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UNIVERSITY OF APPLIED SCIENCES

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SYSTEM INNOVATION FOR
SUSTAINABLE DEVELOPMENT

Subproject
Chemicals and process innovations for the leather supply chain

Final conference

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Outline

1. Objective
2. Approach
3. Project studies
   - Modular reactor concepts for decentral chemical production
   - Synthesis of potential tanning agent family from renewable resources
   - Tool for process assessment in the leather sector
4. Recent innovation trends of leather chemicals and processes

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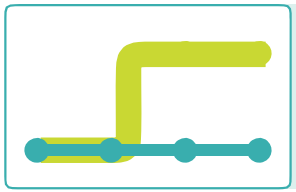
Objectives

Role of chemicals and process innovations viewed from system perspective



Strategies on how **leather chemicals** can be produced and used in a **more sustainable way.**

Identification of possible **technical and organizational potentials for process innovations** including possible contributions of modern process engineering concepts

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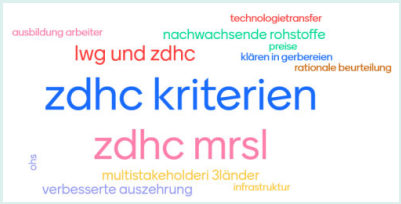
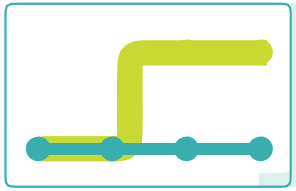
Refined Approach after online conference, two workshops

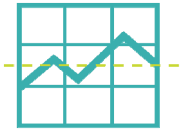
Feedback from online conference





How can **future process innovations** in leather production contribute to making the supply chain as a whole, and in particular the chemicals used, more „sustainable“?

➢ Demonstrate continuous flow synthesis of potential leather chemicals from renewable resources



Which **assessment criteria** for leather chemicals and their future modern manufacturing processes will decide on a long-term successful transformation?

➢ Develop assessment tool for a simplified sustainability assessment

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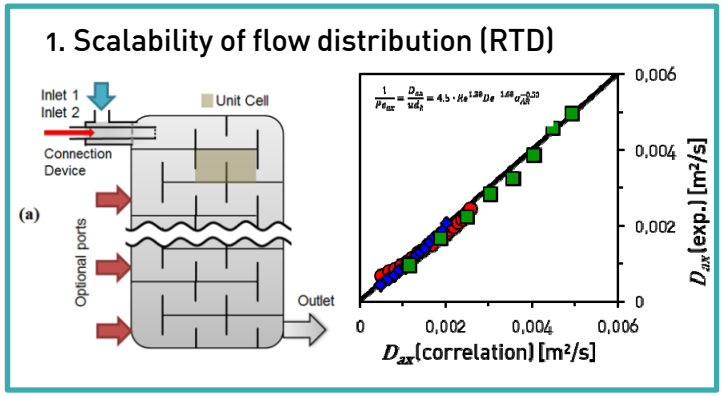
Study 1:
Investigation of selected reactor concepts for continuous flow production

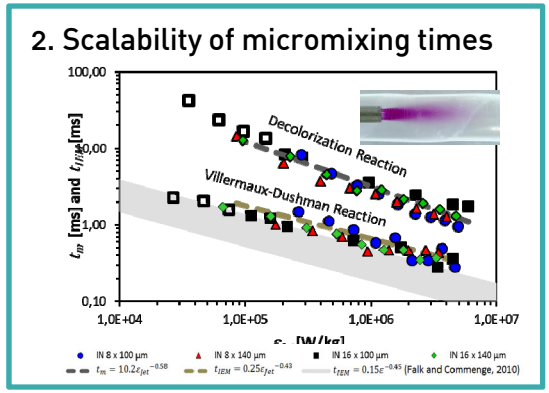
- **Advantages of continuous flow manufacturing of chemicals**
  - Small footprint (space, energy, waste)
  - Improved safety
  - Small-scale decentralized production

- **Main results**

1. Scalability of floe distribution
   - Allows adaption to various production amounts
2. Scalability of mixing performance
   - Allows quantification of preferred reaction rates for operation

