Barriers for the transition towards more sustainable food systems and how to overcome them

Prof. Dr.-Ing. Alexander Mathys
ETH Zurich
28. May 2021

Food systems are at the heart of our 17 Sustainable Development Goals SDGs

(United Nations, 2015)

Food systems are at the heart of our 17 Sustainable Development Goals SDGs

Man buys vegetables at supermarket

About the Summit

What is the Food Systems Summit?

In 2021, UN Secretary-General António Guterres will convene a Food Systems Summit as part of the Decade of Action to achieve the Sustainable Development Goals (SDGs) by 2030. The Summit will launch bold new actions to deliver progress on all 17 SDGs, each of which relies to some degree on healthier, more sustainable and equitable food systems.

The Summit will awaken the world to the fact that we all must work together to transform the way the world produces, consumes and thinks about food. It is a summit for everyone everywhere – a people's summit. It is also a solutions summit that will require everyone to take action to transform the world's food systems.

Guided by five Action Tracks, the Summit will bring together key players from the worlds of science, business, policy, healthcare and academia, as well as farmers, indigenous people, youth organizations, consumer groups, environmental activists, and other key stakeholders. Before, during and after the Summit, these actors will come together to bring about tangible, positive changes to the world's food systems.

(United Nations, 2021)

Recent Relevant Publications on Food System Sustainability

THE LANCET
Planetary Health

Articulating the effect of food systems innovation on the Sustainable Development Goals

Mario Herrero, Philip K Thornton, Daniel Mason-D'Croz, Jeda Palmer, Benjamin L Bodirsky, Prajal Pradhan, Christopher B Barrett, Tim G Benton, Andrew Hall, Ilje Pikaar, Jessica R Bogard, Graham D Bonnett, Brett A Bryan, Bruce M Campbell, Svend Christensen, Michael Clark, Jessica Fanzo, Cecile M Godde, Andy Jarvis, Ana Maria Loboguerrero, Alexander Mathys, C Lynne McIntyre, Rosamond L Naylor, Rebecca Nelson, Michael Obersteiner, Alejandro Parodi, Alexander Popp, Katie Ricketts, Pete Smith, Hugo Valin, Sonja J Vermeulen, Joost Vervoort, Mark van Wijk, Hannah HE van Zanten, Paul C West, Stephen A Wood, Johan Rockström

nature sustainability

comment | Check for updates

Bundling innovations to transform agri-food

Christopher B. Barrett, Tim G. Benton, Karen A. Cooper, Jessica Fanzo, Rikin Gandhi, Mario Herrero, Steven James, Mark Kahn, Daniel Mason-D'Croz, Alexander Mathys, Rebecca J. Nelson, Jianbo Shen, Philip Thornton, Elizabeth Bageant, Shenggen Fan, Andrew G. Mude, Lindiwe M. Sibanda and Stephen Wood

editorial

Innovating the food value chain

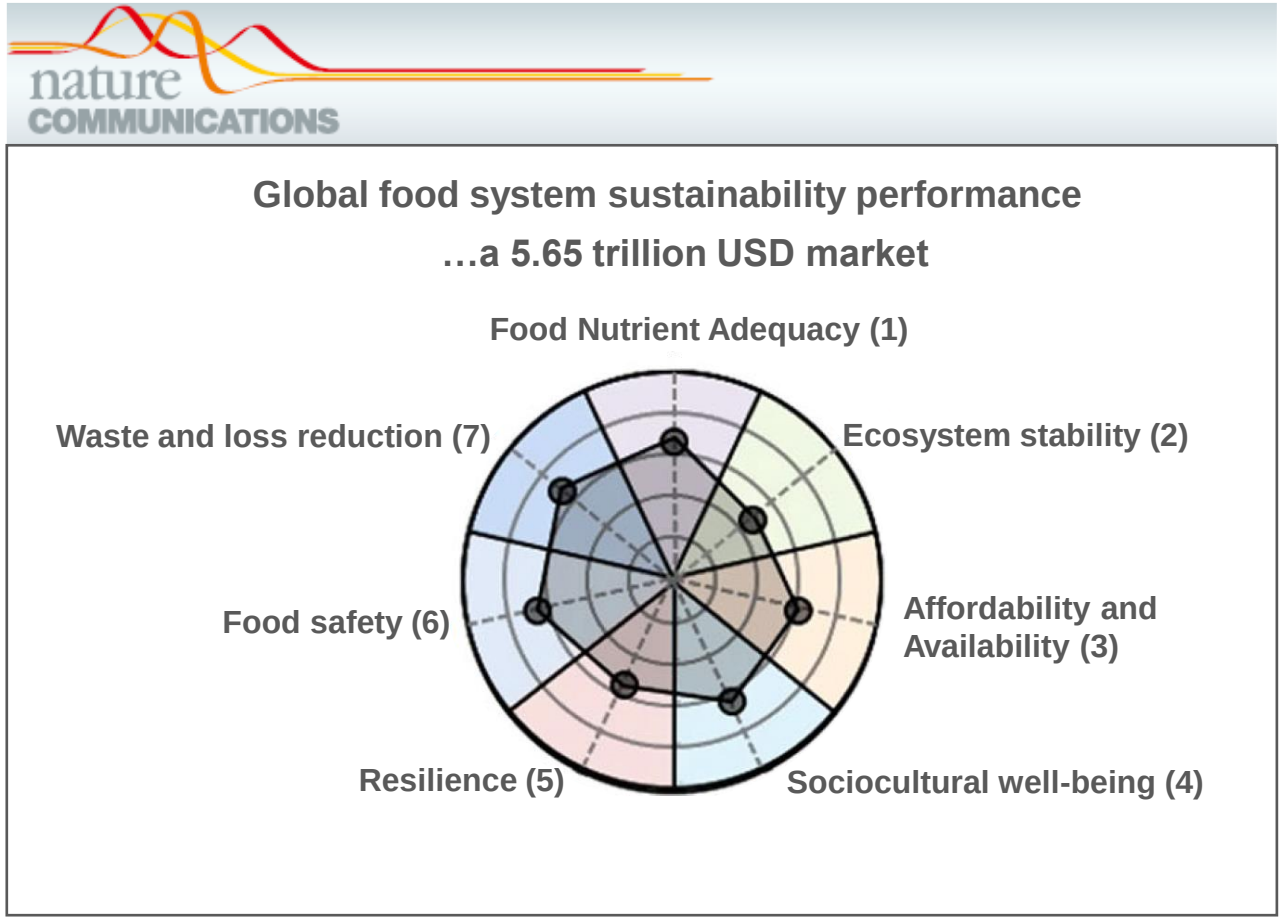
Socio-Technical Innovation Bundles for Agri-Food Systems Transformation

