

Production and Producer of Sodium Gluconate and Glucono-delta-lactone in China

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Researched & Prepared by:

Kcomber Inc.

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Executive summary

Sodium gluconate (SG), the sodium salt of gluconic acid, is used in concrete additive, water quality steadying agent, food and electroplating detergent industries in China. Glucono-delta-lactone (GDL) is a harmless food additive to the human body. In 2022, SG output and consumption decreased in China, while GDL output and consumption increased.

- Sodium gluconate

SG output grew at a CAGR of 2.0% in China during 2018–2020, but it kept declining in 2021 and 2022 due to weak domestic demand. In 2022, national output dropped to 664,100 tonnes, down 1.3% year on year, and the top five domestic SG producers (by output) contributed to 87.5% of the total output. As of Dec. 2022, there were five SG manufacturers with capacity exceeding 100,000 t/a in China.

In 2022, with the decline of corn starch price and the recovery of USD to CNY rate, the annual average ex-works price of SG slipped to USD657/t.

As to SG production technology, the enzyme method has become a mainstream technology thanks to no fungal residue and less energy consumption, and the bio-fermentation method still plays an important role in the industry.

- Glucono-delta-lactone

As of Dec. 2022, there were six active GDL producers in China. The capacity of the top three producers accounted for 61.7% of the national total. Thanks to increasing demand abroad and profitable sales, the output of GDL in China grew at a CAGR of 2.7% from 2018 to 2022, reaching 35,300 tonnes in 2022. China's GDL operating rate stayed at somewhere between 55% and 60% from 2018 to 2022, except a lower rate in 2020.

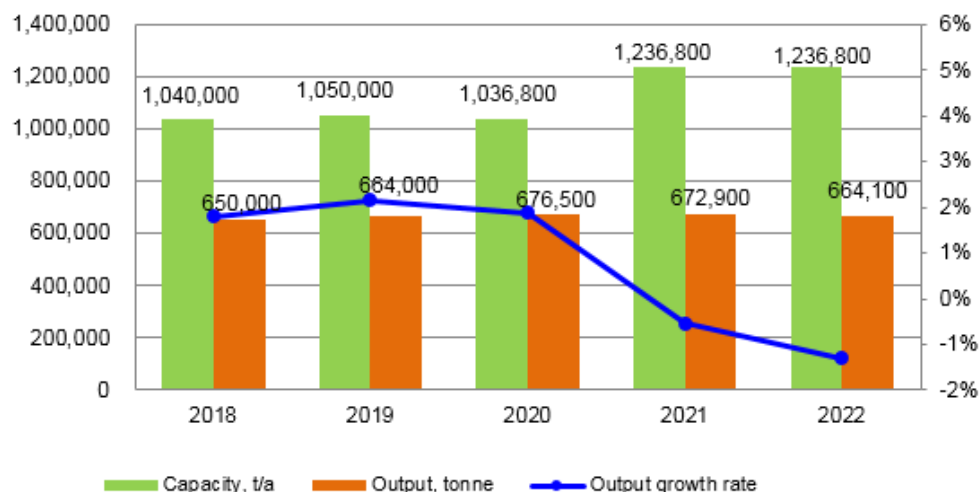
In 2022, annual average ex-works price of GDL decreased by 7.1% year on year to USD1,568/t, along with declined raw material prices.

There are four methods for GDL production, namely fermentation method, catalytic oxidation method, glucose oxidase method and electrolytic oxidation method, with glucose or starch as the starting material.

1 Production of sodium gluconate in China, 2022

1.1 Production

Figure 1.1-1 Capacity and output of sodium gluconate in China, 2018–2022



Source: CCM

In 2012–2015, rapid growth of sodium gluconate capacity and lack of downstream demand led to the overcapacity of sodium gluconate in China. Starting from 2016, some sodium gluconate producers had exited the market due to decreasing profit margin and stricter environmental regulations. By 2018, the capacity of sodium gluconate in China dropped to 1,040,000 t/a.

In 2019, Shandong Fuyang Biotechnology Co., Ltd. (Shandong Fuyang)'s expansion project was completed, while Zhucheng Xingmao Corn Developing Co., Ltd. (Zhucheng Xingmao) reduced its capacity through technological transformation, bringing the national capacity to 1,050,000 t/a.

In 2021, national capacity of sodium gluconate rose to 1,236,800 t/a as Yuxing Biotechnology (Group) Co., Ltd. (Yuxing Biotechnology) entered the market with its 200,000 t/a sodium gluconate production lines put into operation.

In 2018–2020, the output of sodium gluconate in China grew at a CAGR of 2.0%. However, due to weak domestic demand, the output began to decline in 2021, and dropped further to 664,100 tonnes in 2022, down 1.3% year on year.

1.2 Major producers

Since 2014, there has been an overall increase in the concentration of SG production in China. For one thing, the government has paid more attention to the environmental protection and some SG producers have been eliminated from the market because of environmental and economic factors. For another thing, the development of China's construction industry and the profits of SG business have encouraged the producers to enlarge their capacity, with

some big players seeking to gain more market share.

As of Dec. 2022, there were five manufacturers with sodium gluconate (SG) capacity exceeding 100,000 t/a, namely Shandong Fuyang, Zhucheng Xingmao, Baisheng Biotechnology, Xiwang Sugar and Yuxing Biotechnology. From 2019 to 2022, 2021 excluded though, the top five producers (by output) contributed to 87%–90% of total SG output in China; in 2022, the top five SG producers (by output) produced more than 580,000 tonnes, with their combined share to the total at 87.5%.

During the past four years, a big player, Yuxing Biotechnology, entered the market, while Baisheng Biotechnology gradually reduced production and even stopped production since it was mired in financial woes. With the entry and exit of players, China's SG production has increasingly concentrated in the north of China, mainly in the corn-planting regions such as Shandong and Hebei provinces.

