General information	
PPP number	AF-15262
Title	*PPS Personalised Nutrition and Health*
Theme	Consument & Keten; Voeding & Gezondheid; Smart Agri&Food
Executive knowledge institution(s)	TNO, Wageningen Food and Biobased Research (WFBR) and Wageningen Economic Research (WEcR)
Research project leader (name + e-mail address)	Marjan van Erk (marjan.vanerk@tno.nl)
Coordinator (on behalf of private parties)	Jettie Hoonhout (Philips)
Government contact person	Cor Wevers
Total project size (k€)	4.741 kEUR
Address project website	https://www.personalisednutritionandhealth.com
Start date	1-7-2016
End date	31-12-2020

Approval coordinator/consortium The annual report should be discussed with the coordinator/the consortium. The TKIs appreciate being informed of possible feedback on the annual report.	
The coordinator has assessed the annual report on behalf of the consortium:	x approved □ rejected
Possible feedback on the annual report:	

Summary of the project	
Problem definition	The societal and economic effects of unhealthy diet and lifestyle in the Western world are dramatic. Public health campaigns, most of them with a one-size-fits-all approach, have hardly been effective in mitigating the nutrition related non-communicable diseases and its consequences. A new consumer centered paradigm has emerged based on empowered consumers receiving tailored personal dietary advice that takes into account many different individual parameters, such as personal preference, motivational goals, habits, social environment, genotype, phenotype, and broad measures of personal health status.
Project goals	This PPP program is a joint TNO/Wageningen Research initiative to develop innovative systems that enable consumers to make optimal food choices by providing personalized coaching based on smart and easy do-it-yourself measurements of health and behavior. The ultimate goal is to enhance the health and wellbeing of society by empowering consumers to choose and maintain an optimal personalized diet & lifestyle. The consortium has a unique approach in that it combines different scientific disciplines and involves a broad selection of private partners spanning the entire value chain of personalised nutrition and health. The program focuses on developing knowledge and technology (in workpackages) as well as on implementing/piloting a number of

	working prototypes of personalised nutrition concepts (in use cases/business labs/living labs).

Results

Planned results 2019

In 2019, we aimed to successfully finalise the phase-1 study of Living Lab fiber, to wrap up and evaluate the pilot study in Business Lab 'Office Restaurant' and to organize the first European Conference on Personalised Nutrition and Health. In addition, the (delayed) pilot on continuous glucose monitoring was planned for 2019, as well as continuation of the work and deliverables in the work packages according to the workplan.

Achieved results 2019

In 2017, 3 use case pilot studies were performed: Use case A 'highly motivated consumers', Use case B 'low SES families' and Use case C 'employees@work'. In 2018, the results from these 3 pilot studies were analyzed and reported. The lessons learned from these use case pilot studies were the basis of the 6 so-called 'dedicated projects (DPs)' that we defined for 2018. These DPs focused on specific elements of the PNH circle in smaller, dedicated pilots or tests. Partners of the PNH consortium were invited to actively contribute to these Dedicated Projects. In 2019, the results of these DPs fed back into the work packages and the Living Lab Fiber (see also Figure 3 below).

Main activities and outcomes of 2019 are described below.

Living lab Fiber:

Outcome of 2019 is reported separately, see below.

The partners in this project are MaagLeverDarm stichting (MLDS; also PNH partner), Sensus, Bolletje, Sonneveld and Kellogg (partners in this specific living lab).

Pilot study in Business lab:

In 2019 the business lab 'personalised nutrition advice in office restaurant' conducted a pilot study in an office restaurant run by Albron. In this study, specific tools and services from different companies (i.e., OME Health, Albron, and BASF) were combined, adapted and tested in a real-life office setting to gain deeper understanding in user's needs for personalised nutrition advice at the office.

During 12 weeks, 70 office workers received advice about which restaurant offer of that day would best fit their personal health. The advice was based on filled out questionnaires on dietary intake, preferences, health parameters as well as the status of Vitamin D and Omega-3 in their blood (finger prick, only before the study). Apart from the lunch advice, participant received advice on vitamin D supplements, recipe suggestions for breakfast, dinner and snacks, and participants had access to various other app functionalities including food logging and an online coach.

