Chapter 2
Professor József Szejtli: The Godfather of Cyclodextrins

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Abstract Cyclodextrins, natural oligosaccharides obtained from starch by enzymatic degradation, have been discovered more than 129 years ago by the pioneering work of the French pharmacist and chemist Antoine Villiers. These molecules still fascinate researchers and industrials because they are remarkable macrocyclic molecules with major impacts in chemistry, biology, and health science.

When we look at cyclodextrin chemistry today and reflect on how it has developed over the last five decades, no other scientist has been more determining, focused, and inspiring than Professor József Szejtli. Indeed, among the list of prestigious researchers who have contributed to the development of cyclodextrins, Professor Szejtli played a fundamental role as eminent scientist and visionary. Since the mid-1950s, he has devoted his life to cyclodextrins, publishing more than 500 publications, including 106 patent applications. Professor Szejtli knew virtually everything about them. He was most likely the first to believe in the possibilities of industrial production and the multiple applications of cyclodextrins. Professor Szejtli was also an ambitious entrepreneur, creating in 1989 CycloLab Ltd., an independent company totally devoted to cyclodextrins. He is internationally recognized for his outstanding contribution to the cyclodextrin science and considered to be the "Godfather of Cyclodextrins."

This chapter is a tribute to his scientific oeuvre. Firstly, we give a general overview of his outstanding career. Secondly, we have chosen to highlight some of the important works published by Professor Szejtli in more than 50 years of career.

Keywords Tribute · Professor Szejtli · Production · Native cyclodextrins · Cyclodextrin derivatives · Structure · Inclusion complexes · Foods · Cosmetics · Chromatography · Catalysis · Biotechnology · Industry · Awards and distinctions

2.1 Introduction

Cyclodextrins, natural oligosaccharides obtained from starch by enzymatic degradation, were discovered serendipitously in 1891 by the French pharmacist Villiers (Villiers 1891; Cramer 1954; French 1957; Thoma and Stewart 1965; Caesar 1968; Szejtli 1982a; Clarke et al. 1988). However, expensive to produce, the three main native cyclodextrins, i.e., α-, β-, and γ-cyclodextrins, were long considered just laboratory curiosities (Szejtli 1998; Loftsson and Duchêne 2007; Crini 2014). Indeed, until the mid-1970s, the main obstacle was not only their price but also their presumed toxicity (French 1957). Another factor traditionally stood in the way of industrial development was the lack of sufficient knowledge of these molecules. In addition, very few researchers were convinced of the industrial potential of cyclodextrins (Szejtli 1982a; Duchêne 1987; Hedges 1998; Crini 2014; Morin-Crini et al. 2015; Crini et al. 2018).

Native cyclodextrins were only produced on an industrial scale after 1979 (Szejtli 1982a, 1988a; Duchêne 1987, 1991), and they only really took off in the 1980s with the

first applications in the chromatography, pharmaceutical, and food industries (Saenger 1980; Smolková-Keulemansová 1982; Szejtli 1982a; Uekama and Otagiri 1987; Armstrong and Jin 1989; Li and Purdy 1992; Hedges 1998; Crini 2014). With a more accurate picture of their toxicity and better understanding of molecular encapsulation, several inclusion complexes also appeared on the market in the 1980s. The introduction of cyclodextrins into pharmaceutical chemistry led to spectacular progress (Szejtli 1988a, 1998; Duchêne 1991; Uekama et al. 1994; Duchêne and Wouessidjewe 1996; Loftsson and Brewster 1996; Stella and Rajewski 1997; Irie and Uekama 1997).

Several great scientists have left their mark on the history, characterization, properties, and potential applications of these molecules (Crini 2014), e.g., Antoine Villiers from France, Franz Schardinger from Austria, Hans Pringsheim, Karl Freudenberg, Friedrich Cramer, and Wolfram Saenger from Germany, Paul Karrer from Switzerland, Dexter French, Myron L. Bender, Ronald Breslow, and Joseph Pitha from the USA, Benito Casu from Italy, and Tsuneji Nagai from Japan. The list of prestigious researchers who have contributed to the development of cyclodextrins also includes József Szejtli (Fig. 2.1), a Hungarian carbohydrate chemist.

In the mid-1950s, the young Szejtli studied chemical engineering at Technical Sciences of Budapest where he obtained his PhD in starch chemistry in 1961. He also started to study cyclodextrins but published his first results in the 1970s. In the mid-1970s, Professor Szejtli developed cyclodextrin technology in Hungary. He had many varied scientific, technological, and industrial interests in their development.

Professor Szejtli summed up his feelings in the following way: “A starch derivative can be a multifunctional auxiliary agent of real industrial significance” (Szente 1994). At that time, the nontoxicity of cyclodextrins became increasingly accepted, and several manufacturers such as Hungarian Chinoin Pharmaceutical Chemical Works, Japanese Nihon Shokukin Kako, and German Wacker Companies started to produce and to market cyclodextrins.

Professor Szejtli was most likely the first to believe in the possibilities of industrial production and the multiple applications of cyclodextrins (Szente and Fenyvesi 2016; Szente et al. 2016). He believed that cyclodextrins were “cheap, nontoxic, useful, and versatile molecules,” when nobody else believed it (Szente and Fenyvesi 2016).

Fig. 2.1 Professor József Szejtli. (Image credit: CycloLab)

At the beginning of the 1970s, the work on cyclodextrin research started in the Biochemical Research Laboratory of Chinoin. This lab became an independent unit in 1989, and then Professor Szejtli created CycloLab, a private company totally devoted to cyclodextrins. Indeed, he was not only an engineer and academic, occupying a central place in the scientific knowledge of cyclodextrin, but also an entrepreneur and businessman. In the 1980s, Professor Szejtli made an important contribution to chemistry of cyclodextrins, to the dissemination of results and in their industrial applications.

Over a period of 30 years, from 1975 to 2004, Professor Szejtli published more than 500 publications on cyclodextrins and has given more than 200 invited lectures throughout his career. In particular, numerous significant and comprehensive reviews were published on their fundamentals, properties, and applications. His name is very often cited in the bibliographic references of articles speaking of cyclodextrins.

Professor Szejtli is internationally recognized and considered as an eminent scientist and visionary, the "Godfather of Cyclodextrins" (D'Souza and Lipkowitz 1998; Loeve and Normand 2011; Crini 2014). The Professor Tsuneji Nagai designated him as "Mr. Cyclodextrin."

This chapter is a tribute to his scientific oeuvre. First, it gives a general overview of his outstanding scientific career. Then, we highlight selected important works on starch and cyclodextrins published over five decades by Professor Szejtli.

2.2 József Szejtli, 1933–2004

2.2.1 Early Years

József Szejtli was born on December 28, 1933 in Nagykanizsa, Hungary. During 1953–1962, Szejtli studied chemical engineering at the University of Technical Sciences, Budapest, where he received his M.Sc. in 1957 (chemical engineer) and his PhD in starch chemistry in 1961. He worked under the supervision of Professor János Holló, Head of the Department of Agricultural Chemical Technology. During this period, Szejtli studied the structure of starch, its hydrolysis, and the mechanism of starch-iodine reaction (Holló and Szejtli 1957a, b, c, 1958, 1959a, b, 1968; Holló et al. 1959a, b, c, 1962, 1964). At that time, the young student also studied cycloamyloses with the expectation that they would shed some light on the molecular structure of amylose helix.

2.2.2 His Scientific Career

During 1963–1964, Dr. Szejtli was a postdoctorate fellow at the Technical University of Trondheim, Norway, invited by the Royal Norwegian Academy. During this period, he pursued his studies on the hydrolysis of starch and also studied seaweed

polysaccharides (Szejtli 1965a, b, 1965c, 1966). From there, Dr. Szejtli moved to Germany, to the Institute of Nutrition of Potsdam, where he took up the position of research fellow (1965–1966). In this institute, he studied the molecular conformation of amylose and its iodine complexes in aqueous solutions (Richter and Szejtli 1966; Szejtli and Augustat 1966; Szejtli et al. 1967a, b, 1968).

"After spent considerable time in rather cold and foggy climates" (Szente 1994), Dr. Szejtli accepted in 1967 a position of professor at the University of Havana, Cuba, "a decidedly warmer venue." Dr. Szejtli often alluded to the importance of the sun to polysaccharide scientists, saying "as long as the sun shines photosynthesis will provide starch, the inexpensive raw material for polysaccharide scientists" (Szente 1994). In Cuba, Professor Szejtli worked as an advisor of the Cuban government and UNESCO expert for 3 years. At that time, he studied new polysaccharides such as chondroitin sulfate and pursued his studies on cycloamyloses-cyclodextrins, "a fascinating group of compounds with interesting industrial potentialities" (Szejtli 1982a; Szente 1994, 2004; Szente and Fenyvesi 2016).

Following this period (1967–1970), Professor Szejtli returned in Hungary as Head of Biochemical Research Laboratory at the Hungarian CHINOIN Pharmaceutical & Chemical Works. CHINOIN was one of the biggest pharmaceutical companies in Hungary and in Europe. Professor Szejtli served this position from 1971 to 1988, where he first connected universities in Hungary and harmonized the work of the Hungarian teams working on carbohydrate chemistry, enzymology, biotechnology, and technology. Professor Szejtli then connected the best scientists working on cyclodextrins around the world and developed the International Cyclodextrin Science. Its ultimate objective was to create an international cyclodextrin network.

In 1971, Professor Szejtli indeed organized the Biochemical Research Laboratory, renovated an old building, and recruited scientists (Szente 1994, 2004). One year later, Professor Szejtli started the research on polysaccharides including cyclodextrins (Fig. 2.2). This laboratory was the cradle of the Cyclodextrin Research and Development Laboratory, CycloLab Ltd., an independent research organization founded 15 years later (Szente 1994, 2004). He became the managing director of this private company with the main objective to create commercial cyclodextrin-based products from his ideas, by "maintaining a balance between academic research and industrial affairs." Professor Szejtli has acted as a scientific, innovator, inventor, and industrial at the same time (Szente and Fenyvesi 2016; Szente et al. 2016). Actually, CycloLab Ltd. is a worldwide recognized leader of cyclodextrin technology.

In the mid-1970s, Professor Szejtli published his first experimental data on cyclodextrins and also started to collaborate with several universities, research institutes, and companies. He organized the Hungarian Cyclodextrin Workshops twice a year, where the Hungarian and invited researchers could present and discuss their latest results. In 1973, he began "his crusade." Indeed, Professor Szejtli travelled extensively to convince everyone, from scientists and students to industrials, that cyclodextrins held great commercial promise. In the meantime, the first

Fig. 2.2 Professor Szejtli when he received the permission from Chinoin to establish the Biochemical Research Laboratory in 1972. (Source: CycloLab archives)

toxicological studies had established that cyclodextrin administrated orally was a harmless substance.

In 1974, an important research project on cyclodextrins was launched at CHINOIN with the support of Research Director Professor Zoltán Mészáros. In 1982, Professor Szejtli wrote: "Professor Mészáros supported this project by every means, running substantial financial risks" (Szejtli 1982a). The two main objectives of this innovative project were to produce cyclodextrins at a reasonable price and, especially, to investigate every possible field of application for cyclodextrins and their inclusion complexes. In a few years, several patents are registered (Szejtli et al. 1976, 1977a, b, c, 1978c, d, 1980c, d, e, 1981b, 1982b, 1983d, 1985a, b). At the end of the 1970s, Professor Szejtli also published his first general reviews on the potential applications of cyclodextrins (Szejtli 1977a, 1978; Szejtli et al. 1978a, b).

Realizing the exponentially increasing number of articles, chapters, and patents, Professor Szejtli organized the first International Cyclodextrin Symposium in Budapest in 1981 with participants from 17 countries. The eighth symposium was again in Budapest in 1996, organized by him. In the mid-1980s, with his English colleague Professor Pagington, Professor Szejtli founded the scientific monthly newsletter, "Cyclodextrin News" (first issue: November 1986), in order to create a source of information for everyone active in the field, from students and colleagues to industrial engineers (Szente 1994).

During 1975–2004, Professor Szejtli published plentiful experimental data on almost every field of cyclodextrin with major theoretical and practical impacts in chemistry, biology, health science, and agriculture. He knew virtually everything about them. In spring 2004, Professor Szejtli retired from his position in CycloLab but remained active in science (Fig. 2.3). He has devoted his life to cyclodextrins. József Szejtli tragically passed away on November 26, 2004.

Fig. 2.3 With Professor Nagai celebrating the birthday of Professor Szejtli (70), a few months before his death. (Source: CycloLab archives)

2.2.3 Professor Szejtli: An Entrepreneur

Professor Szejtli was really a pioneer making systematic research to answer many unanswered scientific questions about cyclodextrins and also to find new industrial applications. He was an entrepreneur. Indeed, Professor Szejtli made an important contribution in the industrial application of cyclodextrins, notably by the creation of a research lab in 1972 and a private company in 1989, CycloLab Ltd., both totally devoted to cyclodextrins: "From toy to tool with industrial interest" (Szente 1994, 2004; Szente and Fenyvesi 2016; Szente et al. 2016). CycloLab was the first private research institute for the technological transfer between cyclodextrin research and industry. CycloLab grew and evolved into a key organization in the world of cyclodextrins (Szente et al. 2016).

Without Professor Szejtli, the feasible production of cyclodextrins on an industrial scale probably would not be as advanced as it is today. At that time, there was the important question whether these substances will be available in bulk quantities at a reasonable price. Indeed, in 1975, one kilogram of β-cyclodextrin had a price of about 1500 $. At the beginning of the 1980s, cyclodextrins were produced in large quantities and "marketed at a reasonable price" (10–15 $/kg).

2.2.4 Szejtli's Scientific Oeuvre

The scientific oeuvre of Professor Szejtli is remarkable both in its variety of topics and its depth. He published an impressive number of results on cyclodextrins as author and co-author from 268 scientific papers, 184 proceedings, 106 patents, more than 100 general reviews (Table 2.1) and book chapters (Table 2.2), and 5 books (source: Cyclodextrin News Database). Professor Szejtli has given more than 200 invited lectures and regularly presented his research findings within universities and industries throughout Europe, North America, and Asia. CycloLab was also among the registered places for education of students.

Professor Szejtli has supervised numerous graduate students, postdoctoral students, and visiting scientists from various countries. During five decades, more than 20 PhD dissertations were written and defended under the supervision of Professor Szejtli.

In 1982, his first famous book entitled *Cyclodextrins and Their Inclusion Complexes* is published (Fig. 2.4), in which he reviewed the first industrial applications of cyclodextrins in pharmacy, food industry, chromatography, and chemical industry (Szejtli 1982a). In 1988, Professor Szejtli wrote another comprehensive book, *Cyclodextrin Technology*, which is still considered as a reference work in the cyclodextrin community (Szejtli 1988a).

In 1998, while traveling by plane, one of the authors, G. Crini, a French postdoctoral fellow student in Milano, Italy, under the supervision of Research Director Torri and Professor Casu, has just returned from the Ninth International Cyclodextrin Symposium organized in Spain and had the opportunity to speak with Professor Szejtli during flight. He told him: "If you want to be a future expert in cyclodextrin, write a book, not just an article." 17 years later, Crini edited his first cyclodextrin book (Morin-Crini et al. 2015).

2.2.5 Professor Szejtli and the Cyclodextrin Scientific Community

In 2004, Szente wrote: "József was a very energetic person, full of new ideas and always ready to travel the world to propagate cyclodextrin news and technologies" (Szente 2004). Indeed, Professor Szejtli gave numerous conferences and invited lectures throughout the world and was visiting professor in several universities. He was an active member of the Editorial Board of Journal of Inclusion Phenomena. In 1994, a special issue – volume 18, number 3, pp. 207–314 – was dedicated to Professor Szejtli on the occasion of his 60th birthday. His last article was also published in this journal (Fig. 2.5).

During the period 1975–1985, significant collaborations have also been put in place with Japanese, e.g., Professors Koki Horikoshi, Makoto Komiyama, Tetsuo Osa, Tsuneji Nagai, and Kaneto Uekama; English, e.g., Professor James Pagington

Table 2.1 Reviews on cyclodextrins published by Professor Szejtli

Year	Title	Journal	Reference
1977	Some application possibilities of cyclodextrins in pharmaceutical industries	*Starch-Stärke*	Szejtli (1977a)
1978	New analytical methods in chemistry of cyclodextrins	*Starch-Stärke*	Szejtli (1978)
1978	Cyclodextrin polymer	*Starch-Stärke*	Szejtli et al. (1978a)
1982	Cyclodextrins in food, cosmetics, and toiletries	*Starch-Stärke*	Szejtli (1982c)
1983	Physiological effects of cyclodextrins on plants	*Starch-Stärke*	Szejtli (1983a)
1985	Cyclodextrins: A new group of industrial basic materials	*Nahrung Food*	Szejtli (1985a)
1985	Cyclodextrins in pesticides	*Starch-Stärke*	Szejtli (1985b)
1986	Cyclodextrins in biotechnology	*Starch-Stärke*	Szejtli (1986a)
1987	Cyclodextrins and the molecular encapsulation	*Chimica Oggi*	Szejtli (1987a)
1987	Applications of cyclodextrins in the chromatography	*Starch-Stärke*	Szejtli (1987e)
1988	Cyclodextrins in diagnostics	*Kontakte*	Szejtli (1988b)
1990	Complexation of metal ions by cyclodextrins	*Starch-Stärke*	Szejtli (1990a)
1990	The cyclodextrins and their applications in biotechnology	*Carbohydrate Polymers*	Szejtli (1990b)
1992	The properties and potential uses of cyclodextrin derivatives	*Journal of Inclusion Phenomenon*	Szejtli (1992b)
1993	Fatty-acid cyclodextrin complexes: Properties and applications	*Journal of Inclusion Phenomena and Molecular Recognition in Chemistry*	Szente et al. (1993)
1994	Medicinal applications of cyclodextrins	*Medicinal Research Reviews*	Szejtli (1994)
1997	Utilization of cyclodextrins in industrial products and processes	*Journal of Materials Chemistry*	Szejtli (1997)
1998	Introduction and general overview of cyclodextrin chemistry	*Chemical Reviews*	Szejtli (1998)
1998	Non-chromatographic analytical uses of cyclodextrins	*Analyst*	Szente and Szejtli (1998)
1999	Highly soluble cyclodextrin derivatives: Chemistry, properties, and trends in development	*Advanced Drug Delivery Reviews*	Szente and Szejtli (1999)
2000	Drug/cyclodextrin/hydroxyl acid multicomponent systems. Properties and pharmaceutical applications	*Journal of Pharmaceutical Sciences*	Redenti et al. (2000)

(continued)

Table 2.1 (continued)

Year	Title	Journal	Reference
2001	Cyclodextrin complexes of salts of acidic drugs. Thermodynamic properties, structural features, and pharmaceutical applications	*Journal of Pharmaceutical Sciences*	Redenti et al. (2001)
2002	The role of cyclodextrins in chiral selective chromatography	*Trends in Analytical Chemistry*	Szejtli (2002)
2003	Cyclodextrins in the textile industry	*Starch-Stärke*	Szejtli (2003)
2004	Past, present, and future of cyclodextrin	*Pure and Applied Chemistry*	Szejtli (2004a)
2004	Cyclodextrins as food ingredients	*Trends in Food Science and Technology*	Szente and Szejtli (2004)
2005	Elimination of bitter, disgusting tastes of drugs and foods by cyclodextrins	*European Journal of Pharmaceutics and Biopharmaceutics*	Szejtli and Szente (2005)
2005	Cyclodextrin-complexed generic drugs are generally not bioequivalent with the reference products: therefore the increase in number of marketed drug/cyclodextrin formulations is so slow	*Journal of Inclusion Phenomena and Macrocyclic Chemistry*	Szejtli (2005)

and Sir James Fraser Stoddart, the "English-Connection"; Italian, e.g., Professor Benito Casu; German, e.g., Professors Wolfram Saenger and Karl-Heinz Frömming; American, e.g., Professor Josef Pitha; and French, e.g., Professors Jean-Marie Lehn and Dominique Duchêne, groups.

Professor Szejtli also worked with the industrial sector, e.g., Chiesi Farmaceutici Italy, Schwarz Pharma and Hexal Germany, as well as Novartis, Switzerland on the developments of cyclodextrin-based pharmaceutical products, e.g., Brexin® (piroxicam), Prostavasin® (alprostadil), Omebeta® (omeprazole), Xund® (garlic extract), and Voltaren® (diclofenac).

Professor Szejtli not only pioneered the scientific knowledge on cyclodextrin science and technology, but also he had outstanding merits in organizing international life in this field of research (Szejtli 1982a). In 1981, he organized the First International Cyclodextrin Symposium in Budapest, Hungary. This symposium was a great success, with participants coming from all over the world, i.e., more than 180 participants from 17 countries, while Professor Szejtli "expected 25–30 participants outside Hungary." The 63 submitted manuscripts filled a 544-page volume of proceedings published by Reidel Publishing (Szejtli 1982b). Since 1984 and Szejtli's initiative, a broad community of researchers has met every 2 years to exchange and share their works on cyclodextrins. The 20th International Cyclodextrin Symposium will be organized in Sicily, Italy in 2020.