A Cornell Atkinson Center for Sustainability/
Nature Sustainability
Expert Panel Report

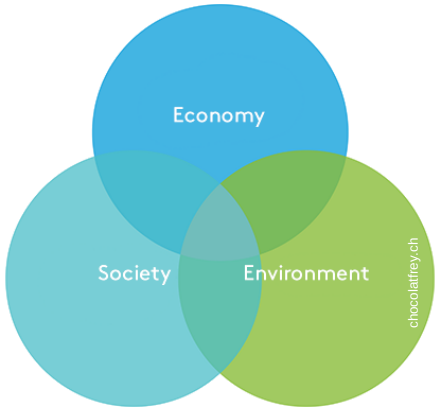
December 2020

nature sustainability

Food system understanding by multi-indicator sustainability analysis of all three dimensions



Chaudhary, Gustafson & Mathys 2018, Nature Communications. 9, 848

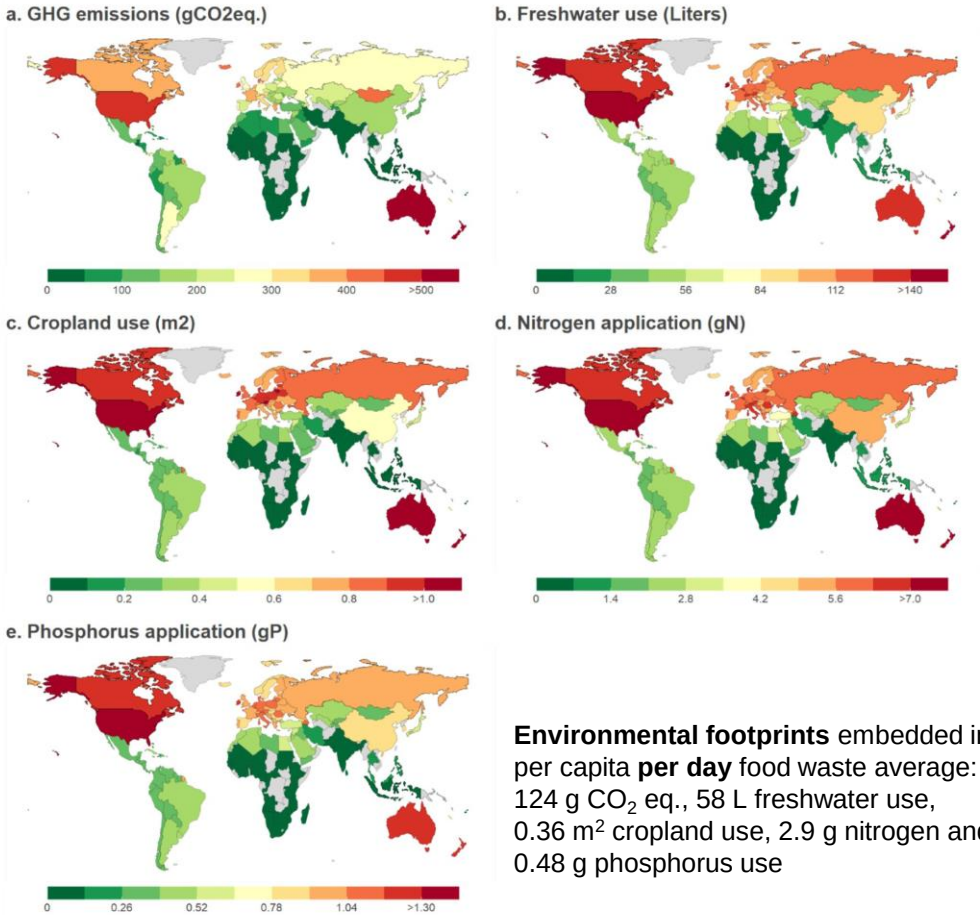


FNSNF
73 NRP Sustainable Economy
National Research Programme

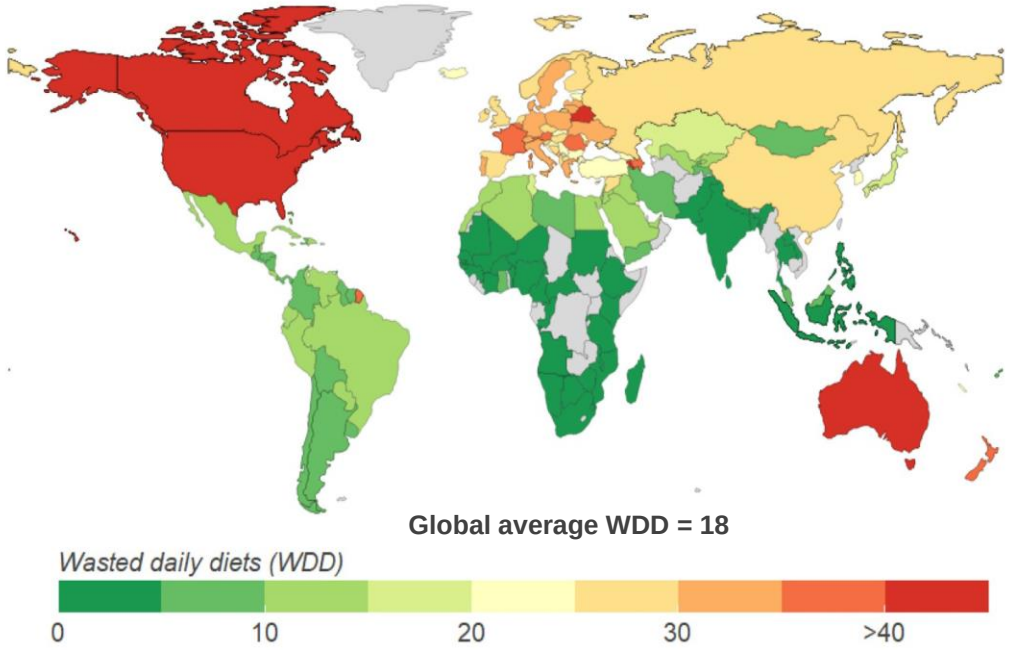
Global food systems are at the heart of our 17 SDGs

(United Nations, 2015)

Nutritional and environmental losses embedded in global food waste



Environmental footprints embedded in per capita **per day** food waste average: 124 g CO_2 eq., 58 L freshwater use, 0.36 m^2 cropland use, 2.9 g nitrogen and 0.48 g phosphorus use



Country-specific Wasted Daily Diets (WDD) embedded in national per capita **per year** food waste. The WDD represents the days for which a person can be fed a healthy diet meeting the daily required nutrient intake of all 24 essential nutrients and calories.

Chen, Chaudhary & Mathys (2020). Resources, Conservation and Recycling, 160: 104912.

