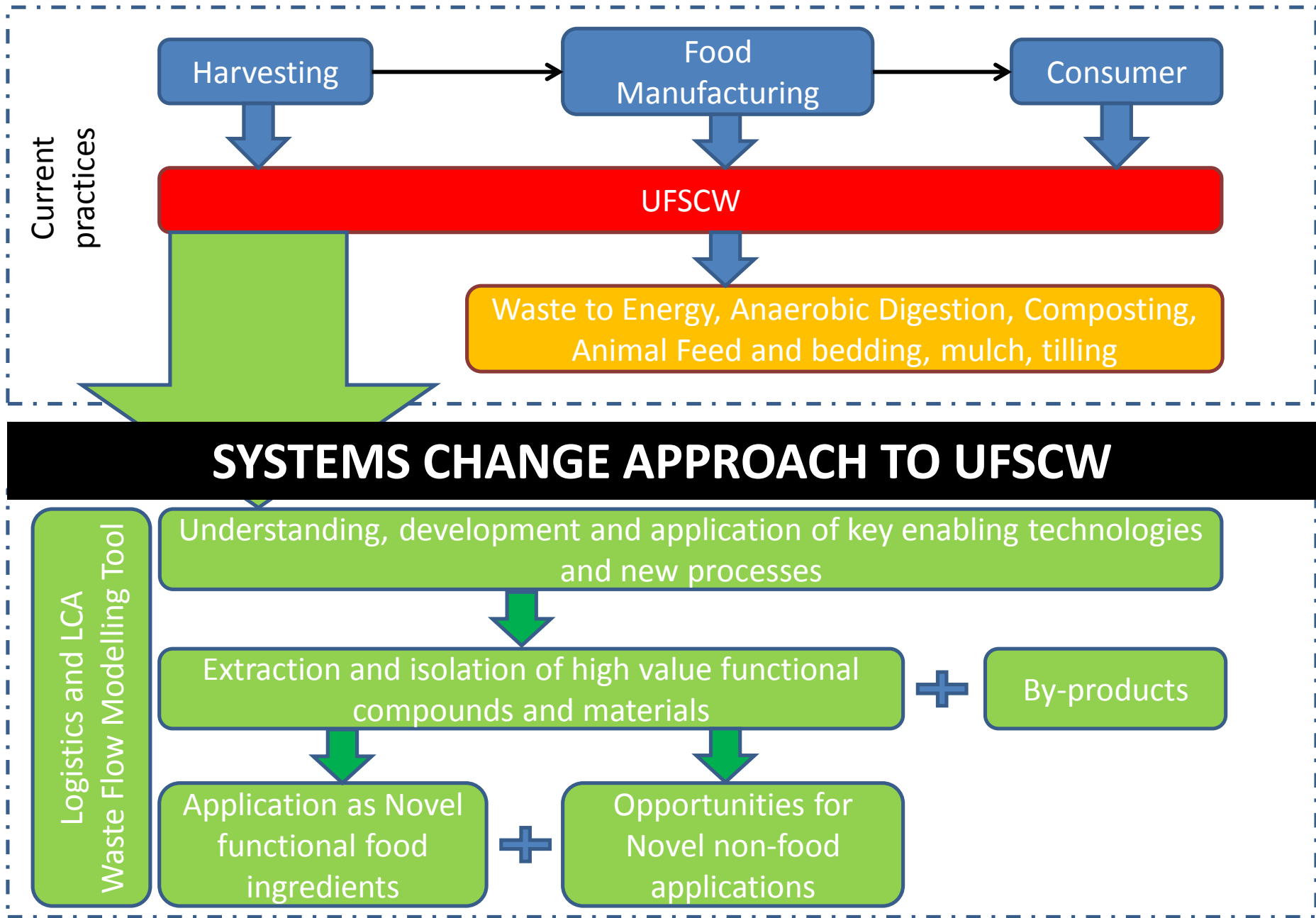


# Squeezing more than just orange juice: Citrus peel valorisation

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Deputy Director  
Green Chemistry Centre of Excellence  
University of York  
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Whole systems understanding of unavoidable food supply chain waste for re-nutrition

EP/P008771/1

# Upgrading unavoidable food supply Chain Wastes

**“it’s a no brainer”**

**“please respect the intelligence of the entire supply chain”**

**Business, social and environmental case for upgrading**

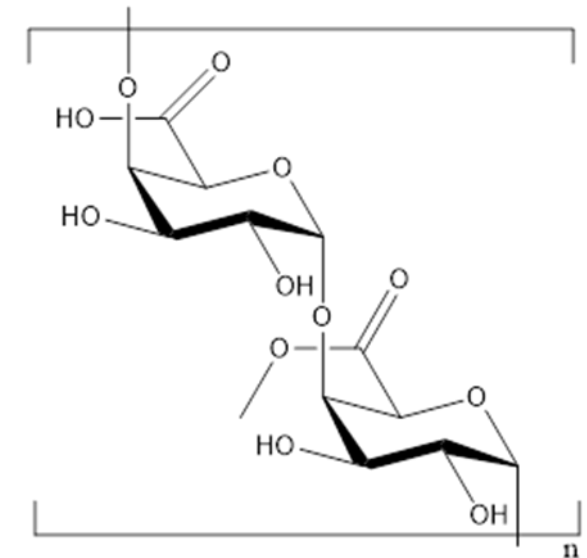
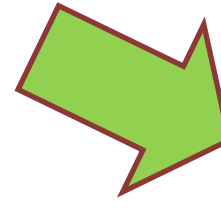
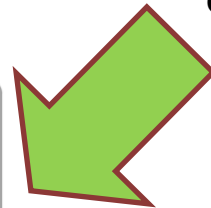
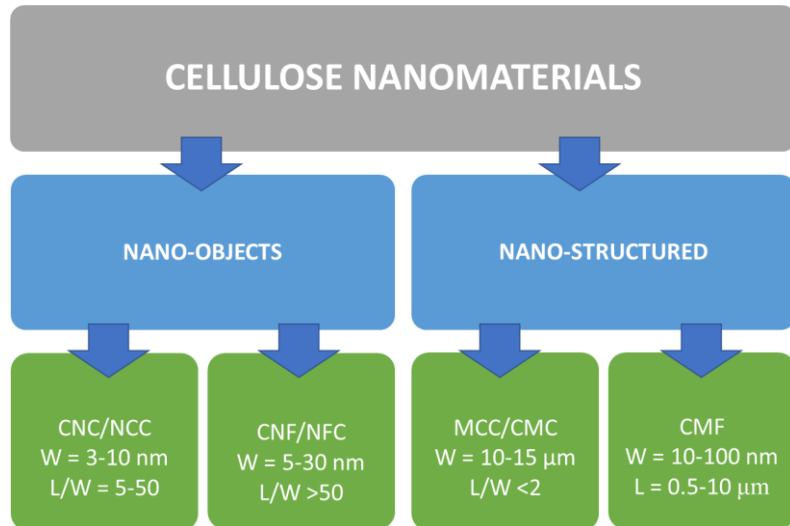
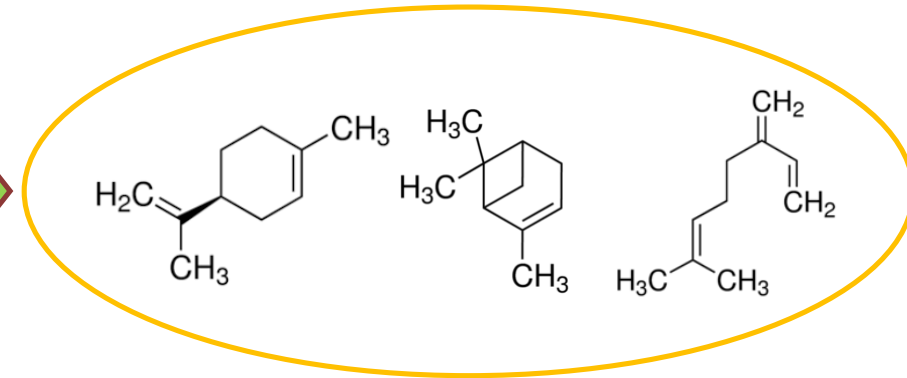
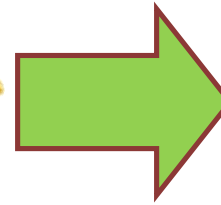
# Squeezing more than just orange juice: Citrus peel valorisation



