Three paths forward for sustainable palm oil

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Palm oil has become the most common source of oil in food today. Every year, global consumption exceeds 70 million metric tons, and the demand is only expected to rise, due in part to palm oil's versatility. Food products from ramen to oat milk incorporate palm oil, as do a diverse array of commercial items, like shampoo and lipstick or biodiesel fuel.

- **The demand for palm oil is expected to increase in the coming years, but the industry is faced with a dilemma—how to meet global requirements without engaging in deforestation and the destruction of peatland to expand the size of oil palm plantations.**
- **Government and non-profit organizations are united in certifying plantations in the use of sustainable practices to limit detrimental environmental effects of farming this commodity.**
- **Researchers are also exploring ways to increase the oil yield, squeezing out more of the product from the land that is already under cultivation.**
- **A myriad of companies have recently formed, specializing in fermentation for bio oil production that replicates the desired characteristics of palm oil to meet industry standards.**

The crop is versatile too. Oil palm trees can produce up to 10 times more oil than other vegetable oil crops. Fruit from the oil palm tree can be harvested every 10 to 14 days, with one tree producing 40 kilograms of oil every year, for up to 30 years. Palm oil accounts for 36% of global vegetable oil consumed. Oil palm trees also produce more oil per unit of cultivated land than other vegetable oil crops. In fact, if all vegetable oil provisions were turned over exclusively to palm oil, it would require 76.87 million hectares of land, or about twice the size of California. For this reason, palm oil is one of the fastest-growing sub-sectors of the global agriculture economy.

Originating in West Africa, oil palm trees have been introduced to tropical regions around the world. Today, Malaysia and Indonesia produce about 90% of global palm oil output. This important agricultural crop has had a stabilizing effect on the economy of both countries. In 2020, Sabah, a state on the northern tip of Borneo's east Malaysia, produced 5 million tons of palm oil, or 6% of the global palm oil production. This impressive output has generated the equivalent of more than $230 million to the country's economy. Across southeast Asia, 4.5 million people participate in the palm oil economy, lifting them out of poverty and opening access to better housing and education.

THE DARK SIDE OF PALM OIL

To keep up with global demand, tropical rainforests and peatlands are increasingly being cleared for oil production. The economic gains of palm oil come at a steep cost to the environment. Tropical forests and peatlands act like sponges, absorbing carbon dioxide, a greenhouse gas. According to the United Nations Environment Programme (https://tinyurl.com/wuumsfh6), 55% of Indonesia's tropical forests have been lost in the past four decades, while Malaysia has lost nearly 20% of its old-growth forest in the past two decades.

FIG. 1. Deforestation along an oil palm plantation.

According to Erik Meijaard, conservation science professor at the University of Kent, in Canterbury, United Kingdom, palm oil cultivation has had a profound effect on the entire region (https://tinyurl.com/2u3ezf3t). Beyond driving deforestation, forest clearance reduces soil fertility, water quality in the surrounding fisheries, water regulation and supply, as well as biodiversity. In addition, deforestation leads to an increased human and wildlife conflict.

The slash-and-burn practices that are used to clear forests and peatland release an estimated one billion tons of carbon dioxide into the atmosphere. The escaping carbon contributes to planetary warming. The fires also release thick plumes of pollutant-laced smoke that choke the region. In Indonesia, more than 900,000 people were hospitalized with respiratory problems due to smoke inhalation from the nearby fires in 2019 (https://tinyurl.com/3r2n76zs).

Last fall, during the COP26 climate summit, 100 nations, including Indonesia and Malaysia, signed a pledge to halt deforestation. While palm oil production is responsible for less than 1% of deforestation globally, it is a major contributor to this practice in tropical regions. To address this concern, conservationists have joined forces with local governments, farmers, and corporations, like Ferrero and General Mills.

These groups are eager to slow the rate of deforestation through sustainable farming practices and increased oil yield. New research is also exploring approaches to optimize fermentation processes to generate a bio oil that can replace palm oil and ensure oil is available for consumer goods without the additional environmental harm.

FIG. 2. Oil palm fruit.

THE PATH TO SUSTAINABILITY

Palm oil growers are keen to decouple their production from deforestation and have begun embracing sustainable agricultural practices. The Roundtable on Sustainable Palm Oil (RSPO) (https://rspo.org), a non-profit organization that unites stakeholders while setting standards, accreditation, and process requirements to ensure sustainable practices are transparent and effective across the palm oil production chain.

RSPO certification is meant to transform the market for palm oil by decreasing the impact of agricultural practices on the environment and making sustainable palm oil more common and accepted by manufacturers. As of 2014, RSPO-certified growers account for 19% of palm oil production, but the road to certification is uneven.

