UDC 330.341.1-027.11: 604.2:661.74

KULAKOVA Olga
Postgraduate Student of the
National Scientific Agricultural
Library of National Academy of
Agrarian Sciences of Ukraine
(Kyiv, Ukraine)
e-mail: agro.insightex@gmail.com

HISTORY OF THE WORLD CITRIC ACID MARKET DEVELOPMENT

Citric acid is the most important organic acid which widely used in the food industry. The discovery of citric acid is attributed to the Arab alchemist Abu Musa Jabir ibn Hayyan (721–815). The Swedish pharmacist Scheele was able to isolate citric acid for the first time in 1784. The production of citric acid was started by John & Edmund Sturge in 1826 in the UK. In 1894, the first industrial fermentation was built using an open tray system.

The aim of the study is to highlight the main milestones in the formation of the citric acid market in terms of the development of the global citric acid industry and individual countries. One of the objectives of the study was to periodize the history of citric acid production from the first industrial fermentation to the recognized world industry.

This paper reviews the path that citric acid went from the first industrial plant to the global industry with an annual production of 1.5 million tons, what problems the industry faced and how it found solutions to reach new altitude. Problems of the citric acid production industry and methods to solve them have been identified.

The importance of establishing a specialized Association for the proper functioning of the citric acid industry in Ukraine, which will include all its producers in the country, has been substantiated.

The research is based on the use of general scientific principles of systematization, complexity, multifactoriality and comprehensiveness, which provide a comprehensive coverage of the chosen problem. General scientific, interdisciplinary and special historical methods, as well as methods of source analysis are used.

***Keywords**: citric acid, steps of development of the citric acid industry, citric acid* capacities, global citric acid production, international trade of citric acid.

ІСТОРІЯ РОЗВИТКУ СВІТОВОГО РИНКУ ЛИМОННОЇ КИСЛОТИ

Лимонна кислота є найважливішою органічною кислотою, яка широко використовується в харчовій промисловості. Відкриття лимонної кислоти приписують арабському алхіміку Абу Муса Джабір ібн Хайян (721–815). Вперше виділити лимонну кислоту вдалося у 1784 шведському аптекарю Шеєле. Виробництво лимонної кислоти почали John & Edmund Sturge у 1826 році у Великобританії. У 1894 році побудована перша промислова ферментація з використанням системи відкритих лотків.

Мета дослідження – висвітлити основні віхи формування ринку лимонної кислоти у розрізі розвитку світової індустрії лимонної кислоти та окремих країн. Одним із завдань дослідження було проведення періодизації історії виробництва лимонної кислоти від першої промислової ферментації до визнаної світової індустрії.

У цій статті розглядається шлях, який пройшла лимонна кислота від першої промислової установки до світової індустрії з щорічним обсягом виробництва понад 2 млн. тон (лимонна кислота, є третьою за величиною категорією продуктів ферментації в світі після антибіотиків і амінокислот), з якими проблемами стикалася галузь і як знаходила рішення, щоб досягати нових вершин. Ідентифіковано проблеми галузі виробництва лимонної кислоти та шляхи їх вирішення.

Обгрунтовано вагоме значення створення для належної роботи галузі виробництва лимонної кислоти в Україні спеціалізованої Асоціації, до якою увійдуть всі її виробники в країні.

Дослідження ґрунтується на використанні загальнонаукових принципів системності, комплексності, багатофакторності та всебічності, що забезпечують цілісне охоплення обраної проблеми. Використано загальнонаукові, міждисциплінарні та спеціальні історичні методи, а також методи джерелознавчого аналізу.

***Ключові слова**: лимонна кислота, етапи розвитку галузі лимонної кислоти, виробничі потужності з лимонної кислоти, світове виробництво лимонної кислоти, міжнародна торгівля лимонною кислотою.*

Introduction. In 2015, the last plant in Ukraine for the production of citric acid in the Ukrainian town – Smile, Cherkasy region, was scrapped. The reason for that was the lack of methods for the plant to counter the crisis. Today, several Ukrainian companies are considering the construction of citric acid plants in Ukraine. The industry needs to identify the risks it may face when installing new facilities and know-how to resolve a potential crisis. The history of the formation of the world citric acid industry can best provide such experience. The main task of this work is to identify possible problems in the formation of the citric acid industry in Ukraine and their best solution.

Analysis of recent research and publications. There are no studies or publications on this topic in Ukraine. For the analysis of the development of the world citric acid industry, publications that are freely available on the Internet were used, namely statistics from UNtrade and the State Customs Service of Ukraine, announcements of world companies about intentions to build new facilities, historical literature, court results and more. No full-fledged research on the development of the global citric acid industry has been identified or used either in Ukraine or abroad.

The purpose and objectives of the study. The aim of the study is to highlight the main milestones in the formation of the citric acid market in terms of the development of the global citric acid industry and individual countries. One of the objectives of the study was to periodize the history of citric acid production from the first industrial fermentation to the recognized world industry.

Research methods. The research is based on the use of general scientific principles of systematization, complexity, multifactoriality and comprehensiveness, which provide a comprehensive coverage of the chosen problem. General scientific, interdisciplinary and special historical methods, as well as methods of source analysis are used.

Presenting main material. The discovery of citric acid is attributed to the Arab alchemist Abu Musa Jabir ibn Hayyan al-Azdi (721–815). In fact, the history of citric acid began in 1784 with the Swedish pharmacist Carl Wilhelm Scheele (1742–1786), who first added calcium hydroxide to extract calcium citrate from lemon juice, treated it

with sulfuric acid, and obtained citric acid in liquid form. In 1838, the German scientist Justus von Liebig discovered that citric acid was a tricarboxylic acid.

According to one source, industrial production of citric acid was started by John & Edmund Sturge in 1826 in Selby, Yorkshire, UK. Another source states that citric acid in its pure form was obtained from calcium citrate only in 1860 in England. Citric acid production in the United States began with Pfizer, Inc. in 1880.