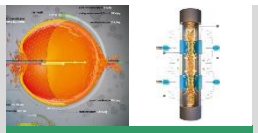
ETH Sustainable Food Processing Research

SFP Flagship Project

Novel Resources | Primary Production | Gentle Release | Functional Ingredients | Structure+Safety | Consumption | Biological Response


Microalgae


Algae Bioreactors

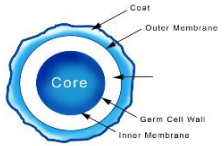

Disintegration


Proteins & Lipids

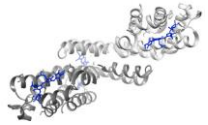

Processing

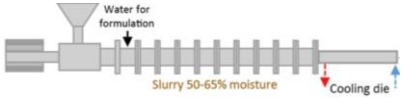

Quality Foods

?
Nutritive Foods



Microbial Ecosystem Analysis and Control


Structure-Process Properties Interactions



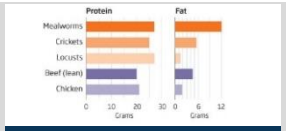
Emerging processing (Structuring/Disintegration/Safety)

Cooperation with nutrition, medicine, and consumer science


Insects


Rearing

Separation



Protein & Lipids


Processing

Quality Food/Feed

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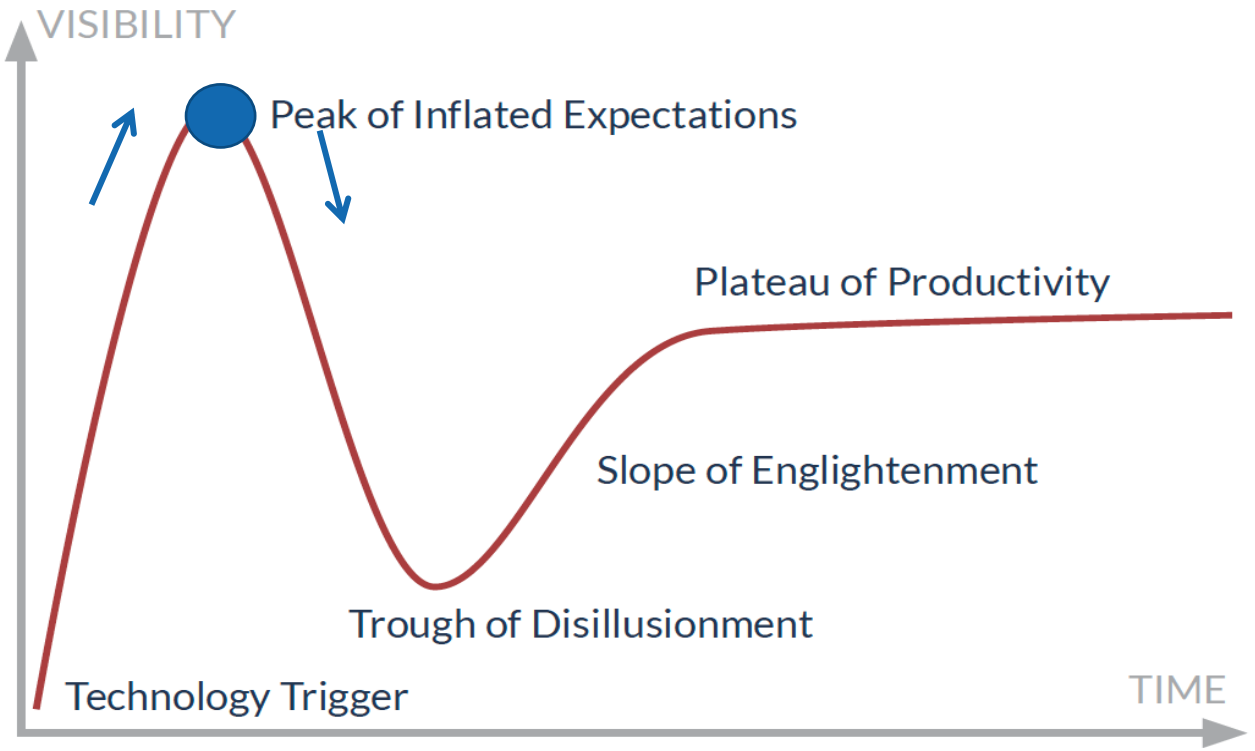
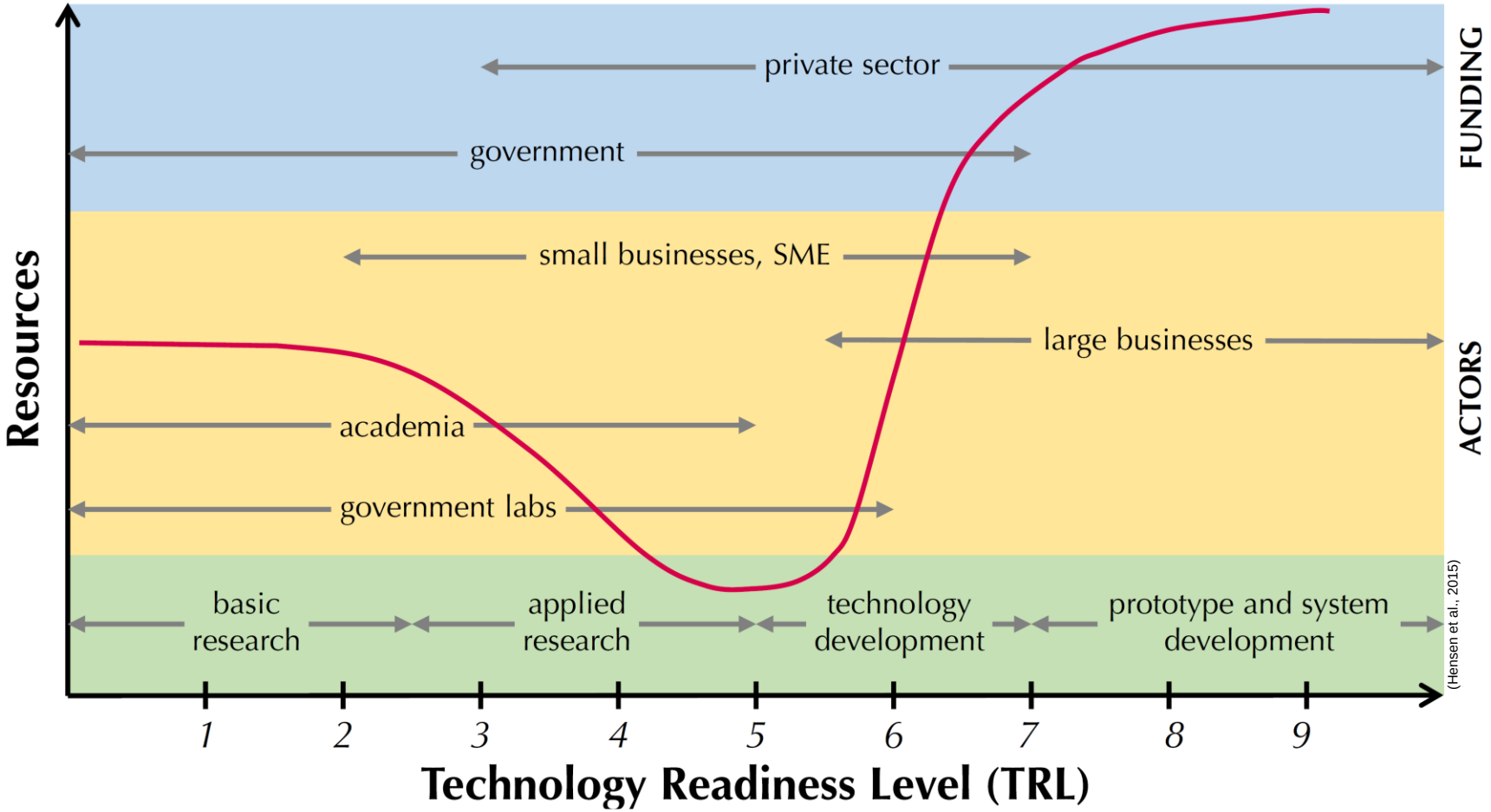
Multi Indicator Sustainability Assessment - Method Development and Case Studies

