

Citric acid's journey from sunny Sicily to industrial London (Martin Adams)



Like other major seaports, the hinterland of London's docks was once a hive of industrial activity, crowded with processing and manufacturing. Though host to some vibrant communities, it's fair to say that the area fell some way short of being a rural idyll. You might therefore think it unlikely if I claim that one local company brought something of the sun-kissed lemon groves of Sicily to the area and, for much of that time, used microorganisms to do it.

In 1867 John Bennet Lawes, the agricultural innovator who famously pioneered the use of superphosphate fertilizer and co-founded the Rothamsted Experimental Station, took over a former cement, tile and terracotta factory near Millwall Docks to establish the Atlas Chemical Works. He was already producing superphosphate elsewhere, and used the Atlas Works to manufacture citric and tartaric acids; both used primarily for their acidulant and chelating properties in the food, beverage and pharmaceutical industries. Their production employed two, rather esoteric, raw materials: calcium citrate from Sicilian lemon juice and argol, a crusty deposit that accumulated in casks used to store wine. Argol, comprising mainly potassium hydrogen tartrate, was also famously used by Louis Pasteur as the source of crystals for his early work on chirality and optical activity, when he painstakingly separated the enantiomeric forms of tartaric acid and its salts using the asymmetry of their crystals.

In 1870 Joseph Kemball, a manager at the Atlas Works, left to set up on his own, moving into the Crown Chemical Works at Three Mills, Bow in 1871 and going into partnership with Colonel Conway Bishop to form Kemball Bishop (KB). The company flourished, initially producing around 10 tons of citric acid and 4 tons of tartaric acid each week, and later acquired Lawes's original plant in Millwall as well as building a factory in Australia. In 1931, however, a serious problem arose when the fascist government of Mussolini in Italy banned the export of calcium citrate obliging KB to seek an alternative source.

A learner-centric microbiology education framework

Production of citric acid by filamentous fungi had been demonstrated in Germany as early as 1893 by Wehmer using what were later identified as penicillia. Wehmer's factory operating the process only lasted for 10 years, but there was considerable interest elsewhere and in 1917 Currie published work from the U.S. Department of Agriculture on citric acid production by *Aspergillus niger* grown in surface culture. Currie later moved to Chas Pfizer & Co. of New York where his work became the basis of a commercially successful process starting in 1919. Kemball Bishop had long had a cordial relationship with Emil Pfizer who agreed to supply them with calcium citrate and later, in 1935, they further agreed to licence the fermentation process itself.

The mould was cultured in shallow aluminium trays containing a medium with a high concentration of sugars, typically 12-15%, (in KB's case, supplied by beet molasses) and gave yields in excess of 55% on a weight basis. After a few days growth, the surface mycelial mat was removed and the citrate extracted from the remaining liquor. For the organism to produce such high levels of what is normally just a Krebs cycle intermediate, vegetative growth of the mould must be restricted, blocking the cycle so that citrate accumulates. This appears to be achieved in a number of ways, primarily by restricting the concentration of metals in the medium, particularly iron. Precise details are vague because, although there is a substantial published literature on the fermentation, those companies successfully producing citric acid rely largely on close-guarded secrecy to protect their methods, so venturing further here might condemn me to a future spent looking anxiously over my shoulder.

The agreement with Pfizer led KB to halt its own project to develop a fermentation process but another British company, J. & E. Sturge of Edgbaston, a Quaker-run concern that had been producing citric acid from Sicilian lemon juice since 1831, adopted their own process. This is believed to have been based on a 1927 patent assigned to the French industrial microbiologist Auguste Fernbach and the confectionary firm Rowntree & Co.

In March 1938 KB diversified its fermentation activities, commissioning a new plant at Bow to produce calcium gluconate, but, with the start of the Second World War, its focus turned elsewhere when it became one of several UK companies contributing to the industrial production of penicillin. ICI were first, converting a former dyeworks in Manchester in 1941 and KB followed shortly afterwards adapting their own fermentation plant for the purpose. Despite an unrelenting bombing campaign, KB increased its penicillin production from 50 fermentation trays in 1942 to 200 in 1944 and 600 in 1945. Initially the fermentation broth was sent to Oxford for extraction but this was later done at the Crown Works along with testing and packaging. Wartime scarcity of steel and enthusiasm for a possible chemical synthesis of penicillin, prevented the rapid adoption of the deep culture fermentation used in the United States where, by 1944, production had dwarfed that of the UK.

Penicillin was produced at Bow until 1947 by which time the deep culture process was well established elsewhere in the UK and the Ministry of Supply indicated that it would no longer purchase penicillin produced by surface culture. KB adapted by converting their penicillin plant to the production of itaconic acid by *Aspergillus terreus* and built an additional citric acid plant at Millwall. The relationship with Pfizer which had become increasingly close over the years culminated in the takeover of KB in 1958. Production at Bow continued until 1971 when the plant was closed and production moved to a Pfizer factory using deep culture at Ringaskiddy in Ireland.

The original Kemball Bishop site on the banks of the Lea Navigation is now a large Tesco supermarket where, during Covid restrictions, shoppers were patiently queuing 2 metres apart to buy, among other things, a wealth of products, many containing citric acid that, unfortunately, no longer comes from Bow or even Sicily.