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# Protein Transition Investment Theme

End-term report 2019-2022



**WAGENINGEN**  
UNIVERSITY & RESEARCH

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# Protein Transition Investment Theme

End-term report 2019-2022

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Wageningen, March 2023

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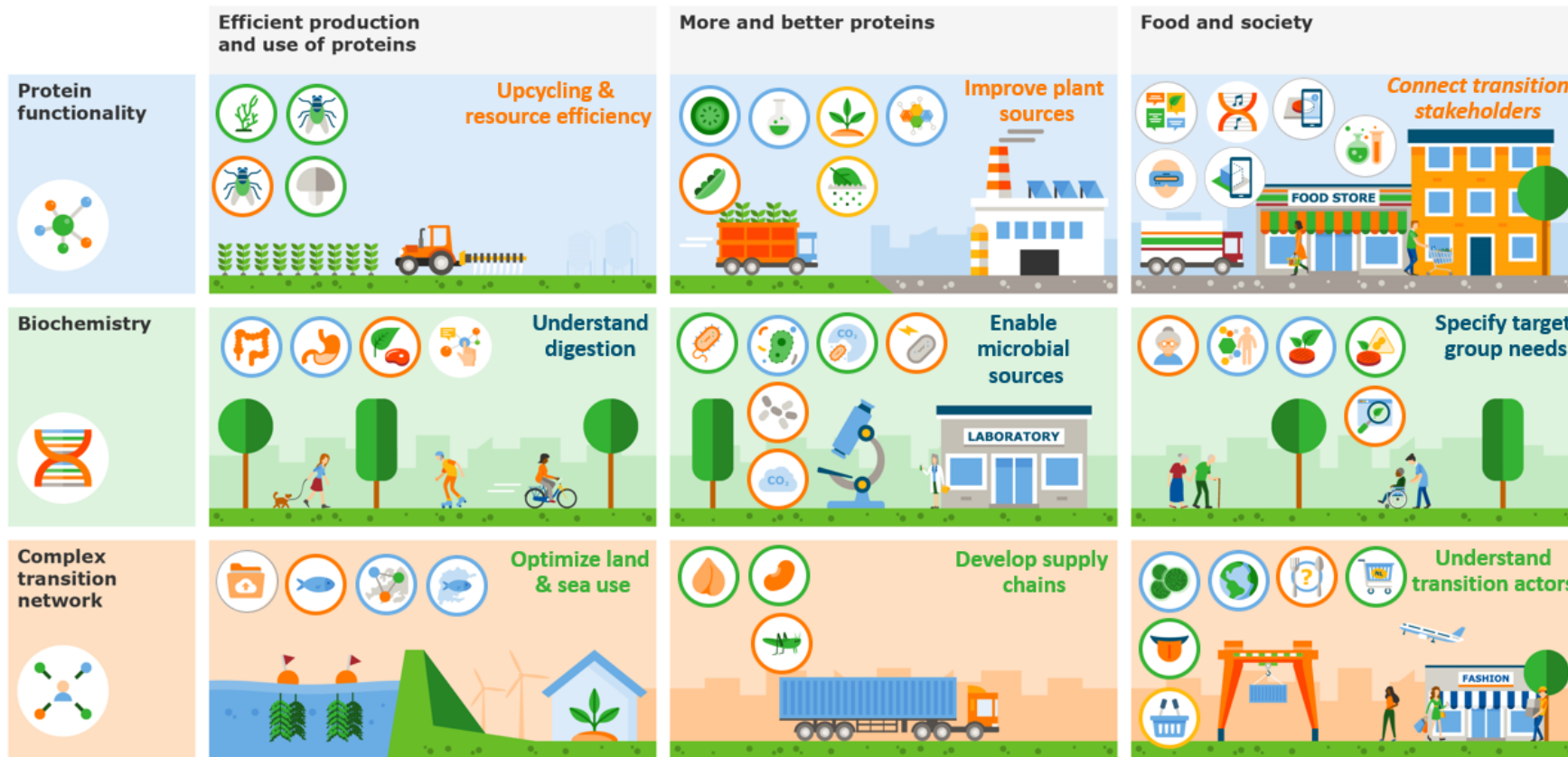
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# 1 Introduction



Protein Tr



● Community-funded projects 
 ● Seed projects 
 ● Directed call projects 
 ● Investment plan PhDs

More information about Protein Transition you can find in our [dossier](#) at the website of Wageningen University & Research.

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## 2 Science Themes

### **Protein functionality**

Structure-function relationships, including both physical and biological functions of proteins, are still poorly understood, owing at least in part to the multi-lengthscale nature of protein structure development. A basic means to understand and model protein behaviour does not yet exist. Molecular understanding is insufficient to describe the complexity of secondary, tertiary, and quaternary structures. Further, structuring and the structure/texture experienced during eating is mostly driven by phase behaviour in complex protein-rich mixtures. In addition, most of the protein structures in traditional food and feed products are pH responsive, modulated by minerals, and processing-history specific. New tools for quantitative study of protein structuring are needed.

*Projects in this science theme advance fundamental understanding of functional pathways, for example by length scale jumping, studying intrinsic functional properties, or mapping functional landscapes.*

### **Biochemical processes**

Proteins are made by and used by living organisms; every protein-related process is biochemistry. This insight, while completely obvious, has sparked ground-breaking innovation worldwide in recent years. From the assumption that every biochemical process which takes place in a plant or animal can also take place in a lab, ground-breaking innovations have appeared in recent years. In-depth understanding of biochemistry in animals and humans provides the development guidelines for production of new functional and nutritional proteins, with demonstrated health, and other safety qualifications. The animal nutrition industry is arguably the most advanced in understanding protein-specific nutrition and conversion to muscle mass. In human nutrition, emerging research delivers insights into how specific protein-derived components impact a spectrum of biological processes: muscle, heart, cognitive, immune, endocrine, and satiety.

*Projects in this science theme deliver new knowledge of biochemical pathways underpinning protein conversion, or apply known biochemical pathways in a new context to deliver new functional or nutritional proteins.*

### **Complex transition network**

The global protein market is a complex network of interconnected actors operating at divergent length scales. Each actor makes a specific individual behaviour choice within the context of societal, social, and environmental cues. The total aggregate result of all individual actions determines the collected outcome: a positive or negative impact toward, for example, the sustainable development goals. Achieving a true protein transition requires a deeper understanding of this complex, interconnected network. A transition follows different pathways and paces. Various stakeholders have different interests, constraints, and mindsets and preferences – constructive or obstructive to protein transition. To be able to achieve protein transition inside this complex network, the desirability and feasibility of various future visions and scenarios should be elucidated. Future scenarios should consider impact on land use, economics, farm livelihoods, public health, and living environment. Transition pathways of designing, experimenting, learning, and institutional innovations toward systems change should be identified and evaluated. Path-breaking ways of triggering systems change should be defined and tested.

*Projects in this science theme deliver understanding of the complex network of protein-related actors, contribute to impact-based prioritization of intervention modes, or provide path-breaking processes for learning and institutional change.*

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## 3 Impact domains

### Efficient production and use of proteins

- a. *We aim to improve the **nitrogen efficiency** of global protein production systems.* Circular systems for protein production can be particularly useful in preventing nitrogen runoff into fresh water and retaining soil quality. Nitrogen-fixing crops contribute to total available protein worldwide. The most novel technologies capture nitrogen directly, for example nitrogen-capturing wind energy systems (wind + air + water = nitrogen).
- b. *We aim to **reduce protein losses**.* Food loss or waste per continent ranges from 15% in Latin America to an astonishing 42% in North America and Oceania. In sub-Saharan Africa 23% of food is lost or wasted, of which 95% before reaching a potential consumer. In an areas of scarcity, this represents an enormous humanitarian crisis. Affordable, robust, and locally-appropriate supply chain solutions are urgently needed.
- c. *We aim to **reposition protein source usage**.* Wageningen scientists have already called for a return to the original role for animals in upcycling waste and valorising land and sea resources. Animals can be used to “upgrade” side streams and sources with low nutritional value, and side streams that are currently used for non-food purposes. Some animal protein sources are clearly more efficient protein providers than others. When using alternative low grade sources to feed animals, the consequences for food safety should be carefully characterized.

### More and better proteins

- a. *We aim to deliver **novel protein sources and production systems**.* Some new source proteins are based on familiar food and feed components, like legumes. Other, much more novel sources, should be explored for the longer term. For example, while single-celled organisms might have the potential to be among the most efficient protein sources, their potential for food and feed production remains largely untapped. Innovative companies are pursuing yeast-expressed ‘clean milk’ or methane-based biomass growth. As-yet unknown, out-of-the-box solutions and production methods should be pursued for their potential to disrupt the status quo.
- b. *We aim to **improve and diversify the existing set of proteins used for food and feed**.* Just 15 plant crops provide 90% of the world’s food energy intake. These crops do not themselves provide adequate nutrition, neither in amino acid profile nor in micronutrient delivery, leading to nutritional (over)dependence on animal proteins. Improvements are needed in protein quantity and quality, and diversity. Existing proteins may also come from side streams, as-yet unused fractions of crops, or even by upcycling from waste.
- c. *We aim to increase **climate-robust protein supplies for fragile areas**.* The FAO estimates that 70% of undernourished people worldwide also live in regions with high exposure to climate extremes. Without climate-robust, financially sustainable supply chains in place, the coming years will see an acceleration in hunger and mass migration. Breakthrough solutions for climate-robust protein sources are urgently needed.

### Food and society

- a. *We aim to integrate and explore protein production systems as an integral part of our **shared landscape**.* Protein production is a pillar of economic activity and a driver of land and sea use. Optimization for more and better proteins should be done in the context of maintaining social and societal well-being.
- b. *We aim to deliver breakthroughs in quality of **plant-based foods**.* Rich-world consumers have increased their animal protein consumption drastically in the past 50 years. A majority of Dutch consumers indicate a wish to eat more plant-based, but many report that the current offering of plant-based alternatives does not meet their demands.
- c. *We aim for a total consumer environment which motivates **(re)balanced plant-animal ratios globally**.* Excellent plant-based foods are an important part of driving consumers toward healthy, sustainable choices, but not the only solution. Various Wageningen groups have already shown that subtle nudges and social signals can influence behaviour. Western consumer culture need not remain the global aspirational standard, and urbanizing consumers in developing countries should be offered appealing and healthy options.

