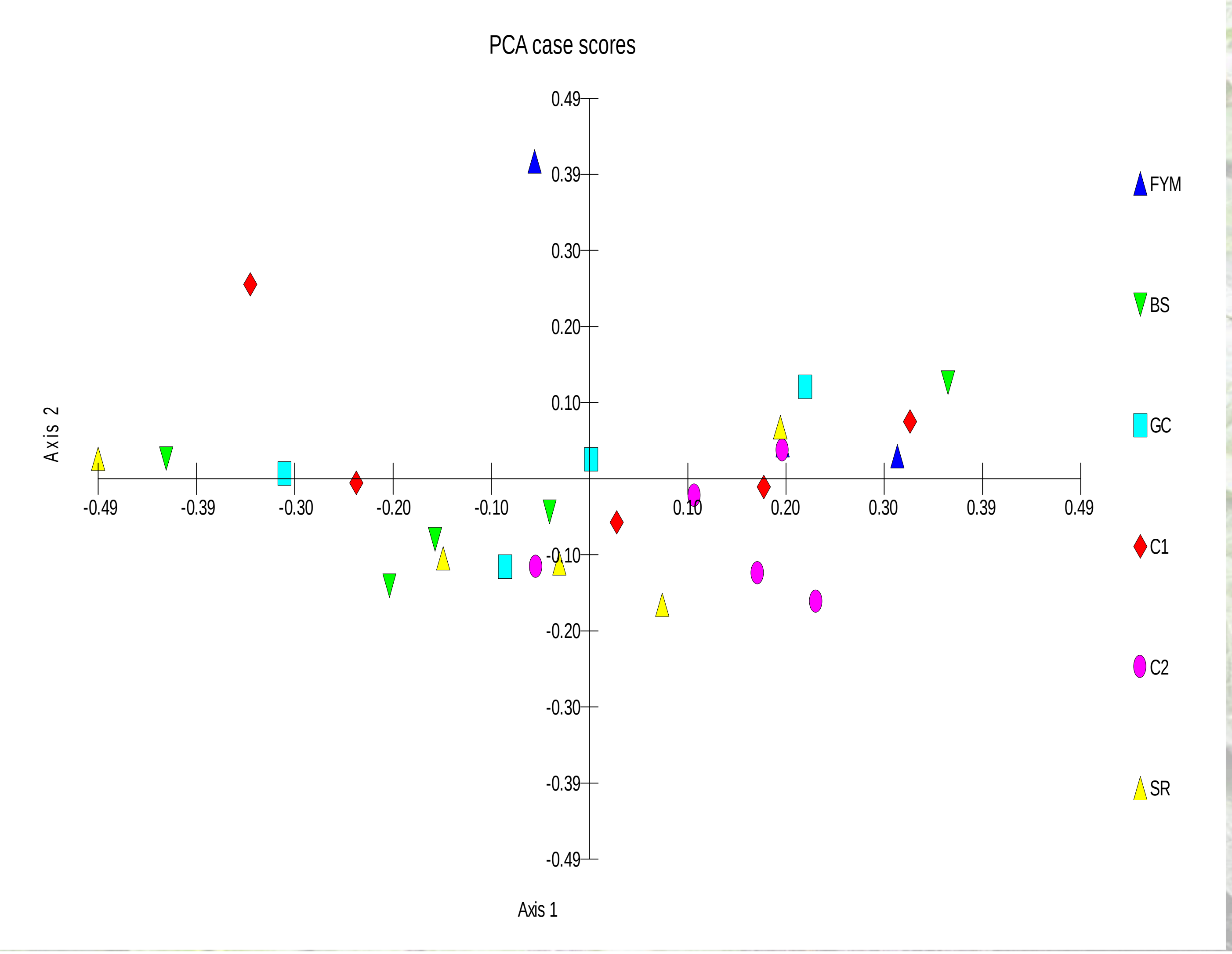
Soil containing peel compared to soil:

- 1.8-fold increase in bacteria (Biolog plate)
- 1.4-fold increase in fungi (ergosterol)
- Quantitative increase in bacterial biodiversity (up to 500 mg peel/kg soil)
- No qualitative change in bacterial functional biodiversity (up to 250 mg peel/kg soil)

Biolog plate system: Community Level Physiological Profiling



Principal component analysis of bacterial diversity in absence (green triangles) and presence of different rates of peel