Hype versus Reality

The Gartner Hype Cycle



Different technology readiness level, the connected ecosystem and relevance of economies of scale



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ECONOMIES OF SCALE

ETH Sustainable Food Processing Research-Focus Insects

Novel Resources | Primary Production | Gentle Release | Functional Ingredients | Structure+Safety | Consumption | Biological Response

Microalgae

Algae Bioreactors

Disintegration

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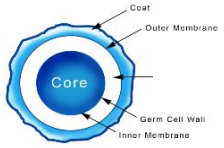

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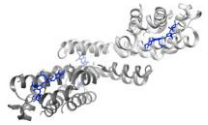
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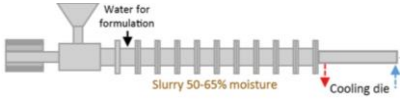

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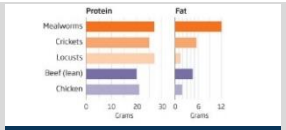

Protein & Lipids


Processing

Quality Food/Feed

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Nutritive Foods

Multi Indicator Sustainability Assessment - Method Development and Case Studies

Alternative animal proteins based on Black Soldier Fly waste utilization for more sustainable feeds

(Stefan Diener, Black Soldier Fly Biowaste Processing Manual, Sandec 2017; ETH Zurich SFP and Eawag facility in Dübendorf, CH)

1) Gold,Tomberlin, Diener, Zurbrügg, & Mathys (2018). Waste Management. 82, 302-318.
2) Aarts, Jansen, Jacobs, Mescher, Prenter, Mathys & De Moraes (2018). Processing of insect larvae. EU patent application. Application No 18175914.3-110
3) Gold, Cassar, Zurbrügg, Kreuzer, Bolus, Diener & Mathys (2019). Waste Management. 102, 319-329.
4) Gold, Egger, Scheidegger., Zurbrügg, Bruno, Bonelli, Tettamanti, Casartelli, Schmitt, Kerkaert, De Smet, van Campenhout & Mathys (2020). Waste Management. 112, 40-51.
5) Gold et al. (2020). Journal of Insect Science, 20: 3, 21ff.
6) Gold, von Allmen, Zhang, Zurbrügg & Mathys (2020). Frontiers in Microbiology, 11: 582867.
7) Gold, Fowles, Fernandez-Bayo, Palma Miner, Zurbrügg, Nansen, Bischel & Mathys (2021). Journal of Insects as Food and Feed. accepted

Black soldier fly larvae-based waste utilization and biorefinery products

BÜHLER

PROTIX

Protein meal

Key benefits: Balanced amino acid profile with very good palatability and digestibility.

Insect lipids

Key benefits: Easy digestible energy with high lauric acid content.

Fertilizer

Key benefits: Slow nutrient release over time with chitin as functional component.

(BITS, 2020)

Smetana, Schmitt & Mathys (2019). Resources, Conservation & Recycling. 144, 285–296.

Environmental sustainability of most relevant protein sources in comparison

Environmental impact comparison of main protein sources used for feed and food (per 1 kg of product)

