BioÖkonomieRat

Background paper

Last updated: October 2023

Novel Foods

Böcher, M.; Bronsema, V.; Brück, T.; Eck, J.; Heiden, S.; Pieschetsrieder, M.

Note

This background paper summarises the key statements and discussion points from various workshops held on this topic between May 2022 and September 2023, under the leadership of the aforementioned authors and with the participation of external stakeholders. This is not a Bioeconomy Council position paper. Its contents, views and conclusions do not represent recommendations for action or the results of studies carried out by the German Bioeconomy Council, rather they exclusively reflect the contents of the discussions conducted by and with experts.

Introduction and Synopsis

Providing humanity with sufficient healthy food is a key humanitarian issue. The international community (UN) agreed on this as part of the Paris Climate Agreement and defined 17 Sustainable Development Goals (SDGs) in its plan of action, known as Agenda 2030. SDG 2 is:

"End hunger, achieve food security and improved nutrition and promote sustainable agriculture."

Corresponding political frameworks at various state levels play a decisive role here. Sufficient nutrition for all people is also considered a significant key to protecting the environment and the climate.

A working unit (WU) within the Bioeconomy Council has discussed the different aspects of food production within the context of a sustainable bioeconomy. The participants explicitly focussed on the topic of (alternative) proteins and, alongside experts, explored these aspects in a workshop dedicated to the topic.

The authors of this background paper are aware that this (bio)technologically focussed perspective only represents a small fragment, whose future role in food systems can only be outlined at this stage. In view of the continuing upward trend in global meat consumption[1], it is important to consider the changes in consumer behaviour that are already evident in parts of Asia and increasingly so in Germany and the rest of Europe. The task will be to come up with a vision that could pave the way for this development in accordance with SDG 2.

While the potential of protein intake as part of vegan and vegetarian diets has long been recognised among certain population groups in Asia[2], it has only recently become more prevalent in Germany and the rest of Europe.[3] Consequently, this background paper will focus, in particular, on new sources of protein in line with this development. As there is an oversupply and excess consumption of protein within the population in our part of the world, the authors wish to shed light on products that could convince consumers to follow a more sustainable diet that features less meat and guarantee people with dysphagia (swallowing disorders) a more balanced diet. Furthermore, an extended supply of proteins can help in regions where the problem of malnutrition needs to be addressed.

Besides the requirements of an adequate and healthy diet, scientists from the EAT-Lancet Commission[4] analysed the requirements of sustainable food production in various scenarios under the scope of a "Planetary Health Diet", especially due to climate protection needs. Even if circumventing 50 % of post-harvest food losses by 2050 proves possible, an approx. 75 % reduction in beef and pork production will still be required. Correspondingly, the production of alternative protein sources from plant proteins and fish, in particular, would have to be increased by around 100 % by 2050. The increasing competition for land needed for more sustainable land use and the limitation of ecologically sensible agricultural land yields and aquacultures alone demonstrate the necessity of considering sustainable food production systems and novel foods. The goal must be to achieve the low use of land and drinking water as well as a small CO_2 footprint.

Novel food is currently a hot topic in the media, which has prompted the authors to enter the discussion. Many approaches that could make a sustainable and healthy diet palatable to consumers in the future and, in doing so, contribute to the transformation of

[1] See diagram: Ahrens (2023b): global meat production, 1961 to 2023 (in million tonnes dressed carcass weight). Statista GmbH. (https://de.statista.com/statistik/daten/ studie/28782/umfrage/die-globale-fleischerzeugung-seit-1990/).
[2] cf. Bashir (2023): countries with the highest percentage of vegetarians in the population worldwide in 2023. Statista GmbH. (https://de.statista.com/prognosen/261627/anteil-von-vegetariern-und-veganern-an-der-bevoelkerung-ausgewaehlter-laender-weltweit).
[3] Per capita meat consumption in Germany has fallen continuously in recent years (cf. Bundesanstalt für Landwirtschaft und Ernährung (BLE) 2023b) and commercial meat production has also decreased in Germany (cf. Bundesanstalt für Landwirtschaft und Ernährung (BLE) 2023a).
[4] Cf. Willett, Rockström, Loken, Springmann, Lang, Vermeulen et al. (2019): Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. In: Lancet 393 (10170).

nutrition in light of climate change and population growth are still in their infancy. Whether they will ever play a role in human nutrition, and to what extent, remains to be seen.

This background paper intends to present some of the new approaches and stimulate discussion on how desired sustainable developments can be supported. Novel foods and new protein sources are presented, highlighting their potential role for environmental and climate protection and technological advancements as well as examining other aspects such as enjoyment. Finally, commercial opportunities and framework conditions for tapping into new markets are addressed, albeit without claiming to be exhaustive.

1. Novel food and innovative production methods

As a rule, foodstuffs are freely marketable, provided they fulfil all food law regulations and quality criteria. However, placing what are known as novel foods on the market requires authorisation in accordance with Article 10 of the Novel Food Regulation (EU) 2015/2283.[5]

Novel Food is defined as food that had not been consumed to a significant degree by humans in the EU before 15 May 1997, when the first Regulation on novel food came into force, and can be assigned to certain food groups listed in the aforementioned regulation.[6]

At present, authorisation procedures under the Novel Food Regulation are sometimes very complex, cost-intensive and lengthy. The European Union considers novel foods to include exotic plants, seeds and fruits, microalgae, insects and other new foodstuffs, such as single-cell proteins generated from fungi fermentation and other microbial sources.

New food crops can be identified and utilised based on this regulation. For example, in the future, the nightshade plant Jatropha Curcas L., which can be cultivated on marginal or devastated land, could form the basis for a novel food – a new plant-based cheese alternative. What is interesting here, in terms of a circular economy, is that this plant can be used in its entirety, as both its proteins and its oil can be refined and used to make high-quality products, thus avoiding the generation of what is known as "residual materials" from the outset.

In recent decades, biological fermentation, a principle that has been known for thousands of years, has been increasingly optimised for food production. Beforehand, cells and microorganisms had primarily been used to produce products that they form naturally as part of their metabolism. The primary research objective was to increase the proportion of these compounds further, to establish more favourable substrates as raw materials or

[5] European Union (EU) (2015): Regulation (EU) 2015/2283 of the European Parliament and of the Council of 25 November 2015. 2015/2283. (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R2283).

