



Potential Impacts of Synthetic Biology on the Economy and Livelihoods: **THE CASE OF COCONUT OIL**



PRODUCT: Industrially useful natural fatty acids known as ‘lauric oils’ (capric acid, lauric acid, myristic acid, palmitic acid) and ‘fatty alcohol’ (lauryl alcohol and myristyl alcohol) - key ingredients for common oleochemical products such as detergents, soaps and cosmetics - are currently derived from coconut oil, palm kernel oil and also babassu seed.

STATUS: Three California-based companies are now producing fatty acids and fatty alcohols using synthetic biology. **Solazyme, Inc.** has created algae strains whose oils are ‘genetically tailored’ to express lauric acid, capric acid or myristic acid. Solazyme is also developing strains to produce palmitic acid and oleic acid.¹ **Codexis, Inc.** and **LS9, Inc.** have developed engineered microbes that produce fatty alcohols for detergents.²

AFFECTED COUNTRIES/REGIONS:

58% of global oleochemicals production is in Asia,³ as is most production of coconut and palm kernel nuts. Countries that will be most affected are the Philippines, Malaysia, Indonesia and India, also Vietnam, Mexico, Nigeria, Thailand and Papua New Guinea. In the Philippines, approximately one quarter of the population depends on coconut production – impacting around 25 million people.⁴

MARKET: The global market for natural fatty acids (primarily derived from coconut, palm and palm kernel oil) was valued at \$7.2 billion in 2011 and is expected to reach \$13 billion by 2017.⁵ The market for lauric acid alone was estimated at about \$1.4 billion in 2008;⁶ the market for myristic acid is estimated at about \$600 million.⁷ This is just part of a larger \$206 billion plant oils market that new SynBio companies are hoping to capture.⁸ Detergent alcohols in particular are a \$6 billion market worldwide, expected to reach \$8 billion in a decade.⁹

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COMMERCIALIZATION: Solazyme already has a production facility in the USA and has partnered with chemical giant Mitsui, household products transnational Unilever, grain traders Archer Daniels Midland and Bunge, as well as chemical firm AkzoNobel to begin commercialization of its lauric oils. Unilever has recently agreed to buy 3 million gallons of algae-produced oil from Solazyme.¹⁰ The company may have the technical capacity to capture up to 40% of global myristic acid production in the coming years with a new 100,000 MT/annum (metric tonnes per year) plant under construction in Brazil in collaboration with Bunge. Codexis is already selling small quantities of its CodeXol fatty alcohols and is hoping to have a 60,000 MT/annum commercial production plant running by 2015. In 2012, LS9, Inc. produced 135,000 litres of synbiotech-derived fatty alcohols and is now scaling up to supply customers, including Procter & Gamble.

BACKGROUND

SYNTHETIC BIOLOGY

“Synthetic biologists” apply computer-aided design and engineering to living organisms. The aim is to redesign existing biological organisms and even to create entirely new ones. Synthetic biology is “extreme genetic engineering” and its goal is to derive commercially-valuable compounds from new living organisms rather than from conventional sources (e.g., crops, petroleum).

Currently, synthetic biology companies are engineering ‘metabolic pathways’ in microbes in order to create ‘biological factories’ that produce desired compounds. In the words of one synthetic biologist: “We ought to be able to make any compound produced by a plant inside a microbe.”¹¹

Some synthetic biology companies are shifting focus from biofuels to high-value / lower-volume products – especially compounds found in plants (e.g., essential oils, flavours, fragrances, colourants and pharmaceuticals) – which are traditionally cultivated by farming communities in the global South. If commercially viable, synthetic biology’s patented organisms have the potential to de-stabilize natural product markets, disrupt trade and eliminate jobs and livelihoods. New, bio-based substitutes that are promoted as ‘equivalent’ to natural products could have far-reaching impacts on agricultural economies, especially for those producers without the information or resources to respond to sudden shifts in natural resource supply chains.