The motivation to participate, the experience during the study, the satisfaction and compliance of participants was measured both quantitatively (questionnaire and app use) and qualitatively (in-depth interviews).

The pilot study clearly showed the potential for offering personalised nutrition in a work setting. The service offered in the pilot study was initially received enthusiastically by employees. Within two days participants were recruited and participants were very positive about the possibility of receiving personalised nutrition advice in the work context. No negative remarks were given. People perceive it among others as convenient, additional to advice in the private sphere and as a token of being a responsible employer. Furthermore, some participants mention that having the support of their employee makes them trust the service better.

The current format, in which lunch advice was embedded in overall personalised health advice, including out-of-office hours was seen as an important aspect. As one of the participants stated: 'Advice in a work environment has added value. As standalone it would not be enough; you need an all-round service for a lifestyle change'. About the format of the offered lunch suggestions, participants were less enthusiastic. As a result, lunch suggestions were mostly not followed up on. Five important prerequisite for lunch suggestions were identified. One of which is that the suggestions should be complete menus including recommended portion size.

Apart from the evaluation of lunch suggestions in an office setting, the study also evaluated the other app functionalities and identified basic requirements of a personalised nutrition advice app in an office setting, as well as those elements that are perceived as 'extra's and the functionalities that caused excitement amongst participants. Interestingly, before the study started, participants

were reluctant about the added value of received supplement advice, identifying this advice mainly as potential disadvantage of participating the study. However at the end of the study, this advice was perceived as one of the main benefits. Understanding how users perceive different app functionalities guides app developers in the type of effort that should be put in the development of specific functionalities to avoid dissatisfaction and boost satisfaction of app-users.
The study also allowed for a better understanding in the impact of such a service on office restaurant practices and showed the importance of developing a roadmap that allows for a gradual development of personalised nutrition in the office setting. The study calls for further testing of various personalised nutrition products and services in various office settings to strengthen the knowledge base on personalised nutrition in an office setting.

DP5 Pilot on continuous glucose monitoring

As follow-up on the study performed for use case C in 2017/2018 on integration of continuous glucose monitoring, food logging and well-being as basis for personalized dietary advice, the DP5 study was organized to improve data quality by: i) only including participants with affinity for nutrition & health research to improve compliance; ii) adding time stamps to food logging; iii) additional measurement of contextual factors (sleep, activity, heart rate). From April to June 2019 the DP5 has been executed (figure 1), after which preliminary data analysis was performed.

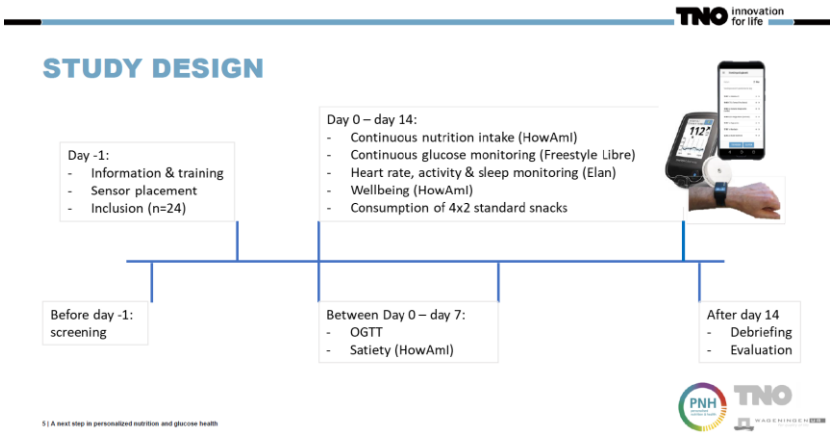

Figure 1. Study design DP5

Preliminary outcomes were the following:

- Data quality was good (figure 2)
- Data coverage was high for food logging (71%), cgm (98%), OGTT (92%), and EMA (100%)
- Satisfaction of participants was reasonable; they perceived food logging as intensive, but acceptable (7/10), CGM as relatively non-intrusive (7/10), OGTT as intrusive (6/10 - e.g., taste), EMA as relatively non-intrusive (7/10), and the Elan as intrusive due to data upload and battery charging (6/10).
- Heart rate, activity, and sleep data are yet available for data analysis (expected 2020)