Due to its excellent properties, the use of citric acid spread rapidly throughout the nineteenth century. Citric acid was obtained exclusively from the juice of unripe lemons, mixing them with quicklime and precipitating, thus, poorly soluble calcium citrate. Treatment of calcium citrate with sulfuric acid led to the formation of a precipitate of calcium sulfate, and citric acid was isolated from the supernatant by crystallization. The yield was 2–3% DS fruit (DS – Dry Substance). The disadvantages of this method were based solely on efficiency – even the heaviest citric acid of citrus – lemon – has a concentration of citric acid of only 7–9%, and to obtain 1 kg of citric acid requires more than 500 lemons. This left the door open for intervention.

In 1880, Grimoux & Adam synthesized citric acid from glycerol. In the late 19th century, it was discovered that Penicillium mold, grown in sugar solutions, produced citric acid, but its amount was too small to justify commercial production.

In 1893, Carl Wehmer (1858–1935) was the first to notice the presence of citric acid as a by-product of calcium oxalate production from a sugar-fermenting culture of Penicillium glaucum. The result of this fermentation prompted him to patent the process of citric acid production. On this basis, in 1894, the first industrial fermentation was built using the open tray system. Ten years later, the plant was closed because the fermentation process was too long and there was partial contamination [7].

From Italian monopoly to fermentation technology (1900–1918)

After 1900, citric acid production in Europe became an Italian monopoly because calcium citrate was extracted from Italian lemons. Italy provided raw materials for almost all world supplies of citric acid, as production was made directly from citrus

crops in its southern regions. Citric acid production in Italy increased from 12,000 tons in 1906 to 17,500 tons in 1916, which was its peak. Until 1918, citric acid was almost exclusively produced in Sicily from lemons: Arenella, Palermo was the world's leading producer of citric acid and a monopolist until the introduction of citric acid fermentation technology in Belgium in 1919 and in the United States in 1923.

Carl Wehmer's research was followed by several other studies, but the intelligent process of citric acid production emerged only after I patented the *Aspergillus niger* strain (1913: 1065358) in 1913. After fundamental research by Thom & Currie in 2016, in 2017 James Currie paved the method for the industrial fermentation of citric acid using a new microorganism and published an article in the Journal of Biological Chemistry, which reported on the study of mold Aspergillus niger. The most important discovery was that Aspergillus niger can grow well at low pH = 2.5–3.5, which prevented contamination. This form produced a relatively large amount of citric acid when grown in a liquid of sucrose, salts, and iron.

The First World War hampered the production of Italian citrus, which led to very high prices for citric acid. The cessation of exports of calcium citrate (a precursor of citric acid) from Italy after the First World War was accompanied by growing global demand for citrus due to the Spanish flu pandemic. In the US, lemon prices have risen by 50% from 20 to 30 cents per dozen. This has led to higher and more volatile prices at all levels of the citric acid supply chain. A small chemical company in the United States, Charles Pfizer & Co, has set out to find alternative supplies. They hired Currie with the bold goal of producing citric acid without citrus [9].

Improvement of citric acid fermentation technology (1919 –1959)

Charles Pfizer, Inc. worked with Currie to expand the process and in 1923 began commercial production of citric acid in the United States at a plant in Brooklyn. With Currie aboard, Pfizer opened a pilot plant for the production of citric acid by fermentation, which they called SUCIAC (Sugar Under Conversion to Citric Acid) – converting sugar to citric acid. The success of this research facility meant that in 1926

when the first large industrial plant opened, the production of citric acid using fermentation technology exceeded the production of CACCS from lemons and limes.

In the first year of its production, Pfizer produced more than 50% of the world's citric acid supply, and Pfizer no longer used lemons and limes to produce citric acid: all 4.5 thousand tons of citric acid were produced by fermentation. It was a rapid transition from business to business, caused by interruptions with ingredients. In about 5 years, the price of citric acid has more than doubled, from $ 0.57 / kg to $ 0.18 / kg. By 1930, 90% of citric acid was produced by fermentation, and improvements continue to this day [3].

Pfizer's experience in fermentation in the production of citric acid proved to be crucial. Not only was it used in the production of various other acids, such as gluconic acid (used as a food preservative and detergent) and ascorbic acid (vitamin C), but ultimately, it was this knowledge that led Pfizer to success in large-scale penicillin production during World War II. Today, we are benefiting from side effects, as Pfizer was one of the first companies to release a vaccine against Covid-19. And it all started with a microbe that could ferment sugar into a really useful ingredient.

In 1928, beet molasses was used as a cheap raw material for the production of citric acid in Czechoslovakia. However, there were difficulties with this source due to the content of traces of metals in it. Using the Mezzadroli patent, this problem was solved in 1938 by using potassium hexacyanoferrate as a chelating agent to remove traces of metal in the beet molasses substrate (Chelating agents – a chemical compound that forms complexes by attaching metal ions).

In 1919, the technology of fermentation of citric acid (based on the studies of Currie) was introduced in Belgium. In 1930, John & E. Sturge, Ltd. implemented the Currie process in the UK. Production spread to Germany, Belgium, and Czechoslovakia, using beet sugar molasses as a basis.

The first industrial fermentations of citric acid were carried out in the form of surface cultures, and the introduction of deep fermentation was a significant improvement in the process. After 1945, there were several improvements: the search

for new and cheaper raw materials (glucose-based), improved yeast strains, the introduction of genetic manipulation techniques to increase acid productivity, and later SSF, a submerged crop that led to high yields [8].

The path to large-scale production (1960–1979)

In the early 1960s, a new process emerged in Japan using *n-alkanes* as a carbon source: yeasts of the genus *Candida* were used, which produced significant amounts of citric acid. In the 1960s, a new technology that applied yeast to n-alkanes derived from petroleum was proven to be technologically feasible, but never commercially successful.

In the early 1970s, the American company Miles Laboratories began producing citric acid in Elkhart, Indiana and began producing citric acid in China. Most plants fermented sweet potatoes on a small scale, some used cassava. In 1975, Miles Laboratories formed a joint marketing company with Liquichimica Biosintensi, a subsidiary of the Italian Liquigas. The Liquigas plant, which was built in Reggio Calabria, Italy, was to produce 50,000 tons of lemon salt as a result of the fermentation of petroleum-based carbohydrates. Charles Pfizer Inc. attributed to the development in the 1970s of a "fermentation process in a small and deep tank", which became the industry standard in the 1980s [9].