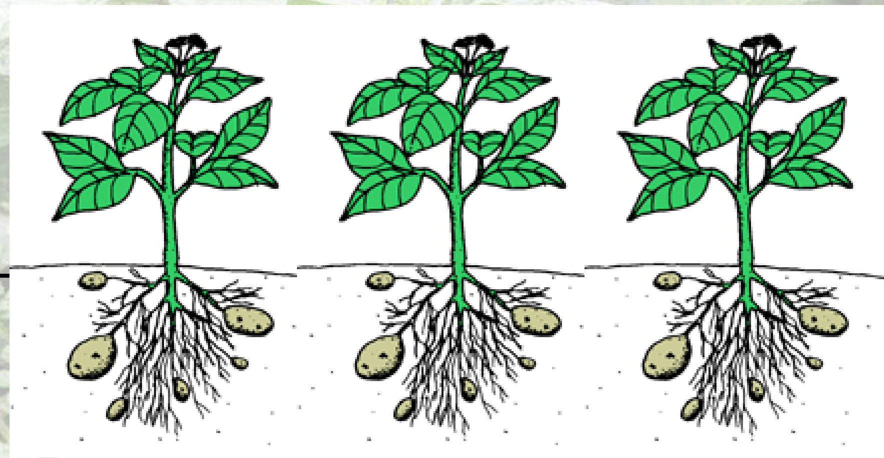
PCN control using induced hatch

HFs in absence of potatoes

Nematodes hatch

No food plant - die

HFs in presence of potatoes



Nematodes hatch early

+ nematicide

More nematodes die

Field trial results: effect of peel on reduction in PCN population in absence of potato

	Control (% reduction in population size)	Plus peel (% reduction in population size)
G. rostochiensis	17 b	73 b
G. pallida	8 a	59 a

Any two samples with a common letter are not significantly different (P>0.05)

Field trial results: effect of peel on nematicidal control of multiplication of PCN in presence of potato

	Control (PCN, potato, no peel, no nematicide)	Treatment 1 (PCN, potato, nematicide)	Treatment 2 (PCN, potato, peel, nematicide)
G.rostochiensis	4.7 d	0.3 ab	0.2 a
G.pallida	4.3 d	1.5 c	0.8 b

Any two samples with a common letter are not significantly different (P>0.05)

Conclusions

- Application of peel to *G.pallida*-infested soil in the absence of a potato crop could shorten the crop rotation period for potato farmers
- Application of peel to *G.pallida*-infested soil in the presence of a potato crop increased the effectiveness of the nematicide oxamyl in controlling PCN

Further research

- Further optimisation needed
- Lower peel dosage rates needed (currently 1 t/ha)

UCC
Coláiste na hOllscoile Corcaigh, Éire
University College Cork, Ireland

BEES
School of Biological, Earth & Environmental Sciences at University College Cork, Ireland

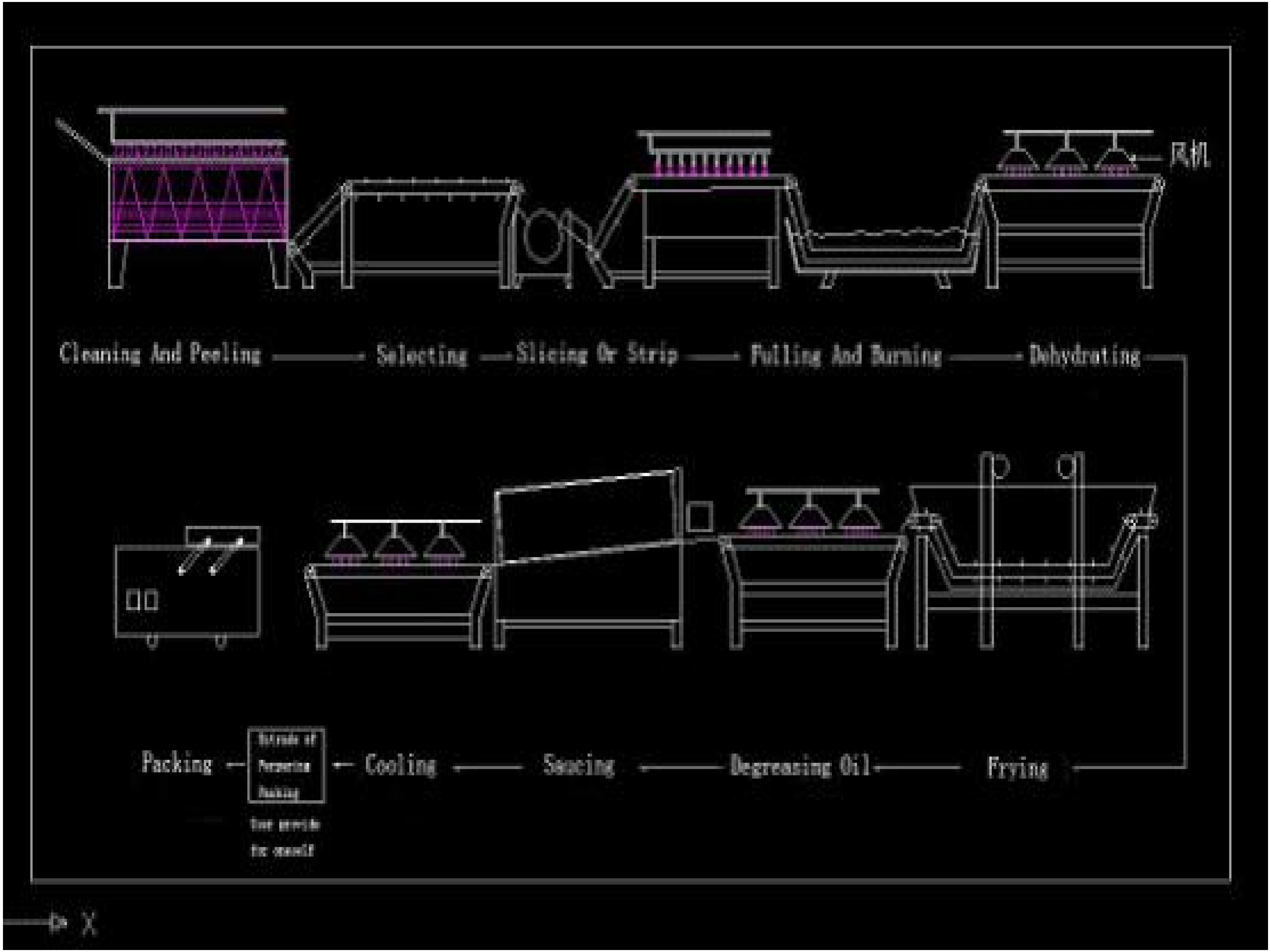
Reducing, re-using and re-cycling waste from a potato processing plant: a desk study