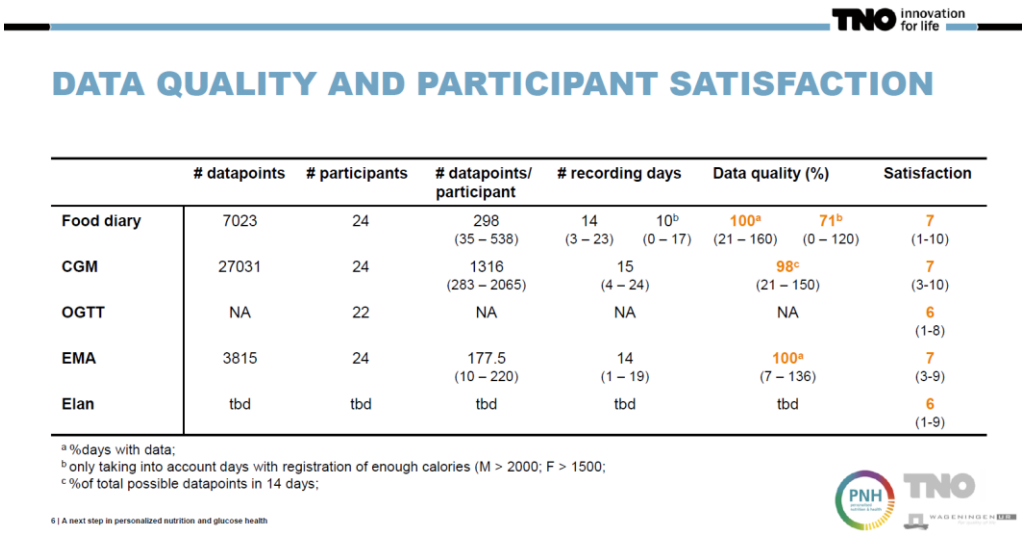

Figure 2. data quality and particpant satisfaction in pilot study

- Reproducibility of the glucose response to a standardized snack (Snelle Jelle) was low to reasonable. Further standardization is needed, as well as correction for contextual factors within the individual.
- Based on preliminary explorative data analysis: continuous glucose patterns (glucovariation) are likely associated with macronutrient intake (carbohydrate, fat, protein, fiber), as well as health status (OGTT response). Further confirmatory data analysis, also including contextual data, is required to substantiate these preliminary conclusions.
- The work has been disseminated at the 1st international PNH conference (8 october 2019, Wageningen) and the 6th Wearables in Practice symposium (3 october 2019, Den Haag)

<u>First European Conference on Personalised Nutrition and Health</u>
On 8 October 2019 PPS PNH organized the first European conference on Personalised Nutrition and Health in Wageningen, which was attended by 110 participants. The program, led by Rosanne Hertzberger, consisted of lectures, workshops and a panel discussion. The program and the aftermovie are available at the PPS PNH website.

<u>Results from work packages</u>
WP1 Measuring food intake and health status
- In 2019 an overview of different chatbot methodologies (conversational artificial intelligence) in area of food intake assessment and currently used within TNO and WR was made (D1.1).
- An algorithm was developed based on available food intake data from use case fibre to determine fibre intake in a less time consuming but accurate manner.

WP2 Data interpretation and reasoning
- In 2019 the work focused on development of the personal dietary advice tool for Living Lab Fibre. In deliverable D2.1 the design of this tool is related to the previous living labs in the PNH program. Some of the challenges in this use case were to measure of food intake (using a food frequency questionnaire), specify a sufficiently large set of food products and possible alternatives, to deal with different levels of 'self-regulation' and to support formulation of 'implementation intentions'. In the subsequent intervention study the participants were positive about the fact that the tool made them aware of their behaviour and choices.
- D2.1 Report describing (1) the advice engine developed use case MLDS in relation to previous use cases, (2) design choices made and (3) lessons learned.
- D2.3 Gives a technical description of the software APIs for the advice engines as developed for the different use cases.