NATURAL OLEOCHEMICALS

Oleochemicals are those chemical products produced from oils, a large part of its market is for ‘natural oleochemicals’ that refine vegetable oils into detergents, soaps, shampoos and other household goods. An important range of starter compounds for oleochemicals is the natural fatty acids known as ‘lauric oils.’ For these, coconut oil and palm kernel oil (different from palm oil, which comes from the pulp of the palm fruit) are the major raw material sources.

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Coconut oil, produced from crushing the copra (flesh of matured fruit) of harvested coconuts is particularly rich in lauric oils and supplies much of the oleochemical market. Coconut oil consists of about 48% lauric acid, 16% myristic acid and 9% palmitic acid.¹² It is also a good source of capric or caprylic acid. Coconut oil and palm kernel oil are also the major industrial sources for C12-C14 fatty alcohols (C12-C14 refers to the length of the chain of carbon molecules), such as lauryl alcohol and myristyl alcohol; these are used primarily for detergents. The largest users of coconut- and palm kernel-derived detergent alcohols are consumer products companies, including US-based Procter & Gamble, Netherlands-based Unilever and Germany-based Henkel.

COCONUT OIL PRODUCTION IN THE PHILIPPINES AND BEYOND

Known in the Philippines as ‘The Tree of Life,’ the coconut tree (*Cocos nucifera*) is celebrated for its many uses, from food and clothing to building materials. However, it is the copra crushed into oil that is primarily sold internationally as a commodity both for food and more commonly for detergents, soaps, etc. Global production of coconut oil is estimated at 3,735,000 MT for 2013¹³ with over 90% of that grown in Asia and the South Pacific. On average, 1000 coconuts yield 110 kg of oil.¹⁴

The Philippines is the world’s leading producer of coconuts accounting for 46.2% of global coconut oil production and 59% of the world’s coconut exports.¹⁵ There are around 3.5 million coconut farmers and as many as 25 million people are directly or indirectly dependent on the coconut industry (e.g., coconut growing, transport, processing and trading). Coconut farming is distributed across the entire country: of 79 provinces, 68 are coconut-growing areas



and coconut is grown on 26% of Philippine farmland (~324 million trees¹⁶). The coconut farms of the Philippines are relatively small – with an average area of 2.4 hectares (ha) and about two-thirds of the country’s 1.4 million coconut farms are owner-operated. Coconut cultivation in the Philippines generally does not require chemical inputs, and other crops are often grown together under the tall trees’ shade. Despite their contribution to the country’s annual GDP, poverty incidence among Filipino coconut farmers is about 62%, due to stagnation of copra prices since 2010, low wages for workers and the agrarian structure in coconut-growing regions. Other major coconut-producing countries include Indonesia (26.1% of world coconut oil production), India (12%) Vietnam (4.1%) and Mexico (3.9%).

Top 10 Coconut Oil Producing Countries / 2013 Estimate¹⁷

Country	Production 2013 (1000 MT)	Market Share (% of world production)
1. Philippines	1,725	46.2
2. Indonesia	974	26.1
3. India	447	12
4. Vietnam	153	4.1
5. Mexico	145	3.9
6. Papua New Guinea	63	1.7
7. Thailand	46	1.2
8. Sri Lanka	43	1.1
9. Malaysia	35	0.9
10. Mozambique	30	0.8
Total top 10	3,661	98%