Growth of citric acid production capacity (1980–1989)

The increase in citric acid production in the 1980s was driven by growing demand for soft drinks and the replacement of phosphorus with citric acid in detergents. In 1982, China's largest citric acid plant, Nantong Fermentation Factory in Nanjing, which exports 30% of its products, doubled its annual production to 4,000 tons, with a plan to reach 7,000 tons in a few years. In 1986, La Citrique Belge, a subsidiary of Hoffman La Roche, spent CHF 800 million to expand a citric acid plant in Tienen, Belgium. In November 1987, Cargill announced, and in June 1988, next to the existing corn processing plant in Eddyville, Iowa began construction of a $ 40 million new plant to produce 25,000 tons of liquid citric acid from liquid dextrose. Citric acid production

began in the spring of 1990, adding 17% to US production capacity. In 1990, the Cargill plant was close to full capacity.

In 1987, the world's capacity for citric acid production amounted to 550 thousand tons, citric acid production in China reached 45 thousand tons. Sales of Pfizer citric acid in 1989 amounted to $ 180 million. In 1989, citric acid cost 1.65 – $ 1.87 / kg [2].

China's actions in the world citric acid market and conspiracy (1990–1999)

In 1992, the demand on the world market of citric acid is estimated at 500 thousand tons, including demand for citric acid in the European market is estimated at 200 thousand tons, in the United States at 181.5 thousand tons. Exports of citric acid from the United States doubled and reached 22,000 tons in 1992. Prices for citric acid at all sellers rose to $ 1.74 / kg, citrates to $ 2.38 / kg.

Citric acid was a well-coordinated business until dozens of Chinese companies began production in the early 1990s. During the 1990s, China steadily increased its presence in the world market: in 1999, China's capacity amounted to 190 thousand tons/year, which provided China with a 20% share of the world market. It came to the point that the products of 100 producers in the country were exported, later their number was reduced to 30.

At the beginning of 1999, SRK Consulting estimated its global citric acid production capacity at 879 thousand tons/year (an increase of almost 60% over ten years, mainly at the expense of China). According to industry sources, in 1999 world consumption of citric acid was estimated at 80% of global capacity. Five major Western players (Jungbunzlauer, Archer Daniels Midland (ADM), Cargill, Tate & Lyle, and Hoffmann – La Roche) and China dominate the oversupply industry, although in Europe the situation is more complicated [2, 3].

US citric acid market

In 1990, the US market for all acidifiers totaled about 204 thousand tons, citric acid accounted for 75% of total acidification consumption and 83% of the total value. The total production capacity for citric acid in the United States amounted to about 147.5

thousand tons. The price of citric acid fell to 1.32 – $ 1.44 / kg, which became unprofitable for all producers. Imports of citric acid decreased from 29.5 thousand tons in 1989 to 21.7 thousand tons in 1990, while exports increased from 7.5 to 9.7 thousand tons.

In 1993, prices strengthened. Prices at the beginning of the year were about $ 1.80 / kg, large orders - $ 1.76 / kg. In September 1993, ADM, Cargill, and H&R increased their published acid prices by $ 1,870 / kg with delivery. Chinese goods are sold for 10 cents cheaper. Citric acid production capacity in the United States in 1993 is estimated at 209 thousand tons, demand - 188.4 thousand tons (beverages 45%, food 23%), exports are stable at 22 thousand tons. Imports increased from 26.7 thousand tons in the 1992 year to 41.3 thousand tons in 1993. Chinese imports from 1992 to 1994 grew by 50%.

In 1995, the production of citric acid in the United States amounted to about 222 thousand tons, some of which were exported. Capacities in the US were: ADM – 82 thousand tons (37%) + H&R 68 thousand tons (31%) + Cargill – 72 thousand tons (33%) = 222 thousand tons (100%).

In 1997, exports to the United States were sporadic, in 1996 it was 30 – 40% lower than in 1995. Prices dropped to $ 1.76 / kg, and large customers buy citric acid for $ 1.67 – $ 1.71 / kg. Producers vertically integrated into ADM and Cargill maize have cost advantages over non-integrated H&R (Haaram & Reimer).

In 1998, H&R sold its citric acid business to Tate & Lyle [8].

ADM. In August 1990, ADM agreed to buy Pfizer's citric acid business. The deal, which was completed in December 1990, included Pfizer technology and two plants: 1) Southport, NC (North Carolina, 45,000 tons) and 2) Ringaskiddy, Cork, Ireland (Ireland, 9,000 tons). It was also agreed that Pfizer's Groton, CT (Connecticut) plant would supply ADM with up to 20,000 tons of citric acid by the end of 1993, but in 1991 ADM expanded its citric acid plant in North Carolina to "refuse" citric acid supplies from

Pfizer. In 1994, when ADM expanded its citric acid plant in North Carolina to 82,000 tons, Pfizer closed its citric acid plant.

As lysine production expanded from 1991 to 1995, ADM also considered many other feed additive options. Rumors have spread that ADM will build a methionine plant in Mexico. Instead, ADM set up a joint venture with Rhône-Poulenc to build a new citric acid plant at the Institute, WV (Iowa) with a capacity of 23,000 tons with a value of $ 44 million. ADM received a 25% stake in the plant, Rhône-Poulenc with a global capacity of 136 thousand tons of citric acid becomes a world leader [7].

Cargill. In March 1992, Cargill planned and by the end of the year expanded its citric acid production capacity in North Carolina from 36,000 to 72,000 tons, adding citrate to the liquid citric acid produced. In addition, in 1993, Cargill began building a $ 30 million citric acid plant with a capacity of 20,000 tons in India. In October 1996, Cargill began construction of a $ 50 million plant in Brazil, with a launch date in 1999.

Tate & Lyle. In June 1996, Tate & Lyle through its subsidiary A.E. Staley buys 20% of the Indian company Bharat Starch Industries Ltd. (BSIL). Investments allow to expand of the existing plant of citric acid BSIL from 30 to 50 thousand tons and to modernize the production of starch and sweeteners. The Indian citric acid market is growing by 5% per year.

