Rose Oil

A Case Study on Use of Synthetic Biology Replacements

Farmers Affected: 75,000 in Turkey and Bulgaria

Volume: 3,000 to 4,500kg/year[1]

Market Value: Exports are valued at 15 million euros[2]

Uses: Perfumes and Cosmetics

Syn Bio Companies: Ginkgo BioWorks in partnership with Robertet, Celbius

Hotspots: Bulgaria (Kazanlak, Karlovo, Streltcha, Zelinkovo and Chirpan regions) and Turkey (southwest province)

Also Grown In: Morocco, Iran, Mexico, France, Italy, Lebanon, India, Russia, China, Ukraine and Crimea. New producers emerging in Afghanistan, Saudi Arabia and Egypt

Cultural Importance: Oil-producing roses of Bulgaria are national symbol linked to tourism, festivals and traditional events.

Biodiversity Considerations: Bred in regions which can not be effectively used for other agriculture. Flowering plants aid natural pest control management. Promotes bee population and pollinator habitat.

Quality Concerns: Because of its complexity, no one has been able to synthesize the true scent of damask roses. It is unlikely that a syn bio product, which is always hampered by molecules of only a few components, will be able to duplicate it.

Commercialization: May already be on the market

Overview

Rose oil[3] – a classic ingredient in perfumes and cosmetics – is the essential oil distilled from freshly harvested rose petals (*Rosa damascena*).[4] Although many molecular components of rose oil have been chemically synthesized, scientists have been unable to match the complex scent of the essential oil derived from Damask roses.[5]

Status: Syn bio rose oil may already be on the market

R&D **Scale Up** **Commercialization**

Now, several syn bio companies, in Boston, the UK and China, are researching and developing syn bio engineered yeast microbes to produce rose scents. Leading the pack is Boston-based Ginkgo Bioworks whose syn bio-derived version of "rose oil" will be commercialized by leading essentials oil producer Robertet.

What Is Rose Oil?

Rose Oil is a perfume and cosmetic essential oil made from rose petals. The most valued variety is *Rosa damascena*, the Damask rose, a very old type. The oil is distilled from the flowers, requiring many workers to care for and pick the plant, and is an important commodity, especially in Bulgaria and Turkey, but also in China, France, Lebanon and Afghanistan. Although many parts of the rose scent have been synthesized for years, industry has not been able to duplicate the true rose fragrance, which is very complex and is worth thousands of dollars per kilo. This is why it's a tempting new product for synthetic biology engineers, who are working on creating novel forms of yeast that will produce rose-like odors.

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For more info on Synthetic Biology please visit the ETC Group website: **www.etcgroup.org/synbio**

Rose Oil as a Natural Product

Rose oil is one of the world's most expensive essential oils,[6] used and appreciated for thousands of years. Today it is produced mostly in Bulgaria and Turkey, but many other countries, including China, France, Lebanon and Afghanistan are also producers. High-quality Bulgarian rose oil was priced at $5,750 US per kg in 2014.[7] The harvest is labor-intensive: it takes 1.25 million hand-picked flowers[8] and about 800 worker hours to produce 1 kg of rose oil. The fragrance/flavor industry, cosmetic and perfume companies are the largest buyers of rose oil. Worldwide production of rose oil ranges from 3,000 to 5,000 kg per annum.[9]

Bulgaria and Turkey, where rose cultivation is centuries old, account for about 80%-90% of rose oil production worldwide.[10] The rose oil industry employs over 75,000 farmers and seasonal harvest workers in these two countries alone. Other rose oil and rose water[11] producing countries include Morocco[12], Iran, India, China, France and Russia. New producers are emerging on the market in Afghanistan, Saudi Arabia and Egypt.[13]

In southwest Turkey, about 12,000 small farmers produce oil-bearing roses on approximately 2,300 ha.[14] Turkey's rose oil exports were valued at $12.6 million in 2012 (940 kg of rose oil; 6900 kg of rose concrete and 1,020 kg of rose absolute).[15]