While large companies may have the resources to obtain RSPO certification, small- and medium-sized growers often struggle to achieve this goal. Non-profits, like Forever Sabah (https://www.foreversabah.org), based in Sabah, Malaysia, are helping small growers adopt better farming practices to improve their readiness for certification. By achieving sustainable certification, small- and medium-sized farmers can improve their productivity and gain access to larger markets for their products.

In addition to the RSPO, the Sabah region of Malaysia has launched the Jurisdictional Certification of Sustainable Palm Oil (JCSPO). The program, which began in 2015, has a goal of achieving 100% ethical, green-certified palm oil production by 2025. With the JCSPO in hand, Malaysian palm oil producers will be more aligned with RSPO certification, which should accelerate their ability to obtain certification.

In a 2022 Reuter's article (https://tinyurl.com/bdhtkhcy), Frederick Kugan, the Sabah state forestry department's chief conservator, noted that 24% of the region's palm oil is now RPSO-certified. This approach is now being explored in other regions of Malaysia.

These efforts are encouraging, but a 2018 study (https://www.pnas.org/content/115/1/121) reveals that while deforestation is on the decline, efforts have not been as effective for slowing peatland clearance. In addition, these practices are more commonly adopted by older plantations that lack forest land in which to expand.

GATHERING THE LAST DROP

The demand for palm oil is anticipated to increase 46% beyond current need. In addition to adopting sustainable agricultural practices, researchers are exploring ways to reduce the gap between the actual oil harvested to the potential yield available. They aim to leverage expertise in production, agronomic science and the environment to bring real solutions that could have an impact across many sectors of the palm oil economy.

A 2021 study (https://doi.org/10.1038/s41893-021-00700-y), published in the journal *Nature Sustainability,* examined palm oil production on Indonesian oil plantations. The study found current yield is only 62% of the total attainable oil at large plantations and 53% at smaller outlets. To close the gap between what an operation can and does capture, the scientists sought an attainable yield of 70% (an increase of 8% on large plantations and 17% for smaller operations).

The researchers identified different cultivation practices, like weed control, pruning techniques and nutrition application, as initial steps to reach the identified attainable yield. Their work also suggests improved harvest methods could increase yield. The model indicates these efforts would save 2.6 million hectares of forests and peatlands. It would also prevent the release of 732 metric tons of carbon dioxide equivalent from the conversion of these ecosystems into plantation.

To actually make this happen and achieve these goals will require education and extension efforts, especially for small plantations. Today, researchers are working with producers, non-government organizations and government officials to fine-tune policy to promote investment in agriculture research that reconciles economic and environmental goals and establishes these management techniques on the ground.

