

Towards an artificial carbohydrates supply on Earth

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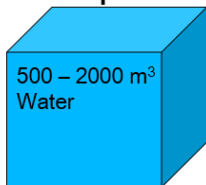
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Conventional Agriculture



+



+

Pesticides, Fungicides,
Fertilizer, 1.4 MWh fuel

Artificial (Vegan+)



35 - 90 m²

+



0.6 m³
Water

| Annual Production of 1 ton of Sugar (Carbohydrate) | | |
|--|--------------------------|---------------------|
| | Conventional Agriculture | Artificial (Vegan+) |
| Area / m ² | ~800 | 35 - 90 |
| Water / m ³ | 500 - 2000 | 0.6 |

How to feed a growing population in a secure and sustainable way?

The conventional, biogenic agriculture

... has yet failed to provide a reliable concept which circumvents its severe environmental externalities such as the massive use of land area, water for irrigation, fertiliser, pesticides, herbicides, and fossil fuel.

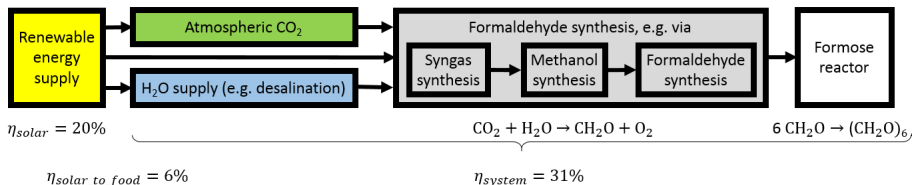
Yet we have to feed a growing population on Earth!

The artificial synthesis of carbohydrates

... from atmospheric carbon dioxide, water, and renewable energy would allow not only for a highly reliable production without those externalities, but would also allow to increase the agricultural capacities of our planet by several orders of magnitude.

We provide a techno-economic assessment of the artificial sugar production and discuss its extension towards any carbohydrate.

Artificial sugar production: solar-to-food efficiency of $\geq 6\%$



Formose reaction (Butlerov, 1861)

... has not been considered economically competitive to the biogenic sugar production.

Targeted stereoisomer production

Research in efficient catalysts for D-glucose not yet conducted.

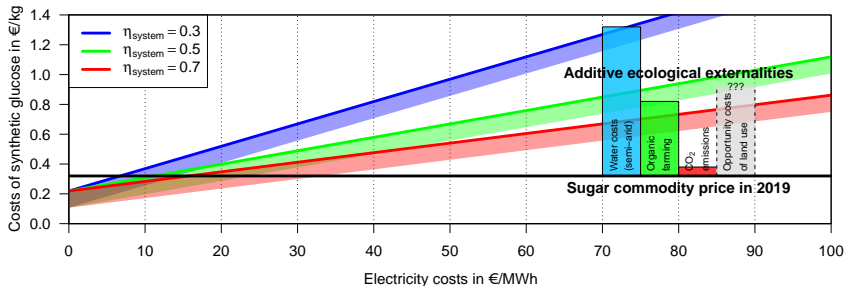
Production costs

Production costs of 1 ton of glucose depends on electricity costs C_{el} and facility costs $C_0 = 219 \text{ €/t}$:

$$C_{\text{glucose}} [\text{€/t}] = \frac{4.5 \cdot C_{el} [\text{€/MWh}]}{\eta_{\text{system}}} + C_0 [\text{€/t}]$$

| Major contributions to C_0 : | Costs [€/t] |
|------------------------------------|-------------|
| CO_2 Direct-Air-Capture device | 110 |
| High-temperature co-electroliser | 36 |
| Formaldehyde reactor | 38 |
| Formose reactor | ≤ 35 |
| (Targeted stereoisomer production) | (?) |

Comparison of total costs for synthetic and biogenic sugar



Production costs of synthetic glucose (slant coloured bands) with the total cost of biogenic sugar production (additive bars on the right hand) for power-to-food energy efficiencies of $\eta_{\text{system}} = 0.3$ (today), 0.5, and 0.7.

Total costs of conventional biogenic sugar are its commodity price (black horizontal line), the costs for about 1m^3 water from desalination plants (blue bar), the avoidance of pesticides and fertilisers (= costs for organic farming, green bar), its greenhouses gas emissions (red bar), and the opportunity costs of land use (grey dashed).

Take home: artificial sugar could be produced for 0.5 – 0.9 €/kg at electricity cost of < 50 €/MWh, which is cheaper than biogenic sugar when produced in a sustainable way.

Artificial carbohydrates

The synthetic production of starch (polysaccharides)

... by polymerisation of synthetic sugar (monosaccharides) is in principle possible. The costs are probably not much higher than for synthetic sugar and the costs of biogenic starch is not much lower than biogenic sugar.

Chances

A transition towards a system where a large part of the macronutrient supply is provided by synthesis would allow to establish a sustainable food supply and in addition free agricultural area for enhanced production in biogenic micronutrients.

Anticipated societal changes

- food production becomes an industry: how to limit corporate power?
- mankind less dependent on nature: vegan+ diets?
- mankind less dependent on Earth: long-term manned space missions?

Take home messages

- 1 Artificial sugar could be produced for 0.5 – 0.9 €/kg at electricity cost of < 50 €/MWh, which is cheaper than biogenic sugar.
- 2 An artificial carbohydrate production could
 - provide an affordable and secure food supply for several trillion humans,
 - drastically lower the ecological externalities of the food system,
 - free valuable land for alternative use, e.g. nature reservations,
 - avoid socio-economic externalities such as national food dependencies.
- 3 A transition towards an at least partially artificial food supply appears not only to be smart but may be the only possibility to avoid future global conflicts on food and water resources.

The study and supporting literature can be found in:

Dinger and Platt: Towards an Artificial Carbohydrates Supply on Earth

- preprint on chemrxiv, 2019, <https://doi.org/10.26434/chemrxiv.9783791.v1>
- frontiers in Sustainable Food Systems, in review