33.2 million T/y

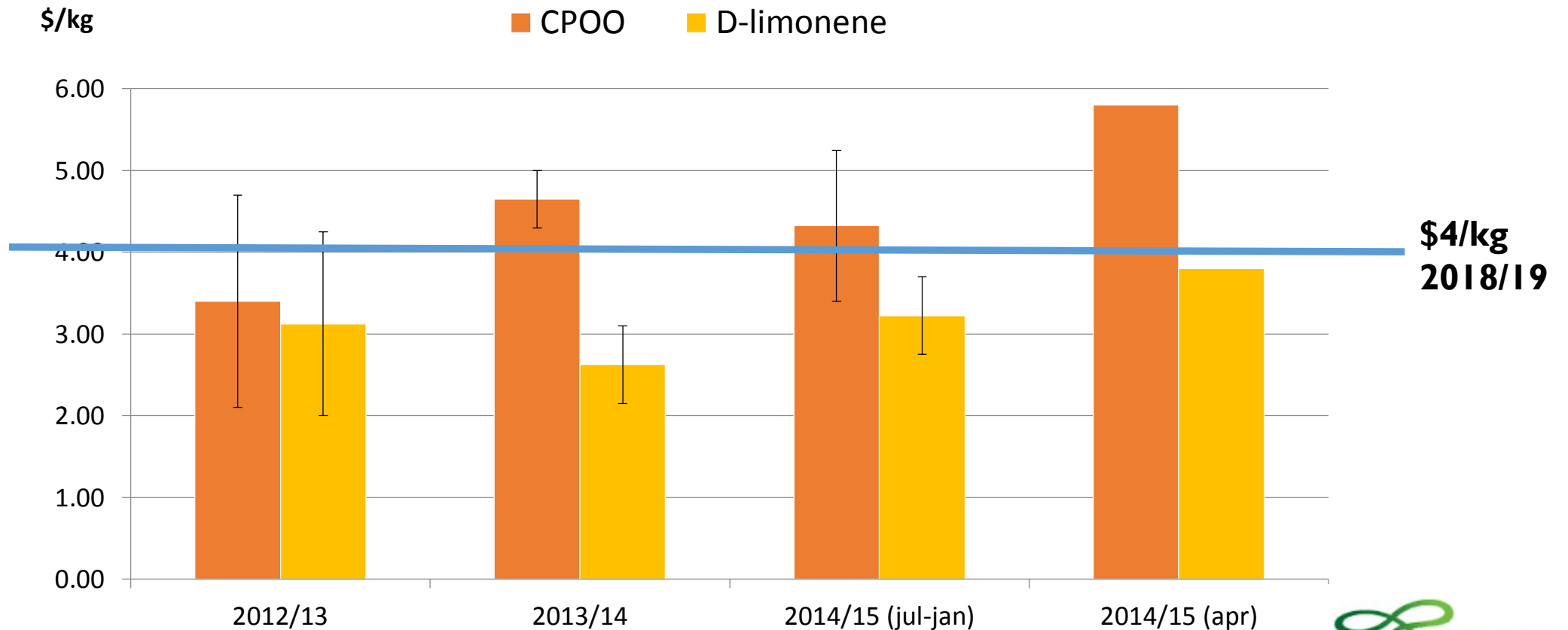


16.6 million T/y  
citrus peel waste



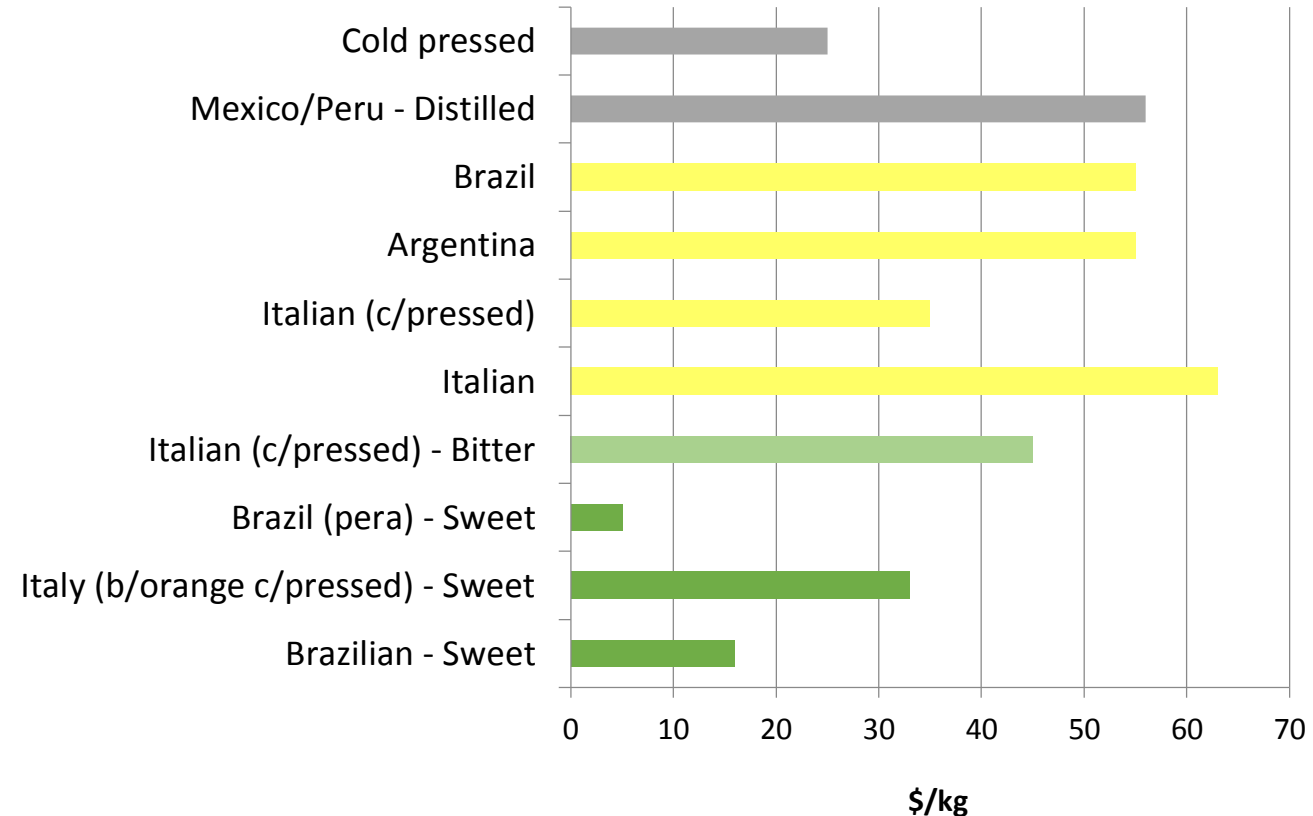
# Squeezing more than just orange juice: Citrus peel valorisation

## Essential oil (oranges)



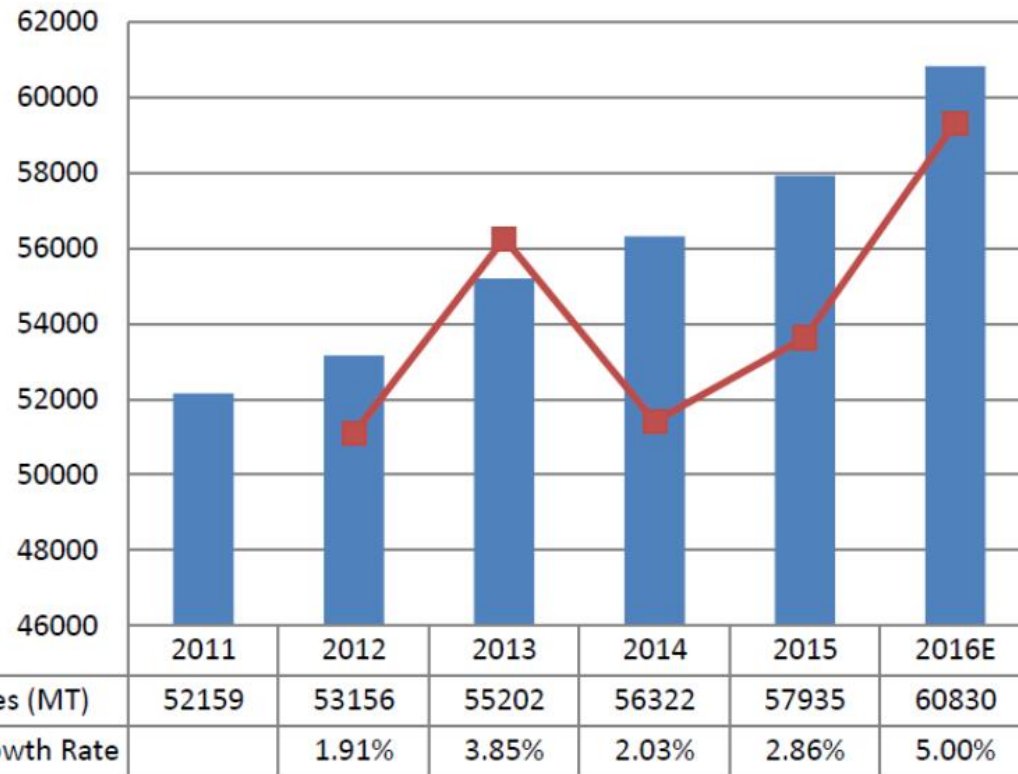
# Squeezing more than just orange juice: Citrus peel valorisation

Choose your feedstock carefully!