Table 2.2 Book chapters on cyclodextrins published by Professor Szejtli

Year	Title	Book	Editor(s)	Reference
1982	Cyclodextrins in foods, cosmetics, and toiletries	*Proceedings of the First International Symposium on Cyclodextrins*	Szejtli J	Szejtli (1982b)
1983	Molecular encapsulation of drugs by cyclodextrins and congeners	*Controlled Drug Delivery*	Bruck SD	Pitha et al. (1983)
1984	Industrial applications of cyclodextrins	*Inclusion Compounds*	Atwood JL, Davies JED and MacNicol DD	Szejtli (1984b)
1984	Limits of cyclodextrin application in oral drug preparations	*Clathrate Compounds, Molecular Inclusion Phenomena, and Cyclodextrins*	Atwood JL, Davies JED and Osa T	Szejtli (1984c)
1984	Non-oral drug preparations containing cyclodextrin complexes	*Clathrate Compounds, Molecular Inclusion Phenomena, and Cyclodextrins*	Atwood JL, Davies JED and Osa T	Szente et al. (1984c)
1987	The metabolism, toxicity, and biological effects of cyclodextrins	*Cyclodextrins and their Industrial Uses*	Duchêne D	Szejtli (1987b)
1987	Cyclodextrin use in separations	*ACS Symposium Series*	ACS Publisher	Szejtli et al. (1987)
1988	Stabilization of flavors by cyclodextrins	*ACS Symposium Series*	ACS Publisher	Szente and Szejtli (1988)
1991	The use of cyclodextrins in biotechnological operations	*New Trends in Cyclodextrins and Derivatives*	Duchêne D	Szejtli (1991a)
1991	Helical and cyclic structures in starch chemistry	*Biotechnology of Amylopectin oligosaccharides*	Friedman R	Szejtli (1991c)
1992	Cyclodextrins in the resolution of environmental pollution	*Minutes of the Sixth International Symposium on Cyclodextrins*	Hedges RA	Szejtli (1992a)
1996	Historical background	*Comprehensive Supramolecular Chemistry*	Szejtli J and Osa T	Szejtli (1996a)
1996	Chemistry, physical, and biological properties of cyclodextrins	*Comprehensive Supramolecular Chemistry*	Szejtli J and Osa T	Szejtli (1996b)
1996	Inclusion of guest molecules, selectivity, and molecular recognition by cyclodextrins	*Comprehensive Supramolecular Chemistry*	Szejtli J and Osa T	Szejtli (1996c)
1996	Use of cyclodextrins in chemical products and processes	*Comprehensive Supramolecular Chemistry*	Szejtli J and Osa T	Szejtli (1996d)

(continued)

Table 2.2 (continued)

Year	Title	Book	Editor(s)	Reference
1999	Cyclodextrins as reagents in analytical chemistry and diagnostics	*Comprehensive Supramolecular Chemistry*	Szejtli J and Osa T	Hinze et al. (1999)
1996	Cyclodextrins in pesticides	*Comprehensive Supramolecular Chemistry*	Szejtli J and Osa T	Szente and Szejtli (1999)
1999	Application of cyclodextrins in nuclear waste management	*Proceedings of Ninth International Cyclodextrin Symposium*	Torres Labandeira JJ and Vila-Jato JL	Szente et al. (1999b)
1999	Sulfated cyclodextrin derivatives	*Proceedings of Ninth International Cyclodextrin Symposium*	Torres Labandeira JJ and Vila-Jato JL	Morva et al. (1999)
2004	Cyclodextrins	*Chemical and Functional Properties of Food Saccharides*	Tomasik P	Szejtli (2004b)
2004	Cyclodextrins: applications	*Encyclopedia of Supramolecular Chemistry*	Marcel Dekker	Szejtli (2004c)

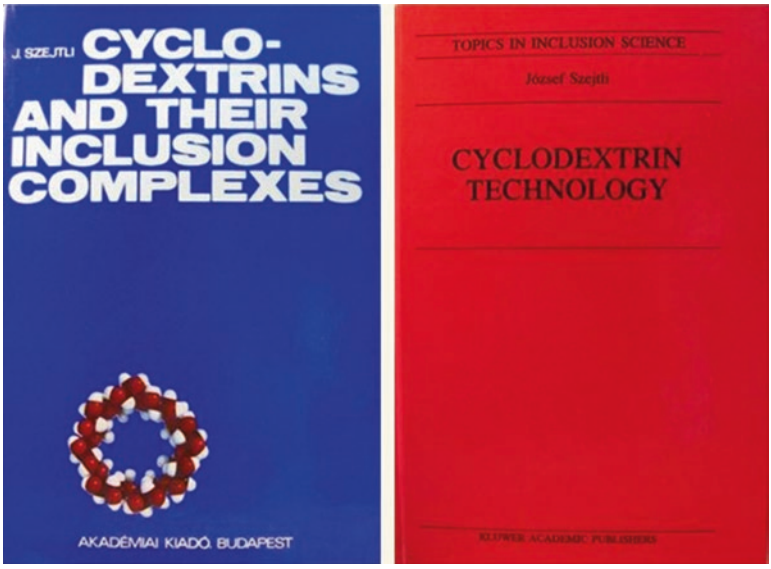

Fig. 2.4 Two books published by Professor Szejtli in 1981 (left) and in 1988 (right). (Source: CycloLab archives)

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DOI 10.1007/s10847-004-7161-z

Review Article

Cyclodextrin Complexed Generic Drugs are Generally not Bio-equivalent with the Reference Products: Therefore the Increase in Number of Marketed Drug/ Cyclodextrin Formulations is so Slow

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(Received: 28 May 2004; in final form: 2 July 2004)

Key words: advantages of complexation, approval status of CDs, bioavailability, cyclodextrin, drug, supergeneric drugs

Fig. 2.5 Extract of the last article published by Professor Szejtli. (Source: Szejtli (2005), with the permission of Springer Nature)

2.2.6 Awards and Distinctions

Professor Szejtli was a member of various academic committees and organizing boards of symposia, e.g., Cyclodextrin Symposia, Symposia on Molecular Recognition. He has received a D.Sc. degree by the Hungarian Academy of Science (1976) and has been Professor since 1980 at Kossuth L. University, Debrecen (Szente 1994). Professor Szejtli received many distinctions for his cyclodextrin research, e.g., Academic Award of Budapest (1986), Gold Medal of the Incheba of Brastislava (1988), the Moët-Hennessy Prize of Paris (1991), and the Széchenyi Prize (Budapest, 2003).

2.2.7 Szejtli Prize

At the 80th anniversary of his birth, in 2013, CycloLab established the Szejtli Prize (Fig. 2.6) to preserve his legacy, keep his memory alive, and recognize his groundbreaking achievements in the area of cyclodextrin research, development, and commercialization of related technologies. This prize aimed to award young researchers demonstrating outstanding results in the cyclodextrin science and technology. It is presented biennially during the International Cyclodextrin Symposium.

The first award was assigned in 2014 to Professor Keiichi Motoyama, Kumamoto University, Japan, in Saarbrücken, at the 17th International Cyclodextrin Symposium for his works in the design of new active pharmaceutical ingredients as anticancer agents. The winner of Szejtli Prize 2016 was Professor Tamer Uyar, Bilkent University, Turkey, for his studies on electrospinning of functional nanofibers with cyclodextrins. In 2018, Dr. Nicolas Blanchemain, University of Lille, France, received the award for his works in the applications of cyclodextrins in biomedicine.

Fig. 2.6 The József Szejtli medal. (Source: CycloLab)

With the ceremony at the International Cyclodextrin Symposia, the CycloLab's team hopes to keep Professor Szejtli in memory for long.

2.3 Szejtli's Scientific Achievements

2.3.1 Early Work in Starch

The young student Szejtli first concentrated on the field of starch chemistry at the University of Technical Sciences, Budapest, between 1957 and 1963, working under the supervision of Professor János Holló. Szejtli studied the structure and conformation of the two components of starch, i.e., amylopectin and amylose. With Professor Holló, Szejtli proposed a new "helical-segment theory" to characterize the possible conformations of amylose in aqueous solution.

The most characteristic feature of starch known for long was its blue color on contacting with iodine. It was well-known that amylopectin was of highly branched structure and gave a violet-red (or brown-red) color with iodine, while blue coloring with iodine occurred only in amylose which consisted of glucose with bonds α-1,4, a linear polymer without branched structure. However, there was a debate on the mechanism of the reaction, i.e., a phenomenon due to adsorption and aggregation or due to the formation of complexes. In addition, at that time, the studies on the conformation of amylose were even marred by hot debate between the different laboratories (Szejtli 1969).

Three "schools of thought" were established (Fig. 2.7): that describing the conformation using a rigid, rod-like helical form, that describing the conformation using a segmented flexible coil-like helical structure, and that describing a random coil (Szejtli 1969). Many studies were also conducted on the retrogradation of amylose from different origins, and this has also remained a subject of debate (Kainuma 1984).

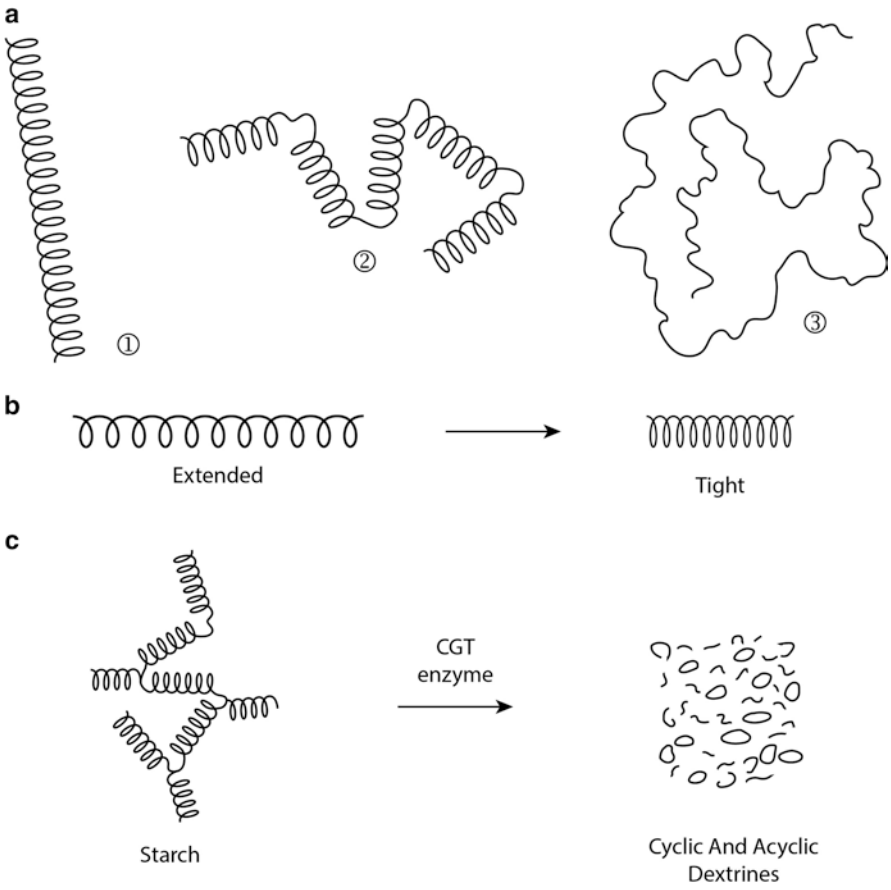

Fig. 2.7 (**a**): The rigid, rod-like helix (1), the segmented flexible coil-like helical structure (2), the random coil (3); (**b**) the extended helix is contracted to a tight-helix upon inclusion complex formation with iodine; and (**c**) degradation of starch to a mixture of cyclic and acyclic dextrins by cyclodextrin-glycosyl-transferase enzyme. (Adapted from Szejtli 1971, 1975, 1982a)

Holló and Szejtli (1957a, b, c, 1958), studying the mechanism of starch-iodine reaction, were among the first to propose that amylose existed as a helix in aqueous solutions. Their conclusions were based on amperometric titration (an innovative method at that time), streaming dichroism (amylose-iodine complex in solution caused dichroism), and on the viscosity studies of amylose. Holló and Szejtli showed that the amylose molecule dissolved in water was not linear and had a structure similar to some helix, in which helical segments were connected by disordered segments. The extended helix was contracted to a tight helix upon inclusion complex formation with iodine (Fig. 2.7). The viscosity remained unchanged until amylose became saturated with iodine but increased thereafter. In the complex formed with iodine, iodine was bound by hydrogen bonds (Holló and Szejtli 1957c). This

was in disagreement with the "theory of physical solution," i.e., a physical solution occurred when iodine dissolved in the helices as in hydrocarbons (Kainuma 1984).

At that time, the young student also studied the formation of cycloamyloses-cyclodextrins with the expectation that they would shed some light on the molecular structure of amylose. Indeed, for him, the degradation of starch to a mixture of cyclic and acyclic dextrins (Fig. 2.7) by the action of *Bacillus macerans* was an interesting reaction in the elaboration of a possible interpretation of the amylose conformation. This was a first step closer to cycloamyloses-cyclodextrins. Later, Professor Szejtli clearly demonstrated that the formation of cyclodextrins, catalyzed by cyclodextrin-glycosyl-transferase enzyme, delivered further proof for the helical structure of amylose (Szejtli 1971, 1991c).

At the end of the 1960s, Szejtli investigated the hydrolysis of starch (Holló and Szejtli 1959a, b), retrogradation of amylose (Holló et al. 1959a, b, c), and mechanism of the gelatinization of potato starch by measuring the amount of the adsorption of iodine and the polarographic maxima suppression power and by the measurement of the light permeability of the suspension (Holló et al. 1962, 1964; Szejtli 1963).

The results showed that the hydrolysis reaction was the resultant of two simultaneously occurring processes, the splitting of the terminal and of nonterminal bonds. The velocity of retrogradation decreased with increasing temperature and potato amylose containing one to two ramifications per molecule aged less rapidly than wheat amylose containing no ramification. The mechanism consisted of three stages: (1) the randomly linked helices were stretched by an intake of energy; (2) after losing their hydrate water hulls, the chains arranged themselves one after the other; and (3) a crystalline structure was formed due to the formation of hydrogen bonds between the hydroxyls of amylose.

At the Technical University of Trondheim, Dr. Szejtli pursued his studies on the characterization of structure and hydrolysis of starch (Szejtli 1965a). He also studied the hydrolysis of other polysaccharides such as dextran (Szejtli 1965b) and alginic acid (Szejtli 1965c). He highlighted a relation between the composition and the IR spectra of polysaccharides of different origins (Szejtli 1966).

During his postdoctoral stay at Potsdam, Dr. Szejtli continued to study the molecular configuration of amylose and its complexes in aqueous solutions (Richter and Szejtli 1966; Szejtli and Augustat 1966; Szejtli et al. 1967a, b, 1968). Studying the amylose-iodine complex at low pH (Fig. 2.8), Dr. Szejtli demonstrated that helices existed in segments and pointed out the fact that the stability of the complexes was dependent on the length of the polyiodide chains, and this length is dependent on the degree of polymerization of amylose (Szejtli et al. 1967a). A value of 100–200 for the chain length was the limit where the rigid linear helix was replaced by a flexible segmented coil form (Szejtli and Augustat 1966; Szejtli et al. 1967a). Other factors, such as temperature, pH, and concentration of iodide and starch, were also important (Szejtli et al. 1967b). For the first time, Dr. Szejtli suggested the host-guest complexes with amylose helix: this was another step closer to cycloamyloses-cyclodextrins.

Molecular Configuration of Amylose and Its Complexes in Aqueous Solutions. Part II. Relation between the DP of Helical Segments of the Amylose–Iodine Complex and the Equilibrium Concentration of Free Iodine

J. SZEJTLI,* M. RICHTER, and S. AUGUSTAT,
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Fig. 2.8 Extract of the article published by Professor Szejtli where he described the interaction between amylose helix and the "guest" substrates. (Source: CycloLab archives)

Fig. 2.9 Profesor Szejtli referring to the *Comandante* Fidel Castro, University of Havana, Cuba, 1970. (Source: CycloLab archives)

At the end of the 1960s, Professor Szejtli summarized all the results on the structure and conformation of amylose and on the reaction of starch with iodine in three comprehensive reviews (Holló and Szejtli 1968; Szejtli 1969, 1971) that were reference works. In particular, he pointed out an interesting relationship between the conformation of the glucopyranoside units and the molecular configuration of amylose, in agreement with the results published by his colleague and friend Professor Casu (Szejtli 1971).

During his position at the University of Havana (Cuba), Professor Szejtli presented his innovative data on polysaccharides to the *Comandante* Fidel Castro (Fig. 2.9). Professor Szejtli then turned exclusively to the cyclodextrins from the

1970s onward. Indeed, after his return in Hungary, he initiated a comprehensive cyclodextrin research and development.

2.3.2 *Fields of Research on Cyclodextrins Studied by Professor Szejtli*

During more than 30 years, Professor Szejtli and his collaborators have written an abundant literature on all the topics related to cyclodextrins as reported in Table 2.3. His works were spread across different disciplines: chemistry, biochemistry, biology, health science, agriculture, environmental sciences, etc. With his results, cyclodextrins have broken barriers between different disciplines.

In the 1970s, Professor Szejtli first focused on the fundamental aspects of native and modified cyclodextrins. He studied their preparation and production at industrial scale, their description and characterization, their structure and properties, and also their solution and solid-state behavior.

Professor Szejtli, investigating in details the complex-forming capacities of cyclodextrins toward a large range of substances, demonstrated that these remarkable encapsulation properties can modify and/or improve the physical, chemical, and/or biological characteristics of the guest molecule, in agreement with the previous conclusions published by Professors Freudenberg, French, and Cramer (Crini 2014). Professor Szejtli also studied various methods for the preparation of cyclodextrin complexes and used various techniques for their characterization.

At the same time, Professor Szejtli also turned his attention to the practical aspects of these molecules. His objective was to find applications in all sectors of industry (Fig. 2.10). With his collaborators, he published numerous patents during the period 1975–1985. Rapidly, his research on cyclodextrins was very active in fields such as chromatography and analytical chemistry, food and cosmetic industries, pharmacy, agrochemistry, catalysis, enzymology, and environmental chemistry.

During the period 1975–1990, Professor Szejtli used cyclodextrins as host molecules for separation and molecular recognition, e.g., separating agents of racemic mixtures or in chiral resolution of enantiomers, as analytical reagents for chemistry and diagnostics, as solubilizing agents for lipophilic drugs, as excipients in formulation pharmaceutical development for stabilization, as capsules for molecular entrapments, as promoters or catalysts of different reactions, as multifunctional ingredients and complexing agents in food applications, as active agents for masking of undesired odor and taste, as plant growth regulators, and as complexing agents for purification purposes or pollutant removal.

Professor Szejtli claimed that the majority of these applications were based on the ability to form inclusion complexes. In 1987, he wrote: “Cyclodextrins can be considered as a new group of industrial basic materials, thanks to the constantly broadening versatility of their applications” (Szejtli 1987a).

Table 2.3 Selected works on cyclodextrins published by Professor Szejtli during the period 1975–2005

General topic	References
Native cyclodextrins	Szejtli (1978, 1982a, 1985a, 1996a, b, c, d, 1998, László et al. (1980, 1981), Neumarkt and Szejtli (1980), Dalla Bella and Szejtli (1983), Kajtár et al. (1989), Szejtli and Osa (1996), Szente et al. (1998a), Fenyvesi et al. (1999a)
History	
Preparation, industrial production	
Technology of conversion	
Structure, structural aspects	
Characterization, analytical chemistry, spectroscopy	
Physical and chemical properties	
Chemical reactivity	
Biological properties	
Inclusion complexes	
Aggregation	
Large cyclodextrins	
Inclusion compounds	Szejtli and Bánky-Elöd (1975a, b), Szejtli (1977b, 1980, 1982a, 1987a, 1990a, 1991b, 1996b, c), Szejtli and Budai (1977); Szejtli et al. (1978b, 1980a, 1981a, 1982a, 1983a, b), Szejtli and Budai (1979), Szejtli and Szente (1979), Szejtli and Bolla (1980), Budai and Szejtli (1981), Paal and Szejtli (1981), Szejtli and Szente (1981), Szente and Szejtli (1981), Pobozsny et al. (1981), Buvari et al. (1982), Daruhazi et al. (1982), Kajtár et al. (1982), Darwish et al. (1984), Habon et al. (1984a), Szemán et al. (1987a), Tetenyi and Szejtli (1984), Lopata et al. (1985), Stadler-Szöke et al. (1985), Furo et al. (1986), Bajor et al. (1988), Fenyvesi et al. (1988, 1999a), Suzuki et al. (1989, 1994), Kato et al. (1992, 1993, 1994), Kralova et al. (1992), Csabai et al. (1993, 1998), Redenti et al. (1994, 2000, 2001), Cserháti et al. (1996), Szente et al. (1998b, 1999a), Szejtli (1996a, b), Kolbe et al. (2002)
History	
Preparation	
Properties	
Characterization	
Structures in the crystalline state	
Spectroscopy	
Types of guest molecules	
Complexation effects in solution	
Inclusion effects in solid state	
Complex equilibria	

(continued)

Table 2.3 (continued)

General topic	References
Modified cyclodextrins and derivatives	Szejtli et al. (1978a, 1980a, e), Szejtli (1996c), Fenyvesi et al. (1982), Otta et al. (1982), Gerlóczy et al. (1983), Kandra et al. (1984), Suzuki et al. (1984), Szejtli (1983b, 1984a, 1992b), Szejtli and Kandra (1987), Szemán et al. (1987a, b, 1996), Fenichel et al. (1988), Otta et al. (1988), Szurmai et al. (1990), Jicsinsky and Szejtli (1992), Novák et al. (1993), Morva et al. (1999), Szente and Szejtli (1999), Lipták et al. (2001, 2002), Buchanan et al. (2002, 2004)
Preparation, characterization	
Properties, inclusion complexes	
Inclusion effects	
Substituted derivatives	
Cyclodextrin polymers	
Grafted polymers	
Organometallic compounds	
Fluorescent cyclodextrins	
Hydrogels/gels, beads, membranes	
Crown ethers	
Toxicology	Szejtli and Budai (1976), Szejtli and Sebestyén (1979), Szejtli et al. (1980b), Jodál et al. (1982, 1984), Gerlóczy et al. (1984, 1985, 1996), Szejtli (1987b, 1998, 1996b, 2004a, b), Verstichel et al. (2004)
Toxicity	
Biochemistry	
Degradation	
Biodegradability	
Chromatography	Zsadon et al. (1978, 1979a, 1979b, 1979c, 1981, 1983), Cserháti et al. (1983a, b, 1984, 1988, 1990a, b, 1995), Szejtli (1986b, 1987e, 2002), Szejtli et al. (1987), Alexander et al. (1988), Juvancz et al. (1988), Ujházy et al. (1988, 1989), Takeoka et al. (1990), Szemán et al. (1996, 2002), Juvancz and Szejtli (1999, 2002), Süvegh et al. (1992), Iványi et al. (2004)
Paper and thin-layer chromatography	
Gel inclusion	
Liquid chromatography	
Affinity chromatography	
Gas chromatography	
Electrophoresis	
Chemistry	Szejtli (1984b, 1986b, 1988a, 1995, 1996, 1996c, d, 1997, 2004a), Szente et al. (1987), Bakó et al. (1988, 1994), Szente and Szejtli (1998), Hinze et al. (1999)
Analytical chemistry	
Catalysis	
Stereoselective reactions	
Polymer science	
Green chemistry	
Click chemistry	

(continued)

Table 2.3 (continued)

General topic	References
Food	Szejtli et al. (1977a, 1979a, b, 1980d), Lindner et al. (1981), Szejtli (1982b, 1982c, 1984b, 2004b), Szente and Szejtli (1986, 1987a, b, 1988, 2004), Weiszfeiler and Szejtli (1988), Szente et al. (1988, 1992, 1993), Szejtli and Szente (2005)
Nutrition	
Flavors	
Aromas	
Packaging	
Tea aromatization	
Pharmacy	Szejtli (1977a, 1981, 1984c, 2004a, 2005), Szejtli et al. (1980f), Fenyvesi et al. (1984a, b, c, d, 1996a, 1999c), Habon et al. (1984b), Stadler-Szöke et al. (1984), Szente et al. (1984a, b, c, 1985), Vikmon et al. (1985, 1988, 1999), Szemán et al. (1987a, b), Weiszfeiler et al. (1988), Frömming and Szejtli (1994), Gerlóczy et al. (1999), Klokkers et al. (1999), Geczy et al. (2000), Szejtli and Szente (2005)
Drug types, drug formulation, drug-cyclodextrin complexes	
Drug delivery, controlled release of drugs	
Excipients, auxiliary substances	
Biological effects of cyclodextrins	
Limits of utilization of cyclodextrins	
Biotechnology	Szejtli (1984b, 1986a, 1989, 1990b, 1991a)
Enzymology	
Enzyme technology	
Cosmetics and toiletry	Szejtli and Szente (1979), Szejtli (1982b, c), Fenyvesi et al. (1999b, 2004)
Hygiene and personal care	
Fragrances	
Essential oils	
UV filters	
Environmental chemistry	Olah et al. (1988), Szejtli (1992a), Fenyvesi et al. (1996b, c, 2002), Molnár et al. (1999, 2002, 2005), Szente et al. (1999b), Fava et al. (2002)
Removal or enrichment of components	
Remediation	
Soil decontamination	
Wastewater treatment	
Textiles	Szejtli (1984b, 1998, 2003)
Fiber modification	
Cosmeto-textiles	

(continued)

Table 2.3 (continued)

General topic	References
Medicine	Gál-Füzy et al. (1984), Szejtli et al. (1986), Felméray et al. (1996), Szejtli (1994)
Biomedicine	
Wound healing	
Cell biology	
Agriculture and agrochemistry	Szejtli and Tétényi (1981), Szente and Szejtli (1981, 1999), Szejtli (1983a, 1985b, 1988a, c, 1996b), Szejtli et al. (1983c), Szente et al. (1990)
Physiological effects	
Pesticides	
Miscellaneous	Szejtli et al. (1980c), Bujtas et al. (1987), Szejtli (1987c, d, 1988b), Szogyi et al. (1987), Cserháti et al. (1992), Fenyvesi et al. (1992), Buchanan et al. (2001), Cserháti and Szejtli (1992)
Plastics	
Tobacco products	
Animal feeds	
Cyclodextrins in diagnostics	
Supramolecular chemistry	
Nanotechnology	
Tensides, detergents, surfactants	

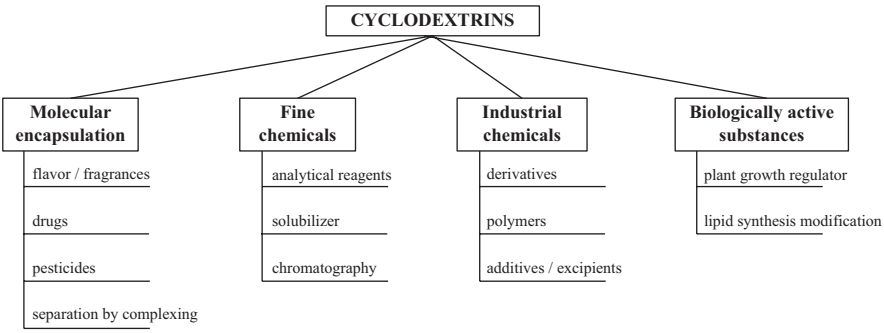

Fig. 2.10 Fields of potential applications of cyclodextrins according to Professor Szejtli. (Adapted from Szejtli 1982a, c)

Professor Szejtli was also a visionary. Since the mid-1980s, he suggested new potential markets for cyclodextrins, e.g., in biotechnology (Szejtli 1985a, 1986a, 1990b, 1991a), agriculture (Szejtli 1985b), fibers (Szejtli 1988a), and medicine (Szejtli 1988b, 1994). During the period 1990–2000, he also proposed to use cyclodextrins as active compounds in functionalized textiles, as encapsulating agents for

antioxidants, flavors, and aromas, as components of artificial enzymatic systems, as drug delivery vehicles, and as vectorizing agents.