Peter Jones,

School of Biological, Earth and Environmental Sciences, UCC

Crisp manufacture

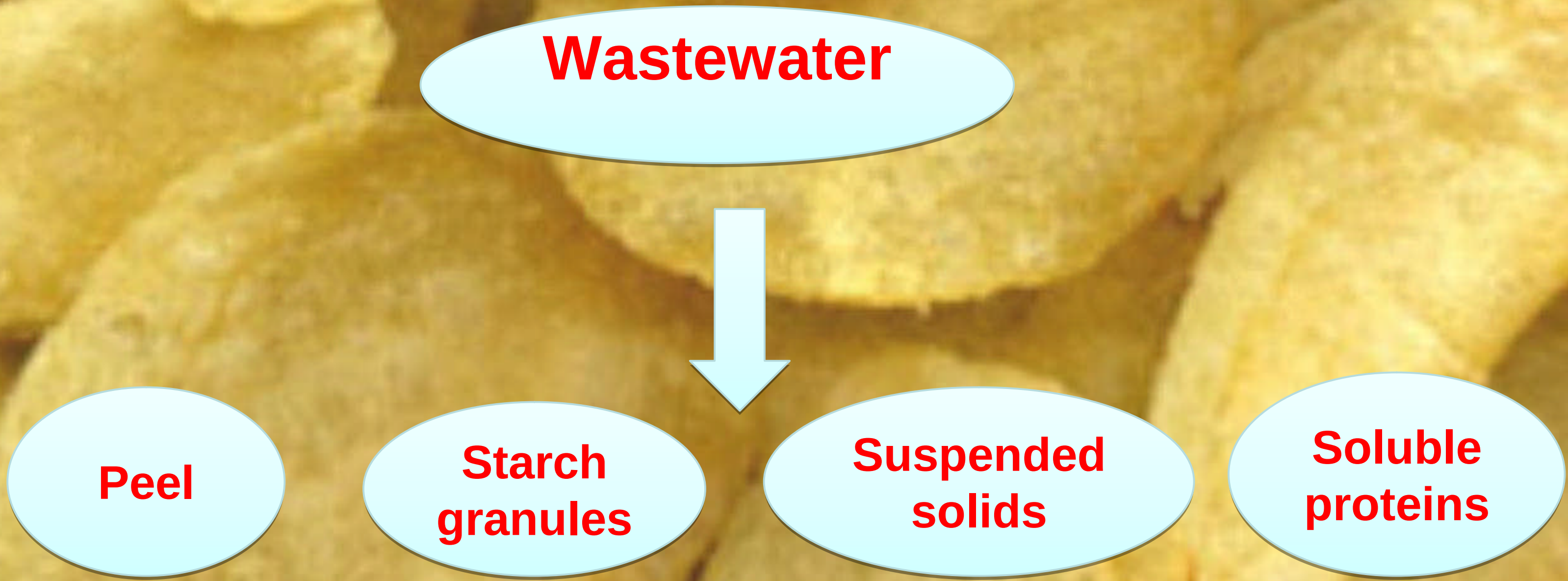
- Highly integrated, automated process
- Several waste streams: peel, wastewater (starch, protein)
- Heavy use of water, power


