

THE CARBOHYDRATE RESEARCH PROGRAM

The research program focuses include:

- Structures and functionality relation of starch
- Structures and physicochemical properties of starch as related to rice quality
- Modification of starch via chemical, physical, and enzymatic reactions to understand starch granule architecture and to produce nano starch particles
- Utilization of starch and interactions of carbohydrates with other food constituents during processing and storage
- Development of value-added products

The Carbohydrate Research Program is supported by U.S. Department of Agriculture, Arkansas Rice Research and Promotion Board, Arkansas Biosciences Institute, Institute of Food Science and Engineering at University of Arkansas, University research incentive grants, and collaborative support from the food industry.

The Carbohydrate laboratory is well equipped and major equipments include:

- High-performance liquid chromatography
 - Waters HPLC with refractive index detector
 - Waters HPLC with MALLS (multiple-angle laser light scattering) detector
 - Dionex HPLC with pulse amperometric detector
- Differential scanning calorimeter (Pyris-1, Perkin-Elmer)
- Polarized light microscope (E400POL, Nikon)
- High intensity ultrasonic processor
- UV/Vis spectrophotometer (DU520 Beckman/Coulter)
- Micro ViscoAmyloGraph (C.W. Brabender)
- Lab-scaled twin screw extruder (Haake PolyLab)
- Hydraulic hot press (Carver)
- Low temperature centrifuge and micro-centrifuge

The Carbohydrate laboratory also has access to the following major equipments within the Food Science department and the University of Arkansas

- Wide-angle X-ray diffractometer (X'Pert dual goniometer XRD system, Philips)
- Scanning electron microscope (SEM) (S-2300, Hitachi) and Environmental SEM
- Atomic force microscope (AFM)
- Transmission electron microscope (TEM)
- Nuclear magnetic resonance (NMR)
- Dynamic thermal analyzer (DTA)
- Dynamic thermomechanical analyzer (DMA)
- Dynamic rheometer (TA Instrument)
- Instron Universal Testing Machine
- Texture Analyser

- Rapid ViscoAnalyzer
- Controlled drying, milling and imaging equipment for rice research
- Freeze dryer

Members in the Carbohydrate Research Program:

There are currently 4 graduate students (1 Ph.D. and 3 M.S.), 2 postdoctoral research associates, and 3 undergraduate students working in the Carbohydrate laboratory.

Current postdoctoral research associates:

- Dr. Linfeng Wang (Structure-function relation of starch, oligosaccharides from rice bran)
- Dr. James Patindol (Relationship of starch and rice quality)

Current graduate students:

- Daris Kuakpetoon, Ph.D. (Structure and physicochemical properties of oxidized starches)
- Devon Cameron, M.S. (Comparative study between U.S. west coast and southern medium-grain rice varieties)
- Enzo Giannoccaro, M.S. (Comparison and improvement of analytical methods for an accurate and efficient protocol of routine analysis of sugar compounds in soybean)
- Ray Stout, M.S. (Tortilla quality)

Current undergraduate students:

- Blanca Gonzalez (Physicochemical properties and leaching characteristics of four long-grain canning rice cultivars)
- Stephen O'Brien (Enzymatic susceptibility of annealed starches)
- Noy Phoumivong (Composition analysis of adjunct material, wort and spent grain for efficient mashing and maximized utilization of adjunct starch)

FIVE MAIN RESEARCH AREAS

➤ Structures and functionality relation of starch

Starch is the leading component of staple foods, such as bread, rice, potato, pasta, and noodles, as well as an important ingredient of many processed foods. Structural changes of starch during processing and storage are critical to food quality and stability. Gelatinization and swelling of starch provide desired functionality to foods, but leaching and fragmentation often result in undesirable changes in quality and stability. The phenomenon that some starches swell to a greater extent and leach more materials but some swell to a less extent and leach less on gelatinization has not been well studied, and the information on the composition/structure of leached components in relation to food quality and stability is limited.

Understanding of starch swelling and leaching is also critical in the development of novel starches with desired functionality by way of plant breeding or modern

biotechnology. The overall goal of this research is to investigate the contribution of starch molecular structure and starch granule microstructure to the leaching characteristics, swelling behavior, and granule integrity of starch. The long-term goal is to extend the shelf-life and to improve the quality of starch-containing foods. Plant breeders and biotechnologists will be able to use the information obtained from this study to select the appropriate enzymes or genes to manipulate the biosynthesis of starch with controlled structures and targeted properties. The food industry will be able to select the appropriate varieties of cereals or tubers for particular applications. The starch industry will also be able to produce improved modified food starches within the existing restrictions.

➤ **Structures and physicochemical properties of starch as related to rice quality**

The major component in rice kernel is starch (90%, dry basis); therefore rice quality is strongly influenced by starch composition and structure. Arkansas is the first and second largest long-grain and medium-grain rice producing states in the U.S., respectively. The eating quality and processing characteristics of a particular rice cultivar grown in Arkansas differ from that grown in west coast and the other southern states. Hence, it is important to investigate how growing locations can affect the specific properties of the rice grains (physically, chemically, and biochemically).