In 2004, Professor Szejtli wrote: "The actual and potential uses of cyclodextrins in products and technologies seem to be inexhaustible" (Szejtli 2004c). Using his own results, Professor Szejtli claimed that cyclodextrins might play a significant role in cosmeto-textiles (Szejtli 2003, 2004a), functional food and therapeutic products (Szejtli 2004b), agrochemistry (Szejtli 2004a), environmental protection, i.e., in terms of removal of pollutants present in all environmental compartments, soils, waters, and air, and in other domains such as cell biology, formulation of detergents, glues and adhesives, packaging, nanotechnology, and sensors (Szejtli 2004a, c).

Professor Szejtli was among the first to introduce the concept of cyclodextrins as active and smart molecules rather than complexing molecules with expected applications in textiles, e.g., "intelligent" materials loaded with biologically active substances such as drugs, insect repellents, and antimicrobial agents, in biotechnology, e.g., biotransformation and fermentation processing, protein and peptide delivery, and vaccine production, and in cell biology (Szejtli et al. 1980i, 1982b; Szejtli 1990b, 2003).

2.4 Selected Highlights in Szejtli's Fundamentals Works

2.4.1 Historical Review

In 1957, Professor Dexter French published "the first historical survey illustrating the metamorphosis of the Schardinger dextrins" (French 1957). In this review, Dexter divided the history of Schardinger dextrins/cycloamyloses into two general periods, the discovery, between 1891 and 1935, and their maturity from 1935 to 1950. Historical milestones on cyclodextrins were also published by Thoma and Stewart (1965), Caesar (1968), and Clarke et al. (1988).

In 1998, the famous journal *Chemical Reviews* published a special issue devoted to cyclodextrins. It contained 13 chapters and is still a reference today, including the excellent introductory review by Professor Szejtli. In this paper, Professor Szejtli pursued the history of cyclodextrins written by Professor French, which was also updated 9 and 16 years later by Loftsson and Duchêne (2007) and Crini (2014), respectively.

The history as written by Professor Szejtli was divided into three major periods (Szejtli 1998): discovery 1891–1935, exploration 1935–1970, and utilization 1970 to the present day (Fig. 2.11). In the first 45 years about 50, in the second period (~35 years) about 2000, and in the third period (during the last 27 years) about 13,000 cyclodextrin-related publications have been published.

In this well-cited review (Szejtli 1998), Professor Szejtli, pointing out the misinformation on the toxicity of cyclodextrins reported by Professor French in 1957,

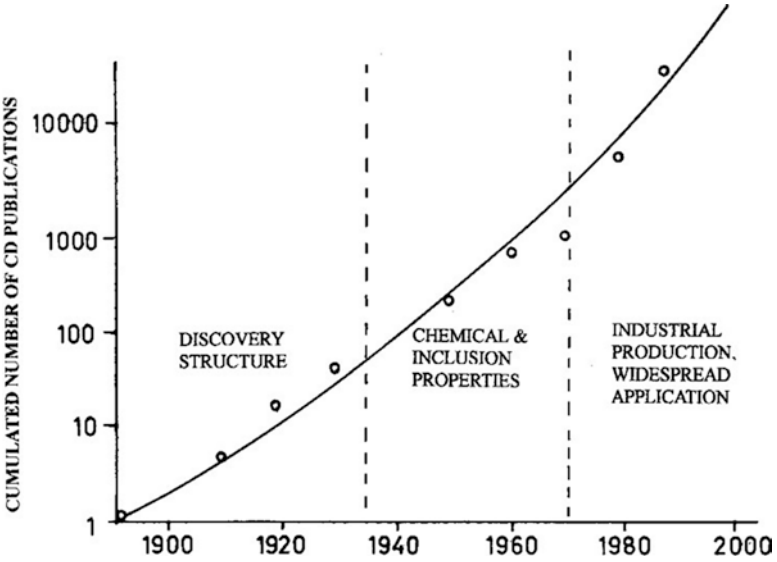

Fig. 2.11 The three stages in the development of cyclodextrin technology according to Professor Szejtli in 1998. (Source: CycloLab archives)

wrote: "Cyclodextrins can be consumed by humans as ingredients of drugs, foods, or cosmetics."

2.4.2 Preparation and Chemistry of Cyclodextrins

In the mid-1970s, Professor Szejtli showed that cyclodextrins can be produced at industrial scale by a relatively simple technology by fermentation of starch (Szejtli 1982a, 1988a), in agreement with the previous results published in the laboratory scale by Professors Freudenberg, Cramer, and French (Crini 2014). This was interesting because, at that time, cyclodextrins still remained as laboratory curiosities and were extremely expensive.

The method of preparation of β-cyclodextrin, illustrated in Fig. 2.12, was detailed in his second book (Szejtli 1988a). In the first step of cyclodextrin production, starch was liquefied at elevated temperatures. It was hydrolyzed to an optimum degree in order to reduce the viscosity of such fairly concentrated (around 30% dry weight) starch solution. After cooling the solution to optimum temperature, the cyclodextrin-glucosyl-transferase enzyme was added. The purification of the enzyme was made by affinity chromatography. In the solvent technology (Fig. 2.12), an appropriate complex-forming agent was added to the conversion mixture. If toluene was added to this system, the toluene/β-cyclodextrin complex formed was separated immediately, and the conversion was shifted toward β-cyclodextrin formation.

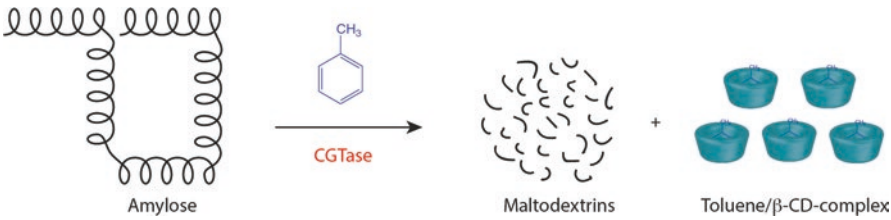

Fig. 2.12 Production of β-cyclodextrin. (Adapted from Szejtli 1988a)

If n-decanol was added to the conversion mixture, α-cyclodextrin was mainly produced, whereas with cyclohexadecenol, γ-cyclodextrin was the main product. The insoluble complexes were then filtered from the conversion mixture. The solvents were removed by distillation or extraction. The aqueous solutions obtained after removing the complexing solvent was treated with activated carbons and filtered. Cyclodextrins were finally separated from this solution by crystallization and filtration. The homogeneity and chemical purity of the industrially produced cyclodextrins exceeded 99% (Szejtli 1988a).

Rapidly, the works of Professor Szejtli not only on the production of cyclodextrins but also on their fundamentals and chemistry were acknowledged to have made an important contribution. Using his great experience on starch chemistry (Szejtli and Augustat 1966; Szejtli et al. 1967a, b, 1968) and the previous conclusions reported by Professor French and Professor Casu on the correlations between the structures of amyloses and cycloamyloses (see Crini 2014), Professor Szejtli summarized and discussed in details the steric structures of amylose and cyclodextrins (Szejtli 1969, 1971).

For a better understanding of their conformational analysis, Professor Szejtli first studied the conformation of dextrins, in particular disaccharides, e.g., maltose and cellobiose. In the maltose, the two D-glucopyranose units were linked by α-1,4 glucosidic linkage, while a β-1,4 glucosidic linkage between them resulted in cellobiose. For the calculation of the favored conformation of a disaccharide, Professor Szejtli pointed out rotations around the glycosidic (or anomeric) bonds linking the two units (dihedral angles ϕ and ψ) and the bond angle of the glycosidic oxygen atom (θ); see Fig. 2.13. It became evident that, owing to hindered rotation, for a given disaccharide, the angles have preferred values. Only the *cis* and the *trans* conformations can exist. Repeating the *cis* conformation resulted in a helical structure, e.g., for maltose, while the *trans* conformation led to a zigzag chain, e.g., for cellobiose. Later, all these results were used in the characterization of the conformational analysis of cyclodextrins and their complexes (Szejtli and Bánky-Elöd 1975a, b; Szejtli and Budai 1976; Szejtli 1977a, b, 1978).

In his various reviews, Professor Szejtli described the particular structure of cyclodextrins. The ring shape of cyclodextrins was a consequence of the C-1 conformation of the glucopyranose subunits and their α-1,4-type glycosidic linkages, in agreement with the conclusions described by Professor Casu (Crini 2014). The same structural units were found in starch.

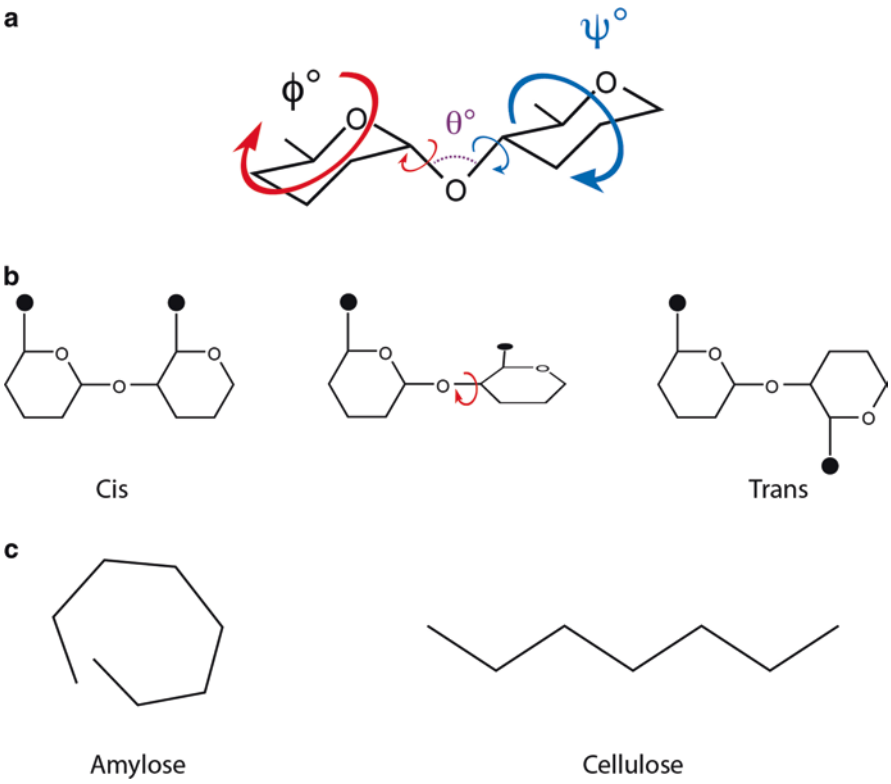

Fig. 2.13 (**a**): The ϕ, ψ-linkage conformation of disaccharides (rotation around the glycosidic bond); (**b**), the most important relative positions of the two-ring planes (only the *cis* and the *trans* conformations can exist); and (**c**), the structure of amylose and cellulose (repeating the *cis* conformation, i.e., maltose, results in a helical structure, while the *trans* conformation, i.e., cellobiose, leads to a zigzag chain. (Adapted from Szejtli et al. 1982a)

As a consequence of the C-1 conformation of the glucopyranose units, all secondary hydroxyl groups were situated on one of the two edges of the ring, whereas all the primary ones were placed on the other edge. The cavity, composed of several glucose units, was lined by the hydrogen atoms and the glycosidic oxygen bridges, respectively. The nonbonding electron pairs of the glycosidic oxygen bridges were directed toward the inside of the cavity producing there a high electron density and lending it some Lewis-base character. A schematic representation of a "cyclodextrin capsule" is reported in Fig. 2.14.

Like Professor French, Professor Szejtli pointed out the fact that a cyclodextrin molecule should be regarded rather as a truncated cone than a cylinder. The core of this structure can trap or encapsulate other substances (Szejtli 1995). Figure 2.15 illustrates the hydrophilic and hydrophobic regions of cyclodextrins.

Using the results of Professor Casu on the chemical structure of cyclodextrins obtained from infrared and NMR experiments, Professor Szejtli also indicated that

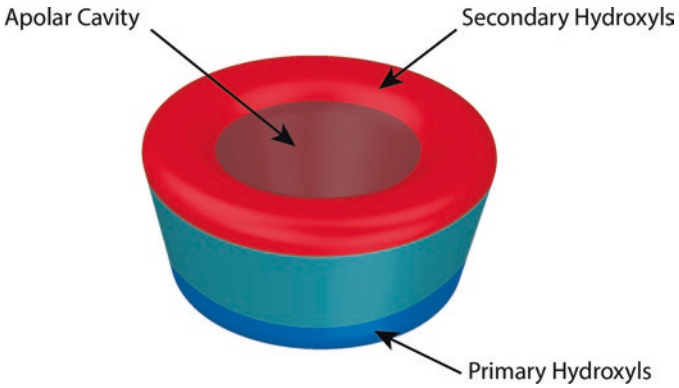

Fig. 2.14 Schematic representation of a cyclodextrin "capsule" or "torus": on the side where the secondary hydroxyl groups are situated, the diameter of the cavity is larger than on the side with the primary hydroxyl groups, since free rotation of the latter reduce the effective diameter of the cavity; rhe lining of the internal cavity is formed by hydrogen atoms and glucosidic oxygen-bridge atoms; therefore this surface is slightly apolar. (Adapted from Szejtli 1978)

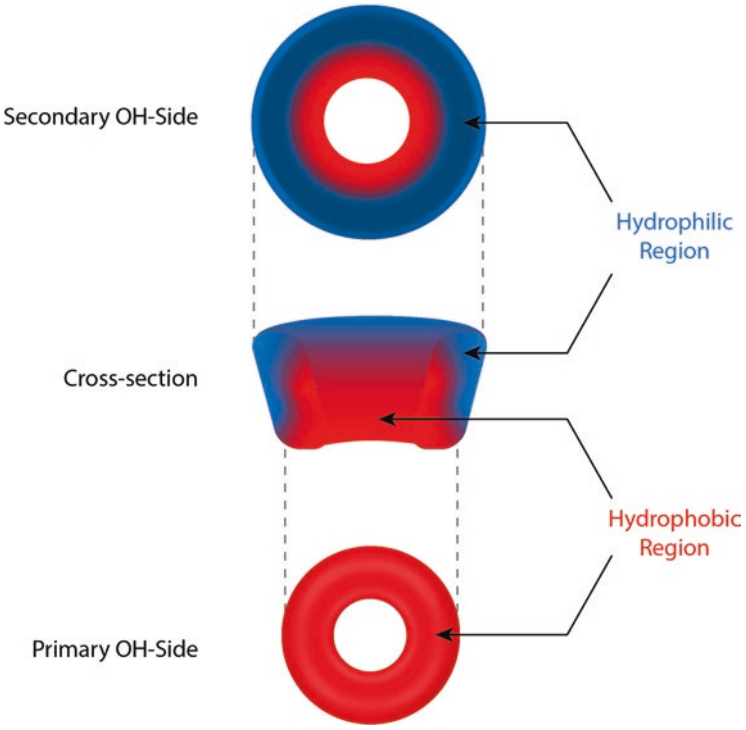

Fig. 2.15 Schematic representation of the hydrophilic and hydrophobic regions of cyclodextrins. (Adapted from Szejtli 2004a)

the structure of cyclodextrins was stabilized by the formation of hydrogen bond between C-2 and C-3 hydroxyl groups of adjacent glucose units. This phenomenon widely affected, in addition to molecular dimensions, the water solubility of cyclodextrins. The formation of a complete ring of intramolecular hydrogen bonds in β-cyclodextrin counteracted its hydration and reduced its solubility as compared to other native cyclodextrins (Szejtli 1978, 1982a, 1995).

2.4.3 Types, Formation, and Structures of Inclusion Complexes

Development of the optimal technology of producing crystalline cyclodextrin inclusion complexes required a knowledge of the crystallization process. However, the literature contained little information concerning crystallization temperatures and other parameters such as pH, concentration, and cooling rate (Saenger 1984; Connors 1997).

In 1977, Professor Szejtli studied the influence of the conditions of crystallization in such a way that the guest molecule was added to a cyclodextrin solution warmed to 60 °C (Szejtli and Budai 1977). Under vigorous stirring the solution was then gradually cooled at a rate of 0.3–0.4 °C/min, and the turbidity was recorded as a function of temperature. His results clearly showed that both cyclodextrin and the guest molecule produced well-defined individual turbidity curves from which it was possible to determine the temperature at which the crystallization started. If the crystallization temperature of the mixture differed from that characteristics of pure β-cyclodextrin under the given circumstances, the formation of an inclusion complex was probable.

The same year, Professor Szejtli studied the interaction of hydrochloric acid with β-cyclodextrin. This work was the first to report adequate kinetic data and activation parameters (Szejtli 1977b). The results showed that the first-order rate constant for the hydrochloric acid-catalyzed degradation of β-cyclodextrin increased during the reaction because the α-1,4-bonds present in the macrocycle and in linear dextrins, i.e., formed by opening of the macrocycles, were split at different rates. The activation energy for hydrolysis of the glycosidic bond of maltose was 30.5 kcal/mole, while the opening of the cyclodextrin ring was characterized with a value of 34.2 kcal/mol. At lower temperatures and higher hydrochloric acid concentrations, a rather stable crystalline acid-cyclodextrin complex was formed with excellent yield (Fig. 2.16). This complex contained 1.8 molecules of hydrochloric acid per cyclodextrin unit. After storage at room temperature for 1 year, it still retained 1 mole of hydrochloric acid, and storing the product in sealed vials for 1 year led to no change in the composition. The complex was adequate for preparing tablets for supply of gastric acid (Szejtli and Budai 1976, 1977, 1979; Szejtli 1977b). Professor Szejtli also proposed new analytical methods such as thin-layer chromatography in chemistry of cyclodextrins (Szejtli 1978).

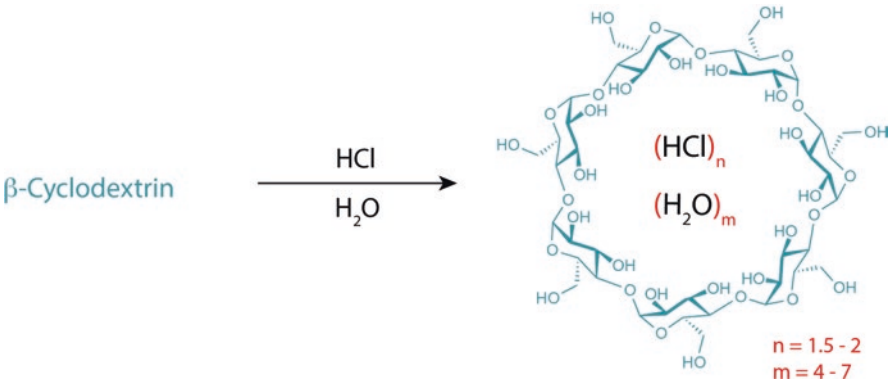

Fig. 2.16 Structure of the β-cyclodextrin-HCl complex proposed by Professor Szejtli. (Adapted from Szejtli et al. 1977b)

In the 1980s, Professor Szejtli pointed out the fact the preparation of cyclodextrin inclusion complexes was simple. Their preparation and characterization were detailed in his two books (Szejtli 1982a, 1988a). Professor Szejtli wrote: "No universal method exists for the preparation of cyclodextrin complexes; the method has to be tailor made for the guest and for the requirements: whether small-scale laboratory preparation or large-scale industrial production" (Szejtli 1982a).

The complexation was performed in homogeneous solution, or in suspension, under pressure, or by simple mixing of the components. The most common procedure was to shake an aqueous solution of cyclodextrin (cold or warm, neutral or acidic) with the guest substance or its solution (Szejtli 1987a). Water can be removed by freeze-drying or spray drying. Other methods such as kneading, slurry complexation, filtration, or heating method were also used in the formation of cyclodextrin complexes (Szejtli 1995).