- 
- d. *We aim to **accelerate the transition**.* A transition follows different pathways and paces, various stakeholders have different interests, possibilities to act as well as different mindsets and preferences – in favour of Protein Transition or obstructive. In order to achieve a true transition, 'alternative' politics, governance, ethics and economics must help to accelerate – rather than frustrate – the protein transition.

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## 4 Project types

### Directed call projects

#### *Investing in teams*

In the areas defined by the intersection of the science themes and impact domains, directed calls are used to invite researchers from Wageningen science groups to design a transdisciplinary project to create breakthrough solutions.

### Community-funded projects

#### *Investing in content*

Community-funded projects are intended for front-line innovation feasibility studies running from 6 months up to 2 years. Projects are pre-selected for their fit to the science themes, contribution to the impact domains, and high-risk, high-reward character. Funding is allocated via a 'crowd funding' type platform.

### Seed projects

#### *Investing in people*

Seed projects are targeted funds to support young professionals to submit grants in topics related to the protein transition in order to attract and maintain talented scholars for WUR.

### PhD projects

Three PhD projects were granted to the Theme in 2019. The PhD topics were selected to deepen the scientific developments of the three science themes.

### Outreach projects

#### *Investing in engagement*

Because of the importance of creating protein literacy and catalysing systems change, the protein transition group also includes the option to fund outreach projects. These projects aim to innovate in dissemination to a broad public and/or to bring together a unique set of actors.

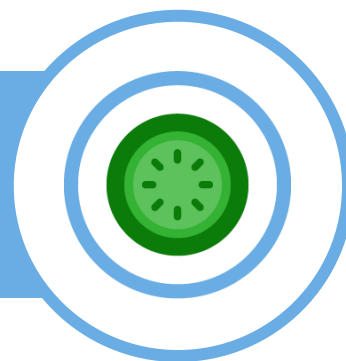
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## 5 Projects

### **PROTEIN FUNCTIONALITIES**

**DIRECTED-CALL PROJECT 2019-2020**

**193.000€**



#### **CONTACT**

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Luisa Trindade, Peter Wierenga,  
Marinus Krimpen  
*Plant Breeding, Food Chemistry,  
Animal Nutrition*

#### **AIM**

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To 1) Plant: chemically characterize proteins from Agricultural side and explore potentialities of novel feedstock's for food and feed applications; 2) nutritional functionality: in vitro testing; 3) feed application: new, more advanced types of in vitro models will be tested and compared with existing ones.

#### **RESULTS**

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- A new high-throughput method for the characterization of foaming properties on protein from different plant sources has been developed.
- The chemical composition of a diverse set of agricultural waste streams has been characterized, including 15-30% amounts of protein.
- Potential toxic effects of protein extracts from different waste streams has been investigated on animal cells (no toxicity).

#### **OUTPUT**

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- [NEW PROJECT] TKI proposal: results of chemical and functional analysis have been input.
- [NEW PROJECT] TTW proposal: toxicity of different agriculture side streams have been input.
- [NEW PROJECT] Two PhD projects have been financed and informed by the results of this project. (approved).
- [OTHER] Prototype testing of screening method implemented in TIFN projects.

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# GGI FERMENTATION

DIRECTED-CALL PROJECT 2019-2020  
193.000€



## CONTACT

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Nikkie van der Wielen, Edoardo Capuano  
*Human Nutrition & Health, Animal Nutrition, Food Quality & Design*

Edith Feskens, Vincenzo Fogliano, Wouter Hendriks, Renger Witkamp, Hauke Smidt, Paul Moughan

## AIM

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To link amino acid composition and digestibility of an array of protein sources to the formation of metabolites and changes in microbial composition that may be beneficial or harmful.

## RESULTS

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- Protocol for applying human ileal digesta in the Simulator of Human Intestinal Microbial Ecosystem (SHIME®) model, a semi-dynamic fermentation model that allows to study the metabolic fate of dietary components in different segments of the large intestine.
- The highest level of protein metabolites was detected upon fermentation of commercial SHIME feed, which also contained more protein available for fermentation compared to the ileal digesta samples.
- Level of protein fermentation metabolites differed among ileal digesta samples collected after ingestion of different protein sources. Strong correlations were shown between protein amino acid composition and fermentation metabolites produced. These metabolites generally derived with known catabolic pathways.
- In the SHIME system the majority of protein fermentation took place in the distal colon. Higher carbohydrate to nitrogen ratio resulted in lower protein fermentation in the proximal colon. These results are consistent with the well-known paradigm that protein fermentation mostly occurs in the distal part of the colon after the depletion of carbohydrates in more proximal segments of the colon. However, some specific tryptophan catabolites were present in higher concentrations in the proximal colon.
- The largest comparison among protein sources in terms of protein fermentation in the large intestine.

## OUTPUT

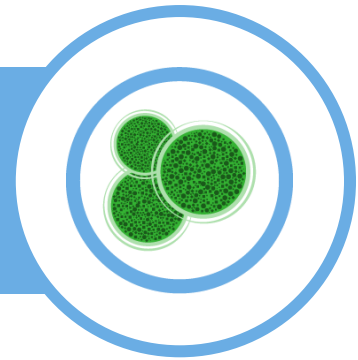
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- [PUBLICATION] Scientific publication (in preparation).
- [NEW PROJECT] PhD student continues to study protein fermentation with supervision from three involved groups in the project: "Ingestible sensor for protein fermentation". (approved).



# SUSTAINABLE PROTEIN ACCEPTANCE

DIRECTED-CALL PROJECT 2019-2020  
193.000€



## CONTACT

Siet Sijtsema, Geertje van Bergen,  
Hans Dagevos  
*Consumer and Chain, Consumer  
Science Urban Economics*

Machiel Reinders, René de Wijk,  
Gertrude Zeinstra, Mariët van  
Haaster-de Winter

## AIM

To understand the (sub)conscious drivers and barriers underlying sustainable protein consumption and adoption:  
(a) targeting (sub)conscious processes in consumers;  
(b) defining and comparing consumers segments;  
(c) comparing multiple protein categories instead of investigating one protein category in isolation, and  
(d) targeting intrinsic and extrinsic product properties.

## RESULTS

- Focus group study: the need of psychological support in terms of knowledge and skills (nutrition, recipes, preparation), and support from social and physical context for flexitarians.
- Online survey: for some visually identical dishes, consumers preferred a sustainable protein over an animal protein if they were unaware of the other option. When given the choice, animal proteins were preferred over sustainable proteins in all dishes. Consumers would rather order bean and mushroom dishes in a restaurant relative to preparing these dishes at home.
- Sensory study: meat replacers were liked better and tasted more tender to consumers who eat meat replacers more often, showing that taste preferences can change with experience. At the same time, flavour expectations prior to tasting were not met upon tasting. Highlighting the animal comparison hinders more often than drives sustainable protein acceptance.

## OUTPUT

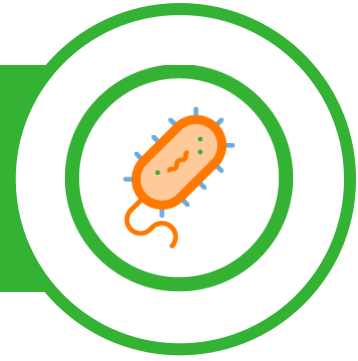
- [PUBLICATION] Dagevos (2021). [Finding flexitarians: Current studies on meat eaters and meat reducers](#). Trends in Food Science & Technology, 114, 530-539. (published; IF: 12.563)
- [PUBLICATION] Sijtsema, S. J., Dagevos, H., Nassar, G., van Haaster de Winter, M., & Snoek, H. M. (2021). [Capabilities and opportunities of flexitarians to become food innovators for a healthy planet: two explorative studies](#). Sustainability, 13(20), 11135. (published; IF: 3.889).
- [PUBLICATION] Manuscript on sensory study results to Food Quality and Preference (in preparation).
- [OTHER] Management summary including recommendations for intervention strategies (pending).

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# MICROBIAL MEAT

COMMUNITY-FUNDED PROJECT 2019-2020

89.000€



## CONTACT

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Jeroen Hugenholtz  
*BBP Bioconversion*

Mark Sturme, Laurice Pouvreau,  
Piyali Chakraborty,  
Rick van de Vondervoort,  
Frits de Wolf, Marc Werten

## AIM

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All required components for “microbial meat”- various proteins, fat, and nutrients – can be produced by fermentation.

A meat-like food product can be constructed from these individual components.

## RESULTS

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- Protein content in microbial biomass was above the minimum required values for good processing by 3D-printing and shear cell technology, while dry weight and fat (lipid) content were a bit below the desired levels for good processing by both technologies.
- IP opportunities with regard to protein production by *Yarrowia lipolytica* and *Bacillus subtilis*.

## OUTPUT

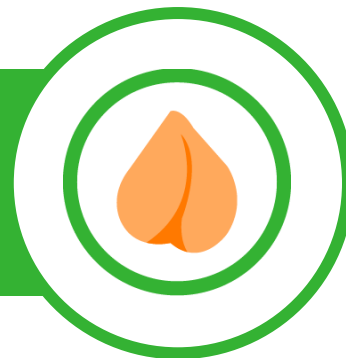
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- [PRESENTATION] GFI Symposium on Fermentation, 20/10/20.
- [NEW PROJECT] TKI 2020 project on Microbial Heme for meat alternatives; start: April 2021 (approved).
- [NEW PROJECT] Two bilateral projects with new partner on microbial heme production. (approved).
- [OTHER] Contribution to the Nationale Eiwitstrategie.

# WEST AFRICAN PROTEIN CROPS

COMMUNITY-FUNDED PROJECT 2019-2020

114.000€



## CONTACT

Thom Achterbosch & Gijs Kleter  
*Wageningen Economic Research,  
Wageningen Food Safety Research*

Arnout Fischer, Ruerd Ruben,  
Atze-Jan van der Goot,  
Matthijs Montsma, Klaas van Rozen,  
Ken Giller, and other WUR experts

## AIM

To highlight how African pulses can serve as novel, nutritious and more diversified protein sources, and to search for novel applications for pulse & legume proteins in human food and livestock feed. For the latter it is also important to stress that it will aid in diversifying the supply of sustainably produced plant protein for the EU, whilst contributing to sustainable food systems and food safety & quality in Africa.