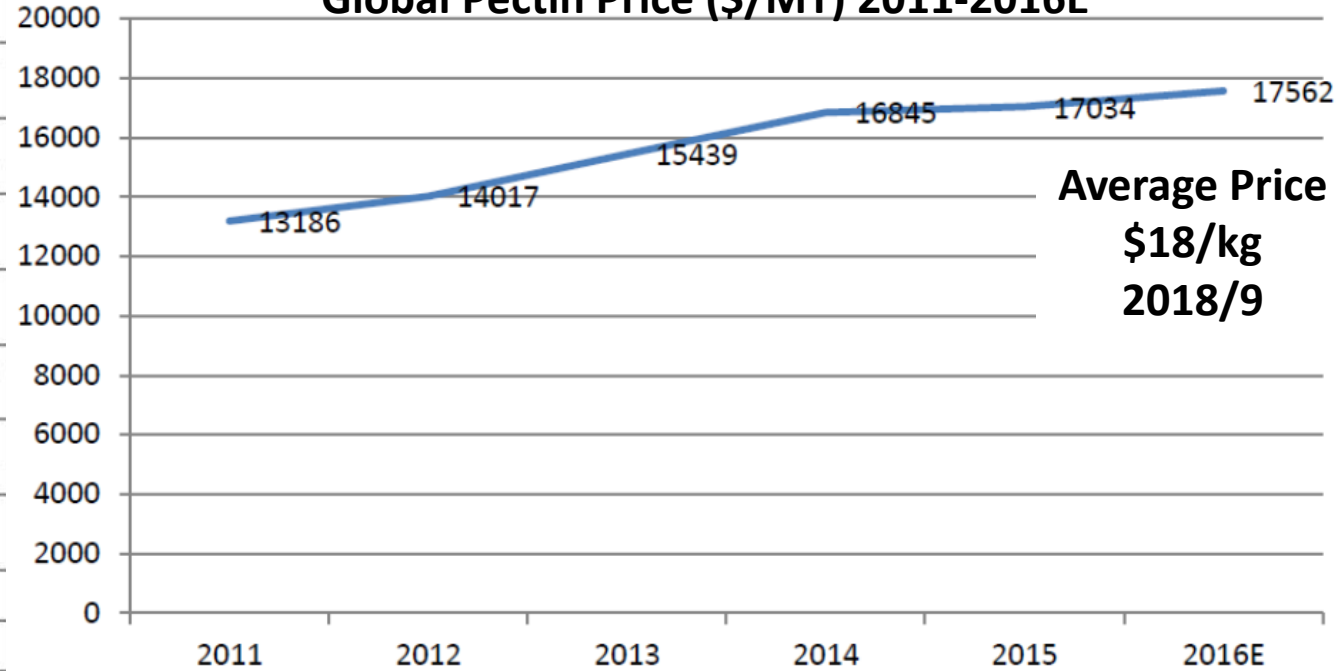


# Squeezing more than just orange juice: Citrus peel valorisation

## Global Pectin sales and Growth (2011-2016E)

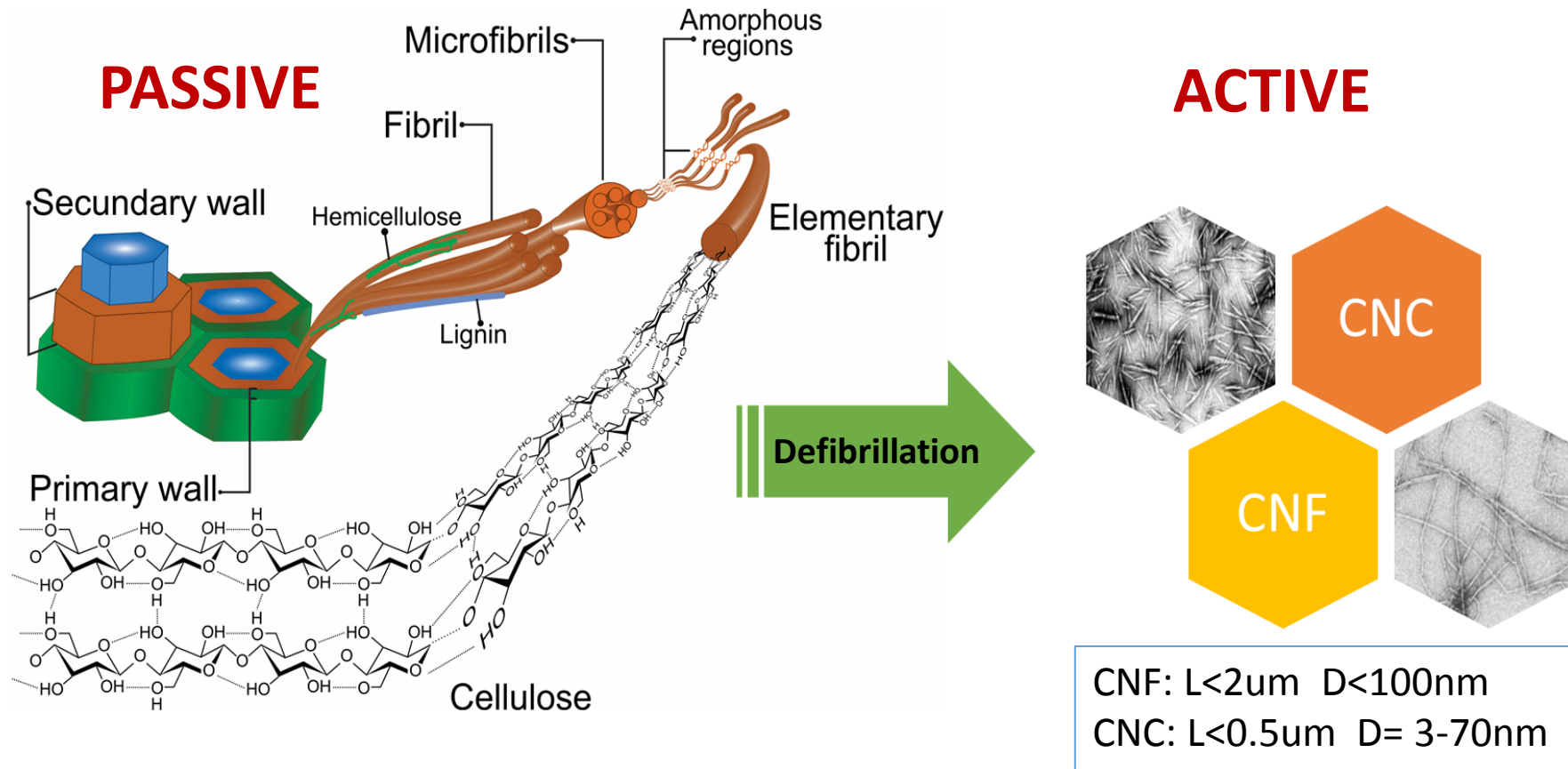


## High methoxyl (HM) pectin Global Pectin Price (\$/MT) 2011-2016E



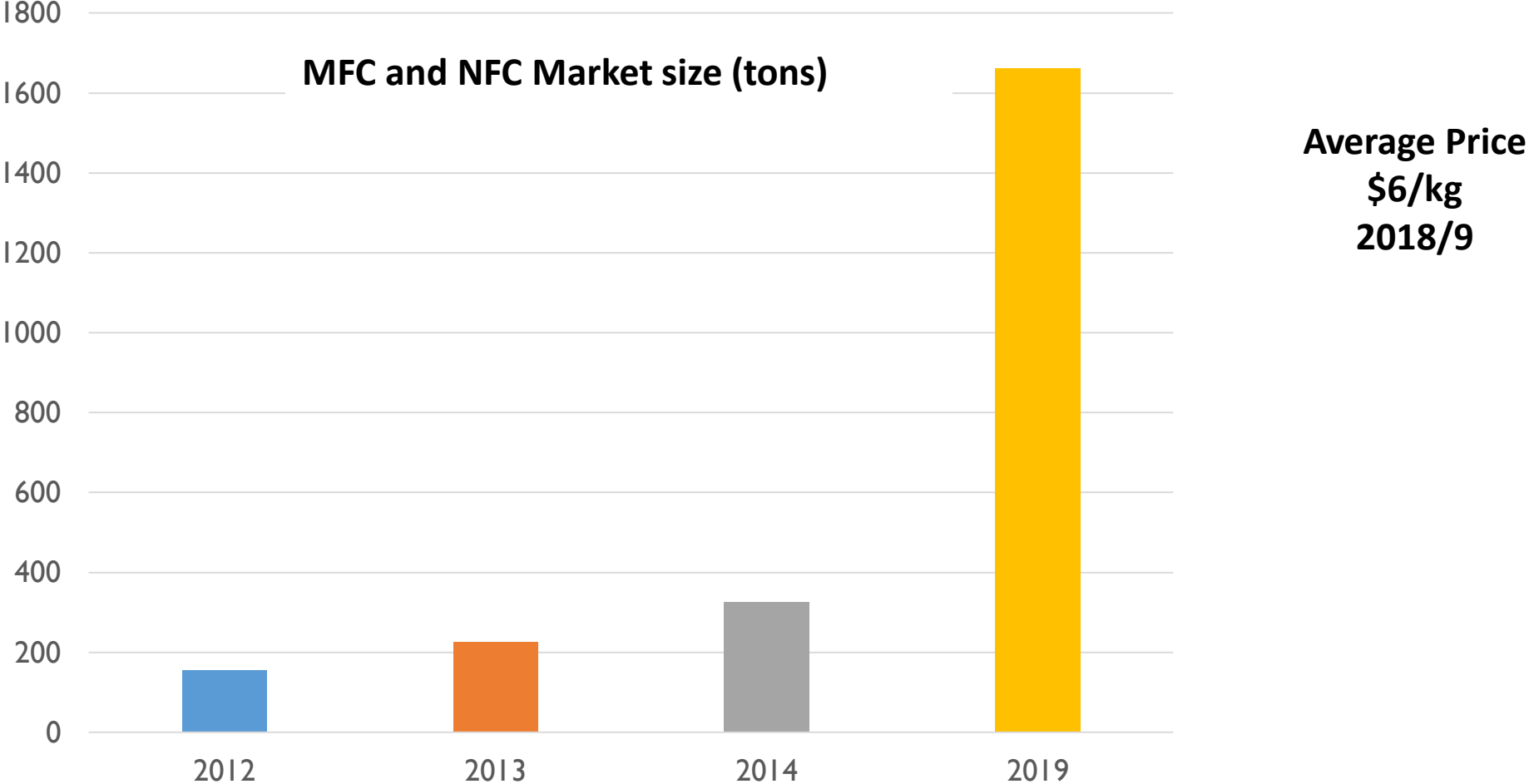
# Squeezing more than just orange juice: Citrus peel valorisation

.....and there's (nano)cellulosic residues





# Squeezing more than just orange juice: Citrus peel valorisation



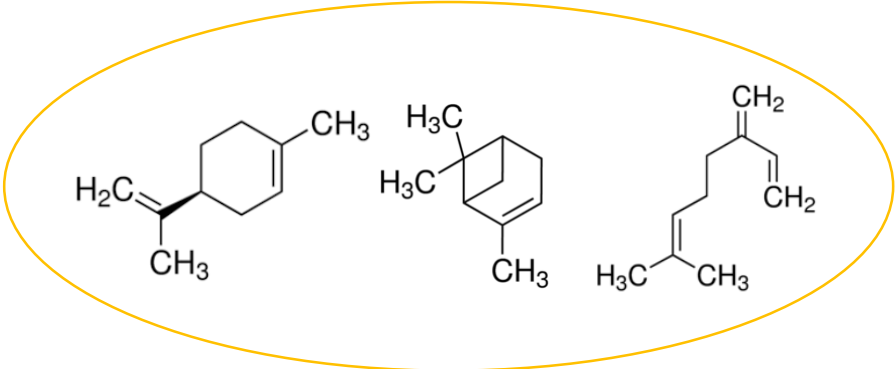
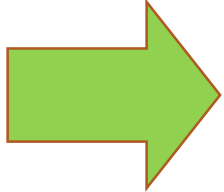
# Squeezing more than just orange juice: Citrus peel valorisation



