Institute for
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Process Technology

# Freeze Concentration

Economically feasible bulk dewatering technology with intrinsic benefits in specific energy consumption and product quality

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# Final Public Report

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| Project Number RVO and/or ISPT(-TKI) | TEEI116084 – DR-20-08 |
| Project Title + Acronym | Freeze Concentration - FreezeCon |
| Secretary (penvoerder) | ISPT |
| Name Cluster Director | Peter de Jong |
| Name project leader | Maarten Schutyser - WUR<br>(formerly 2016-okt. 2019 Robert de Smidt - TNO) |
| PhD (name & title thesis) | Jan-Eise Vuist |
| Funding | EBI2016 |
| Project start | 1-1-2017 |
| Project original end date | 31-12-2020 |

## Project Consortium partners:

ECN part of TNO – Cosun – Nouryon - Wageningen University - ISPT

Cosun

Institute for Sustainable Process Technology

TNO innovation for life

WAGENINGEN UNIVERSITY & RESEARCH

Nouryon

Institute for Sustainable Process Technology

# Final Public Report

# 1. Public Summary

## Background

Several technologies are available for liquid concentration in the food industry, the most common being evaporation. However, evaporation processes cause product degradation and have high energy consumption. Freeze concentration, which separates water by freezing, maintains high product quality and uses intrinsically less energy. Current solutions in freeze concentration do not bring the potential energy efficiency gains and capital- and operating costs are high.

## Project objective

The overall objective was to demonstrate that progressive freeze concentration can be an economically feasible bulk dewatering technology with intrinsic benefits in specific energy consumption and product quality. The project team expects to be able to reach this objective via:

- The use of equipment already available for industrial refrigeration allowing for cost efficiency and quick scale up;
- Focus on the balance between separation efficiency and bulk processing, using temperature and pressure as degrees of freedom during crystallization on a heat exchanger surface.

## Short description of activities

The project started with establishing a program of requirements for a full-scale progressive freeze concentration system. The program of requirements was defined in close cooperation among the end-users (product and business case), the WUR (fundamentals of freeze concentration) and ECNpoTNO (heat pump technology). Based on the program of requirements a pilot-scale system was designed, a first business case evaluation was made and the specifications for the prototype lab scale freeze concentration unit were defined.

Using the information from the pilot-scale design, the product and process parameters were defined, and a prototype lab scale freeze concentration unit was developed, build and tested with a focus on separation efficiency, bulk processing, product quality and energy efficiency. The measured data was used to determine the benefits with respect to energy efficiency and product quality. The experiences gained during design, building and commissioning the lab scale unit were used to determine the CapEx of a full-scale system. The business case was then reevaluated using the information from the project. Dissemination of results was an integral part of the project and was coordinated by ISPT.

## Results

A new design for energy efficient bulk dewatering through progressive freeze concentration. A laboratory test unit and experimental results and theories were developed to evaluate energy efficiency, ice growth rate and solute inclusion. From experimental and theoretical analysis it was concluded that progressive freeze concentration is primarily suited for solutions with solutes that have a larger molecular weight. This is due to the large freezing point depression for smaller solutes leading to large amounts of inclusions. The business case evaluation for a full-scale system was based on the experimental results from the pilot-scale unit and showed that progressive freeze concentration is competitive in terms of energy use. Challenges for further development of the technology are especially the relative larger solute inclusion for small molecular weight (e.g. sucrose and salt) solutes in the current pilot-scale set-up. For large molecular weight solutes (e.g. proteins) the technology has much potential, but adhering solution decreases the separation efficiency. This would be possible to solve by implementing a post-treatment of the formed ice layer such as washing or sweating. Another challenge is to increase the concentration factor for the equipment. This would require multistage treatment, possibly also in combination with another freeze concentration technique.

# 2. Follow-up project

Progressive freeze concentration is a more beneficial option than suspension freeze concentration regarding CAPEX and OPEX because the unit is less complex. Difference is however with suspension freeze concentration a low molecular solute can be simpler concentrated.

To be investigated further is, if based on the composition that causes the freezing point reduction and the possibility to form a gel layer at higher concentrations progressive freeze concentration is an option.

