OLIGOSACCHARIDES: PRODUCTION PROPERTIES AND APPLICATIONS

Oligosaccharides

Production, Properties, and Applications

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Volume 3, Number 2
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Preface to the Series

Modern technology has a great impact on both industry and society. New technology is first created by pioneering work in science. Eventually, a major industry is born, and it grows to have an impact on society in general. International cooperation in science and technology is necessary and desirable as a matter of public policy. As development progresses, international cooperation changes to international competition, and competition further accelerates technological progress.

Japan is in a very competitive position relative to other developed countries in many high technology fields. In some fields, Japan is in a leading position; for example, manufacturing technology and microelectronics, especially semiconductor LSIs and optoelectronic devices. Japanese industries lead in the application of new materials such as composites and fine ceramics, although many of these new materials were first developed in the United States and Europe. The United States, Europe and Japan are working intensively, both competitively and cooperatively, on the research and development of high-critical-temperature superconductors. Computers and communications are now a combined field that plays a key role in the present and future of human society. In the next century, biotechnology will grow, and it may become a major segment of industry. While Japan does not play a major role in all areas of biotechnology, in some areas such as fermentation (the traditional technology for making sake), Japanese research is of primary importance.

Today, tracking Japanese progress in high technology areas is both a necessary and rewarding process. Japanese academic institutions are very active; consequently, their results are published in scientific and technical journals and are presented at numerous meetings where more than 20,000 technical papers are presented orally every year.

However, due principally to the language barrier, the results of academic research in Japan are not well-known overseas. Many in the United States and in Europe are thus surprised by the sudden appearance of Japanese high technology products. The products are admired and enjoyed, but some are astonished at how suddenly these products appear.

With the series Japanese Technology Reviews, we present state-of-the-art Japanese technology in five fields:

Electronics

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Each tract deals with one topic within each of these five fields and reviews both the present status and future prospects of the technology, mainly as seen from the Japanese perspective. Each author is an outstanding scientist or engineer actively engaged in relevant research and development.

The editors are confident that this series will not only give a deep insight into Japanese technology but will also be useful for developing new technology of interest to our readers.

As editor in chief, I would like to sincerely thank the members of the editorial board and the authors for their contributions to this series.

TOSHIAKI IKOMA

Preface

Oligosaccharides are an important group of polymeric carbohydrates that are found either free or in combined forms in all living organisms. The generic term "oligosaccharides" is customarily used for saccharides having a degree of polymerization of two to ten. Structurally, oligosaccharides are composed of between two and ten monosaccharide residues joined by glycosidic bonds that are readily hydrolyzed to their constituent monosaccharides in acid solution or by the reaction of specific enzymes.

Research into the production of oligosaccharides for food was started around 1970–1975 in Japan and several oligosaccharides discussed in this book were produced on an industrial scale during the 1980s. Recently, various new biologically active oligosaccharides have been developed and some are now produced on a large scale using bioreactor systems. Improving health when used as food additives, these oligosaccharides are creating a sensation in Japan. With the increasing health consciousness of consumers and their increasing awareness of the bioavailability of food, the future for products containing oligosaccharides looks very bright.

Reviewing the recent progress of oligosaccharides in Japan is a rewarding task for the contributors, all outstanding biochemists actively engaged in relevant research and development. The details of production, properties, and applications of the respective oligosaccharides are described.

I wish to thank the coauthors for their contributions to this book. I also would like to express my gratitude to Prof. Isao Karube for giving me the opportunity to review the status of development of oligosaccharides in Japan.

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CHAPTER 1

Maltooligosaccharides

Teruo Nakakuki

The production of starch sweeteners by enzymatically decomposing starch started many years ago, but, industrially, starch syrup, glucose, etc., were first produced by acid hydrolysis. However, because of the discovery of various kinds of amylases produced by microorganisms, the acid hydrolysis process has given way to the enzymatic process of starch hydrolysis in most cases. Glucose production by the enzymatic process started with the discovery by Fukumoto et al.[1] in 1959 of *Rhizopus*-origin glucoamylase, which produced glucose by 100% decomposition. This triggered the growth of the glucose industry. Then, with the discovery[2-3] of debranching enzymes such as pullulanase and isoamylase, it became possible to produce pure-grade maltose through their combined use with β-amylase. Then, the situation in which the use of synthetic sweeteners such as sodium cyclohexylsulfamate was prohibited resulted in stepping up the production of high-fructose corn syrup, which was expected to have a stronger sweetness than glucose. Although studies on the production of high-fructose corn syrup were focused on chemical isomerization at the beginning, various microorganism-origin glucose isomerases have been discovered,[4-6] following the discovery of glucose isomerase produced by microorganisms by Marshall and Kooi[7] in 1957. Thus, the technology for high-fructose corn-syrup production by the enzymatic method was established. The technique was long a glimmer in the eyes of hydrolysis researchers. A continuous isomerization process by immobilized glucose isomerase is now in wide use. Also, a process for separating glucose and fructose by using affinity liquid chromatography with cation-exchange resins has been established.[8] As a result, starch hydrolyzates account for about 60% of starch consumption.

As is seen from the foregoing, the starch sweetener industry has developed together with the discovery of new enzymes, though there has been a dynamic flow of domestic and international economic factors and various changes in needs in its background. It can be said that technological applications of enzymes have progressed in parallel with the advance of the starch-hydrolyzing industry.

Starch syrup, glucose, and maltose produced from starch, and their hydrogenated saccharides – hydrogenated syrup, sorbitol, and maltitol – high-fructose corn syrup, and cyclodextrins are almost established for commercial manufacture and application. However, maltooligosaccharides of more than DP3 are expected as newcomer saccharides in the starch-sweetener production industries. Under these circumstances, new enzymes have been recently discovered one after another, including various oligosaccharide-forming amylases that specifically produce maltotriose (G3), maltotetraose (G4), maltopentaose (G5), and maltohexaose (G6) by acting on starch or amylase[9-25] (Table 1). Therefore, it is possible to produce a high content of every maltooligosaccharide using these new amylases.

Table 1. Various maltooligosaccharide-forming amylases.

Product	Origin	References
[a] α-maltotriose	*Streptomyces griseus*	14
	Bacillus subtilis	21
α-maltotetraose	*Pseudomonas stutzeri*	9
	P. saccharophila	23
	B. circulans	24
α-maltopentaose	*B. licheniformis*	11
		12
		16
		17
	B. subtilis	13
	Pseudomonas sp.	20
	B. cereus	22
α-maltohexaose	*Klebsiella pneumoiae*	10
	B. subtilis	15
	B. circulans F-2	18
	B. circulans G-6	19
	Bacillus sp.	25

[a] α: anomeric configuration.