To prove the formation of an inclusion complex, various methods were used, e.g., circular dichroism (Szejtli 1978, 1983b), spectroscopy optical rotatory dispersion (Szejtli 1978), powder X-ray diffraction (Szejtli 1977b, 1978), polarography (Daruhazi et al. 1982, Szejtli 1982a), thin-layer chromatography (Szejtli 1978, 1982b), gas chromatography (Szejtli 1982c), UV-visible spectroscopy (Szejtli et al. 1978b), nuclear magnetic resonance spectroscopy (Szejtli 1983b), infrared spectroscopy (Szejtli et al. 1978b), thermoanalysis (Szejtli 1978), mass spectrometry (Szejtli 1977a, b), and differential scanning calorimetry (Novák et al. 1993).

For instance, mass spectrometric investigations proved that from a mixture of (*O*,*O*-dimethyl *O*-(2,2-dichlorovinyl)-phosphate with β-cyclodextrin, this insecticide was completely evaporated between 50 and 120 °C, i.e., before the beginning of the decomposition of cyclodextrin. In the mass spectrum of the insecticide-cyclodextrin complex, the peaks characteristics of (*O*,*O*-dimethyl *O*-(2,2-dichlorovinyl)-phosphate appeared only above 200 °C, simultaneously with the degradation products of β-cyclodextrin, demonstrating that the insecticide was bound in the complex.

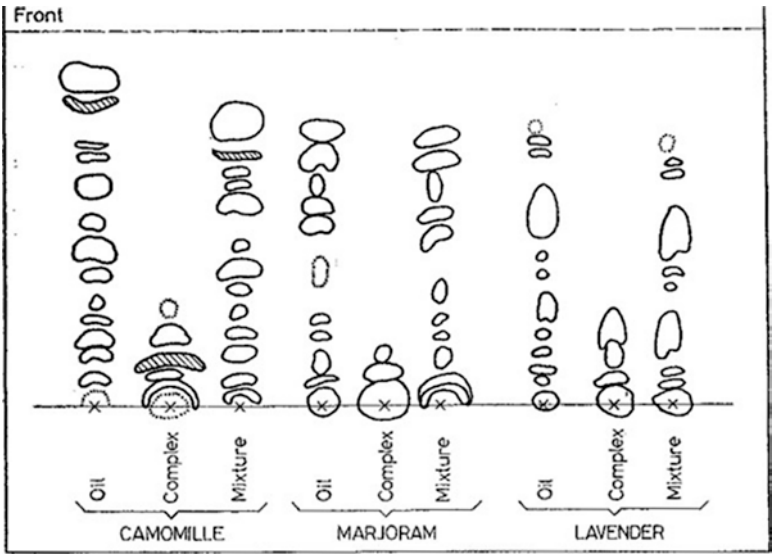

Fig. 2.17 Thin-layer chromatograms of essential oils and their mechanical mixtures and complexes with β-cyclodextrin performed by Professor Szejtli in 1978. (Source: CycloLab archives)

Figure 2.17 shows another example (Szejtli 1978). Thin-layer chromatography was useful for the verification of complex formation since this method altered the retardation factor values considerably. The values were strongly diminished, demonstrating that the complex was sufficiently stable in the solvent mixture used. The chromatograms of volatile oils and their complexes (protocol: solvent = benzene and detection = with vanillin in concentrated sulfuric acid) indicated that the value obtained was between the value of the pure guest molecule and that of the complex (Fig. 2.17).

2.4.4 The Mechanism of Formation of Inclusion Complexes

In 1954, Professor Cramer was the first to demonstrate that the main value of cyclodextrins resided in their ring structure and their consequent ability to include guest molecules inside their internal cavity (Cramer 1954, 1956; Saenger 1984; Clarke et al. 1988; Connors 1997; Szejtli 1998; Crini 2014). Professor Cramer introduced the notion of "inclusion complex." Formation of an inclusion complex was the result of an association/dissociation equilibrium between a free guest and a free host and a complex. The complex was strong when there was size complementarity between the guest and the cyclodextrin cavity (Cramer 1954, 1956).

In 1976, Professor Saenger pointed out that the complexation mainly involved hydrophobic interactions (Saenger et al. 1976). Two years later, Professor Bender

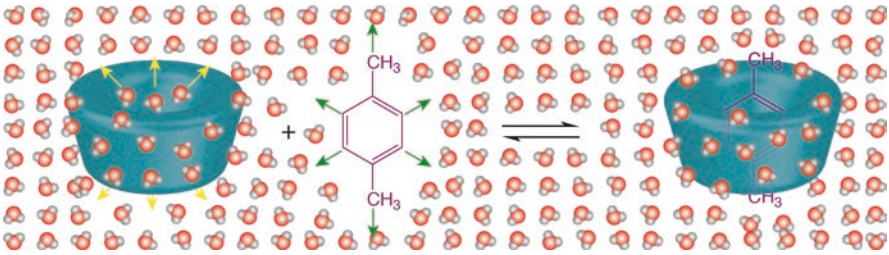

Fig. 2.18 Schematic representation of the formation of an inclusion complex between *p*-xylene, the guest, and a cyclodextrin molecule. (Adapted from Szejtli 1978)

showed that the complexation reaction involved a gain in enthalpy and a loss of entropy (Bender and Komiyama 1978).

In 1982, Professor Szejtli published a thorough state of the art of inclusion complexes (Szejtli 1982a), which was updated 2 years later by Saenger (1984). Professor Szejtli summarized and reformulated all the interpretations made on the mechanism of formation of inclusion complexes.

His three main conclusions, illustrated by a famous scheme (Fig. 2.18), were (1) the guest molecule, less polar than water, directly replaced the water molecules in the cavity; (2) the cyclodextrin molecules absorbed the energy of the water molecules retained in the cavity; and (3) the organic guest dissolved in water entered in the cavity because it had a preference for hydrophobic environment (Szejtli 1978, 1982a; Szejtli et al. 1979a). Professor Szejtli concluded that the complexation phenomenon resulted from a multitude of interactions between the three components of the system cyclodextrin-substrate-solvent leading to a state that was more thermodynamically stable overall (Szejtli 1995).

2.4.5 Inclusion Complexation Effects

Professor Szejtli showed that the various applications mainly take advantage of the different possible consequences of the encapsulation of the guest molecule within the cyclodextrin (Szejtli et al. 1979a, 1980f; Szejtli 1981, 1982b). In the 1980s, he summarized them in six points (Table 2.4). Later, Professor Szejtli also pointed out another outstanding fact: cyclodextrins were highly versatile molecules that lend themselves to being modified and used either in the dissolved form or as solids. This means that the different physical or chemical forms they can take can include particles, i.e., aggregates and microspheres, soluble or insoluble polymers, gels and hydrogels, polymers with cyclodextrins grafted on, cyclodextrin-based materials such as modified silica or organic resins, membranes, and also molecular superstructures (polyrotaxanes, etc.) or nanoparticles (Szejtli 1988a, b, 1992b, 1998). These different soluble and insoluble forms were very useful when considering chemical (Szejtli 1997), analytical (Szejtli 1997, 1998, 2002), pharmaceutical

Table 2.4 The possible consequences of the encapsulation of the guest molecule within the cyclodextrin cavity according to Professor Szejtli

1) *The modification of the physicochemical properties of the guest molecule*
Liquid compounds can be transformed into crystalline, compressible forms
Substances with low solubility in water become more soluble after complexation
The rate of dissolution of poorly soluble substances can be increased
Certain unpleasant tastes can be eliminated; smell can be covered by complex forming
The color of certain substances can be altered since inclusion can change the spectral properties of the guest
The complexed substance can be molecularly dispersed in a carbohydrate matrix
2) *The modification of the chemical activity of the guest*
Reactive substances can be protected by inclusion reducing the risks when they are mixed with other substances
Chemical reactions can be carried out selectively, the cyclodextrins playing the role of catalysts
Reactions can be promoted or suppressed
In the solid state, sublimation and volatility can be reduced to a low level
3) *The stabilization of substances sensitive to light or to oxygen*
Protection of active ingredients against oxidation, heat-promoted decomposition, or light-induced reactions
4) *The uptake of volatile substances*
Volatile drugs can be stabilized without losses through evaporation
The quantity of the volatile substance required can be reduced
Storage and handling of certain toxic substances such as pesticides can be improved
Savings can be made on the quantity of substance required owing to reduced evaporation
5) *The complexation and transport of substances*
Extraction and elimination of substances
Extraction and transport of pollutants
6) *Technical advantages*
Stable, standardized compositions, simple dosage, and handling of dry powders
Reduced packing and storage costs
Saving of energy and manpower

(Szejtli 1987b, 1988a; Szejtli et al. 1987), biotechnological (Szejtli 1990b, 1991a), or medical (Szejtli 1994) applications.

2.4.6 Cyclodextrins Derivatives

Besides being "molecular capsules," cyclodextrins were "basic materials" for the production of derivatives and polymers, biologically active substances, and reagents in analytical chemistry and diagnostics. Professor Szejtli prepared various cyclodextrin derivatives and polymers (Szejtli 1982a, 1984a, 1988a, 1998; Szente and Szejtli 1999).

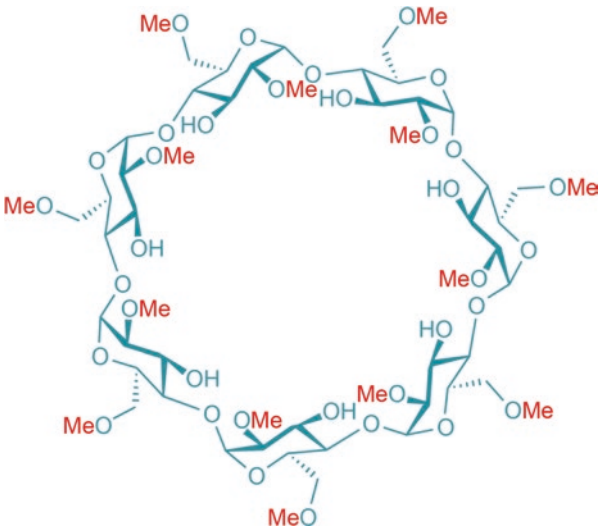

Fig. 2.19 Structure of heptakis-(2,6-di-*O*-methyl)-β-cyclodextrin or dimethyl-β-cyclodextrin, abbreviated DIMEB

Cyclodextrins can be modified by substituting one or more hydrogen atom of the primary and/or secondary hydroxyls, e.g., esters, ethers, or glycosyl-cyclodextrins, by substituting one or more primary and/or secondary hydroxyls, e.g., halogeno and aminocyclodextrins, by eliminating the hydrogen atom of the C5-CH_2OH group, or splitting one or more C2-C3 bonds by periodate oxidation. The substitution of highly reactive hydroxyl groups with either polar or apolar moieties permitted the disruption of intermolecular hydrogen bonds, and this produced cyclodextrin derivatives with anomalous increased solubility. The problems of selectivity and strategies for selective modification of hydroxyl groups have also been discussed by Professor Szejtli (Szejtli 1982a, 1984a, 1988a, 1998; Szente and Szejtli 1999).

The aim of such derivatizations may be (i) to improve the solubility of the native cyclodextrins, (ii) to improve the association between the cyclodextrin and its guest, (iii) to reduce its reactivity, (iv) to bind specific functional groups, and/or (v) to create new molecular of macromolecular structures, e.g., for chromatographic purposes.

Among the numerous cyclodextrin derivatives, heptakis-(2,6-di-*O*-methyl)-β-cyclodextrin or dimethyl-β-cyclodextrin, abbreviated DIMEB, has been particularly studied by Professor Szejtli (Szejtli et al. 1980f, 1982a; Szejtli 1983b, 1984a). Its structure is reported in Fig. 2.19. DIMEB was prepared, using a previous protocol published by Professor Casu in 1968 (Szejtli et al. 1980a, 1983b; Crini 2014), by selective methylation of all C-2 secondary and all C-6 primary hydroxyl groups of β-cyclodextrin, while C-3 hydroxyl groups remained unsubstituted (Szejtli et al. 1980a; Lipták et al. 1982).

In 1994, a simple method of methylation of cyclodextrins by phase-transfer catalysis was proposed (Fenichel et al. 1988; Bakó et al. 1994). This reaction

proceeded in the heterogeneous phase with dimethyl sulfate, using a solvent in which cyclodextrins and bases used were poorly soluble or insoluble. However, in the presence of phase transfer catalysts, methylation proceeded with good yields. The products were a mixture of randomly methylated β-cyclodextrins containing 60–70% of DIMEB, 10–15% of heptakis-(2,3,6-tri-*O*-methyl)-β-cyclodextrin TRIMEB, and some mono-methylated isomers. These methylated derivatives were used as new detergents and also as solubilizing agents, e.g., to increase the solubility of hydrocortisone (Bakó et al. 1994).

Professor Szejtli also studied the complex-forming ability of partially acetylated cyclodextrins which proved to be useful for complexation of taxoid anticancer drugs, especially when applied together with hydroxypropyl cyclodextrin (Szejtli et al. 2004). On the other hand, the water-insoluble peracetylated derivatives gave the opportunity to study inclusion complex formation in organic solvents (Buchanan et al. 2001). His group participated in the development of hydroxybutenyl cyclodextrins on the analogy of hydroxypropyl derivatives (Buchanan et al. 2002, 2004), sulfate, phosphate, and amino derivatives to mention only a few (Morva et al. 1999; Mikuni et al. 2000; Kis et al. 2003).

A special HPLC column was developed for the analysis of cyclodextrin derivatives based on inclusion complex-forming ability with phenyl moieties on the surface of the stationary phase (Varga et al. 2005). This column was useful for detecting residual unreacted cyclodextrins as well as separating the isomer groups with different degrees of substitution, thus providing a fingerprint characteristic to the product and the manufacturing process. Therefore, it was later selected by the European Pharmacopoeia for official identification of hydroxypropyl-beta-cyclodextrin.

2.5 Selected Highlights in the Fields of Applications Studied by Professor Szejtli

2.5.1 Cyclodextrin in Foods

Table 2.5 describes the applications of cyclodextrins as multifunctional food ingredients in various domains (Szejtli et al. 1977a, 1979a; Dalla Bella and Szejtli 1983; Szente and Szejtli 1988, 2004). As "empty capsules," native cyclodextrins can be used either for stabilization of substances or for the elimination of undesired compounds and microbial contaminations. They also served to protect lipophilic food components or to encapsulate substances, e.g., vitamins, aroma, and flavors.

In 1977, Professor Szejtli and his collaborators patented a promising method for the stabilization of food flavors and fragrances using cyclodextrins, which was realized on industrial scale (Szejtli et al. 1977a, 1979a). The active ingredient content of complexes, e.g., benzaldehyde, was 6–15% w/w, and the complexes were very stable in dry state. Their oxygen uptake, measured by the Warburg method, was less than that of free benzaldehyde (Szejtli et al. 1979a).

Table 2.5 Cyclodextrins as multifunctional food ingredients

Domain	Applications	References
Food technology	Protectants of food ingredients, e.g., against oxidation, light-induced degradations, heat-induced changes	Szejtli et al. (1977a, 1979a), Lindner et al. (1981), Szente and Szejtli (1986, 1987a, 1988, 2004), Szente et al. (1988, 1992, 1993), Szejtli and Szente (2005)
Functional foods	To solubilize ingredients, e.g., food colorings, vitamins	
Food protection	To improve shelf life of products	
Food preservation	To modify the physical properties of foods	
Flavors/aromas	To stabilize flavors, color, vitamins	
Elimination of undesired tastes/odors	Flavors carriers	
Taste modification	To reduce cholesterol	
Production of juices	To mask or reduce undesired tastes	
Removal of substances	To suppress unpleasant odors	
Packaging materials	Elimination of bitter components of foods, beverages	
	To improve microbiological preservation during storage, e.g., as antiseptic, conserving agents Edible films	

Later, Professor Szejtli suggested practical applications of cyclodextrin-complexed flavors (Szejtli 1982b) such as in households, in the catering trade, in dietetics and hospitals, and in the tinned food and meat industry (Fig. 2.20). In this paper, Professor Szejtli pointed out the fact that Japan was the only country where the application of cyclodextrin in food products was not limited (Szejtli 1982b). Coffee flavors were also stabilized by complexation with β-cyclodextrin as reported by Szente and Szejtli et al. (1986). In contact with water, the complex-bound flavor substances were released immediately. In a previous work (Lindner et al. 1981), flavor-β-cyclodextrin complexes were used in sausages, e.g., 1 g complex was equivalent to 130–150 g and 3–100 g of onion and cumin, respectively.

2.5.2 Cyclodextrin in Cosmetics and Toiletry

The two first reviews on the potential applications of cyclodextrins in cosmetics and toiletry were published in 1982 (Szejtli 1982b, c). These applications were presented at the 33rd Starch Convention of the Arbeitsgemeinschaft Getreideforschung

1., In households

It simplifies cooking by providing a wider choice of tastes and aromas. The dispensing units (e.g. tablets) containing various aromas can be stored in a small place for a long time without risking any loss of the active ingredient.

2., In the catering trade

By the elimination of manual processing of raw materials containing aroma substances, work and storage room can be saved, transport is simple, loss on storage can be avoided and a wider variety of tastes and aromas is provided. By using proper recipes identical taste and aroma can be provided independently of the location.

3., In dietetics and hospitals

The consumption of fibrous and seed shaped aroma carrying raw materials irritating the gastro-intestinal tract can be avoided, appetizing aromas can be applied in hospitals, many - otherwise forbidden - aromas can be consumed by persons on diet, the majority of problems with their eating being caused not by the aroma itself, but its vehicle mostly of plant origin.

4., In the tinned food and meat industry

In dehydrated soups or sausages without risking microbiological contamination stable aroma products resisting environmental effects can be used in a constant composition and in a well processable form.

Fig. 2.20 The main potential fields of applications of cyclodextrin-complexed flavors suggested by Professor Szejtli in the 1980s. (Source: CycloLab archives)

at Detmold (Germany, April 21–23, 1982). During this lecture, Professor Szejtli demonstrated that "cyclodextrins can be utilized for molecular encapsulation of flavors and fragrances and for water retention improving homogeneous pure active substances."

The main advantages of cyclodextrin complexation in cosmetics and toiletry were the protection of active ingredients, e.g., against oxidation, hydrolysis, or loss by evaporation, the solubilization of the guest substances in water, e.g., increase of the rate of solubilization or avoid the use of organic solvents, the elimination or at least reduction of undesired tastes and odors, the protection against microbial contaminations, and the improvement of handling, e.g., of liquid or oily substances as powders (Szejtli 1982c). In contrast to starch, cyclodextrins were not a nutrient medium for microorganisms. In this paper, Professor Szejtli also suggested that cyclodextrin polymers can be utilized in smoke filters (Szejtli 1982c).

2.5.3 Cyclodextrin and Drugs

The first studies on the complex formation of cyclodextrins with pharmaceuticals were carried out in the middle of the 1950s in Germany, e.g., with the important contributions made by Professors Cramer and Frömming, in Japan in the 1970s, e.g., with the works by Professors Nagai and Uekama, and also in Hungary. Indeed, Professor Szejtli made a significant contribution on the use of cyclodextrins in pharmacy (Pitha et al. 1983; Szente and Fenyvesi 2016).

In 1977, Professor Szejtli, reviewing the possible applications of β-cyclodextrin in pharmaceutical industries, pointed out the enhancement of drug bioavailability by β-cyclodextrin due to the molecular encapsulation, e.g., indomethacin, hydrocortisone, progesterone, lidocaine, etc. (Szejtli 1977a). The poorly soluble drug became molecularly dispersed in a hydrophilic matrix; therefore the drug became more soluble and dissolved with an increased dissolution rate in aqueous medium. The improved solubility led to higher blood level of the drug, which was manifested also in the biological response (Szejtli et al. 1980h; Szejtli 1981; Szente et al. 1984a).

Two years later, in 1979, Professor Szejtli unambiguously proved that orally applied β-cyclodextrin was not toxic (Szejtli and Sebestyén 1979). Further metabolic studies delivered explanation for the safety of cyclodextrin consumption (Gerlóczy et al. 1982; Gergely et al. 1982; Szabo et al. 1982).

For instance, ^{14}C-β-cyclodextrin or ^{14}C-glucose were given orally to rats, and the radioactivity was measured in the blood by liquid scintillation method. The results showed that the peak of radioactivity appeared in the blood within 10 min in the case of labelled glucose, while a rather protracted and low maximum was found between 2 and 10 h in the case of labelled β-cyclodextrin. The values of respiration of $^{14}CO_2$ proved that β-cyclodextrin was metabolized in rat. 8 hours after oral administration of 313 mg/kg ^{14}C-β-cyclodextrin, a very small amount (3 μg) was detected in 1000 μg of the blood. On the basis of investigations of radioactivity distribution, it was claimed that β-cyclodextrin was excreted by the feces after high dose of cyclodextrin treatment.

During the First International Symposium organized in Budapest in 1981, Professor Szejtli stated: "Some years ago, cyclodextrins seemed to be expensive and highly toxic substances of very limited accessibility, representing more scientific curiosity than industrial tangibility. The recent years however brought about dramatic change… We are entering a new era."

At the beginning of the 1980s, several patents on highly soluble cyclodextrin derivatives including DIMEB and polymers were patented by Professor Szejtli and his collaborators (Szejtli et al. 1980d, e, 1980g, h, 1981b, 1982b). The DIMEB was an interesting substance in drug formulation due to the fact that it was very soluble in cold water and also in organic solvents (Szejtli et al. 1980g). In such aqueous solutions, many insoluble and/or poorly soluble compounds can be easily dissolved, e.g., the solubility of steroids in water increased by a factor of 40–1200; 13 mg/mL progesterone or 20 mg/mL hydrocortisone can be dissolved in a 100 mg/mL DIMEB solution (Szejtli et al. 1980g).

In 1983, Professor Szejtli proposed to use DIMEB as parenteral drug carrier (Szejtli 1983b, 1984a). The results were explained by the molecular encapsulation concept. The complexation of a drug with DIMEB allowed a considerable increase in the molecular mass of the guest, without establishing covalent bond. The consequence was a reduced diffusion rate. This behavior was interesting for specific applications such as intramuscular or subcutaneous drug injections in rats (Szejtli 1983b, 1984a), e.g., on the action of lidocaine, a local anesthetic drug was nearly doubled injecting the drug dissolved in aqueous DIMEB solution. The solubility of lidocaine increased in presence of DIMEB. An increase of 2 mol in DIMEB concentration resulted in an increase of 1 mol in the concentration of dissolved lidocaine base. Chemical stability and duration of the biological effects of drug were enhanced. Diffusion and biological elimination were also decreased on interaction with DIMEB. NMR and circular dichroic spectra clearly showed the formation of inclusion complexes as illustrated in Fig. 2.21. The same techniques were previously used to demonstrate the formation of an inclusion complex between DIMEB and vitamin D3 (Szejtli et al. 1980f, g) or vitamin K3 (Szejtli et al. 1982a).