[6] Bundesministerium für Ernährung und Landwirtschaft (BMEL) (2020): Neuartige Lebensmittel - Novel Food. (https://www.bmel.de/DE/themen/verbraucherschutz/lebensmittelsicherheit/spezielle-lebensmittel/novel-food.html).

to optimise the processing conditions and the subsequent purification steps to ensure a higher yield and better quality.

Since the 1980s, genetic engineering has been used to control the metabolism of production organisms, in order to make them produce large quantities of the desired products, preventing the formation of undesirable by-products. Since then, the range of tools used in industrial biotechnology has expanded considerably, leading today's experts to coin the term "precision fermentation".[7] Today, precision fermentation can also be used to produce vegetarian or vegan cheese alternatives from lipid and protein products, using either genetically modified organisms (GMOs) or conventionally (classically) cultivated microorganisms.

Animal cells grown in tanks, known as "cell cultures", complement these procedures. These can be used to make meat or fish dishes.[8] The use of these new production sources and processes also mean that the resultant products are labelled "novel foods".

2. Protein supply in Germany and nutrition trends

Experts in the field of food research and human nutrition argue that the question of the basic availability of proteins or their limited quantities is irrelevant for implementing SDG 2. Rather, the intensification of military conflicts, weather extremes, economic shocks and growing inequality – which often occur together – lead to difficulties in ensuring their quantity and quality, thereby preventing or circumventing food insecurity and malnutrition.[9] The German Nutrition Society (DGE) currently recommends that adults up to the age of 64 should consume 0.8 grammes of protein per kilogramme of body weight per day, with a slightly higher intake recommended for children, pregnant women and the elderly (e.g. one gramme of protein per kilogramme of body weight per day from the age of 65).[10] In our part of the world, these values are exceeded on a regular basis. This is also due to the fact that, although declining slightly, meat consumption levels are still far above the recommended amounts.[11]

[7] Vgl. Lohmann und Graf (2022): Präzisionsfermentation: Maßgeschneiderte Bioproduktion. BIOCOM Interrelations GmbH. (https://biooekonomie.de/themen/dossiers/praezisionsfermentation-massgeschneiderte-bioproduktion).
[8] Siehe Abbildung: Englbrecht und Höpner (2023): Positionspapier des BIO Deutschland. Biotechnologische Alternativprodukte zu Fleisch, Fischgerichten, Eiern und Milchprodukten. BIO Deutschland e. V. (https://www.biodeutschland.org/de/positionspapiere/positionspapier-der-bio-deutschland-biotechnologische-alternativprodukte-zu-fleisch-fischgerichten-eiern-und-milchprodukten.html).
[9] Cf. Food and Agriculture Organization of the United Nations (FAO) et. al. (2023): The State of Food Security and Nutrition in the World. Urbanization, agrifood systems transformation and healthy diets across the rural–urban continuum. Rome.
[10] Cf. Deutsche Gesellschaft für Ernährung e. V. (DGE) (2023b): Leitlinie Protein. (https://www.dge.de/wissenschaft/dge-leitlinien/leitlinie-protein/).
[11] a) Cf. Deutsche Gesellschaft für Ernährung e. V. (DGE) (2023a): Wie beeinflusst die Proteinzufuhr unser Gewicht? (https://www.dge.de/presse/meldungen/2023/wie-beeinflusst-die-proteinzufuhr-unser-gewicht/); b) Cf. Bundesanstalt für Landwirtschaft und Ernährung (BLE) (2023b): Fleischverzehr 2022 auf Tiefstand. (https://www.ble.de/SharedDocs/Pressemitteilungen/DE/2023/230403_Fleischverzehr.html).

With a reduced protein intake, particular attention must be paid to a diet containing high-quality proteins that fulfil the human requirement for essential amino acids. This means that, in the case of a purely plant-based diet, a mixture of plant proteins and new protein sources such as single-cell proteins or individual essential amino acids from yeasts, microorganisms or cell cultures can be useful for ensuring people consume enough protein.[12]The development of new protein sources and technologies (e.g. 3D printing) is an ideal opportunity to switch to a healthier, age-appropriate diet, particularly for older people, half of whom do not consume nearly enough high-quality proteins.[13]

An age-appropriate diet is not only important for senior citizens living in care facilities, but also for those over the age of 75 who may be mentally or physically impaired. The demographic change in Germany also requires us to rethink our nutritional system.[14] Incidentally, the number of people in Germany who largely abstain from eating meat has also been increasing for around seven years.

The global picture looks different, however, and shows the need for action. The Food and Agriculture Organization of the United Nations (FAO) predicted that around 364 million tonnes of meat would be produced worldwide in 2023, signifying an increase of more than 100 million tonnes compared to 2000. A change in global agriculture has also been observed in recent years – meat production costs have fallen due to the fact more feedstuffs such as soya and maize are being produced, which has resulted in an increase in meat production in many countries. The demand for different types of meat has risen, particularly in Asia's more populous countries. This is why most meat, primarily pork and poultry, is now produced on the Asian market.

[12] a) Cf. Hertzler, Lieblein-Boff, Weiler, Allgeier (2020): Plant Proteins: Assessing Their Nutritional Quality and Effects on Health and Physical Function. In: Nutrients 12 (12); b) Cf. Al-Mudhafr (2019): Microbiological Sources and Nutritional Value of Single Cell Protein (SCP). In: JNFP 2 (2).
[13] a) Cf. Hanke, Rittig, Simonis, Mohra, Füsgen, Riecker (2014): Konsensuspapier — Bedarfsgerechte Medikation bei neurologischen und geriatrischen Dysphagie-Patienten. In: MMW - Fortschritte der Medizin 156 (13); b) Cf. Guo, Arslan, Li, Cen, Shi, Huang et al. (2022): Application of Protein in Extrusion-Based 3D Food Printing: Current Status and Prospectus. In: Foods 11 (13); c) Cf. Nachal, Moses, Karthik, Anandharamakrishnan (2019): Applications of 3D Printing in Food Processing. In: Food Engineering Reviews 11 (3); d) Cf. Liu, Zhang, Bhandari, Wang (2017): 3D printing: Printing precision and application in food sector. In: Trends in Food Science & Technology 69; e) Cf. Rasouli, Valverde- Pérez, D'Este, Francisci, Angelidaki (2018): Nutrient recovery from industrial wastewater as single cell protein by a co-culture of green microalgae and methanotrophs. In: Biochemical Engineering Journal 134.
[14] a) Cf. The University of Sheffield (2020): More than half of older people don't consume enough protein to stay healthy. (https://www.sheffield.ac.uk/healthy-lifespan/news/more-half-older-people- dont-consume-enough-protein-stay-healthy); b) Cf. Rogeri, Zanella, Martins, Garcia, Leite, Lugaresi et al. (2021): Strategies to Prevent Sarcopenia in the Aging Process: Role of Protein Intake and Exercise. In: Nutrients 14 (1); c) Cf. Leung, Cheng, Tyrovolas, Tang, Liu, Tse et al. (2021): Magnitude, Temporal Trends, and Inequalities in the DALYs and YLDs of Nutritional Deficiency among Older Adults in the Western Pacific Region: Findings from the Global Burden of Disease Study 1990-2019. In: Nutrients 13 (12); d) World Health Organization (WHO) (2023): Supplemental nutrition with dietary advice for older people affected by undernutrition. (https://www.who.int/tools/elena/interventions/nutrition-older- people); e) Assisting Hands Home Care LLC. (2023): The Importance of Sufficient Protein Intake for the Elderly. (https://www.assistinghands-il-wi.com/blog/importance-of-sufficient-protein-intake-for-the- elderly/); f) Hadi und Brightwell (2021): Safety of Alternative Proteins: Technological, Environmental and Regulatory Aspects of Cultured Meat, Plant-Based Meat, Insect Protein and Single-Cell Protein. In: Foods 10 (6).