In May 1998, Bayer AG sold its global citric acid business to Tate & Lyle for $ 219 million. The deal included: 60,000 tons/year plant in Dayton, OH (Ohio, USA); plant in Duluth, MN (Minnesota, USA); Selby plant, UK (UK); share in joint ventures in Sucromiles (Colombia); Mexama de CV (Mexico) and Mercocitrico Fermentacos (Brazil). The Indian plant owned by H&R has been closed. Despite having a capacity of 68,000 tons in the United States, which accounted for 33% of total capacity in the United States, H&R's operations were low-yielding. In 1997, pre-tax profit was $ 8.3 million or 2.8% of sales with balance sheet assets of $ 203 million. Haarmann & Reimer focused on fragrances and perfumes.

As a result of the acquisition of the citric acid division of Haarmann & Reimer, a subsidiary of Bayer, Tate & Lyle has increased its share of the global citric acid market to 17%. Following the acquisition of Haarmann & Reimer's assets by Tate & Lyle, all three US citric acid producers became fully integrated into the corn supply [9].

Conspiracy. In 1994, the first signals emerged that ADM was fixing prices for biotech products, including citric acid, in a global conspiracy. Bayer AG, which produces citric acid in Europe and at the Miles Labs plant in Elkhart, ID, Indiana, says it is working with the Department of Justice and has met with conspirators at hotels in London and Paris. In Nov. 1995, ADM faced 4 private price-fixing lawsuits; by February 1996, the number of lawsuits will increase to 7 (seven). But despite the antitrust investigation, the demand for citric acid is high, and manufacturers do not offer lower prices.

In March 1995, the Department of Justice, based in the US Attorney's Office in San Francisco, launched an investigation into price-fixing but moved slowly. ADM claimed that the conspiracy arose outside the United States without the involvement of ADM. However, on September 27, 1996, with surprising surprise, ADM proposed a $ 35 million class-action lawsuit. The plaintiffs had not yet received a class-action lawsuit in the San Francisco District Court. It turned out that the Committee of 7 "external" directors of ADM was authorized to conclude any necessary plea agreements with the Ministry of Justice in October 1995.

On October 15, 1996, ADM announced a plea agreement with the Ministry of Justice for lysine and citric acid. The $ 100 million fine is seven times higher than ever before. ADM also agrees to help bring its own managers, Michael Andreas and Terrence Wilson, to justice. In turn, the Ministry of Justice agrees not to prosecute ADM for setting prices for corn fructose, which has global sales of $ 3 billion against $ 1.5 billion for the other two products.

All in all, the criminal charges against ADM as a company have been resolved, but criminal charges against M. Andreas and T. Wilson are still pending, as are dozens of civil lawsuits for damages.

The first offer from ADM of $ 35 million was received in October 1996. Later in October, two importers of citric acid also made settlement proposals: Hoffmann-LaRoche of Basel, Switzerland offered $ 5.68 million, Jungbunzlauer AG of Vienna, Austria offered $ 7.57 million. The fifth defendant in the case, Cargill Inc. refused to negotiate with the plaintiffs. Lawyers representing the plaintiffs in the citric acid class action claim that the loss in this market could reach $ 400 million, but they agree on $ 94 million. Of the total settlement of $ 117.5 million, 25% are court costs [11].

On December 9, 1996, Haarmann & Reimer Corp., based in Springfield, NJ, New Jersey, became the fourth company to file a proposed amicable settlement in a civil lawsuit in a citric acid class-action lawsuit. H&R, a 100% subsidiary of Bayer, AG in Basel, Switzerland, offers to pay $ 46 million to citric acid buyers. A federal judge in San Francisco must approve the proposed settlement.

On January 29, 1997, Haarmann & Reimer GmbH, a subsidiary of Bayer AG in New Jersey, pleaded guilty to criminalizing global citric acid prices. The company will pay a $ 50 million fine, the second-highest antitrust fine ever imposed. The Ministry of Justice said the conspiracy was "one of the largest, if not the largest, conspiracies ever prosecuted by the Ministry of Justice". Officials reiterated that ADM and Bayer's fines would have been much higher if the firms had not cooperated with investigators.

On March 26, 1997, the two largest U.S. importers of citric acid, Jungbunzlauer, and Hoffmann-LaRoche pleaded guilty to criminal pricing and paid $ 25 million in fines. These fines increased the total U.S. corporate criminal fines for lysine and citric acid to $ 195 million, which is several times higher than previous fines.

The case against Cargill continues. Four major buyers (who bought citric acid for $ 350 million in 1991–1995) dropped the class action lawsuit and demanded $ 1 billion in damages. PepsiCo and Coca-Cola did not join any of the lawsuits, possibly because

the defendants sold them citric acid at a reduced price. Coca-Cola and PepsiCo account for 30 – 40% of citric acid purchases or 36 – 51% of the US market. The reimbursement of $ 86.2 million was an inflated price of $ 1.7 million to $ 2.4 million per market percentage point. By refusing to participate, the companies received from $ 4.7 to $ 6.0 million per percentage point or 2 – 3.5 times more than the federal class [10].

On January 24, 1998, Cargill was removed from the federal civil class action in the U.S. District Court in San Francisco. The testimony of a former Bayer official convicted of criminal pricing was acquitted by Cargill. U.S. Judge Fern Smith in San Francisco ruled that no reasonable jury could establish that Cargill was involved in the citric acid conspiracy. The judge's decision is based on the fact that Cargill did not send representatives to face-to-face price meetings; Cargill collaborated with the Citric Acid Association, submitting monthly reports on its production for audit purposes.

In March 1998, ADM agreed to pay $ 36 million to four buyers of citric acid who waived the antitrust settlement of a civil class action in July 1997. These companies were: 1) Procter & Gamble Co.; 2) Quaker Oats Co., a division of Kraft Food; 3) Philip Morris, and 4) Schreiber Foods, Inc., a cheese company located in Green Bay, state. Wisconsin. Although nowhere reported, it is thought that Bayer, Jungbunzlauer, and Hoffmann-LaRoche paid four buyers an additional $ 52.7 million, of which four sellers paid Unilever about $ 25 million.

On March 4, 1998, it was announced that ADM was the last of four companies to settle with their customers in a price-fixing lawsuit [11].

European citric acid market. In September 1997, the EU antitrust authorities launched an investigation against ADM and other companies into fixing citric acid prices.

