Project brief

Thünen Institute of Agricultural Technology 2026/18a

# The Future Eats Different – Concept Design for Sustainable Global Food Systems in the Year 2100

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- **To ensure food security for the world's population while protecting the environment, new concepts for global food production are necessary.**
- **One option could be "landless food production," based on bioreactors and nutrient recycling.**
- **The combination of microalgae with filamentous fungi could, in particular, meet the caloric needs of the diet.**

## Background and Objectives

To be able to feed the world's population by the year 2100, global agriculture and the entire food value chain must change. Africa, in particular, faces major challenges. By the end of the century, around 80% of global population growth is expected to occur here – an increase from 1.2 to 4.4 billion people. Climate change and the depletion of finite resources needed to intensify agriculture also pose major challenges to the agricultural system.

The "LandLessFood" project is developing new concepts for food and feed production that allow nutrients to be extracted from waste streams and thus recycled. In the "LandLessFood_blue" subproject, we are investigating the potential of bioreactors as components of a sustainable, circular agricultural system. The primary goal here is to meet the body's energy needs—such as those derived from carbohydrates and fats—regardless of soil fertility and freshwater resources, in order to supplement the diet in a space-efficient and sustainable manner.

## Approach

Certain microalgal species can make an important contribution to supplementing the human diet thanks to their high protein, carbohydrate, and lipid content. Our primary focus has been on the production of carbohydrates by microalgae. Since only a fraction of microalgal species have been scientifically studied in this regard to date, we are comparing species from various strain collections as well as species from environmental samples.

Promising strains are cultivated in a photobioreactor using waste streams. In doing so, we optimize various parameters such as medium composition, temperature, light intensity and duration, pH, gas supply, etc.

In microalgae cultivation, *downstream processing* – that is, all process steps following cultivation – is one of the limiting factors. This is due to the low biomass density per unit volume, the small cell diameter, and the minimal density difference between the microalgae and the culture medium.

Consequently, there is significant interest in alternative, cost-effective processes for separating and concentrating microalgae, such as bioflocculation. In this process, microorganisms aggregate fine particles into larger flocs. With the aid of filamentous fungi, the nutritional properties of the microalgae can also be enhanced.

Another major cost factor in the production of sustainable, affordable food based on microorganisms is the use of high-purity substances and complex media components for cultivation. To this end, we first conducted a screening aimed at identifying robust, food-grade microalgae and fungis. These should be able to grow in seawater without the addition of expensive micronutrients. Instead, alternative nutrient sources from waste streams are to be utilized.

Based on this work, we subsequently optimized the bioflocculation process and analyzed the resulting composite biomass of fungi and microalgae for its nutritional value.

## Results

To select suitable microalgae, two different fermentation residues from biogas plants as well as pig and human urine were used as waste streams in the culture medium. Human urine proved to be a suitable waste substrate, and *Dunaliella bioculata* emerged as a particularly promising microalgal species. It stood out due to its high starch production, stable growth, and ease of handling.

Since open-pond systems are also planned for the cultivation of microalgae in the future, it must be possible to minimize contamination as much as possible. This can be achieved, among other things, by using high salt concentrations. At seawater concentrations of 40, 50, and 60 g/L, it was shown that this increase in salt concentration is possible without significant losses in biodrymass (BDM), starch, and lipid production (Fig. 1).

In a further growth experiment, even higher salt concentrations of 80, 120, 160, and 200 g/L were investigated. Although the required cultivation time was significantly longer under these high salinity conditions, even at the highest salt concentration, 0.9 g/L of BDM with a starch content of 45 % was still produced after 28 days (data not shown). This demonstrates that *Dunaliella bioculata* is capable of growing

even under extremely high salinity conditions and accumulating starch as a storage compound.
To reduce the costs of separating the microalgal biomass from the culture medium, the influence of the filamentous fungi *Aspergillus oryzae* DSM63303 on bioflocculation was investigated. The microalga *Tetraselmis subcordiformis* SAG161-1a proved particularly suitable for these experiments. As alternative nutrient sources human urine was used for the microalgae, and apple pomace and rice bran were used for the fungus.