风机
Cleaning And Peeling
Selecting
Slicing Or Strip
Pulling And Burning
Dehydrating
Packing
Cooling
Saucing
Degreasing Oil
Frying

Crisp manufacture: annual requirements (moderate scale operation)

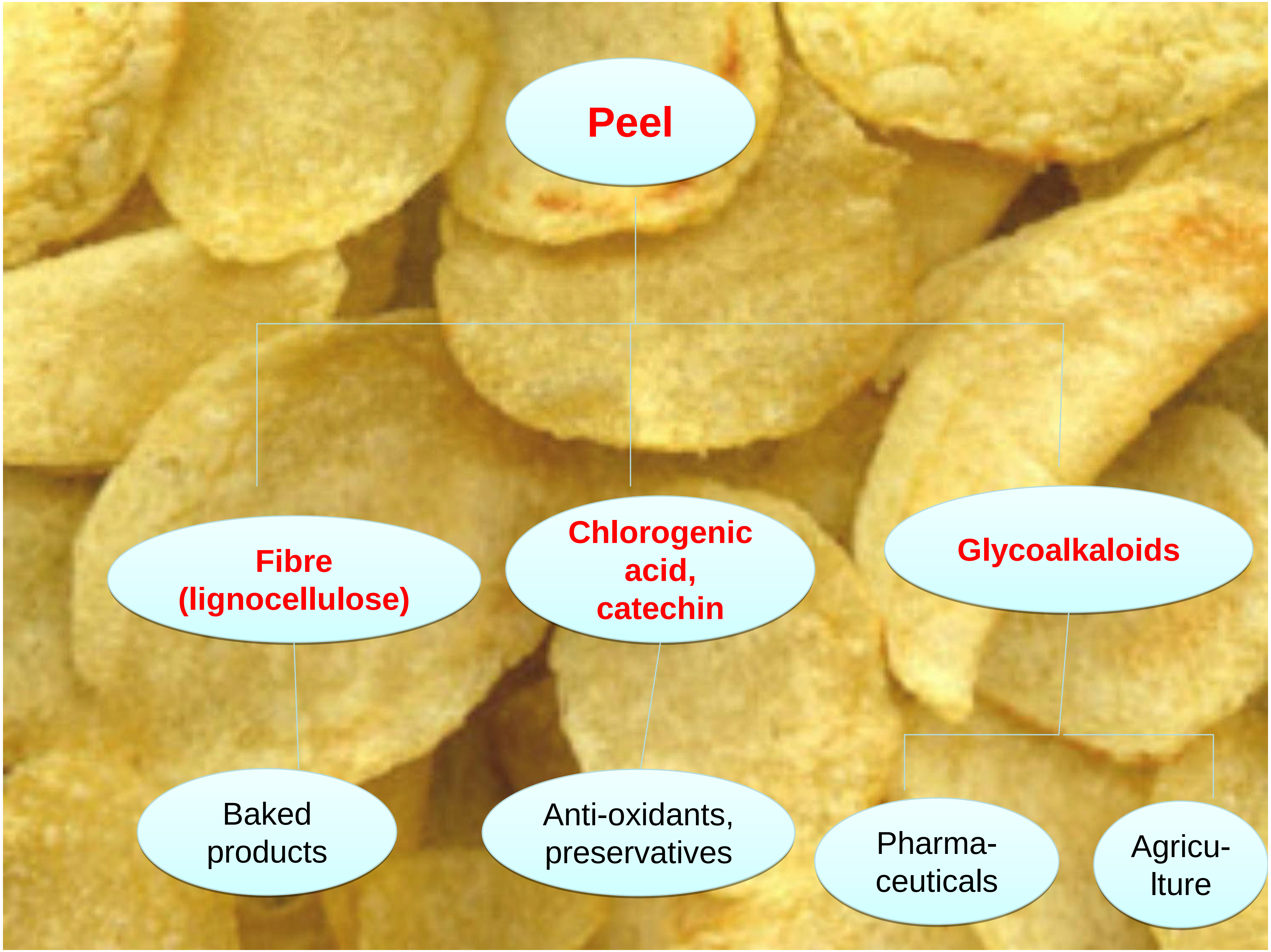
- 20,000 t potatoes
- 90,000 m^3 water
- 2 M kW energy (processing: heating, etc.; plant maintenance)