Solutions of soluble cyclodextrin polymers were also able to enhance the solubility of substances, e.g., drugs, vitamins, pollutants, etc., that were sparingly soluble or practically insoluble in water (Szejtli 1984a; Szemán et al. 1987a, b), e.g., in a 10 g/100 mL β-cyclodextrin-epichlorohydrin polymer solution, 16 g cholic acid or 0.4 g benzene can be dissolved at room temperature; the solubility enhancement factors were more than 50 and 6, respectively. These results were also explained by molecular encapsulation (Szejtli 1984a).

In 1994, Professors Frömming and Szejtli wrote a famous monograph on the role of cyclodextrins in pharmacy, which is still considered as a reference book in the cyclodextrin community (Frömming and Szejtli 1994).

2.5.4 Applications of Cyclodextrins in Chromatography

Inclusion complexation of lipophilic guest molecules by soluble α- and β-cyclodextrin polymers, prepared by cross-linking cyclodextrins using epichlorohydrin, showed to be useful in reversed phase thin-layer chromatography, e.g., for separation of prostaglandins (Szejtli 1978, 1984b, 1985a; Cserháti et al. 1983a, 1984, 1988). The method was also used for the determination of cyclodextrin inclusion complex stability (Cserháti et al. 1983a, 1990a).

An interesting field of applications of insoluble β-cyclodextrin polymers (Zsadon et al. 1979b; Szejtli 1980), also prepared by cross-linking cyclodextrins using epichlorohydrin, was in gel-inclusion chromatography for amino acids (Zsadon et al. 1979a), alkaloids (Zsadon et al. 1981, 1983), and proteins separation (Ujházy et al. 1988, 1989) and in gas chromatography or in liquid chromatography as packings (Cserháti et al. 1983b; Szejtli 1985a). The separation was based either on selective inclusion or on specific affinity. Preparative chromatography was also interesting for separation of racemic mixtures. Figure 2.22 shows the resolution of 500 mg

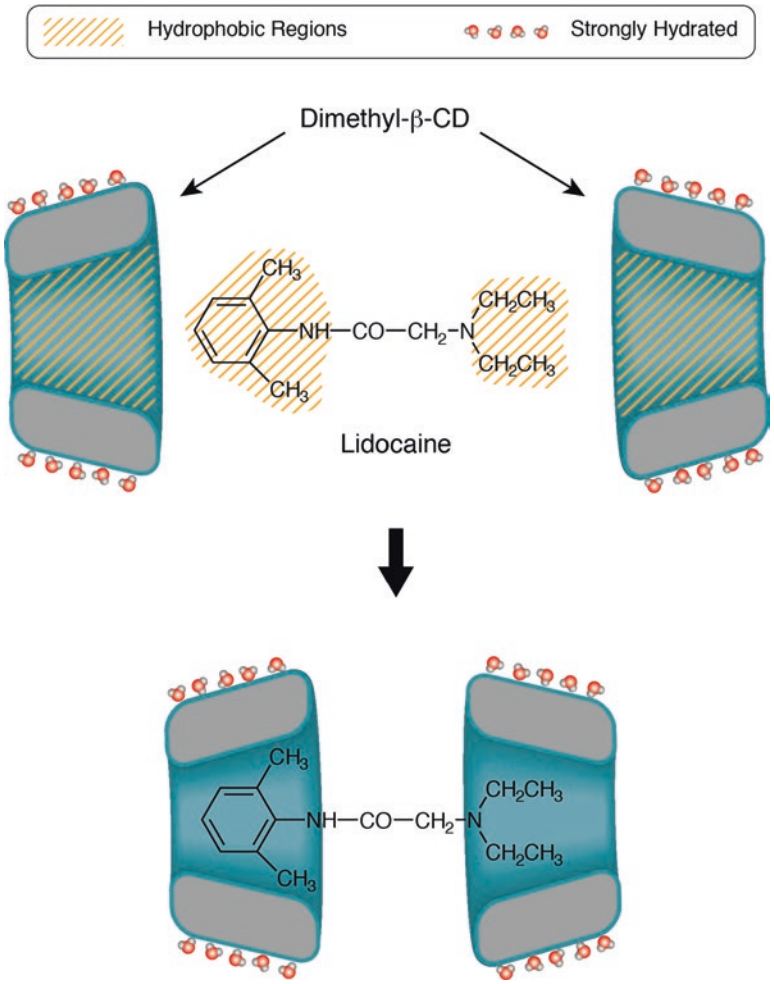

Fig. 2.21 Schematic illustration of the interaction between lidocaine and dimethyl-β-cyclodextrin DIMEB. (Adapted from Szejtli et al. 1983b)

racemic mixture of (+) and (−) enantiomers of vincadifformine on a β-cyclodextrin-polymer column (5 × 90 cm, pH 5.5, flow rate 300 mL/h, 25 °C) in one run. The relative retention volumes were 1.9–2.1 for the (+) enantiomer and 2.2–2.4 for (−) enantiomer (Szejtli 1985a, 1987e).

Later, insoluble β-cyclodextrin polymer was used as thin-layer chromatographic adsorbent, and the method was a very simple tool used to separate a wide variety of compounds with similar chemical structure (Cserháti et al. 1995). Table 2.6 summarized the known possibilities of the applications of cyclodextrins in chromatographic methods according to Professor Szejtli, "which did not implicate that no further combinations will be exploited in the future" (Szejtli 1987a, e).

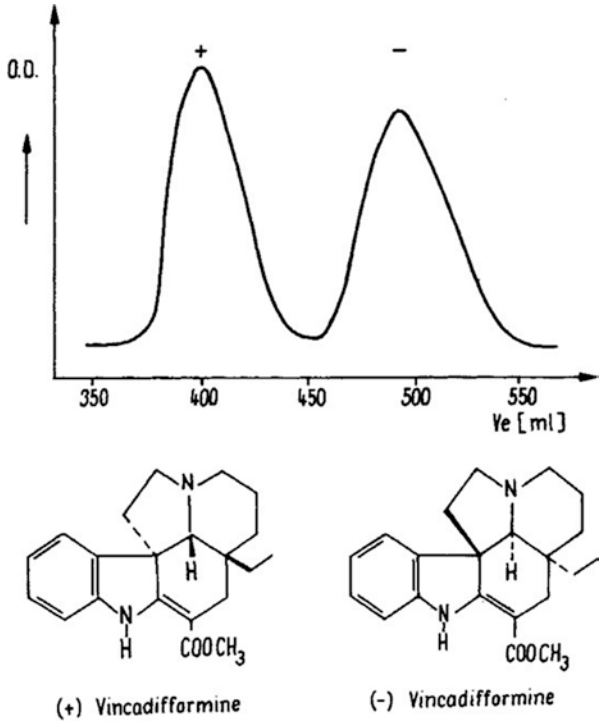

Fig. 2.22 Separation of the enantiomers of racemic vincadifformine by passing its aqueous solution through a β-cyclodextrin-polymer column. (Source: CycloLab archives)

Table 2.6 Applications of cyclodextrins in chromatographic methods (*MP* mobile phase; *SP* stationary phase)

Cyclodextrins	Thin layer	Gas-liquid	Gas-solid	Gel inclusion	High-performance liquid	Affinity	Electrokinetic
Native	MP	SP	SP		MP	MP	
Modified	MP	SP	SP		MP		MP
Soluble polymers	MP						
Insoluble polymers		SP	SP	SP			
Immobilized	SP				SP	SP	

Later, the capillary electrophoresis technique was developed for enantioseparation of racemic mixtures using various cyclodextrin derivatives as chiral selectors (Szemán et al. 1996; Iványi et al. 2004). Professor Szejtli has recognized the importance of this, at that time novel, technique. CycloLab was among the first in Hungary

to purchase such an equipment. Professor Szejtli also observed the business opportunities in selling cyclodextrin derivatives for chiral separations.

2.5.5 *Cyclodextrin in Catalysis*

Cyclodextrins and their derivatives had an enzyme-like activity (Bender and Komiyama 1978). Considerable reaction rate enhancements, stereoselective effects, and other catalytic phenomena can be accounted to the cyclodextrins. Inclusion catalysis revealed several characteristics of enzyme-catalyzed reactions, e.g., saturation limit, competitive inhibition, and unproductive bonding. The correlation between the acceleration of the reaction rate and cyclodextrin concentration was not linear; it approached asymptotically the maximum value. This saturation feature was characteristic of such reactions in which the rate-determining step was preceded by complex formation.

Professor Szejtli showed that cyclodextrins can accelerate or decelerate various kinds of reactions, e.g., oxidation, hydrolysis, decarboxylation, nitrosation, and isomerization (Szejtli 1984a, 1985a, 1988a). The reaction rates depended on the cyclodextrin used and the kind and stability of the inclusion compound formed. His conclusions were in accordance with those previously reported by Bender and Komiyama (1978). Professor Szejtli described cyclodextrin-catalyzed reactions in details in his second book *Cyclodextrin Technology* (Szejtli 1988a).

Figure 2.23 shows a schematic representation of selective chlorination of anisole in presence of soluble α-cyclodextrin polymers (Szejtli 1984a, 1985a). 99% p-isomer was obtained in presence of cyclodextrin polymer, in agreement with the results previously published by Breslow and Campbell (1969).

In 1990, Professor Szejtli indicated that organic ligand containing coordination metal ion complexes and the organometallic compounds in which the metal atoms were covalently bound can form regular inclusion complexes with cyclodextrins (Szejtli 1990a).

Metal ions can be complexed with cyclodextrins in three ways as reported in Fig. 2.24: (a) the metal reacted with the hydroxyl groups of the cyclodextrin

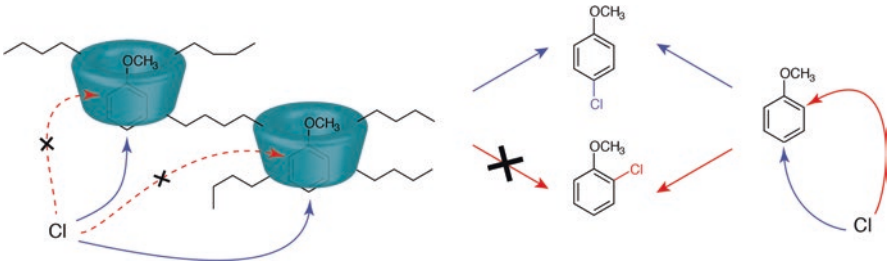

Fig. 2.23 Schematic representation of selective chlorination of anisole in presence of α-cyclodextrin polymers. (Adapted from Szejtli 1984a, 1985a)

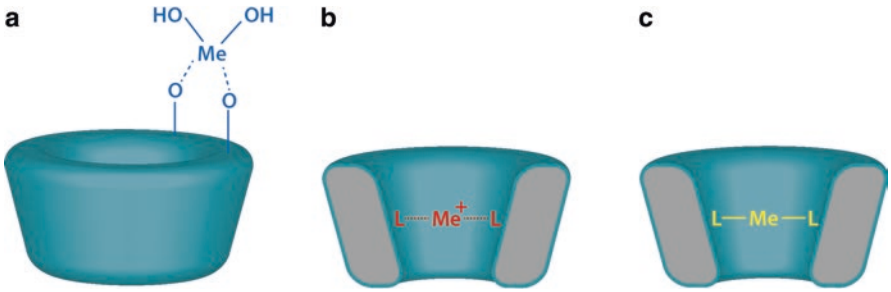

Fig. 2.24 Three types of metal-cyclodextrin complexes: (**a**) hydroxo complex, (**b**) ternary ligand-coordinated metal inclusion, and (**c**) metal-organic compound inclusion. (Adapted from Szejtli 1990a)

molecule to form a hydroxo complex; this was not an inclusion complex strictly speaking; (b) the metal forms coordination complex with organic ligands, and this coordination complex will be included into the cavity, i.e., formation of ternary complexes cyclodextrin + organic ligand + metal ion; and (c) the metal was bound covalently in a metal-organic compound, i.e., a binary complex, which will form a regular inclusion complex with a cyclodextrin molecule. These complexes were used as catalysts, enzyme models, siderophores, color, and fluorescence-enhancing reagents (Szejtli 1990a).

2.5.6 Cyclodextrin in Biotechnology

The application of cyclodextrins in biotechnology began in the 1980s (Szejtli 1986a, b; Duchêne 1987; Hedges 1998). Cyclodextrins were interesting in this domain because they did not damage the microbial cells or the enzymes. The majority of processes involved an enzyme-catalyzed transformation of a substrate in aqueous solution. In enzymic and microbiological transformations of various substrates, e.g., microbiological substrate conversion, fermentation, enhancement of vaccine production, enzymic reaction of lipids, tissue cultures, and also detoxification of industrial wastewaters, the main aims were to enhance the yield, to accelerate the conversion, to protect the microorganisms, and/or to substitute more expensive components of the medium.

In 1990, Professor Szejtli published a comprehensive review with 44 significant references on their applications in biotechnology (Szejtli 1990b). One year later, this review was updated (Szejtli 1991a). Professor Szejtli discussed the principle of intensification of the enzymatic (microbial) transformation of poorly soluble lipophilic substrates as illustrated in Fig. 2.25 (Szejtli 1991a). The cyclodextrin complexation of the substrates improved their wettability and solubility, i.e., enhanced their concentration in the aqueous phase where the reaction took places (Szejtli 1990b). In many cases, the reaction was accelerated through continuous removal of

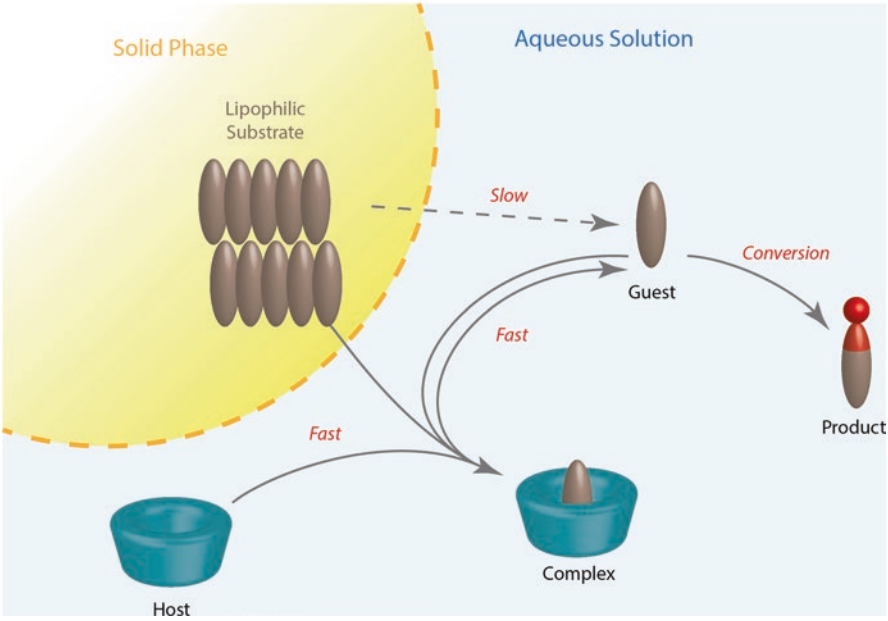

Fig. 2.25 Principle of intensification of the enzymatic transformation of poorly soluble lipophilic substrates. The cyclodextrin complexation of the substrates improves their wettability and solubility. (Adapted from Szejtli 1990b)

the inhibiting products by cyclodextrin molecular encapsulation (Szejtli 1990b, 1991a, 1996; Szejtli and Osa 1996).

2.5.7 Potential Industrial Applications

An interesting field of application of insoluble polymers prepared by cross-linking of cyclodextrins using epoxide cross-linking agents was the purification and separation processes, including isolation or concentration of products, e.g., antibiotics and aroma substances, elimination of undesired substances, purification processes, and wastewater treatment (Szejtli et al. 1978a; Zsadon et al. 1979a; Otta et al. 1982). Polymers containing cyclodextrins can bind efficiently pollutants from aqueous solutions via inclusion complexes. The same materials can also be used for the removal of substances from vapor phase (Otta et al. 1982). They can be applied in two forms: (1) as a powder or granulate, e.g., particles of irregular shape or regular beads, and (2) as column packings.

The first cellulose-cyclodextrin copolymer was patented in 1980 (Szejtli et al. 1980i, 1982b; Otta et al. 1982). Alkali-swollen cellulose fibers were reacted with cyclodextrin and epichlorohydrin. The chemically bound cyclodextrin retained its complex-forming ability and could be loaded with biologically active substances

such as drugs, insect repellents, and antimicrobial agents. These polymers were also found to be efficient adsorbents for environmental purposes (Otta et al. 1988).

Ten years later, Professor Szejtli patented a method to bind cyclodextrins chemically to fibers in order to prepare medical bandages (Szejtli et al. 1991). A cellulose fabric (2.5 g) containing chemically bound β-cyclodextrin was treated with 50 mL solution of 1% I_2 and 0.7% KI in 75% ethanol, followed by solvent removal, to give a medicated bandage. Binding cyclodextrin to fibers chemically opened up new ways for the preparation of perfumed textiles and cosmeto-textiles. The applications of cyclodextrins in the textile industry were published in 2003 (Szejtli 2003).

In 1983, at the 34th Starch Convention at Detmold, Professor Szejtli presented his results on the physiological effects of cyclodextrins on plants (Szejtli 1983a). As biologically active substances, cyclodextrins can be used as plant growth regulators. Treating cereal seeds with cyclodextrin, germination, i.e., development of shoots and roots, was retarded in the first few days as compared to the control seeds, but after some days, this initial stress effect was followed by a more vigorous growing of the new plant; the accelerated development resulted in higher green mass, enhanced ramification, more ears per plant, and higher crop yield. In several cases, a higher resistance of the cyclodextrin-treated plants to phytotoxic herbicides was also observed. The height and dry mass of 4-week-old plants developed from cyclodextrin-treated seeds under laboratory conditions were significantly higher than those of the control plants.

The most significant effects published in agrochemistry and complexation of pesticides were the increase of solubility, the stabilization of substances against rapid decomposition by sunlight, conversion of volatile insecticides into nonvolatile, long-lasting formulations, prevention of the phytotoxic effect of certain fungicides, etc. (Szejtli 1983a, 1984a, 1985a, b).

The interaction of some nonionic tensides with native cyclodextrins (Szejtli 1987c, d; Bujtas et al. 1987; Szogyi et al. 1987) and insoluble β-cyclodextrin polymer was studied (Fenyvesi et al. 1992). The results showed a reduction of the phytotoxicity of tensides after complexation with cyclodextrins (Szejtli 1987c; Bujtas et al. 1987). Cyclodextrin polymer can also bind alkylphenol polyoxyethylene glycol ethers (Fenyvesi et al. 1992) more effectively than polymer produced from linear dextran. Professor Szejtli suggested that polymer could efficiently be used for the elimination of tensides from aqueous solutions.

In 1996, the same material was proved to be effective in healing the wounds inflicted on the back of rats and in healing venous leg ulcers of human patients (Felméray et al. 1996). According to microscopic studies, cyclodextrin polymer in bead form implanted into the muscular tissue of rats did not cause inflammation cell reaction for up to 6-week observation period.

In 1999, Professor Szejtli demonstrated that cyclodextrins were ideal candidates for iodine adsorption from nuclear waste gases (Szente et al. 1999a, b). In particular, methylated α-cyclodextrin and α-cyclodextrin polymers had high adsorption capacity. Such materials could also be used in the air filtration systems.

The same year, a work on the inclusion complexes of UV filters in solution and in solid state was published (Fenyvesi et al. 1999b). The aqueous solubility of the

UV absorbers used in sunscreen cosmetics can be improved by inclusion complexation. Later, the authors demonstrated that randomly methylated β-cyclodextrin was the best solubilizing agent of UVA and UVB filters (Fenyvesi et al. 2004).

The same year, the solubility of β-cyclodextrin was studied in aqueous solutions of various organic acids (Fenyvesi et al. 1999a). The hydroxyl acids such as citric and tartaric acids were found to increase the solubility of β-cyclodextrin, while other carboxylic acids reduced it. From solubility data, the apparent complex association constants were calculated. The authors have also discovered that the inclusion complexes with hydroxyl acids as ternary components may have an outstanding solubility (Chiesi et al. 1994).

In 2004, the biodegradation of several types of cyclodextrins, e.g., acetylated α- and β-cyclodextrins and hydroxypropyl-β-cyclodextrin, under laboratory-controlled composting conditions was investigated (Verstichel et al. 2004). Fully acetylated cyclodextrins were found to be nonbiodegradable during 45 days of composting. Reducing the degree of acetylation had a positive effect on the biodegradation. The authors also showed that the incorporation of antimicrobial agents, e.g., imazalil, into cyclodextrins might open new possibilities for active packaging. The low concentration of the inclusion products in the final packaging did not affect the biodegradability of the biodegradable packaging under composting conditions.

The last paper of Professor Szejtli was published in 2005 in the journal *Journal of Inclusion Phenomena and Macrocyclic Chemistry* (Fig. 2.5) where he tried to respond to the following fact: "The increase in number of marketed drug/cyclodextrin formulations is so slow" (Szejtli 2005). Another important question was "Which cyclodextrin for what purpose?" A possible response was given in Table 2.7 (Szejtli 2005).

2.6 Conclusions

This chapter is a tribute to the immense scientific career of Professor József Szejtli. We have attempted to highlight his many scientific achievements and also provided insight into his formative years and into the importance of cyclodextrin community in his life.

Professor Szejtli has devoted his life to cyclodextrins, and he is considered to be the "Godfather of Cyclodextrins." He is distinguished not only for his contribution to chemistry, biology, and technology of cyclodextrins but also for his important contribution to the dissemination of knowledge about cyclodextrins from the end of the 1970s. Professor Szejtli was a giant among cyclodextrin chemists, an eminent scientist and visionary, a businessman, a wonderful mentor, and a warm, friendly, and generous communicator.

Professor Szejtli did attract and recruit young scientists by his own enthusiasm and oversee the everyday research at the lab, thus creating a dedicated team under his mentorship. Teaching and convincing his carefully selected young co-workers about the usefulness of cyclodextrins is probably one of the most important reasons

Table 2.7 What cyclodextrin for what purpose? (CD, cyclodextrin; SBE, sulfobutyl-β-cyclodextrin; MeCD, methylated cyclodextrin)

	Drugs/parenteral	Drugs/per os	Drugs/topical	Cosmetics	Foods	Biotechnology	Analytical chemistry	Chemical industry
αCD	+	+++	+++	+++	+	+	+	+
βCD	−	+++	+	+	++	++		+++
γCD	+	+++	+++	+++	+++	−		+++
HPβCD	++	++	+++	+++	−	++	++	++
SBE	+++	+	−	−	−	−	++	−
MeCD	+	+	+	−	−	+++	++	+++

"−": not recommended, either on account of toxic side effects or too high prices
"+": in limited number of cases
"++": can be recommended, but for the same purpose, there is better or cheaper candidate
"+++": most recommended because of existing approval, acceptable price, and technical performance

for Szejtli's ultimate success in the introduction of cyclodextrins into commercially useful applications.

