Spotlight on Starch: An Update from the Carbohydrate Division

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CURRENT CHALLENGES IN STUDYING THE INTERNAL STRUCTURE OF AMYLOPECTIN

Amylopectin is the major component in starch. It is elongated through α-(1→4)-linked D-glucosyl residues with α-(1→6)-linkages as branches. In the granules, branches form the internal parts of amylopectin, are found inside amorphous lamellae, and from these external chains are clustered in double helices and build up the crystalline lamellae. The internal structure of amylopectin (i.e., the composition and arrangement of branches) and their relationships to the functionality of starch are still largely unclear.

Amylopectin Internal Structure in Relation to Biosynthesis

Starch branching and debranching enzymes are responsible for the generation of the branched structure in amylopectin during biosynthesis. Recent evidence has shown that diverse biosynthetic enzymes interact in the formation of starch granules. It is still not clear how the enzymes are coordinating with each other to create desired starches with unique branching patterns. The development of branches in starch during grain kernel development is fundamental to our understanding of synthesis-structure relationships. For better understanding of these issues, one strategy is to look at the internal structure of starch from plant mutants with defined genetics. Studies on the internal structure of amylopectins from mutants such as high amylose and dulla1 corn genotypes are underway.

Amylopectin Internal Molecular Structure in Relation to Physical Structure of Starch Granules

The branches of amylopectin in the internal parts of the molecule are packed in the amorphous lamellae, and the external chains are clustered in crystalline lamellae. Thus the starch granules, consisting of alternating amorphous and crystalline lamellae, are semi-crystalline. The exact contribution of the internal molecular structure of amylopectin to the architecture of starch granules remains largely unknown. This issue may be addressed from the changes in properties and physical structure of the granules as a result of processing, such as annealing and heat-moisture treatment of starches with defined internal amylopectin structure. Research on these topics is underway.

Amylopectin Internal Structure in Relation to Functional and Nutritional Properties

Functional properties of starch, such as pasting, gelatinization and retrogradation, gelling, syneresis, and freeze-thawing stability are critical to the processing and application of starch-related products. Theories and models on how the internal part of amylopectin influence the functional properties have been proposed. It has been suggested that the internal part of starch granules in the presence of water during heating are first hydrated, leading to further break down of the crystalline part. However, the exact mechanism on how the internal structure of amylopectin affects this functionality remains to be explored. Studies are underway to link the internal structure to the physical properties of starches from a diverse botanical collection.

Nutritional properties such as digestibility of starch are becoming a major social issue in many countries around the world. Since relationships between physical properties and amylopectin internal structure have been suggested, it is expected that possible linkages exist between starch digestion and internal structure of amylopectin. Studies on the internal structure in relation to starch digestibility are being investigated.

FUTURE CHALLENGES IN INTERNAL STRUCTURE RESEARCH

Definition of Cluster

All the branches in the internal part of amylopectins are clustered. One of the major challenges in studying the internal structure is to define the clusters. Models of the clusters have been proposed and a definition has been suggested, but the exact structure of a cluster remains to be explored. Conceptually, this question may be re-addressed by considering the branches organized as building blocks, which are practically α-limit dextrans formed by α-amylose of Bacillus amyloliquefaciens and can be structurally defined. α-Limit dextrans formed by α-amylases from other sources may also be produced and characterized to provide an alternative view and could be a direction for future research.

Developing Small-scaled Analytical Methods When Samples are Limited

Starch from certain biological sources, like pericarp tissues, leaves, algae, and breeding lines of crops are only available in very limited quantities for analysis. Common ways of separating amylose and amylopectin (e.g., butanol precipitation) are time consuming and usually require large amounts of starch to get enough samples for the analysis of the clusters and building blocks. This limits the possibilities to explore structural features of interesting mutants or other questions related to starch synthesis and structure. A method of using whole starch to obtain a reasonable analysis on starch branching patterns may provide a solution.
MEMBER FOCUS

George Amponsah Annor is a Ph.D. candidate at Grain Biopolymer Research Laboratory, in the University of Guelph Department of Food Science. He is also presently the coordinator for the West African Food Data Systems (WAFOODS) of the International Network of Food Data Systems (INFOODS) of the Food and Agriculture Organization (FAO). Currently a lecturer at the Department of Nutrition and Food Science of the University of Ghana, George is on study leave to pursue his Ph.D. degree at the University of Guelph. Now in the final year of his Ph.D. program, George's research is focused on studying the unit and internal chain profile of millet amylopectin and investigating the reasons for the hypoglycemic property of millets (Figure 1).

Research

Millets are known to be useful in the management of type 2 diabetes due to its low insulinemic response. Understanding the attributes of millets that confer this hypoglycemic property is important in maintaining its low glycemic index during processing. George's research has so far shown that the interaction between proteins, starch, and lipids play a significant role in the low hypoglycemic property of millets. He observed that, when proteins and lipids were removed from millet flour, its expected glycemic index increased significantly. The effect of lipids on the expected glycemic index of millet flour was found to be much more than that of proteins. This observation set the stage for investigating whether the amount and type of fatty acid present in the millet lipids influenced the enzymatic hydrolysis of millet starch. After adding fatty acids to cooked millet starch and subjecting the starch-fatty acid complexes to in vitro starch digestibility, the results showed that the amount of the fatty acids present in millets played a significant role in its low hypoglycemic property (Figure 2). Unsaturated fatty acids were also generally found to be more effective in reducing millet starch hydrolysis, as with the cis configuration compared to the trans. George is still currently collecting data on the unit and internal chain profile of millet amylopectin; information which does not exist (Figure 3). On completion of his Ph.D. program, George intends to move back to the University of Ghana to continue his research on cereals with close collaboration with his supervisors, Koushik Seetharaman, Massimo Marcone, and Eric Bertoft.

Figure 1. George showing a sample of Foxtail millet.

Figure 2. Expected glycemic index of cooked foxtail millet starch-fatty acid complexes with fatty acids added in the amounts present in foxtail millet. The amounts of fatty acid added were 2.56 mg, 6.59 mg, and 19.50 mg palmitic, oleic, linoleic and elaidic acid per gram foxtail millet starch.

Figure 3. George loading his debranched millet amylopectin samples into the auto sampler of the Dionex IC-3000 High Performance Anionic Ion Exchange Chromatographic System (HPAEC) fitted with a Pulsed Amperometric Detector (PAD).