3. Nutrition in light of environmental and climate protection

Climate change will reduce the intended uses of agricultural land available in the future to varying degrees, based on the geographical location. At the same time, climate and biodiversity policy requirements are also heightening the demand for land, leading to increased land pressure and conflicts of use. In Germany, the primary causes of this are non-agricultural use and continued global population growth. As part of the agreement reached at the Convention on Biological Diversity (CBD) held in Montreal in 2022, countries committed to conserving 30 % of land and marine areas. Germany intends to increase the percentage of renewable energies in the electricity mix to 80 % by 2030. This can only be achieved if more land is made available for wind power and solar parks. Achieving all these goals simultaneously will increase the pressure on traditional agricultural production and the availability of agricultural land.

Greenhouse gas (GHG) emissions are one of the environmental factors that strongly influence dietary habits. This was shown in a 2018 study[15] and has recently been reconfirmed.[16] Currently, food-related greenhouse gas emissions (including transportation) account for about one quarter of total emissions in Germany. In 2021, around 36 million tonnes of CO_2-equivalent GHG emissions were attributable to direct livestock farming alone. This equates to 66 % of all agricultural emissions. The change in dietary habits in developing and emerging countries towards a Western-oriented diet has resulted in a sharp increase in the demand for animal-based foods (the Food and Agriculture Organization [FAO] of the United Nations forecasts a demand of 160 % of current production). This inevitably leads to a significant increase in GHG emissions. To counteract this global trend, the goal should be to reduce meat consumption by at least 75 %.

Fermentative processes have the potential to contribute to the sustainable transformation of food production and, ultimately, to a more sustainable diet, which could significantly reduce the amount of land required for food production. According to experts, biotechnology and the resulting new types of food have the potential – if they replace food derived from living animals in our diets – to reduce many environmental impacts by over 80 % without compromising on nutritional value, flavour or practical consumption (met nutrition and feasible consumption constraints). Experts see particularly strong effects in terms of land and water consumption.[17] Alternative proteins that require no or significantly less arable land to produce appear to be particularly advantageous here. Single-cell proteins from

[15] Cf. Springmann, Clark, Mason-D'Croz, Wiebe, Bodirsky, Lassaletta et al. (2018): Options for keeping the food system within environmental limits. In: Nature 562 (7728).
[16] Cf. Scarborough, Clark, Cobiac, Papier, Knuppel, Lynch et al. (2023): Vegans, vegetarians, fish- eaters and meat-eaters in the UK show discrepant environmental impacts. In: Nature Food 4 (7).
[17] Cf. Mazac, Meinilä, Korkalo, Järviö, Jalava, Tuomisto (2022): Incorporation of novel foods in European diets can reduce global warming potential, water use and land use by over 80. In: Nature Food 3 (4).

microorganisms such as filamentous fungi, yeasts and microalgae are likewise noteworthy.[18] [19] [20] In photoautotrophic production – i.e. production using light as an energy source – the latter also offer the possibility of acting as an active sink for greenhouse gases such as CO_2.[21] [22] [23] Microalgae cultivation also requires no agricultural land, as this can be performed without using fresh water, thus conserving valuable resources for conventional or organic farming. The resulting microalgae biomass has a tenfold higher yield per hectare than any land plant and has a three to fivefold higher yield of protein-based nutrients in relation to the parts of the plant that contain protein (e.g. soya beans).[24]

Using side streams from agricultural and food production as substrates for the production of protein-rich food and animal feed from fungi and insects and as a basis for flavourings would also conserve land.[25]

Assuming that consumer behaviour remains the same, the production of alternative protein sources must not lead to additional land requirements and a further loss of biodiversity.

Consequently, experts consider expanding biotechnological processes using heterotrophic and (photo)autotrophic processes to be a particularly significant tool for meeting climate protection targets.[26] Applying and implementing them in the food production sector can make further contributions beyond the solutions already in place for better climate protection and resource conservation. Residual material streams from the food industry can be used, in particular, to produce single-cell proteins by means of fermentation in such a way that maximises land and resource conservation and can result in high-quality and tasty products for consumers.[27]