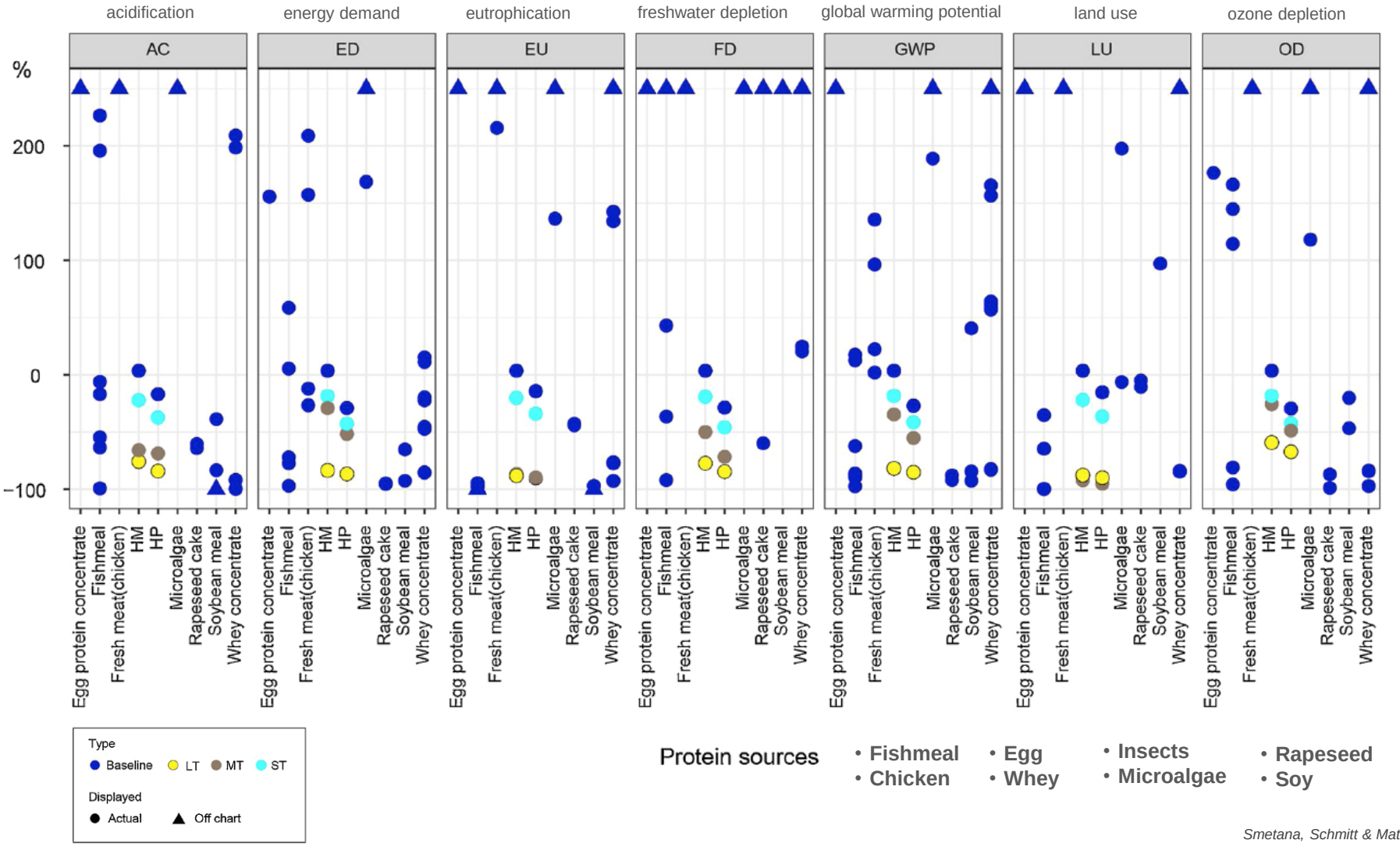
	DM %	Protein, %	GWP, kg CO_2 eq. global warming potential	OD, mg CFC11 ozone depletion	AC, g SO_2 eq. acidification	EU, g N eq. eutrophication	ED, MJ energy demand	FD, m^3 freshwater depletion	LU, m^2a land use
Soybean meal	87.5[1]	49.1[1]	0.34-0.72[1] 6.52[19]	0.2-0.3[1,17]	−1.2 – 3.1[1] 11.4[17]	−81-2[1] (g NO_3 eq.)	5.37[6] 25.5[19]	0.04[6]	3.26[6]
Rapeseed cake	89[1]	34.8[1]	0.37-0.57[6]	0.004-0.05[6]	6.8-7.5[6]	8.9-9.1[6]	3.3-3.8[6]	0.001-0.03[6]	1.5-1.6[6]
Pea protein meal	n/a	n/a	0.44[6] 4-10[8] (pulses)	0.057[6]	21.8[6]	7.94[6]	5.25[6]	0.03[6]	2.85[6]
Fishmeal	90[4]	60-72[5]	0.12-0.58[18] 0.65-1.8[14,3,4,13] 0.48-5.6[15,16] 5.37[17]	0.016-0.073[18] 0.83[3] 0.947-1.03[17,4]	0.12-8.7 [14,18] 7.0[13] 15.9-18.0[4.16] 56.7-62.6[19,3]	−16[4] 0.4-0.87 [3.18]	2.13-17.1[18,4,3] 21[13] 79.8[17] 120[16]	0.0002-0.0016[18] 0.0036[3] 0.347[4]	0.0005-0.0052[1] [8,3] 0.6-1.1[14]
HM (this study)	96.6	56	5.3	0.43	21.3	17.9	84.18	0.0028	1.89
HP (this study)	30	17	1.16	0.091	5.3	4.6	17.9	0.0006	0.48
Fresh meat (chicken)	25-30	23-24	1.62-3.12[10]	1.8[10]	44.25[10]	75[10] (g NO_3 eq.)	18.5-65[10]	0.053-0.155[11]	19.5-31.3[11]
Whey concentrate	86-89[3]	60[3,7] 80[11,kp]	7.48[7] 0.8-7.4[6] 12.1[2] 28–43[8,kp] 40.6[11,kp]	0.01-0.06[9] 3.33[7] 3.8[11,kp]	0.05-1.5[6] 56.6[7]	1.14[6] 37.3[2] 3.59-101[9] 229.3[11,kp]	58.1[2] 83.3[7] 10.7-39.4[6]	0.003-0.066[6] 1.45[2] 9.58[7]	0.26-8.27[6]
Egg protein concentrate[9]	85	80	23.4	1.01	4000	139	183	2.65	40.1
Microalgae[9]	96	55	14.7-245.1	0.9-19.8	260.5-1407.5	40.6-105.3	217.1-4181.3	0.3-3.9	1.7-5.4

HM-Insect meal (defatted protein concentrate)
HP-Insect puree (fresh insect production)

Sources: [1] – (Dalgaard et al., 2008); [2] – (Kim et al., 2013); [3] – own calculations, [4] – Danish LCA Food Database; [5] – (Hall, 2011); [6] – ecoinvent 3 and Agrifootprint databases; [7] – (Smetana et al., 2016); [8] - (Nijdam et al., 2012); [9] – (Smetana et al., 2017); [10] – (González-García et al., 2014; Weidema et al., 2008); [11] – (Wiedemann et al., 2017); [12] – (Bacenetti et al., 2018); [13] – (Papatryphon et al., 2004); [14] – (Samuel-Fitwi et al., 2013); [15] – (Cashion et al., 2017); [16] – (Smárason et al., 2017); [17] – (Silva et al., 2017); [18] – (Fréon et al., 2017); [kp] – per kg protein. Note: HP – *H. illucens* puree (fresh insect production); HM – *H. illucens* meal (defatted protein concentrate); DM – dry mass, GWP – global warming potential; OD – ozone depletion; AC – acidification; EU – eutrophication; ED – energy demand; FD – freshwater depletion; LU – land use.

Smetana, Schmitt & Mathys (2019). Resources, Conservation & Recycling. 144, 285–296.