33.2 million T/y



16.6 million T/y  
citrus peel waste



\$4/kg

CELLULOSE NANOMATERIALS

NANO-OBJECTS

NANO-STRUCTURED

CNC/NCC  
W = 3-10 nm  
L/W = 5-50

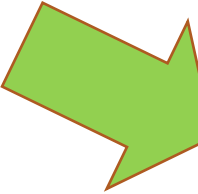
CNF/NFC  
W = 5-30 nm  
L/W >50

MCC/CMC  
W = 10-15 μm  
L/W <2

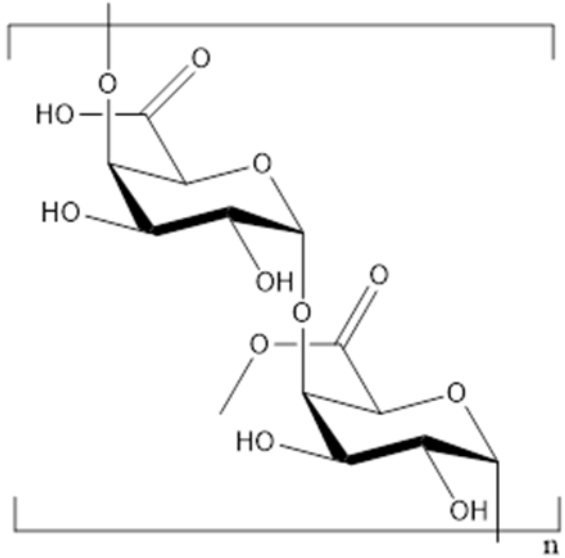
CMF  
W = 10-100 nm  
L = 0.5-10 μm



Average Price  
\$6/kg



Average Price  
\$18/kg

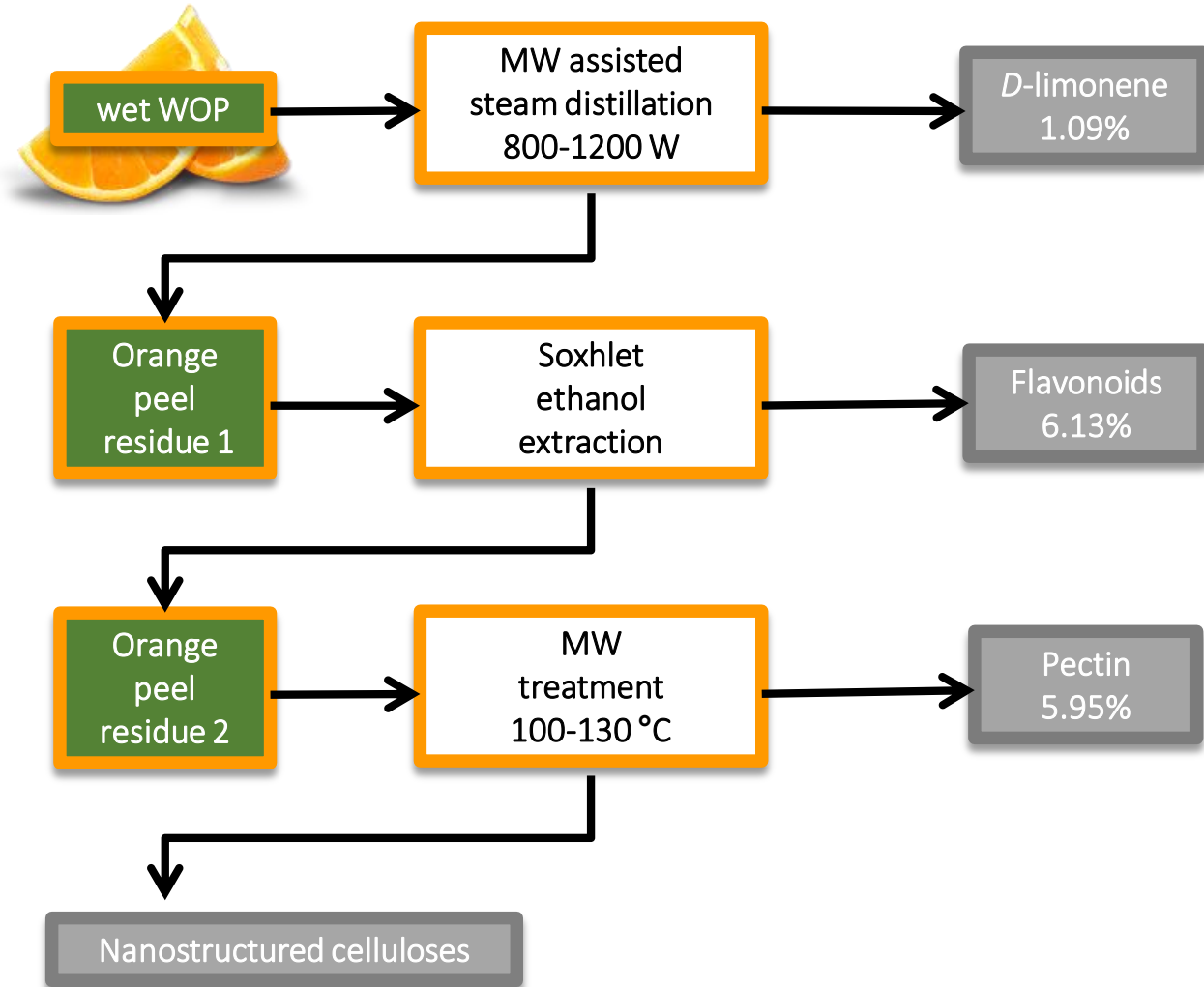


# Squeezing more than just orange juice: Citrus peel valorisation

## Integrated microwave waste biorefinery

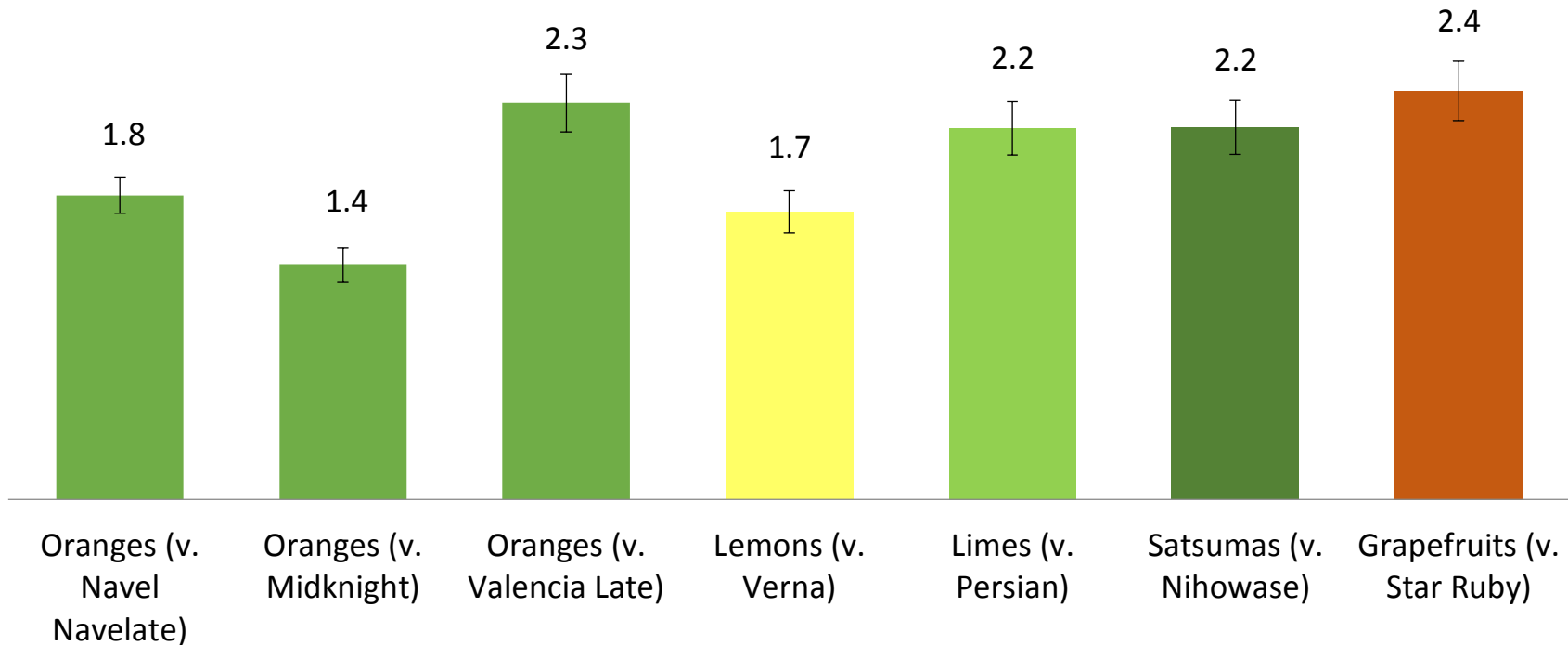
- ✓ Scalable
- ✓ Flexible
- ✓ Allows continuous processing
- ✓ Allows the use of wet feedstock –  
no drying step is necessary
- ✓ No necessary pre-treatment
- ✓ **No acid used**

Easier/more efficient extraction of  
marketable chemicals generated by a  
single industry in-situ

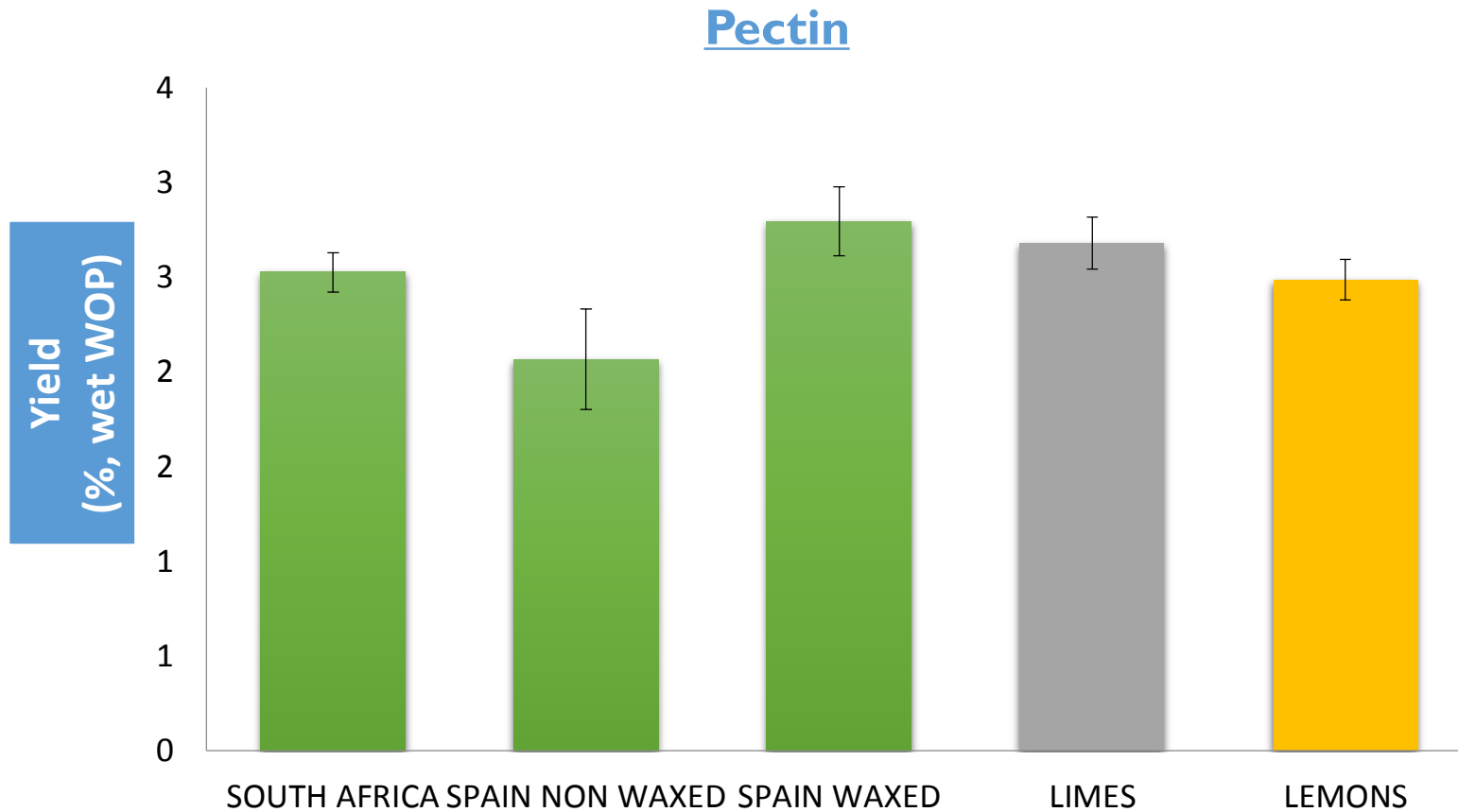


# Squeezing more than just orange juice: Citrus peel valorisation

Essential oil (%) - dry basis

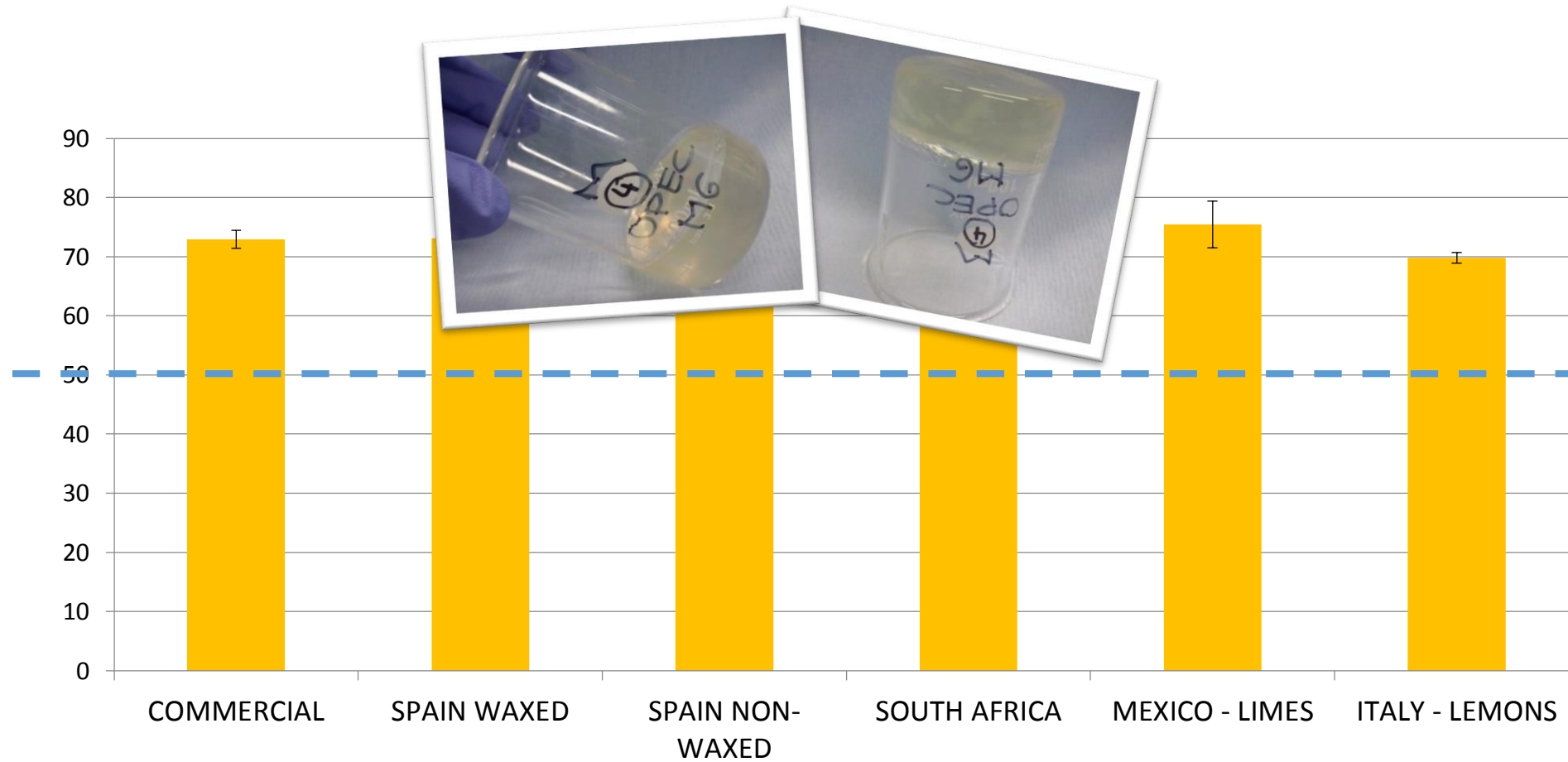


# Squeezing more than just orange juice: Citrus peel valorisation



# Systems Change Thinking

## Upgrading unavoidable food supply Chain Wastes: Citrus wastes

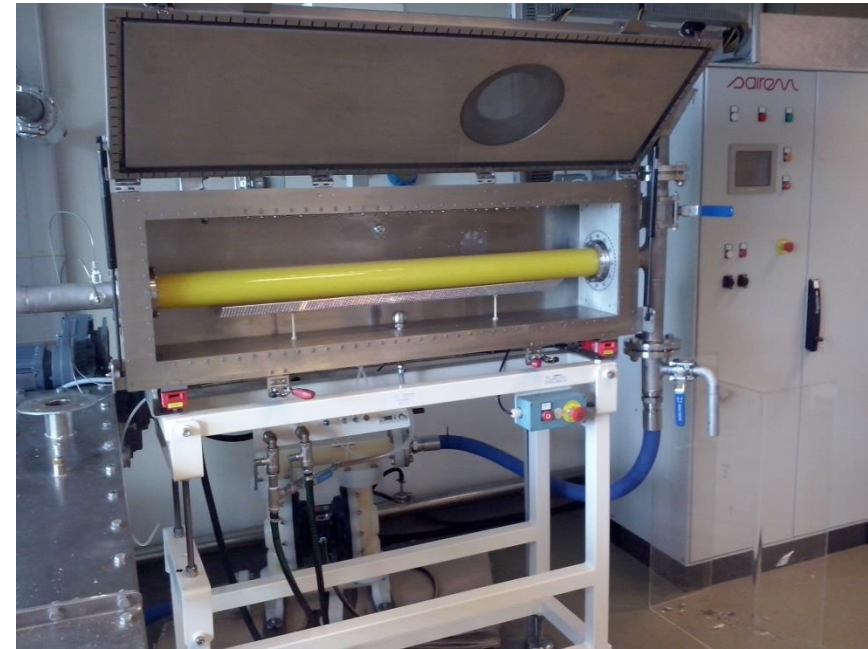


# Squeezing more than just orange juice: Citrus peel valorisation

**HOW? Modified pyrolysis MW rig  
(Just for pectin – acid-free)**



20 L scale MW rig (6 kW) able to withstand slurries, work in a semi-continuous up to 95°C and with a flow rate up to 200 L min<sup>-1</sup>