[18] Cf. Pereira, Fraga-Corral, Garcia-Oliveira, Otero, Soria-Lopez, Cassani et al. (2022): Single-Cell Proteins Obtained by Circular Economy Intended as a Feed Ingredient in Aquaculture. In: Foods 11 (18).
[19] Cf. Nyyssölä, Suhonen, Ritala, Oksman-Caldentey (2022): The role of single cell protein in cellular agriculture. In: Current Opinion in Biotechnology 75.
[20] Cf. Bratosin, Darjan, Vodnar, (2021): Single Cell Protein: A Potential Substitute in Human and Animal Nutrition. In: Sustainability 13 (16).
[21] Cf. Janssen, Wijffels, Barbosa (2022): Microalgae based production of single-cell protein. In: Current Opinion in Biotechnology 75.
[22] Cf. Brune, Lundquist, Benemann (2009): Microalgal Biomass for Greenhouse Gas Reductions: Potential for Replacement of Fossil Fuels and Animal Feeds. In: Journal of Environmental Engineering 135 (11).
[23] Cf. Zabochnicka, Krzywonos, Romanowska-Duda, Szufa, Darkalt, Mubashar (2022): Algal Biomass Utilization toward Circular Economy. In: Life 12.
[24] Cf. Janssen, Wijffels, Barbosa (2022): Microalgae based production of single-cell protein. In: Current Opinion in Biotechnology 75.
[25] Cf. Tian, Li, Meng, Li (2023): High-yield production of single-cell protein from starch processing wastewater using co-cultivation of yeasts. In: Bioresource Technology 370.
[26] a) Cf. Zabochnicka, Krzywonos, Romanowska-Duda, Szufa, Darkalt, Mubashar (2022): Algal Biomass Utilization toward Circular Economy. In: Life 12; b) Cf. Molitor, Mishra, Angenent (2019): Power-to-protein: converting renewable electric power and carbon dioxide into single cell protein with a two-stage bioprocess. In: Energy & Environmental Science 12 (12); c) See diagram: Springmann, Clark, Mason-D'Croz, Wiebe, Bodirsky, Lassaletta et al. (2018): Options for keeping the food system within environmental limits. In: Nature 562 (7728).
[27] Cf. Durkin, Guo, Wuertz, Stuckey (2022): Resource recovery from food-processing wastewaters in a circular economy: a methodology for the future. In: Current Opinion in Biotechnology 76.

The development and market launch of these new, innovative (bio)technological processes also make it possible to take on a global pioneering role in commercialising innovative technologies for an environmentally and climate-friendly food supply and, if necessary, to achieve leadership in technology and even in the market.[28]

Alternative protein sources can, if production costs permit – and this may be the case for insect proteins in the future – be favoured as a component of animal feed and the legumes (soya), thereby saved, used to feed humans. Appropriate quota regulations would be helpful here to promote market penetration. Furthermore, new food crops can be identified and used.[29]

Proteins such as casein or solein from precision fermentation could form part of the food mix in the future.[30] The business model of German start-up Formo, which produces milk proteins using the fermentation method, is based on the assumption that 10 % of dairy products can be replaced by products derived from precision fermentation by 2030.

While proteins produced by precision fermentation require 3 to 8 times less drinking water and 35 to 400 times less land use compared to soya protein[31], the energy requirement remote from agricultural land is high and should be covered by renewable energies. The accelerated expansion and provision of renewable energies from solar or wind energy and what is known as "green hydrogen" are required for the sustainable production of both alternative proteins and meat in cell culture using precision fermentation.[32]

4. Novel foods and new cultivation methods without an agricultural setting

Besides precision fermentation and meat and fish dishes made from cell cultures, new cultivation methods such as vertical or urban farming are also emerging.
Growing mushrooms and other fungi on sterilised substrates without the need for soil[33]

[28] a) Cf. Ritala, Häkkinen, Toivari, Wiebe (2017): Single Cell Protein-State-of-the-Art, Industrial Landscape and Patents 2001-2016. In: Frontiers in microbiology 8; b) Cf. Matassa, Papirio, Pikaar, Hülsen, Leijenhorst, Esposito et al. (2020): Upcycling of biowaste carbon and nutrients in line with consumer confidence: the "full gas" route to single cell protein. In: Green Chemistry 22 (15).
[29] Cf. Janssen, Wijffels, Barbosa (2022): Microalgae based production of single-cell protein. In: Current Opinion in Biotechnology 75.
[30] Cf. Tian, Li, Meng, Li (2023): High-yield production of single-cell protein from starch processing wastewater using co-cultivation of yeasts. In: Bioresource Technology 370.
[31] a) Cf. Zabochnicka, Krzywonos, Romanowska-Duda, Szufa, Darkalt, Mubashar (2022): Algal Biomass Utilization toward Circular Economy. In: Life 12; b) Cf. Molitor, Mishra, Angenent (2019): Power-to-protein: converting renewable electric power and carbon dioxide into single cell protein with a two-stage bioprocess. In: Energy & Environmental Science 12 (12); c) See diagram: [15] Cf. Springmann, Clark, Mason-D'Croz, Wiebe, Bodirsky, Lassaletta et al. (2018): Options for keeping the food system within environmental limits. In: Nature 562 (7728).
[32] Cf. Durkin, Guo, Wuertz, Stuckey (2022): Resource recovery from food-processing wastewaters in a circular economy: a methodology for the future. In: Current Opinion in Biotechnology 76.
[33] Cf. Mushroom Research Center Austria GmbH (MRA) (o. J.): Pilzarten. (https://gluckspilze.com/Pilzarten).

and promising approaches for what is known as indoor farming are increasingly being used in Europe.[34] In regions of Asia with little (arable) land, such as Japan and Singapore, growing lettuce and vegetables in closed rooms and a sterile atmosphere is becoming increasingly popular.[35] Although such farming and cultivation systems can generally forego the use of pesticides and fungicides, the fact that no agricultural environment is required is also viewed critically. The same could apply to what is known as cellular agriculture[36] as an argument against producing meat from cell cultures.

Countries and regions, in particular, which cannot or do not wish to be exclusively dependent on imports benefit from the advantages of achieving comparatively high yields and improved quality with lower water consumption by means of targeted nutrient supply and light exposure. Energy optimisation is the focus of future economic efficiency and is a priority for developers and manufacturers.

Vertical farming is just one area (albeit an important one) of what is known as smart farming. These are processes that are based on linking modern area-dependent or independent agricultural production technology with information and communication technologies and making agriculture more resource-efficient, energy-efficient and sustainable. This also includes the integration of autonomous agricultural equipment, improved farm management and the use of sensor and drone data to monitor machinery, assess plant condition and measure harvest volumes. Smart crops, involving the more economical use of pesticides and fertilisers in the context of integrated crop protection, also form part of the equation. There are already investment models for investors in the field of smart farming.[37]

5. Novel foods and enjoyment

The consumption of animal products can be significantly reduced through a plant-based diet or opting for alternative protein sources. Alternative protein sources include technologically modified vegetable proteins, such as extruded pea proteins in meat substitutes, and biotechnologically produced proteins. Biotechnological processes mainly include the in vitro cultivation of animal cells (cultured meat) or products of precision fermentation. Alternative protein sources make an important contribution, as they enable consumers to transform their diet without having to give up their usual eating habits. Such products can take the consumer's individual preferences into account in the most ideal manner possible.