His tireless efforts, dedication, and trust in the cyclodextrins helped him retain the best of his co-workers, even when the cyclodextrin product development was still in its infancy and so much unappreciated. Many of those young co-workers Professor Szejtli attracted in the early 1980s are today worldwide acknowledged cyclodextrin experts and core members of CycloLab.

Professor Szejtli has received much recognition for his immense scientific and industrial oeuvre, but more important than all the honors he has received and the prizes is the affection in which he is held worldwide.

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References

Alexander G, Juvancz Z, Szejtli J (1988) Cyclodextrins and their derivatives as stationary phases in GC capillary columns. J High Resolution Chromatogr 11:110–113

Armstrong DW, Jin HL (1989) Liquid-chromatographic separation of anomeric forms of saccharides with cyclodextrin bonded phases. Chirality 1:27–37. https://doi.org/10.1002/chir.530010108

Bajor T, Szente L, Szejtli J (1988) Methods for characterization of the wettability of cyclodextrin complexes. In: Huber O, Szejtli J (eds) Proceedings of the fourth international symposium on cyclodextrins. (Munich, April 20–22, 1988). Advances in inclusion science. Kluwer Academic Publishers, Dordrecht, pp 237–242. https://doi.org/10.1007/978-94-009-2637-0

Bakó P, Fenichel L, Tóke L, Szente L, Szejtli J (1988) Selective reductions of cyclodextrin complexes. In: Huber O, Szejtli J (eds) Proceedings of the fourth international symposium on cyclodextrins. (Munich, April 20–22, 1988). Advances in inclusion science. Kluwer Academic Publishers, Dordrecht, pp 519–524. https://doi.org/10.1007/978-94-009-2637-0

Bakó P, Fenichel L, Tóke L, Szente L, Szejtli J (1994) Methylation of cyclodextrins by phase-transfer catalysis. J Incl Phenom Mol Recogn Chem 18:307–314. https://doi.org/10.1007/BF00708737

Bender ML, Komiyama M (1978) Cyclodextrin chemistry. Springer, Berlin

Breslow R, Campbell P (1969) Selective aromatic substitution within a cyclodextrin mixed complex. J Am Chem Soc 91:3085–3087. https://doi.org/10.1021/ja01039a044

Buchanan CM, Tindall D, Wood MD, Szejtli J, Szente L (2001) Triacetylcyclodextrin complexes as polymer additives for cellulose ester thermoplastics. Abstracts Papers Am Chem Soc 221:U181–U182

Buchanan CM, Alderson SR, Cleven CD, Dixon DW, Iványi R, Lambert JL, Lowman DW, Offerman RJ, Szejtli J, Szente L (2002) Synthesis and characterization of water-soluble hydroxybutenyl cyclomaltooligosaccharides (cyclodextrins). Carbohydr Res 337:493–507. https://doi.org/10.1016/S0008-6215(01)00328-7

Buchanan CM, Buchanan NL, Jicsinszky L, Posey-Dowty J, Szejtli J, Szente L (2004) Solubilization of poorly water-soluble drugs by hydroxybutenyl cyclodextrins. Abstracts Papers Am Chem Soc 228:U241–U242

Budai ZS, Szejtli J (1981) Cyclodextrin inclusion complexes of 2-chloroethyl phosphonic acid. Acta Chim Acad Sci Hung 107:231–236
Bujtas K, Cserhati T, Szejtli J (1987) Reduction of phytotoxicity of nonionic tensides by cyclodextrins. J Incl Phenom 5:421–425. https://doi.org/10.1007/BF00664097
Buvari A, Szejtli J, Barcza L (1982) The 1-1 and 1-2 complex-formation between beta-cyclodextrin and benzoic-acid. Acta Chim Acad Sci Hungarica 110:51–55
Caesar GV (1968) Chapter X: The Schardinger dextrins. In: Radley JA (ed) Starch and its derivatives, 4th edn. Chapman and Hall Ltd., EC4, London, pp 290–305
Chiesi P, Ventura P, Pasini M, Szejtli J, Vikmon M, Redenti E (1994) World Patent:WO9416733
Clarke RJ, Coates JH, Lincoln SF (1988) Inclusion complexes of cyclomalto-oligosaccharides (cyclodextrins). Adv Carbohydr Chem Biochem 46:205–249
Connors KA (1997) The stability of cyclodextrin complexes in solution. Chem Rev 97:1325–1357
Cramer F (1954) Einschlussverbindungen. Springer, Berlin. ISBN: 978-3-642-49192-4
Cramer F (1956) Einschluβverbindungen. Angew Chem 68(1956):115–120
Crini G (2014) Review: a history of cyclodextrins. Chem Rev 114:10940–10975. https://doi.org/10.1021/cr500081p
Crini G, Fourmentin S, Fenyvesi É, Torri G, Fourmentin M, Morin-Crini N (2018) Cyclodextrins, from molecules to applications. Environ Chem Lett 16:1361–1375. https://doi.org/10.1007/s10311-018-0763-2
Csabai K, Cserhati T, Szejtli J (1993) Interaction of some barbituric-acid derivatives with hydroxypropyl-beta-cyclodextrin. Int J Pharm 91:15–22. https://doi.org/10.1016/0378-5173(93)90416-D
Csabai K, Vikmon M, Szejtli J, Redenti E, Poli G, Ventura P (1998) Complexation of manidipine with cyclodextrins and their derivatives. J Inc Phenom Mol Recogn Chem 31:169–178. https://doi.org/10.1023/A:1007959417684
Cserháti T, Szejtli J (1992) Inclusion complexes of some nonionic surfactants with cyclomaltooligosaccharides. Carbohydr Res 224:165–173. https://doi.org/10.1016/0008-6215(92)84102-X
Cserháti T, Fenyvesi É, Szejtli J (1983a) Determination of cyclodextrin inclusion complex stability by reversed-phase thin-layer chromatography. Acta Biochim Biophys Hungarica 18:60–60
Cserháti T, Dobrovolszky A, Fenyvesi É, Szejtli J (1983b) Beta-cyclodextrin polymer beads as GC packings. J High Res Chromatogr Chromatogr Comm 6:442–443. https://doi.org/10.1002/jhrc.1240060809
Cserháti T, Szente L, Szejtli J (1984) Complex-forming eluent additives in reversed-phase thin-layer chromatography of methylated beta-cyclodextrins. J High Res Chromatogr Chromatogr Comm 7:635–636. https://doi.org/10.1002/jhrc.1240071108
Cserháti T, Szejtli J, Fenyvesi É (1988) Reversed-phase thin-layer chromatography of some chlorophenols in the presence of a soluble beta-cyclodextrin polymer. J Chromatogr 439:393–403. https://doi.org/10.1016/S0021-9673(01)83851-6
Cserháti T, Szejtli J, Bojarski J (1990a) Charge-transfer chromatographic study on the inclusion complex-formation between of some barbituric-acid with various cyclodextrins. Chromatographia 28:455–458. https://doi.org/10.1007/BF02261059
Cserháti T, Szejtli J, Szogyi M (1990b) Charge-transfer chromatographic study on inclusion complex-formation between 2-hydroxypropyl-beta-cyclodextrins and some chlorophenols. J Chromatogr 509:255–262
Cserháti T, Fenyvesi É, Szejtli J (1992) Interaction of nonylphenyl and tributylphenyl ethyleneoxide ionic surfactants with highly soluble cyclodextrin derivatives. J Incl Phenom Mol Recogn Chem 14:181–188. https://doi.org/10.1007/BF01029666
Cserháti T, Fenyvesi É, Szejtli J, Forgacs E (1995) Water-insoluble beta-cyclodextrin polymer as thin-layer chromatographic sorbent. Chimica Oggi Chem Today 13:21–24
Cserháti T, Forgacs E, Szejtli J (1996) Inclusion complex formation of antisense nucleotides with hydroxypropyl-beta-cyclodextrin. Int J Pharm 141:1–7. https://doi.org/10.1016/0378-5173(96)04583-8
D'Souza VT, Lipkowitz KB (1998) Cyclodextrins: introduction. Chem Rev 98:1741–1742

Dalla Bella M, Szejtli J (1983) Cyclodextrins. Drugs Future 8:391–394
Daruhazi L, Szejtli J, Barcza L (1982) Polarographic-determination of potential guest molecules in the presence of cyclodextrin. Acta Chim Acad Sci Hung 110:127–132
Darwish YM, Cserhati T, Matolcsy G, Szejtli J, Fenyvesi E (1984) Complexing of some bioactive heterocyclic quaternary ammonium salts by beta-cyclodextrin polymer. Acta Phytopathol Acad Sci Hung 19:359–364
Duchêne D (1987) Cyclodextrins and their industrial uses. Éditions de santé, Paris
Duchêne D (1991) New trends in cyclodextrins and derivatives. Éditions de santé, Paris
Duchêne D, Wouessidjewe D (1996) Chapter 19: Pharmaceutical and medical applications of cyclodextrins. In: Dumitriu S (ed) Polysaccharides in medicinal applications. Marcel Dekker, Inc, New York, pp 575–602
Fava F, Di Gioia D, Marchetti L, Fenyvesi É, Szejtli J (2002) Randomly methylated beta-cyclodextrins (RAMEB) enhance the aerobic biodegradation of polychlorinated biphenyl in aged-contaminated soils. J Incl Phenom Mol Recognit Chem 44:417–421. https://doi.org/10.1023/A:1023019903194
Felméray I, Fenyvesi É, Neumark T, Takács J, Gerlóczy A, Szejtli J (1996) Effect of cyclodextrin bead polymer on wound healing. In: Szejtli J, Szente L (eds) Proceedings of the eight international symposium on cyclodextrins (Budapest, March 31–April 2, 1996). Springer, Dordrecht, pp 491–494. https://doi.org/10.1007/978-94-011-5448-2
Fenichel L, Bakó P, Tóke P, Szente L, Szejtli J (1988) Methylation of cyclodextrins via phase-transfer catalysis. In: Huber O, Szejtli J (eds) Proceedings of the fourth international symposium on cyclodextrins (Munich, April 20–22, 1988). Advances in inclusion science. Kluwer Academic Publishers, Dordrecht, pp 113–118. https://doi.org/10.1007/978-94-009-2637-0
Fenyvesi É, Szilasi M, Zsadon B, Szejtli J, Tüdös F (1982) Water-soluble cyclodextrin polymers and their complexing properties. In: Szejtli J (ed) Proceedings of the first international symposium on cyclodextrins (Budapest, 30 September-2 October 1981). Springer, Dordrecht, pp 345–356
Fenyvesi É, Shirakura O, Szejtli J, Nagai T (1984a) Pharmaceutical interactions in dosage forms and processing. 44. Properties of cyclodextrin polymer as a tableting aid. Chem Pharm Bull 32:665–669
Fenyvesi É, Takayama K, Szejtli J, Nagai T (1984b) Pharmaceutical interactions in dosage forms and processing. 45. Evaluation of cyclodextrin polymer as an additive for furosemide tablet. Chem Pharm Bull 32:670–677
Fenyvesi É, Antal B, Zsadon B, Szejtli J (1984c) Cyclodextrin polymer, a new tablet disintegrating agent. Pharmazie 39:473–475
Fenyvesi É, Nagai T, Antal B, Zsadon B, Szejtli J (1984d) Evaluation of cyclodextrin polymer as a disintegrating agent. J Incl Phenom 2:645–654. https://doi.org/10.1007/978-94-009-5376-5_69
Fenyvesi É, Décsei L, Ujházy A, Zsadon B, Szejtli J (1988) Complexes of insoluble cyclodextrin polymers. In: Huber O, Szejtli J (eds) Proceedings of the fourth international symposium on cyclodextrins (Munich, April 20–22, 1988). Advances in inclusion science. Kluwer Academic Publishers, Dordrecht, pp 227–235. https://doi.org/10.1007/978-94-009-2637-0
Fenyvesi É, Cserhati T, Szejtli J (1992) Interaction of some non-ionic tensides with insoluble β-cyclodextrin polymer. In: Hedges RA (ed) Minutes of the sixth international symposium on cyclodextrins (Chicago, 21 to 24 April 1992). Editions de Santé, Paris, pp 267–273
Fenyvesi É, Ujhazy A, Szejtli J, Pütter S, Gan TG (1996a) Controlled release of drugs from CD polymers substituted with ionic groups. In: Szejtli J, Szente L (eds) Proceedings of the eight international symposium on cyclodextrins (Budapest, March 31-April 2, 1996). Springer, Dordrecht, pp 443–447. https://doi.org/10.1007/978-94-011-5448-2_98
Fenyvesi É, Szemán J, Szejtli J (1996b) Extraction of PAHs and pesticides from contaminated soils with aqueous CD solutions. J Incl Phenom Mol Recognit Chem 25:229–232. https://doi.org/10.1007/BF01041575
Fenyvesi É, Szemán J, Szejtli J (1996c) Extraction of PAHs and pesticides from contaminated soil with aqueous cyclodextrin solutions. In: Szejtli J, Szente L (eds) Proceedings of the eight

international symposium on cyclodextrins (Budapest, March 31April 2, 1996). Springer, Dordrecht, pp 605–608. https://doi.org/10.1007/978-94-011-5448-2

Fenyvesi É, Vikmon M, Szemán J, Redenti E, Delcanale M, Ventura P, Szejtli J (1999a) Interaction of hydroxy acids with beta-cyclodextrin. J Incl Phenom Mol Recognit Chem 33:339–344. https://doi.org/10.1023/A:1008094702632

Fenyvesi É, Jicsinszky L, Szejtli J, Schwarzenbach R (1999b) Inclusion complexes of UV filters in solution and in solid state. In: Torres Labandeira JJ, Vila-Jato JL (eds) Proceedings of the ninth international symposium on cyclodextrins (Santiago de Compostela, May 31-June 3, 1998). Springer, Dordrecht, pp 639–644. https://doi.org/10.1007/978-94-011-4681-4

Fenyvesi É, Szejtli J, Trotta F, Redenti E, Ventura P (1999c) Comparison of the solubilizing effect of ethyl carbonate of γ-cyclodextrin to other cyclodextrin derivatives. In: Torres Labandeira JJ, Vila-Jato JL (eds) Proceedings of the ninth international symposium on cyclodextrins (Santiago de Compostela, May 31–June 3, 1998). Springer, Dordrecht, pp 289–292. https://doi.org/10.1007/978-94-011-4681-4

Fenyvesi É, Csabai K, Molnar M, Gruiz K, Muranyi A, Szejtli J (2002) Quantitative and qualitative analysis of RAMEB in soil. J Incl Phenom Mol Recognit Chem 44:413–416. https://doi.org/10.1023/A:1023067819124

Fenyvesi É, Otta K, Kolbe I, Novak C, Szejtli J (2004) Cyclodextrin complexes of UV filters. J Incl Phenom Macrocycl Chem 48:117–123. https://doi.org/10.1023/B:JIPH.0000022518.38097.55

French D (1957) The Schardinger dextrins. In: Wolfrom ML (ed) Advances in carbohydrate chemistry, vol 12. Academic, New York, pp 189–260

Frömming KH, Szejtli J (1994) Cyclodextrins in pharmacy. Kluwer Academic Publishers, Dordrecht. https://doi.org/10.1007/978-94-015-8277-3

Furo I, Pocsik I, Tompa K, Stadler-Szóke A, Szejtli J (1986) Solid state 1H-NMR study of β-cyclodextrin-water complexes. J Carbohydr Polym 6:85–93. https://doi.org/10.1016/0144-8617(86)90036-6

Gál-Füzy M, Szente L, Szejtli J, Harangi J (1984) Cyclodextrin-stabilized volatile substances for inhalation-therapy. Pharmazie 39:558–559

Geczy J, Bruhwyler J, Scuvee-Moreau J, Seutin V, Masset H, Van Heugen JC, Dresse A, Lejeune C, Decamp E, Szente L, Szejtli J, Liegeois JF (2000) The inclusion of fluoxetine into gamma-cyclodextrin increases its bioavailability: behavioural, electrophysiological and pharmacokinetic studies. Psychopharmacology 151:328–334. https://doi.org/10.1007/s002130000512

Gergely V, Sebestyén G, Virag S (1982) Toxicity studies of beta-cyclodextrin. In: Szejtli J (ed) Proceedings of the first international symposium on cyclodextrins (Budapest, 30 September–2 October 1981). Springer, Dordrecht, pp 109–113

Gerlóczy A, Fónagy A, Szejtli J (1982) Absorption and metabolism of β-cyclodextrin by rats. In: Szejtli J (ed) Proceedings of the first international symposium on cyclodextrins (Budapest, 30 September–2 October 1981). Springer, Dordrecht, pp 101–108

Gerlóczy A, Fónagy A, Szejtli J (1983) Reduction of residual toluene in beta-cyclodextrin through preparing inclusion complexes. Star 35:320–322. https://doi.org/10.1002/star.19830350907

Gerlóczy A, Fónagy A, Fenyvesi É, Szejtli J (1984) Absorption and excretion of tablet disintegrating beta-cyclodextrin polymer in rat after per os administration. Acta Biochim Biophys Hung 19:89–89

Gerlóczy A, Fónagy A, Fenyvesi É, Szejtli J (1985) Absorption and excretion of tablet disintegrating β-cyclodextrin polymer in rats. Carbohydr Polym 5:343–349. https://doi.org/10.1016/0144-8617(85)90042-6

Gerlóczy A, Szemán J, Csabai K, Kolbe I, Jicsinszky L, Acerbi D, Ventura P, Redenti E, Szejtli J (1996) Pharmacokinetic study of orally administered ketoconazole and its multicomponent complex on rabbits of normal and low gastric acidity. In: Szejtli J, Szente L (eds) Proceedings of the eight international symposium on cyclodextrins (Budapest, March 31-April 2, 1996). Springer, Dordrecht, pp 515–518. https://doi.org/10.1007/978-94-011-5448-2

Gerlóczy A, Vikmon M, Szejtli J, Redenti E, Ventura P (1999) Mutual solubility enhancement by binary and multicomponent complexation of clomiphene and tamoxifen. In: Torres Labandeira

JJ, Vila-Jato JL (eds) Proceedings of the ninth international symposium on cyclodextrins (Santiago de Compostela, May 31-June 3, 1998). Springer, Dordrecht, pp 277–280. https://doi.org/10.1007/978-94-011-4681-4

Habon I, Stadlerszoke A, Szejtli J (1984a) Improvement of the solubility of steroids by formation of cyclodextrin inclusion complex. Acta Biochim Biophys Hung 19:86–86

Habon I, Fritsch S, Szejtli J (1984b) Simulation of pharmacokinetic behavior of drug-cyclodextrin complexes. Pharmazie 39:830–834

Hedges AR (1998) Industrial applications of cyclodextrins. Chem Rev 98:2035–2044

Hinze WL, Dai F, Frankewich RP, Thimaiah KN, Szejtli J (1999) Chapter 20: Cyclodextrins as reagents in analytical chemistry and diagnostics. In: Comprehensive supramolecular chemistry. Atwood JL, Davies ED, MacNicol DD and Vögtle F (executive eds), Volume 3: Cyclodextrins. Szejtli J and Osa T (eds). Pergamon Oxford, London, pp. 587–601. ISBN: 9780080912844

Holló J, Szejtli J (1957a) The mechanism of starch-iodine reaction. I. Critical investigation of actual viewpoints. Periodica Polytechnica Chem Eng 1:141–115

Holló J, Szejtli J (1957b) The mechanism of starch-iodine reaction. II. Experiments performed in order to clear up our problems. 1. Amperometric titration. Periodica Polytechnica Chem Eng 1:223–238

Holló J, Szejtli J (1957c) Untersuchung der Jod-reaktion von stärke. Eur J Lipid Sci 59:94–98. https://doi.org/10.1002/lipi.19570590207

Holló J, Szejtli J (1958) The mechanism of starch-iodine reaction. III. The supposed structure of iodine-amylose. Periodica Polytechnica Chem Eng 2:25–37

Holló J, Szejtli J (1959a) Über einige probleme bei der sauren stärkehydrolyse I. Mitteilung. Starch/Stärke 11:239–244. https://doi.org/10.1002/star.19590110804

Holló J, Szejtli J (1959b) Über einige probleme bei der sauren stärkehydrolyse II. Mitteilung. Starch/Stärke 11:244–246. https://doi.org/10.1002/star.19590110805

Holló J, Szejtli J (1968) Chapter VII: The reaction of starch with iodine. In: Radley JA (ed) Starch and its derivatives, 4th edn. Chapman and Hall, Ltd, EC4, London, pp 203–246

Holló J, Szejtli J, Gantner GS (1959a) Investigation of the retrogradation of amylose. Periodica Polytechnica Chem Eng 3:95–104

Holló J, Szejtli J, Gantner GS (1959b) The mechanism of the retrogradation of amylose. Periodica Polytechnica Chem Eng 3:163–166

Holló J, Szejtli J, László E (1959c) Das verhalten von stärke im alkalischen medium II. Die alkalische degradation von stärke. Fette Seifen Anstrichmittel 61:759–764. https://doi.org/10.1002/lipi.19590610904

Holló J, Szejtli J, László E, Vándor E (1962) Neuere beiträge zur chemie der stärkefraktionen. XI. Die herstellung von mit C^{14} markierter stärke und von glucose-1-phosphat. Starch/Stärke 14:53–58. https://doi.org/10.1002/star.19620140204

Holló J, László E, Szejtli J, Lux A (1964) Bedeutung und degradation der stärke im bayer-verfahren. II Mitteilung: Ursache der verminderung der absetzwirkung. Starch/Stärke 16:167–169. https://doi.org/10.1002/star.19640160506

Irie T, Uekama K (1997) Pharmaceutical applications of cyclodextrins. III Toxicological issues and safety evaluation. J Pharm Sci 86:147–162

Iványi R, Jicsinszky J, Juvancz Z, Roos N, Otta K, Szejtli J (2004) Influence of (hydroxy)alkylamino substituents on enantioseparation ability of single-isomer amino-beta-cyclodextrin derivatives in chiral capillary electrophoresis. Electrophoresis 25:2675–2686. https://doi.org/10.1002/elps.200406030

Jicsinsky L, Szejtli J (1992) Effect of catalysts on the acylation of cyclodextrins. In: Hedges RA (ed) Minutes of the sixth international symposium on cyclodextrins (Chicago, 21 to 24 April 1992). Éditions de santé, Paris, pp 96–100

Jodál I, Harangi J, Liptak A, Nánási P, Szejtli J (1982) Degradation of cyclodextrin with *Aspergillus oryzae* alpha-amylase. Acta Biochim Biophys Hung 17:102–102

Jodál I, Kandra L, Harangi J, Nánási P, Szejtli J (1984) Hydrolysis of cyclodextrin by *Aspergillus oryzae* α-amylase. Starch/Stärke 36:140–143. https://doi.org/10.1002/star.19840360408