Macerated orange peel & water mixture pumped through the rig



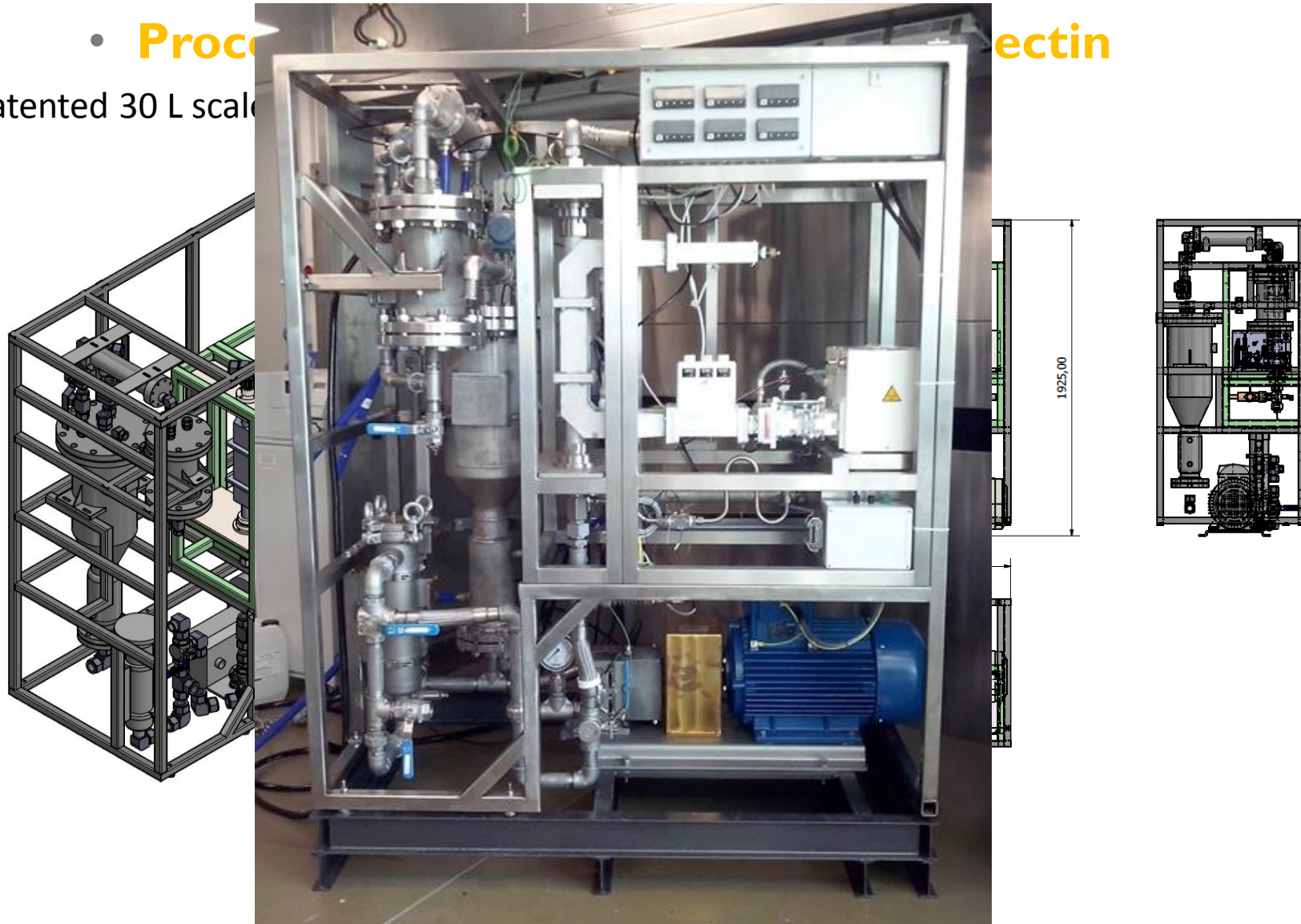


# Squeezing more than just orange juice: Citrus peel valorisation

- **Process**

Patented 30 L scale

**ectin**

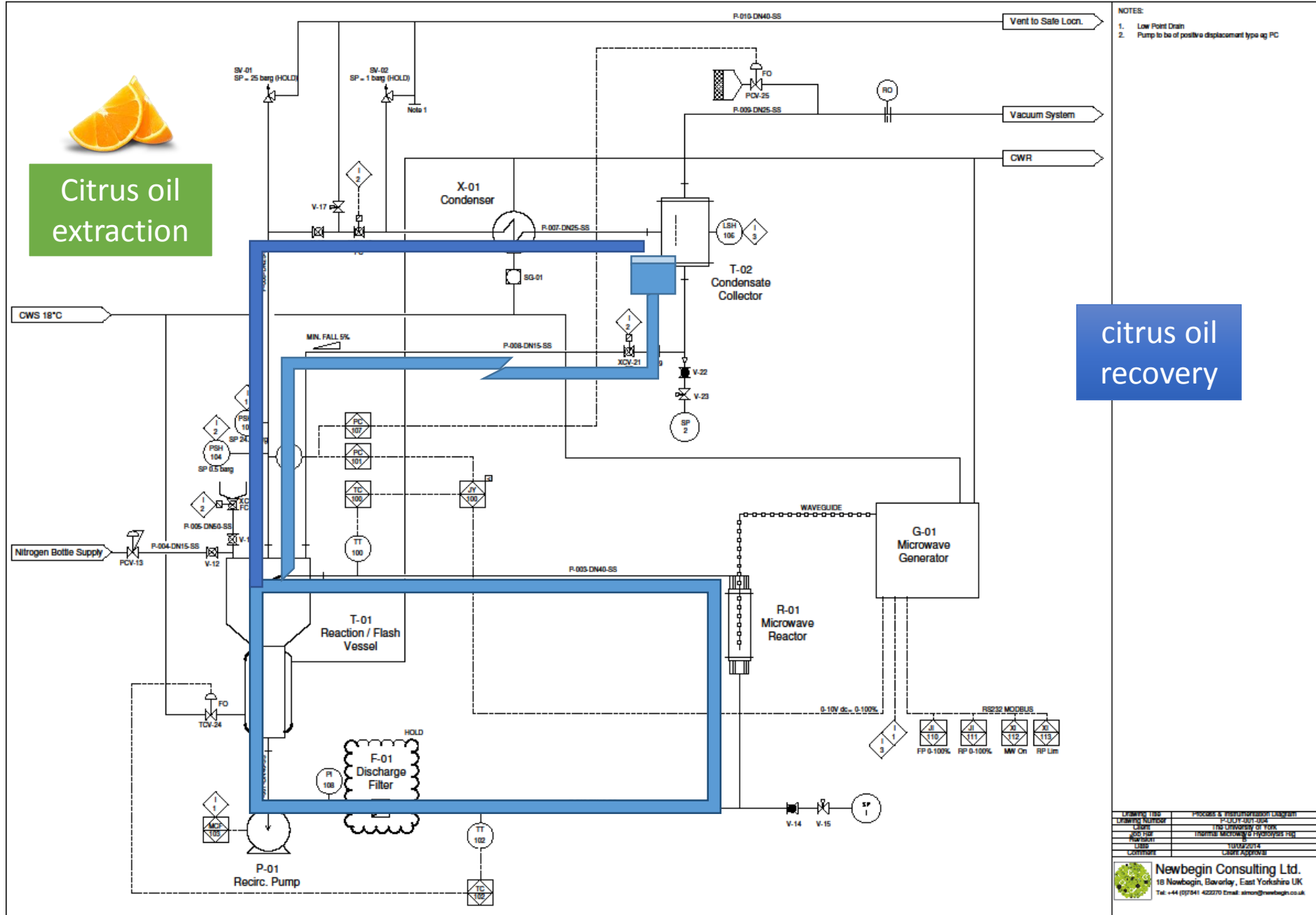






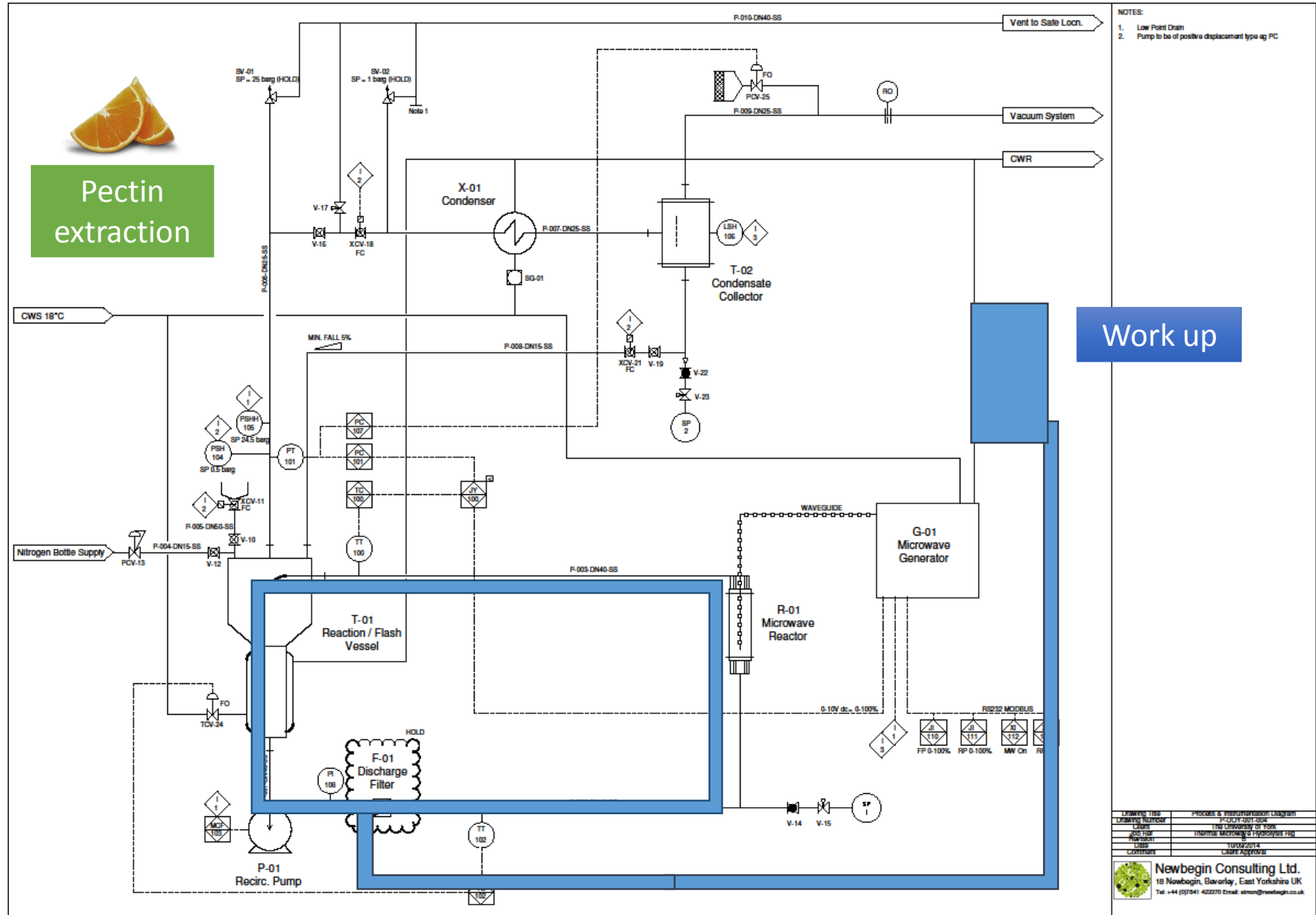
# Citrus oil extraction

# citrus oil recovery





# Pectin extraction



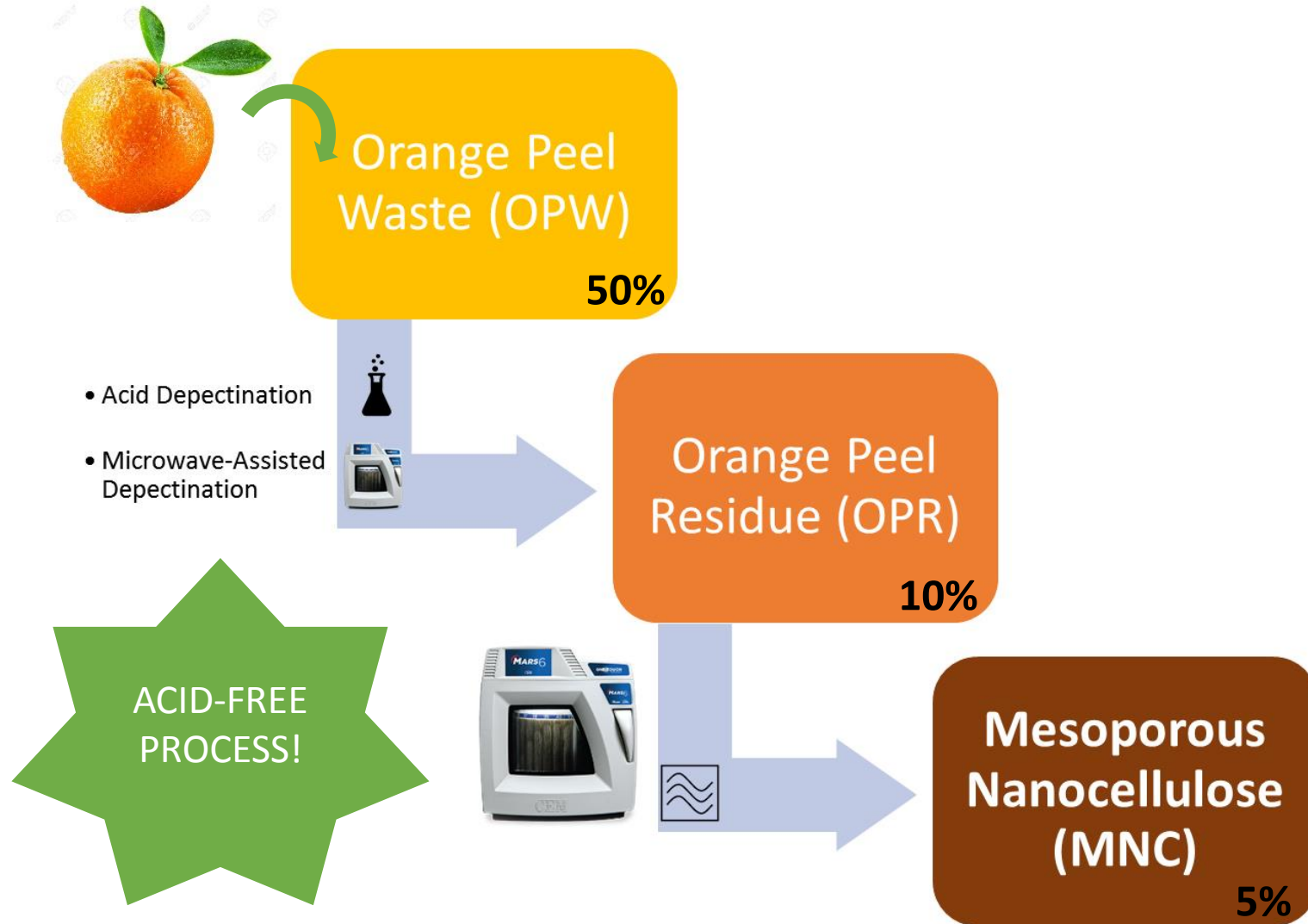
NOTES:  
 1. Low Point Drain  
 2. Pump to be of positive displacement type eg PC

Work up






Drawing Title	Process & Instrumentation Diagram
Drawing Number	P-001-100-001