Environmental factors under which rice is grown (soil type, crop management practices, rainfall, solar radiation, and growth temperature) are known to affect rice composition and functionality although there is still a lack of knowledge regarding the exact physicochemical and biochemical basis for the variability. For instance, the temperature during grain filling has been shown to affect amylose content. It generally decreases as the environmental temperature increases and the decrease depends on the variety and inherent level of amylose content. Amylose also decreases with nitrogen fertilization but is not affected by the stage of application. Protein content tends to be low when high solar radiation occurs during grain development. Late nitrogen fertilizer application can increase both protein content and yield, with improved head rice and translucency.

It is hypothesized that the environmental conditions under which the rice is grown can influence the synthesis and accumulation of both macronutrients (starch, protein, and lipids) and micronutrients (minerals) that make up the rice grains. This in turn is assumed to have a major impact on the functionality of the grain. Thus, the complex nature of the rice grain requires that it should be studied in details not just by analyzing a single component but all its chemical constituents. An integrated approach of studying the different constituents of the rice grain (to include starch fractions and fine structures, protein fractions, and lipids) is crucial in resolving the causes of location variability in the functionality of rice cultivars grown in the southern states and California. The outcomes of this research will be valuable for rice breeders in modifying varieties for specific applications.

➤ **Modification of starch via chemical, physical, and enzymatic reactions to understand starch granule architecture and to produce nano starch particles**

Most commercial starches employed in either food or industrial applications have been chemically modified to improve their functionality. At the present time, modification via chemical routes is the most widely used method to produce starch derivatives and chemical modification is indispensable in the continued and increased use of starch to provide thickening, gelling, binding, adhesive, and film-forming properties. Nevertheless, modification by physical and enzymatic means present great potentials to provide unique products, such as nano starch particles, when combined with chemical modifications.

Work to study modification of starch by oxidation, phosphorylation, chemical surface gelatinization, annealing, heat-moisture treatment, and enzymatic reactions and their combinations is underway. This research tries to better understand the location of modification, to characterize the effects of starch origins on properties of modified starches, to improve modification efficiency, and to produce new modified starches with improved physicochemical and functional properties. This research will therefore provide unique information about starch architecture and starch molecular arrangement within starch granules. By understanding starch granule architecture, it is then possible to produce nano starch particles for food, pharmaceutical, and industrial applications.

➤ **Utilization of starch and interactions of carbohydrates with other food constituents during processing and storage**

Starch is the major component of many staple foods and also one of the most versatile ingredients in the food industry. Cooking is to gelatinize and/or free starch molecules for specific functions, e.g. thickening or allowing enzymes to break these large molecules into sugars and dextrans. Availability of starch from food matrix is affected by a number of factors such as particle size (exposed surface area), heating and shearing rate, cooking temperature, presoaking treatment, and starch make-up. Therefore, it is necessary to understand how these factors affect starch utilization during processing, storage stability of starchy foods, and interactions of starch and other carbohydrates with other food constituents. This research uses rice grits and corn grits as model systems to study type and composition of grits, e.g. starch structure and protein content and composition, in relation to physicochemical properties of starch.

➤ **Development of value-added products**

▶ **High-intensity ultrasound and enzyme treatment in improving starch isolation**

The application of high intensity ultrasound and enzyme treatment in starch recovery is explored. Ultrasound may selectively degrade the protein component by disrupting or breaking the ternary or secondary structures of protein without damaging starch and enzyme treatment will further reduce the residual protein content. Protease has been shown to effectively remove protein from rice flour and corn flour at a neutral pH. Work continues in combining ultrasound and protease treatment to further improve starch isolation efficiency.

▶ **Oligosaccharides from rice bran or other sources as nutraceuticals**

Non-digestible oligosaccharides have been claimed to benefit the colon by selectively stimulating the growth of bifidobacteria and by decreasing the toxicity of the colon contents. Oligosaccharides are short-chain saccharides and usually composed of 2-10 glycosidically linked monosaccharides. Human can not digest oligosaccharides because our bodies do not produce the enzymes necessary for their digestion. Instead, they are fermented and consumed by the beneficial intestinal bacteria, bifidobacteria, in the colon. Generally, oligosaccharides are classified as "prebiotics" because they are preferentially chosen by beneficial bacteria, which are termed probiotics, to promote intestinal health, i.e., a balance between the beneficial and harmful microbes. Currently, the criteria used for classification of a food component as a prebiotic include: resistance to digestion, hydrolysis and fermentation by colonic microflora, and selective stimulation of growth of one or a limited number of bacteria in the feces. In addition, a prebiotic may repress the growth of pathogens for overall beneficial health.

The U.S. rice production was close to 210 million cwt. (rough rice basis) in 2001 and the state of Arkansas accounts for about 45% of the total rice production. During milling process, about 10% of rough rice is removed as rice bran to produce milled rice. Arkansas produced about 7.5 million cwt. of rice bran in 2001, which is used for rice bran oil manufacture or as a low-valued by-product, e.g. feed. Rice bran contains about 15-20% oil, 12-16% protein, 6.5% oligosaccharides, 35-55% other carbohydrates, and 7-10% silica. Recent studies have shown many health benefits of proteins and oils from rice bran, but little research has been conducted to understand the composition of rice bran oligosaccharides and their contribution to human health. Therefore, oligosaccharides from rice bran present a tremendous potential to offer unique health benefits that are not present in current commercial products. This work will not only provide fundamental knowledge about the structure, composition, and physicochemical properties of oligosaccharides in rice bran, but also develop procedures to increase its quantity for further animal or clinical trials.