[34] Cf. Anand (2023): Die Vertical-Farming-Revolution gerät ins Stocken. Capital.de. (https://www.capital.de/wirtschaft-politik/die-vertical-farming-revolution-geraet-ins-stocken-33064902.html).
[35] Cf. Spread Co. Ltd. (2015): Spread's Vertically Farmed Lettuce Sales Exceed 100 Million Servings in Japan. (https://spread.co.jp/en/news-release_20230515/).
[36] Cf. Schnack (2022): Fischstäbchen aus dem Labor. Das ist zelluläre Landwirtschaft. DER SPIEGEL. (https://www.spiegel.de/wissenschaft/fischstaebchen-aus-dem-labor-das-ist-zellulaere-landwirtschaft-a-2ec7bf55-05b3-46dd-abfa-d2e6e283915d).
[37] Cf. Eder (2023): Smart-Farming als Zukunftstrend – So verdienen Anleger damit. Börsenmedien AG. (https://www.boerse-online.de/nachrichten/aktien/smart-farming-als-zukunftstrend-so-verdienen-anleger-damit-20326329.html).

The following elements all play a major role in the enjoyment of food: flavour, health benefits, familiarity, attitudes, fear of the unknown or (un)willingness to experiment, aversion, social norms and price. Flavour, health benefits and price are the decisive barriers or acceptance factors. When pulses, algae, insects, plant-based meat alternatives and cell culture meat are compared as protein sources, pulses and plant-based meat alternatives perform best among consumers in our part of the world, and cell culture meat and insects perform worst. Algae falls somewhere in between.

Grouped together, pescetarians, vegetarians and vegans are more favourable towards cell culture meat than "meat eaters".[38] For over 50 % of the former group, "in vitro meat" is synonymous with "can be produced under controlled conditions", "sustainable" and "future-oriented", although over 60 % assume that "unnatural processes or production methods" are used. In general, various political tactics, including "nudging", are required if the consumption of animal proteins is to be reduced.[39]

Measures that would result in an immediate reduction and scarcity of the meat supply, such as bans, would probably place our society and our democracy under enormous stress. When seeking public acceptance, the social perception of implementing such drastic measures, in particular, must not be ignored. Nevertheless, the state also has various instruments at its disposal to facilitate or promote the market diffusion of alternative, more sustainable proteins. Economic instruments such as green taxes and subsidies (possibly also via emission certificates) would be suitable for favouring sustainably produced protein sources and making non-sustainable or less sustainable products correspondingly more expensive. Sustainably produced protein sources would then have a price that better reflects the manner in which they are produced. Plus, of course, the state would be free to play a pioneering role through public procurement, which would be based on circularity and net-zero criteria, and favour more sustainable products in its own procurement. Furthermore, the development and production of sustainable food must be supported within politics, and the corresponding research, development and innovation must be promoted.[40]

From the perspective of policy and consumer advice, one possible example for communicating this appropriately to the public is to allow for novel food tastings to occur, even before the foods in question have been widely authorised. This is already possible

[38] See diagram: Ahrens (2023a): Laborfleisch: Beurteilung der Eigenschaften nach Ernährungsstil 2020. Statista GmbH. (https://de.statista.com/statistik/daten/studie/1186804/umfrage/beurteilung- der-eigenschaften-von-laborfleisch-nach-ernaehrungsstil/).
[39] The concept of "nudging" stems from behavioural economics and was developed by Richard Thaler and Cass Sunstein. It describes various methods of influencing people's behaviour without having to resort to visible prohibitions and mandates. It is particularly effective in changing consumer behaviour.
[40] Cf. Bioökonomierat (2023): Bioökonomie nachhaltig umsetzen! Erste Handlungsempfehlungen des Bioökonomierats zur Umsetzung der Nationalen Bioökonomiestrategie. (https://www.biooekonomierat.de/media/pdf/stellungnahmen/biooekonomierat-broschuere-nachhaltig-umsetzen-DE.pdf?m=1684941445&).

in the Netherlands, for example, as the Dutch parliament has passed a regulation on tasting (Code of Practice).[41] Tastings in the Netherlands are authorised for a maximum of ten similar products within a maximum period of one year, with 30 test participants per session. A "streamlined" version of a risk assessment must also be performed before a tasting can commence.

When addressing the public, experts recommend both emphasising the benefits and, in particular, the added value compared to conventional or familiar products (health, sustainability) and taking barriers into account, i.e. by not elaborating on the immense technical effort involved in producing cultured meat (CM), for example. There is a great deal of resistance to be overcome among certain sections of the public. Despite the need to present and discuss the current developments and possibilities openly, alongside their pros and cons, emotions are at the forefront where food is concerned. Indeed, "emotional factors are perhaps the most important – convenience, habit, repression – and we tend to make excuses."[42]

6. Novel food as a business model

If the public sector offers both financial and communicative support for research and development, company growth and spin-off companies in the novel food sector, the following benefits and more can be seen for Europe:

Agricultural businesses and start-ups that want to adopt the new cultivation and food production methods as a business model can build up markets within Europe and do not have to aim for initial approval in Asia or the USA. The results of privately funded research and development can be considered trade secrets. Usually, the results and findings of public research funding have to be made public, which can benefit a wide range of stakeholders.

Public funding also continues to play an important role in the context of biotechnology. For example, biotechnological production usually begins on a small scale and must be scaled up in order to produce economically necessary product and generate market yields required. This means that such scaling is particularly significant, as this step alone will make it possible to estimate production costs more realistically and, therefore, lay the appropriate foundations for investors to make decisions. This, in turn, is vital for the survival of companies that are aiming for growth. There are still some hurdles to overcome in the area of protein alternatives, which will ultimately benefit animal welfare (e.g. biopsies instead of factory farming, replacement of foetal calf serum with alternative growth factors) and the environment (e.g. recycling of materials required for growth).

[41] Cf. NDFR (2023): Code of Practice for Safely Conducting Tastings of Cultivated Foods Prior to EU Approval. (https://www.ndfr.nl/content/blg-1108513).

[42] Kessen (2021): "Menschen neigen zu Ausreden. Und dazu, andere zum Sündenbock zu machen.". Bethmann Bank. (https://tenor.bethmannbank.de/gesellschaft/felix-ekardt-menschen-neigen-zu-Ausreden).