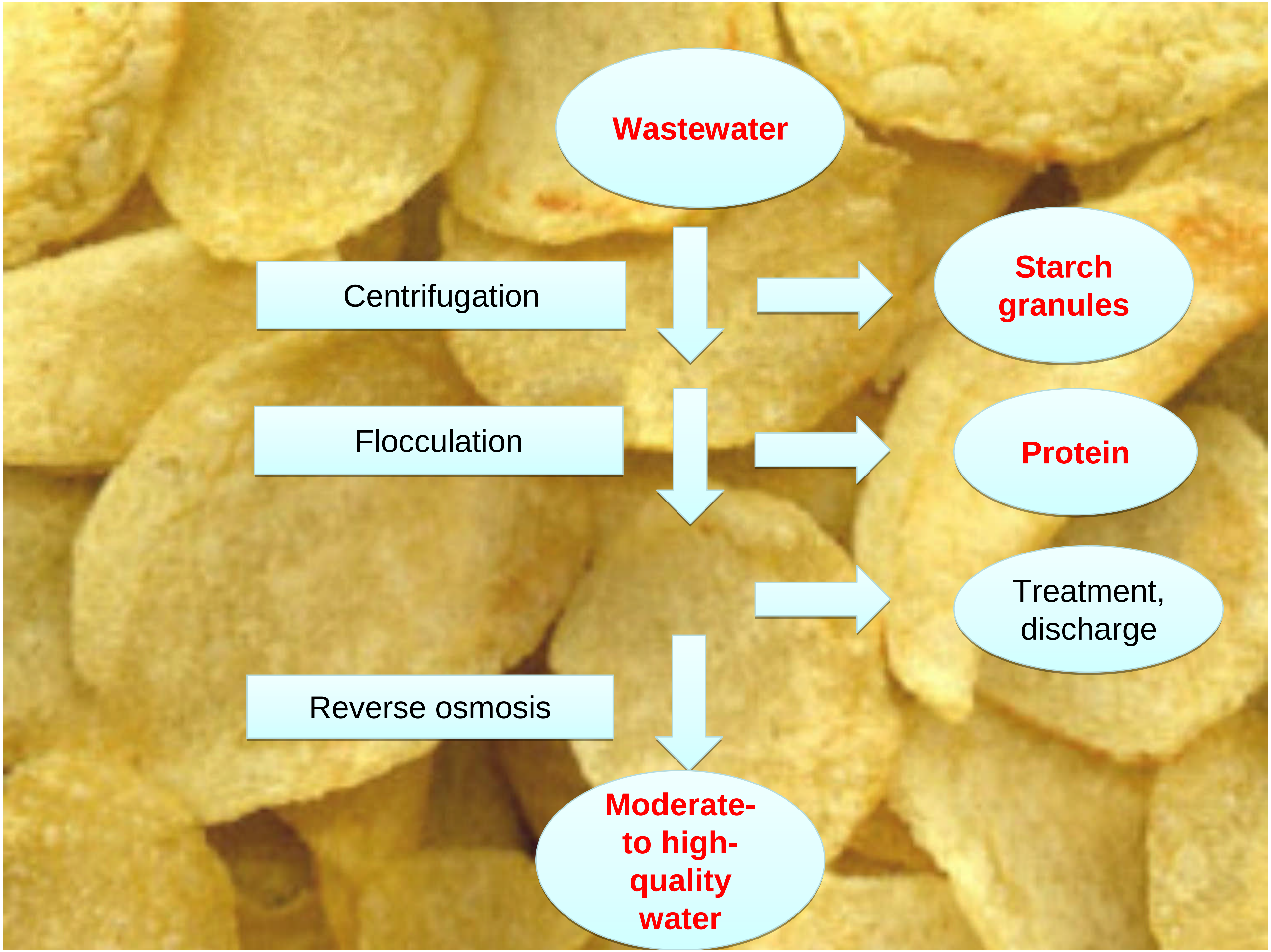
Crisp manufacture: waste streams



Crisp manufacture: peel waste stream

- Collect peel by settling
- Microbial spoilage is rapid, high water content.
- Collected for use in stockfeed (8% protein – can constitute 5-15% feed ration)
- Reduce water content by 40% using screw press


Peel
Fibre (lignocellulose)
Chlorogenic acid, catechin
Glycoalkaloids
Baked products
Anti-oxidants, preservatives
Pharma-ceuticals
Agricu-lture