Estimated world coconut oil production for 2013: 3,735,000 MT

CURRENT STATE OF SYNTHETIC BIOLOGY ALTERNATIVES TO FATTY ACIDS AND ALCOHOLS

SOLAZYME: MAKING FATTY ACIDS IN ALGAE

Solazyme, Inc. of California, USA is a publicly-traded synthetic biology company with a business plan to engineer algae in order to change the chemical profile of algal oil. Unlike most algae companies, Solazyme works with heterotrophic algae – strains that feed on sugar instead of sunlight and so can be grown in closed vats in an industrial facility rather than shallow ponds.¹⁸ While Solazyme was initially founded as a biofuels business, like many synthetic biology companies, it has shifted its business plan to produce natural compounds, flavours and food ingredients. Solazyme has engineered its algae to produce a range of “genetically tailored oils,” which each express high levels of a particular fatty acid. The company claims it has developed algal strains that express up to 80% of their oil as lauric oils (cf. palm kernel oil’s 55% lauric oils and coconut oil’s 68%). Solazyme claims that an oleochemical facility utilizing its tailored oil rather than standard palm kernel oil could increase output of the desired fatty acid components such as capric, lauric and myristic acid by more than 30%.¹⁹

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In particular, Solazyme boasts its ability to compete against natural coconut oil as a better source of myristic acid. According to Solazyme, coconut oil can sometimes reach concentrations of up to 15% myristic acid. By contrast, Solazyme's engineered algal oil currently boasts 60% concentration of myristic acid, almost four times more than any widely available oil today.²⁰ As market analyst Kevin Quon points out:

"This results in more than a 150% increase over that which is found in coconut oil. Through rough calculations, it would appear that in order to get 1 MT of myristic acid, it would either take 2.5 MT of tailored algal oil yielding 40% or it would take 6.67 MT of coconut oil yielding 15%. If we were looking just for myristic acid, it would therefore take 63% less oil in order to get it from Solazyme's tailored algal oil."²¹

Solazyme says their lauric oils will become commercially available toward the end of 2013.

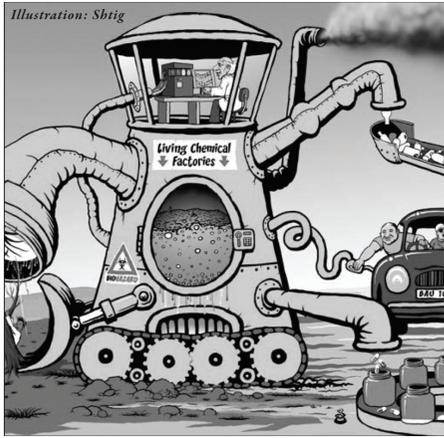
How Solazyme's algal myristic acid will fare against coconut-derived myristic acid in the marketplace depends in part on coconut oil prices and sugarcane prices (sugar is the feedstock for the company's engineered algae). Solazyme is keen to point out that while most coconut is sourced from the Philippines and takes several years to grow, sugarcane can be grown quickly in many locations, including in coconut-producing countries such as the Philippines. In time, Solazyme hopes to feed cheaper cellulosic sugars to their algae (e.g., grasses or wood pulp): "...oil supply can be unlocked from a regional land restriction. Instead, the range is increased to include anywhere in which more-readily abundant sugarcane is grown. Once the ideal infrastructure is developed, it can even be produced at any location where cellulosic biomass is found."²²

Solazyme has told investors that it would be able to manufacture oils at a cost below \$1000 per MT if produced in a built-for-purpose commercial plant,²³ although they currently plan to sell their myristic acid for around \$3000/MT.²⁴ Today, myristic acid sells for more than \$4200/MT.²⁵ Solazyme is building at least two large commercial plants: a facility in Illinois, USA producing approximately 500,000 gallons (1.89 million L) of oil/annum and a facility in Brazil able to ferment over 28 million gallons/annum (105 million L). At 60% concentration, the Brazilian facility alone would theoretically be able to meet about 40% of global myristic acid market.²⁶

Solazyme has signed a number of joint ventures and agreements with some of the world's largest sugar, chemical and oleochemical players, including Bunge, Archer Daniels Midland, Dow, Akzonobel and Mitsui. The \$20 million Mitsui deal is especially relevant for coconut and palm kernel oil markets since it focuses specifically on the further development of high myristic algal oil.²⁷ Mitsui has been producing oleochemicals for 20 years through its subsidiary Palm Oleo and is a significant investor in Kuala Lumpur Kepong Berhad (KLK), which owns palm oil and rubber plantations and is the world's largest oleochemical company. On signing the multi-year deal, Mitsui stated that it "looks forward to strengthening its position in the oleochemicals industry through the successful development and commercialization of these novel products."²⁸ Solazyme also has an agreement with Unilever, one of the world's largest end-users of oleochemical ingredients for production of consumer soaps and detergents. In this way, Solazyme appears to have secured partners all along the supply chain – from initial sugar to final consumer product.