Environmental sustainability of most relevant protein sources in comparison



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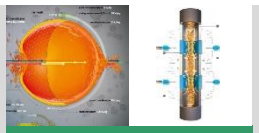
ETH Sustainable Food Processing Research-Focus Microalgae

Novel Resources | Primary Production | Gentle Release | Functional Ingredients | Structure+Safety | Consumption | Biological Response


Microalgae


Algae Bioreactors


Disintegration


Proteins & Lipids


Processing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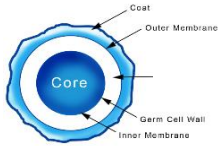
Nutritive Foods



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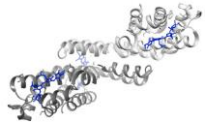
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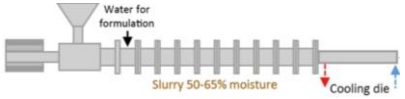

Emerging processing (Structuring/Disintegration/Safety)

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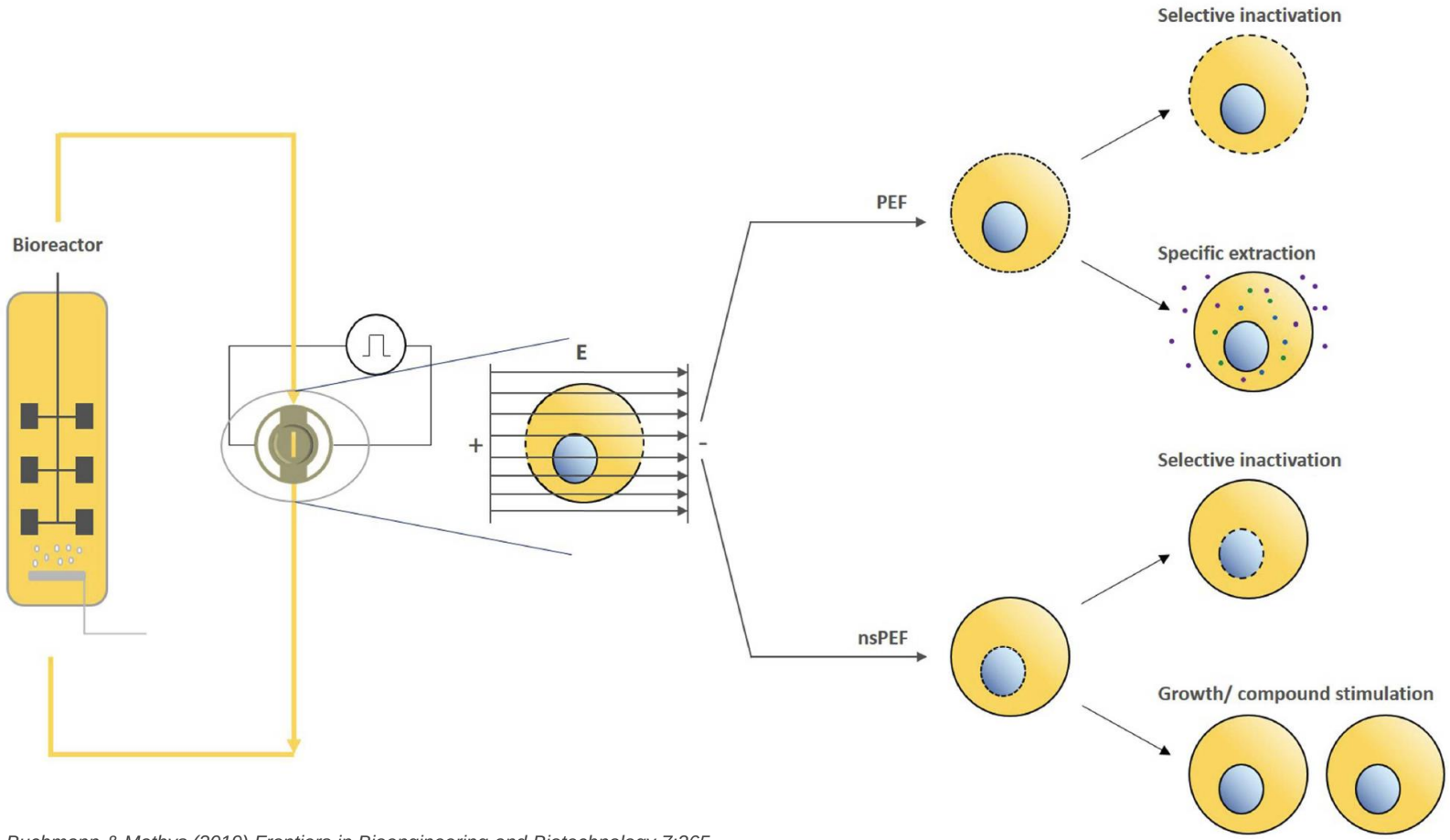
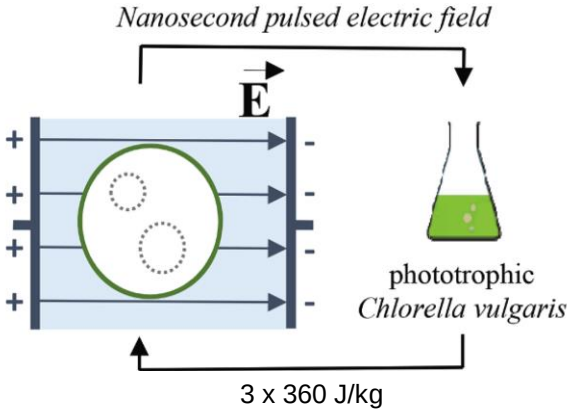
Multi Indicator Sustainability Assessment - Method Development and Case Studies

Pulsed electric field PEF for more efficient up and downstream bioprocessing, case studies on microalgae