Table 1.2-1 Major sodium gluconate producers in China, as of April 2023

No.	Producer	Abbreviation	Location	Produce glucono-delta-lactone, Yes/No	Status, as of April 2023
1	Shandong Fuyang Biotechnology Co., Ltd.	Shandong Fuyang	Shandong	Yes	Active
2	Zhucheng Xingmao Corn Developing Co., Ltd.	Zhucheng Xingmao	Heilongjiang, Inner Mongolia	No	Active
3	Yuxing Biotechnology (Group) Co., Ltd.	Yuxing Biotechnology	Hebei	No	Active
4	Shandong Baisheng Biotechnology Co., Ltd.	Baisheng Biotechnology	Shandong	Yes	Idle
5	Shandong Xiwang Sugar Co., Ltd.	Xiwang Sugar	Shandong	No	Active
6	Zhucheng Shuguang Biotechnology Co., Ltd.	Zhucheng Shuguang	Shandong	No	Active
7	Weifang Jianbao Biotechnology Co., Ltd.	Weifang Jianbao	Shandong	No	Active
8	Qingdao Kehai Biochemistry Co., Ltd.	Qingdao Kehai	Shandong	No	Active
9	Shandong Kaixiang Biochemical Co., Ltd.	Shandong Kaixiang	Shandong	Yes	Active
10	Zhejiang Wulong New Materials Co., Ltd.	Zhejiang Wulong	Zhejiang	No	Active
11	Zhejiang Tianyi Food Additives Co., Ltd.	Zhejiang Tianyi	Zhejiang	Yes	Active
12	Deqing Yuansu Gaoke Biotechnology Co., Ltd.	Deqing Yuansu	Zhejiang	No	Active
13	Xinxiang Zhongxin Chemicals Co., Ltd.	Xinxiang Zhongxin	Henan	No	Suspended
14	Xinxiang Huaxing Biotech Co., Ltd.	Xinxiang Huaxing	Henan	No	Suspended

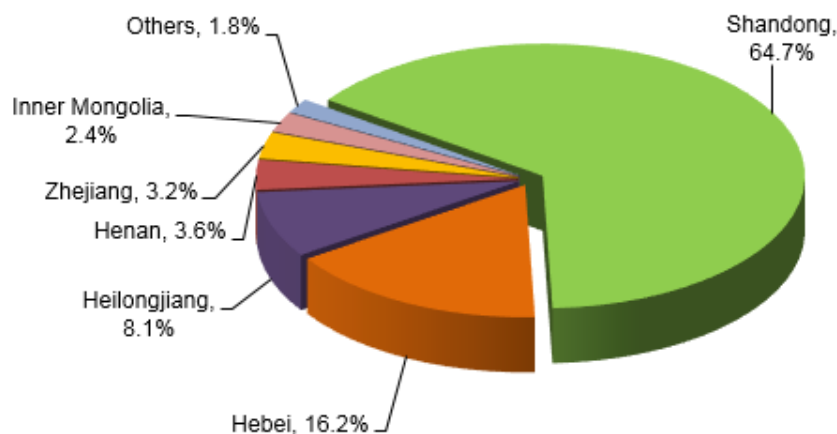
Source: CCM

Table 1.2-2 Capacity and output of major sodium gluconate producers in China, 2019–2022

No.	Producer	Capacity, t/a				Output, tonne							
						2022		2021		2020		2019	
		2022	2021	2020	2019	Solid	Liquid	Solid	Liquid	Solid	Liquid	Solid	Liquid
1	Shandong Fuyang	250,000	250,000	250,000	250,000	210,000	0	188,000	0	215,000	0	188,000	0
2	Yuxing Biotechnology	200,000	200,000	/	/	110,000	0	98,000	0	/	/	/	/
3	Baisheng Biotechnology	150,000	150,000	150,000	150,000	0	0	32,000	2,000	105,000	6,000	138,000	8,500
4	Zhucheng Xingmao	130,000	130,000	130,000	130,000	116,000	6,000	120,000	6,000	120,000	6,500	120,000	6,000
5	Xiwang Sugar	120,000	120,000	120,000	120,000	103,000	0	107,000	0	115,000	0	117,000	0
6	Zhucheng Shuguang	100,000	100,000	100,000	100,000	42,000	0	43,000	0	44,200	0	32,000	0
7	Weifang Jianbao	100,000	100,000	100,000	100,000	29,000	0	32,000	0	35,000	0	28,000	0
8	Qingdao Kehai	50,000	50,000	50,000	50,000	15,000	0	12,000	0	0	0	0	0
9	Shandong Kaixiang	30,000	30,000	30,000	30,000	25,800	2,000	26,500	3,000	27,000	2,000	27,000	2,000
10	Zhejiang Wulong	30,000	30,000	30,000	30,000	2,500	0	3,000	0	2,500	0	2,000	0
11	Zhejiang Tianyi	6,000	6,000	6,000	6,000	4,500	0	4,900	0	5,000	0	4,300	0
12	Deqing Yuansu	4,000	4,000	4,000	4,000	2,300	400	2,500	400	3,000	400	2,800	400
13	Xinxiang Zhongxin	15,000	15,000	15,000	15,000	0	0	0	0	800	100	1,000	200
14	Xinxiang Huaxing	30,000	30,000	30,000	30,000	0	0	0	0	0	0	0	0
Others		21,800	21,800	21,800	35,000	4,000	3,000	4,000	3,000	4,000	3,000	3,900	10,500
Total		1,236,800	1,236,800	1,036,800	1,050,000	664,100	11,400	672,900	14,400	676,500	18,000	664,000	27,600

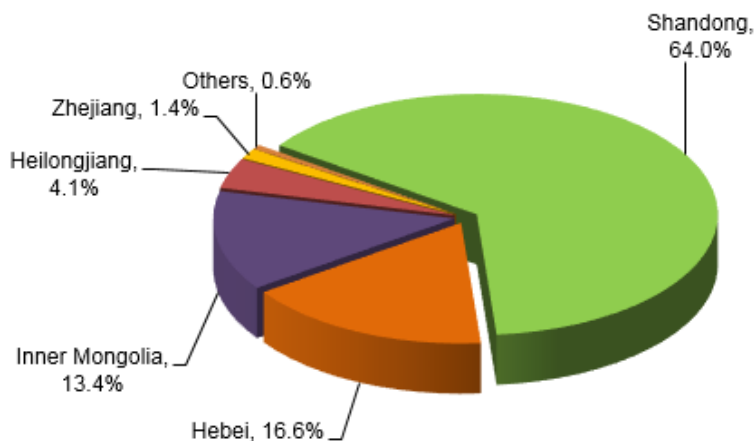
Source: CCM

Figure 1.2-1 Capacity distribution of sodium gluconate in China, 2022



Source: CCM

Figure 1.2-2 Output distribution of sodium gluconate in China, 2022



Source: CCM

In Jan. 2019, Shandong Kaixiang's SG technical transformation project (SG capacity decreased from 50,000 t/a to 30,000 t/a) was completed. In May 2019, Shandong Fuyang's 100,000 t/a SG expansion project was built up and put into production. Also this year, Tongliao Zhongyuan Biological Development Co., Ltd., a subsidiary of Zhucheng Xingmao, reduced its SG capacity from the original 100,000 t/a to 30,000 t/a through a starch sugar technology transformation project.

Since 2020, Guangdong Redwall has stopped producing liquid SG due to its business adjustment.

Yuxing Biotechnology completed the construction of 200,000 t/a SG production lines in Xingtai City, Hebei Province, and put them into production in 2021, while Baisheng Biotechnology, due to a shortage of working capital, has been restructuring its business and its factory shut down in 2022.