Where precision fermentation is concerned, experts expect a significant reduction in costs by 2030 and competitive market opportunities within the food industry as a result.[43]

7. Conclusion

The experts involved in the various workshops agree that the state should use a combination of different policy instruments to reduce meat consumption further, which is already on the decline in Germany. These not only include informative tactics (e.g. tastings, labelling), but also behavioural economic tools (e.g. nudging), industrial policy and economic methods. In addition, research funding in the field of sustainable alternative proteins should be expanded to include perspectives identified by the social sciences (e.g. the understanding and acceptance of certain nutritional policy instruments and alternative protein sources in general). The experts involved see concrete approaches in the following points, among others:

Promoting general knowledge about novel foods – the state should use a combination of different tactics here (financial and economic support, education, information, nudging, etc.) to increase knowledge and acceptance.

Promotion of research – the state should expand programmes to promote basic research and scaling further. At the Federal State level, studies and (further) education should be organised in such a way that experts in the relevant technologies are available in the public and private sectors and can be approached for discussion on the topic.
Preparing the market launch – the German government should enable the upscaling of laboratory facilities and not hinder it with bureaucratic hurdles.[44] Business campus models should be established at Federal State level. Politics and industry should install demonstration facilities through private-public partnerships.

Tastings as part of the development of novel foods – following the Dutch example, policy should enable novel food tastings in Germany to allow manufacturers to adapt to customer needs, on the one hand, and enable consumers to experience the new offerings on the other.

Product authorisation – at EU level, there should be a product authorisation guideline for the approval of novel foods in the European Union by the European Food Safety Authority (EFSA). This will enable companies and businesses that wish to develop and market alternative proteins or an alternative protein source to understand what information is required quickly, what is assessed in the authorisation application and how this is carried out. The authorisation process should also be transparent.

[43] Cf. Seba und Tubb (2020): The Roadmap to Disruption and Market Opportunities - Rethink Disruption. RethinkX. (https://rethinkdisruption.com/the-roadmap-to-disruption/).
[44] If products are confluent or filamentous, specialised demonstration plants for both phototrophic and heterotrophic processes, as well as for specialised downstream processing plants, are required.

Product evaluation and labelling – to answer the question as to whether foods based on alternative protein sources are really more sustainable and climate-friendly, these food groups should be evaluated using suitable balancing models such as life cycle assessment (LCA) or an ecological audit. Where state support is concerned, a standardised method should be chosen in advance. This would be binding for all funded approaches, thus ensuring comparability.

The corresponding product labelling (eco-score labelling) would then be determined by the life cycle assessment or other evaluation. Finance concepts – the development of new products is not worthy of funding per se. Funding should only be provided if the innovative products prove to be of significant benefit, all the while posing no serious disadvantage when compared to established products. This means that such products must not only be comparable with the current meat-intensive diet, but also with a "normal" vegetarian or vegan diet. If necessary, innovative finance concepts can close the cost gaps between established and newly developed products. Start-ups require special financing models for innovators, e.g. through dedicated funding from Kreditanstalt für Wiederaufbau (KfW), the German state-owned investment and development bank.

Sources:

Ahrens, Sandra (2023a): Laborfleisch: Beurteilung der Eigenschaften nach Ernährungsstil 2020. Hg. v. Statista. Available online under: https://de.statista.com/statistik/daten/studie/1186804/umfrage/beurteilung-der-eigenschaften-von-laborfleisch-nach-ernaehrungsstil/, last checked: 15.11.2023.

Ahrens, Sandra (2023b): Produktion von Fleisch weltweit in den Jahren 1961 bis 2023 (in Millionen Tonnen Schlachtgewicht). Hg. v. Statista. Available online under: https://de.statista.com/statistik/daten/studie/28782/umfrage/die-globale-fleischerzeugung-seit-1990/, last checked: 15.11.2023.

Aidoo, Raphael; Kwofie, Ebenezer M.; Adewale, Peter; Lam, Edmond; Ngadi, Michael (2023): Overview of single cell protein: Production pathway, sustainability outlook, and digital twin potentials. In: Trends in Food Science & Technology 138. DOI: 10.1016/j.tifs.2023.07.003.

Al-Mudhafr, Adnan (2019): Microbiological Sources and Nutritional Value of Single Cell Protein (SCP). In: JNFP 2 (2). DOI: 10.31579/2637-8914/013.

Anand, Priya (2023): Die Vertical-Farming-Revolution gerät ins Stocken. Hg. v. Capital. Available online under: https://www.capital.de/wirtschaft-politik/die-vertical-farming-revolution-geraet-ins-stocken-33064902.html, last checked: 14.11.2023.

Assisting Hands Home Care LLC (Hg.) (2023): The Importance of Sufficient Protein Intake for the Elderly. Available online under: https://www.assistinghands-il-wi.com/blog/importance-of-sufficient-protein-intake-for-the-elderly/, last checked: 14.11.2023.

Bashir, Umair (2023): Länder mit dem höchsten Anteil von Vegetariern an der Bevölkerung weltweit im Jahr 2023. Hg. v. Statista GmbH. Available online under: https://de.statista.com/prognosen/261627/anteil-von-vegetariern-und-veganern-an-der-bevoelkerung-ausgewaehlter-laender-weltweit, last checked: 14.11.2023.

Bioökonomierat (Hg.) (2023): Bioökonomie nachhaltig umsetzen! Erste Handlungsempfehlungen des Bioökonomierats zur Umsetzung der Nationalen Bioökonomiestrategie. Available online under: https://www.biooekonomierat.de/media/pdf/stellungnahmen/biooekonomierat-broschuere-nachhaltig-umsetzen-DE.pdf?m=1684941445&, last checked: 15.11.2023.

Bratosin, Bogdan Constantin; Darjan, Sorina; Vodnar, Dan Cristian (2021): Single Cell Protein: A Potential Substitute in Human and Animal Nutrition. In: Sustainability 13 (16). DOI: 10.3390/su13169284.

Brune, D. E.; Lundquist, T. J.; Benemann, J. R. (2009): Microalgal Biomass for Greenhouse Gas Reductions: Potential for Replacement of Fossil Fuels and Animal Feeds. In: Journal of Environmental Engineering 135 (11). DOI: 10.1061/(ASCE)EE.1943-7870.0000100.

Bundesanstalt für Landwirtschaft und Ernährung (Hg.) (2023a): Fleisch. Available online under: https://www.bmel-statistik.de/ernaehrung-fischerei/versorgungsbilanzen/fleisch, last checked: 14.11.2023.