Bulgaria exports an estimated 1,500 to 1,800 kg of rose oil annually[16] from damascena roses grown on approximately 3,500 ha in the Rose valley regions of Kazanlak and Karlovo.[17] The Bulgarian rose oil industry employs an estimated 65,000 workers – 50,000 of them seasonally.[18] Production is divided almost evenly between plantations (owned by distillers) and small farmers.[19] Bulgarian rose oil exports are valued at approximately $9-$11 million per annum.[20] Bulgaria's exports of all essential oils were valued at $35.2 million in 2012.[21]

Cultural and Biodiversity Considerations

Sustainable tourism driven by the rose sector is of economic importance for Bulgaria. Bulgarian roses and rose oil are an important symbol of national identity and pride. This is not only due to their unique geographical origin traced to the Rose Valley, but also due to the distinctive social and cultural capital of the people involved in the process and development of skills, techniques, traditions, rituals, and diligence in growing roses and producing various rose-derived products.[22] Festivals and traditional events drive national and international tourism during May and June.

Currently industrial production uses agrochemicals . However, there is increasing acreage of organic production of rose petals. As a flowering plant such crops can be beneficial for pollinators. Like any labour-intensive, high-value product, the crop tends to favour biodiversity and long-term soil management.

Synthetic Biology Production

Ginkgo BioWorks, a USA-based synthetic biology company, is partnering with fragrance/flavor company Robertet (France) to engineer yeast microbes that biosynthesize the production of rose oil compounds. Robertet is one of the world's largest buyers and processors of rose oil.

According to an article published in Fortune magazine of July 2015, Robertet's and Ginkgo BioWorks' rose oil is already on the market, sold as a perfume.[23] Although Ginkgo BioWorks holds a number of patents and patent applications related to microbial biosynthesis, published patents do not specifically refer to rose oil biosynthesis.[24]

Robertet (France) is the 10th largest flavour and fragrance company (2013 sales: $536.6 million). The company describes itself as a "global leader in natural ingredients." Robertet operates rose oil processing facilities in Bulgaria and Turkey – the world's two largest producers of roses used for extraction of rose oil (or its by-products). Robertet's self-professed motto is: "Natural, always natural." However, although a Fortune article mentioned above says the syn bio rose oil is for sale, nowhere on the Robertet or Ginkgo BioWorks websites is that verifiable.[25]

Gingko BioWorks, which describes itself as "an organism engineering company," reportedly has 20 contracts with companies to develop syn bio flavors, fragrances, cosmetics, sweeteners and natural pesticides.[26] The company's partnership with the all-natural Robertet to produce rose oil compounds in engineered yeast is one of the few targets announced publicly. CEO Jason Kelly told the Boston Globe that he expects the first products made by Ginkgo-crafted organisms "to be sold by our partners by the end of the year, or first quarter of 2016."[27]

The new rose oil may not even come from roses. In 2015, Patrick Boyle of Gingko BioWorks told New Scientist:

"Our goal is to recreate the rose biosynthetic pathways, even if we don't use rose genes to do it...We often find that a different but highly related gene from a different species works better in yeast than the rose gene that has the function we want."[28]

In his remarks before the 2014 annual meeting of the International Federation of Essential Oils and Aroma Trades, Jason Kelly of Ginkgo BioWorks stated that his company's goal is not to replace existing ingredients but to provide "creative opportunities" such as a rose oil that is chemically distinct from its botanically-derived counterpart.[29] Ginkgo claims on its website that "instead of just limiting ourselves to what naturally-occurring roses provide," the company's custom-made microbes will "expand the variety of rose oil and rose scents even further."[30]