ART©FlowReactor





Rojahn *et al.* Ind. Eng. Chem. Res. 2020, 59, 9, 3655–3668

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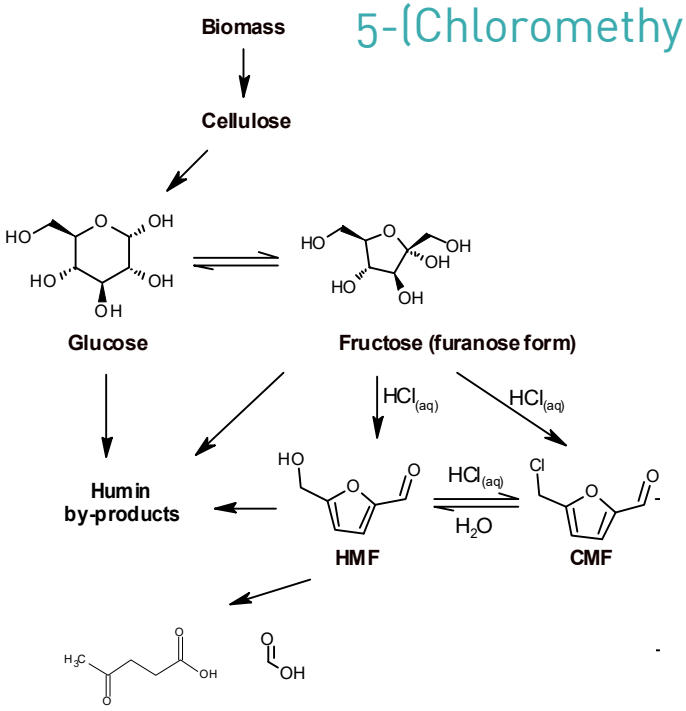
Study 2:
Continuous flow synthesis of renewable alternative platform chemicals: 5-(Chloromethyl)furfural (CMF) and 5-Hydroxymethylfurfural (HMF)



- Biofuels
- Specialty Chemicals
- Pharmaceuticals
- Precursers for Polymers
- Agro Chemicals
- Others

➢ Family of leather chemicals (Project Multibiosol, Univ. Pisa 2017)

Green engineering principles (selection)

- P12 Renewable materials and energy
- P6 Keep molecular complexity
- P3 Design for separation

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- HMF under intensive investigation as potential platform chemical
- CMF is more stable than HMF

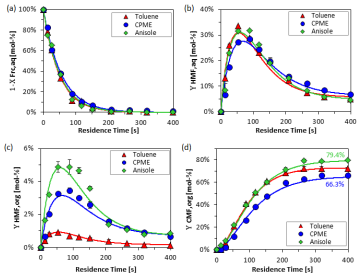
Rojahn, Nigam, Schael, *Chem. Eng J.* 2022
Cf. Mascal, *ACS Sustainable Chem. Eng.*, 2019

Study 2: Results

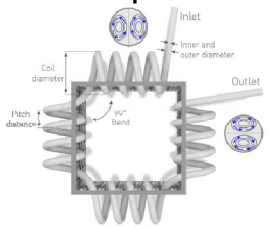
- Continuous CMF process
  - Solvent, Temperature, starting concentration, reactor design for optimum yield, operational stability, green engineering principles
  - Time evolution of formation of various species, kinetic modeling
  - Continuous process superior over batch process
  - Process technically feasible, basis for decentral production

- ToDo
  - More detailed scale-up investigation, mass & heat integration
  - Adaption to leather fabrication demands

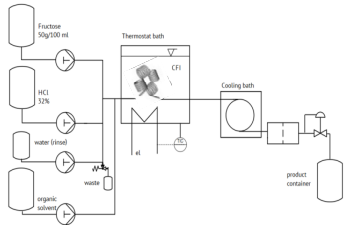
1. Kinetic modelling



2. Reactor optimization



3. Process design



Rojahn, Nigam, Schael, *Chem. Eng. J.* 2022

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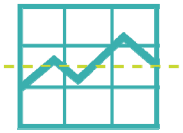
Study 3: Process Assessment Tool



Which **assessment criteria** for leather chemicals and their future modern manufacturing processes will decide on a long-term successful transformation?