In August 1990, Bayer AG bought a $ 100 million citric acid plant in Selby, Yorkshire, the UK, owned by Rhône-Poulenc (Lyons, France). The British 21 thousand tons plant could be increased to 32 thousand tons by "minor adjustments". A subsidiary of Bayer Miles Labs, it later merged with Haarmann & Reimer Corporation of

Springfield, NJ (New Jersey), which owns two plants in Elkhart, IN (Indiana) and Dayton, OH (Ohio) with a total capacity of 63.5 thousand tons. In addition, the Bayer joint venture in Mexico, Colombia and Brazil provides it with a total of 136 thousand tons of capacity, which together accounts for 30% of world consumption.

Following allegations of conspiracy in the United States, in 1997 H&R (Bayer) announced its intention to sell its 7-citric acid plant, which employed 1,310 people in 1996 and sold $ 293 million in citric acid. Plants: 3 in the United States, 1 in the United Kingdom, 1 in Brazil, and 2 subsidiaries with controlling stakes in Mexico and Colombia. In the United States, H&R's capacity was 68,000 tons, and H&R was the only producer not integrated into corn processing [1].

In May 1998, Bayer AG sold its global citric acid business to Tate & Lyle for $ 219 million, and Haarmann & Reimer focused on fragrances and perfumes. Bayer (H&R) has relocated its citric acid headquarters from New Jersey to the UK and fired several executives.

The company – Jungbunzlauer Suisse AG, headquartered in Basel, Switzerland, Switzerland, is a citric acid producer with a global network of 130 countries and had 3 European plants in 1994:

1. Citrate plant with a capacity of 50 thousand tons in Lunenburg. Since the summer of 1992, the Lunenberg plant has started producing 60,000 tonnes of citric acid, up from 20,000 tonnes at the beginning of the year. The citric acid plant in Ladenberg, Germany is operated by Montana AG, a subsidiary of Jungbunzlauer Spiritus und Chemische Fabrik AG, Vienna.

2. The citric acid plant in Pernhofen, Austria, near Vienna, has been expanded to 100,000 tons.

3. Integrated plant for the production of starch and citric acid with a capacity of 40 thousand tons Construction began in 1992 in Marckolsheim, near Strasbourg, France. The plant was launched in October 1993.

In October 1991, Jungbunzlauer (Vienna) and Sungai Budi group (Jakarta) agreed to build a 10,000-tonne citric acid plant in Sumatra, Indonesia. The Indonesian JV Jungbunzlauer came into operation in late 1993. In 1994, Jungbunzlauer added 40,000 tons to the plant's existing capacity of 80,000 tons and covered 20% of world demand.

In 1990, the only Italian producer of citric acid was the Biacor (Padova) plant with a capacity of 24 thousand tons, located in Casei Gerola, Italy, near Pavia. In March 1990, the plant in Biacor was sold by the British company Sturge Biochemicals to Cremonini, a division of the Consorgio Imprenditoriale Ligure Padano. In October 1991, Biacor was again sold to Cerestar, a subsidiary of Ferruzzi-Montedison in Milan. Now the Biacor Ferruzzi plant is called Eridania. Eridania occupies about 10% of the European citric acid market. In December 1992, the Palma Group began construction of a new 35,000-tonne citric acid plant in Calitri, Italy [7].

Asia Citric Acid Market. In November 1991, the Austrian government provided China with a $ 50 million loan to build five citric acid plants, each with a capacity of about 3,000 tons, using technology from the Austrian company Vogelbusch. The Chinese government news agency claims that in 1993 China produced 163,000 tons of citric acid, of which 110,000 tons were exported. The country ranked second in the world after the United States. In 1994, China's citric acid production reached 200,000 tons, making it the highest in the world.

In 1995, in retaliation for failing to protect intellectual property rights, the US government announced foreign tariffs on Chinese imports of $ 1.1 billion, including citric acid. Why citric acid? It has been suggested that ADM or Cargill put pressure on a US trade representative through Congress to dump Chinese citric acid exports to the United States. The introduction of tariffs was to lead to higher prices for citric acid in the United States. However, Chinese concessions and problems with citric acid production have led to tariffs never being introduced. Among the concessions – the abolition of state subsidies to exporters of citric acid.

Problems with production and reduced government subsidies in China have forced import prices to rise by 10%. However, some large customers say that domestic prices were $ 1.76 / kg and were lower than import prices and $ 0.11 / kg lower than US prices. In 1994, Chinese imports of 15.4 thousand tons accounted for only 7% of 215.6 thousand tons of consumption in the US market. The reduction in Chinese government subsidies has led to a reduction in citric acid exports to the United States for all but the most efficient producers [3, 4].

In January 1996, the Japanese chemical company Fuso, which had been importing citric acid for 10 years and processing it in Japan, began building a 20,000-tonne citric acid plant in Qingdao, China, with the launch in February 1998. In June 1997, the construction of the Fuso Chemical citric acid plant in Qingdao with a capacity of 10,000 tons was completed, and the plant uses sweet potatoes as raw material. The plant uses high purity filtration. In 1997, Roche Holding (60%) formed a joint venture with the Chinese chemical company Wuxi (40%) to produce 20,000 tons of citric acid per year, of which 80% will be exported.

According to official statistics, China's citric acid production in 1997 was about 300,000 tons, the highest in the world. Exports of citric acid from China increased by 33.7% from 1977 to 1994. However, most of China's 103 plants are small: 74% are 3,000 tons or less. Only 6 plants have a capacity of 10 thousand tons and more. Small producers produce lower quality acid, which they sell for 30 – 40% cheaper than large companies in the West.

In December 1997, Bajrai International of Yanbu, Saudi Arabia, announced that it would build a $ 140 million citric acid plant using Lurgi Technology [5].

Anti-dumping duty on citric acid in the US and EU (2000–2009)

In 2008, the world market for citric acid is estimated at € 1.36 billion and grows by 3–5% per year. Spot prices vary depending on the region and are estimated at 1.69–2.30 € / kg in Latin America, 1.22–135 € / kg in Asia, and 1.50–1.70 € / kg in Europe.