Besides this effort, scientists at the Jiao Tong University in Shanghai, China are also conducting research on the biosynthesis of rose essential oil.[31] Celbius, an industrial biotechnology based in the UK, has developed the production of 2-phenylethanol (2PE) using synthetic biology. 2PE is an aromatic alcohol with rose-like odour and is used in the food, drink and cosmetic industry, particularly when the smell of rose is desired. 2PE occurs widely in nature, being found in a variety of essential oils, including rose. Its floral odour means it is used in flavour and perfumery, also as a preservative in soaps due to its antimicrobial properties.[32]

Implications and the Future

Rose oil extracted from harvested petals of *Rosa damascena* contains at least 8 major chemical compounds[33] and more than 275 minor constituents.[34] It is unlikely that synthetic biology companies will be able to replicate the complexity of rose oil molecules extracted from damask flowers. However, it won't be necessary to fully duplicate the molecular composition in order to disrupt the global market for botanically-derived rose oil – especially if much lower-priced rose-scented oil and by-products are offered. It is too soon to predict if Ginkgo BioWorks or some other company will be able to engineer microbes to biosynthesize aroma molecules that are comparable to rose oil.

Endnotes

1 N. Kovacheva, K. Rusanov & I. Atanassov (2010) Industrial Cultivation of Oil Bearing Rose and Rose Oil Production in Bulgaria During 21st Century, Directions and Challenges, Biotechnology & Biotechnological Equipment, 24:2, 1793-1798, DOI: 10.2478/ V10133-010-0032-4

2 Turkish rose farmers struggle to keep tradition alive. Reuters, Thu Jul 2, 2015. www.reuters.com/article/turkey-roses-idUSL5N0ZF35L20150702

3 Also known as rose attar or rose otto. The essential oil is also used in small amounts as a flavor/fragrance in cooking.

4 The genus Rosa comprises ~200 species but the *Rosa damascena* hybrid is the most important species of oil bearing rose. Other oil-bearing roses include: *Rosa alba* (the white flowered form), and *Rosa centrifolia* (cabbage rose) . which is the basis of the industry in Morocco & Egypt and France.

5 www.fastcoexist.com/3039743/the-quest-to-reproduce-the-scent-of-a-rose-with-designer-microbes. See also: http://old.omda.bg/engl/ethnography/rose_oil_production.htm

6 H. Wang, L. Yao, "Cloning and expression profile of 1-deoxy-D-xylulose 5-phosphate reductoisomerase gene from an oil-bearing rose," *Russian Journal of Plant Physiology,* July 2014, Volume 61, Issue 4, pp 548-555.

7 Steve Caiger, Market Insider Essential Oils & Oleoresins, October 2014. www.intracen.org

8 Anonymous. "Crucial Ingredient Issues Dominate IFEAT 2014," Vol. 39, *Perfumer & Flavorist,* December 2014, p.24.

9 Brian Lawrence, "A Preliminary Report on the World Production of Some Selected Essential Oils and Countries," *Perfumer & Flavorist,* Vol. 34, January 2009. Personal communication with Dr. Natasha Kovatsheva, Institute of Rose and Aromatic Plants, Kazanlak, Bulgaria. April 29, 2015.

10 *Ibid*.

11 A commercial by-product of rose petal distillation is "rose water." Rose water contains aroma compounds that don't separate with the oil during the condensation stage of distillation. Commercially produced rose water may be diluted with additional pure water or rose water can be produced by adding a small amount of rose oil to pure water. up to 1% oil being used.

12 70 ha in Morocco yielding 1.5 tonne of *Rosa damascena* concrete; 50 kg of *Rosa damascena* and 200 kg of *Rosa centifolia* concrete. Anon., "Overview of Essential Oil Production from North Africa." International Trade Center. www.intracen.org/uploadedFiles/intracenorg/Content/Exporters/Market_Data_and_Information/Market_information/Market_Insider/Essential_Oils/Essential%20oil%20production%20in%20North%20Africa.pdf

13 N. Kovacheva, K. Rusanov, I. Atanassov, "Industrial Cultivation Of Oil Bearing Rose and Rose Oil Production In Bulgaria During the 21st Century, Directions and Challenges," *Biotechnol. & Biotechnol.* Eq. 2010, 24(2), 1793-1798. Available at: www.tandfonline.com/doi/pdf/10.2478/V10133-010-0032-4

14 Rose cultivation for rose oil centred in Isparta (1600 ha), in SW of Turkey. Minor production in Burdur (380ha); Afyon (280 ha); Denizli (30 ha).

