the product begins caking and taste and physical appearance rapidly change. Therefore adequate attention should be given to containers including their orifice to prevent moisture absorption.

Footnotes:

Sencha - the most popular tea in Japan. It accounts for 80 percent of total green tea production.

Hojicha- made of larger leaves of *sencha*, or *bancha* (coarse tea) heated at 150°—180°C. It is characterized by flavor of roasting.

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A Survey on the Dextrose Industry in Japan and Its Future

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History of Japanese Dextrose Industry

We have seen remarkable progress in Japan in the manufacturing technology of dextrose by the enzymatic method of starch hydrolysis. Up to the end of 1958, almost all Japanese dextrose manufacturing palnts used the method of acid hydrolysis as used in other countries. During the latter half of 1959, dextrose manufacture was substituted by the enzymatic method very rapidly, until 100% of the dextrose industry in Japan adopted the enzymatic method by the end of 1960.

The rapid development of this industry is owed to the governmental subsidation for the purpose of the consumption of sweet potato starch. The sweet potato is a very important agricultural product in Japan from the standpoint of the farmers income. It ranks second only to rice among all agricultural products. The Japanese government supported the price of sweet potato indirectly by purchasing sweet potato starch under "The Agricultural Stabilization Act" whenever the consumption was less than the supply and price of raw potatoes fell. In 1960, the accumulation of the government stocks of surplus sweet potato starch eventually reached 350,000 tons. Since the production of sweet potato starch was expected to increase year by year, the Japanese government decided to subsidize the dextrose industry. Dextrose manufacturers are supported by government loans, by supply of sweet potato starch at a low price, by technical guidance of the government research institute, and by the promotion of consumption of dextrose that meets Japanese Agricultural Standard (JAS) Specification.

As the results of the rapid expansion of dextrose industry, the stock of sweet potato purchased under the Agricultural Stabization Act was decreased and in 1963, all the stock was used up for dextrose production.

The production capacity of the dextrose industry expanded to 400,000 tons year in 1963.

Recently, a big change has been observed in the dextrose industry in the situation of starch supply. In contrast with the time when the dextrose industry was established to eliminate the stock of sweet potato starch, today, the raw materials of this industry are insufficient by the domestic sweet potato starch and are supplemented by corn starch or other imported starch.

Technical Back Ground of Dextrose Industry

As mentioned above, the Japanese government subsidized the dextrose industry both economically and technically.

Today, the technical situation of this industry of Japan holds the first position in the world. They adopted the enzymatic method for starch hydrolysis in the first and lead the dextrose industry of the world. These surprising developments of dextrose production have been owed to the scientific achievement in the field of enzymology of this country. Works on amylolytic enzyme were started early in Japan and Japanese methods lead the world, especially in crystallization techniques for enzymes. For instance, Tsuzisaka and Fukumoto[1] used crystal amylase preparation produced by Rhizopus delemar to elucidate the mechanism of starch hydrolysis. They claimed that almost 100% of starch was hydrolyzed into glucose, and suggested that the enzyme method should be very profitable for dextrose production. No β- linkage oligosaccharides, especially undesirable gentiobiose are formed by the enzyme process, and after saccharification, dextrose can be centrifuged out and the green (hydrol) are used as a kind of starch syrup. This method made the saccharification simple, fast and high yield.

Another fact which supported the industrial application of the enzyme process was the success in industrial production of amylase preparation. We have had a special enzyme culture technique, i. e. koji method, solid or liquid culture of microorganisms, for a long time as used for typical Japanese fermented foods, Sake, Soysauce and Miso etc. Using this enzyme culture technique, Rhizopus was cultured for glucoamylase production. Some dextrose manufacturers cultured a strain of Endomyces by the submerged culture method. As amylase was supplied sufficiently, the method of starch hydrolysis was changed from acid conversion into enzymatic saccharification within a short time.

In the enzyme - enzyme method, i. e. α-amylase liquefaction and glucoamylase saccharification process, starch is hydrolyzed easily over 97 DE. without recombination of splitted glucose to undesirable oligosaccharides, or destruction to hydroxymethylfurfural compared with the acid conversion. One fortunate circumstance of Japanese dextrose industry for enzyme process is that raw material was mainly sweet potato starch, which is the easiest starch for enzyme liquefaction. These characteristics of starch accelated the process change to the enzyme method.

As the results of application of enzyme method, we easily obtained high DE. starch hydrolyzate compared with acid hydrolysis. The Japanese dextrose manufacturers established the new method of production, called the total sugar process. The product produced by this method is classified as fine powder dextrose abreast with crystalline dextrose in the Japanese Agricultural Standard.

Easy to understand the special feature of this process, compared with the process of crystalline dextrose, flow sheet of both processes is shown in Fig. 1.