There are four potential SG producers in China, namely Qingzhou Huakang Biotechnology

Co., Ltd. (Qingzhou Huakang), Heilongjiang Zhonglang Biotechnology Co., Ltd. (Heilongjiang Zhonglang), Anhui BBKA Biochemical Co., Ltd. (Anhui BBKA) and Dezhou Heyang Biotechnology Co., Ltd. (Dezhou Heyang).

- The environmental impact (EI) report of Qingzhou Huakang's 85,000 t/a SG project was submitted to the local government in April 2019, but this project hasn't started as of April 2023 and may have already run aground.

- Heilongjiang Zhonglang's corn deep-processing project (300,000 t/a corn starch, 100,000 t/a SG, and 50,000 t/a itaconic acid) was under construction, which is planned to be built up in 2023.

- The EI report of Anhui BBKA's 10,000 t/a SG and 20,000 t/a L-alanine technical transformation project was approved on Feb. 15, 2023. And previously on April 29, 2022, the company publicized the EI report of a 50,000 t/a SG project, yet there has been no update on this project.

- Dezhou Heyang, a subsidiary of Shandong Fuyang, made the second public announcement for the EI report of its 200,000 t/a SG project on April 6, 2022, and the lines were expected to be operational in Jan. 2024.

Link of expansion project:

<http://www.qingzhou.gov.cn/detail/front/details/temp470129.html>

http://www.qth.gov.cn/xxgk_12340/szyw/202112/t20211230_306739.htm

<https://www.bengbu.gov.cn/public/25821/49793343.html>

<https://www.bengbu.gov.cn/public/22131/50418393.html>

<http://dzhbkys.cn/index.php/content/1292>

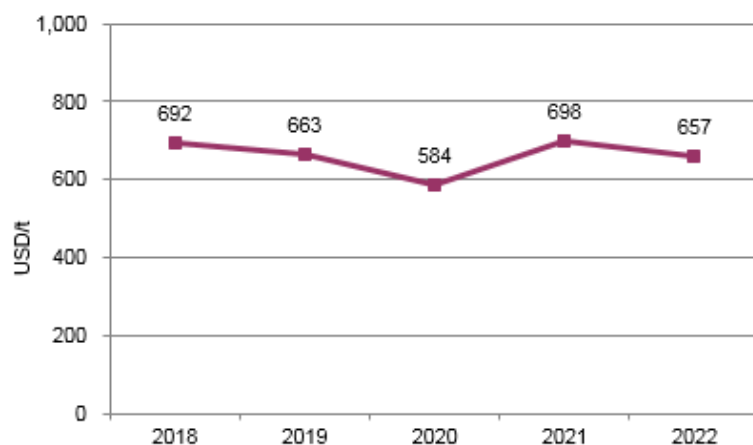
1.3 Price

Table 1.3-1 Ex-works price of sodium gluconate by major producers in China, April 2023

No.	Producer	Food grade		Industrial grade	
		RMB/t	USD/t	RMB/t	USD/t
1	Shandong Fuyang	4,600	669	4,600	669
2	Zhucheng Xingmao	4,000	581	N/A	N/A
3	Yuxing Biotechnology	3,960	576	3,960	576
4	Qingdao Kehai	5,200	756	5,000	727
5	Shandong Kaixiang	4,300	625	5,300	770
6	Deqing Yuansu	5,500	799	N/A	N/A

Source: CCM

Figure 1.3-1 Annual average ex-works price of sodium gluconate in China, 2018–2022



Source: CCM

Affected by the increasing price of corn starch and the tightening environmental regulation, the ex-works price of sodium gluconate surged since H2 2017. In April 2018, the average ex-works quotation of sodium gluconate by major producers in Shandong Province exceeded USD680/t, up by about 27.8% year on year from USD532/t.

In 2019, as the price of raw material corn came down, the annual average ex-works price dropped to USD663/t, down 4.2% year on year. The annual average price plunged to USD584/t in 2020, due to factors like the outbreak of COVID-19, sufficient supply of sodium gluconate, stronger USD against CNY, etc.

Throughout the year 2021, monthly ex-works price of sodium gluconate stayed above USD660/t as USD continued to weaken against CNY. The price surpassed USD700/t in Q4 and peaked at USD779/t in Nov. as the price of corn starch rose.

With the decline of corn starch price and the strengthening of USD against CNY, the annual average ex-works price of sodium gluconate retreated to USD657/t in 2022.

1.4 Production technology

Currently, there are mainly three sodium gluconate production methods in China, namely catalytic oxidation method, bio-fermentation and enzyme method, in which bio-fermentation method is the most commonly adopted method in industrial production of sodium gluconate.

Bio-fermentation method is mainly adopted by sodium gluconate producers which are located in the surrounding areas of corn-planting regions such as Shandong Province.

Catalytic oxidation method developed rapidly in the 1980s and 1990s. However, due to the use of costly metal catalysts, the production cost is subject to the number and efficiency of metal catalyst cycles. Besides, due to the presence of excess heavy metals, products thus produced are not allowed to be used as food additives in food production. Therefore, the development of catalytic oxidation method is limited. At present, this method is mainly adopted by small and medium-sized enterprises to produce industrial grade products for the concrete industry.

Enzyme method has developed rapidly in recent years and is receiving increasing attention from the sodium gluconate industry. Weifang Jianbao Biotechnology Co., Ltd. and Shandong Kaixiang Biochemical Co., Ltd. started to adopt the enzyme method in sodium gluconate production in 2016 and 2018, respectively. In 2019, Qingzhou Huakang Biotechnology Co., Ltd., a potential producer, also chose this method to produce SG. No fungal residue is generated during the production process by enzyme method, which overcomes the disadvantage of impure products produced by bio-fermentation method. Besides, this method consumes less energy than the bio-fermentation method.

Moreover, Zhucheng Dongxiao Biotechnology Co., Ltd., applied a patent for an energy-efficient and environment-friendly enzyme method of sodium gluconate production in 2016. Different from the traditional enzyme method, this new approach uses starch milk as starting material and improves SG quality by saccharification. According to the company, the method is safer, easier to extract and refine products. In addition, through comprehensively utilizing the heat released during the process, the method can bring down energy consumption and carbon emission.

Therefore, it is foreseeable that enzyme method will be more widely used in SG production.