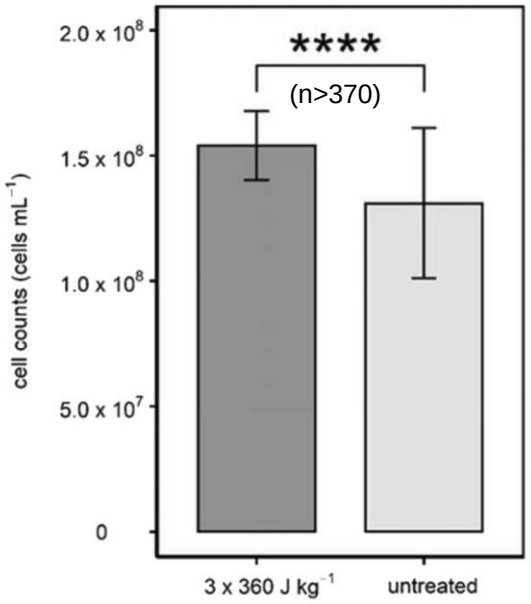


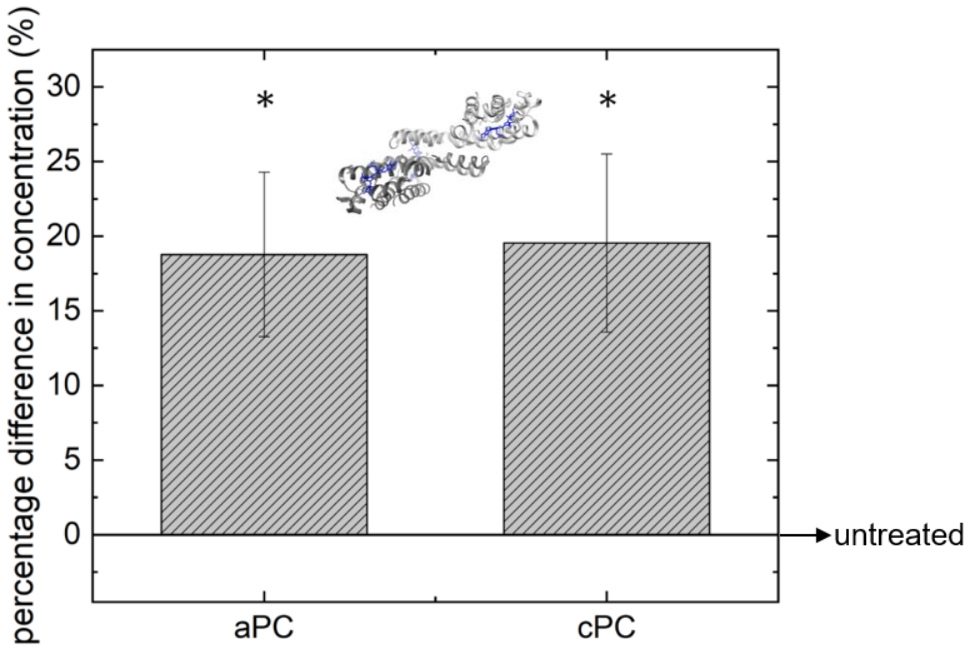
Buchmann & Mathys (2019).Frontiers in Bioengineering and Biotechnology.7:265.
Haberkorn, Siegenthaler, Buchmann, Neutsch & Mathys (2021). Biotechnology Advances. 107780

Increased cell proliferation in *Arthrospira* and *Chlorella,* plus high value-added pigment content (phycocyanin) in *Arthrospira*



Flow cytometry-based assessments

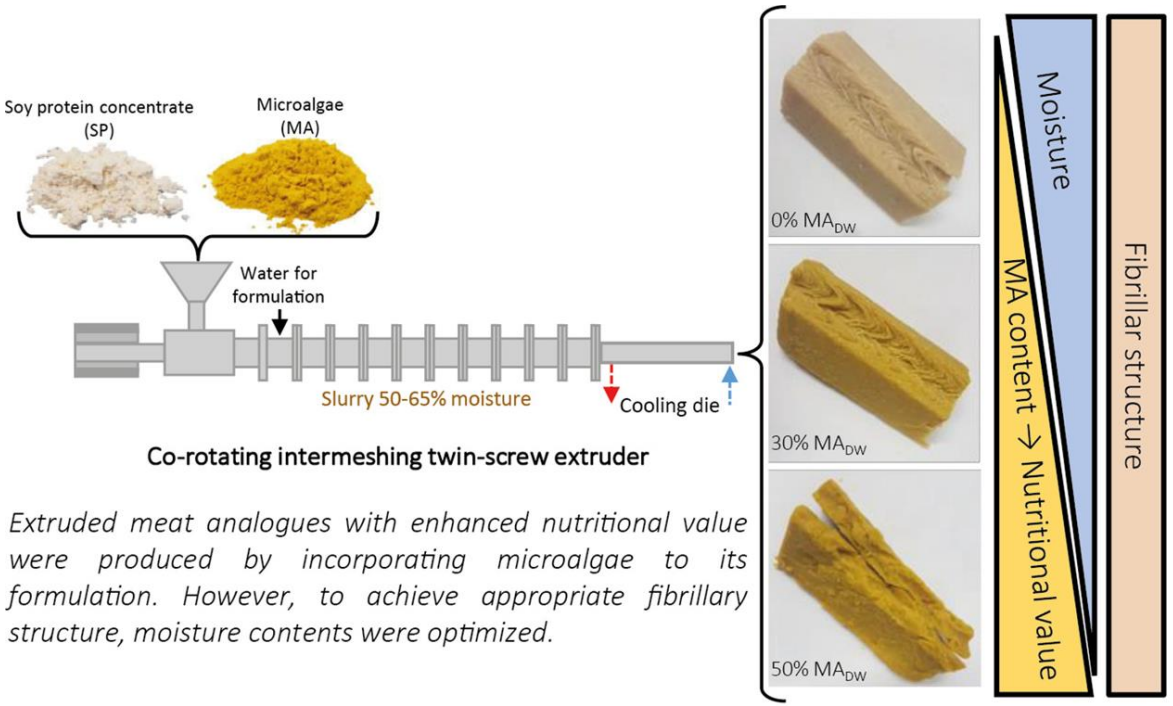




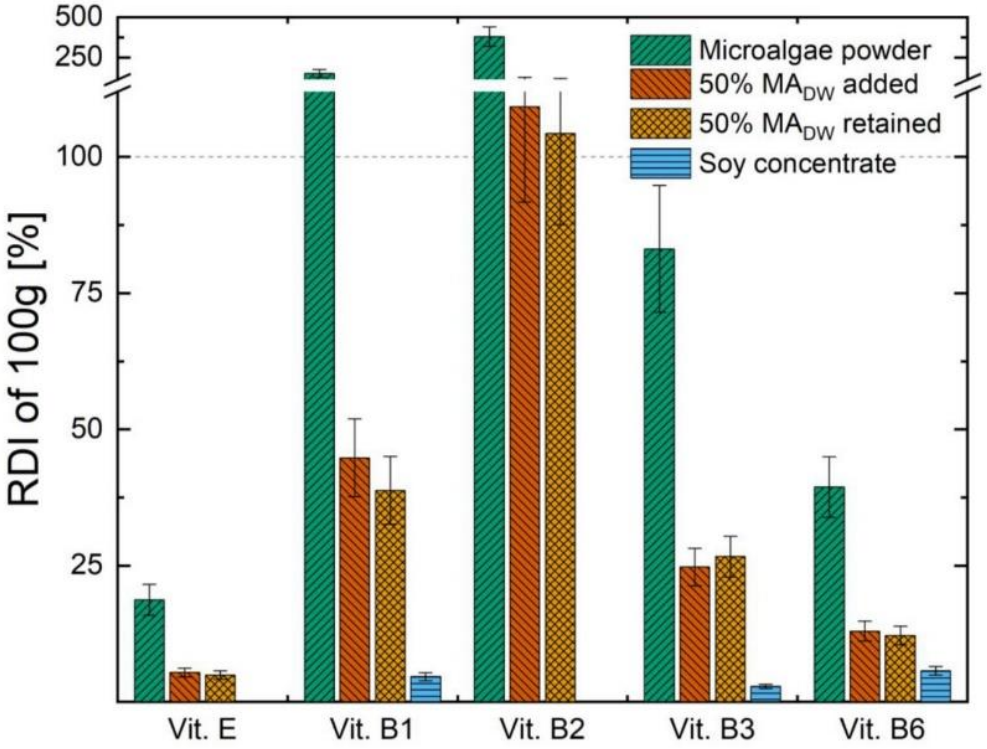
Phycocyanin protein complex
Allophycocyanin (aPC) and C-Phycocyanin (cPC)

Buchmann, Frey, Gusbeth, Ravaynia & Mathys (2019). Bioresource Technology 271, 402-408.
Haberkorn, Buchmann, Hiestand & Mathys (2019). Bioresource Technology, 122029.