Client	1163 University of York
Project	Thermal Microwave Hydrolysis of Pectin
Issue	10/02/2014
Control	Client Approval

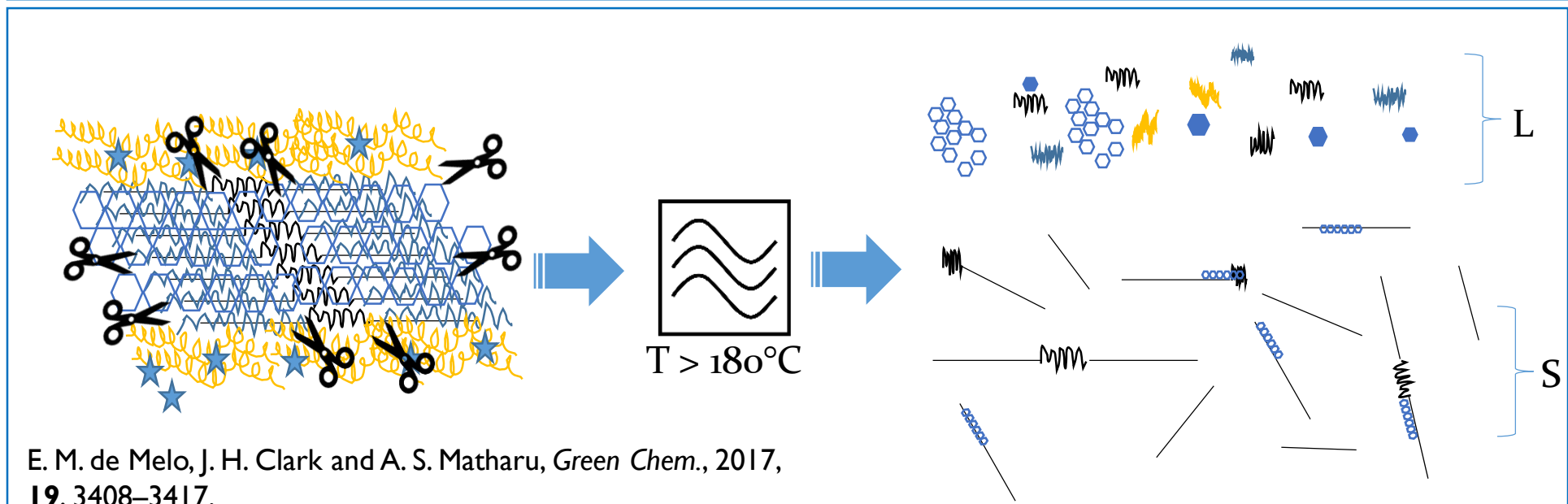
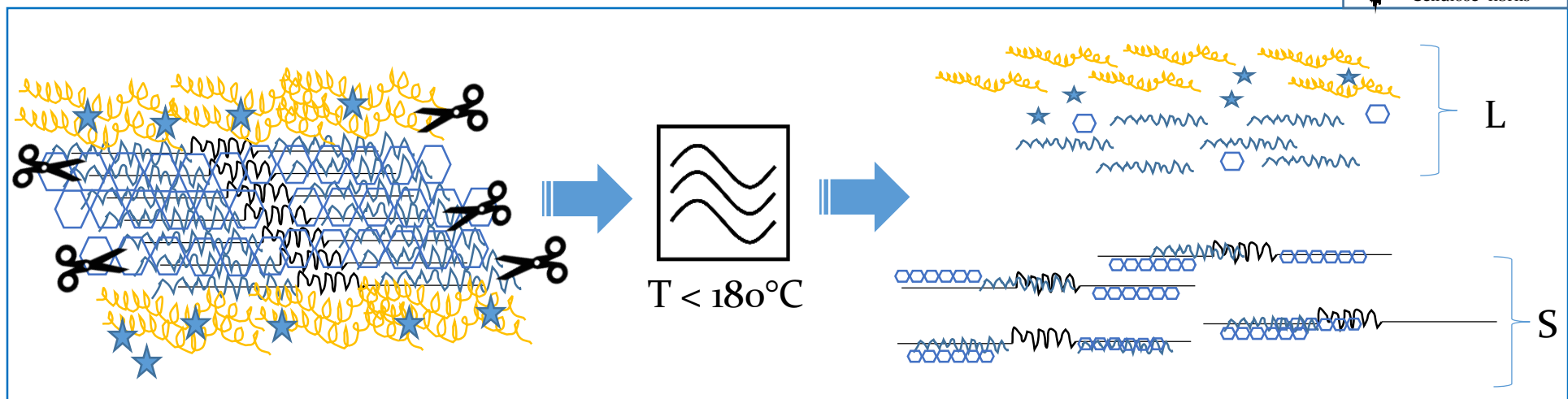
**Newbegin Consulting Ltd.**  
 18 Newbegin, Bawtry, East Yorkshire UK  
 Tel: +44 (0)1751 422070 Email: simon@newbegin.co.uk

# Squeezing more than just orange juice: Citrus peel valorisation



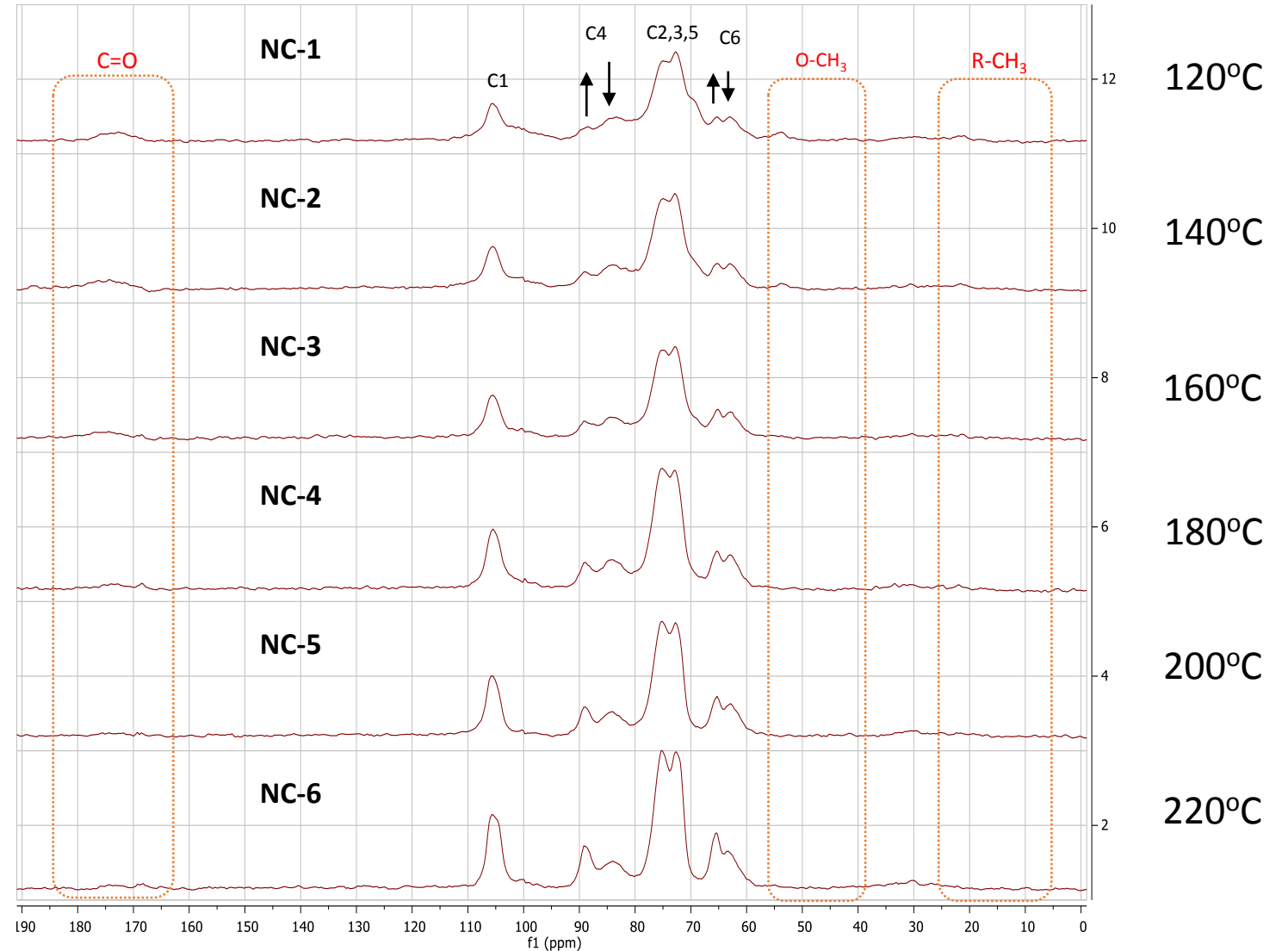
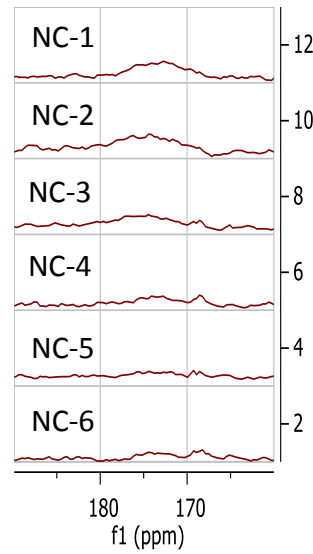
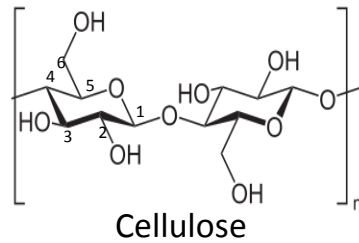
# Hy-MASS: Hydrothermal Microwave Assisted Selective Scissoring