In theory, this would allow Codexis to produce a competitor to coconut- and palm kernel oil-derived detergents using so-called agricultural 'waste' and forest 'residues' as feedstock.

CODEXIS AND LS9: MAKING FATTY ALCOHOLS IN MICROBES



Codexis is a synthetic biology company using computer-based techniques to artificially 'evolve' and re-engineer enzymes and microorganisms.²⁹ LS9, founded by leading synbio researchers Jay Keasling and George Church, is focused on engineering microbes – primarily *E. coli* – to produce industrial compounds.³⁰ Both are based in California and both were initially focused on biofuels but are now moving into other markets. Both companies have developed the

technology to produce fatty alcohols. According to Codexis, so-called "detergent alcohols" for use in household products represent a \$6 billion market worldwide, expected to reach \$8 billion in a decade.³¹

While there is a range of different fatty alcohols, the popular C12-14 alcohols, known as lauric alcohols, are usually derived from coconut oil and palm kernel oil. Codexis has developed a microorganism that produces a new lauric alcohol dubbed CodeXol and in collaboration with Chemtex, a subsidiary of Italian chemical company Gruppo M&G, is scaling up production of CodeXol; they aim to reach full-scale commercialisation by 2015.³² In June 2013, Codexis and Gruppo M&G announced that they had successfully scaled up a process that would transform cellulosic biomass into lauric alcohols.³³ In theory, this would allow Codexis to produce a competitor to coconut- and palm kernel oil-derived detergents using so-called agricultural 'waste' and forest 'residues' as feedstock.

LS9 has agreements with Procter & Gamble³⁴ and a facility in Florida, USA that produces 135,000 liters of fatty alcohols at a time and has reportedly been producing batches for commercial partners. LS9 plans three 750,000-liter fermenters in Brazil, which could produce 10,000-25,000 MT/year of fatty alcohols, while a large-scale commercial facility is expected (in 2017-2018) to have a capacity of 200,000 MT/year.³⁵

POTENTIAL IMPACTS ON THE ECONOMY AND LIVELIHOODS

The commercialization of lauric oils and fatty alcohols derived from algae and microbes developed through synthetic biology potentially have devastating impacts on the economy and livelihoods in countries that produce and export coconut oil such as the Philippines and oil palm like Indonesia and Malaysia.

Substitution of lauric oils and fatty alcohols derived from traditional crops and agricultural commodities by those produced from engineered organisms have the potential to drastically reduce the demand for naturally-derived products in the export market. The recent announcement of Unilever to buy three million gallons of algae-derived oils from Solazyme is an early warning of that shift. As the price of oils derived from new organisms become more competitive with natural oils, through the help of business partnerships and guaranteed market from major industrial consumers, the economic and social havoc that may result from such shift become more imminent.

Product substitution or alternative sources of a product could have far-reaching impacts on economies that depend on production and export of traditional commodities where the livelihoods and income of farmers, producers, processors and those in the entire supply chain are derived. A new competing source could potentially depress the world market price of oils produced through conventional/traditional means. Reduced demand for a product will result to lower income, even job displacement, among those involved in the production and processing chain.

The Philippines had a direct experience in the tragic impacts of product substitution when high-fructose corn syrup (HFCS) was introduced as cheaper alternative to sugarcane as sweeteners in food manufacturing and processing. The shift devastated the country's sugarcane industry in the 1980s, resulting to widespread hunger and massive destitution among farmers and agricultural workers and their families whose livelihoods, income and economic survival solely depended on the crop. The lessons from that not-so-distant tragedy should not be lost to coconut farmers and other players in the industry so vital to the country's economy.