The citric acid market has been under considerable pressure for several years, mainly due to a structural overcapacity in China.

US citric acid market. From 2006 to 2008, demand for CACCS in the United States was strong and growing, as evidenced by the percentage increase in consumption compared to 2006. The high demand was partly due to economic growth, relatively low CACCS costs, reformulation of processed products to increase citric acid use, increased detergent use, sodium reduction initiatives, new products, and increased demand for citric acid products. Several relatively large buyers account for a significant share of total purchases, despite the fact that the number of small buyers is in the hundreds. Factors that determine the demand for CACCS are carbonated beverages, while other uses include other beverages, food, detergents, personal care products, and pharmaceuticals. Citric acid has limited substitutes that make up a small proportion of end-use products. A relatively small number of buyers in the United States account for a large percentage of CACCS purchases. Demand for citric acid is mild [1].

In 2008, US domestic industry grew at a slower pace than consumption and was therefore unable to take full advantage of high demand. The capacity of American citric acid producers amounted to 251.4 thousand tons, CACCS production at domestic facilities – 230. housand tons, capacity utilization – 91.7%. The average price for the year is $ 1.17 / kg. In the period from 2006 to 2008, the volume of total imports in the US market increased and occupied an increasing share of the US market. The largest sources of non-representative imports in 2018 were Israel, Colombia, Germany, Thailand, Austria, and Belgium.

April 14, 2008, CAACS domestic manufacturers Archer Daniels Midland Company (Decatur, Illinois), Cargill Inc. (Wayzata, Minnesota), and Tate & Lyle Ingredients Americas LLC (Decatur, Illinois) have filed anti-dumping and countervailing duties on China and Canada. ADM, Tate & Lyle, and Cargill have called for a 65% duty on ingredients from Canada and 188% from China. On 1 May 2008, the Commission initiated inspections.

On May 22, 2009, the commission determined that the US industry was significantly affected by CACCS imports from China (due to subsidized citric acid exports from China and sales to the US at below fair prices) and Canada. The Ministry of Trade issued a decree on May 29, 2009, to apply anti-dumping duties, to Chinese exporters, ranging from 94.61% to 156.87% and a net subsidy rate of 3.60% to 118.95%. The set anti-dumping duty for Canada is 23.21%. There is only one CACCS manufacturer in Canada – JBL Canada Inc. [1].

In Mexico, the Quimixa Mexama plant, owned by Tate & Lyle, was closed.

European citric acid market. In 2015, ADM closed its business in Ireland in 2005. In 2007, Tate & Lyle sold its only citric acid plant in Europe to North Eastern Biotech, a subsidiary of Biotech Consult, Slovakia. Located in Selby, UK, the plant had a capacity of 40,000 tons, but the new owners do not use it to produce citric acid. In the same year, Aktiva closed production in the Czech Republic.

Another European citric acid producer, La Roche, opened a joint venture to produce citric acid, Wuxi Zhongya Chemical, in Wuxi, China, and the company was looking for a partner to operate its plant in Tienen, Belgium, which was well below its 120,000 tonne capacity. Belgian production required a lot of investment and could no longer be sold as a citric acid plant.

At the end of 2007, the Swiss Jungbunzlauer, with its plant in Austria with a capacity of 200 thousand tons/year, became almost the last producer of citric acid in Europe. The influx of Chinese citric acid into Western markets has led to the closure of factories and provoked allegations of dumping in Europe. Jungbunzlauer has applied to the European Commission. In 2007, the demand for acidification was high and in anticipation of strict anti-dumping duties, citric acid prices rose sharply (≈ by 30%).

In June 2008, the European Commission concluded that Chinese suppliers were dumping citric acid on European markets and imposed a tariff of up to 50% on Chinese imports for five years. The 27 Member States of the European Union must decide after 5 years whether to maintain customs duties for another five years.

On August 28, 2008, the Dutch company DSM announced the shutdown of its citric acid plant in Wuxi, China, after the Chinese government announced that its site was needed for urban development. Closing is scheduled for early 2009. DSM will receive compensation from the Chinese government in the form of a social plan designed to help affected workers. DSM said it had decided to concentrate citric acid supplies in Tienen, Belgium, rather than looking for another site in China, as the Belgian plant's competitiveness had been significantly improved "through restructuring and process optimization". Relying on structural surplus capacity on the world market, DSM decided to produce citric acid exclusively at its plant in Tienen, Belgium, which has been producing citric acid since 1929 [10].

Asia Citric Acid Market. The Chinese citric acid industry is the largest in the world. In 2008, Chinese producers accounted for 60% of world sales or 1.5 million tons, in Europe – 60 – 70% of total sales. Leading Chinese players have invested heavily in modern equipment for fermentation, purification, and purification of water, most of which, ironically, was provided by Western companies. The Chinese have begun to produce high-quality citric acid in modern plants, whose capacity is large enough to make them highly competitive in the world market. At the end of 2008, the number of Chinese exporting producers fell to 5; 2 manufacturers based in Shandong, Ttca Biochemistry and Rzbc Group, Bbca Group from Anhui, but the feeling that they are distorting the market has not disappeared [2, 4].

Reduction of Chinese citric acid exports (2010–2019)

US Citric Acid Market. CACCS consumption in the United States increased from 2009 to 2013, but there has been a decline in some performance indicators. In 2013, the capacity of American citric acid producers amounted to 253.5 thousand tons, CACCS production at American facilities 218.7 thousand tons, capacity utilization 86.3%. The average annual price is $ 1.70 / kg. The United States continues to be the world's largest market for CACCS. Brazil, the EU, India, Russia, Thailand, and Ukraine have maintained anti-dumping duties on CACCS imports from China, which is an additional

incentive for CACCS supplies to the United States. Following the imposition of additional tariffs, the United States was the third country in the world in terms of barriers to CACCS imports.

The volume of non-entity imports to the United States increased from 2014 to 2015, but then declined sharply in 2016 and fluctuated around this low level until 2019. The highest decline in non-entity CACCS imports to the United States occurred between 2015 and 2016, which can be largely explained by the decline in CACCS imports from Singapore, which fell from 635 thousand tons to zero [7].