It will also be investigated if next to project partners Cosun and Nouryon, and equipment builder IBK other industrial partners are interested to participate in a follow-up project with focus on scaling-up in order to commercialize the freeze concentration unit, especially animal and dairy protein producing partners.

# 3. Communication and Dissemination

Below a list with publications of the project is provided:

## 3.1 Activities

| Publ.ID | Year | Pub. Type | Reference |
|---|---|---|---|
| 1565 | 2017 | Poster | dr-20-08 project poster |
| 1645 | 2017 | Abstract | J.E. Vuist, Abstract for FPE PhD trip 2018 |
| 1675 | 2018 | Abstract | J.E. Vuist, M.F. van der Vis, M.A.I. Schutyser, R.M. Boom, Inclusions and ice growth during film freeze concentration of sucrose solutions |
| 1766 | 2018 | Presentation | Jan-Eise Vuist, Martijn van der Vis, Maarten Schutyser, Remko Boom, Inclusions and ice growth during film freeze concentration of sucrose solutions |
| 1838 | 2018 | Abstract | Jan-Eise Vuist, Maarten Schutyser, Remko Boom, A systematic parameter study on film freeze concentration |
| 1840 | 2018 | Draft Paper | J.E. Vuist, M.A.I. Schutyser, R.M. Boom; Inclusions and ice growth during film freeze concentration of sucrose and maltodextrin solutions |
| 2066 | 2019 | Presentation | Jan-Eise Vuist, Maarten Schutyser, Remko Boom; A Systematic Parameter Study on Film Freeze Concentration |
| 2076 | 2019 | Abstract | J.E. Vuist, M.A.I. Schutyser, R.M. Boom; Predicting solute inclusions during film freeze concentration |
| 2084 | 2019 | Abstract | J.E. Vuist, Abstract for FPE PhD Trip 2020 |
| 2105 | 2019 | Draft Paper | J.E. Vuist, R.M. Boom, M.A.I. Schutyser; Solute inclusion and freezing rate during film freeze concentration of sucrose and maltodextrin solutions |
| 2157 | 2019 | Poster | New project poster for the annual ISPT Conference, November 2019 |
| 2190 | 2019 | Poster | J.E.Vuist, EFFoST presentation, October 2019 |
| 2214 | 2019 | Presentation | J.E.Vuist, NWGD Symposium presentation, November 2019. |

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| 2355 | 2020 | Draft Paper | Jan-Eise Vuist, Rikke Linssen, Remko Boom, and Maarten Schutyser, Modelling ice growth and inclusion behaviour of sucrose and proteins during progressive freeze concentration |
| PUB03 | 2021 | Manuscript 3 | Jan-Eise Vuist, Remko Boom,Maarten Schutyser; Freeze Concentration of Protein-Sucrose-Salt Mixtures; March 2021. |
| PUB05 | 2021 | Manuscript | Jan-Eise Vuist, Maarten Schutyser, Remko Boom, Solute inclusion during progressive freeze concentration. Conceptual model preducts solute concentration in ice. |
| PUB72 | 2021 | Thesis | Jan-Eise Vuist, Remko Boom, Maarten Schutyser; Progressive Freeze Concentration; July 2021. |

**Thesis**

Manuscripts will be finalized in June 2021; Thesis booklet is to be expected in October 2021, and thesis defence is planned for 5 November 2021.

## 3.2 Public references

**Project page on ISPT website** https://ispt.eu/projects/freezecon/.

**Project poster** https://ispt.eu/publications/?project-tag=DR-20-08.

**ISPT News items**

News item 6th of February 2020 in ISPT newsletter on ‘Scaling-up of film freeze concentration as innovative energy efficient and mild technology’ https://ispt.eu/news/scaling-up-of-film-freeze-concentration-as-innovative-energy-efficient-and-mild-technology/

News item regarding project results and thesis defece of Jan-Eise Vuist is planned in November 2021.

**Item in WUR magazine Resource** in February 2020 ‘’Jan-Eise + IBK film freeze concentrator’.

# 4. Acknowledgement

This project is co-funded with subsidy from the Topsector Energy by the Ministry of Economic Affairs and Climate Policy.