WP3 Consumer behaviour
- In 2019, we further tested consumer acceptance of personalised nutrition & health concepts in the 'Business Lab Canteen' (see pilot study in Business Lab). By evaluating the experience with this field study, we gain further insight in consumers' (latent) needs,

motives and barriers with regard to the personalised nutrition (PN) advice. Additional consumers interviews were used to gain more in-depth insight in specific consumer preferences. Together, these activities resulted in Deliverable Business Lab Canteen.

- In 2019 we started writing two scientific articles based on the work of 2018: 1) "Personalised nutrition and health advice: preferred way of receiving information related to psychological characteristics" (Dijksterhuis et al.) and 2) "Identification of healthy eating strategies: predictors and consumer differences" (Verain et al.).
- In 2019 a revision for the journal PLOS ONE was made for the article "Consumer acceptance of personalised nutrition: The role of ambivalence, contextual factors and different target groups." (Reinders, M.J., et al.).
- In 2019, in a new consumer survey (n = 754), we further tested the attractiveness of different personalised feedback/advice-concepts taking the results from 2018 into account. For this purpose, we made pictures of how an interface could look like in different formats. First results show that the advice should be concise and easy. Participants who chose the 'whole grain scenario' seem to have a higher need preference for: 1) a more detailed explanation (e.g. a fixed plan on how to implement the advice), 2) insight in their own performance history and 3) receiving reminders with why it is important for them to adhere to the advice. As a next step, analyses linking the preferences to different types of consumers are carried out. In 2019 the effectiveness of advice was further examined in an experimental study where we looked at so-called 'spillover effects': When getting a personalised advice at work, are consumers going to follow-up the advice at other meal moments/ contexts (positive spillover) or just the opposite (negative spillover). Fieldwork was conducted in December 2019.

WP4 Health data

- In 2019 activities focused on personal health data storage framework.

WP 5 Food data

- This work package produced a data model and list of products and their properties for use in the living lab Fibre. One of the issues is that different data sources apply different classifications, which make it difficult to relate them. In addition, an overall taxonomy of food products has been created, that serves as a backbone for further use cases. In these cases specific extensions (for example 'fitting eating moments' or 'typical taste' can be added). For this development we also link to the international food supply chain ontology 'FoodOn.org'.
- D5.4 describes the publicly available nutritional ontology on http://www.foodvoc.org. It contains 6000 products with Dutch and English labels.

WP6 Business models

- Activities focused on the business lab 'personalised advice in office canteen'.