In 2012, citric acid exports from China to the United States: 36.7 thousand tons, $ 123.3 million, $ 3.35 / kg. In 2016, citric acid exports from China to the United States: 3.28 thousand tons, $ 6.2 million, $ 1.89 / kg. In 2017, exports of citric acid from China to the United States: 3.89 thousand tons, $ 6.9 million, $ 1.78 / kg [8].

In 2018, Belgium, Colombia, and Thailand will also be subject to anti-dumping duties in the United States. The investigation period is from April 1, 2016, to March 31, 2017. The determination was postponed until December 29, 2017, in order to give the parties a period (6 months) to discuss product-related issues and responses to the rebuttals. The Commission acknowledged that no compensatory subsidies were provided for the production and export of the relevant goods, so no adjustment for export subsidies was included in the calculations. For manufacturers and exporters (referred to as "others"), the Commission calculated an individual weighted-average duty of the following states:

Belgium: S. A. Citrique Belge N. V. – 24.41%, others – 24.41%.

Thailand: COFCO-15.73%, Niran – 12.95%, Sunshine – 4.77%, others – 10.55%.

Colombia: Sucroal S. A. – 27.48%, others – 27.48%.

The main raw materials for citric acid production in the United States are substrates such as corn starch, molasses, dextrose, and corn extract CSL + calcium carbonate and sulfuric acid; the cost of electricity and steam production also make up a significant part of the production. The price of citric acid is an important factor in deciding to buy, as

well as the reliability of supply and quality. The interchangeability between domestic CACCS and imports is moderate. American manufacturers sell CACCS under long-term contracts, while importers sell their goods mainly in the spot market. Contracts of American manufacturers, as a rule, do not allow revision of prices during the term of the contract, even when spot market prices fall [9].

According to domestic manufacturers, the share of three market participants – Archer Daniels Midland Company, Cargill Inc., and Tate & Lyle Ingredients Americas LLC – in 2019 had all or almost all domestic production of CACCS. Capacities of American citric acid producers amounted to 252 thousand tons, production of SASS at domestic capacities - 215.4 thousand tons, loading 85.4%. Consumption of CACCS in the United States in 2019 is estimated at 194.5 thousand tons. The average price for the year - is $ 1.61 / kg. Imports mainly came from Thailand and Israel, as well as from Canada after the removal of anti-dumping duties.

The Commission contacted the top 5 buyers of domestically produced CACCS: 3 out of 5 buyers that all grades and sizes of citric acid granulation in dry and soluble forms meet US standards, CACCS prices are adequate. The commission also examined CACCS's imports and found no clear differences between domestic and imported products based on chemical and physical form, variety, and type of product [7].

European citric acid market (2) In 2018, Belgium will be subject to anti-dumping duties in the United States and a 24.41% duty will be imposed on S. A. Citrique Belge N. V. for the supply of citric acid to the United States.

Ukraine. On January 27, 2012, the Ukrainian authorities initiated an anti-dumping investigation into imports of citric acid from China. HTS code: 2918.14.00. On April 27, 2013, the Ukrainian authorities imposed an anti-dumping duty on imports of citric acid from China. The duty rate was 8.15% for the exporting producer Cofco Biochemical (Anhui) Co., Ltd. The rate of duty applicable to other exporters is 24.74%, except for Weifang Ensign Industry Co., Ltd and Ttca Co., Ltd., whose exports are not subject to duty. Until 2019, Ukraine had an order on anti-dumping duties on citric acid from

China, but it expired and was not extended. Thus, Ukraine de jure abolished anti-dumping duties on imports of citric acid from China [5].

Asia Citric Acid Market

China. CACCS exports of goods from China to all countries in 2014 amounted to 953.3 thousand tons, exports to the United States: 38.9 thousand tons worth $ 126.3 million, at a price of $ 3.24 / kg.

Since 2015, after the imposition of anti-dumping duties, imports of CACCS to the United States have seen a significant reduction in imports of citric acid from China. In 2015, the Chinese CACCS industry operated with a capacity utilization rate of 68.7%. CACCS manufacturers have an economic incentive to operate at or near full capacity due to the high fixed costs and capital-intensive nature of CACCS production. China's capacity utilization rate indicates that the Chinese CACCS industry will have to try to increase production and exports to operate more efficiently.

Based on open data, in 2017 the total capacity for the production of citric acid was 2610 thousand tons/year in terms of dry matter. This is several times more than the potential of American industry in 302 thousand tons. From 2006 to 2017, five Chinese manufacturers increased their production capacity by 700 thousand tons and in 2017 there were at least ten major CACCS manufacturers in China. Exports to the United States: 7.22 thousand tons, $ 12.1 million, $ 1.67 / kg [2].

In 2019, China's citric acid industry accounted for more than two-thirds of the world's CACCS (citric acid and certain citrate salts) production capacity. Four of the world's, five largest CACCS manufacturers were Chinese and operated only in China. The CACCS industry in China is very large compared to the US market. The total export of CACCS of Chinese origin in 2019 amounted to 1.18 million tons in terms of dry matter of anhydrous citric acid. In 2019, imports of citric acid from China amounted to: 5.10 thousand tons worth $ 9.7 million, price $ 1.89 / kg.

The US market is attractive to China because it remains one of the largest in the world for CACCS sales, with several large companies buying CACCS from China and

other markets. Goods in the United States are often sold at significantly higher prices than in other export markets. However, imports of CACCS from China to the United States during the 4 years of 2016 – 2019 remained modest, from 3.28 thousand tons in 2016 to 6.22 thousand tons in 2018 in dry weight. Reductions in supplies are caused by the deterrent effect of anti-dumping and countervailing duties. Information concerning Chinese producers is limited because they refused to participate or provide information [4].

While American producers use more corn and molasses as raw materials, producers in China use a wider range of substrates.

Recent history of the citric acid market (2020–2021)

The CACCS industry has a high fixed cost because the capital-intensive industry depends on the continuous production of the fermentation process, which cannot be easily slowed down or stopped. Although there are still plants where citric acid is isolated from unripe citrus, currently more than 99% of world production of citric acid is produced microbiologically through various fermentation processes, substrates, and microorganisms. Since the first synthesis, various methods of the chemical production of citric acid have appeared in the chemical and patent literature, but none of them has reached a commercial status competitive with fermentation [7].