Wastewater
Centrifugation
Starch granules
Flocculation
Protein
Treatment, discharge
Reverse osmosis
Moderate- to high-quality water

Uses of products from wastewater

- **Starch**: on-site – biofuel, soil amendment; off-site – biodegradable plastics, lactic acid, etc.
- **Protein**: high quantity (30%), quality – use as stockfeed supplement

Biofuel from waste streams

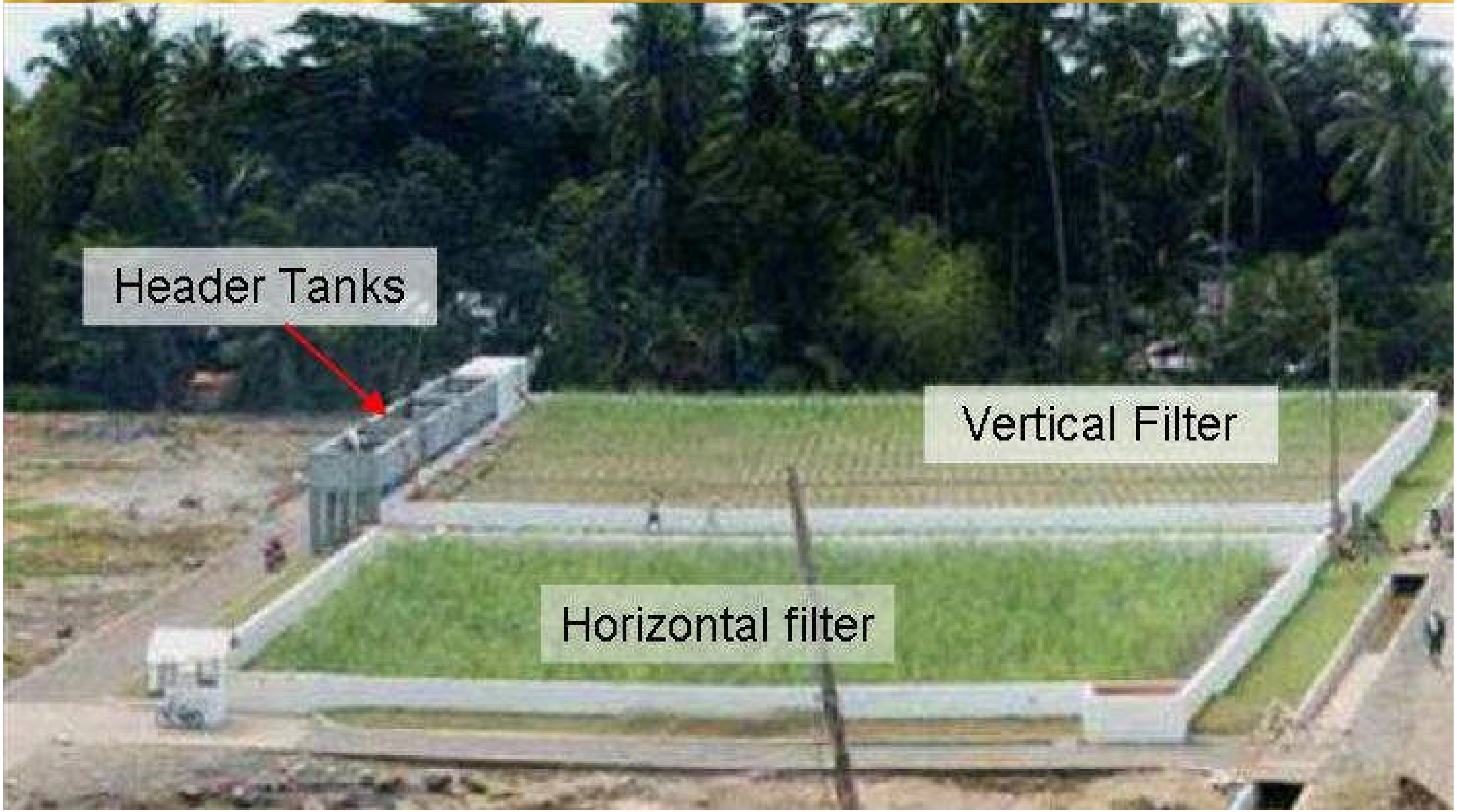
hydrolysis fermentation

- **Starch** → sugars → **bioethanol**

esterification

- **Waste cooking oil → biodiesel**

Wastewater treatment using hybrid vertical-horizontal flow sub-surface flow constructed wetlands