15 According to Liat Murat Barbut, MG Gu.lc.ic.ek International Fragrance Company, Turkey. Source: Crucial Ingredient Issues Dominate IFEAT 2014. *Perfumer & Flavorist,* Vol. 39, December 2014. p. 24. Note: When the extraction process involves a chemical solvent [i.e., hexane] it yields a product called rose concrete. When it is reextracted with alcohol it is known as rose absolute.)

16 Turkey: Rose and other essential oils, 2014. www.intracen.org

17 N. Kovacheva, K. Rusanov, I. Atanassov.

18 *Ibid*.

19 Personal communication with Dr. Natasha Kovatsheva, Institute of Rose and Aromatic Plants, Kazanlak, Bulgaria. April 29, 2015.

20 Bulgarian rose oil sold for EUR 7,200 per kg. in 2013. Maria Dimitrova- Picho, "Bulgarian rose oil remains standard of quality," *Radio Bulgaria.* May 6, 2014. http://bnr.bg/en/post/100418719/bulgarian-rose-oil-remains-standard-of-quality

21 https://atlas.media.mit.edu/en/explore/tree_map/hs/export/bgr/all/show/2012/

22 Vesselin Loulanski, Tolina Loulanski, "The Heritization of Bulgarian Rose," *Acta geographica Slovenica,* 54-2, 2014, 401.410.

23 Fortune Magazine. http://fortune.com/2015/07/23/ginkgo-bioworks/

24 However, metabolic pathways for aroma compounds are mentioned in the following Ginkgo BioWorks application: WO 2014089436 A1, Methods and systems for methylotrophic production of organic compounds, published June 12, 2014.

25 www.robertet.com/uk/parfumerie/presentation.php

26 Brian Gormley, "Ginkgo Bioworks Raises $9M to 'Engineer' Food Flavors, Fragrances," *Wall Street Journal* blog. Mar 18, 2015. http://blogs.wsj.com/venturecapital/2015/03/18/ginkgo-bioworks-raises-9m-to-engineer-foodflavors-fragrances/

27 *The Boston Globe.* www.betaboston.com/news/2015/07/23/synthetic-biology-startup-gingkobioworks-gets-45-million-in-new-funding/

28 Aviva Rutkin, "Would you wear yeast perfume? Microbes used to brew scent," *New Scientist.* 4 March 2015. www.newscientist.com

29 Anonymous. "Crucial Ingredient Issues Dominate IFEAT 2014," Vol. 39, *Perfumer & Flavorist,* December 2014.

30 Remarks transcribed from video on company website: http://ginkgobioworks.com Viewed on April 27, 2015.

31 H. Wang, L. Yao.

32 www.celbius.com/index.php/products

33 Major compounds include citronellol, geraniol, nerol, 2phenylethanol, linalool, farnesol, eugenol and eugenol methyl ether. The four major aroma compounds collectively account for slightly over 1% of rose oil: betadamascenone; beta-damascone; (-) rose oxide; 3-hydroxy-beta-damascone. Source: G. Ohloff, W. Pickenhagen, P. Kraft. 2012. *Scent & Chemistry: The Molecular World of Odors,* VHCA and Wiley-VCH, p. 269.

34 Chittaranjan Kole, *ed.* Wild Crop Relatives: Genomic and Breeding Resources: Plantation and Ornamental Crops, Springer-Verlag, 2011, p. 263.