High moisture extrusion to produce bright algae-based meat analogs, with increase of nutritional value



Extruded meat analogues with enhanced nutritional value were produced by incorporating microalgae to its formulation. However, to achieve appropriate fibrillary structure, moisture contents were optimized.



Recommended daily intake (RDI) of the selected vitamins in 100 g of unprocessed microalgae (MA) powder, extrudate with 50% MA$_{DW}$ before and after extrusion, and soy protein concentrate powder according to FDA (2016).

Caporgno, Böcker*, Müssner, Stirnemann, Haberkorn, Adelmann, Handschin, Windhab & Mathys (2020). Innovative Food Science and Emerging Technologies, vol. 59, pp. 102275*

ETH Sustainable Food Processing Research and Future Outlook

Novel Resources | Primary Production | Gentle Release | Functional Ingredients | Structure+Safety | Consumption | Biological Response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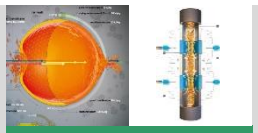
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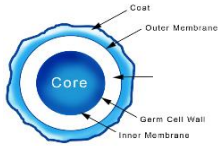

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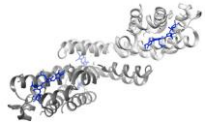
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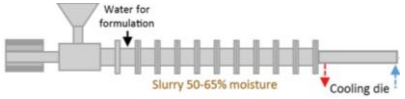

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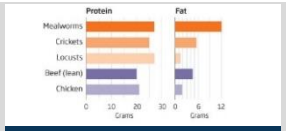

Protein & Lipids


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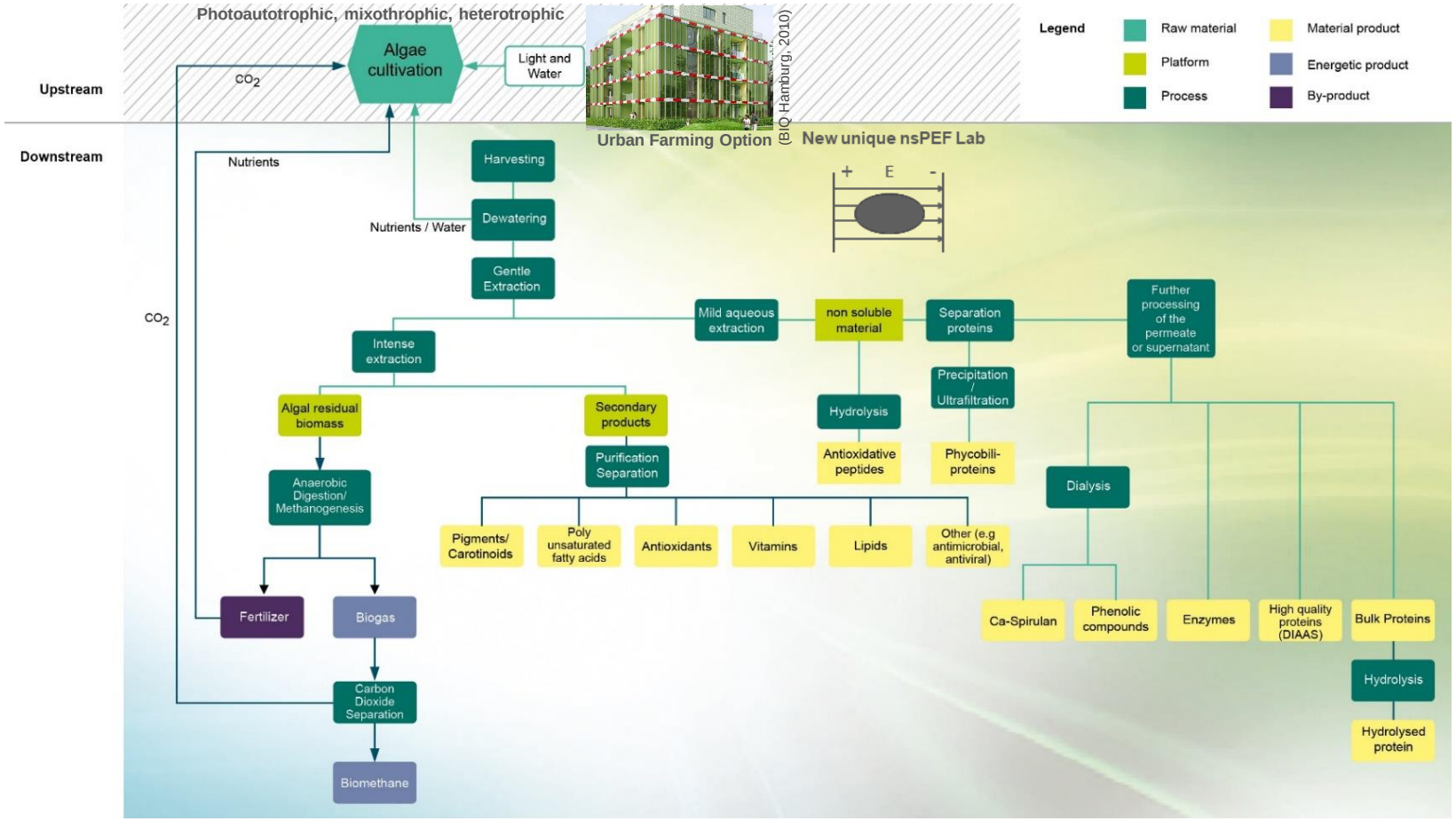
Multi Indicator Sustainability Assessment - Method Development and Case Studies

Innovative Algae Biorefinery Concept based on emerging Up- and Downstream How to integrate our R&D



World Food System Center

Nestlé BÜHLER GNT PHARMA BIOME planted. hilcona FÜR BESSERESSER. (SEC) SINGAPORE-ETH CENTRE

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16) Haberkorn, Walser, Helisch, Böcker, Belz, Schuppler …Mathys, 2020
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22) Haberkorn, Off, Besmer, Buchmann & Mathys, 2021
23) Haberkorn, Siegthaler, Buchmann, Neutsch & Mathys, 2021

Thank you very much

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