In 2020, due to the Covid pandemic, beverage consumption is declining, resulting in falling demand for CACCS products.

US Citric Acid Market. On May 1, 2020, the US Department of Commerce Commission initiated re-inspections and, starting June 24, 2020, repealed the anti-dumping duty on CACCS from Canada after US manufacturers withdrew their intention to participate in the review. The abolition of anti-dumping and countervailing duties was made with caution: it is likely that the repeal will result in a recurrence of material injury within a reasonable time.

The Commission was instructed to consider whether the likely volume of imports would be significant in absolute terms or in % to production or consumption. The

commission must take into account 4 factors: 1) the probable increase in capacity utilization or expansion of production; 2) existing inventories and factors that may lead to increased inventories; 3) the existence of barriers to imports into the United States and in other countries; 4) the capacity to produce at existing facilities Alternative products in foreign countries. An assessment should also be made of the likely effects of changes in the price of imports, the value of domestic prices for lifting the suspension of duties, and the value of prices at which the product will become competitive in world markets. All relevant economic factors should be considered in the context of the business cycle and the conditions of competition-specific to the industry.

Following the Commission's conclusions, a decision was taken on the current additional duties on Chinese products: CACCS imports from China continue to be subject to additional interest, with an ad valorem duty of 25%. In 2021, the production of CACCS products exceeded 2 million tons [11].

Conclusions. Thus, we have identified 7 periods of formation of the citric acid market and described the most characteristic trends of its development in some countries of the world.

Identified problems of the citric acid industry and ways to solve them:

- *Risk:* Introduction of subsidies for the citric acid industry in the country of origin. *Possible consequences:* Reduction of prices to an unreasonable level, which may lead to bankruptcy of the enterprise in Ukraine.

Ways to solve the problem: Appeal to the Government of Ukraine on behalf of the Association, which unites Ukrainian citric acid producers, with a request to launch an anti-dumping investigation against the country that applied subsidies to the industry, which led to an unjustified reduction in prices for CACCS products. Conducting an anti-dumping investigation and imposing anti-dumping and countervailing duties in case of violations of the rules of world trade in citric acid and its compounds. Six months before the imposition of the anti-dumping and countervailing duties, inform the subsidizing

producer country and the WTO. Review of the anti-dumping duty every 5 years according to the same procedure.

- *Risk:* Conspiracy of citric acid producers to fix prices on CACCS.

Possible consequences: Suspicion of participation of the Ukrainian citric acid producer in collusion with foreign producers and application of sanctions to it.

Ways to solve the problem: At the first obvious or implicit sign of conspiracy, provide a reasoned notice to the Antimonopoly Committee of Ukraine and the Antimonopoly Committees of the countries whose companies have conspired to fix prices on CACCS to avoid suspicion of participation in such conspiracies. Cooperation with the authorities until the final solution of the issue.

- *Risk:* Technological breakthrough of global brands.

Possible consequences: Technological backwardness of Ukraine, which will lead to unprofitable production of citric acid and the risk of bankruptcy

Ways to solve the problem: Cooperation of citric acid producers with recognized world-leading technology companies, continuous improvement of production, tracking global trends, attending conferences, exhibitions, and shows, cooperation with scientists. Establishment in Ukraine of a research laboratory that will deal with biotechnology issues, including in the field of citric acid.

For the proper functioning of the citric acid industry, it is recommended to create a specialized Association in Ukraine, which will include producers of citric acid in the country. The main task of such an Association will be to maintain constant contacts with the Government of Ukraine, monitor world prices for CACCS products, control the absence on the world market of conspiracies and subsidies in the citric acid industry in producer countries, and, also, preparing inquiries and dealing with violations of the rights of Ukrainian citric acid producers in global markets.

References

1. Citric Acid: emerging applications of key biotechnology industrial product. Chem Cent J. 2017; 11: 22. Published online 2017 Mar 8. doi: 10/1186/s13065-017-

0251-y. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5342991/ (дата звернення 24.10.2021).

2. Citric Acid and Certain Citrate Salts from Canada and China, Inv. Nos. 701-TA-456 and 731-TA-1151-1152 (Review), USITC Pub. 4076 (May 2009), at 1 (“Original Determinations”).

3. Citric Acid and Certain Citrate Salts from Canada and China, 74 Fed. Reg. 25771 (May 29, 2009). 3 Citric Acid and Certain Citrate Salts from Canada and the People's Republic of China: Antidumping Duty Orders, 74 Fed. Reg. 25703 (May 29, 2009).

4. Citric Acid and Certain Citrate Salts from the People's Republic of China: Notice of Countervailing Duty Order, 74 Fed. Reg. 25705 (May 29, 2009).

5. Citric Acid and Certain Citrate Salts from Canada and China; Institution of Five-Year Reviews, 79 Fed. Reg. 18311 (Apr. 1, 2014).

6. Citric Acid and Certain Citrate Salts from Canada and China; Notice of Commission Determination to Conduct Full Five-Year Reviews, 79 Fed. Reg. 42049 (July 18, 2014).

7. Ciriminna, R., Meneguzzo, F., Delisi, R. et al. Citric acid: emerging applications of key biotechnology industrial product. Chemistry Central Journal 11, (2017).

8. Connor John M. What can we learn from the ADM global price conspiracies? / Dept. of Agricultural Economics, Purdue University, West Lafayette, Indiana 47907-1145. Август 1998. connor@agecon.purdue.edu. (дата звернення 22.10.2021)

9. Information of the United Nations statistics UNcomtrade. Shandong TTCA Biochemistry Co. v. the United States, 774 F. Supp. 1317 (Ct. lnt’l Trade 2011). URL: https://comtrade.un.org/ (дата звернення 12.11.2021).

10. The Court of International Trade affirmed the Commission's affirmative injury determination with respect to CACCS from China.

11. The Fermentation Led Disruption of Citric Acid. January 6, 2021 / Catherine Tubb, URL: https://rethinkdisruption.com/citric-acid/. (дата звернення 4.11.2021).

Рецензенти:
Салата Г.В., д.і.н., доцент
Гутник М.В., к.і.н., доцент

Надійшла до редакції 23.11.2021 р.