Manufacturing principle of various sodium gluconate production methods

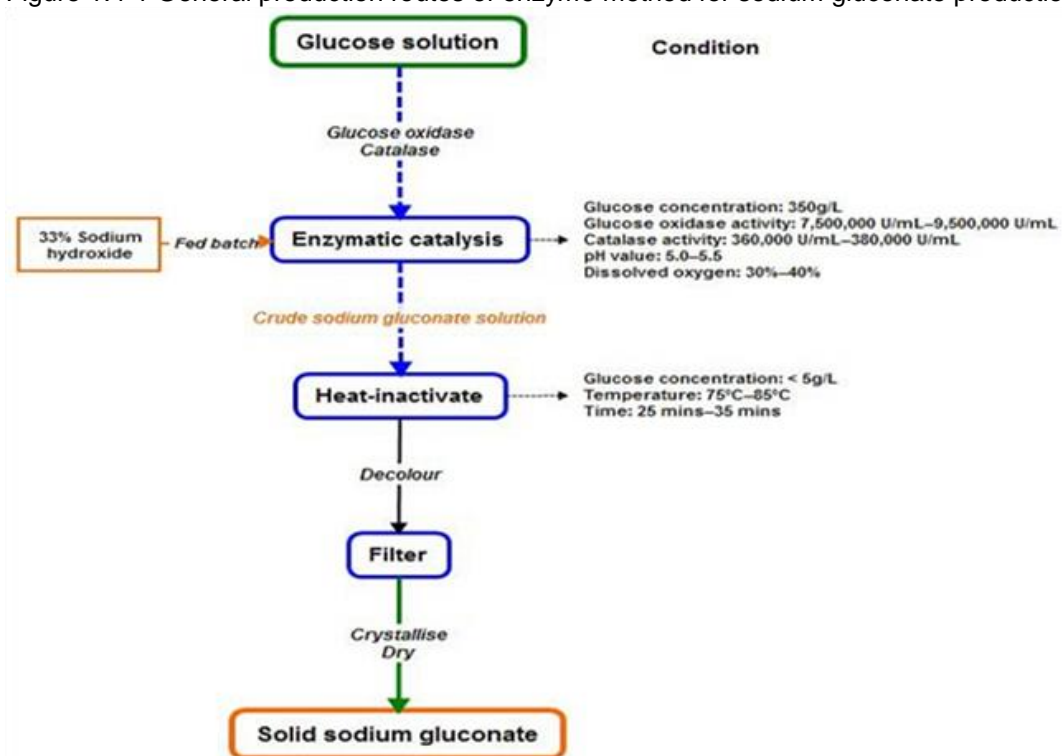
- Catalytic oxidation method: Oxidate glucose solution into gluconic acid using a metal catalyst, add sodium hydroxide to neutralize gluconic acid into sodium gluconate.
- Bio-fermentation method: Using *Aspergillus niger* to ferment glucose solution into gluconic acid, add sodium hydroxide to neutralize gluconic acid into sodium gluconate.
- Enzyme method: Ferment glucose solution using glucose oxidase and catalase, in which the glucose oxidase will convert glucose into gluconic acid and hydrogen peroxide, while catalase will decompose hydrogen peroxide into oxygen and water. Add sodium hydroxide to neutralize gluconic acid into sodium gluconate.

Table 1.4-1 Comparison of various sodium gluconate production methods in China

Item	Catalytic oxidation method	Bio-fermentation method	Enzyme method
Raw materials	Glucose solution, metal catalyst, sodium hydroxide	Glucose solution, <i>Aspergillus niger</i> , sodium hydroxide	Glucose solution, glucose oxidase, catalase, sodium hydroxide
Production route	Simple	Complicated	Simple
Production cost	High	Low	Relatively high
Product purity	Relatively low	Low	High

Source: CCM

Figure 1.4-1 General production routes of enzyme method for sodium gluconate production



Source: CCM

Table 1.4-2 Production method of sodium gluconate by producer in China, 2022

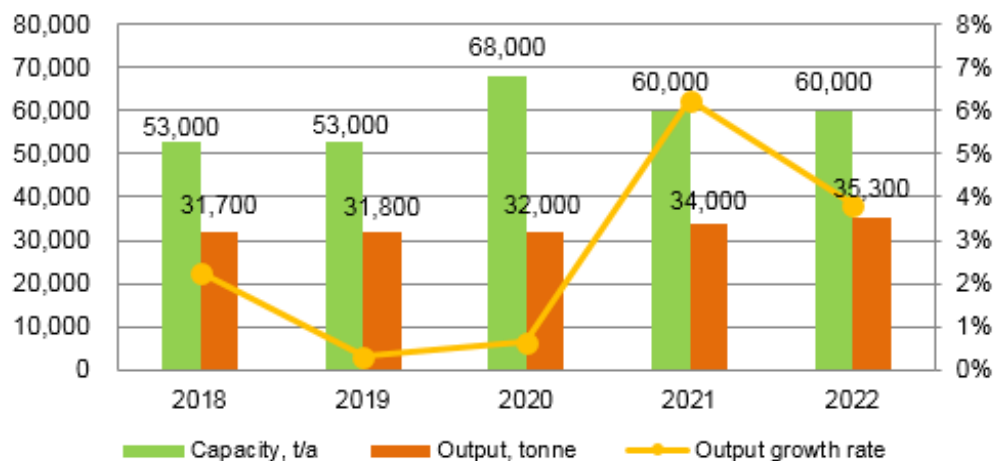
Production method	Producer
Bio-fermentation method	Shandong Fuyang, Zhucheng Xingmao, Baisheng Biotechnology, Xiwang Sugar, Zhucheng Shuguang, Xinxiang Zhongxin, Zhejiang Tianyi, Qingdao Kehai
Enzyme method	Weifang Jianbao, Shandong Kaixiang, Yuxing Biotechnology
Catalytic oxidation method	Zhejiang Wulong, Deqing Yuansu, Xinxiang Huaxing

Source: CCM

2 Supply of glucono-delta-lactone in China, 2022

2.1 Production

Figure 2.1-1 Capacity and output of GDL in China, 2018–2022

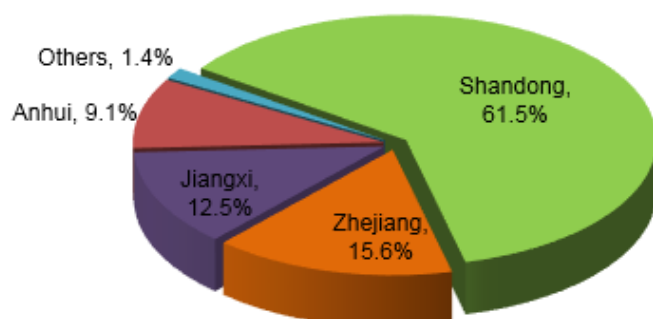


Source: CCM

In 2020, Shandong Xinhong joined the market and thus brought China's total GDL capacity to 68,000 t/a. However, from 2018 to 2021, due to increasingly stricter environmental production inspections, Zhangshu Guanyi Food Additive Co., Ltd., Shanggao Jinyang Food Technology Co., Ltd. and Yibin GraceBIO Biological Technology Co., Ltd. suspended or stopped production, and national GDL capacity was reduced to 60,000 t/a in 2021. The figure remained unchanged in 2022.