Bundesanstalt für Landwirtschaft und Ernährung (Hg.) (2023b): Fleischverzehr 2022 auf Tiefstand. Available online under: https://www.ble.de/SharedDocs/Pressemitteilungen/DE/2023/230403_Fleischverzehr.html, last checked: 15.11.2023.

Bundesministerium für Ernährung und Landwirtschaft (Hg.) (2020): Neuartige Lebensmittel - Novel Food. Available online under: https://www.bmel.de/DE/themen/verbraucherschutz/lebensmittelsicherheit/spezielle-lebensmittel/novel-food.html, last checked: 14.11.2023.

Deutsche Gesellschaft für Ernährung e. V. (Hg.) (2023a): Leitlinie Protein. Available online under: https://www.dge.de/wissenschaft/dge-leitlinien/leitlinie-protein/, last checked: 14.11.2023.

Deutsche Gesellschaft für Ernährung e. V. (Hg.) (2023b): Wie beeinflusst die Proteinzufuhr unser Gewicht? Available online under: https://www.dge.de/presse/meldungen/2023/wie-beeinflusst-die-proteinzufuhr-unser-gewicht/, last checked: 14.11.2023.

Durkin, Alex; Guo, Miao; Wuertz, Stefan; Stuckey, David C. (2022): Resource recovery from food-processing wastewaters in a circular economy: a methodology for the future. In: Current Opinion in Biotechnology 76. DOI: 10.1016/j.copbio.2022.102735.

Eder, Emmeran (2023): Smart-Farming als Zukunftstrend – So verdienen Anleger damit. Hg. v. Börsenmedien AG. Available online under: https://www.boerse-online.de/nachrichten/aktien/smart-farming-als-zukunftstrend-so-verdienen-anleger-damit-20326329.html, last checked: 14.11.2023.

Englbrecht, Claudia; Höpner, Nils (2023): Positionspapier des BIO Deutschland. BiotechnologischeAlternativproduktezuFleisch,Fischgerichten,EiernundMilchprodukten. Hg. v. BIO Deutschland e. V. Available online under: https://www.biodeutschland.org/de/positionspapiere/positionspapier-der-bio-deutschland-biotechnologische-alternativprodukte-zu-fleisch-fischgerichten-eiern-und-milchprodukten.html, last checked: 15.11.2023.

Europäische Union (EU) (2015): Verordnung (EU) 2015/2283 des Europäischen Parlaments und des Rates vom 25. November 2015. 2015/2283. Available online under: https://eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=CELEX:32015R2283, last checked: 21.11.2023.

FAO; IFAD; UNICEF; WFP; WHO (2023): The State of Food Security and Nutrition in the World. 2023 : Urbanization, agrifood systems transformation and healthy diets across the rural–urban continuum. Rome: FAO.

Guo, Ziang; Arslan, Muhammad; Li, Zhihua; Cen, Shaoyi; Shi, Jiyong; Huang, Xiaowei et al. (2022): Application of Protein in Extrusion-Based 3D Food Printing: Current Status and Prospectus. In: Foods 11 (13). DOI: 10.3390/foods11131902.

Hadi, Joshua; Brightwell, Gale (2021): Safety of Alternative Proteins: Technological, Environmental and Regulatory Aspects of Cultured Meat, Plant-Based Meat, Insect Protein and Single-Cell Protein. In: Foods 10 (6). DOI: 10.3390/foods10061226.

Hanke, Frank; Rittig, Tanja; Simonis, Dirk; Mohra, Amira; Füsgen, Ingo; Riecker, Axel (2014): Konsensuspapier — Bedarfsgerechte Medikation bei neurologischen und geriatrischen Dysphagie-Patienten. In: MMW - Fortschritte der Medizin 156 (S13). DOI: 10.1007/s15006-014-3228-y.

Hertzler, Steven R.; Lieblein-Boff, Jacqueline C.; Weiler, Mary; Allgeier, Courtney (2020): Plant Proteins: Assessing Their Nutritional Quality and Effects on Health and Physical Function. In: Nutrients 12 (12). DOI: 10.3390/nu12123704.

Janssen, Marcel; Wijffels, Rene H.; Barbosa, Maria J. (2022): Microalgae based production of single-cell protein. In: Current Opinion in Biotechnology 75. DOI: 10.1016/j.copbio.2022.102705.

Kessen, Maria (2021): „Menschen neigen zu Ausreden. Und dazu, andere zum Sündenbock zu machen.". Hg. v. Bethmann Bank. Available online under: https://tenor.bethmannbank.de/gesellschaft/felix-ekardt-menschen-neigen-zu-Ausreden, last checked: 14.11.2023.

Leung, Doris Y. P.; Cheng, Hui-Lin; Tyrovolas, Stefanos; Tang, Angel S. K.; Liu, Justina Y. W.; Tse, Mimi M. Y. et al. (2021): Magnitude, Temporal Trends, and Inequalities in the DALYs and YLDs of Nutritional Deficiency among Older Adults in the Western Pacific Region: Findings from the Global Burden of Disease Study 1990-2019. In: Nutrients 13 (12). DOI: 10.3390/nu13124421.

Liu, Zhenbin; Zhang, Min; Bhandari, Bhesh; Wang, Yuchuan (2017): 3D printing: Printing precision and application in food sector. In: Trends in Food Science & Technology 69. DOI: 10.1016/j.tifs.2017.08.018.

Lohmann, Björn; Graf, Philipp (2022): Präzisionsfermentation: Maßgeschneiderte Bioproduktion. Hg. v. BIOCOM Interrelations GmbH. Available online under: https://biooekonomie.de/themen/dossiers/praezisionsfermentation-massgeschneiderte-bioproduktion, last checked: 14.11.2023.

Matassa, Silvio; Papirio, Stefano; Pikaar, Ilje; Hülsen, Tim; Leijenhorst, Evert; Esposito, Giovanni et al. (2020): Upcycling of biowaste carbon and nutrients in line with consumer confidence: the "full gas" route to single cell protein. In: Green Chemistry 22 (15). DOI: 10.1039/D0GC01382J.

Mazac, Rachel; Meinilä, Jelena; Korkalo, Liisa; Järviö, Natasha; Jalava, Mika; Tuomisto, Hanna L. (2022): Incorporation of novel foods in European diets can reduce global warming potential, water use and land use by over 80. In: Nature Food 3 (4). DOI: 10.1038/s43016-022-00489-9.