¹Doris De Guzman, "Solazyme files for IPO," ICIS Green Chemicals, 21 March 2011: <http://www.icis.com/blogs/green-chemicals/2011/03/solazyme-files-for-ipo.html>.

²Doris De Guzman, "Codexis Enters Detergent Alcohols Market," ICIS Green Chemicals, 5 March 2011: <http://www.icis.com/blogs/green-chemicals/2011/03/codexis-enters-detergent-alcoh.html>.

³Anon., IHS Natural Fatty Acids Report, July 2012: <http://www.ihs.com/products/chemical/planning/ceh/natural-fatty-acids.aspx>.

⁴25% figure via Danilo Suarez, "Save The Coconut Farmer," Manila Standard, 7 May 2013: <http://manilastandardtoday.com/2013/05/07/save-the-coconut-farmer/>. The population of the Philippines is currently around 103 million.

⁵BCC Research, "Global Market for natural Fatty Acids to reach 13 billion in 2017," 21 December 2012: <http://www.bccresearch.com/pressroom/report/code/CHM062A>.

⁶J.M. Dyer, S. Stymne, A.G. Green, A.S. Carlsson, "High-value oils from plants," *Plant J.*, 54, 2008, pp. 640–655.

⁷Kevin Quon, "Can Solazymes Potential Outweigh its Skeptics?" SeekingAlpha.com, 24 June 2013: http://seekingalpha.com/article/1518442-can-solazyme-s-potential-outweigh-it-s-skeptics?source=email_rt_article_readmore

⁸Solazyme Investor presentation: <http://www.scribd.com/doc/111084056/110805-Solazyme-Investor-Presentation-Canaccord-Compressed>.

⁹Codexis website: <http://www.codexis.com/codexol>.

¹⁰Dianne Cardwell, "Unilever to buy oil derived from algae from Solazyme", New York Times, 25 September 2013, [http://www.nytimes.com/glogin?URI=http://www.nytimes.com/2013/09/25/business/energy-environment/unilever-to-buy-oil-derived-from-algae-from-solazyme.html&OQ=rQ3D1Q26&OP=2cf3049bQ2FPk6-PQ5BE-PDDDPc-jYPUkA!IkK-Q22PQ22hLQ20Ph2PQ221PeG!_Q5BX!!PXQ5BXIbEQ7CXQ5Bx_IkQ5BjXQ5B-PGQ5B_YXxXIQ7C-kQ7CeGEQ7Ck_YQ7CUXI_xXUQ7CZIkjQ7CQ7BYbQ7BXQ7CZIkjQ7C!kYQ7B\)EjXyc-jY](http://www.nytimes.com/glogin?URI=http://www.nytimes.com/2013/09/25/business/energy-environment/unilever-to-buy-oil-derived-from-algae-from-solazyme.html&OQ=rQ3D1Q26&OP=2cf3049bQ2FPk6-PQ5BE-PDDDPc-jYPUkA!IkK-Q22PQ22hLQ20Ph2PQ221PeG!_Q5BX!!PXQ5BXIbEQ7CXQ5Bx_IkQ5BjXQ5B-PGQ5B_YXxXIQ7C-kQ7CeGEQ7Ck_YQ7CUXI_xXUQ7CZIkjQ7CQ7BYbQ7BXQ7CZIkjQ7C!kYQ7B)EjXyc-jY)

¹¹Jay Keasling, quoted in Michael Specter, "A Life of its Own: Where will synthetic biology lead us?," *The New Yorker*, 28 September 2009, p. 59.

¹²AOCS Lipid Library, "Oils and Fats in the Marketplace, Commodity Oils and Fats: Palm Kernel and Coconut (Lauric) Oils:" <http://lipidlibrary.aocs.org/market/lauric.htm>

¹³USDA figures indexed at <http://www.indexmundi.com/agriculture/?commodity=coconut-oil>.

