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RESEARCH BRIEF

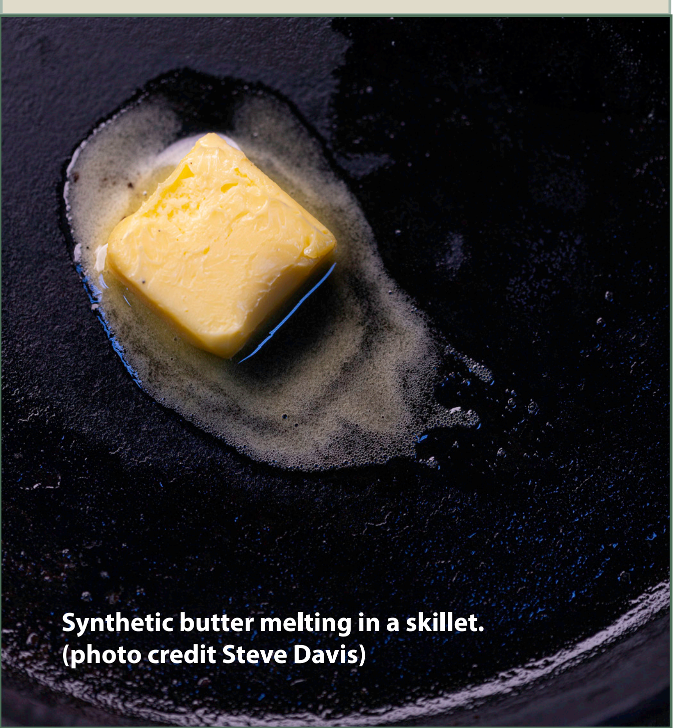
NOVEMBER 2023

KEY POINTS FOR DECISION MAKERS

Synthetic foods could have big environmental and social benefits. We use the majority of the planet's habitable land and drinkable water to grow food, and pour hard-won and energy-intensive nitrogen on the ground where less than 20% is incorporated in crops. Synthetic food could avoid the environmental burdens of agriculture and reconcile restoration and protection of natural ecosystems with human food security.

Synthesizing edible fats might reduce GHG emissions per kcal of food produced relative to current agriculture. This is true even if using fossil carbon feedstocks or fossil-energy inputs, but sustainable production will depend on renewable energy and atmospheric carbon.

There are barriers to large-scale synthesis of foods for human consumption. Projected costs to synthesize fats are ~20% higher than market prices of soybean and palm oil. Consumer preferences and impacts on working people are also key hurdles.



Synthetic butter melting in a skillet. (photo credit Steve Davis)

It is possible to greatly reduce GHG emissions and land use by synthesizing food without agricultural inputs.

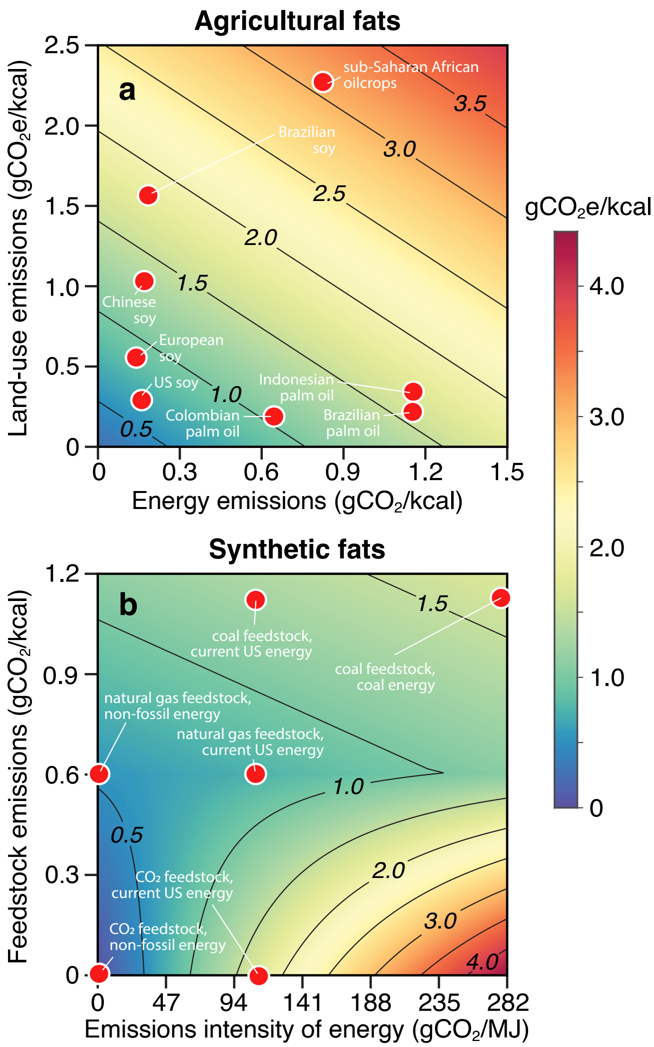
Efforts to reduce impacts of global agriculture have focused on limiting demand for the most resource- and pollution-intensive foods, decreasing the inputs to (and thereby impacts of) agricultural production, and using produced food more efficiently. We highlight another possibility: producing food without agriculture.

Edible molecules can be synthesized via chemical and biological processes without need of agricultural feedstocks. Such synthetically-produced food may contain carbon from fossil fuels, waste, or the atmosphere—i.e. feedstocks which are not the product of agricultural photosynthesis.

There may be many environmental and societal benefits to such foods, including reduced water use, decreased air and water pollution, improved food security and food sovereignty, resistance to some global catastrophe scenarios, less need for low-paying and physically-demanding agricultural labor, and vast tracts of land made available for reforestation, with attendant benefits to biodiversity and natural carbon sinks.

In particular, we focus on fats because they are the simplest nutrients to synthesize thermochemically (i.e. achiral and simply structured, compatible with large-scale soap-making and polymer chemistry techniques). For example, whereas agricultural fats correspond to roughly 1-3 g CO_2-eq/kcal, we estimate that molecularly-identical fats synthesized from natural gas feedstock using current average U.S. electricity would produce ~0.8 g CO_2-eq/kcal—and nearly zero emissions if using carbon captured from the air and non-emitting sources of electricity (see **Figure**).

At scale, the aggregate benefits could be enourmous. Palm oil alone accounts for 450 Mt CO_2-eq GHG emissions per year worldwide, and 20 million hectates of once biodiverse tropical forest.



Comparison of emissions per calorie of edible fats. Shading and contours show grams of CO_2-equivalent GHG emissions per kilocalorie of edible fat produced by conventional agriculture (**a**) and chemical synthesis (**b**). Agricultural emissions are shown as the sum of land-use emissions (y-axis) and energy-related emissions (x-axis), and emissions from synthesis are shown as a function of feedstock emissions intensity (y-axis) and emissions intensity of energy inputs (x-axis). Red circles denote specific estimates based on literature and assumed values. Feedstock emissions include process-related conversion of feedstock to CO_2—for example, during extraction of natural gas, gasification of coal, and the eventual human respiration of fossil feedstock.

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Aerial view of oil palm plantation in Thailand