



Algemene gegevens	
TKI-projectnummer	AF-EU-14006
Titel	MIRACLES: Multi-product Integrated Biorefinery of Algae
Topsector en innovatiethema	A&F Circulair
Projectleider (onderzoek)	Dr. Lolke Sijtsma
Werkelijke startdatum	1 November 2013
Werkelijke einddatum	30 Oktober 2017
Korte omschrijving inhoud (bij voorkeur 4 regels, max. half A4)	WR (previously DLO) is involved in the development and management of integrated biorefinery technology, employing mild disruption, green extraction and fractionation technologies to produce multiple specialty products from microalgae biomass.

uitvoerende partijen	
betrokken kennisinstellingen	Wageningen Food & Biobased Research
overige partijen	<p>1 WAGENINGEN UNIVERSITY WU Netherlands</p> <p>2 FUNDACION CANARIA PARQUE CIENTIFICO TECNOLOGICO DE LA UNIVERSIDAD DE LAS PALMAS DE GRAN CANARIA FCPCT Spain</p> <p>3 UNIVERSITEIT TWENTE UT Netherlands</p> <p>4 UNIVERSITETET I BERGEN UiB Norway</p> <p>5 UNIVERSIDAD DE HUELVA UHU Spain</p> <p>6 Universidad de Antofagasta UA Chile</p> <p>7 STICHTING DIENST LANDBOUWKUNDIG ONDERZOEK DLO Netherlands</p> <p>8 AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS CSIC Spain</p> <p>9 VLAAMSE INSTELLING VOOR TECHNOLOGISCH ONDERZOEK N.V. VITO Belgium</p> <p>10 EWOS INNOVATION AS EWOS Norway</p> <p>11 DYADIC NEDERLAND BV DNL Netherlands</p> <p>12 FITOPLANCTON MARINO, S.L. FITO Spain</p> <p>13 SPAROS LDA SPAROS Portugal</p> <p>14 RODENBURG BIOPOLYMERS BV BIOPOL Netherlands</p> <p>15 IMENZ BIOENGINEERING BV IMENZ Netherlands</p> <p>16 CHIMAR HELLAS AE CHIMAR Greece</p> <p>17 VALUE FOR TECHNOLOGY BVBA VFT Belgium</p> <p>18 NATAC BIOTECH SL NATAC Spain</p> <p>19 NOVA-INSTITUT FUR POLITISCHE UND OKOLOGISCHE INNOVATION GMBH NOVA Germany</p> <p>20 IDCONSORTIUM SL IDC Spain</p>

Resultaten en deliverables

<p>1. Welke deliverables zijn opgeleverd, en is dit conform het projectplan? (geef een korte beschrijving per deliverable uit het projectplan)</p>	<p>Full characterization of biomass components and cell wall structure. ACHIEVED</p> <p>Results screening, disruption, extraction, fractionation and purification technologies and integration of biorefinery configurations. ACHIEVED</p> <p>Fractionated materials for product development. Starting at M12 throughout the project. ACHIEVED</p> <p>Tailor-made enzyme mixture developed, evaluated and produced for demonstration. PARTLY ACHIEVED</p> <p>Results optimization of selected integrated biorefinery value chains. ACHIEVED</p>
<p>2. Indien bepaalde deliverables niet gehaald zijn, wat was daarvoor de reden?</p>	<p>The deliverable: "tailor made enzymes" is partly achieved due to the rather unknown and complex structure, composition and variety of algal cell walls</p>
<p>3. Heeft het project onverwachte (neven)uitkomsten opgeleverd, die vooraf niet waren voorzien? Zo ja, benoem deze.</p>	<p>No</p>
<p>4. Op welke wijze is over het project en de resultaten gecommuniceerd</p>	<p>Project results were communicated to potential stakeholders via scientific publications and presentations, the MIRACLES website and regular newsletters. Furthermore, we contributed to a summerschool on algal biorefinery.</p>
<p>5. In hoeverre heeft het project bijgedragen aan de ontwikkeling van de betrokken kennisinstelling(en)? (bijv. wetenschappelijk track record, nieuwe technologie, nieuwe samenwerkingen)</p>	<p>WFBR has a generated a lot of knowledge and know how in the field of algal biorefinery. This knowledge is exploited in a number of presentations and publications and will be used for future projects.</p>
<p>6. Krijgt het project een vervolg in de vorm van een nieuw project of een nieuwe samenwerking? Zo ja, geef een toelichting.</p>	<p>The generated knowledge is used in projects but in 2017 no new projects were granted.</p>

Highlights: geef een korte beschrijving van de belangrijkste resultaten (deze beschrijving wordt als publieke samenvatting op de websites van de TKI's/topsectoren geplaatst)

Microalgae are a promising feedstock for the sustainable supply of commodities and specialties for food and non-food products. Despite this potential, currently implementation is limited, mainly due to unfavourable economics. Major bottlenecks are the lack of available biomass at acceptable costs and the absence of appropriate biorefinery technologies

We analysed the composition of different algal biomass in detail and, together with project partners, developed integrated biorefinery technologies employing mild disruption, green extraction and fractionation/purification technologies to produce multiple products from algae biomass by valorising all biomass components. Applications are tested by project partners in food, aquaculture and selected non-food applications. The concept of producing multiple products from the biomass using an integrated biorefinery approach increased the benefits.