## RESULTS

- The European protein transition might give traction to the development of West-African food systems. West-African pulses and legume crops in the EU have market prospects in the EU as a safe, ethical, and environmentally acceptable alternative to current imports.
- There is untapped consumer demand and supply potential for pulses for human consumption in West Africa. Finding market opportunities abroad that will strengthen Africa's pulses and legume sectors.
- Future trade and business opportunities with EU are for pulse grains in low-processed and high-processed form and must be rooted in an African pulses transition (soybean, cowpea, bambara groundnut).

## OUTPUT

- [PUBLICATION] Schlangen et al. (2022). Dry fractionation to produce functional fractions from mung bean, yellow pea and cowpea flour. *Innovative Food Science & Emerging Technologies*, 78, 103018. (published; IF: 5.916). <https://doi.org/10.1016/j.ifset.2022.103018>
- [REPORT] Kleter et al. (2020). Pulse of Africa: Exploring West-African soybean, cowpea, and Bambara groundnut.
- [PUBLICATION] (trade journal paper) Kleter et al. (2022) Are changing preferences an opportunity for grain legumes from West Africa? *New Food* (4), 50-52. (published)
- [MEDIA COVERAGE] (trade journal paper) Biedt Europese vraag naar plantaardig eiwit kansen voor West-Afrikaanse peulvruchten? (Dutch) [Does European demand for plant protein offer opportunities to West-African legumes?]. *VMT Voedingsmiddelentechnologie*, August 2022

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# TASTY PROTEINS

COMMUNITY-FUNDED PROJECT 2019-2020

88.000€



## CONTACT

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Guido Sala, Elke Scholten, Layla Broers  
*Physics and Physical Chemistry of Foods*

## AIM

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To understand more about the perception of alternative protein-based foods (meat analogues); improve the quality of foods with regard to mouthfeel and to develop tools to improve their quality; overall aim: improvement in quality would increase acceptability of meat analogues to increase choice for consumers; RQ: What is the relationship between Sensory, Texture & Structure of meat analogues?

## RESULTS

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- To increase liking of different meat analogues, it is very important to further understand the link between structural and textural aspects and juiciness.
- Also, we have shown that this is not a simple relation, but that juiciness is a combination of multiple aspects.
- Reasons for not buying meat analogues were linked to unappealing flavour and texture:
  - in terms of texture, hardness, chewiness, cohesiveness were not related to liking;
  - in terms of sensory properties, juiciness was related to liking, yet, no structural characteristics could explain juiciness (e.g. moisture or fat).

## OUTPUT

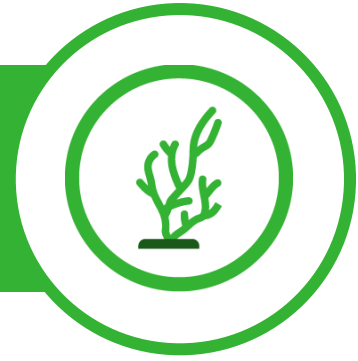
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- [PRESENTATION] shared with other FBR project "Plant Meat Matters" and "PlantPROMISE" and discussions are ongoing.
- [PUBLICATION] Godschalk-Broers et al., (2022). [Meat Analogues: Relating Structure to Texture and Sensory Perception](#). *Foods*, 11(15), 2227. (published; IF: 5.561).
- [NEW PROJECT APPROVED] Overview of results as input for PPS proposal "Improved sensory quality of meat analogues".

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# SEaweEDS

COMMUNITY-FUNDED PROJECT 2019-2020  
164.000€



## CONTACT

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Adrie van der Werf, Ingrid van der Meer, Romyana Karlova  
*Agrosystems Research, Bioscience, Laboratory of Plant Physiology*

## AIM

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To research seaweed extract application, to increase drought and salinity stress resistance of protein crops which will enable the substantial augmentation of arable land use especially under the climate change challenges that are expected.

## RESULTS

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- Seaweed extract (SWE) treatment is linked to improved salt tolerance of plants and they are reported to affect the early root formation.
- Strong link between an enhanced primary root elongation (tomato *Solanum lycopersicum L.*) and Seamel (commercial SWE) treatment is found in seedlings grown under salt stress.
- 25-40% yield increase under salt stress of the SWE-treated plants in hydroponics system.
- Metabolomics analysis of the plants and of the SWE were performed, giving insight in the molecular reaction of the plants treated with SWE and of the compounds present in SWE.

## OUTPUT

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- [PUBLICATION] Deolu-Ajayi et al., (2022). [The power of seaweeds as plant biostimulants to boost crop production under abiotic stress](#). *Plant Cell Environ.* 2022 Sep;45(9):2537-2553. (published; IF: 6.362). doi: 10.1111/pce.14391.

# WATER LENTILS

COMMUNITY-FUNDED PROJECT 2019-2020

15.000€



## CONTACT

Ingrid van der Meer  
*Bioscience*

## AIM

To finalise research on using the WUR patented extraction method that was developed for extraction of high value protein (mainly RuBisCO) from sugar beet leaves for the extraction of high value protein from the new plant protein source, water lentils.

## OTHER

Sub project of "Seaweeds" that was conducted in 2020

## RESULTS

- Insight in the use of water lentils as source for high-value proteins (mainly RuBisCO).
- Possibility to use water lentils in between the campaign of sugar beets of which the leaves are used for extraction of RuBisCO.
- Proteomics analysis applied to show the composition of the raw protein extract and the concentration/ extraction of water lentils high-value proteins that mainly consist of RuBisCO after extraction.

## OUTPUT

- [PUBLICATION] Nieuwland, M., Geerdink, P., Engelen-Smit, N. P., Van Der Meer, I. M., America, A. H., Mes, J. J., ... & Mulder, W. J. (2021). [Isolation and gelling properties of duckweed protein concentrate](#). ACS Food Science & Technology, 1(5), 908-916. (published).
- [MEDIA] I.v/d Meer (2020). [Eendenkroos ook voor mens een smakelijk en gezond hapje?](#) Scientias.
- [MEDIA] Meer, Ingrid van der (2022). [Eiwittransitie: waar staan we en waar gaan we naartoe?](#), EVMI, 2022-02-22, Mischa Brendel.
- [MEDIA] Meer, Ingrid van der , Pyett, Stacy (2022). [In het spoor van de eiwittransitie](#), Voeding Nu, p. 24-28, 2022-02-01, Mischa Brendel.
- [MEDIA] Nieuwland, M. (2021). [De drijvende kracht van eendenkroos : Onderzoek naar nieuwe eiwitten](#). Voedingsindustrie: vakblad 28 (2021)6. - ISSN 2213-5758 - p. 30 - 31.



# INSECT BREEDING

SEED PROJECT 2019

15.000€



## CONTACT

Esther Ellen, Aniek Bouwman  
*Animal Breeding & Genomics*

## AIM

To apply quantitative genetics and animal breeding that will be applied supporting development of healthy insect populations and to capture variation between individuals, to breed specific populations with distinct traits on waste products.

## INTENDED FUNDING

TKI Agri & Food – PPS Call

## OUTPUT

- [PRESENTATION] EAAP, exploiting genetic variation in insect populations, 03/12/2020.
- [NEW PROJECT] contributed to an IRFD research proposal in collaboration with Aalborg University (Denmark). (approved).
- [COLLABORATION] Started to collaborate with an insect company.
- [OUTREACH] initiated an EAAP session on insect genetics (2020).
- [OUTREACH] Masterclass 'Insect Biology, genetics and breeding'.
- [OTHER] Wrote a vision for Wageningen Livestock Research and Animal Breeding to use animal breeding to improve health and performance of insect populations.
- [OTHER] Signed up for cost-action on insects.
- [NEW PROJECT] PPP project on BSF breeding (start 2023). (approved).

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# ANIMAL FREE MILK

SEED PROJECT 2019

17.000€



## CONTACT

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Etske Bijl  
*Food Quality and Design*

## AIM

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To make large steps towards developing a sustainable, highly nutritious and animal-free alternative to cow's milk proteins that can be used to make vegan milk and dairy products.

## INTENDED FUNDING

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NWO (proposal NWA-ORC 2019- for grant of 1.9 million €)

## OUTPUT

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- [NEW PROJECT] Submitted to NWO; approved by NWA-ORC, "[Animal-free milk proteins](#)" (approved).

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# PROTEIN PUZZLE LATER LIFE

SEED PROJECT 2019

25.000€



## CONTACT

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Pol Grootswagers  
*Human Nutrition & Health*

## AIM

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To benefit our understanding of the potential of alternative protein sources in improving muscle mass in older adult.

## INTENDED FUNDING

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ZonMW calls

## OUTPUT

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- [NEW PROJECT] Submitted proposal to AAL Call 'Healthy Ageing with the Support of Digital Solutions' August 2020 (not approved).
- [NEW PROJECT] Successfully obtained by EU project AAL. Project successfully completed in 2022, and new grant proposals have been written.

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# FROM LEGUME PROTEIN MOLECULES

TO PROTEIN FUNCTIONALITY  
DIRECTED-CALL PROJECT 2020  
200.000€



## CONTACT

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Laurice Pouvreau, Twan America,  
Peter Wierenga  
*FFC Food Technology, Bioscience,  
Food Chemistry*

## AIM

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- To provide new tools to screen for glycosylation of storage proteins in different cultivars of seeds.
- To provide insight to which extent the glycosylation of plant proteins determines their bio-/techno-functionality.

