Model-Based Monitoring of an Industrial Batch Pectin Extraction

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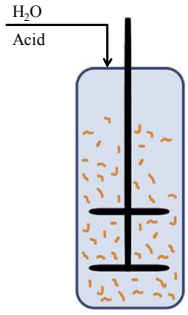
1. Pectin Extraction Process

Extraction by acidic hydrolysis from peels of citrus fruits

- Batch operation with several tanks
- The pectin quality can be characterized by intrinsic viscosity (IV) and degree of esterification (%DE)
- Process conditions (Temperature and pH) and proportions of peel/solvent vary within a limited range which is known to result in a desired particular KPI profile



Key Performance Indicators:

- IV
- %DE
- $C_{pectin,bulk}$

2. Objective and Motivation

From recipe-driven to a model-based approach

Lean and robust operation

↓ Waste ↓ Time ↑ Capacity ↑ Product Quality

Knowledge-based decisions to reach target KPI's

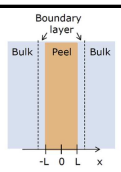
Development of monitoring strategy scheme

3. Dynamic Modelling

First principle model describing the non-linear process in respect to the KPI

- Prediction of the desired KPI
- Flexible applicability over a wide operational range of T & pH
- Central role in model-based approaches
  - ➢Process understanding
  - ➢Troubleshooting
  - ➢Monitoring
  - ➢Continuous process optimization

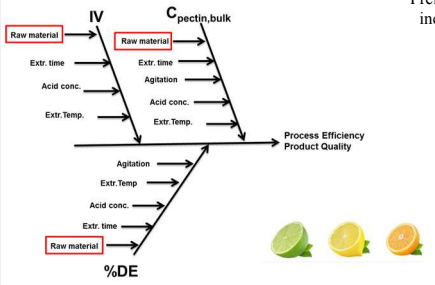
$C_{pectin,bulk}$	$\frac{\partial c_{pectin\ (peel)}(t,x)}{\partial t} = D_{pectin}\ \frac{\partial^2 c_{pectin\ (peel)}(t,x)}{\partial x^2} + k_{hydrolysis}\ \cdot c_{pectin\ (peel)}(t,x)$
	$\frac{\partial c_{protopectin\ (peel)}(t,x)}{\partial t} = -k_{hydrolysis}\ \cdot c_{pectin\ (peel)}(t,x)$
	$\frac{\partial c_{pectin\ (bulk)}(t,L)}{\partial t} = \frac{A_{total}\ \cdot k_{masstransfer}}{V_{total}} \cdot \left(c_{pectin\ (peel)}(t,L) - c_{pectin\ (bulk)}(t,L)\right) - k_{degradation}\ \cdot c_{pectin\ (bulk)}(t,L)$
%DE	$\frac{\partial c_{estergroup}\ (t,L)}{\partial t} = DE_0 \cdot f_{GA}\ \frac{A_{total}\ \cdot k_{masstransfer}}{V_{total}} \cdot \left(c_{pectin\ (peel)}(t,L) - c_{pectin\ (bulk)}(t,L)\right) - k_{de-esterification}\ \cdot c_{estergroup}\ (t,L)$
IV	$IV = IV_0 \cdot \exp(-k_{IV} \cdot t)$



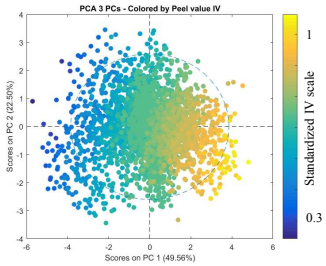
Development based on fundamental physical phenomena and a parameter training set: ●Pilot scale ●T vs pH DoE ●one peel type

4. Identified Problems

➢ **Lack flexibility for different peels**

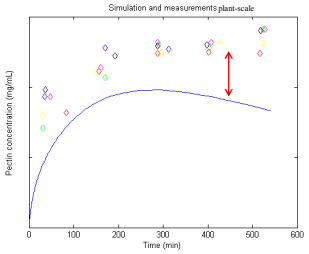


Preliminary exploratory analysis of historical dataset includes 3530 peels from a 10 year period (05-15)



Parameters that are inherently different from peel-to-peel are fixed or estimated for the training peel → **Unaccounted uncertainty propagating into the output uncertainty**

➢ **Cross-scale application issues**

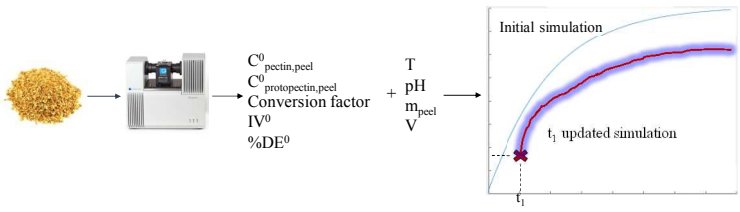


Sensitive parameters estimated at a different scale of application:

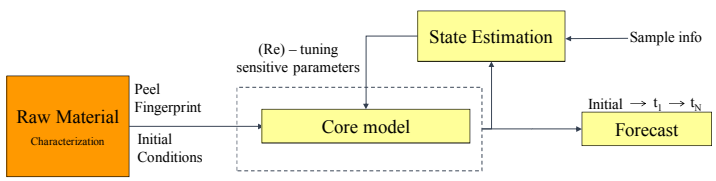
- **Model alteration**
- **Re-tuning of parameters**
- **Hybrid approaches**

5. Monitoring Strategy

Flexible model scheme that copes with raw material discrepancies by providing better initialization parameters for each different peel that arrives at the process line



Combination of state-of-the-art state estimation algorithms together with chemometric techniques to provide the process operators with a decision making tool for process optimization



6. References

The 1st principle model used in this research was developed in :
N.M. Andersen, T. Cognet, P.A. Santacoloma, J. Larsen, I. Armagan, F.H. Larsen, K.V. Gernaey, J. Abildskov, J.K. Huusom, Dynamic modelling of pectin extraction describing yield and functional characteristics, Journal of Food Engineering, Volume 192, January 2017, Pages 61-71