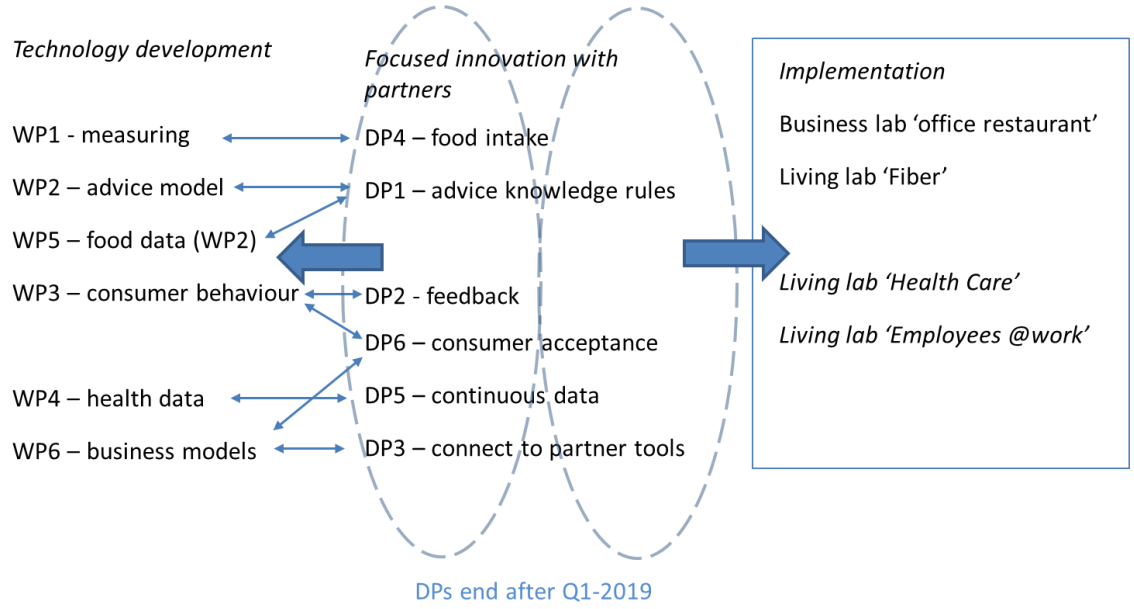

Figure 3. Overview of the PNH activities in 2019, with results of the Dedicated Projects feeding

back into the technology development and the implementation activities. Living lab 'Health Care' and 'Employees@work' will be set-up as new projects (PPS), separate from PPS PNH.

Planned results 2020

In 2020, the phase-2 study of the Living Lab fiber will be conducted and outcomes evaluated. Furthermore, the team will focus on wrap up of activities and dissemination of results; a limited set of research and tool optimization activities will be conducted, a.o. in connection with the phase-2 study of Living Lab fiber.

This is the final year for the PPS PNH in its current form. The team will work towards 2-3 new, dedicated PPS projects that build upon the outcomes of this PPS. Planned results in the work packages are as follows.

WP1 will further test and evaluate the smart tool for assessing fiber intake and will write a paper on the methodology.

WP3 will finalize the 2019 papers and will write a paper on the role of personal characteristics and context-specific factors (such as the type of product category to which the advice relates) in understanding and predicting the way consumers would like to receive feedback and advice about their diet. The analysis of the results of the spillover study will be reported and incorporated in a paper.

WP2 and WP5 will finalize a number of deliverables. D2.4 reports on the acquisition and modelling of context-specific food-health relations. In PNH we have constructed a number of knowledge rules that directly relate health parameter values to food categories that need attention. D5.3 (that includes D5.1) is an extensive report available data sources, data quality and data models (vocabularies) that are currently available.

WP4 will write and publish a white paper on governance of (health) data.

Deliverables/products in 2019

Scientific articles:

- Reinders, M.J., et al. "Consumer acceptance of personalised nutrition: The role of ambivalence, contextual factors and different target groups." (under review PLOS ONE)
- Verain, M.C.D., et al. "Identification of healthy eating strategies: predictors and consumer differences." (to be submitted to Appetite)
- Dijksterhuis, G., et al. "Personalised nutrition and health advice: preferred way of receiving information related to psychological characteristics." (rejected Psychology & Health, to be resubmitted to another health psychology journal)Van de Haar et al. Personalized dietary advice: Exploring its potential for health improvement in highly motivated persons with metabolic syndrome (to be submitted)
- De Hoogh et al. "Design issues in personalized nutrition advice systems" (to be submitted)

(External) reports:

- Bouwman, E. et al. (2019). Consumer preferences for different formats of personalised nutrition and health services.
- Reinders, M. et al. (2019). Acceptance of Personalised Nutrition & Health by consumers - Consumer study report results.
- Savelkouls, C. et al. (in preparation). Personalised Nutrition in the Office Restaurant: The motivations, experiences, compliance and satisfaction of participants - Business Lab Outcomes.
- Featured in Personalised Nutrition Trend report - Qina Consultancy
- Interview for PN trend report - ShootMyFood

Articles in professional journals/magazines:

Doets, E., & Hoogh, I. de (2019). Gepersonaliseerde leefstijladviezen ook bij ouderen effectief. *Voeding NU*, 20 november 2019 (https://www.voedingnu.nl/voedingswetenschap/artikel/2019/11/gepersonaliseerde-leefstijladviezen-ook-bij-ouderen-effectief-10113398)

Interview Food Industry hi-tech

Article, Food Ingredients

(Poster) presentations at workshops, seminars, or symposia.