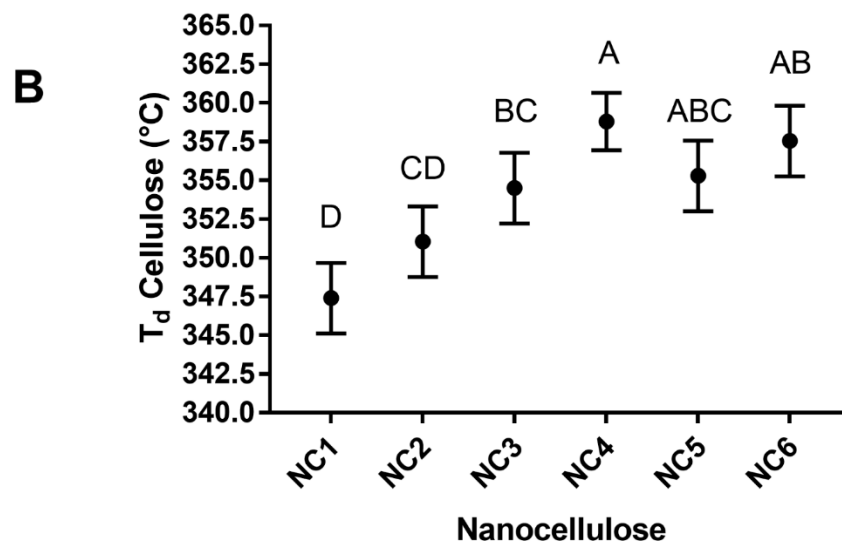
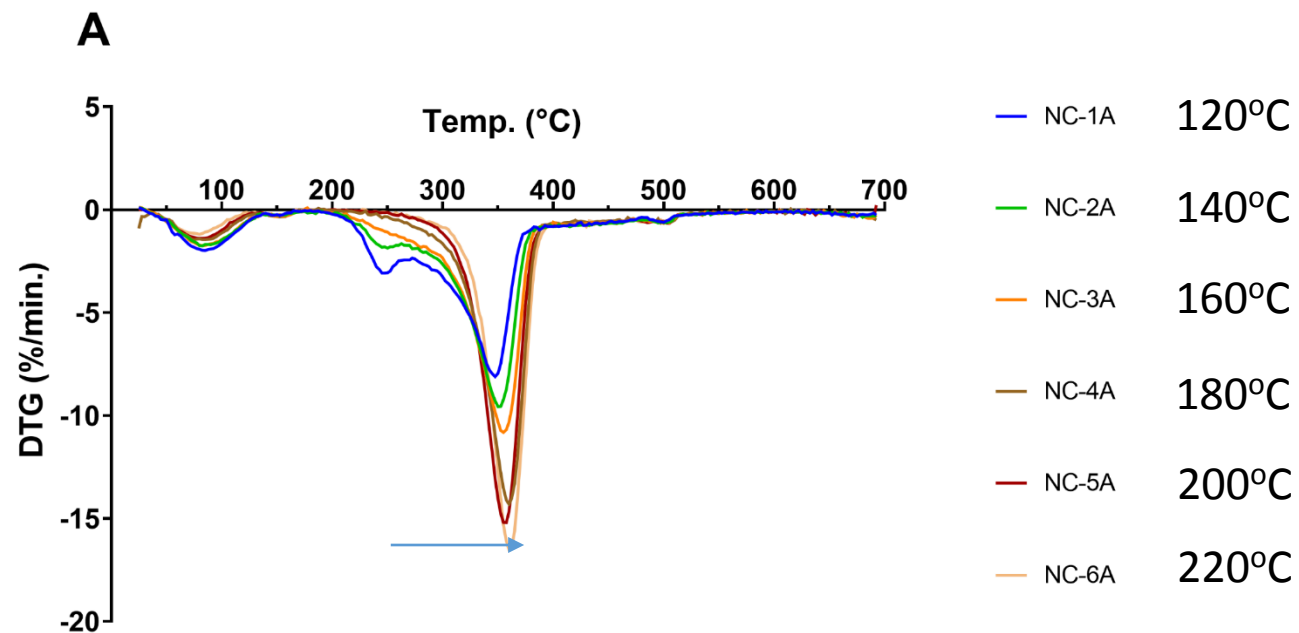
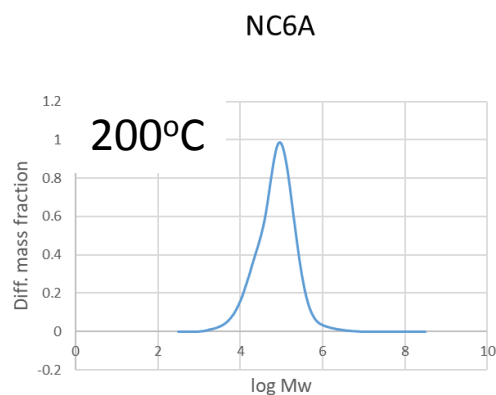
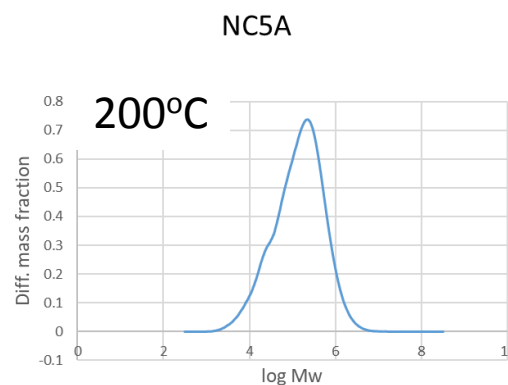
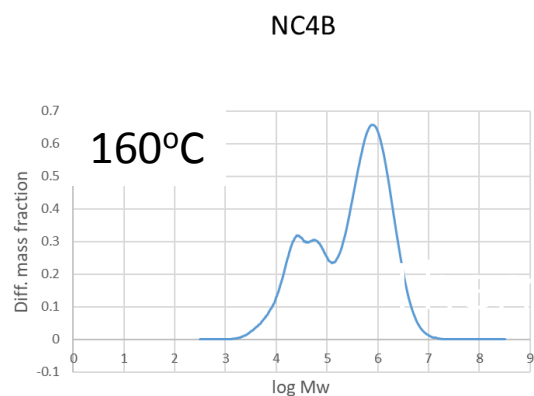
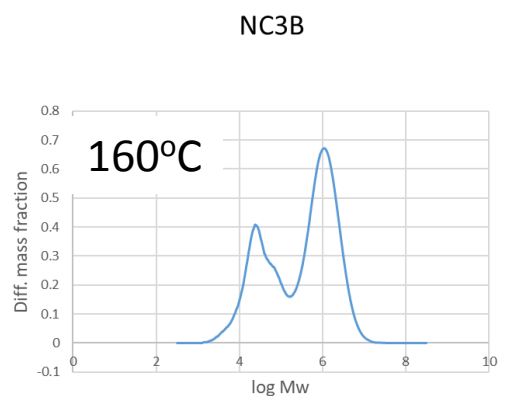
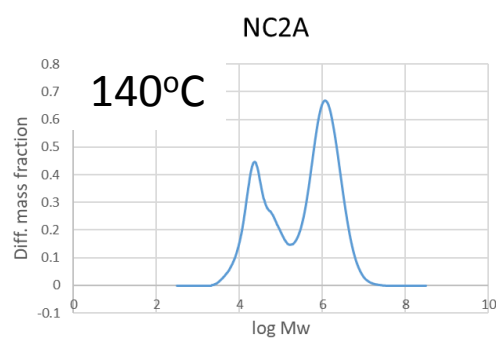
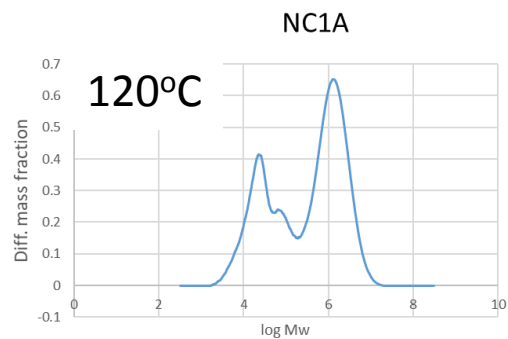
Key	
	Phenolics
	Pectins
	Hemicelluloses
	Lignins
	Cellulose fibrils



