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Editorial

STRUCTURED AND MODIFIED STARCH FOR FOOD INDUSTRY – HOW FAR CAN MICROBIAL ENZYMES AND TRANSGENIC PLANT COOPERATIVELY WORK WITH?

With the history of mankind, starch has been utilized as the most popular raw food material. As the human social life is getting well-to-do, a demand for fresh starch-based goods that do not stale within a reasonable time period is highly increased, while the taste and texture expected from such products should be maintained. Consequently, the prevention of starch retrogradation has been an important issue in the food industry. Recently, significant progress has been made in the fundamental understanding of the retrogradation of starch-based food stuffs. The main transformation of starch upon aging is the aggregation of polysaccharide chains, which may form crystal phases of the native starch granules.

Recent advances in protein engineering and molecular biology related with various enzymes involved in the degradation and biosynthesis of carbohydrate lead us to a new possible way to create a so-called "structured and modified starch". As a result, a few designed carbohydrate-based-foods and -nutraceuticals are already available in the market. How far can the recent knowledge of carbohydrate enzymes obtained by prosperous biotechnology help to improve the quality of starch in vivo and in vitro?

One of the most desired property may be freeze-thaw stability of gelatinized starch used in the food industry to make the products, which need to be frozen or stored at chilled temperature. Under this low temperature condition, the starch is readily retrograded, resulting in a deterioration in product quality. In general, it is accepted that the long unbranched amylose chains have a greater tendency to retrograde than the highly branched, much shorter chains of amylopectin.

What is a possible approach to create a freeze-thaw stable starch in the laboratory? – Several amylolytic enzymes might possess the catalytic ability to generate freeze-thaw stable starch. It has been known that the addition of the exo-acting enzyme such as maltogenic α-amylase inhibits the retrogradation of amylopectin by shortening the side chain of amylopectin to a length which would not crystallize. It may also be proposed that small maltodextrin molecules attenuate retrogradation behavior by interfering with the crystallization of amylopectin side chains. However, further research is required to elucidate the mechanism of action since the explanations are speculative up to now.

Alpha-glucanotransferase (α-GTase) has been known as disproportionating enzyme in plants. The enzyme is able to attack an α-1,4-glucosidic bond and transfer part of the glucooligosaccharide of donor molecule to another oligosaccharide acceptor by forming a new α-1,4-glucosidic linkage. When potato starch is α-GTase treated, the

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size of side chains in amylopectin is changed significantly without producing small size oligosaccharides. Analysis of the side chain distribution of the amylopectin shows that the number of short side chains up to 10 increases, whereas the number of chains higher than DP 11 decreases. In addition, parts of amylose are transferred to the shorter side chain of amylopectin, thereby removing amylose from the starch mixture. Repeated heating and cooling of the solution results in reversible changes in gel structure (TNO Nutrition and Food Research).[1]

Recently, KAMASAKA and his colleagues[2] suggest that there is an alternative approach, in which starch structure is modified by removal of the long chains of amylose. When the specificity of CDases, such as neopullulanase, cyclomaltodextrinase and maltogenic amylase, toward amylose and amylopectin was analyzed, they easily hydrolyzed amylose to produce maltose, but hardly degraded amylopectin. It was also observed that the CDases selectively degraded amylose when starch was used as a substrate. In contrast to α-GTase, the selective degradation of amylose by CDase produced significant amounts of reducing sugar, mostly maltose, in the reaction from starch. Unlike α-GTase, however, it was assumed that parts of amylose were scarcely transferred to the side chain of amylopectin. Thus, CDases can be employed in production of amylose-free starch. Furthermore, a partially degraded starch generated by CDases can be widely used in the food since this new type of dextrin exhibits favorable properties in viscosity and retrogradation of gelatinized starch paste.

Can transgenic plants be a potential source of modified starch? – JOBLING and co-workers[3] accomplished the reduction of the activity of three starch synthase isozymes by antisense downregulation. The analysis of the modified starch from the transgenic plant demonstrated that rearrangement of side chain distribution of the amylopectin was displayed, and the amylose had disappeared from the modified starch. The resulting starch was extremely freeze-thaw stable and showed no syneresis after five freeze-thaw cycles.

It has also been tried to engineer potato tubers for producing novel carbohydrates by introduction of maltogenic amylase gene into the potato genome.[4] It was found that the recombinant enzyme was successfully produced in transgenic plants and was enzymatically active. The average size of transgenic starch granule from transgenic potato was slightly smaller than that from nontransgenic control plant.

Regardless of this successful story to create the modified starch with improved property, there is still insufficient scientific knowledge currently available to allow to

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[1] BINNEMA, D.J. & HEERES-PESTMAN, J.M. (2002): AMAZ – An amazing thermoreversible gel derived from starch. *Bulletin of TNO Nutrion Food Research.*

[2] KAMASAKA, H., SUGIMOTO, K., TAKATA, H., NISHIMURA, T. & KURIKI, T. (2002): *Bacillus stearothermophilus* Neopullulanase selective hydrolysis of amylose to maltose in the presence of amylopectin. *Appl. environ. Microbiol.*, *68*, 1658–1664.

[3] JOBLING, S. A., WESTCOTT, R. J., TAYAL, A., JEFFCOAT, R. & SCHWALL, G. P. (2002): Production of a freeze-thaw-stable potato starch by antisense inhibition of three starch synthase genes. *Nature Biotechnol.*, *20*, 295–299.

[4] PARK, S. S. (1999): *Development and molecular analysis of potato plants transformed with a gene for* Bacillus *maltogenic amylase*. PhD Thesis, Seoul National University.

construct the tailor-made starch structure by cooperation of enzymatic modifications and transgenic plants. However, it is clear that in the past decades a considerable progress has been made in understanding starch structure and carbohydrate enzymes. Therefore, accumulated knowledge about the action mode of various amylolytic enzymes and detailed study on the mechanism, by which the structure of starch is modified, will allow us to generate the desired tailor-made starch with appropriate properties. At the same time, many new varieties of starch-based products will be offered in the food industry in the near future.

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