Organisation of First European conference on Personalised Nutrition and Health (8 October 2019),

with oral and poster presentations on PPS Personalised Nutrition and Health activities.

Personalised Nutrition and Health- an integrative approach. Presentation given by Marjan van Erk at TIFN Food Summit on Personalised Nutrition: High hopes from the low lands. 4 Dec 2019

Consumer science in personalised nutrition and health. Presentation given by Machiel Reinders at Big data meets food - Sweden meets The Netherlands, Malmö, 15 May 2019

Poster on *Designing automated dietary guidance* at 34th EFFoST International Conference 2019, Rotterdam, The Netherlands,

Presentations by Nard Clabbers on PPS PNH at:
- Personalised Nutrition Hackathon Berlin
- NX Food Seminar on personalised Nutrition, Germany
- BASF corporate presentation Ludwigshafen
- BASF Business presentation, Manchester
- Vitafoods chair Personalised Nutrition Seminar
- HI Paris, chair, panel leader and presentation on personalised nutrition
- Rabobank corporate presentation Personalised Nutrition, Ireland
- Personalised Nutrition seminar, presentation, Sweden
- Brain health and personalisation, Presentation FML, London
- Presentation European Personalised Nutrition Summit, London
- Corporate presentation CJ, Korea
- Emerce Digital Food conference, presentation, Amsterdam

TV/ radio / social media / newspaper:
- ONVZ special NRC addition on personalized nutrition

Remaining deliverables (techniques, devices, methods, etc.):
A webtool for personalised advice related to fibre intake, www.vezelup.nl
Smart tool for assessing fiber intake.

https://www.wur.nl/nl/Onderzoek-Resultaten/Topsectoren/show/Personalized-Nutrition-Health.htm

Living Lab Fiber

General information	
PPP-number	AF-15262
Title	Stimulating fibre intake by personalized dietary advice (PNH – Living Lab More Fibre phase 1)
Theme	
Implementing institute	WFBR, WEcR, TNO
Project leader research (name + e-mail address)	Nicole de Wit (nicole.dewit@wur.nl)
Coordinator (on behalf of private partners)	MLDS
Project-website address	
Start date	1-8-2018
Final date	31-12-2020

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:	

Summary of the project	
Problem definition	Within the Personalised Nutrition & Health (PNH) program, this project (LL More Fiber) was initiated in collaboration with the Maag Lever Darm Stichting (MLDS). In phase 1, this project focusses on supporting healthy people to increase their daily fibre intake, which is in general below the recommended intake of 30 or 40 grams/day for women and men, respectively (or 14 grams/1000 kcal). An adequate fibre intake can improve gut health, can reduce the risk for various diseases, such as cancer and cardiovascular disease and it can support maintenance of a healthy body weight.
Project goals	The aim of this project is to increase daily fibre intake, ideally up to the recommended intake by generating and providing personalized dietary advice (PDA). Knowledge obtained from the previous projects within PNH are enrolled in this new project. This project will generate valuable, digitized knowledge on the added value of personalized dietary advice to increase fibre intake. This knowledge empowers consumers to change their dietary habits and thereby improve their health status. Next to question on effectiveness of a personalized dietary advice to increase the daily fibre intake, it will be evaluated how the advice will be perceived by the consumer. The knowledge obtained within this project will also be expressed (formalized) in such a way that it can be used in smart software solutions.

Results	
Planned results 2019	-Development of the personalized dietary advice (modelling) to increase fiber intake. -Development of a (digital) tool to provide the personalized dietary advice (PDA). -An intervention study that will be performed to validate whether personalized dietary advice adds additional value to the current general advice of 'Voedingscentrum' and 'MLDS' for increasing fiber intake.