Among many starches, corn starch has been the most difficult starch for enzyme liquefaction in the past because of its high gelatinization temperature and its hard structure of micelle in granule. Recently, this difficulty of corn starch was overcome by the appearance of strong heat resistant α-amylase.[2]

Another topic of the improvement of enzyme process is liquefaction of starch by mechanical force at the elevated temperature

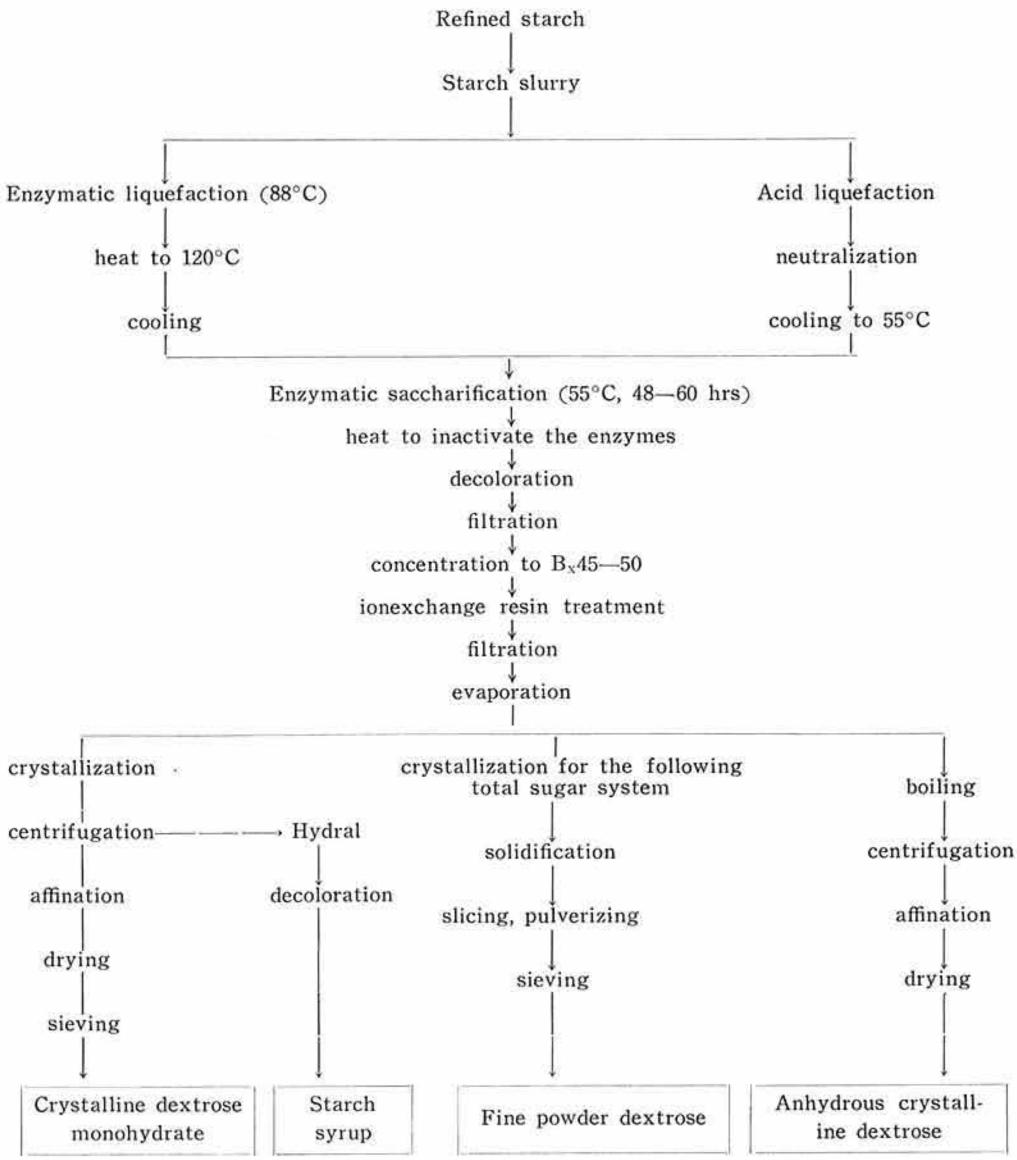

Fig. 1 The manufacturing Process of Dextrose by the enzymtic Method.

by strong shearing force.[3]

The technial problems on the enzymatic saccharification process of Japan, for example the process of liquefaction, saccharification, ion exchange purification, pulverization of total sugar etc. are reviewed in detail in other papers of the same author.[4,5]

Production and Consumption of Dextrose

Two varieties of dextrose are produced in Japan - one is crystalline dextrose (monohydrate and anhyrous) and the other is fine powder dextrose. The former has the same character and quality as dextrose of other countries. The latter is a special type of this country produced by the above mentioned total sugar method. Recently, European and American dextrose industries tried to introduce this new process. The J.A.S. was provided to regulate the quality of dextrose and the Japanese government gives charge of grade testing to the special organization.

Table 1. The Japanese Agricultural Standard of Crystalline Dextrose and Fine Powder Dextrose.