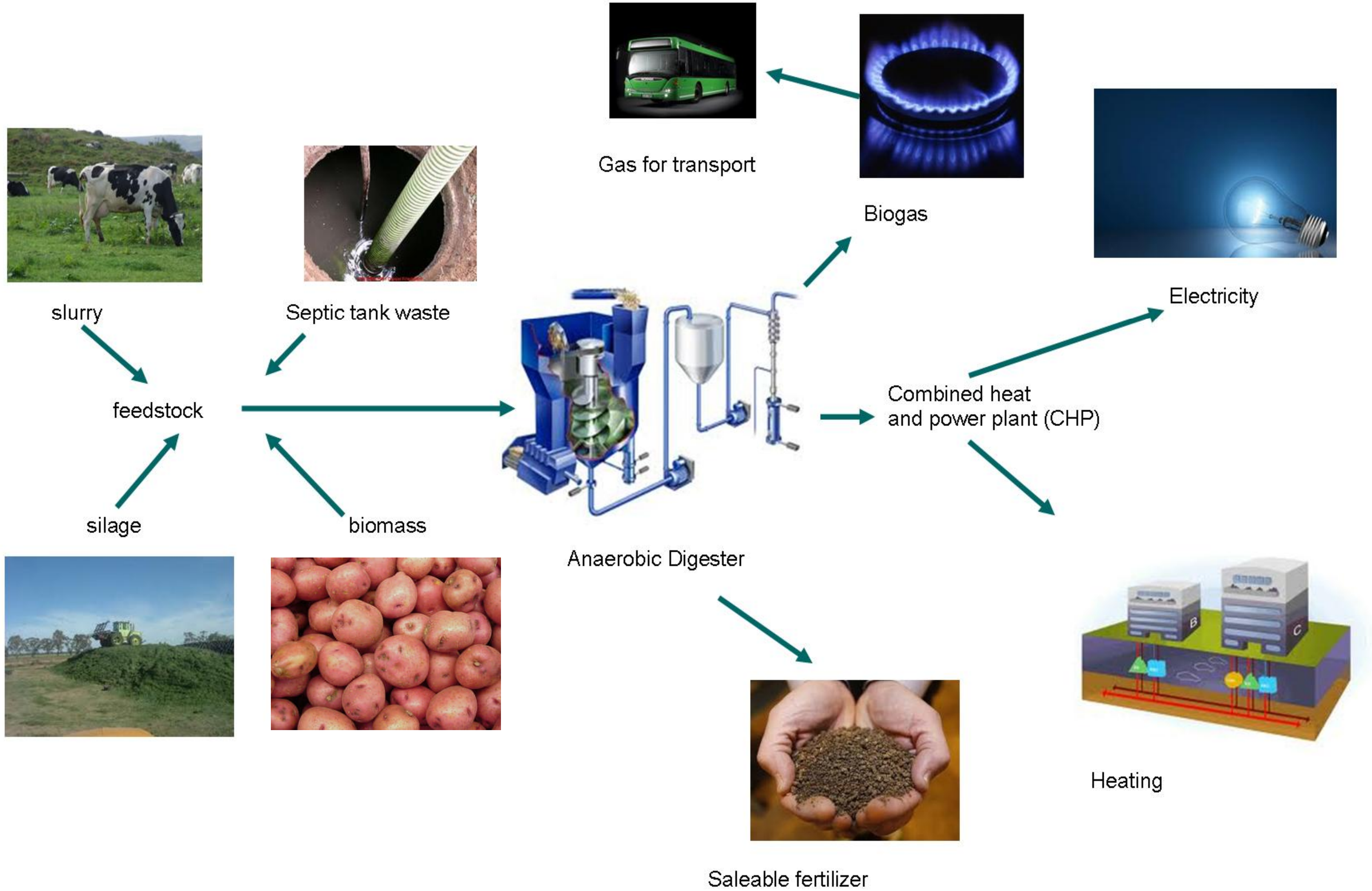


Composting of potato waste

- Aerobic → compost (soil amendment; garden product, €1-300/ tonne)
- Anaerobic → biogas + digestate