Molitor, Bastian; Mishra, Akanksha; Angenent, Largus T. (2019): Power-to-protein: converting renewable electric power and carbon dioxide into single cell protein with a two-stage bioprocess. In: EneEnergy & Environmental Science 12 (12). DOI: 10.1039/C9EE02381J.

MRCA Mushroom Research Center Austria GmbH (Hg.) (o. J.): Pilzarten. Available online under: https://gluckspilze.com/Pilzarten, last checked: 14.11.2023.

Nachal, N.; Moses, J. A.; Karthik, P.; Anandharamakrishnan, C. (2019): Applications of 3D Printing in Food Processing. In: Food Engineering Reviews 11 (3), S. 123–141. DOI: 10.1007/s12393-019-09199-8.

NDFR (Hg.) (2023): Code of Practice for Safely Conducting Tastings of Cultivated Foods Prior to EU Approval. Available online under: https://www.ndfr.nl/content/blg-1108513, last checked: 15.11.2023.

Nyyssölä, Antti; Suhonen, Anniina; Ritala, Anneli; Oksman-Caldentey, Kirsi-Marja (2022): The role of single cell protein in cellular agriculture. In: Current Opinion in Biotechnology 75. DOI: 10.1016/j.copbio.2022.102686.

Pereira, Antia G.; Fraga-Corral, Maria; Garcia-Oliveira, Paula; Otero, Paz; Soria-Lopez, Anton; Cassani, Lucia et al. (2022): Single-Cell Proteins Obtained by Circular Economy Intended as a Feed Ingredient in Aquaculture. In: Foods 11 (18). DOI: 10.3390/foods11182831.

Rasouli, Zahra; Valverde-Pérez, Borja; D'Este, Martina; Francisci, Davide de; Angelidaki, Irini (2018): Nutrient recovery from industrial wastewater as single cell protein by a co-culture of green microalgae and methanotrophs. In: Biochemical Engineering Journal 134. DOI: 10.1016/j.bej.2018.03.010.

Ribeiro, Gislane Oliveira; Rodrigues, Leticia de Alencar Pereira; Dos Santos, Thiale Borges Silva; Alves, João Pedro Santos; Oliveira, Roseane Santos; Nery, Tatiana Barreto Rocha et al. (2022): Innovations and developments in single cell protein: Bibliometric review and patents analysis. In: Frontiers in microbiology 13. DOI: 10.3389/fmicb.2022.1093464.

Ritala, Anneli; Häkkinen, Suvi T.; Toivari, Mervi; Wiebe, Marilyn G. (2017): Single Cell Protein-State-of-the-Art, Industrial Landscape and Patents 2001-2016. In: Frontiers in microbiology 8. DOI: 10.3389/fmicb.2017.02009.

Rogeri, Patricia S.; Zanella, Rudyard; Martins, Gabriel L.; Garcia, Matheus D. A.; Leite, Geovana; Lugaresi, Rebeca et al. (2021): Strategies to Prevent Sarcopenia in the Aging Process: Role of Protein Intake and Exercise. In: Nutrients 14 (1). DOI: 10.3390/nu14010052.

Scarborough, Peter; Clark, Michael; Cobiac, Linda; Papier, Keren; Knuppel, Anika; Lynch, John et al. (2023): Vegans, vegetarians, fish-eaters and meat-eaters in the UK show discrepant environmental impacts. In: Nature Food 4 (7). DOI: 10.1038/s43016-023-00795-w.

Schnack, Thies (2022): Fischstäbchen aus dem Labor. Das ist zelluläre Landwirtschaft. Hg. v. DER SPIEGEL. Available online under: https://www.spiegel.de/wissenschaft/fischstaebchen-aus-dem-labor-das-ist-zellulaere-landwirtschaft-a-2ec7bf55-05b3-46dd-abfa-d2e6e283915d, last checked: 14.11.2023.

Seba, Tony; Tubb, Catherine (2020): The Roadmap to Disruption and Market Opportunities - Rethink Disruption. Hg. v. RethinkX. Available online under: https://rethinkdisruption.com/the-roadmap-to-disruption/, zuletzt aktualisiert am 30.03.2022, last checked: 14.11.2023.

Sillman, Jani; Nygren, Lauri; Kahiluoto, Helena; Ruuskanen, Vesa; Tamminen, Anu; Bajamundi, Cyril et al. (2019): Bacterial protein for food and feed generated via renewable energy and direct air capture of CO2: Can it reduce land and water use? In: Global Food Security 22. DOI: 10.1016/j.gfs.2019.09.007.

Spread Co. Ltd. (Hg.) (2015): Spread's Vertically Farmed Lettuce Sales Exceed 100 Million Servings in Japan. Available online under: https://spread.co.jp/en/news-release_20230515/, last checked: 14.11.2023.

Springmann, Marco; Clark, Michael; Mason-D'Croz, Daniel; Wiebe, Keith; Bodirsky, Benjamin Leon; Lassaletta, Luis et al. (2018): Options for keeping the food system within environmental limits. In: Nature 562 (7728). DOI: 10.1038/s41586-018-0594-0.

The University of Sheffield (Hg.) (2020): More than half of older people don't consume enough protein to stay healthy. Available online under: https://www.sheffield.ac.uk/healthy-lifespan/news/more-half-older-people-dont-consume-enough-protein-stay-healthy, last checked: 14.11.2023.

Tian, Yajie; Li, Jianzheng; Meng, Jia; Li, Jiuling (2023): High-yield production of single-cell protein from starch processing wastewater using co-cultivation of yeasts. In: Bioresource Technology 370. DOI: 10.1016/j.biortech.2022.128527.

WHO (Hg.) (2023): Supplemental nutrition with dietary advice for older people affected by undernutrition. Available online under: https://www.who.int/tools/elena/interventions/nutrition-older-people, last checked: 14.11.2023.

Willett, Walter; Rockström, Johan; Loken, Brent; Springmann, Marco; Lang, Tim; Vermeulen, Sonja et al. (2019): Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. In: Lancet 393 (10170). DOI: 10.1016/S0140-6736(18)31788-4.

Zabochnicka, Magdalena; Krzywonos, Małgorzata; Romanowska-Duda, Zdzisława; Szufa, Szymon; Darkalt, Ahmad; Mubashar, Muhammad (2022): Algal Biomass Utilization toward Circular Economy. In: Life 12. DOI: 10.3390/life12101480.