	Cryst. dextrose (Anhydrous)	Cryst. dextrose (Monohydrate)	Fine powder dextrose
Specific rotation $[\alpha]_D^{20}$	52.5—53.0	52.5—53.0	—
Size	—	—	smaller than 840 μ
Whiteness	—	—	above 90%
Dextrin (Oligo-saccarides)	below 0.5%	below 0.5%	below 3.0%
Moisture content	below 0.5%	8.0—10.0%	below 10%
Ash	below 0.05%	below 0.1%	below 0.1%
Hydroxy Methyl Furfural	—	—	below 5mg%
Colour of solution*	below 0.250	delow 0.250	below 0.250
Turbidity of solution**	below 0.200	below 0.200	below 0.200

* Difference of $O.D._{420}$- and $O.D._{720}$ (30w/v% aqueous solution by 100 mm light path)
** O.D. of 30w/v% aqueous solution (720 mμ by 100 mm light path).

The J.A.S. includes several specifications, for instance, external appearance, crystalline form by microscope, taste etc.

By the way, production and consumption of dextrose during the past few years are shown in Table 2, 3.

Table 2. Production of dextrose in past few years in Japan

unit: ton

	J. A. S. *			Out of J. A. S.				Total
	Enzyme			Enzyme			Acid conversion	
	Crystalline		Fine powder dextrose	Crystalline		Fine powder dextrose		
	Anhydrous	Monohydrate		Anhydrous	Monohydrate			
1962	47,982		50,014	94,468			24,666	217,130
1963	55,324		56,624	——	47,380	60,472	17,158	236,958
1964	1,504	62,492	64,302	13,476	17,996	41,061	10,096	210,927
1965	3,816	43,697	47,066	13,523	21,563	39,133	9,911	179,611

* Japanese Agricultural Standard (J. A. S.)

Tabel 3. Consumption of dextrose in past few years in Japan
unit: ton

year / use	1962	1963	1964	1965	1966
Juice powder	68,587	68,685	51,177	48,775	47,110
Instant powder food*	2,305	3,802	7,479	5,539	9,020
Chewing gum	14,274	12.923	10,201	10,016	10,185
Confectionery	36,297	32,902	25,778	24,014	31,971
Canned fruit	10,073	12,218	7,751	9,444	12,294
M. S. G.	13,695	8,428	5,125	1,592	2,097
Medical use	4,261	4,080	4,444	4,270	6,373
Sorbitol	2,951	4,499	3,318	4,562	3,978
Juice	4,106	3,407	4,687	4,358	7,904
Soft drinks	8,775	8,154	9,157	5,153	3,477
Mix sugar	8,609	24,342	20,689	14,051	11,257
Domestic use	654	144	375	127	378
Ice cream	768	1,568	4,635	4,443	6,007
Boiled fish paste	…	…	920	2,423	2,466
Jam	…	…	179	74	151
Soy sauce	…	…	402	785	1,420
Tsukudani**	…	…	122	223	291
Sake	11,547	11,583	10,542	13,150	11,659
Bread	20,971	25,601	24,118	21,064	22,300
Others	9,373	5,393	24,885	8,309	6,670
Total	217,246	227,729	215,984	182,372	197,008

* Instant cocoa, Instant shiruko etc.
** Sweetened fish preserved.

Works on the Isomerization of Dextrose to Fructose

The Japanese dextrose industry produces about 200,000–250,000 tons of dextrose every year, which is only 45–50 % of production capacity of this industry.

In the use as sweetener, dextrose is less sweet compared with sucrose in its nature. This characteristic limits the use of dextrose in many foods as a sweetener.

Since 1960, many laboratories have worked on the reaction of isomerization of glucose to fructose, the sweetest sugar, by enzymatic and chemical ways. In chemical method, Kainuma, Suzuki[6] worked on the transformation of Lobry de Bruyn-Alberda van Ekenstein. This reaction had been said that isomerization of glucose by alkali method was unsuitable for the fortification of the sweetness of glucose because of the undesirable side reactions, for instance, formation of mannose, objectionable odor, color substances. After their systematically planned experiments, they made clear a lot of things on this reaction. They concluded that high temperature and very short time reaction conditions of alkali isomerization made this reaction possible for the industrial application. These experimental results of laboratory was proved by the experiment of half industrial scale equipment.[7,8]

On the other hand, Tsumura, Sato[9,10], Takasaki[11] worked on the glucose isomerase from the strain of Streptomyces. They elucidated many characteristics of this enzyme both in academic standpoint and industrial application of this enzyme. Yamanaka[12], Natake[13] studied on this enzyme from other microorganisms in the theoretical aspect.

Both alkali and enzymatic isomerization will be applied to industry for the purpose of the fortification of sweetness of glucose in Japan in the near future.

Conclusion

In conclusion, the many problems of the Japanese dextrose industry have being solved by the improvement of production process, the appearance of new techniques, for example, spray crystallization of total sugar[14], mechanical liquefaction of starch by high shearing force, industrial production of heat resistant α-amylase, or the fortification of sweetness of glucose by isomerization to enlarge the use of dextrose. Author believes this progress in chemistry and technology of dextrose in Japan will contribute many things to development of the dextrose industries of the world.

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