E. M. de Melo, J. H. Clark and A. S. Matharu, *Green Chem.*, 2017, **19**, 3408–3417.

# Squeezing more than just orange juice: Citrus peel valorisation

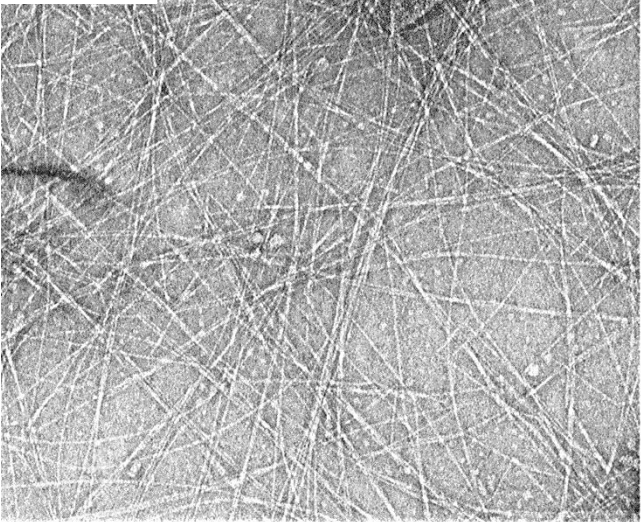




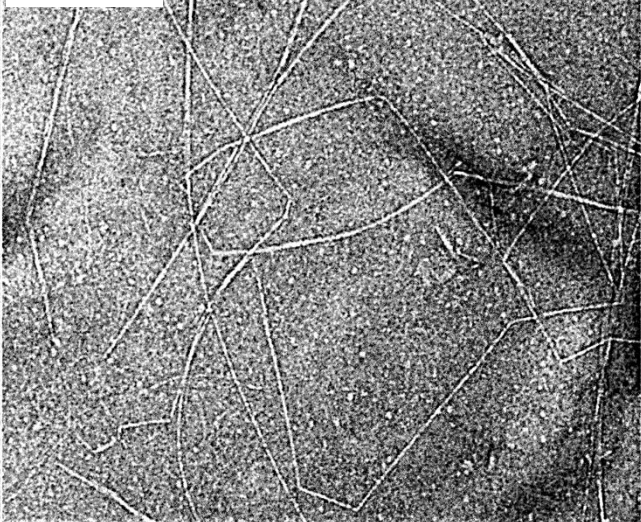


# TEM

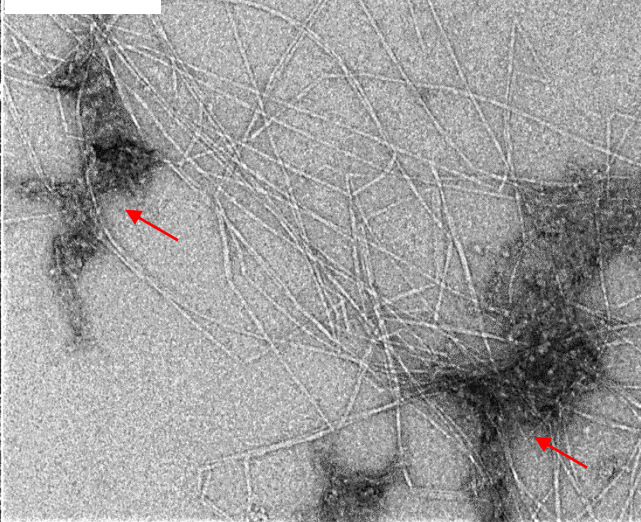
120°C



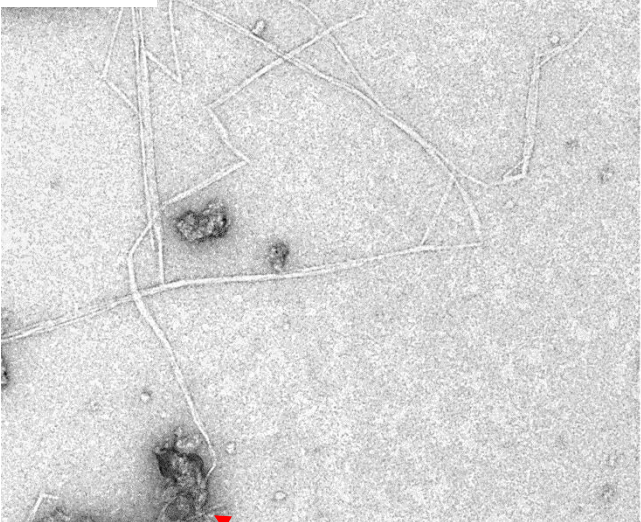
140°C



160°C



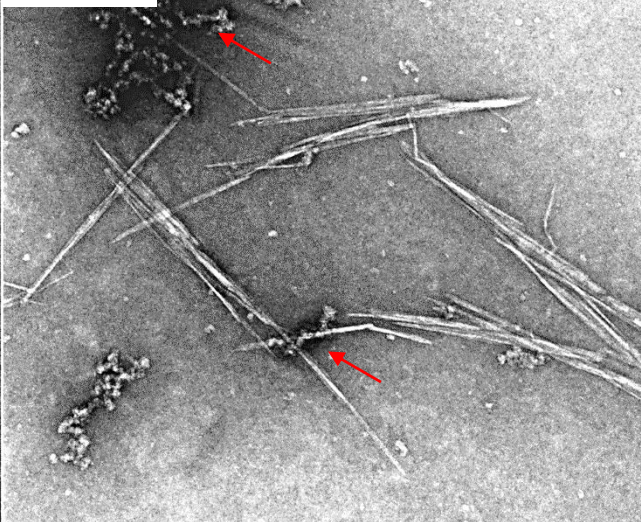
180°C



200°C

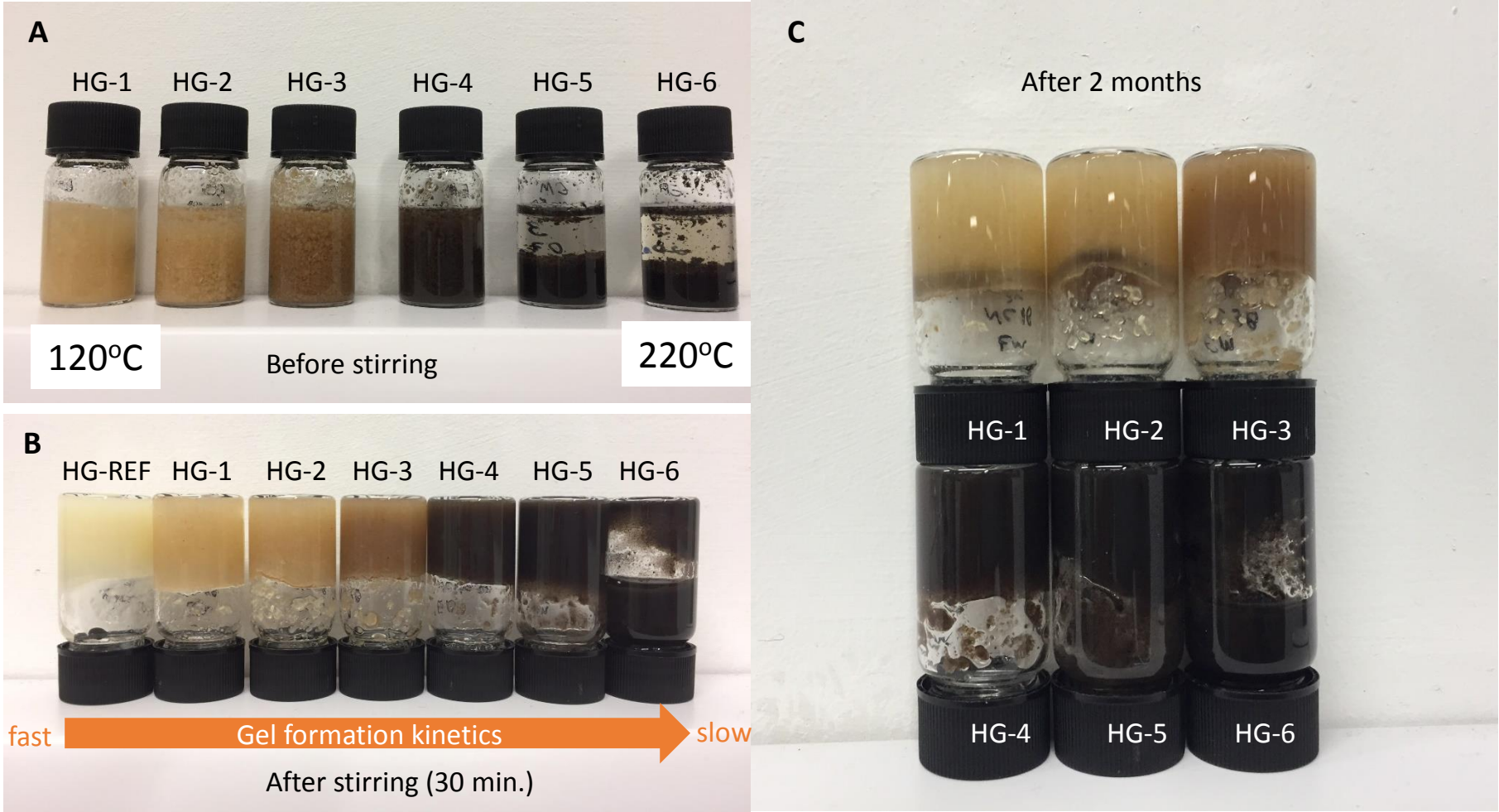


200°C



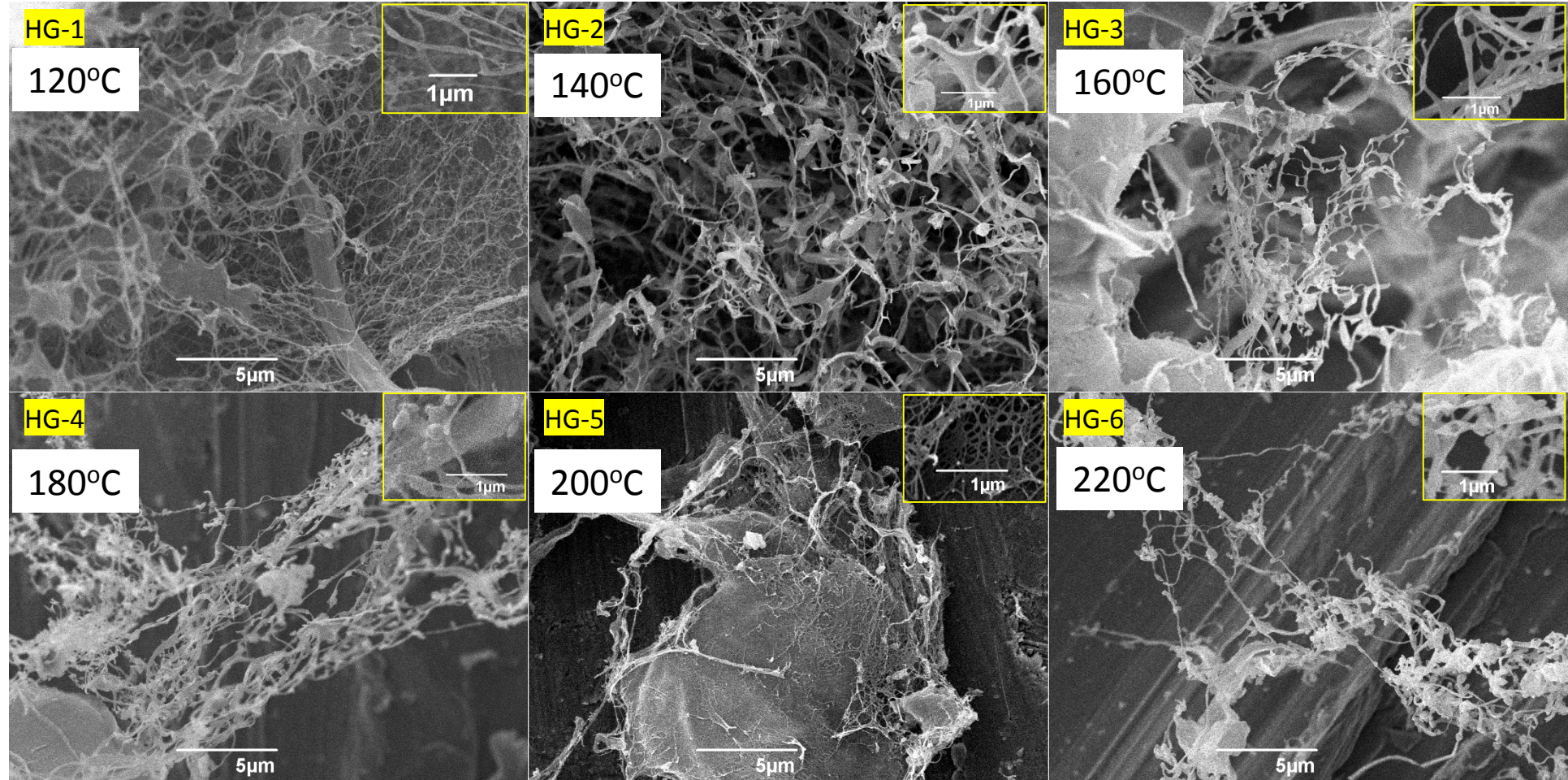


# Hydrogels





# SEM of Hydrogels

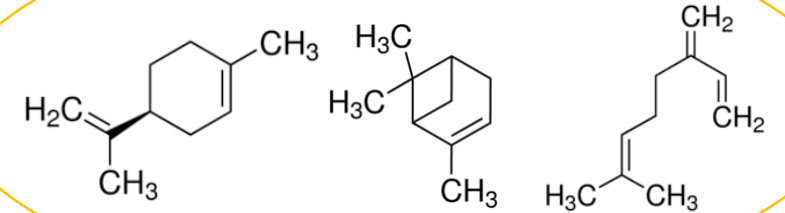


# Squeezing more than just orange juice: Citrus peel valorisation



33.2 million T/y

50% waste



\$4/kg

CELLULOSE NANOMATERIALS

NANO-OBJECTS

NANO-STRUCTURED

CNC/NCC

W = 3-10 nm  
L/W = 5-50

CNF/NFC

W = 5-30 nm  
L/W >50

MCC/CMC

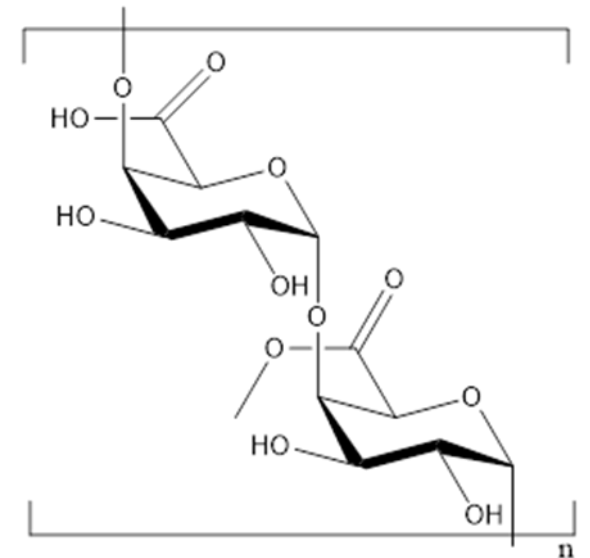
W = 10-15 μm  
L/W <2

CMF

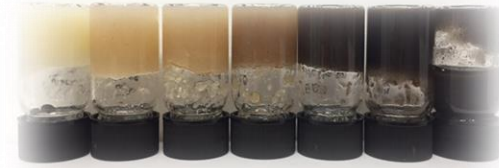
W = 10-100 nm  
L = 0.5-10 μm

Average Price  
\$6/kg

Average Price  
\$18/kg







**Squeezing more than just orange juice:  
Citrus peel valorisation**

# **Thank you and Acknowledgements**



**Molson Coors, Branstons Ltd, Green Pea Company, Chingford Fruits, New Food Innovation, Link2Energy, Nestle, Anthesis, WRAP, Nestle**

**EPSRC Whole systems understanding of unavoidable food supply chain wastes for re-nutrition EP/P008771/1**