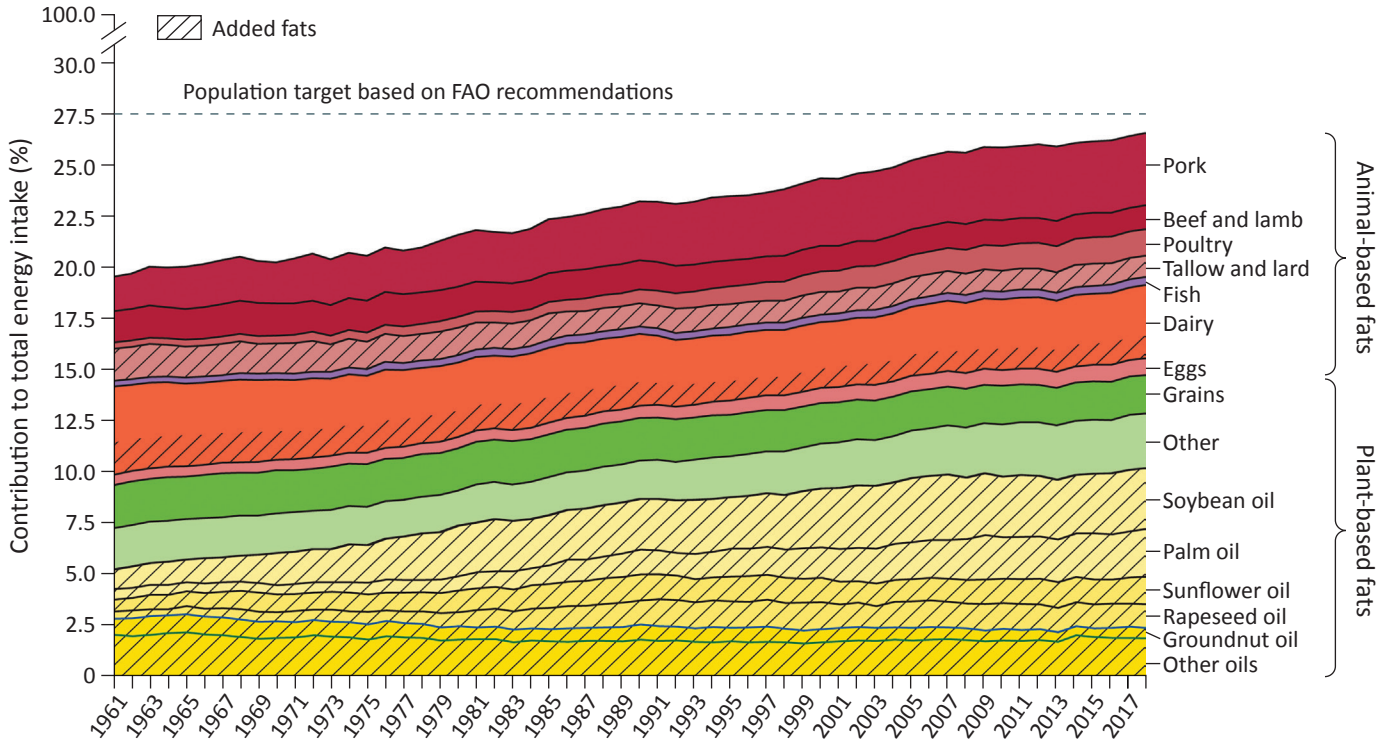

FIG. 3. Historical contribution of different plant and animal sources of fat to global average fat supply per person (1961–2018).
Source: Bajželj, *et al.*, *Lancet Planet Health, 5*, 9, E644-E653, 2021.

Making non-meat, meaty

Bio oil producers may have an ace up their sleeve.

The demand for protein-alternative products to replace meat are growing in popularity. According to the Good Food Institute (https://tinyurl.com/7efr5wuy), next-generation protein-alternative meat, eggs and dairy products are a growing $7 billion market. In particular, the market for plant-based meat is worth $1.4 billion, increasing in sales by more than $430 million from 2019 to 2020.

Perhaps one of the biggest hurdles this sector has to address is recreating the satisfying texture and taste of meat. Meat is a mixture. It contains 20% protein and 10% fat. Current plant-based meats use coconut oil to replace the fat content, but coconut oil does not produce the flavor of meat. To compensate, these products often disregard current trends and contain a litany of chemicals in the ingredient list to match the flavor requirements. Because bio oil is so similar to palm oil, it could produce a desirable mouthfeel and flavor for plant-based protein products.

A new company highlighted in a 2022 Tech Crunch article (https://tinyurl.com/yckz2nre) is focused on tackling the plant-based meat market. Yali Bio (https://www.yalibio.com) is developing a microbial strain library and is testing them out to find the right match. Microbe-produced fats may be the key to revolutionizing a dietary shift from animal-based food to sustainable plant-based foods. As more plant-based protein products begin to taste and feel like meat, it could be the key to moving meatless products from the store shelves to the check-out line at your local grocery store.

FIG. 4. Meat-free vegan steaks.

YEAST TO THE RESCUE?

Despite efforts to curb deforestation and improve product yield, sustainable palm oil faces a difficult path forward. Finding an agricultural alternative is also frustrating. Other options, like coconut oil, produce a lower yield with an even greater environmental impact when production is scaled to meet the industry need. Corn and soybean are non-tropical oils options, but these crops require additional processes to meet the yield of palm oil.

Numerous synthetic biology companies are exploring opportunities to manufacture bio oil through fermentation processes similar to brewing beer. Fermentation is a biochemical reaction that has been used for generations to produce everything from yogurt to ethanol. Organisms, like bacteria or yeast, power the process by extracting energy from carbohydrates or other sugars and converting it into the desired byproduct. Bio oil fermentation takes place in large bioreactors. The microorganisms, often yeast, convert agricultural feedstocks into bio oils that have a lipid profile that mimic the characteristics of palm oil without the environmental implications of growing palm trees. Synthetic biology companies are now exploring various approaches to fermentation to produce a bio oil with the right characteristics at the right cost to meet industry needs.

THE MANY FLAVORS OF FERMENTATION

Located in the heart of Manhattan, C16 Biosciences (https://www.c16bio.com) is optimizing conditions to brew alternative oils, fats and lipids. The company is using genetically-modified strains of yeast to produce a bio oil that is chemically near identical to palm oil. The company has recently received a $20 million Series A round of investment from Breakthrough Energy Ventures. C16 Biosciences first plans to tackle the personal care market with its bio oil product. Clean ingredients are in demand for personal care products and bio oil addresses this need. Personal care products are also a good first step for bio oil production. These products have less stringent regulatory requirements than food products.