Thanks to increasing demand abroad and profitable sales, the output of GDL in China grew at a CAGR of 2.7% from 2018 to 2022; in 2022, the output reached 35,300 tonnes. In this five-year period, yearly GDL operating rate was basically kept within the range of 55%–60%, except a less-than 50% in 2020 due to addition of new capacity in Shandong Xinhong.

Figure 2.1-2 Output distribution of GDL in China, 2022



Source: CCM

Shandong Province is a major producing region for GDL and its raw materials—glucose and sodium gluconate. In 2022, Shandong's GDL output accounted for 61.5% of the national total.

As of Dec. 2022, there were six active GDL producers in China. The capacity of the top three producers accounted for 61.7% of the total. State-owned companies rarely enter the GDL market because GDL is not an important product affecting people's livelihood, so most Chinese GDL enterprises are private. And as of Dec. 2022, there was no foreign investment in China's GDL industry. So far, the Chinese government has no intention to restrict the business.

Table 2.1-1 Basic information about GDL producers in China, 2022

No.	Producer	Abbreviation	Status 2022	Location	Launch time
1	Shandong Xinhong Pharmaceutical Co., Ltd.	Shandong Xinhong	Active	Shandong	2020
2	Shandong Kaixiang Biochemical Co., Ltd.	Shandong Kaixiang	Active	Shandong	2006
3	Shandong Hongsheng Biotechnology Co., Ltd.	Shandong Hongsheng	Idle	Shandong	2014
4	Zhejiang Tianyi Food Additives Co., Ltd.	Zhejiang Tianyi	Active	Zhejiang	2011
5	Anhui Xingzhou Pharma Co., Ltd.	Anhui Xingzhou	Active	Anhui	2003
6	Jiangxi New Huanghai Food Co., Ltd.	Jiangxi New Huanghai	Active	Jiangxi	2003
7	Dezhou Huiyang Biotechnology Co., Ltd.	Dezhou Huiyang	Active	Shandong	2014
8	Zhangshu Guanyi Food Additive Co., Ltd.	Zhangshu Guanyi	Idle	Jiangxi	2008

Source: CCM

Table 2.1-2 Capacity and output of GDL producers in China, 2019–2022

No.	Producer	Capacity, t/a				Output, tonne			
		2022	2021	2020	2019	2022	2021	2020	2019
1	Shandong Xinhong	15,000	15,000	15,000	/	9,100	6,400	2,000	/
2	Shandong Kaixiang	12,000	12,000	12,000	12,000	9,600	7,000	6,500	6,000
3	Shandong Hongsheng	10,000	10,000	10,000	10,000	0	5,500	8,000	9,600
4	Zhejiang Tianyi	6,000	6,000	6,000	6,000	5,500	5,600	5,500	5,200
5	Anhui Xingzhou	5,000	5,000	5,000	5,000	3,200	1,500	0	0
6	Jiangxi New Huanghai	5,000	5,000	5,000	5,000	4,400	4,500	4,500	4,500
7	Dezhou Huiyang	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
8	Zhangshu Guanyi	3,000	3,000	3,000	3,000	0	0	0	0
Others		1,000	1,000	9,000	9,000	500	500	2,500	3,500
Total		60,000	60,000	68,000	53,000	35,300	34,000	32,000	31,800

Source: CCM

Anhui Xingzhou suspended GDL production in 2018–2020 due to environmental protection inspections and resumed production in 2021. At present, it also sells GDL products of Shandong Hongsheng, Shandong Kaixiang and Dezhou Huiyang as an agent.

Shandong Xinhong had 15,000 t/a GDL capacity added in Oct. 2020, upon completion of its 18,000 t/a gluconate project. In 2021, it became a major GDL producer with the largest capacity and the second largest output.

Shandong Kaixiang, the largest GDL producer by output in 2022, usually sells GDL products through Anhui Xingzhou. In July 2021, the EI report of Shandong Kaixiang's GDL technical transformation project was publicized, and the company has planned to increase its GDL capacity from 12,000 t/a to 15,000 t/a. Although the construction project was scheduled to be completed in 12 months, as of April 2023, it has not finished yet.

Link of expansion project:

http://www.wulian.gov.cn/art/2021/7/5/art_34021_10293546.html

http://www.wulian.gov.cn/art/2021/9/26/art_34021_10297719.html

In April 2022, the EI report of Dezhou Huiyang's 20,000 t/a GDL expansion project was publicized; the project could be completed as early as 2023.

Link of expansion project:

<http://dzpyzfwf.sd.gov.cn/py/icity/publishdetail?id=8d87fda3bed94588a1cfff4edd6f4c3c>

There are also four potential GDL producers in China: Yuxing Biotechnology, Shandong Liujiangyuan Food Technology Co., Ltd. (Shandong Liujiangyuan), Angel Yeast (Yichang) Co., Ltd. (Yichang Angel) and Shandong Zhongxing Food Technology Co., Ltd. (Shandong Zhongxing).

- Yuxing Biotechnology acquired construction land use permit for the 10,000 t/a GDL project in Dec. 2020, but the project has not been completed as of April 2023.

Link of expansion project:

<https://www.ningjin.gov.cn/xxgk/content/27007.html>

- In July 2021, the EI report of Shandong Liujiangyuan's 10,000 t/a gluconic acid and derivatives project was approved by local authorities. The project is divided into two phases, with production scale of 7,500 t/a GDL and 1,000 t/a 50% glucose solution planned in phase I.

Link of expansion project:

http://www.wenshang.gov.cn/art/2021/7/29/art_20173_2716261.html

http://xxgk.wenshang.gov.cn/art/2021/7/21/art_20172_2716228.html

- In Dec. 2021, Angel Yeast Co., Ltd. announced that its subsidiary Yichang Angel would undertake the construction of the 150,000 t/a hydrolyzed sugar deep processing project. According to the planning, some 35,000 tonnes of hydrolyzed sugar produced will be used for the production of GDL and in other deep processing projects. This large-scale project is planned at two phases: the construction of hydrolyzed sugar workshop in phase I and the construction of GDL production line in phase II. But the company has not disclosed design capacity for its GDL production line.

Link of expansion project:

<http://www.cninfo.com.cn/new/disclosure/detail?plate=sse&orgId=gssh0600298&stockCode=600298&announcementId=1211947750&announcementTime=2021-12-18>

- In Jan. 2023, the EI report of Shandong Zhongxing's 20,000 t/a gluconate series food additives (including 17,500 t/a GDL) project was publicized and announced to be approved by local authorities. The project could be put into production as early as 2024.