## RESULTS

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- The aim of the project was to evaluate difference in legumin:vicilin ratio and in glycosylation between different pulses, and moreover to determine if these differences are linked to differences in functional properties.
- Five different legumes were selected, with different protein composition and differing in glycosylation: soybean, yellow pea yellow lentil, faba bean and kidney beans.
- This project implemented a new experimental and data processing approach to detect and quantify protein glycosylation by LC-MS, which revealed in high detail the presence of different glyco-forms of peptides. When compared to periodic acid staining (PAS) of protein gels, the LC-MS method proved to be more sensitive and provided actual isoform specificity.
- Surprisingly, a glycosylated isoform of vicilin was detected which was only abundantly expressed in two out of eight yellow pea cultivars tested.
- Differences in protein solubility, in protein aggregation and in emulsifying property were found but no correlation could be found between glycosylation and functional properties.
- Digestibility differed between legume sources (soy flour showed the lowest digestion, while faba bean flour the highest). In addition, differences in the digestibility in protein type was also detected.

## OUTPUT

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- [PRESENTATION] Protein Nutritional & Functional Quality at The Nature of the Protein Transition, online event. 22 April 2021.

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# UNDERSTANDING PROTEIN DIGESTION

## OF NEW ALTERNATIVE SOURCES THROUGH A UNIQUE MULTI-PLATFORM PIPELINE

### DIRECTED-CALL PROJECT 2020

200.000€



## CONTACT

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Diederik Esser, Sylvia Brugman  
*FFC Food, Health & Consumer  
Research, Host-Microbe  
Interactomics*

Kasper Hettinga, Nikkie van der  
Wielen, Paul Smeets, Anja Janssen

## AIM

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- To better understand structure-function relations underlying protein digestion.
- To connect expertise to create a multi-platform pipeline that can be used to test and quantify specific properties that affect digestibility.
- To better understand the ground rules of protein digestion and to facilitate the protein transition towards more sustainable sources of high nutritional quality.

## RESULTS

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- A literature study was used to select a protein source to be characterized across platforms. Pea protein was selected.
- In-vitro digestion reveal that a suspension of pea protein is better digestible after heat-treatment at 90C. Also, the digestion rate is highest in the gel without pea fiber. The digestion rate is dependent on the gel properties, such as the hardness of the gel, the swelling behaviour and the buffering capacity.
- Zebrafish experiments reveal that unheated PPI does not seem to have any negative effect on zebrafish gut parameters such as innate immune cell presence in the gut area, cytokine expression or intestinal permeability markers.
- In vivo human study indicated that a higher viscosity results in a faster initial gastric emptying up until 50 minutes post-prandial. Heat treatment did not affect gastric emptying.

## OUTPUT

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- [PUBLICATION] One scientific paper (in preparation).
- [PUBLICATION] One scientific paper based on a spin-off (in preparation).
- [OUTREACH] ICFD22, Cork.
- [OUTREACH] Nutritional Science Days, Heeze.
- [COLLABORATION] Biometris to build a R package to analyse AA responses.

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# UNDERSTANDING GEOGRAPHIES OF PROTEIN TRANSITIONS

CROSS-SCALE INTERACTIONS IN THE ALTERNATIVE PROTEIN INNOVATION SYSTEM  
DIRECTED-CALL PROJECT 2020  
200.000€



## CONTACT

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Laurens Klerkx, Alwin Gerritsen  
*Knowledge Technology & Innovation, Regional Development and Spatial Use*

Barbara van Mierlo, Anne-Charlotte

## AIM

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To identify entry points for advancing the protein transition and to offer guidance for the knowledge intensive activities as part of the larger alternative protein innovation system that contribute to the transition. This was done by focussing on a regional sub-system.

## RESULTS

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- 7 protein search directions were identified: 1. New protein sources; 2. Improving and understanding protein quality and functionality; 3. Improved taste and texture of alternative protein products; 4. Towards a local (self-sufficient) alternative protein system; 5. Optimizing alternative protein production processes; 6. Linking local to global solutions; 7. Towards a circular animal- and plant-based food system.
- These search directions manifest differ with regards to: 1. Differing visions on how to achieve “the” protein transition ; 2. Smaller organizations are confined to one or a limited number of search directions; 3. Larger organizations are typically involved in one dominant search direction; 4. Those with close ties to WUR are active in multiple trajectories.

## OUTPUT

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- [PUBLICATION] Diversity in protein transition pathways: current status, key concerns and ways forward. In Protein Transition Book. (submitted).
- [PUBLICATION] Regional innovation ecosystems in the protein transition. (in preparation).
- [PUBLICATION] Friend or foe in sustainability transitions? The interplay of diversity and directionality in the Wageningen-based Alternative Protein Innovation System (APIS). (in preparation).



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# IMPROVED STATISTICAL ANALYSIS OF IN VIVO DIAAS

DIRECTED-CALL PROJECT 2020  
28.000€



## CONTACT

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Diederik Esser  
*FFC Food, Health & Consumer  
Research*

## AIM

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- To calculate the total taken up by the blood during digestion.
- The new approach, based on curve-fitting is relevant as the blood samples were taken in a three-hour period and in some cases the amino acid levels did not fall back to the original steady state level. In addition, the results are more robust against noise and outlying observations and provide us with a standardised fast tool to handle such datasets.

## OTHER

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Sub project of “Understanding protein digestion of new alternative sources through a unique multi-platform pipeline” and started in July 2020 – November 2020.

## RESULTS

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To evaluate the digestion derived amino acid contents it is important to obtain an accurate description of the data in the form of a mathematical function. This will lead to an accurate determination of the area under the curve, representative for the amino acid uptake, and the speed of the uptake, even in cases where the amino acid levels were not back at their starting value at the end of sampling. The model explicitly incorporates sampling times which means that even using different sampling frequencies, or irregular samplings, results can be compared.

## OUTPUT

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- [PRESENTATION] Outcomes will be presented in a workshop about statistical challenges in chemometrics, April 2021.
- [OTHER] A software package was developed which allows accurate and fast statistical analysis of amino acids in the blood in future studies (already applied in 5 studies).
- [PUBLICATION] A manuscript about the methodology (in preparation).

# BREEDING BETTER PROTEIN-BUILDING INSECTS

COMMUNITY-FUNDED PROJECT 2020-2021  
100.000€



## CONTACT

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Esther Ellen, Bas Zwaan  
*Animal Breeding & Genomics,  
Laboratory of Genetics*

Aniek Bouwman, Bart Pannebakker,  
Teun Veldkamp, Adriaan Vernooij

## AIM

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To develop insect breeding programmes aimed at tailoring the use of insects in protein transition and test them on the black-soldier-fly.

## RESULTS

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- A simulation study revealed that selection for body mass is feasible, as in ten generations, an improvement in body mass and development time is possible when selecting on the phenotype or the breeding value. Using estimated genetic parameters from literature, an improvement of 146-150% in biomass yield per year was observed.
- A proof-of-principle revealed the potential of improving traits important in black-soldier-fly and shows the feasibility of collecting individual traits and to estimate genetic parameters, which is important when designing a breeding program.

## OUTPUT

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- [PUBLICATION] Bouwman et al., (2022). [Genetic parameters of Black Soldier Flies estimated in full sib design](#). In Proceedings of 12th World Congress on Genetics Applied to Livestock Production (WCGALP). (published).
- [PUBLICATION] Rijkers et al., (2022). [Impact of genetic selection in insect populations using different selection designs, a simulation study](#). (published).
- [OTHER] Masterclass "Insect Biology, genetics & breeding".

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# MUSHROOM-FORMING FUNGI

COMMUNITY-FUNDED PROJECT 2020-2021

178.000€



## CONTACT

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Arend van Peer, Karin Scholtmeijer  
*Plant Breeding*

Arnout Fischer, Ben van den Broek

## AIM

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To explore the opportunities to produce new proteins by using the mycelia and the fruiting bodies of mushroom-forming fungi.

## RESULTS

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- Literature study concluded that a proper comparison between protein levels of different species is not possible and that little is known about the nutritional value of these proteins.
- Experiments revealed that species show clear differences in their growth performance on the different substrates.
- An online experimental survey revealed that processing is likely to remove feelings of disgust and revulsion with the idea of eating mycelia (moulds), but at the same time, processing is likely to reduce naturalness perceptions and hence lower perceived environmental and health benefits.

## OUTPUT

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- [PUBLICATION] Mushrooms and proteins, facts and perspectives. In Protein Transition Book. (submitted).
- [PUBLICATION] Harvesting edible protein from woody materials; The potential of basidiomycetes. (submitted).
- [NEW PROJECT] Avina Foundation 2021. (not granted).
- [NEW PROJECT] Erasmus student 2022 (3 months). (approved).
- [NEW PROJECT] Erasmus student 2023 (8 months). (approved).
- [NEW PROJECT] TKI Proposal 2023. (in preparation).
- [NEW PROJECT] NWO proposal 2023. (in preparation).

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# SOY10: ETHIOPIA AND NL

COMMUNITY-FUNDED PROJECT 2020-2021

150.000€



## CONTACT

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Judit Snethlage  
*Water and Food*

Sneha Chevuru, Marleen Hermelink,  
Confidence Duku, Remko Vonk,  
Sjaak Conijn, Tewodros Tefera

## AIM

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To calculate potential effects on the climate, health and the environment if consumers switch from cow's milk to soy drink and from meat to soy alternatives, comparing the Netherlands and Ethiopia.

For this study hypothetically, ten percent of the protein consumed through cereal was replaced by soy protein (Ethiopia) and ten percent of the cow milk protein was interchanged by ten percent of soy drink (the Netherlands).

## RESULTS

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- Environment: For both nations interchanging ten percent of protein consumption to soy protein will result in a reduction of land use for agricultural purposes. Both countries currently experience a great pressure on land use. Replacing a small part of the protein to soy will therefore be considered as a positive development in this setting.
- Health: Overconsumption of calories and fat is becoming a problem in the Netherlands, whereas Ethiopia encounters areas with food insecurity, and could therefore be beneficial for the Netherlands.
- Climate change: Yields will increase for soy in Ethiopia, whereas the soy yield will increase but with less protein content and higher fat content in the Netherlands.

## OUTPUT

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- [REPORT] Modelling Crop Yields and Water Balances for Ethiopia with LPJmL.
- [REPORT] Modelling Crop Yields and Water Balances for the Netherlands with WOFOST.
- [REPORT] Soy transition Ethiopia and the Netherlands.
- [COLLABORATION] Informal conversations with private sector.