Achieved results 2019	-In 2019, an algorithm was developed to generate a PDA to increase fibre intake based on the current eating pattern of people. This algorithm was incorporated into a digital tool (website: www.vezelup.nl) where people, by personal login, could generate their own personalized advice: 1) They could choose fibre-rich alternatives for the products that they currently eat (e.g. fibre-rich pasta instead of refined pasta). By choosing these fibre-rich alternatives, people got immediate feedback on their fibre-intake, so 'what does it mean for me if I make these changes in my diet', 2) additionally to these fibre-rich alternatives, people could also choose extra fibre-rich products (fruit, vegetables, legumes and nuts) to add to their diet to reach the fibre intake recommendations. -After finalizing the digital tool (website: www.vezelup.nl), an intervention study, called Vezel UP, was performed. This was a single-blind randomized controlled trial, which included a 6-week intervention and 3-month follow-up with two groups: the 'intervention' group that received the general advice of 'Voedingscentrum' and 'MLDS' + PDA (n=34) and a 'control' group that only received the general advice (GA) (n=47). After the 6-weeks intervention, the control group also got access to the PDA. Dietary intake and psychological questionnaires were assessed during week 1 and 6, and at 3-month follow-up. Fecal short chain fatty acid (SCFA) were measured during week 1, 3 and 6. Stool pattern and self-reported efficacy of high-fibre intake were assessed daily. The website www.vezelup.nl was evaluated after 6 weeks. *Results:* After 6 weeks, both groups increased fibre intake per 1000 kcal (ΔPDA=0.5±2.8, ΔGA=0.8±3.1, p=.128). Significantly more PDA-participants adhered to the recommendation of 14 grams/1000 kcal (PDA=21% increase, GA=4% increase, p=<.001). Self-reported efficacy of increasing fibre showed a dip in the weekend (p=.58). At 3-month follow-up (both groups had now access to the PDA), both groups increased fibre intake compared to baseline, but was not different between groups. The PDA-group evaluated the advice significantly better regarding knowledge on how to improve fiber intake (5.9±0.9, 5.3±1.4, p=.033), liking the advice (5.5±1.4, 4.4±1.3, p<.001), easiness of the advice (5.1±1.3, 4.2±1.8, p=.010), motivating to make high-fiber choices (5.2±1.4, 4.5±1.7, p=.055), personal fit (4.8±1.6, 4.0±1.7, p=.032) and working towards a goal (5.0±1.6, 4.1±1.6, p=.021). There were no significant differences in psychological factors between the groups. Within participants, subjective health (4.9 versus 5.1, p=.010), self-efficacy (5.1 versus 5.3 p=.030), subjective knowledge (3.4 versus 4.5 p<.000) and outcome beliefs (5.1 versus 5.5, p=<.000) increased after the 6-week intervention compared to baseline. Although both groups showed variations in fecal SCFA concentrations over time, the average concentrations did not significantly change over time. *Conclusions* (including potential implications): the PDA tool is well-accepted by participants, and feasible for increasing long-term dietary fibre intake. This knowledge helps to design and further develop future personalized dietary advice tools.
Planned results 2020	In phase 1 of this project, we targeted healthy people to increase their fibre intake. In phase 2, that is planned in 2020, we aim to support especially constipated people to increase their fibre intake by providing personalized dietary advice. Next to the effect of PDA on increased fibre intake, this study will now also focus more on subsequent effects on stool pattern and relieve of constipation symptoms. In phase 2, we also want to improve the PDA-tool and implement the 'lessons learned' from phase 1.

Deliverables/products in 2019 (provide the titles and /or a brief description of the products/deliverables or a link to a website.
Scientific articles:
External reports:
Articles in professional journals/magazines:
(Poster) presentations at workshops, seminars, or symposia. - Poster 1st European Conference Personalised Nutrition & Health (8-10-2019, Wageningen) - Poster PhD tour Iris Rijnaarts (October, Canada) - Workshop Business day WUR (26-9-2019, Wageningen)
TV/ radio / social media / newspaper: - MedicalFacts.nl: Massale vezel-dip op zaterdag - Margriet online: op deze dag in de week eet bijna iedereen te weinig vezels - Meerovervezel.nl: Maag Lever Darm Stichting: 'Vezelrijk voedsel ook in het weekend van groot belang voor een gezonde spijsvertering' - MLDS (website, facebook, LinkedIn, Instagram): Massale vezeldip op zaterdag
Remaining deliverables (techniques, devices, methods, etc.): - PDA tool: www.vezelup.nl (mainly a research tool, not commercially available yet)