Aantal opgeleverde producten (geef in een bijlage de titels en/of omschrijving van de producten of een link naar de producten op openbare websites)

Wetenschappelijke artikelen /abstract	Rapporten	Artikelen in vakbladen	Inleidingen/workshops/invited lectures	Aangevraagde octrooien /first filings	Spin-offs (*)
12			9		

(*) Hiermee wordt bedoeld: contractonderzoek dat voortkomt uit dit project, aanvullende subsidies die zijn verkregen en spin-off bedrijvigheid.

Verwacht u nog een octrooiaanvraag naar aanleiding van dit project?	NEE
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Akkoord: Hans van der Kolk (Topsectorsecretaris)

Bijlage: Titels van de producten of een link naar de producten op een openbare website

<http://miraclesproject.eu/>

<https://www.wur.nl/nl/project/MIRACLES-1.htm>

2015

Bienvenida Gilbert-López, José A. Mendiola, Javier Fontecha, Lambertus A. M. van den Broek, Lolke Sijtsma, Alejandro Cifuentes, Miguel Herrero, Elena Ibáñez. (2015) Downstream processing of *Isochrysis galbana*: a step towards microalgal biorefinery. *Green Chemistry* 17, 4599 - 4609.

Hans Reith, Bert Lemmens, Hans Kleivdal, Lolke Sijtsma, Philippe Willems, Carlos Unamunzaga, Elke Breitmayer, Macarena Sanz, René Wijffels (2015). Production of specialties for food, aquaculture and non-food applications via multi-product biorefinery of microalgae: Progress of the EU FP7 project MIRACLES. 2nd EABA and EC Algae contractors conference and the 9th international algae congress. Lisbon, 1-3 December 2015

2016

Lambertus van den Broek, Carl Safi, Jelle van Leeuwen, Lolke Sijtsma (2016) Algae biorefinery: proteins for technical applications, Lecture, Workshop Algae & Seaweed, 18 February 2016, Wageningen, The Netherlands

Lambertus van den Broek, Carl Safi, Jelle van Leeuwen, Lolke Sijtsma (2016), Algae biorefinery for non-food applications, Poster, Workshop Algae & Seaweed, 18 February 2016, Wageningen, The Netherlands

Lambertus van den Broek, Carl Safi, (2016) Protein biorefinery. Lecture, 12th International Conference on Renewable Resources and Biorefineries, 30-31 May & 1 June, 2016, Ghent, Belgium

L.A.M. van den Broek, C. Safi, J.J.A. van Leeuwen, W.J. Mulder, L. Sijtsma (2016) Algae Biorefinery: protein for non-food applications, Abstract, Abstract book 12th International Conference on Renewable Resources and Biorefineries 30-31 May & 1 June, 2016, Ghent, Belgium. P68

Carl Safi, Lambertus van den Broek, Lolke Sijtsma (2016) Microalgae biorefinery, Poster, European roadmap for an algae-based industry, 6-8 April, Olhão, Portugal

Carl Safi (2016) La technologie des microalgues: quel potentiel? L'Orient Le Jour. Article <https://www.lorientlejour.com/article/991452/la-technologie-des-microalgues-quel-potentiel-.html>

C. Safi, L.A.M. van den Broek, W. Mulder, L. Sijtsma (2016) Microalgae Biorefinery: Obtaining an enriched protein fraction after cell disruption and ultrafiltration. Abstract, Booklet for the European Conference 6-8 April 2016, Olhão, Portugal. p45.

L. Sijtsma, B. Gilbert-López, E. Ibáñez, L.A.M. van den Broek, C. Safi, R. Floor, K. Schatteman, M. de Filette, C. Sagt, B. van den Burg, G. Olivieri, C. Unamunzaga (2016) MIRACLES: Development of integrated algae biorefinery technology, Abstract, Booklet for the European Conference 6-8 April 2016, Olhão, Portugal. p46

Reith, H., Leen Bastiaens, Hans Kleivdal, Lolke Sijtsma, Philippe Willems, Carlos Unamunzaga, Elke Breitmayer, Macarena Sanz, René Wijffels. (2016) Production of specialties for food, aquaculture and non-food applications via multi-product biorefinery of microalgae.