Juvancz Z, Szejtli J (1999) Cyclodextrins dominate the chiral chromatography. In: Torres Labandeira JJ, Vila-Jato JL (eds) Proceedings of the ninth international symposium on cyclodextrins (Santiago de Compostela, May 31–June 3, 1998). Springer, Dordrecht, pp 621–624. https://doi.org/10.1007/978-94-011-4681-4

Juvancz Z, Szejtli J (2002) The role of cyclodextrins in chiral selective chromatography. Trends Anal Chem 21:379–388. https://doi.org/10.1016/S0165-9936(02)00506-X

Juvancz Z, Zs R, Alexander G, Szejtli J (1988) Gas chromatographic capillary columns with cyclodextrins as stationary phases study. In: Huber O, Szejtli J (eds) Proceedings of the fourth international symposium on cyclodextrins (Munich, April 20–22, 1988). Advances in inclusion science. Kluwer Academic Publishers, Dordrecht, pp 479–484. https://doi.org/10.1007/978-94-009-2637-0

Kainuma K (1984) Chapter V: Starch oligosaccharides: linear, branched, and cyclic. In: Whistler RL, BeMiller JN, Paschall EF (eds) Starch – chemistry and technology, 2nd edn. Academic, London, pp 125–152. https://doi.org/10.1016/B978-0-12-746270-7.50011-2

Kajtár M, Horvath-Toro C, Kuthi E, Szejtli J (1982) A simple rule for predicting circular-dichroism induced in aromatic guests by cyclodextrin hosts in inclusion complexes. Acta Chim Acad Sci Hung 110:327–355

Kajtár M, Vikmon M, Morlin E, Szejtli J (1989) Aggregation of amphotericin B in the presence of γ-cyclodextrin. Biopolymers 28:1585–1596

Kandra L, Lipták A, Jodál I, Nánási P, Szejtli J (1984) Preparation of macro crown ether-like compounds by the Smith degradation of cyclodextrins. In: Atwood JL, Davies JED, Osa T (eds) Clathrate compounds, molecular inclusion phenomena, and cyclodextrins, Advances in inclusion science. D. Reidel Publishing Company, Dordrecht, pp 869–876. https://doi.org/10.1007/978-94-009-5376-5

Kato L, Szejtli J, Szente L (1992) Water-soluble complexes of palmitic acid and palmitates for metabolic studies and cultivation trials of *Mycobacterium leprae*. Int J Leprosy Mycrobact Dis 60:105–107

Kato L, Szejtli J, Szente L (1993) Water soluble complex of palmitic acid in media for cultivation of leprosy-derived psychrophilic mycobacteria from *Mycobacterium leprae* infected tissues. Acta Microbiol Hung 40:47–58

Kato L, Szejtli J, Szente L (1994) Water-soluble complexes of C-14 and C-16 fatty-acids and alcohols in media for cultivation of leprosy-derived psychrophilic mycobacteria. Int J Leprosy Mycrobact Dis 62:55–88

Kis GL, Schoch C, Szejtli J (2003) PCT Appl:WO03105867

Klokkers K, Fenyvesi É, Szente L, Szejtli J (1999) Solubility enhancer decreases the dissolution of complexed drugs: effect of sodium-lauryl-sulfate on dissolution profile of complexed drugs. In: Torres Labandeira JJ, Vila-Jato JL (eds) Proceedings of the ninth international symposium on cyclodextrins (Santiago de Compostela, May 31–June 3, 1998). Springer, Dordrecht, pp 333–336. https://doi.org/10.1007/978-94-011-4681-4

Kolbe I, Vikmon M, Gerloczy A, Szejtli J (2002) Preparation and characterization of Clopidogrel/DIMEB complex. J Incl Phenom Macrocycl Chem 44:183–184. https://doi.org/10.1023/A:1023054915605

Kralova K, Cizmarik, Szejtli J (1992) Crystalline inclusion complex of heptacaine with beta-cyclodextrin. Pharmazie 47:460–461

László E, Bánky B, Szejtli J (1980) Vergleich der cyclodextrintransglykosylase-erzeugung bei verschiedenen *Bacillus macerans*-stämmen. Starch/Stärke 32:27–29. https://doi.org/10.1002/star.19800320109

László E, Bánky B, Seres G, Szejtli J (1981) Purification of cyclodextrin-glycosyltransferase enzyme by affinity chromatography. Starch/Stärke 33:281–283

Li S, Purdy WC (1992) Cyclodextrins and their applications in analytical chemistry. Chem Rev 92:1457–1470

Lindner K, Szente L, Szejtli J (1981) Food flavoring with beta-cyclodextrin-complexed flavor substances. Acta Aliment 10:175–186

Lipták A, Fügedi P, Szurmai Z, Imre J, Nánási P, Szejtli J (1982) The chemistry of cyclodextrin derivatives. In: Szejtli J (ed) Proceedings of the first international symposium on cyclodextrins (Budapest, 30 September–2 October 1981). Springer, Dordrecht, pp 275–287

Lipták A, Janossy L, Batta G, Borbas A, Szejtli J (2001) A new mixed acetal-type substitution pattern for alpha-cyclodextrin. Preparation of hexakis (3-O-benzyl)-alpha-cyclodextrin. Carbohydr Lett 4:111–116

Lipták A, Janossy L, Borbas A, Szejtli J (2002) Mixed acetals of cyclodextrins. Preparation of hexakis-, heptakis- and octakis[2,6-di-O-(methoxydimethyl)methyl]-alpha-, beta- and gamma-cyclodextrins. Carbohydr Res 337:93–96. https://doi.org/10.1016/S0008-6215(01)00279-8

Loeve S, Normand M (2011) How to trust a molecule? The case of cyclodextrins entering the nanorealm. In: Zülsdorf TB, Coenen C, Ferrari A, Fiedeler U, Milburn C, Wienroth M (eds) Quantum engagements. Social reflections of nanoscience and emerging technologies. IOS Press, Heidelberg, pp 1–23. ISBN: 978-3-898338-659-3

Loftsson T, Brewster M (1996) Pharmaceutical applications of cyclodextrins. I Drug solubilization and stabilization. J Pharm Sci 85:1017–1025

Loftsson T, Duchêne D (2007) Cyclodextrins and their pharmaceutical applications. Int J Pharm 329:1–11. https://doi.org/10.1016/j.ijpharm.2006.10.044

Lopata A, Darvas F, Stadler-Szóke Á, Szejtli J (1985) Quantitative structure-stability relationships among inclusion complexes of cyclodextrins I: Barbituric acid derivatives. J Pharm Sci 74:211–213

Mikuni K, Nakanishi K, Hashimoto H, Jicsinszky L, Fenyvesi E, Szejtli J, Szente L (2000) Japanese patent JP 2000191704

Molnár M, Fenyvesi É, Gruiz K, Szejtli J (1999) Application of randomly methylated β-cyclodextrin for bioremediation of contaminated soil. In: Torres Labandeira JJ, Vila-Jato JL (eds) Proceedings of the ninth international symposium on cyclodextrins (Santiago de Compostela, May 31-June 3, 1998). Springer, Dordrecht, pp 599–603. https://doi.org/10.1007/978-94-011-4681-4

Molnár M, Fenyvesi É, Gruiz K, Leitgib L, Balogh G, Murányi A, Szejtli J (2002) Effects of RAMEB on bioremediation of different soils contaminated with hydrocarbons. J Incl Phenom Macrocycl Chem 44:447–452. https://doi.org/10.1023/A:1023032305920

Molnár M, Leitgib L, Gruiz K, Fenyvesi É, Szaniszlo N, Szejtli J, Fava F (2005) Enhanced biodegradation of transformer oil in soils with cyclodextrin – from the laboratory to the field. Biodegradation 16:159–168. https://doi.org/10.1007/s10532-004-4873-0

Morin-Crini N, Fourmentin S, Crini G (eds) (2015) Cyclodextrins. PUFC, Besançon, 370 p. ISBN: 978-2-84867-520-6

Morva A, Fenyvesi É, Roos N, Zsadon B, Szejtli J (1999) Sulfated cyclodextrin derivatives. In: Torres Labandeira JJ, Vila-Jato JL (eds) Proceedings of the ninth international symposium on cyclodextrins (Santiago de Compostela, May 31–June 3, 1998). Springer, Dordrecht, pp 53–56. https://doi.org/10.1007/978-94-011-4681-4

Neumarkt T, Szejtli J (1980) High-resolution electron-micrographs of crystalline beta-cyclodextrin. Star 32:90–91. https://doi.org/10.1002/star.19800320305

Novák C, Pokol G, Sztatisz J, Szente L, Szejtli J (1993) Determination of the degree of substitution of hydroxypropylated beta-cyclodextrins by differential scanning calorimetry. Anal Chim Acta 282:313–316. https://doi.org/10.1016/0003-2670(93)80216-8

Olah J, Cserhati T, Szejtli J (1988) Beta-cyclodextrin enhanced biological detoxification of industrial wastewaters. Wat Res 22:1345–1351. https://doi.org/10.1016/0043-1354(88)90090-5

Otta K, Fenyvesi É, Zsadon B, Szejtli J, Tüdös F (1982) Cyclodextrin polymers as specific sorbents. In: Szejtli J (ed) Proceedings of the first international symposium on cyclodextrins (Budapest, 30 September–2 October 1981). Springer, Dordrecht, pp 357–362

Otta K, Zsadon B, Faragó J, Szejtli J, Tüdos F (1988) Cyclodextrin-cellulose copolymers. In: Huber O, Szejtli J (eds) Proceedings of the fourth international symposium on cyclodextrins (Munich, April 20–22, 1988). Advances in inclusion science. Kluwer Academic Publishers, Dordrecht, pp 139–143. https://doi.org/10.1007/978-94-009-2637-0

Paal TL, Szejtli J (1981) Study of interactions in aqueous-solutions containing cyclodextrin, glucose and borate. Exclusion of the formation of stable D-glucose-cyclodextrin complexes on the basis or potentiometric and kinetic measurements. Acta Chim Acad Sci Hung 106:9–15

Pitha J, Szente L, Szejtli J (1983) Molecular encapsulation of drugs by cyclodextrins and congeners. In: Bruck SD (ed) Controlled drug delivery, vol I. CRC Press, pp 125–148

Pobozsny K, Kernoczi I, Tetenyi P, Hethelyi I, Szejtli J (1981) Assay of volatile oil-cyclodextrin complexes by pyrolysis gas-chromatography. Planta Med 42:255–259. https://doi.org/10.1055/s-2007-971636

Redenti E, Pasini M, Ventura P, Spisni A, Vikmon M, Szejtli J (1994) The terfenadine beta-cyclodextrin inclusion complex. J Incl Phenom Mol Recognit Chem 15:281–292. https://doi.org/10.1007/BF00709073

Redenti E, Szente L, Szejtli J (2000) Drug/cyclodextrin/hydroxy acid multicomponent systems. Properties and pharmaceutical applications. J Pharm Sci 89:1–8. https://doi.org/10.1002/(SICI)1520-6017(200001)89:1<1::AID-JPS1>3.0.CO;2-W

Redenti E, Szente L, Szejtli J (2001) Cyclodextrin complexes of salts of acidic drugs. Thermodynamic properties, structural features, and pharmaceutical applications. J Pharm Sci 90:979–986. https://doi.org/10.1002/jps.1050

Richter M, Szejtli J (1966) Photometrische titration der stärkepolysaccharide mit Jod. III. Die automatische titration. Die Stärke 18:95–100. https://doi.org/10.1002/star.19660180402

Saenger W (1980) Cyclodextrin inclusion-compounds in research and industry. Angewandte Chemie Int Ed 19:344–362. https://doi.org/10.1002/anie.198003441

Saenger W (1984) Structural aspects of cyclodextrins and their inclusion complexes. In: Atwood JL, Davies JED, MacNicol DD (eds) Inclusion compounds, vol 2. Academic, London, pp 231–260

Saenger W, Noltemeyer M, Manor PC, Hingerty B, Klar B (1976) "Induced fit" type complex formation of the model enzyme α-cyclodextrin. Bioorg Chem 5:187–195. https://doi.org/10.1016/0045-2068(76)90007-9

Smolková-Keulemansová E (1982) Cyclodextrins as stationary phases in chromatography. J Chromatogr 251:17–34

Stadler-Szöke A, Vikmon M, Szemán J, Szejtli J (1984) Examples of the application of cyclodextrin in formulation of oral drug preparations. In: Atwood JL, Davies JED, Osa T (eds) Clathrate compounds, molecular inclusion phenomena, and cyclodextrins, Advances in inclusion science. D. Reidel Publishing Company, Dordrecht, pp 503–510. https://doi.org/10.1007/978-94-009-5376-5

Stadler-Szöke A, Vikmon M, Szejtli J, Kajtár M (1985) Fendiline-beta-cyclodextrin inclusion complex. J Incl Phenom 3:71–84. https://doi.org/10.1007/BF00658864

Stella VJ, Rajewski RA (1997) Cyclodextrins: their future in drug formulation and delivery. Pharm Res 14:556–567

Süvegh G, Zsadon B, Szejtli J (1992) Separation of diastereomer vincamine derivative by chromatography on β-cyclodextrin polymer stationary phase. In: Hedges RA (ed) Minutes of the sixth international symposium on cyclodextrins (Chicago, 21 to 24 April 1992). Éditions de santé, Paris, pp 584–587

Suzuki M, Fenyvesi É, Szilasi M, Szejtli J, Kajtár M, Szadon B, Sasaki Y (1984) Spectroscopic investigation of cyclodextrin monomers, derivatives, polymers and azo dyes. In: Atwood JL, Davies JED, Osa T (eds) Clathrate compounds, molecular inclusion phenomena, and cyclodextrins, Advances in inclusion science. D. Reidel Publishing Company, Dordrecht, pp 715–724. https://doi.org/10.1007/978-94-009-5376-5

Suzuki M, Szejtli J, Szente L (1989) Inclusion compounds of cyclodextrins and azo dyes. 7. Molecular-dynamics of derivatives of cyclomalto-oligosaccharides and their complexes with azo dyes. Carbohydr Res 192:61–68. https://doi.org/10.1016/0008-6215(89)85165-1

Suzuki M, Ohmori H, Kajtár M, Szejtli J, Vikmon M (1994) The association of inclusion complexes of cyclodextrins with azo dyes. J Incl Phenom Mol Recognit Chem 18:255–264. https://doi.org/10.1007/BF00708732

Szabo P, Ferenczy T, Serfözö J, Szejtli J, Liptak A (1982) Absorption and elimination of cyclodextrin derivatives by rabbits and rats. In: Szejtli J (ed) Proceedings of the first international symposium on cyclodextrins (Budapest, 30 September–2 October 1981). Springer, Dordrecht, pp 115–122
Szejtli J (1963) Untersuchung der Jod-amylose-einschlussverbindung. Periodica Polytechnica Chem Budapest 7:259–288
Szejtli J (1965a) Acid hydrolysis of starch. Acta Chim Acad Sci Hung 46:77–84
Szejtli J (1965b) Acid hydrolysis of dextran. Acta Chim Acad Sci Hung 46:153–162
Szejtli J (1965c) Acid hydrolysis of alginic acid. Acta Chim Acad Sci Hung 46:369–379
Szejtli J (1966) Zusammenhang zwischen zusammensetzung und IR-spektrum bei alginsäuren verschiedener Herkunft. Mol Nutr Food Res 10:291–296. https://doi.org/10.1002/food.19660100403
Szejtli J (1969) Molecular configuration of amylose and non-statistical character of its hydrolysis. Kémiai Közlemények 31:59–60
Szejtli J (1971) Relationship between conformation of glucopyranoside units and molecular configuration of amylose. Starch/Stärke 23:295–300. https://doi.org/10.1002/star.19710230902
Szejtli J (1975) Säurehydrolyse glykosidischer bindungen (acid hydrolysis of glycosidic bonds). Übersetzung aus dem Ungarischen ins Deutsche. VEB Fachbuchverlag, Leipzig, p 398
Szejtli J (1977a) Einige anwendungsmöglichkeiten der cyclodextrine in der arzneimittelindustrie (some application possibilities of cyclodextrins in pharmaceutical industries). Starch/Stärke 29:26–33. https://doi.org/10.1002/star.19770290107
Szejtli J (1977b) Interaction of hydrochloric-acid with cyclodextrin. Starch/Stärke 29:410–413. https://doi.org/10.1002/star.19770291204
Szejtli J (1978) Neue untersuchungsmethoden in der cyclodextrinchemie (new analytical methods in chemistry of cyclodextrins). Starch/Stärke 30:427–431. https://doi.org/10.1002/star.19780301207
Szejtli J (1980) Complexing properties of substituted cyclodextrins and cyclodextrin polymers in aqueous-solutions. Abstracts Papers Am Chem Soc 179:65–66
Szejtli J (1981) Enhancement of drug bioavailability by cyclodextrins. Starch/Stärke 33:387–390. https://doi.org/10.1002/star.19810331108
Szejtli J (1982a) Cyclodextrins and their inclusion complexes. Akadémiai Kiadó, Budapest, p 296. ISBN: 963 05 2850 9
Szejtli J (1982b) Cyclodextrins in foods, cosmetics and toiletries. In: Szejtli J (ed) Proceedings of the first international symposium on cyclodextrins (Budapest, 30 September–2 October 1981). Reidel Publishing Company, Dordrecht, pp 469–480. https://doi.org/10.1007/978-94-009-7855-3_55
Szejtli J (1982c) Cyclodextrins in food, cosmetics and toiletries. Starch/Stärke 34:379–385. https://doi.org/10.1002/star.19820341106
Szejtli J (1983a) Physiological effects of cyclodextrins on plants. Starch/Stärke 35:433–438. https://doi.org/10.1002/star.19830351208
Szejtli J (1983b) Dimethyl-β-cyclodextrin as parenteral drug carrier. J Incl Phenom 1:135–150
Szejtli J (1984a) Highly soluble β-cyclodextrin derivatives. Starch/Stärke 36:429–432. https://doi.org/10.1002/star.19840361207
Szejtli J (1984b) Industrial applications of cyclodextrins. In: Atwood JL, Davies JED, MacNicol DD (eds) Inclusion compounds, vol 3. Academic, London, pp 331–390
Szejtli J (1984c) Limits of cyclodextrin application in oral drug preparations. In: Atwood JL, Davies JED, Osa T (eds) Clathrate compounds, molecular inclusion phenomena, and cyclodextrins, Advances in inclusion science. D. Reidel Publishing Company, Dordrecht, pp 487–502. https://doi.org/10.1007/978-94-009-5376-5
Szejtli J (1985a) Cyclodextrins: a new group of industrial basic materials. Food Nahrung 29:911–924
Szejtli J (1985b) Cyclodextrins in pesticides. Starch/Stärke 37:382–386. https://doi.org/10.1002/star.19850371106

Szejtli J (1986a) Cyclodextrins in biotechnology. Starch/Stärke 38:388–390. https://doi.org/10.1002/star.19860381107
Szejtli J (1986b) Cyclodextrins and their use in separations. Abstracts Papers Am Chem Soc 191:80–81
Szejtli J (1987a) Cyclodextrins and the molecular encapsulation. Chimicaoggi:17–21
Szejtli J (1987b) Chapter 5: The metabolism, toxicity and biological effects of cyclodextrins. In: Duchêne D (ed) Cyclodextrins and their industrial uses. Éditions de sant, Paris, pp 173–210
Szejtli J (1987c) Reduction of phytotoxicity of nonionic tensides by cyclodextrins. J Incl Phenom Macrocyl Chem 5:421–425
Szejtli J (1987d) Cyclodextrins lessen the membrane damaging effect of nonionic tensides. J Incl Phenom Macrocyl Chem 5:433–437
Szejtli J (1987e) Application of cyclodextrins in the chromatography. Starch-Stärke 39:357–362. https://doi.org/10.1002/star.19870391006
Szejtli J (1988a) Cyclodextrin technology. Kluwer Academic Publishers, Dordrecht, p 450. ISBN: 90-277-2314-1
Szejtli J (1988b) Cyclodextrins in diagnostics. Kontakte (Darmstadt) 1:31–36
Szejtli J (1988c) Fungicidal activity of benomyl in presence of β-cyclodextrin. In: Huber O, Szejtli J (eds) Proceedings of the fourth international symposium on cyclodextrins (Munich, April 20–22, 1988), Advances in inclusion science. Kluwer Academic Publishers, Dordrecht, pp 561–568. https://doi.org/10.1007/978-94-009-2637-0
Szejtli J (1989) Downstream processing using cyclodextrins. Trends Biotechnol 7:171–174. https://doi.org/10.1016/0167-7799(89)90094-
Szejtli J (1990a) Complexation of metal-ions by cyclodextrins. Starch-Stärke 42:444–447. https://doi.org/10.1002/star.19900421108
Szejtli J (1990b) The cyclodextrins and their applications in biotechnology. Carbohydr Polym 12:375–392. https://doi.org/10.1016/0144-8617(90)90088-A
Szejtli J (1991a) Chapter 17: The use of cyclodextrins in biotechnological operations. In: Duchêne D (ed) New trends in cyclodextrins and derivatives. Éditions de santé, Paris, pp 595–626
Szejtli J (1991b) Complexation of metal ions by cyclodextrins. ChemInform 22:313–313
Szejtli J (1991c) Helical and cyclic structures in starch chemistry. In: Friedman R (ed) Biotechnology of amylopectin oligosaccharides, ACS Symposium Series 458, Washington, DC, pp 2–10. https://doi.org/10.1021/bk-1991-0458.ch001
Szejtli J (1992a) Cyclodextrins in the reduction of environmental pollution. In: Hedges RA (ed) Minutes of the sixth international symposium on cyclodextrins (Chicago, 21 to 24 April 1992). Editions de Santé, Paris, pp 380–390
Szejtli J (1992b) The properties and potential uses of cyclodextrin derivatives. J Incl Phenom Mol Recognit 14:25–36. https://doi.org/10.1007/BF01041363
Szejtli J (1994) Medicinal applications of cyclodextrins. Med Res Rev 14:353–386. https://doi.org/10.1002/med.2610140304
Szejtli J (1995) Selectivity/structure correlation in cyclodextrin chemistry. Supramol Chem 6:217–223. https://doi.org/10.1080/10610279508032537
Szejtli J (1996a) Chapter 1: Historical background. In: Comprehensive supramolecular chemistry. Atwood JL, Davies ED, MacNicol DD and Vögtle F (executive eds), Volume 3: Cyclodextrins. Szejtli J and Osa T (eds). Pergamon Oxford, UK, London, pp. 1–4. ISBN: 9780080912844
Szejtli J (1996b) Chapter 2: Chemistry, physical and biological properties of cyclodextrins. In: Comprehensive supramolecular chemistry. Atwood JL, Davies ED, MacNicol DD and Vögtle F (executive eds), Volume 3: Cyclodextrins. Szejtli J and Osa T (eds). Pergamon Oxford, London, pp. 5–40. ISBN: 9780080912844
Szejtli J (1996c) Chapter 5: Inclusion of guest molecules, selectivity and molecular recognition by cyclodextrins. In: Comprehensive supramolecular chemistry. Atwood JL, Davies ED, MacNicol DD and Vögtle F (executive eds), Volume 3: Cyclodextrins. Szejtli J and Osa T (eds). Pergamon Oxford, London, pp. 189–203. ISBN: 9780080912844