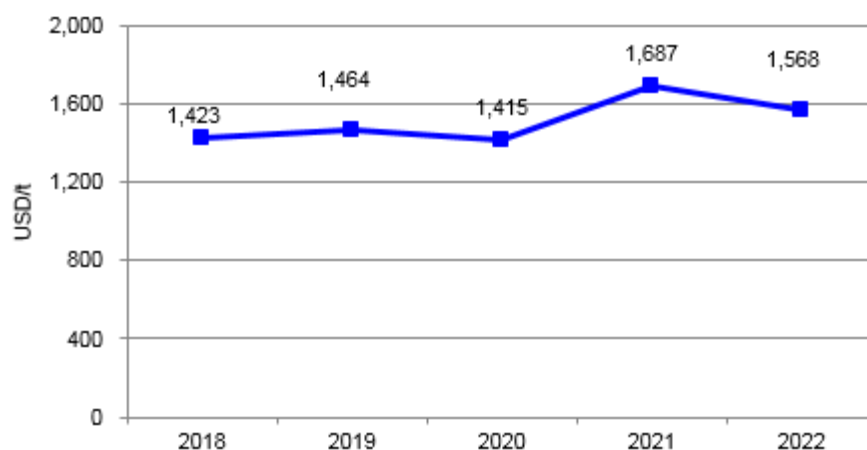
Link of expansion project:

http://www.zouping.gov.cn/art/2023/1/6/art_231675_10539287.html

http://www.zouping.gov.cn/art/2023/1/28/art_231675_10540837.html

2.2 Price

Figure 2.2-1 Annual average ex-works price of GDL in China, 2018–2022



Source: CCM

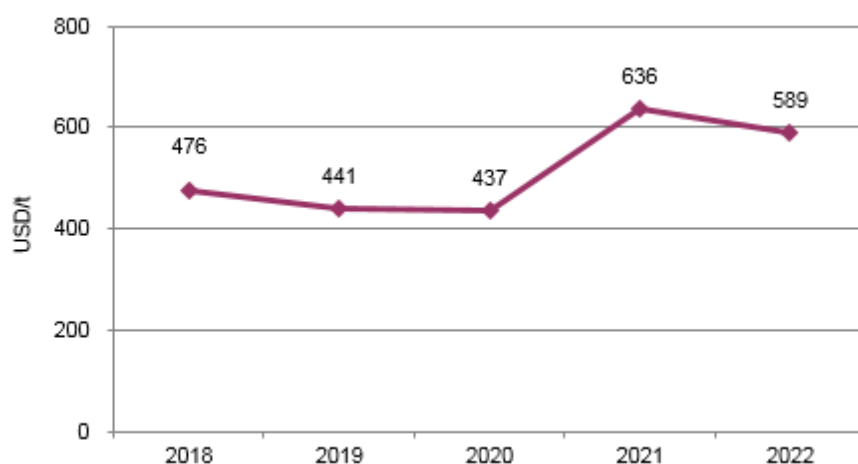
In 2018, the annual average ex-works price of GDL increased by 28.4% year on year. Besides, there were only seven active GDL producers in China, and Anhui Xingzhou had strong pricing power after taking charge of a large part of domestic GDL sales.

As people's health consciousness constantly enhanced, the demand for GDL, a harmless food additive to the human body, grew 2%–4% annually in recent years. The growth of demand outpaced that of supply, so the year 2019 saw the price further increase by 2.9% year on year.

In 2020, the annual average ex-works price of GDL decreased a little by 3.4% year on year.

In 2021, as raw material price rose, the annual ex-works price of GDL averaged at USD1,687/t, rising 19.2% year on year. In 2022, it decreased by 7.1% year on year to USD1,568/t, along with declined prices of raw materials.

Figure 2.2-2 Annual average ex-works price of glucose monohydrate in China, 2018–2022



Source: CCM

Generally, the price of glucose fluctuates with the price of corn starch, as well as that of corn.

In 2018, as prices of raw material corn and corn starch went up, the cost of starch sugar increased. The annual average ex-works price of glucose monohydrate was USD476/t, edging up 1.5% year on year.

However, in 2019, the price of corn slipped by 3.0% year on year, primarily due to lower demand for corn feed caused by African swine fever. As a result, the annual average price of glucose monohydrate reduced by 7.4% year on year. The price of glucose monohydrate continued to fall in H1 2020 influenced by the outbreak of COVID-19, but rose in H2 along with the rising price of corn.

In 2021, the price of glucose monohydrate was kept high throughout the year. Monthly price jumped to USD581/t in Jan. and shot further to USD681/t in Feb. before some small pullbacks were seen. In Q4, as the corn price rose, it again climbed to around USD655/t.

In Feb. 2022, the price of glucose monohydrate came to a peak at USD682/t, but then began to decline, falling all the way to USD521/t in Oct. The price ended at USD552/t in Dec. 2022.

2.3 Production technology

2.3.1 Different pathways/methods

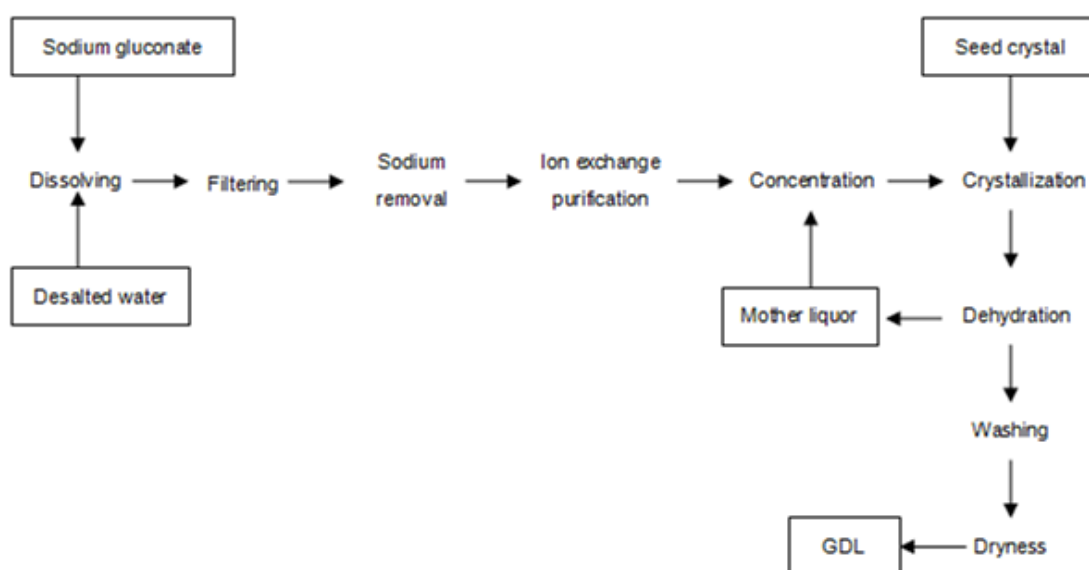
There are four methods for GDL production, namely fermentation method, catalytic oxidation method, glucose oxidase method and electrolytic oxidation method, with glucose or starch as the starting material.