Objective

New quantitative tool to be used internally by tanneries:

- Identification of improvement potentials
- Virtual testing of new raw materials / chemicals / process parameters on quantitative level
- Self Education regarding sustainability and process evaluation
- Coverage of economic, EHS, process, social and other aspects

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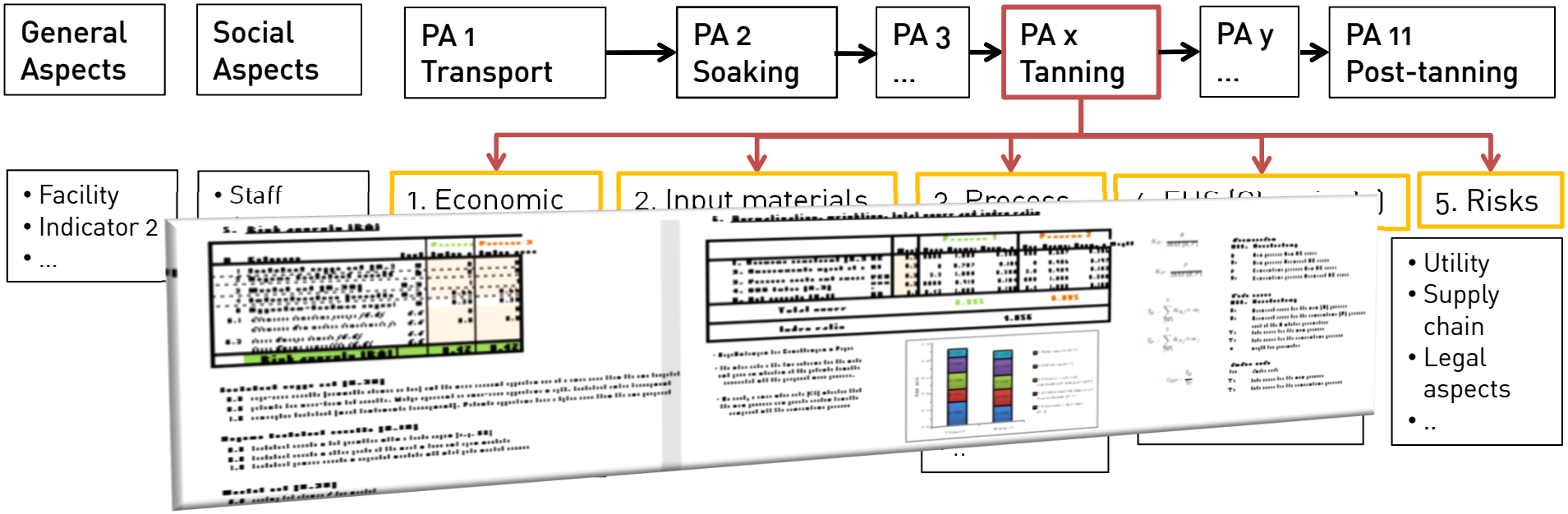
Study 3: Implementation of Process Assessment Tool



Approach

- Implementation in MS Excel for easy use and full transparency
- Data base of ca. 400 indicators

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Study 3: Results Display of Process Assessment Tool

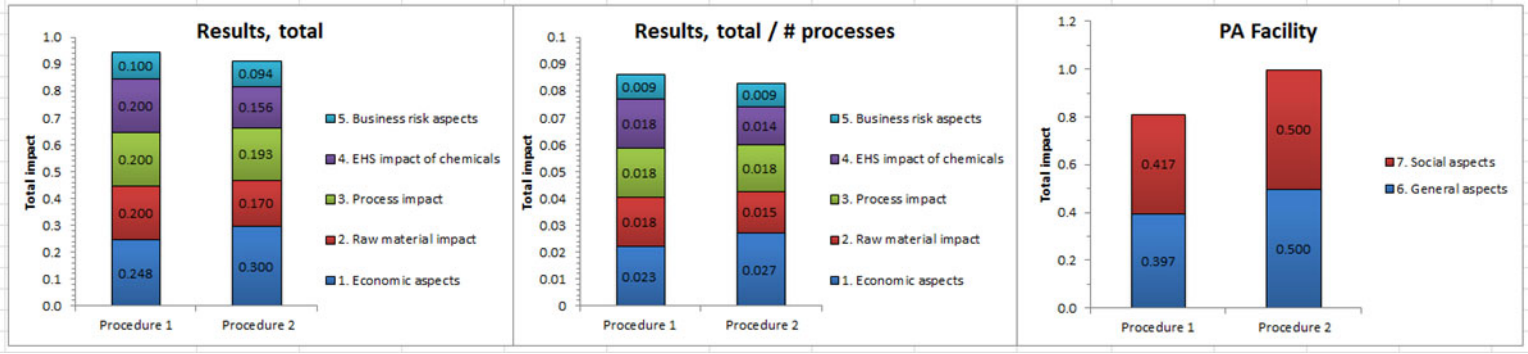
Results, Summary:

