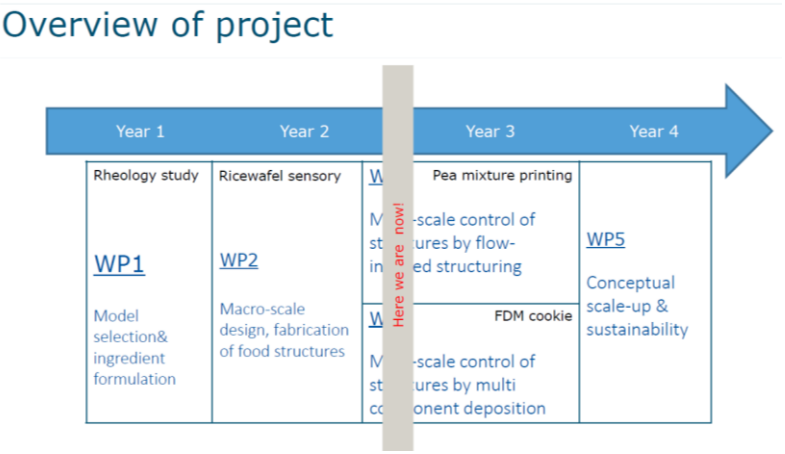
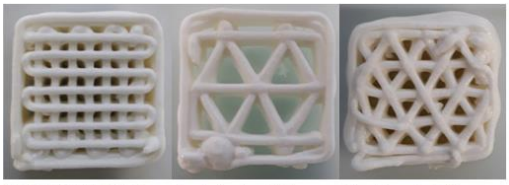
General information	
PPP-number	**TKI-AF-AF16508**
Title	Design and sensory perception of multi-scale food structures fabricated by 3D printing
Theme	
Implementing institute	Wageningen University & Research
Project leader research (name + e-mail address)	Maarten Schutyser (Maarten.schutyser@wur.nl)
Coordinator (on behalf of private partners)	Daniel Florea, FrieslandCampina
Project-website address	https://topsectoragrifood.nl/project/af-16508-design-and-sensory-perception-of-multi-scale-food-structures-fabricated-by-3d-printing/
Start date	1/9/2017
Final date	31/8/2021 -> maternity leave & 4 days working after maternity leave. New end date is 1/2/2022

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

Summary of the project	
Problem definition	3D Food printing is a rapidly emerging research area with much attention in the media and from consumers. Current technologies however only allow its use as small-scale 'gimmick': the use of ingredients is limited, one cannot yet create a multiscale food structure as is present in natural foods, and its use of energy and other resources per kg product is still prohibitive for larger-scale use. This is why it holds great potential as method for point-of-sale assembly, which can strongly reduce the amount of waste in the chain, which ranges from around 30% in Europe, to 50% in the United States.
Project goals	The overall objective of this PhD project is to develop a scientific base to prepare printed food structures that have excellent sensorial properties with focus on structure formation at multiple length scales.

Results	
Planned results 2019	Below a schematic representation can be found on the progress with respect to the planning. ○ Understand the rheological properties of ingredients for a suitable FDM printing. A model system should be selected and a relationship between its rheological properties and printability

	(extrudability and stability) needs to be built. An article was planned for the study result. ○ 3D printing can be used for macro-scale design of food products, e.g. create inhomogeneous distribution of tastants and alter people's sensory perception. Two studies were done using FDM printing and jet printing techniques to structure food product. An article was planned for this study result. ○ Ingredient formulation is crucial for a smooth extrusion. A complex mixture consisting of protein, fiber and starch was studied. Understanding what could be the cause of an irregular extrusion can help us better design the printing recipe. An article was planned for this study result. 
Achieved results 2019	In 2018 and early 2019 we investigated the relationship between rheology and on the one hand extrusion behaviour and on the other hand stability during printing. This resulted in a publication that was published in August 2019 (see publication list). Sicong was on maternity leave from mid-July till mid-November. Following follow-up projects were carried out: ○ Extrusion of plant protein or any formulations in general should be smooth. Particulate suspensions with pea ingredients with low viscous continuous phase can lead to blockage of nozzles, which is not-desired. Particle properties, nozzle design and medium properties are key parameters investigated. In 2020 this topic will be further investigated. ○ Printing of cookies with distributed sugar to examine the influence of concentration gradients and location. A new thesis project (end 2019/start 2020) is continuing on the printing of cookies with distributed sugar to examine the influence of concentration gradients and location. The previous study was ill-designed in the sense that the sweetness difference between sugar and non-sugar layer (with xylitol/FOS) was too little. ○ Printing of rice waffles with chocolate to influence chocolate perception e.g. in terms of liking, sweetness, creaminess. This project is carried out in collaboration with Foodjet. In one day 600 wafels were printed with a chocolate topping pattern. Sicong analysed the sensory panel data on the rice waffles covered with different layers of chocolate. By using advanced statistics, Sicong did observe significant differences between different distributions and the reference. In the end she could conclude that

	heterogeneous distribution of chocolate coating influence consumers' overall sensory perception towards the entire sample. One combination (MTH) provided a more creamier sensation while it still was liked as much as the reference. An example of jet printed rice wafel is shown below. A paper is being written on this study. 
Planned results 2020	○ FDM and powder bed printing of protein bars, resp. • FDM at ambient and elevated temperature were successfully used to make bars using spray dried CaCas. Coming period bars with different porosities will be printed and a preliminary sensorial analysis in February will be done for which users will be invited, if interested. There was some discussion on how to compare different porosities, i.e. comparable in portion size, mass. Examples of 3D printed protein bar with varying porosity is shown below:  *Bar rectilinear 40%* *Bar triangle 40%* *Bar triangle 70%* • For powder bed printing first the addition of moisture on the properties of powder is investigated and post-treatment. In January/February powder bed printing experiments will be done at Oceanz with a lecithinated CaCas recipe, which seems to work best for printing. The students will finalize in March. ○ A new thesis student will come in April to continue on the protein bars. Also printing of pea-based ingredients, a subject which was on hold for some time, will be picked up again.

Deliverables/products in 2019 (provide the titles and /or a brief description of the products/deliverables or a link to a website.
Scientific articles: Zhu, S., Stieger, M. A., van der Goot, A. J., & Schutyser, M. A. I. (2019). Extrusion-based 3D printing of food pastes: Correlating rheological properties with printing behaviour. Innovative Food Science & Emerging Technologies, 58(July), 102214.
External reports: Thesis reports: • Tessa Kokje: Sensory perception of 3D printed cookie with inhomogeneous spatial distribution of sucrose, Bsc Thesis • Marieke Ribberink: Sensory Perception of 3D Printed Chocolate Waffles, Bsc Thesis • Xinwei He: 3D food printing – irregular extrusion performance related to pea protein isolate concentration and the presence of pea fiber, Msc Thesis

Articles in professional journals/magazines: NA
(Poster) presentations at workshops, seminars, or symposia. Presentations Sicong EFFOST annual meeting (13-11-2019, Rotterdam): 3D printing: relationship between printability of ingredients and their rheological properties 3D Food Printing Conference (27-06-2019, Venlo): 3D printing: relationship between printability of ingredients and their rheological properties Meeting with Eindhoven 3D printing PhD's (13-06-2019): 3D printing: relationship between printability of ingredients and their rheological properties
TV/ radio / social media / newspaper: NA
Remaining deliverables (techniques, devices, methods, etc.): NA