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# LEGUME PROCESSING

SEED PROJECT 2020

20.000€



## CONTACT

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Konstantina Kyriakopoulou  
*Food Process Engineering*

Eddy Smid,  
Atze Jan van der Goot,  
Maarten Schutyser

## AIM

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To design processes to obtain sustainably refined protein enriched components from otherwise underutilized legumes and seeds due to their high content in antinutritional factors (ANFs).

## INTENDED FUNDING

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Open NWO-TTW program, domain Applied and Engineering Sciences.

## OUTPUT

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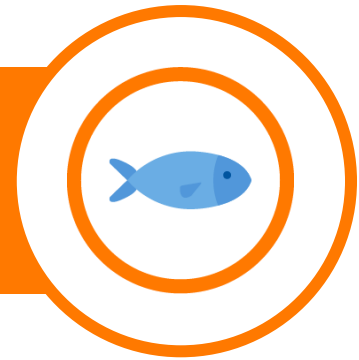
- [NEW PROJECT] Healthy & Tasty Protein; beginning 2021 to NWO. (not granted).

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# SUSTAINABLE AQUACULTURE

SEED PROJECT 2020

20.000€



## CONTACT

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Sem Jacobs  
*Cell Biology and Immunology*

Sylvia Brugman

## AIM

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To test sustainable proteins sources (seaweed, duckweed, microalgae, etc.) in fish for their ability to provide healthy, nutritious fish filets for human consumption.

## INTENDED FUNDING

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NWO-TTW, Applied Sciences

## OUTPUT

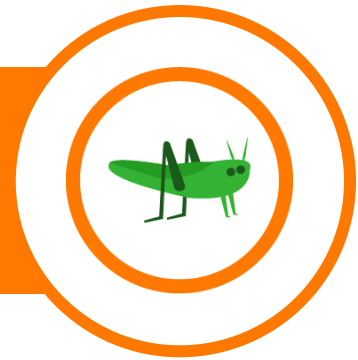
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- [NEW PROJECT] Successfully submitted the proposal and got support letters from Radicle Crops, Skretting, Duynie and the Banks foundation but unfortunately this TTW proposal was not granted. (not granted).

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# INSECT VALUE CHAINS

SEED PROJECT 2020  
25.000€



## CONTACT

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Dorothy Kanorio Murugu  
*Marketing and Consumer Behaviour*

Paul Ingenbleek

## INTENDED FUNDING

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INREF or comparable cross-disciplinary funding opportunities.

## OTHER

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Delaying to 2023, due to Covid-19 and withdrawal of the original candidate.

## AIM

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To develop value chains for insects consumption in the context of food systems of developing and emerging (D&E) countries.

## OUTPUT

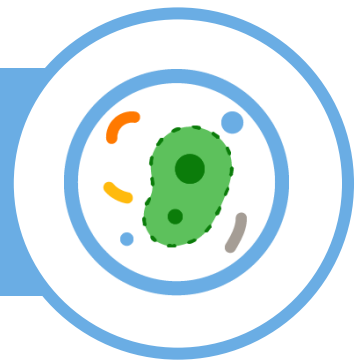
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- [NEW PROJECT] to be submitted in 2023.

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# MICROBIAL PROTEIN FOR FOOD AND FEED

DIRECTED-CALL PROJECT 2021  
128.000€



## CONTACT

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Jeroen Hugenholtz  
*Wageningen Food & Biobased  
Research*

Eddy Smit, Jasper Zwinkels, Sylvia  
Brugman, Michiel Kleerebezem

## AIM

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To research the feasibility and the nutritional potential of microbial protein in animal feed.

## RESULTS

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- Solid state fungal fermentation has been developed as a method for improvement of protein quality in low protein quality, staple, plant foods.
- Fermented rice is safe to use as fish feed and does not seem to contain antinutritional factors.

## OUTPUT

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- [PUBLICATION] "Solid-state fungal fermentation for superior protein quality in low-quality staple plant foods" submitted to LWT Food Science and Technology (submitted).
- [PUBLICATION] two publications planned with regard to zebrafish-model work
- [PRESENTATION] Bridge2food Summit 21-22 June 2022, Ede, the Netherlands
- [NEW PROJECT] Good Food Institute: Upgrading Plant-Derived Proteins By Novel Solid-State Fungal Fermentations. (granted).



# HOW DO YOU DIGEST YOUR PROTEINS

IDENTIFYING PERSONAL VARIATION IN AA UPTAKE KINETICS FROM ALTERNATIVE PROTEINS, IMPLICATIONS FOR A HEALTHY PROTEIN TRANSITION  
DIRECTED-CALL PROJECT 2021  
175.000€



## CONTACT

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Diederik Esser, Jurriaan Mes  
*Wageningen Food & Biobased  
Research, Human Nutrition & Health*

Meeke Ummels, Els Oosterink,  
Marco Mensink, Ron Wehrens,  
Nikkie van der Wielen

## AIM

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Considerable variation in postprandial amino acid kinetics can be expected between individuals due to, amongst others, differences in an individual's digestion and absorption capacity. As more attention should be given to inter-individual variation of nutrient uptake, this study aimed to quantify the variation in postprandial AA profiles between and within individuals after consumption of a good (whey) and moderate (lucerne) digestible protein source.

## RESULTS

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- On average, lucerne was associated with ~ 50% lower postprandial AA profile (AUC), a lower peak height and a delayed time to peak compared to whey. Substantial variation between individuals was observed, with the AUC for whey being 2.1 higher for the highest versus the lowest subject for AA totals (TAA). For lucerne protein this differences was 3.1 times for TAA. Also substantial 'day-to-day' variation was seen. There was little to no correlation between the personal response on the two proteins sources; in other words those with a high AUC for one protein source were not necessarily those with a high AUC for the other protein source.
- This indicates that individual variation in protein uptake kinetics should not be neglected and insights in this variation is warranted to support future optimized protein intake advice to prevent deficiency.

## OUTPUT

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- [PRESENTATION] Plant-Based Foods & Protein Summit Europe, 21-23 June 2022, Ede, The Netherlands.
- [PRESENTATION] Joint IAES-FAO Technical Meeting on the Development of a Protein Database and the Way Forward for Reviewing Protein Requirements, 10-13 October 2022, Vienna, Austria.
- [PRESENTATION] 22nd IUNS-ICN 2022, 6-11 December 2022, Tokyo, Japan.

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# FOOD SYSTEM REDESIGN

SHIFTING THE PROTEIN CONTENT IN PRODUCTION AND DIETS FROM ANIMAL BASED TO PLANT BASED IN THE EU  
DIRECTED-CALL PROJECT 2021-2022  
367.000€



## CONTACT

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Hannah van Zanten  
*Farm Systems Ecology*

Martin van Ittersum, Jim Groot, Edo Gies, Marijke Kuiper, Elise Talsma, Renée Cardinaals

## OTHER

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The project 'Insight Platform' has been integrated to this project in 2021.

## AIM

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To evaluate the nutritional and environmental consequences of shifting the protein content in the EU food system from animal-based to plant-based.

## RESULTS

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- European soybean production on current area can be increased only modestly, and that substantial expansion must come from area expansion. Climate change could potentially add to the suitable area for soybean cultivation. Faba bean and peas offer greater scope to increase production on existing areas.
- A new database was created that combines data from different food composition databases. The database provides information on each nutrient and enables to estimate how much is produced, imported, exported, processed, wasted, consumed or used as feed and seed. This on country level for each country in the world for multiple years.
- Different scenarios showed that 1) current animal:plant protein ratio should be at least reversed as the current ratio is 60:40, 2) when total protein consumption is lower, the share of animal protein becomes larger and 3) animal protein would be sourced differently than today with large decreases in beef, pork and chicken and increases in fish consumption.

# FOOD SYSTEM REDESIGN

SHIFTING THE PROTEIN CONTENT IN PRODUCTION AND DIETS FROM ANIMAL BASED TO PLANT BASED IN THE EU  
DIRECTED-CALL PROJECT 2021-2022  
367.000€



## CONTACT

Hannah van Zanten  
*Farm Systems Ecology*

Martin van Ittersum, Jim Groot, Edo Gies, Marijke Kuiper, Elise Talsma, Renée Cardinaals

## OTHER

The project 'Insight Platform' has been integrated to this project in 2021.

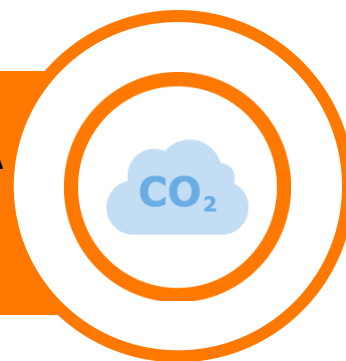
## OUTPUT

- [DATASET] Groot, J.J., Guo, X., Kok, M.G., Dastoum, S., Pyett, S.C. 2021, A Food Composition Database of 4 different datasets from Denmark, Japan, FAO and the USA, electronic dataset, Wageningen University and Research.
- [DATASET] Groot, J.J., Guo, X., Kok, M.G., Dastoum, S., Pyett, S.C. 2021, Protein Levels in Food Balance Sheets based on datasets of the FAO, electronic dataset, Wageningen University and Research.
- [DATASET] Human biomass calculations including amino acid requirements, country level. This dataset is linked to the other two and a tool is created to make graphs per country
- [DATABASE] Publication data of yield gap soybean in Europe in global yield gap atlas: <https://www.yieldgap.org/>
- [PUBLICATION] From the main deliverable (report), a scientific publication is currently being prepared and will be submitted to Nature Food (in preparation, Nature Food; IF: 20.430).
- [PUBLICATION] Guo et al., 2023. A global study on nutrient gap identifications and the potentials of food loss and waste reduction to close the gap. (in preparation).
- [PUBLICATION] Van Ittersum, et al.,. European soybean consumption and production. (submitted).
- [PUBLICATION] van Loon et al. [Can Europe produce enough plant-based proteins? An assessment of yield gaps of grain legume crops, XVII](#). Congress of the European Society of Agronomy, August 29 – September 2 2022, Potsdam, Germany. (published).
- [MEDIA] Hettterscheid, B. 2021. [De toekomst van ons Eiwit, De Vegetariërs Bond](#), 2021-06-28, De toekomst van ons eiwit I Vegetariërsbond.
- [COLLABORATION] The main deliverable is used in a collaboration with the Dutch Health Council to inform the Dutch government on the animal protein:plant protein ratio in a healthy and sustainable diet for the Dutch population.
- [PRESENTATION] Congress of the European Society of Agronomy, August 29-September 2 2022, Potsdam, Germany.
- [OUTREACH] Plant-based proteins: Building a sustainable future - Economist Impact: The first two datasets were used by The Economist – Intelligence Unit

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# PRO-AMBER

**AUTOTROPHIC MICROBES-BASED BIO-REFINERY: POTENTIAL ORGANISMS TO GENERATE VALUE OUT OF CO<sub>2</sub> AND CO ELIMINATION**  
**SEED PROJECT 2021**  
**17.400€**



## CONTACT

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Stefan Hol, Martijn Diender, Sara Cantera  
*Wageningen Plant Research, Microbiology*

## AIM

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To investigate whether it is possible to establish a process which is able to make high-value chemicals while simultaneously extracting the single cell protein content. The aim was to obtain initial funding for studying the feasibility of simultaneously producing protein and high value chemicals in a lab and/or small pilot scale setting. Such funding could (in case of positive feasibility) be used to apply for bigger grants.

