General information	
PPP-number	**TKI-AF-15235**
Title	PPS Tasty Sustainable Frozen Foods
Theme	Topsector Agri & Food, Roadmap High quality products and processing, Theme Healthy and Safe
Implementing institute	Wageningen Food & Biobased Research
Project leader research (name + e-mail address)	Theo Verkleij theo.verkleij@wur.nl
Coordinator (on behalf of private partners)	Bjorn van den Oudenhoven, LambWeston / Meijer
Project-website address	https://www.wur.nl/nl/Onderzoek-Resultaten/Onderzoeksprojecten-LNV/Expertisegebieden/kennisonline/Duurzaam-ingevroren-smaakvol-sustainable-frozen-and-tasty.htm
Start date	01 January 2016
Final date	31 December 2019

Approval by the coordinator of the consortium The final report must be discussed with the coordinator of the consortium. The "TKI's" appreciate additional comments concerning the final report.	
Assessment of the report by the coordinator on behalf of the consortium:	V Approved □ Not approved
Additional comments concerning the final report:	

Consortium	
Mention any changes in the composition of the project partners:	**No changes during the execution of the project**

Summary of the project	
Problem definition	Freezing of food is a frequently used method to extend shelf life, to avoid spoilage and loss of value in the chain. Energy consumption, quality, weight and aggregation during frozen storage have led to a worse image of frozen food compared with food directly prepared from fresh products. The objective of this project is to improve the final quality of frozen products after processing by consumers and reduce energy consumption during storage and processing of frozen products.
Project goals	The objective of this project is to understand the physical causes of the loss of product quality of frozen foods, with the aim to improve their quality at the point of consumption and to reduce energy consumption during storage and processing of frozen products.

Results	
Planned results in the original project plan	• Understanding of ice formation due to conditions in processing, such as freezing rate and fluctuation of temperature during storage • Understanding of clumping of individual products in packaging, impermeable to water • The influence of very low storage temperatures on the crystal growth of both ice and fat • The influence of temperature fluctuations at very low temperatures on product quality, and energy savings.
Achieved results	<u>Understanding ice formation in par-fried potatoes</u> Detailed measurements were done on an industrial freezing line to determine temperature profiles of individual products in different stages of the production process. These temperature profiles were used to develop a predictive model, in which the effect of freezing on temperature behaviour and therefore on product quality can be determined. Also a lab scale system for pre-treatment and freezing of vegetables was set up, to determine the impact on quality after freezing and during frozen storage. With the lab scale system, extreme conditions were evaluated to test the hypotheses on effect of processing conditions on product quality. By performing research both on industrial scale and lab scale, the project made sure that relevant conditions are researched and results can be applied on industrial scale. <u>Understand clumping</u> Detailed measurements were carried out on an industrial freezing line to determine temperature profiles of individual products in different stages of the production process and related to clumping if it happened. On lab scale several hypotheses were tested to validate the possible occurrence of clumping. Testing at industrial scale has confirmed the conclusions of the lab scale experiments. One of the factors contributing to clumping, is the melting temperature of the frying oil relative to the frozen product temperature and the product storage temperature. <u>Visualisation ice and fat crystal formation</u> An X-ray Tomography method to characterize the ice crystals in frozen vegetable products was developed. With this method it is possible to visualise the size and distribution of ice domains in frozen vegetable which can give insight in the effect of e.g. different processing and storage conditions on quality of frozen vegetables. The analytical method was adapted to visualize the ice distribution in products and between products. <u>Energy saving</u> By arranging the freezing process in a different way and controlling the temperature during freezing, it is possible to freeze partially fried fries well with less energy. The developed predictive model showed that energy saving can be substantial. This needs to be proven with new experiments.
Explanation of changes relative to the project plan	

What was the added value created by the project for:	
Participating "Knowledge Institutes" (scientific, new technologies, collaboration)	Development of a predictive model on ice formation as function of food composition and heat transfer. Models are developed on the microstructural scale, using phase field, and on the product scale predicting freezing during industrial processing. These models can be used for further research.

Participating private partners (practical application of the results, within which period of time?)	More insight in the physics of processes in their production line (LWM). Insight in the role of oil composition on freezing process of the customer(s) (Cargill). Insight in the details of a freezing operation (FPS) Knowledge of ice formation in frozen products and the way it can damage food structure (KNVvK)
Society (social, environment, economy)	Energy saving by applying a more efficient freezing process. (To be developed further)
Possibly other stakeholders (spin-offs)	

Follow-up	
Did the PPP result in one or more patents (first filings)?	One patent under discussion
Are there any follow-up projects planned? If yes, explain. (Contract research resulting from this project, additional funding, or new PPP projects)	One contract research project executed A new PPP project submitted

Deliverables/products during the entire course of the PPP (provide the titles and/or a brief description of the products/deliverables or a link to a website.

Scientific articles:

- R.G.M. van der Sman. Clumping of frozen par-fried foods: Lessons from frosting on structured surfaces. Food Structure 17 (2018) 9-20
- In press : R.G.M. van der Sman. Impact of processing factors on quality of frozen vegetables and fruits. Food Engineering Reviews

External reports:

Articles in professional journals/magazines:

- R.G.M. van der Sman. A deep drive into the deep freeze. New Food, Vol. 19, issue 2, 2016, p.13-15

(Poster) presentations at workshops, seminars or symposia.

- R.G.M. van der Sman. Phase field simulation of directional freezing of sugar solutions. Presentation at DSFD2017, 26th International conference on discrete simulation of fluid dynamics. 10-14 July 2017. Erlangen, Germany
- R.G.M. van der Sman. Phase field simulation of ice formation in sugar solutions. Presentation at Symposium Thermodynamics and Phase Transitions in Food Processing. 29-30 January 2018 Wageningen University
- Public workshop at Wageningen University & Research: Diepvriesgroente en fruit: wat is de impact van invriezen op de kwaliteit. 2 February 2018
- Barbier (interview Erik Esveld, Ariette Matser). Diepvriesproducten bekijken in 3D , VMT . 1 JUNI 2018 . NR 7

TV/ radio / social media / newspaper:

Remaining deliverables (techniques, devices, methods, etc.):

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