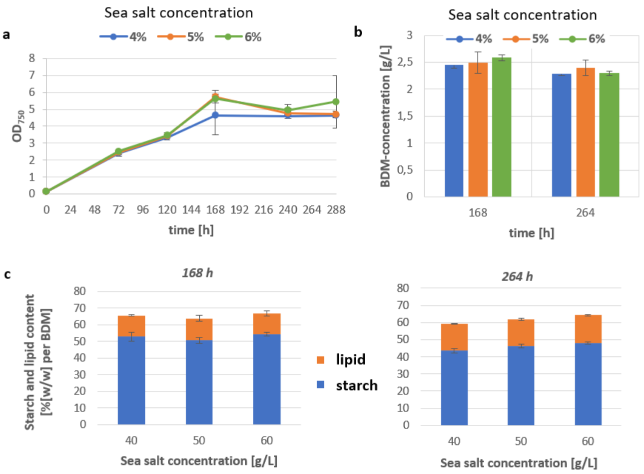


**Figure 1:** Effect of sea salt concentration on the microalga *Dunaliella bioculata* a) Growth curves, b) Biodrymass concentrations, c) starch and lipid contents (source: own illustration)

The nutrient compositions and caloric values were calculated for the resulting combined biodrymass of *T. subcordiformis* and *A. oryzae* (Table 1). For the bioflocculation, we assumed a ratio of two parts fungal dry matter to one part microalgal dry matter.
With a caloric value of 601.8 kJ per 100 g, the composite biomass generally provides a lower energy density than the most commonly consumed staple foods, e.g., in Africa. However, the value is overall comparable to the caloric values of root vegetables such as yam and cassava or plantains. It does, however, provide a completely different nutrient profile than these carbohydrate-rich foods. With a high protein content (15.9 %) and moderate fatty acid content (5 %), it is more comparable to animal-based foods such as tilapia or chicken. A clear advantage of composite biomass derived from microalgae and filamentous fungi lies in its short production cycle: While conventional staple foods require several months to reach harvest, the biomass can be produced within about two weeks. This enables rapid, flexible, and continuous availability, which is particularly advantageous in times of crisis or under unstable supply conditions.

**Table 1:** Combined biodrymass of *A. oryzae* and *T. subcordiformis* at a dry weight ratio (DWR) of 0.5 (source: own data).

| | Caloric value per 100 g [kJ] | Protein [%] | Carbo-hydrates [%] | Fatty acid [%] |
|---|---|---|---|---|
| *T. subcordiformis* SAF161-1a | **1123** | **24.3** | **23.2** | **8.5** |
| *A. oryzae* DSM63303 | **309** | **11.7** | **1.6** | **3.2** |
| Combined biodrymass DWR 0.5 | **602** | **15.9** | **8.8** | **5.0** |

## Conclusion

We have identified microalgae that are highly suitable for alternative food production. This approach aims to incorporate waste streams and conserve soil and freshwater resources. Bioflocculation using a filamentous fungus is suitable for preparing effective *downstream processing*. As nutritional and food safety requirements continue to evolve, our work can make a valuable contribution to sustainable food production in the future.

## Further information

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**Duration**
3.2020–12.2025

**Project ID**
2268

**Publications**
Tölle M, Kuenz A. (2024). Optimizing separation: Utilizing *A. oryzae* for bioflocculation of marine *T. subcordiformis* on agricultural residues. J. Appli. Phycol. doi.org/10.1007/s10811-024-03400-0.

Hußmann W, Tölle M, Kuenz A. (2023). LandLessFood-blue: Mikroalgen als wichtige Komponente der Ernährungssicherheit im Jahr 2100. In: Symposium der Blauen Bioökonomie 2023, 2023, S. 40–41.

**DOI: 10.3220/253-2026-86**