## INTENDED FUNDING

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The Good Food Institute (GFI) - research grant

NWO – XS

## OUTPUT

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- [NEW PROJECT] We wrote our original grant to be used for applying for initial research funding (e.g. GFI, NWO XS): our initial target of applying for a GFI grant was not achieved due to deemed unfeasibility of the original idea. (not granted).
- [NEW PROJECT] Part of the original idea was however translated into another project application, that was successfully achieved: AMBIENT (6142021490 NWO XS). Autotrophic Microbes-based Bio-refinery: Generating value out of CO<sub>2</sub> and CO Elimination: AMBIENT (approved).
- [NEW PROJECT] Part of the applicants followed the "Proposal Writing And Project Management for EU Horizon Europe Program" course of vocal Europe to improve their skills. (submitted).
- Additionally, writing and application experience obtained from establishing and writing the ProAmber project, was beneficial to write (and successfully obtain) other grants related to autotrophic microbes in different settings (e.g. NWO XS, Microbes in shining armor: exploring copper recovery using carboxydrotrophic microorganisms. OCENW.XS21.1.023).

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# EATING THE UNKNOWN

HOW NOVEL ORGANISMS BECOME SUSTAINABLE FOOD  
SEED PROJECT 2021  
20.000€



## CONTACT

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Jonas House  
*Consumption and Healthy Lifestyles*

## AIM

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To systematically theorize of how the 'edibility' of (novel) foods is established, maintained and changes.

## INTENDED FUNDING

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NWO Talent Scheme Veni

## OUTPUT

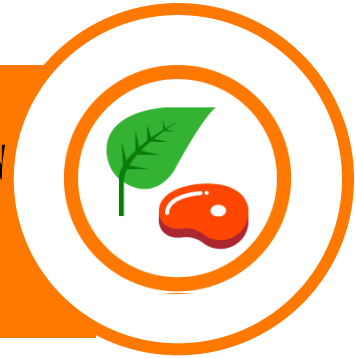
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- [NEW PROJECT] NWO Talent Scheme Veni (not granted).

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# PLANT-BASED MEAT ALTERNATIVES CONSUMPTION

EFFECTS ON HUMAN INTESTINAL MICROBIOME, HEALTH,  
AND SUSTAINABILITY  
SEED PROJECT 2021  
20.000€



## CONTACT

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Annelies Kers  
*Gerrit Grijns Initiative*

## AIM

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To investigate if plant-based alternatives that replace meat have in addition to sustainability, an advantageous effect on human health with a special focus on the intestinal microbiome.

## INTENDED FUNDING

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TKI-AF

## OUTPUT

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- [NEW PROJECT] Improving plant-based meat analogues by evaluating effects on human health - LWV21.170 (approved).

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# NOVEL NON-PLANT FEEDSTOCKS FOR INDUSTRIAL APPLICATIONS

SEED PROJECT 2021  
16.000€



## CONTACT

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Carl Safi, Koen Jans, Jeroen Hugenholtz  
*BBP Biorefinery & Sustainable Value Chains, Business Development Manager*

## AIM

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To mobilize novel forms of non-plant biomass by combining the utilisation of currently under-utilized, undervalued feedstocks through innovative integrated fermentation technology and downstream processing to extract valuable compounds for food, feed and agro applications, creating new value chains and business cases. The project will also focus on sustainable supply chain models, consumer acceptance, legal aspects, techno-economic feasibility, environmental impact and rural development.

## INTENDED FUNDING

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EU funding novel non-plant feedstocks for industrial applications.

## OUTPUT

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- [NEW PROJECT] EU project (not granted).

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# GIANT LEAPS PROPOSAL WRITING

SEED PROJECT 2021

16.000€



## CONTACT

---

Paul Vos  
*Wageningen Food & Biobased  
Research*

## AIM

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To build an international consortium and develop a full Horizon Europe grant proposal on the topic of Filling knowledge gaps on the nutritional, safety, allergenicity and environmental assessment of alternative proteins and dietary shift (call HORIZON-CL6-2021-FARM2FORK-01-12).

## INTENDED FUNDING

---

EU funding on nutritional, safety, allergenicity and environmental assessments of alternative proteins.

## OUTPUT

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- [NEW PROJECT] This seed project was successfully used to build a consortium and get the project GIANT LEAPS funded. This project is coordinated by Wageningen Research and started on 1 September 2022. (approved).



# PROTEIN FUNCTIONALITY – “MINOR COMPONENTS”

DIRECTED-CALL PROJECT 2022  
240.000€



## CONTACT

Judith Müller-Maatsch, Maaïke  
Nieuwland  
*Wageningen Food Safety Research,  
Wageningen Food & Biobased  
Research*

## AIM

To improve and diversify the existing sources of proteins used for food and feed, focussing not only on currently important, but also on new, promising protein sources.

## RESULTS

- A comprehensive overview of minor components available in plant materials was delivered.
- Commercially available samples of faba bean ingredients vary significantly in the type and levels of minor components present. The variability could not be directly linked to processing history and was likely attributable to starting material differences.
- Addition of specific soluble phenolics led to increased gelation capacity of faba bean concentrate. The effect of phenolics on the protein functionality is highly dependent on the structure of the phenolic compound.

## OUTPUT

- [PUBLICATION] Review: The influence of minor components in protein products on processing, sensory quality and functionality and safety (in preparation).
- [PUBLICATION] [Effect minor components uit plantmateriaal, een overzicht](#), professional journal 'VoedingNU', October 2022. (published).
- [PRESENTATION] Poster 'Effects of minor components on the final product and in the processing of alternative protein sources.'; 2nd NIZO Plant Protein Functionality Conference, 11-13 October 2022.
- [NEW PROJECT] PPS project 'Interactions with minor components (approved).
- [NEW PROJECT] PhD project 'ProTip: Understanding Protein-Phenolic Interactions: Tipping the Scales in our Favour!'; Financing: PhD costs and WR supervision until 2024. (approved).
- [OUTREACH] De verrassende chemie van de natuur; professional journal 'EVMI', November 2022.

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# MEAT ANALOGUES

DEVELOPING INNOVATIVE METHODS TO UNDERSTAND RISK  
AND UNCERTAINTY IN THE PROTEIN TRANSITION  
DIRECTED-CALL PROJECT 2022  
160.000€



## CONTACT

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Jonas House, Annelies Kers  
*Environmental Policy Group,  
Laboratory of Microbiology*

## AIM

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To provide insights into whether commercially-available meat analogues meet consumers' nutritional and health requirements (vis-à-vis meat or other alternatives).

To generate valuable insights into whether these products meet consumers' day-to-day culinary needs, investigating their impact on consumer diets (vis-à-vis consumption of meat or other alternatives), and exploring who is excluded by this approach to a protein transition.

## OTHER

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Experimental study will be delayed to 2023.

## RESULTS

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- A set of 20 popular meat replacer products were chemically tested for pesticide residue; all within safe limits.
- A sociological 'experiment' was carried out, in which consumers were asked to incorporate meat analogues into their diets for two weeks. Meat analogues seem to offer an easy alternative. However, barriers were encountered when cooking (i.e., disrupting established food practices, using (more) butter instead of oil). For some consumers, switching to regular consumption of meat analogues requires a major reconfiguration of shopping practices. Differences between the packaging of meat and meat analogues made it difficult for people to work out what to buy, how much, and what would fit in familiar recipes.
- A study on the impact of 20 popular meat replacers on the human microbiome will be carried out during 2023.

## OUTPUT

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- [REPORT] Explorer piece (peer-reviewed explorations of contested issues in food and sustainability) to be published by TABLE (platform for dialogue & reflection on food system issues (Oxford/WUR/SLU) – <https://tabledebates.org>)
- [PUBLICATION] Planned for mid-2023.
- [OUTREACH] The 'Good' Food Dialogues #2: Exploring the Dark Side of Meat Analogues, Wageningen. Dialogue session organised by us / TABLE / WUR Dialogues / Pakhuis de Zwijger.
- [OUTREACH] Follow-up event early 2023.

# ALTERNATIVE FISH FEED SOURCES FROM LOCAL RESOURCES IN LAKE VICTORIA REGION

DIRECTED-CALL PROJECT 2022  
200.000€



## CONTACT

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Adriaan Vernooij, Maria Barbosa  
*Wageningen Livestock Research,  
Bioprocess Engineering*

## AIM

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To improve the knowledge on the application of adapted algae production systems, supporting and improving existing insect production and establishing the feasibility of the use of other potential local side streams as alternative feed ingredients.