¹⁴Feedipedia, "Copra meal and coconut byproducts:" <http://www.feedipedia.org/node/46>

¹⁵Philippine Coconut Authority, "Magnitude of the Industry:" <http://www.pca.da.gov.ph/magnitude.html>.

¹⁶Ibid.

¹⁷Indexmundi, "Coconut oil production by Country in 1000 MT, 2013 Estimate:" <http://www.indexmundi.com/agriculture/?commodity=coconut-oil&graph=production>.

¹⁸See Solazyme website, "Biotechnology that Creates Renewable Oils from Microalgae:" <http://solazyme.com/technology>.

¹⁹Solazyme SEC Filings Form S-1 March 11 2011: <http://www.sec.gov/Archives/edgar/data/1311230/000119312511064209/ds1.htm>.

²⁰Anon., "Solazyme Management Discusses Q1 2013 Results - Earnings Call Transcript," Seeking Alpha.com, 8 May 2013: <http://seekingalpha.com/article/1417141-solazyme-management-discusses-q1-2013-results-earnings-call-transcript?page=2>.

²¹Kevin Quon, "Solazyme Addresses The Limitations Of Oil Production - An Interview With Solazyme's Director (Part 2)," SeekingAlpha.com, 10 February 2013: <http://seekingalpha.com/article/1170001-solazyme-addresses-the-limitations-of-oil-production-an-interview-with-solazyme-s-director-part-2>.

²²Ibid.

²³Solazyme SEC Filings Form S-1 March 11 2011: <http://www.sec.gov/Archives/edgar/data/1311230/000119312511064209/ds1.htm>.

²⁴See Powerpoint slide: <http://seekingalpha.com/article/1217241-partners-embrace-win-win-proposition-in-solazyme-s-tailored-oils>.

²⁵Kevin Quon, "Can Solazymes Potential Outweigh Its Skeptics?" SeekingAlpha.com, 24 June 2013: http://seekingalpha.com/article/1518442-can-solazyme-s-potential-outweigh-it-s-skeptics?source=email_rt_article_readmore.

²⁶Calculation for 40% figure: Solazyme's Brazilian facility has a projected capacity of 100,000 MT of algal oil – 60% concentration = 60,000 MT of Myristic Acid. According to Solazyme, the global market size is 150,000 Mt – see Powerpoint slide at <http://seekingalpha.com/article/1217241-partners-embrace-win-win-proposition-in-solazyme-s-tailored-oils>.

²⁷Solayme press release, "Solazyme and Mitsui Enter into Multi-Year Agreement to Jointly Develop a New Suite of Tailored Algal Oils," 6 February 2013: <http://solazyme.com/media/2013-02-06>.

²⁸Ibid.

²⁹See <http://www.codexis.com/technology>.

³⁰See <http://www.ls9.com/technology/technology-overview>.

³¹Anon., Codexol detergent alcohol: <http://www.codexis.com/codexol>.

³²Doris de Guzman "Sugar Fatty Alcohols near commercialization," ICIS Green Chemicals, 20 April 2012: <http://www.icis.com/Articles/2012/04/20/9552164/sugar+fatty+alcohols+near+commercializati on.html>

³³Codexis press release, "Codexis and Chemtex Achieve Key Milestone in Commercial Development of Bio-Based Chemicals from Non-Food Cellulosic Biomass," 14 June 2013: <http://ir.codexis.com/phoenix.zhtml?c=208899&p=irol-newsArticle&cat=news&id=1829906>

³⁴Doris de Guzman, "Sugar Fatty Alcohols near commercialization," ICIS Green Chemicals, 20 April 2012: <http://www.icis.com/Articles/2012/04/20/9552164/sugar+fatty+alcohols+near+commercializati on.html>

³⁵Ibid.



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