Biogas by anaerobic digestion

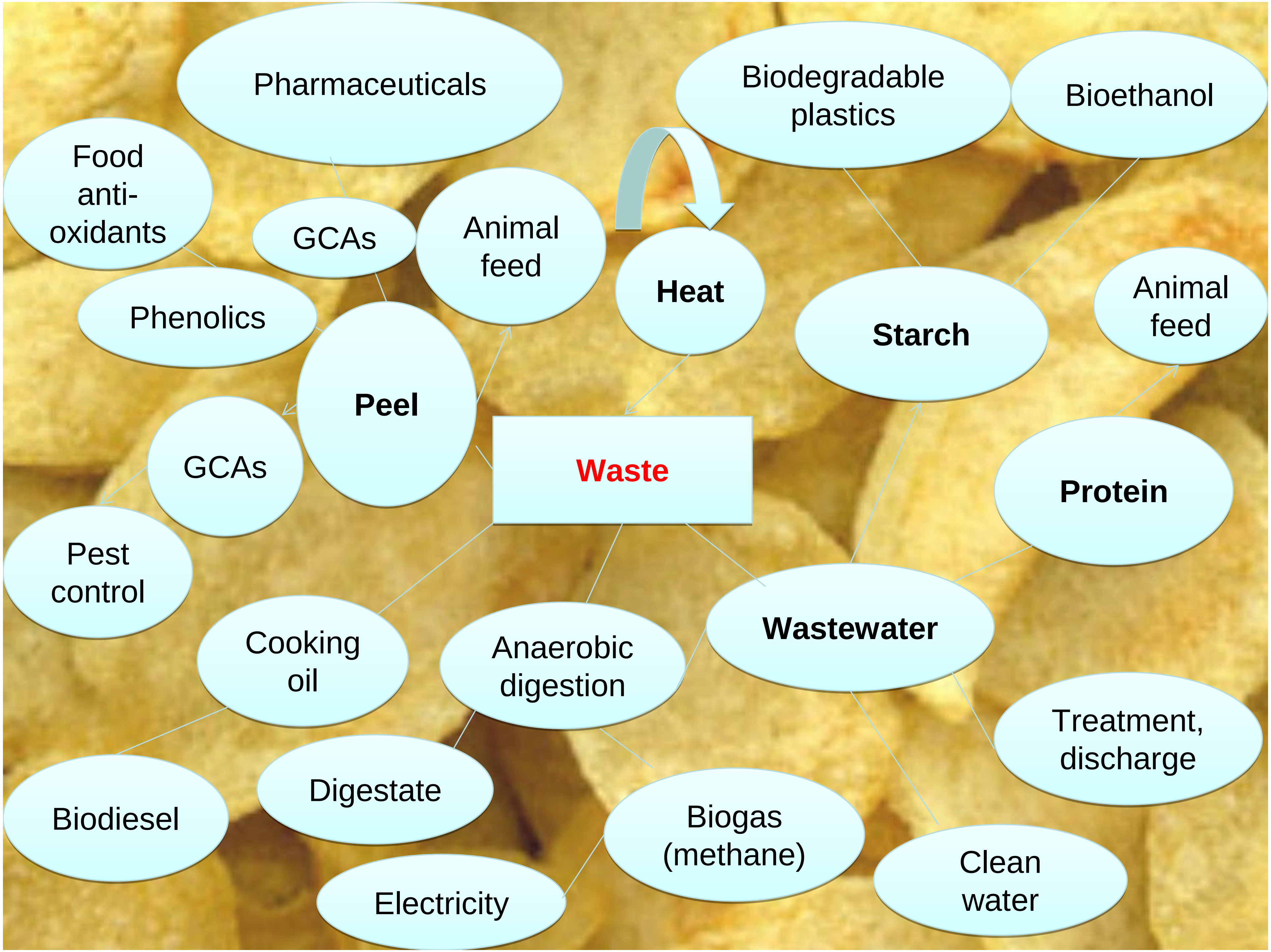
- Small- to large-scale sealed tanks
- **Services**: waste disposal and biogas production
- **Products**: biogas (methane) and digestate (fertiliser, biostimulant, peat-free compost)
- Biogas from potato waste: potential for generation of 25% of the electricity requirement of the processing plants



Gas for transport
Biogas
Electricity
slurry
Septic tank waste
feedstock
Combined heat
and power plant (CHP)
silage
biomass
Anaerobic Digester
Heating
Saleable fertilizer

Additional opportunities for large-scale operations

- **Starch**: for manufacture of biodegradable crisp packets
- **Heat**: captured using heat exchangers
- **Water**: recovered by condensor pipesfrom steam released during frying



Pharmaceuticals
Biodegradable plastics
Bioethanol
Food anti-oxidants
GCAs
Animal feed
Heat
Phenolics
Starch
Animal feed
Peel
GCAs
Waste
Protein
Pest control
Cooking oil
Anaerobic digestion
Wastewater
Treatment, discharge
Biodiesel
Digestate
Biogas (methane)
Clean water
Electricity

Biorefinery model

- Environmentally protective and economically viable
- Bottom-up: expansion of existing facility
- Top-down: design of purpose-built facility

Conclusions

Significant opportunities for:

- Reducing waste disposal
- More sustainable use of resources, e.g. water
- Reduced costs (electricity, water)
- Generation of additional income streams from waste