## RESULTS

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- Promising rest streams came from market and retail waste, slaughterhouse waste and crop processing waste in East Africa. A decision tree was developed.
- Two Black Soldier Fly (BSF) producers have been assisted with advice on improving their operations, with a focus on using different waste ingredients (water hyacinth, slaughterhouse waste, by-products from rice milling), and a focus on improving technical operations (harvesting, cleaning and sieving larvae).
- Fish feeding trials using 1) BSF as a protein ingredient and 2) Spirulina as component showed promising results as both Spirulina and BSF can be replacing traditional protein ingredients such as fish meal with levels up to 20 to 30 % replacement of its protein.
- A hybrid workshop with fish producers, researchers, government officers and representatives from international organisations, who showed great interest in using BSF and Spirulina and when possible, even to produce it themselves.
- Policy brief on aspects of operationalizing the use of BSF Larvae and Spirulina as feed ingredients in Kenya and Uganda.

## OUTPUT

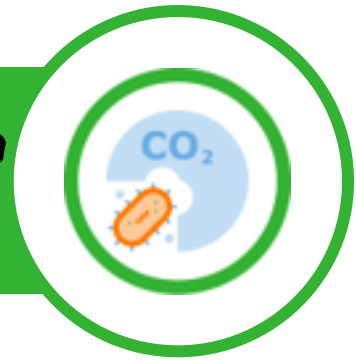
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- [REPORT] Two reports on Waste to wealth & Black Soldier Fly Larvae (BSFL) and Spirulina - As protein ingredients in affordable, accessible and sustainable feed in Uganda & Kenya?
- [PUBLICATIONS]. Two articles on effects of feeding alternative feed ingredients (BSF, Spirulina) to fish in Kenya and Uganda in East African aquaculture journal. (in preparation).
- [PUBLICATION]. Towards sustainable aquaculture around Lake Victoria. (in preparation).

# CO<sub>2</sub>-EATING MICROBES4FOOD

COMMUNITY-FUNDED PROJECT 2022

96.000€



## CONTACT

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Julia Keppler, Nico Claassens,  
Laurice Pouvreau  
*Laboratory of Microbiology, Food  
Process Engineering, Protein  
Technology*

## AIM

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To investigate microorganisms that grow on CO<sub>2</sub> for the sustainable production of food and proteins for human consumption. The research will focus on the production of microbial biomass from CO<sub>2</sub> and green hydrogen one-carbon substrates in bioreactors and the separation and techno-functional characterization of the protein fraction.

## RESULTS

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- This project successfully fractionated bacterial biomass and produced a proof-of-concept meat alternative with a pleasant taste and colour without the necessity to add any further colorants or flavours.
- The unprocessed biomass contains about 70% protein, and in the shear cell it gives a fibrous texture with a pinkish hue and a pleasant umami smell. There was no need to fractionate it further or add other plant proteins such as wheat gluten as a binder, showing the potential for sustainable meat alternative production.

## OUTPUT

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- [PUBLICATION] "Methylotroph bacteria for meat alternatives: Physico-chemical, gelling and texturing properties of crude biomass and processed fractions". (in preparation)
- [NEW PROJECT] TTT Voucher on microbial proteins. (approved).
- [NEW PROJECT] NWO TTW, GGI, Marie-Curie. (in preparation).

# HARNESSING THE POTENTIAL OF PUBLIC PROCUREMENT FOR THE PROTEIN TRANSITION

COMMUNITY-FUNDED PROJECT 2022

96.000€



## CONTACT

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Sanne Djojoseparto, Muriel Verain,  
Jeroen Candel

*Wageningen Economic Research*

Hanna Schebesta, Maartje Poelman,  
Sander Biesbroek, Florine Kremer

## AIM

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To explore how food-service public procurement can unlock new pathways for the protein transition.

## RESULTS

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- Based on selected good practice cases and expert interviews five main categories of barriers and facilitators were identified:
  - support and motivation
  - financial means
  - food offer and products
  - policies and contracts
  - transition process and external factors
- Results were discussed during a summit (100 participants) and translated in action points.

## OUTPUT

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- [PRESENTATION] Seminar Series: Local policies & regulations for healthy and sustainable food environments; Presentation: Food service procurement in public settings: examples, barriers and opportunities, Wageningen.
- [SUMMIT] "Symposium: Eiwittransitie versnellen in het inkoopbeleid", Wageningen.
- [PRESENTATION] Strategies for a consumption shift: Towards a more plant-based diet; Presentation: Harnessing the Potential of Public Procurement for the Protein Transition.
- [PUBLICATION] Policy letter with recommendations for actions to public organisations, to foster the protein transition in their organisation. (in preparation).
- [PUBLICATION] Policy letter with recommendations for governments, to empower and stimulate public organisation to implement the protein transition. (in preparation).
- [PUBLICATION] Scientific article presenting the barriers and facilitators resulted from the interviews. (in preparation).

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# WILL PROCESSED MEAT REPLACERS DRIVE YOU NUTS?

COMMUNITY-FUNDED PROJECT 2022  
95.000€



## CONTACT

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Gosia Teodorowicz, Tamara Hoppenbrouwers  
*Cell Biology and Immunology Group, Food Quality & Design*

Janneke Ruinemans-Koerts, Anja Janssen, Joost van Neerven

## AIM

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To develop a new method to predict, based on serum from peanut-allergic patients, whether (new) processed proteins from legumes can trigger an allergic reaction cascade at a cellular level.

## RESULTS

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- IgE binding was used as a measure of cross-reactivity between peanut and other plant protein allergies. Processing of pea resulted in a reduction in IgE binding. IgE cross-reactivity between peanut and pea allergens was found in all groups but most present in peanut allergic patients without a pea allergy.
- Cross-reactivity between all proteins (soy, pea and lupin) and peanut-allergic plasma confirmed that the untreated proteins showed the highest cross-reactivity.
- Interestingly, all proteins heated in the presence of glucose showed high cross-reactivity to the peanut-allergic plasma, whereas this was more limited in heat-treated samples. This indicates that protein aggregates are more capable of cross-linking IgE when sugars are present.

## OUTPUT

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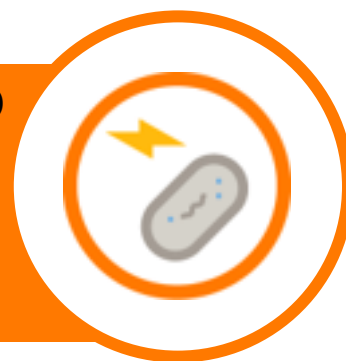
- [REPORT] Four reports on the results of the project.
- [NEW PROJECT] To be drafted to NWO-STW or TKI.

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# FROM CO<sub>2</sub> AND ELECTRICITY TO FOOD VIA THE ELECTRO-MICROBIAL ROUTE

SEED PROJECT 2022

15.600€



## CONTACT

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Nico Claassens, Julia Keppler  
*Food Process Engineering,  
Laboratory of Microbiology*

## AIM

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We will write a proposal exploring the bacterium *Cupriavidus necator* for the production of microbial food protein. This bacterium is relatively unique as it can grow on CO<sub>2</sub> and use the energy of hydrogen or formate, which can be generated from (renewable) electricity. This organism has hardly been explored for the production of food, and we will also employ genetic engineering strategies to improve its protein functionality. This project fits both to the science theme of biochemical processes, including the microbial biochemistry from CO<sub>2</sub> to protein, as well as protein functionality of the microbial protein fraction.

## INTENDED FUNDING

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NWO-TTW Open Technology programs.

## OUTPUT

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- [NEW PROJECT] NWO TTW (in preparation).
- [NEW PROJECT] GGI (in preparation).
- [NEW PROJECT] Marie-Curie proposal (in preparation).
- [NEW PROJECT] TKI proposal (not granted).
- [NEW PROJECT] EU Pathfinder proposal (submitted).
- [OUTREACH] Online magazine and NPO Radio 1 interview.

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# PERSONALIZE AND NUDGE

PROVIDING USER-TAILORED, SUSTAINABLE FOOD ADVICE  
BY COMMUNICATING THE ENVIRONMENTAL IMPACT OF  
INTERNET-SOURCED FOOD PRODUCTS  
SEED PROJECT 2022  
18.363€



## CONTACT

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Alain Starke  
*Marketing & Consumer Behavior*

Ellen van Loo

## AIM

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- Consumer acceptance of foods that contain plant-based protein is one of the final obstacles in the larger protein transition. Despite the presence of large food databases on online food platforms (e.g., supermarkets, food delivery services, recipe websites), there is little decision support for consumers to nudge them towards more sustainable food choices. Reliable information on the sustainability impact of foods is lacking and not communicated to end users. To stimulate the protein transition towards plant-based food and recipes, we expect that providing user-tailored food advice in an online food platform is more effective than employing a one-size-fits-all approach.
- This project investigates how algorithms and interfaces can be designed to support sustainable decisions, combining personalization and interface nudges

## INTENDED FUNDING

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NWO Open Competition ENW – M  
Research Council of Norway –  
Scientific Renewal

## OUTPUT

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- Not proceeded.
- [NEW PROJECT] 'FoodNudge: Supporting Healthy and Sustainable Food Choices through Smart Nudging in Recommender Systems'. (not granted).
- [PUBLICATION] Starke et al., (2023). [Examining the User Evaluation of Multi-list Recommender Interfaces in the Context of Healthy Recipe Choices](#). ACM Transactions on Recommender Systems (published).



# AGRICULTURAL SIDE STREAMS

PHD PROJECT



## CONTACT

Yafei Yu

*Food Process Engineering*

Marietheres Kleuter

*Plant Breeding*

## AIM

To develop genetic and processing tools that enable efficient extraction of high-quality proteins from agricultural side streams, namely leaves and stems. For that we will aim to:

1. Understand the fundamental mechanisms behind protein accumulation in stems and leaves and how these are genetically controlled.
2. Design new processes for efficient extraction of high-quality protein.

If time allows we aim to apply these tools in major crops in Sub-Saharan Africa.

## TIME FRAME

**Yafei Yu**

Start: 15-09-2020

End: 14-09-2024

**Marietheres Kleuter**

Start: 01-11-2020

End: 01-11-2024

## RESULTS

- Protein extractability varies in tomato leaves at different stages of plant development and in different sections of the plant.
- Protein extraction from young tomato leaves is more efficient than that of old leaves.
- Cell wall composition does not seem to play a major role in protein extractability in leaves, which is contrasting to what happen in leaves.