Multi-product Integrated bioRefinery of Algae: from Carbon dioxide and Light Energy to high-value Specialties (2013-2017). Invited lecture: European roadmap for an algae-based industry, 6-8 April, Olhão, Portugal
http://eualgaeroadmapconference.eu/fileadmin/intesusal_docs/Documents/Industry_Seminars/Presentations_2016/Welcome/7.MIRACLES_FINAL_Olhao_Pitch_Presentation.pdf

Reith, H., Leen Bastiaens, Hans Kleivdal, Lolke Sijtsma, Philippe Willems, Carlos Unamunzaga, Elke Breitmayer, Macarena Sanz, René Wijffels. (2016) Production of specialties for food, aquaculture and non-food applications via multi-product biorefinery of microalgae: Progress in the EU FP7 project MIRACLES". Abstract. ALGAEUROPE, 13-15 December, Madrid, Spain, pp79

Reith, H., Leen Bastiaens, Hans Kleivdal, Lolke Sijtsma, Philippe Willems, Carlos Unamunzaga, Elke Breitmayer, Macarena Sanz, René Wijffels. (2016) Production of specialties for food, aquaculture and non-food applications via multi-product biorefinery of microalgae: Progress in the EU FP7 project MIRACLES" Invited lecture. ALGAEUROPE, 13-15 December, Madrid, Spain, pp79

Slegers, P. M., Olivieri, G., van Boxtel, A. J. B., Sijtsma, L. Process chain development of five algae-to-product value chains, integrating novel process technologies. Abstract. ALGAEUROPE, 13-15 December, Madrid, Spain, <http://edepot.wur.nl/405389>

Slegers, P. M., Olivieri, G., van Boxtel, A. J. B., Sijtsma, L. Process chain development of five algae-to-product value chains, integrating novel process technologies. Poster. ALGAEUROPE, 13-15 December, Madrid, Spain

2017

Reviewed scientific Publications

Gilbert-López B, Mendiola JA, Van den Broek LAM, Houweling-Tan B, Sijtsma L, Cifuentes A, Herrero M, Ibáñez E (2017) Green compressed fluid technologies for downstream processing of *Scenedesmus obliquus* in a biorefinery approach. *Algal Res* 24:111-121. <http://dx.doi.org/10.1016/j.algal.2017.03.011>

Safi, C., Olivieri, G., Campos, R. P., Engelen-Smit, N., Mulder, W. J., Van den Broek, L. A. M., Sijtsma, L. (2017). Biorefinery of microalgal soluble proteins by sequential processing and membrane filtration. *Bioresource Technology*, 225, 151–158.

Safi C, Cabas Rodriguez L, Mulder WJ, Engelen-Smit N, Spekking W, Van den Broek LAM, Olivieri G, Sijtsma L (2017) Energy consumption and water-soluble protein release by cell wall disruption of *Nannochloropsis gaditana*. *Bioresour Tech* 239:204-210. <http://www.sciencedirect.com/science/article/pii/S096085241730651X>

(Key note) Presentation

Sijtsma, L. (2017) Multiple products from algal biomass: Need for integrated Biorefinery approaches", *Algae Biorefineries for Europe*, 17-18 October 2017, Brussels, Belgium <https://algaebiorefineryconference.eu/documents/>

Reith, H., Leen Bastiaens, Hans Kleivdal, Dorinde Kleinegris, Lolke Sijtsma, Philippe Willems, Carlos Unamunzaga, Elke Breitmayer, Macarena Sanz, René Wijffels (2017). Production of specialties for food, aquaculture and non-food applications via multi-product biorefinery of microalgae. *Algae Biorefineries for Europe*. 17-18 October 2017, Brussels, Belgium <https://algaebiorefineryconference.eu/documents/>

van den Broek, L.A.M. (2017). Analytics and a practical on filtration and homogenisation of microalgae. *Microalgaebiorefinery – Summerschool*, 31-8-2017, Wageningen, The Netherlands

van den Broek, L.A.M. (2017). Miracles project. Algae-based materials and products. *Workshop BISIGODOS-EU-project*, 20-4-2017, Warwick, England

van den Broek, L.A.M (2017). Biobased Economy and Microalgae. *Biotalk: Aquatic Harvesting*, Mediamatic, 13-7-2017, Amsterdam, The Netherlands

Safi, C. (2017). Microalgae protein biorefinery, *13th International Conference on Renewable Resources & Biorefineries*, 8-6-2017, Wroclaw, Poland.

Poster Presentations/Abstracts

Safi, C, van den Broek, L.A.M., Sijtsma, L. (2017) *Nannochloropsis gaditana* protein biorefinery" *Algae Biorefineries for Europe*, 17-18 October 2017, Brussels, Belgium

Safi, C., Lambertus A.M. van den Broek, Wim Mulder, Lolke Sijtsma (2017). *Algae Biorefinery: Proteins for Technical Applications*. 5th Central European Biomass Conference (CEBC2017), 19-2-2017, Graz, Austria

van den Broek, L.A.M. Houweling-Tan, B., Safi, C., Sijtsma, L. (2017) *Chemical characterization of microalgae" Algae Biorefineries for Europe*, 17-18 October 2017, Brussels, Belgium