The fermentation method has become the most important production technology in recent years in China, mainly attributed to its low manufacturing cost and sufficient raw material supply. And there are three paths to produce GDL through the fermentation method. One is getting the GDL directly through fermentation; the other two paths are transferring glucose liquid to sodium gluconate (SG) or to calcium gluconate (CG), and eventually turning it into GDL. Currently, only the latter two paths, namely the SG method and CG method, are applied in China.

In the fermentation method, glucose or maltose is used as starting material. In China, glucose is made into glucose solution first, then transferred to CG or SG after fermentation, and made into GDL finally. Dezhou Huiyang adds trehalase into maltose solution (75%) to get the mixture of trehalose and maltose first, then gets the mixture of trehalose and glucose by adding glucose oxidase, and finally gets GDL after further processing.

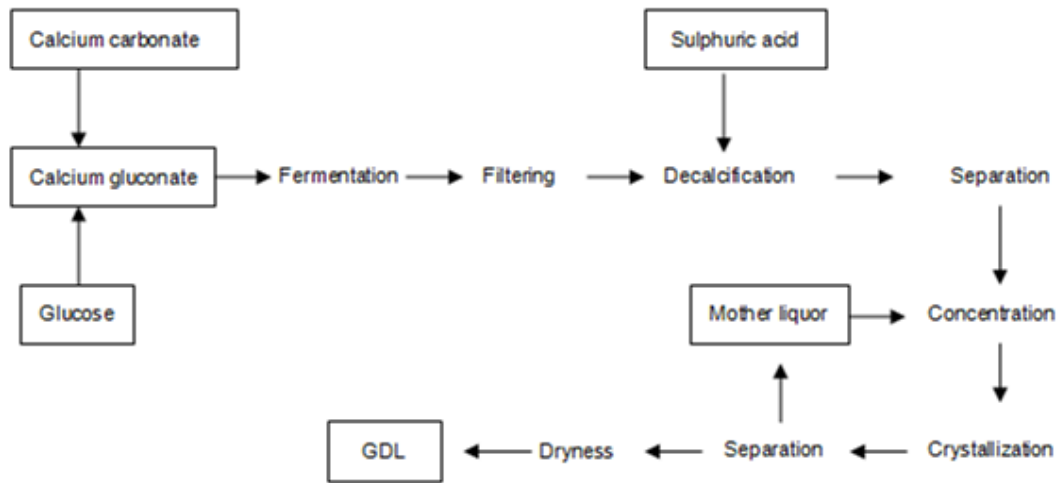
Shandong Xinhong adopts glucose oxidase method, with glucose as a raw material. It adds oxidase and sodium hydroxide into glucose solution for oxidation treatment. After that, sodium ion is absorbed by resin to obtain gluconic acid solution, and then GDL is extracted through crystallization.

Figure 2.3.1-1 Flowchart of sodium gluconate method in China



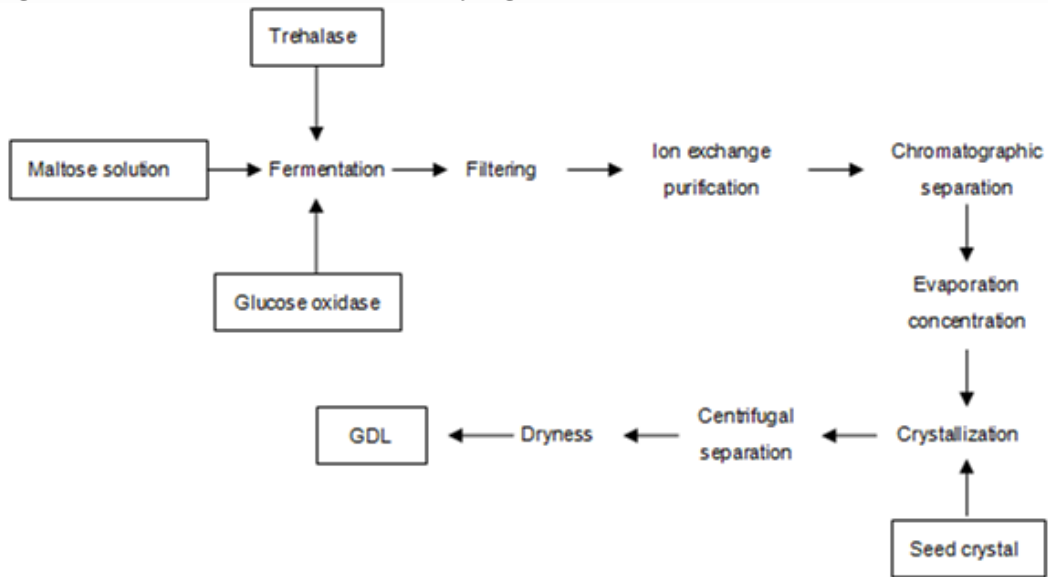
Source: CCM

Figure 2.3.1-2 Flowchart of calcium gluconate method in China



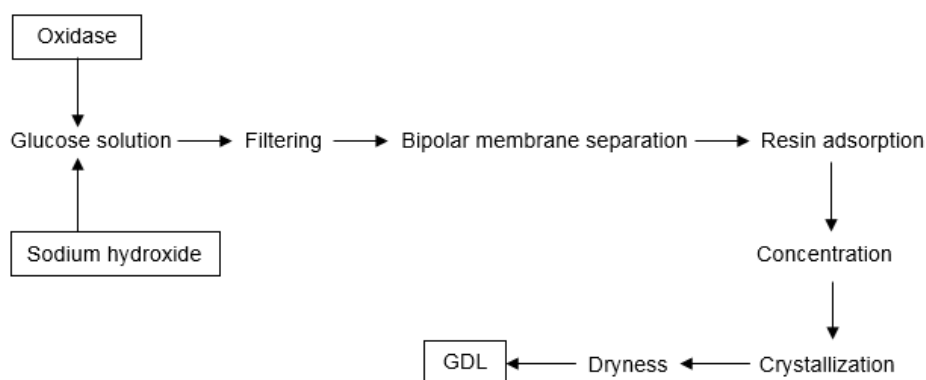
Source: CCM

Figure 2.3.1-3 Flowchart of Dezhou Huiyang's GDL method



Source: CCM

Figure 2.3.1-4 Flowchart of Shandong Xinhong's GDL method



Source: CCM

Table 2.3.1-1 Production method of GDL by producer in China, 2022

No.	Producer	Technology	Raw material	Raw material source
1	Shandong Kaixiang	SG method	SG	Captive
2	Shandong Xinhong	Glucose oxidase method	Glucose	Outsourcing
3	Zhejiang Tianyi	Fermentation method	Glucose	Outsourcing
4	Jiangxi New Huanghai	Fermentation method	Glucose	Outsourcing
5	Dezhou Huiyang	Fermentation method	Maltose	Captive
6	Anhui Xingzhou	Fermentation method	Rice/Corn starch	Outsourcing
7	Shandong Hongsheng	SG method	SG	Shandong Baisheng Biotechnology Co., Ltd.