Process Assessment (PA)	1. Economic aspects		2. Raw material impact		3. Process impact		4. EHS impact of chemicals		5. Business risk aspects		6. General aspects		7. Social aspects	
	Process 1	Process 2	Process 1	Process 2	Process 1	Process 2	Process 1	Process 2	Process 1	Process 2	Process 1	Process 2	Process 1	Process 2
PA 1, Transport											-	-	-	-
PA 2, Soaking	0.248	0.300	0.200	0.170	0.200	0.193	0.200	0.156	0.100	0.094	-	-	-	-
PA 3, Unhairing											-	-	-	-
PA 4, Deliming														
PA 5, Enzymatic Pickling														
PA 6, Decreasing														
PA 7, Pickling														
PA 8, Tanning														
PA 9, Neutralization														
PA 10, Post-tanning 1														
PA 11, Post-tanning 2														
PA Facility														
Sum														
Sum / # processes														
(# processes)														

Status:

- Results allows comparison of processes
- Detailed data available
- Transparent normalization, allocation, weighting factors

➢ Status: Application tests with companies from the supply chain



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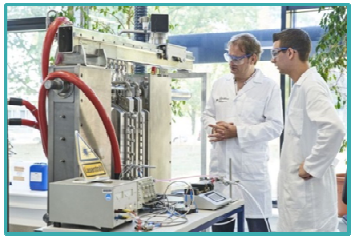
Summary

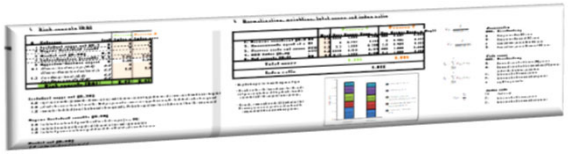
- 3 Concept studies on the basis of two workshops and online conference
  - Facilitate collaboration among the leather supply chain
  - Proposal for assessment criteria
  - Technical demonstrations on basic feasibility
- 2 Publications in leading Chemical Engineering Journals
- Research to be continued

1. Continuous flow reactor concepts



2. Continuous flow synthesis of renewable leather chemicals

3. Tool for sustainability assessment in the leather supply chain



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IULTCS conference Vicenca 2022

https://www.iultcs2022italy.org/

New developments in chemicals for the Leather tanning industry

Innovative chemicals capable of producing high performance leathers (wet processing and finishing) with the lowest environmental impact. The inclusion of Green Chemistry in innovative proposals is recommended.

Chemicals and Leather test methods: new developments/approaches

Standardized analytical methods are necessary for monitoring the regulatory parameters and requirements required by the market. New synergies to create new analytical methods and to manage updates for chemicals and leather.

Innovative technologies for Leather manufacturing processes

Innovative technologies in the tanning process, including machines and systems, with performance optimization of the leather and the resources needed to make it.

Focus on environmental aspects (e.g. LCA, by-product, wastewater, emission)

Innovative solutions and new proposals for wastewater treatment, sludge management. Use of LCA to assess the environmental impacts of the tanning product and chemicals used in the process. Evaluation of new proposals for recovery, valorization of by-product and other environmental aspects including emissions, through the LCA approach.

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Selection of recent trends of chemicals and process innovations

- Process optimization in tanneries
  - Variety of tanning types (instead of a single one)
  - Increase of **machine effectivity**, optimization of **energy supply and use** etc.

- Optimization of tanning process
  - **Minimization of amounts of chemicals, salt, and water**
  - **Replacement** of certain chemicals
  - **Recycling** of waste chemicals and materials
  - **Metal-free, renewable, plant-based agents and excipients**
    - Various vegetable-based tanning agents (derived from, e.g., oak, rhubarb, olive leaves, mimosa, others)
  - **Improved environmental footprint**
  - **Chemical management**

- Leather finishing
  - mechanical, embossing, splitting, reduced chemical, dying, aqueous solutions, minimizing VOC emissions, laminating...