Szejtli J (1996d) Chapter 21: Use of cyclodextrins in chemical products and processes. In: Comprehensive supramolecular chemistry. Atwood JL, Davies ED, MacNicol DD and Vögtle F (executive eds) Volume 3: Cyclodextrins. Szejtli J and Osa T (eds). Pergamon Oxford, London, pp. 603–614. ISBN: 9780080912844

Szejtli J (1997) Utilization of cyclodextrins in industrial products and processes. J Mater Chem 7:575–587. https://doi.org/10.1039/A605235E

Szejtli J (1998) Introduction and general overview of cyclodextrin chemistry. Chem Rev 98:1743–1753. https://doi.org/10.1021/cr970022c

Szejtli J (2002) The role of cyclodextrins in chiral selective chromatography. Trends Anal Chem 21:379–388

Szejtli J (2003) Cyclodextrins in the textile industry. Starch-Stärke 55:191–196. https://doi.org/10.1002/star.200390050

Szejtli J (2004a) Past, present and future of cyclodextrin research. Pure Appl Chem 76:1825–1845. https://doi.org/10.1351/pac200476101825

Szejtli J (2004b) Chapter 17: Cyclodextrins. In: Tomasik P (ed) Chemical and functional properties of food saccharides. CRC Press, New York, pp 272–290. ISBN 0-8493-1486-0

Szejtli J (2004c) Cyclodextrins: applications. In: Encyclopedia of supramolecular chemistry. Marcel Dekker, Inc, New York, pp 405–413. https://doi.org/10.1081/E-ESMC120012796

Szejtli J (2005) Cyclodextrin complexed generic drugs are generally not bio-equivalent with the reference products: therefore the increase in number of marketed drug/cyclodextrin formulations is so slow. J Incl Phenom Macrocycl Chem 52:1–11. https://doi.org/10.1007/s10847-004-7161-z

Szejtli J, Augustat S (1966) Über die configuration der amylosemoleküle in wäβriger lösung. Die Stärke 18:38–42

Szejtli J, Bánky-Elöd E (1975a) Inclusion complexes of unsaturated fatty acids with amylose and cyclodextrin. Starch/Stärke 27:368–376. https://doi.org/10.1002/star.19750271104

Szejtli J, Bánky-Elöd E (1975b) Catalysis of decomposition of trichlorphon by inclusion complexe formation. Acta Biochim Biophys Hung 11:234–234

Szejtli J, Bolla E (1980) Stabilization of fat-soluble vitamins with beta-cyclodextrin. Starch/Stärke 32:386–391. https://doi.org/10.1002/star.19800321108

Szejtli J, Budai ZS (1976) Acid-hydrolysis of beta-cyclodextrin. Acta Chim Acad Sci Hung 91:73–80

Szejtli J, Budai ZS (1977) Crystalline hydrogen halide complexes of cyclodextrins. Acta Chim Acad Sci Hung 94:383–390

Szejtli J, Budai ZS (1979) Turbidimetric study of the crystallization of beta-cyclodextrin inclusion complexes. Acta Chim Acad Sci Hung 99:433–436

Szejtli J, Kandra L (1987) Crown ethers derived from cyclodextrin: interaction with triphenylmethane derivatives. J Incl Phenom Macrocycl Chem 5:639–643. https://doi.org/10.1007/BF00663005

Szejtli J, Osa T (eds) (1996) Cyclodextrins. In: Comprehensive supramolecular chemistry, vol 3, Pergamon Oxford, London

Szejtli J, Sebestyén GY (1979) Resorption, metabolism and toxicity studies on the peroral application of beta-cyclodextrin. Starch/Stärke 31:385–389. https://doi.org/10.1002/star.19790311108

Szejtli J, Szente L (1979) Stabilization of volatile, oxidizable flavor substances by beta-cyclodextrin. Planta Med 36:292–293

Szejtli J, Szente L (1981) Interaction between indomethacin and beta-cyclodextrin. Pharmazie 36:694–698

Szejtli J, Szente L (2005) Elimination of bitter, disgusting tastes of drugs and foods by cyclodextrins. Eur J Pharm Biopharm 61:115–125. https://doi.org/10.1016/j.ejpb.2005.05.006

Szejtli J, Tétényi M (1981) Increase in the yield of wheat by seed treatment with beta-cyclodextrin. Nahrung Food 25:765–768

Szejtli J, Richter M, Augustat S (1967a) Molecular configuration of amylose and its complexes in aqueous solutions. Part II Relation between the DP of helical segments of the amylose-iodine

complex and the equilibrium concentration of free iodine. Biopolymers 5:5–16. https://doi.org/10.1002/bip.1967.360050103
Szejtli J, Richter M, Augustat S (1967b) Molecular configuration of amylose and its complexes in aqueous solutions. Part III Investigation of the DP distribution of helical segments in amylose-iodine complexes. Biopolymers 5:17–26. https://doi.org/10.1002/bip.1967.360050104
Szejtli J, Richter M, Augustat S (1968) Molecular configuration of amylose and its complexes in aqueous solutions. IV Determination of DP of amylose by measuring the concentration of free iodine in solution of amylose-iodine complex. Biopolymers 6:27–41. https://doi.org/10.1002/bip.1968.360060103
Szejtli J, Bánky-Elöd, Fónagy A (1976) Ungarische Patent-anmeldung CI 1661
Szejtli J, Szente L, Kolta R, Lindner K, Zilahy T, Köszegi B (1977a) Hungarian Patent 174,699
Szejtli J, László E, Bánky G, Seres G (1977b) Hungarian Patent 175,584
Szejtli J, Szente L, Kis G, Jakus K, Horváth G, Radványi B (1977c) Hungarian Patent 174,699
Szejtli J, Fenyvesi É, Zsadon B (1978a) Cyclodextrinpolymere. Starch/Stärke 30:127–131. https://doi.org/10.1002/star.19780300407
Szejtli J, Budai ZS, Kajtar M (1978b) Cyclodextrin dye inclusion compounds. Magyar Kémiai Folyóirat 84:68–78
Szejtli J, Budai ZS, Dávid A (1978c) Hungarian Patent 172,936
Szejtli J, Szente L, Dávid A, Virág S, Sebestyén G, Mándi A (1978d) Hungarian Patent 176,215
Szejtli J, Szente L, Bánky-Elöd EI (1979a) Molecular encapsulation of volatile, easily oxidizable labile flavor substances by cyclodextrins. Acta Chim Acad Sci Hung 100:27–46
Szejtli J, Bánky-Elöd E, Stadler A, Tetenyi P, Hethelyi I (1979b) Enrichment of the unsaturated components in fatty-acid ester mixtures by cyclodextrin complex-formation. Acta Chim Acad Sci Hung 99:447–452
Szejtli J, Lipták A, Jodál I, Fügedi P, Nánási P, Neszmélyi A (1980a) Synthesis and ^{13}C-NMR spectroscopy of methylated beta-cyclodextrins. Starch/Stärke 32:165–169. https://doi.org/10.1002/star.19800320506
Szejtli J, Gerloczy A, Fonagy A (1980b) Intestinal-absorption of C-14-labeled beta-cyclodextrin in rats. Arzneimittel Forschung Drug Res 30:808–810
Szejtli J, Szejtli M, Szente L (1980c) Hungarian Patent 02027
Szejtli J, Szente L, Gál-Füzy M, Szejtli M, Köszegi B (1980d) Hungarian Patent:1287
Szejtli J, Fenyvesi E, Zoltán S, Zsadon B, Tüdös F (1980e) Hungarian Patent 177,419; Belgium Patent 877,653; US Patent 4,274,985; German Patent 2,927,733
Szejtli J, Bolla-Pusztai E, Szabo P, Ferenczy T (1980f) Enhancement of stability biological effect of cholecalciferol by beta-cyclodextrin complexation. Pharmazie 35:779–787
Szejtli J, Bolla E, Stadler A (1980g) Hungarian Patent 1141
Szejtli J, Zsadon B, Fenyvesi E, Szilasi M, Décsei L (1980h) Hungarian Patent 488/83
Szejtli J, Zsadon B, Fenyvesi É, Otta K, Tüdős F (1980i) Hungarian Patent 181 733
Szejtli J, Gerlóczy A, Sebestyén G, Fónagy A (1981a) Influencing of resorption and side-effects of salicyclic-acid by complexing with beta-cyclodextrin. Pharmazie 36:283–286
Szejtli J, Fenyvesi É, Zoltan S, Zsadon B, Horvath O, Tüdős F (1981b) US Patent 4,274,985
Szejtli J, Bolla-Pusztai E, Kajtár M (1982a) The beta-cyclodextrin inclusion complex of menadione (vitamin K3). Pharmazie 37:725–728
Szejtli J, Zsadon B, Fenyvesi É, Otta K, Tüdős F (1982b) US Patent 4,357,468
Szejtli J, Bolla-Pusztai E, Tardylengyel M, Szabo P, Ferenczy T (1983a) Preparation, properties and biological activity of beta-cyclodextrin inclusion complex of menadione. Pharmazie 38:189–193
Szejtli J, Gerlóczy A, Fónagy A (1983b) Improvement of the absorption of H-3 labeled cholecalciferol by formation of its cyclodextrin complex. Pharmazie 38:100–101
Szejtli J, Tetenyi M, Rajki E (1983c) Effect of cyclodextrin treatment on the development and yield of wheat. Acta Agronomica Acad Sci Hung 32:74–78
Szejtli J, Stadler-Szöke A, Vikmon A, Piukovich S, Inczefy I, Kulcsár G, Zlatos G (1983d) Hungarian Patent 35,172

Szejtli J, Szente L, Kálói K, Marton J, Gerlóczy A (1985a) Hungarian Patent 75,85
Szejtli J, Fenyvesi É, Zsadon B, Szilasi M, Décsei L (1985b) US Patent 4,535,152
Szejtli J, Cserháti T, Szögyi M (1986) Interactions between cyclodextrins and cell-membrane phospholipids. Carbohydr Polym 6:35–49. https://doi.org/10.1016/0144-8617(86)90011-1
Szejtli J, Zsadon B, Cserhati T (1987) Cyclodextrin use in separations. ACS Symposium Series Am Chem Soc (ed) 342:200–217
Szejtli J, Zsadon B, Horvath OK, Ujhazy A, Fenyvesi É (1991) Hungarian Patent 54 506
Szejtli J, Vikmon M, Szente L, Szemán J (2004) Hungarian Patent Application
Szemán J, Ueda H, Szejtli J, Fenyvesi E, Machida Y, Nagai T (1987a) Complexation of several drugs with water-soluble cyclodextrin polymer. Chem Pharm Bull 35:282–288
Szemán J, Fenyvesi É, Szejtli J, Ueda H, Machida Y, Nagai T (1987b) Water-soluble cyclodextrin polymers – their interaction with drugs. J Incl Phenom 5:427–431. https://doi.org/10.1007/BF00664098
Szemán J, Ganzler K, Salgo A, Szejtli J (1996) Effect of the degree of substitution of cyclodextrin derivatives on chiral separations by high-performance liquid chromatography and capillary electrophoresis. J Chromatogr 728:423–431. https://doi.org/10.1016/0021-9673(95)01312-1
Szemán J, Gerloczy A, Csabai K, Szejtli J, Kis GL, Su P, Chau RY, Jacober A (2002) High-performance liquid chromatographic determination of 2-hydroxypropyl-gamma-cyclodextrin in different biological fluids based on cyclodextrin enhanced fluorescence. J Chromatogr B Anal Technol Biomed Life Sci 774:157–164. https://doi.org/10.1016/S1570-0232(02)00182-4
Szente L (1994) Cyclodextrins – perseverance pays off. J Incl Phenom Molecular Recognit Chem 18:207–209. https://doi.org/10.1007/BF00708727
Szente L (2004) Prof. Dr. Szejtli József. 1933–2004. Cyclodextrin News 18:268–269
Szente L, Fenyvesi É (2016) József Szejtli and his important findings in the pharmaceutical application of cyclodextrins. Magyar Kémiai Folyóirat 122:60–64
Szente L, Szejtli J (1981) Cyclodextrin complex of a volatile insecticide (DDVP). Acta Chim Acad Sci Hung 107:195–202
Szente L, Szejtli J (1986) Molecular encapsulation of natural and synthetic coffee flavor with β-cyclodextrin. J Food Sci 51:1024–1027. https://doi.org/10.1111/j.1365-2621.1986.tb11224.x
Szente L, Szejtli J (1987a) Stabilization of flavors by cyclodextrins. Abstracts Papers Am Chem Soc 194:96–97
Szente L, Szejtli J (1987b) Formulation of propolis with beta-cyclodextrin. Acta Pharm Technol Int J Drug Formulation Biopharm 33:218221
Szente L, Szejtli J (1988) Stabilization of flavors by cyclodextrins. ACS Symp Ser 370:148–157
Szente L, Szejtli J (1996) Chapter 17: Cyclodextrins in pesticides. In: Comprehensive supramolecular chemistry. Atwood JL, Davies ED, MacNicol DD and Vögtle F (executive eds), Volume 3: Cyclodextrins. Szejtli J and Osa T (eds). Pergamon Oxford, London, pp. 503–514. ISBN: 9780080912844
Szente L, Szejtli J (1998) Non-chromatographic analytical uses of cyclodextrins. Analyst 123:735–741. https://doi.org/10.1039/a707413a
Szente L, Szejtli J (1999) Highly soluble cyclodextrin derivatives: chemistry, properties, and trends in development. Adv Drug Del Rev 36:17–28. https://doi.org/10.1016/S0169-409X(98)00092-1
Szente L, Szejtli J (2004) Cyclodextrins as food ingredients. Trends Food Sci Technol 15:137–142. https://doi.org/10.1016/j.tifs.2003.09.019
Szente L, Apostol I, Szejtli J (1984a) Suppositories containing beta-cyclodextrin complexes. 1. Stability studies. Pharmazie 39:697–699
Szente L, Szejtli J, Gál-Füzy M (1984b) Non-oral drug preparations containing cyclodextrin complexes. J Incl Phenom Macrocycl Chem 2:631–636
Szente L, Szejtli J, Gál-Füzy M (1984c) Non-oral drug preparations containing cyclodextrin complexes. In: Atwood JL, Davies JED, Osa T (eds) Clathrate compounds, molecular inclusion phenomena, and cyclodextrins, Advances in inclusion science. D. Reidel Publishing Company, Dordrecht, pp 631–636. https://doi.org/10.1007/978-94-009-5376-5

Szente L, Apostol I, Gerlóczy A, Szejtli J (1985) Suppositories containing beta-cyclodextrin complexes. 2. Dissolution and absorption studies. Pharmazie 40:406–407
Szente L, Szejtli J, Chau LT (1987) Effect of cyclodextrin complexation on the reduction of menthone and isomenthone. J Incl Phenom Macrocycl Chem 5:439–442. https://doi.org/10.1007/BF00664100
Szente L, Gál-Füzy M, Szejtli J (1988) Tea aromatization with beta-cyclodextrin complexed flavors. Acta Aliment 17:193–199
Szente L, Magisztrak H, Szejtli J (1990) Formulation of insect controlling agents with beta-cyclodextrin. Pesticide Sci 28:7–16
Szente L, Szejtli J, Kato L (1992) Solubilization of fatty acids and similar lipids by methylated cyclodextrins. In: Hedges RA (ed) Minutes of the sixth international symposium on cyclodextrins (Chicago, 21 to 24 April 1992). Éditions de santé, Paris, pp 340–344
Szente L, Szejtli J, Szemán J, Kato L (1993) Fatty-acid cyclodextrin complexes – properties and applications. J Incl Phenom Mol Recognit Chem 16:339–354. https://doi.org/10.1007/BF00708714
Szente L, Szejtli J, Kis GL (1998a) Spontaneous opalescence of aqueous γ-cyclodextrin solutions: complex formation or self-aggregation? J Pharm Sci 87:778–781. https://doi.org/10.1021/js9704341
Szente L, Mikuni K, Hashimoto H, Szejtli J (1998b) Stabilization and solubilization of lipophilic natural colorants with cyclodextrins. J Incl Phenom Mol Recognit Chem 32:81–89. https://doi.org/10.1023/A:1007970501916
Szente L, Fenyvesi É, Szejtli J (1999a) Entrapment of iodine with cyclodextrins: potential application of cyclodextrins in nuclear waste management. Environ Sci Technol 33:4495–4498. https://doi.org/10.1021/es981287r
Szente L, Fenyvesi É, Szejtli J (1999b) Application of cyclodextrins in nuclear waste management. In: Torres Labandeira JJ, Vila-Jato JL (eds) Proceedings of the ninth international symposium on cyclodextrins (Santiago de Compostela, May 31–June 3, 1998). Springer, Dordrecht, pp 577–582. https://doi.org/10.1007/978-94-011-4681-4
Szente L, Szilágyi E, Szejtli G (2016) CycloLab Ltd: from the Chinoin biochemical lab to the pharmaceutical factory. Magyar Kémiai Folyóirat 122:57–59
Szogyi M, Cserhati T, Szejtli J (1987) Cyclodextrins lessen the membrane damaging effect of nonionic tensides. J Incl Phenom 5:433–437
Szurmai Z, Lipták A, Szejtli J (1990) Halogen azide displacement to prepare some symmetrically substituted beta-cyclodextrin derivatives. Starch-Stärke 42:447–449
Takeoka G, Flath RA, Mon TR, Buttery RG, Teranishi R, Güntert M, Lautamo R, Szejtli J (1990) Further applications of permethylated β-cyclodextrin capillary gas chromatographic columns. J High Resolut Chromatogr 13:202–206. https://doi.org/10.1002/jhrc.1240130317
Tetenyi M, Szejtli J (1984) Prolongation of ethylene effect by cyclodextrin complexation of 2-chloroethanephosphonic acid. Acta Agronomica Acad Sci Hung 33:345–348
Thoma JA, Stewart L (1965) Chapter IX: Cycloamyloses. In: Whistler RL, Paschall EF (eds) Starch, chemistry and technology, Fundamental aspects, vol 1, New York, Academic, pp 209–249
Uekama K, Otagiri M (1987) Cyclodextrins in drug carrier systems. Crit Rev Ther Drug Carrier Syst 3:1–40
Uekama K, Hirayama F, Irie T (1994) Application of cyclodextrins in pharmaceutical preparations. Drug Target Del 3:411–456
Ujházy A, Zsadon B, Szejtli J (1988) Gel chromatographic separation of proteins on cyclodextrin bead polymers. In: Huber O, Szejtli J (eds) Proceedings of the fourth international symposium on cyclodextrins (Munich, April 20–22, 1988), Advances in inclusion science. Kluwer Academic Publishers, Dordrecht, pp 497–501. https://doi.org/10.1007/978-94-009-2637-0
Ujházy A, Zsadon B, Szejtli J (1989) Gel chromatographic separation of proteins on cyclodextrin bead polymer stationary phases. J Liq Chromatogr 12:2877–2885. https://doi.org/10.1007/978-94-009-2637-0_70
Varga G, Szemán J, Szente L, Csabai P, Kékesi K (2005) PCT Int. Appl WO 2005105257

Verstichel S, De Wilde B, Fenyvesi É, Szejtli J (2004) Investigation of the aerobic biodegradability of several types of cyclodextrins in a laboratory-controlled composting test. J Polym Environ 12:47–55. https://doi.org/10.1023/B:JOOE.0000010050.52967.94

Vikmon M, Stadlerszoke A, Szejtli J (1985) Solubilization of amphotericin-B with gamma-cyclodextrin. J Antibiot 38:1822–1824. https://doi.org/10.7164/antibiotics.38.1822

Vikmon M, Gerlóczy A, Szejtli J (1988) Complexation of polyene antibiotics with γ-cyclodextrin. In: Huber O, Szejtli J (eds) Proceedings of the fourth international symposium on cyclodextrins (Munich, April 20–22, 1988), Advances in inclusion science. Kluwer Academic Publishers, Dordrecht, pp 307–312. https://doi.org/10.1007/978-94-009-2637-0

Vikmon M, Kolbe I, Szejtli J, Redenti E, Ventura P (1999) Preparation and characterization of piroxicam alkali-salt-γ-cyclodextrin. In: Torres Labandeira JJ, Vila-Jato JL (eds) Proceedings of the ninth international symposium on cyclodextrins (Santiago de Compostela, May 31–June 3, 1998). Springer, Dordrecht, pp 281–284. https://doi.org/10.1007/978-94-011-4681-4

Villiers A (1891) Sur la transformation de la fécule en dextrine par le ferment butyrique. Chimie organique – Compte rendus des séances de l'Académie des Sciences (France) Février CXII:435–437

Weiszfeiler V, Szejtli J (1988) Bitterness reduction with beta-cyclodextrin. In: Huber O, Szejtli J (eds) Proceedings of the fourth international symposium on cyclodextrins (Munich, April 20–22, 1988), Advances in inclusion science. Kluwer Academic Publishers, Dordrecht, pp 359–367. https://doi.org/10.1007/978-94-009-2637-0

Weiszfeiler V, Stadler-Szóke A, Szejtli J (1988) Solubility enhancement of ipriflavone by cyclodextrin complexation. In: Huber O, Szejtli J (eds) Proceedings of the fourth international symposium on cyclodextrins (Munich, April 20–22, 1988), Advances in inclusion science. Kluwer Academic Publishers, Dordrecht, pp 329–336. https://doi.org/10.1007/978-94-009-2637-0

Zsadon B, Szilasi M, Szejtli J, Seres G, Tüdös F (1978) Chromatography of alpha-, beta- and gamma-cyclodextrin on dextran gel columns. Starch/Stärke 30:276–279. https://doi.org/10.1002/star.19780300807

Zsadon B, Szilasi M, Tüdös F, Fenyvesi É, Szejtli J (1979a) Inclusion chromatography of amino acids on beta-cyclodextrin-polymer gel beds. Starch/Stärke 31:11–12. https://doi.org/10.1002/star.19790310104

Zsadon B, Szilasi M, Otta KH, Tüdös F, Fenyvesi É, Szejtli J (1979b) Characterization and chromatographic behavior of cyclodextrin polymers. Acta Chim Acad Sci Hung 100:265–273

Zsadon B, Otta KH, Tüdös F, Szejtli J (1979c) Separation of cyclodextrins by high-performance liquid-chromatography. J Chromatogr 171:490–492. https://doi.org/10.1016/S0021-9673(00)91004-5

Zsadon B, Szilasi M, Tüdös F, Szejtli J (1981) Inclusion chromatography of alkaloids on cyclodextrin polymer gel. J Chromatogr 208:109–112. https://doi.org/10.1016/S0021-9673(00)87970-4

Zsadon B, Decsei L, Szilasi M, Tüdös F, Szejtli J (1983) Inclusion chromatography of enantiomers of indole alkaloids on a cyclodextrin polymer stationary phase. J Chromatogr 270:127–134. https://doi.org/10.1016/S0021-9673(01)96357-5