## OUTPUT

- [PUBLICATION] Yu et al., 2023. [The role of plant age and leaf position on protein extraction and phenolic compounds removal from tomato \(\*Solanum lycopersicum\*\) leaves using food-grade solvents](#). Food Chemistry. (published; IF: 8.69) <https://doi.org/10.1016/j.foodchem.2022.135072>
- [2 DISSERTATIONS 2024].

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# FROM GOOD BEHAVIOR CHANGE INTENTIONS

TO A POPULATION-LEVEL CONSUMPTION SHIFT  
PHD PROJECT



## CONTACT

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Christa Blokhuis  
*Consumption and Healthy Lifestyles*

## AIM

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To research why and for whom consumer-reported behavior changes do not align with (aggregated) consumption data.

## TIME FRAME

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Start: 15-11-2020  
End: 14-11-2024

## RESULTS

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These insights are needed to draw valid and reliable conclusions about the state of a consumption shift, and to develop adequate methods for evaluating efforts to shift consumption at the population level. The focus will be on the global North.

## OUTPUT

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- [PUBLICATION] Sharing expert knowledge through a system lens. A literature review and panel study on consumption of protein sources. (in preparation)
- [PUBLICATION] Identification of system archetypes in the dynamic relationships between the food environment and consumption practices of animal- and plant-based protein sources. A systematic literature review. (in preparation)
- [DISSERTATION 2024].

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# INSIGHT PLATFORM

400.000€



## CONTACT

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Jim Groot  
*FFC Supply Chain & Information  
Management, Wageningen Food &  
Biobased Research*

## OTHER

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This project has been integrated to the directed call project 'Food System Redesign' in 2021.

## AIM

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To create a comprehensive database of global protein production and consumption worldwide.

## RESULTS

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Insight platform: The general approach is to create a database on country level consisting of volumes of production, import, export, processing, seed, feed, waste and consumption of food (related) products. These data is enriched with amounts of protein and even amounts of essential amino acids. The database gives a 'current situation' or 'protein map' of the protein network of the world on country level and is the basis for comparing future scenario's. These future scenarios can help other research on i.e. individual behaviour choices within the context of societal, social, and environmental issues. The future scenarios can also be made linked to other performance indicators like costs or GHG emissions.

## OUTPUT

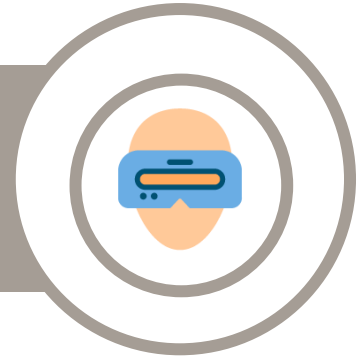
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- [PRESENTATION] Results included in "Plant-based protein future: myths and realities" presentation.
- [PUBLICATION] Guo et al., (2020). [A worldwide hotspot analysis on food loss and waste, associated greenhouse gas emissions, and protein losses](#). Sustainability, 12(18), 7488. (published; IF: 3.889).

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# TASTE LESSONS

OUTREACH  
90.000€



## CONTACT

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Fieke Franken  
*Consumer and Chain, Wageningen  
Economic Research*

## AIM

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If we would like to make an impact on the consumption on alternative proteins, children are a valuable target group. They form a new generation to be exposed to new innovative foods. We can educate them and let them experience alternative proteins by enriching and adding these new proteins and their applications to our existing food education lesson programme.

## RESULTS

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Our delivery is a new 'Taste Mission' Lesson, which fit within the broader existing offer of Taste Missions within Taste Lessons. The Taste Mission new proteins was launched in 2020, including a VR tour of a plant-based burger factory.

## OUTPUT

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- [MEDIA]: Wageningse schoolklas heeft primeur: leren over duurzame eiwitten met een VR-bril. *De Gelderlander* (23-06-20).
- [MEDIA]: Wageningen Universiteit & Research lanceert gratis Virtual Reality les voor basisscholen. *Emerce* (24-06-20).
- [MEDIA]: WUR lanceert virtual reality-les over alternatieve eiwitbronnen voor basisscholen. *The Economic Board* (25-06-20).
- [MEDIA]: Smaaklessen voor een gezond eetpatroon: smaakmissie avontuurlijke eiwitten. *Regio Foodvalley* (30-06-20).

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# TASTE MISSIONS

OUTREACH  
10.000€



## CONTACT

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Fieke Franken  
*Consumer and Chain, Wageningen  
Economic Research*

## AIM

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In order to be able to provide the growing world population with sufficient protein sources in the future, we will also have to look for alternative protein sources in addition to known protein sources. Children are introduced to new protein sources in this Junior Science Lab, on the 8th of June 2022. In order to be able to provide the growing world population with sufficient protein sources in the future, we will also have to look for alternative protein sources in addition to known protein sources. A Junior Science Lab will be organized in collaboration with Taste Lessons and Science Hub Wageningen University, to make children (age 10-12) aware of this. During the Junior Science Lab, children are introduced to alternative protein sources. They will listen to a lecture from a scientist, taste insects and they will cook a recipe with these new protein sources. An attempt will also be made to improve the Dutch record 'Cooking by children'. The current record is in the hands of children in Heerenveen, where 200 children cooked together. You can register for the event via the website of Science Hub Wageningen University.

## RESULTS

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- 200 children participated in the Junior Science Lab.
- World Record of 199 children who cooked their own poké bowl.

## OUTPUT

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- [OUTREACH]. Junior Science Lab.
- [OUTREACH]. [World Record](#).

# WUR GO

OUTREACH  
80.000€



## CONTACT

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Esther Hogeveen  
*FFC Post Harvest Technology*

Marieke Bruins, Sabine Desczka,  
Bernardo Maestrini, Marjolein  
Elings, Koos van der Meij, Keiji  
Jindo, Lan van Wassenaar

## AIM

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How will our life and work look like with all the green proteins WUR envisions? How has protein transition impacted the way we live and work, for better or for worse? This project will deliver an imaginary documentary and an augmented reality (AR) version of WUR's vision on protein transition using the WUR Go App and G.O. caching. Through storytelling by 'WUR-actors' and the artist in residence, the documentary will provide a realistic 'look and feel' of the Post Protein Transition (PPT) world WUR envisions and enable critical assessment and improvement of different scenarios.

## RESULTS

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- WUR experts developed different challenges that outline the future of proteins, connected to the Wageningen University & Research campus.

## OUTPUT

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- [OUTREACH]. [WUR GO app](#).

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# PROTEIN XR

OUTREACH  
86.000€



## CONTACT

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Ioana Mereuta  
*WANDER*

Dienke Stomph, Bas Hetterscheid,  
Jim Groot, Xuezheng Guo, Hannah  
van Zanten, Alexander Klippel

## AIM

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The project will deliver a web-based AR application aiming to create awareness about the impact and trade-offs in our dietary choices from a protein angle. Within the application, users can explore different protein transition scenarios. In the application, the user is seated at a regional dining table and chooses the food items or food pattern. The impact of user's choices is immediately visible through the visualization of the consequences on land use, greenhouse gas emissions, the water footprint and personalized protein requirements. In this way, the user will get a deeper understanding of the current global protein production, trade and consumption patterns, including indicational impact on environment and intake.

## OTHER

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The output of the results will be released together with the results of the directed-call project "Food System Redesign". The results are release date of the application are expected in 2023.

## RESULTS

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- WUR experts developed an AR application based on the findings of the directed call project "Food System Redesign".

## OUTPUT

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- [OUTREACH] Protein XR app.

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# ARTIST-IN-RESIDENCE ARNE HENDRIKS

OUTREACH  
30.000€



## CONTACT

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Arne Hendriks  
[www.arnehendriks.net](http://www.arnehendriks.net)

## AIM

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To identify narratives from researchers, lecturers, students, initiative to create space for debate about our identity and relationship with proteins.

## OUTPUT

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- [ART]. Newspainting: Eating ourselves towards a resilient now.
- [LECTURE]. Eating ourselves towards a resilient now.
- [OUTREACH]. Dutch Design Week 2021.



# ARTIST-IN-RESIDENCE REMCO DE KLUIZENAAR

OUTREACH  
20.000€



## CONTACT

Remco de Kluisenaar  
[www.remcodekluisenaar.nl](http://www.remcodekluisenaar.nl)

## AIM

Being a sound artist in residence, Remco hunts for the sound of Protein Transition, and uses that to engage a non-scientific audience with PT research, and to inspire scientists to “look” differently at PT research. The sound of PT is gathered in interviews, recordings from research, varying from the hums of bumblebees and DNA sequencers to the rhythms of shaking dried lupine pods and 3D printers at work. Musical compositions made from such audio fragments, are brought to ear in several theatrical, musical and AR experiences to emotionally and intellectually engage audiences. The process of co-creation with scientist welds new connections between people, institutions and thoughts, focussing on “what is The Greater Good in PT”.

## OUTPUT

- [ART] Collaborative protein Game-artwork [Bigfood](#) (July '21).
- [ART] [GPS/AR audio tour](#) (Feb '22).
- [ART] Music-theatre show “[intention behaviour gap](#)” (April '22).
- [ART] Guided theatrical tour with female dancer and actors “[Everything is Connected](#)” shown to 350+ non-scientist and scientist, including Giant Leaps consortium (Sept '22).
- [ART] Conceptual artwork “[Boviphone and Aqualentiphone](#)” a musical instrument made from cows blood and its plant based alternative from duckweed, as a vehicle for thoughts and stories. Exhibited at Dutch Design Week (Oct '22).
- [OUTREACH] [CIW](#), [WUR News](#), [Gelderlander](#) (regional).
- [OUTREACH] interview @ NPO Radio1 [DeNieuwsBV](#) and @ NPO Radio1 [De Nacht van](#).
- [OUTREACH] “Pop-up Pop” launches audio tour in [Songlines](#) program.
- [OUTREACH] [talkshow & concert](#) on boviphone and aqualentiphone, @WED.
- [OUTREACH] [article](#) in online mag “DU” about Dutch design week exhibition.



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Wageningen University & Research  
P.O. Box 9101  
6700 HB Wageningen  
The Netherlands

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The mission of Wageningen University & Research is "To explore the potential of nature to improve the quality of life". Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to finding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 6,500 employees (5,500 fte) and 12,500 students, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.

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