Source: CCM

2.3.2 Research status

There are only a small number of researchers, research institutes/companies involved in GDL production technology development in China, with 8 patents of GDL producing methods in total since 2009.

Four production methods are adopted for commercial use:

- Shandong Kaixiang adopts the method developed by Xiamen Starmem Scitechnology Co., Ltd. and the equipment made by Nanjing Gaojie Light Industrial Equipment Co., Ltd.
- Dezhou Huiyang adopts the method developed by its parent company—Shandong Fuyang Biotechnology Co., Ltd.
- Jiangsu Huanyu Kangli Technology Co., Ltd. (Jiangsu Kangli) adopts its own designed methods and equipment to produce GDL (usually for its own use). And Jiangsu Zhuoyun Doubao Food Co., Ltd. (Jiangsu Zhuoyun Doubao) is its affiliated company.

Two preparation methods (developed by China Tobacco Hubei Industrial LLC and Jinan

University) are suitable for pilot-line production only.

Two production methods (developed by Xu Jiaying and Zhu Zhongliang) have not been adopted by the domestic GDL producers.

Table 2.3.2-1 Patents of GDL production/preparation in China, as of April 2023

No.	Patent	Application No.	Applicant	Date of application
1	A production process and equipment for preparing GDL from sodium gluconate	CN202111232278.8	Jiangsu Kangli	Oct. 2021
2	A production method of GDL	CN202011539600.7	Jiangsu Zhuoyun Doubao	Dec. 2020
3	A preparation method of GDL and its application in essence for tobacco	CN201711089899.9	China Tobacco Hubei Industrial LLC	Nov. 2017
4	A production method of GDL	CN201710300026.1	Xu Jiaying	May 2017
5	A method of preparing trehalose and GDL at the same time	CN201610710587.4	Shandong Fuyang	Aug. 2016
6	A production method of GDL	CN201410618065.2	Zhu Zhongliang	Nov. 2014
7	A preparation method of GDL	CN201110338402.9	Jinan University	Oct. 2011
8	A production method of GDL	CN200910192646.3	Xiamen Starmem Technology Co., Ltd.	Sept. 2009

Source: China National Intellectual Property Administration

3 Forecast on sodium gluconate and GDL production in China

Although the domestic supply can basically meet the demand, there are still some enterprises planning to launch new sodium gluconate projects. Such projects are often taken as a move to expand their presence along the corn deep-processing industrial chain.

If it goes well, China's capacity of sodium gluconate may exceed 1,346,800 t/a in 2023. With the completion of Shandong Fuyang's 200,000 t/a sodium gluconate project in 2024, the capacity will be over 1,546,800 t/a.

Table 3-1 Forecast on SG capacity in China to 2026

No.	Producer	Capacity, t/a							
		2019	2020	2021	2022	2023	2024	2025	2026
1	Shandong Fuyang	250,000	250,000	250,000	250,000	250,000	450,000	450,000	450,000
2	Zhucheng Xingmao	130,000	130,000	130,000	130,000	130,000	130,000	130,000	130,000
3	Baisheng Biotechnology	150,000	150,000	150,000	150,000	150,000	150,000	150,000	150,000
4	Xiwang Sugar	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000
5	Zhucheng Shuguang	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
6	Weifang Jianbao	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
7	Qingdao Kehai	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
8	Shandong Kaixiang	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
9	Zhejiang Wulong	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
10	Xinxiang Huaxing	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
11	Xinxiang Zhongxin	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
12	Zhejiang Tianyi	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
13	Deqing Yuansu	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
14	Yuxing Biotechnology	/	/	200,000	200,000	200,000	200,000	200,000	200,000
15	Heilongjiang Zhonglang	/	/	/	/	100,000	100,000	100,000	100,000
16	Anhui BBCA	/	/	/	/	10,000	10,000	10,000	10,000
	Others	35,000	21,800	21,800	21,800	21,800	21,800	21,800	21,800
	Total	1,050,000	1,036,800	1,236,800	1,236,800	1,346,800	1,546,800	1,546,800	1,546,800

Source: GCM

In the coming years, the demand for GDL exports will continue to grow, and GDL industry will welcome new players, so GDL capacity in China will increase. Dezhou Huiyang's 20,000 t/a GDL expansion project, Yuxing Biotechnology's 10,000 t/a GDL project, Shandong Liujiangyuan's 7,500 t/a GDL project and Shandong Kaixiang's GDL expansion project are

estimated to be accomplished within this year, bringing the total GDL capacity in China to 97,500 t/a in 2023.

Table 3-2 Forecast on GDL capacity in China to 2026

No.	Producer	Capacity, t/a							
		2019	2020	2021	2022	2023	2024	2025	2026
1	Shandong Kaixiang	12,000	12,000	12,000	12,000	15,000	15,000	15,000	15,000
2	Shandong Hongsheng	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
3	Zhejiang Tianyi	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
4	Anhui Xingzhou	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
5	Jiangxi New Huanghai	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
6	Dezhou Huiyang	3,000	3,000	3,000	3,000	20,000	20,000	20,000	20,000
7	Zhangshu Guanyi	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
8	Shandong Xinhong	/	15,000	15,000	15,000	15,000	15,000	15,000	15,000
9	Yuxing Biotechnology	/	/	/	/	10,000	10,000	10,000	10,000
10	Shandong Liujiangyuan	/	/	/	/	7,500	7,500	7,500	7,500
11	Yichang Angel	/	/	/	/	N/A	N/A	N/A	N/A
12	Shandong Zhongxing	/	/	/	/	/	17,500	17,500	17,500
Others		9,000	9,000	1,000	1,000	1,000	1,000	1,000	1,000
Total		53,000	68,000	60,000	60,000	97,500	115,000	115,000	115,000

Source: CCM

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17th Floor, Huihua Commercial & Trade Building, No. 80 Xianlie Zhong Road Guangzhou,
510070, P.R.China

Website: <http://www.cnchemicals.com>

Tel: +86-20-37616606

Fax: +86-20-37616968

Email: econtact@cnchemicals.com