Locus Fermentation Solutions (https://locusfs.com), a biotech conglomerate based in Solon, Ohio, USA, is already producing palm-free ingredients using patented production process that leverage bioinformatics and fermentation technology. In their process, microbes are fed renewable raw materials, like canola and corn, to produce sophorolipids, a biosurfactant. Unlike synthetic surfactants, the sophorolipids have a lower toxicity and higher biodegradability.

"We launched Locus Performance Ingredients in July 2020, to replace legacy chemical surfactants used in product formulations with safer, sustainable, low-carbon, high-performance biosurfactants," said Tim Staub, CEO of Locus Performance Ingredients, a subsidiary located in Bon Air, Virginia, USA. "Our technology and resulting sophorolipids are multifunctional, highly efficacious and USDA BioPreferred certified 100% bio-based."

Locus Performance Ingredients plans to create a palm-free bio oil that has a zero carbon footprint. The company uses crops grown on established agricultural land for

renewable energy in its production process. According to Staub, the company can scale rapidly anywhere in the world where the feedstocks, electricity and water are available.

"Our innovative, very-low-carbon modular fermentation platform allows us to rapidly scale as needed near end-use markets, further reducing the carbon impact of long supply chains," said Staub. "This allows formulators to simultaneously simplify their formulas and increase the bio-based content and sustainability of their products while improving performance."

The company has joined into a globally exclusive distribution agreement with Dow Chemical. It is now selling their product in a series of personal care products found in and marketed by multiple consumer packaged goods (CPG) companies. They are also exploring collaborations with other applications, from industrial water treatment to textiles pulp and paper production.

AOCS MEETING WATCH

July 31–August 3, 2022. Edible Oil Products Processing Course, Fats and Oils R&D Center LLC, College Station, Texas, USA. (https://fatsandoilsrnd.com/annual-courses/)

October 4-6, 2022. Sustainable Protein Forum, Millennium Knickerbocker Hotel, Chicago, Illinois, USA and Online.

August 27–September 1, 2022. World Congress on Oleo Science, hosted by the Japan Oil Chemists' Society, Online. (https://jocs.jp/en/conference-meeting/)

April 30–May 3, 2023. AOCS Annual Meeting & Expo, Colorado Convention Center, Denver, Colorado, USA.

For in-depth details on these and other upcoming meetings, visit http://aocs.org/meetings or contact the AOCS Meetings Department (email: meetings@aocs.org; phone: +1 217-693-4831).

Kiverdi, a company in Pleasanton, California, USA (https://www.kiverdi.com) is exploring an alternative to palm oil through a process that directly captures carbon dioxide from the atmosphere. The company is also using directed evolution, which applies stress to yeast colonies to spur them to produce more oil from cheaper feedstocks. According to the company, this approach is advantageous because it will avoid the regulations that govern genetically-modified organisms used by other companies in bio oil production. Kiverdi aims to produce yeast strains that are not only highly productive but also more robust.

The Wisconsin, USA-based company, Xylome (https://www.xylome.com), has leveraged yeast fermentation to produce the bio oil, 'Yoil.' The process uses a genetically-modified strain of yeast, *Lipomyces starkeyi*, which are fed corn syrup. The process yields bio oil that has the same chemical profile as palm oil.

In a 2022 *Fast Company* article (https://tinyurl.com/29hyynyj), the company's CEO, Thomas Kelleher, noted that Yoil can be used as a one-to-one drop-in replacement for palm oil. Yoil has another benefit. Unlike palm oil, Yoil does not require bleaching, which removes chlorinated hydrocarbons from the production process and ultimately the food chain. Xylome is sharing samples of Yoil with companies to see how it stands up to traditional palm oil in products like ice cream. The company is also looking into alternative approaches that use waste feedstock from cornfields to make a similar, but less expensive, bio oil product.

Each company faces the same hurdle—scaling production at a price that is profitable. To accomplish this feat, they are optimizing their processes by improving strains, enhancing fermentation efficiencies, identifying the best, most cost-effective and environmentally-sustainable feedstocks, and obtaining additional byproducts from the fermentation stream to improve profitability.

The future of palm oil lies at the intersection of sustainability, agronomic management improvements, and laboratory processes innovations. As more corporations require certification, governments and growers will be motivated to adopt sustainable management practices. Such practices could fold in new research to improve yield and address the immediate need for oil without converting more land for cultivation. Finally, biotechnological advances will improve bio oil characteristics in a cost-effective process that can scale production to augment—if not replace—the demand for palm oil in food and commercial products. The end results may soon be on your supermarket shelves. Stay tuned.

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