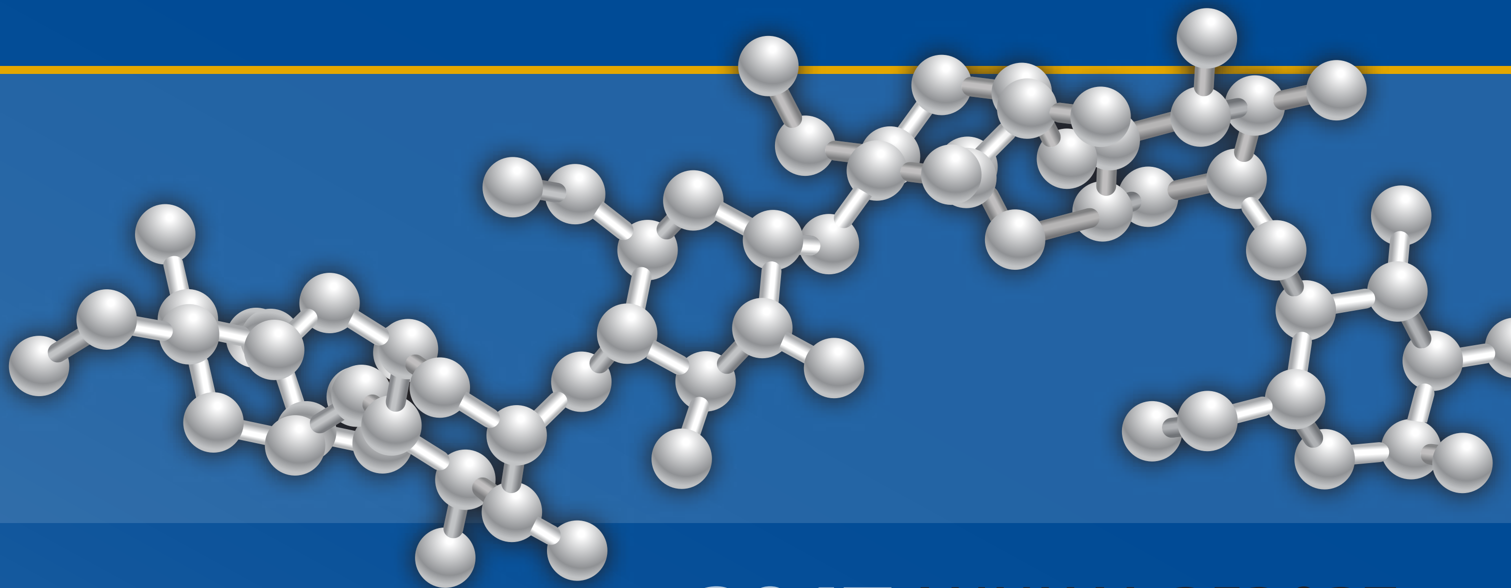
WHISTLER CENTER
for Carbohydrate Research



2017 ANNUAL REPORT

PURDUE UNIVERSITY

Industrial Members

(Members of 2017 Industrial Advisory Board)

Archer Daniels Midland

Cargill

General Mills

Grain Processing Corporation

Hayashibara Co.

Ingredion

Kaleido Biosciences

McCain Foods

Mondelēz International

Nestlé

PepsiCo

Roquette

Tate & Lyle

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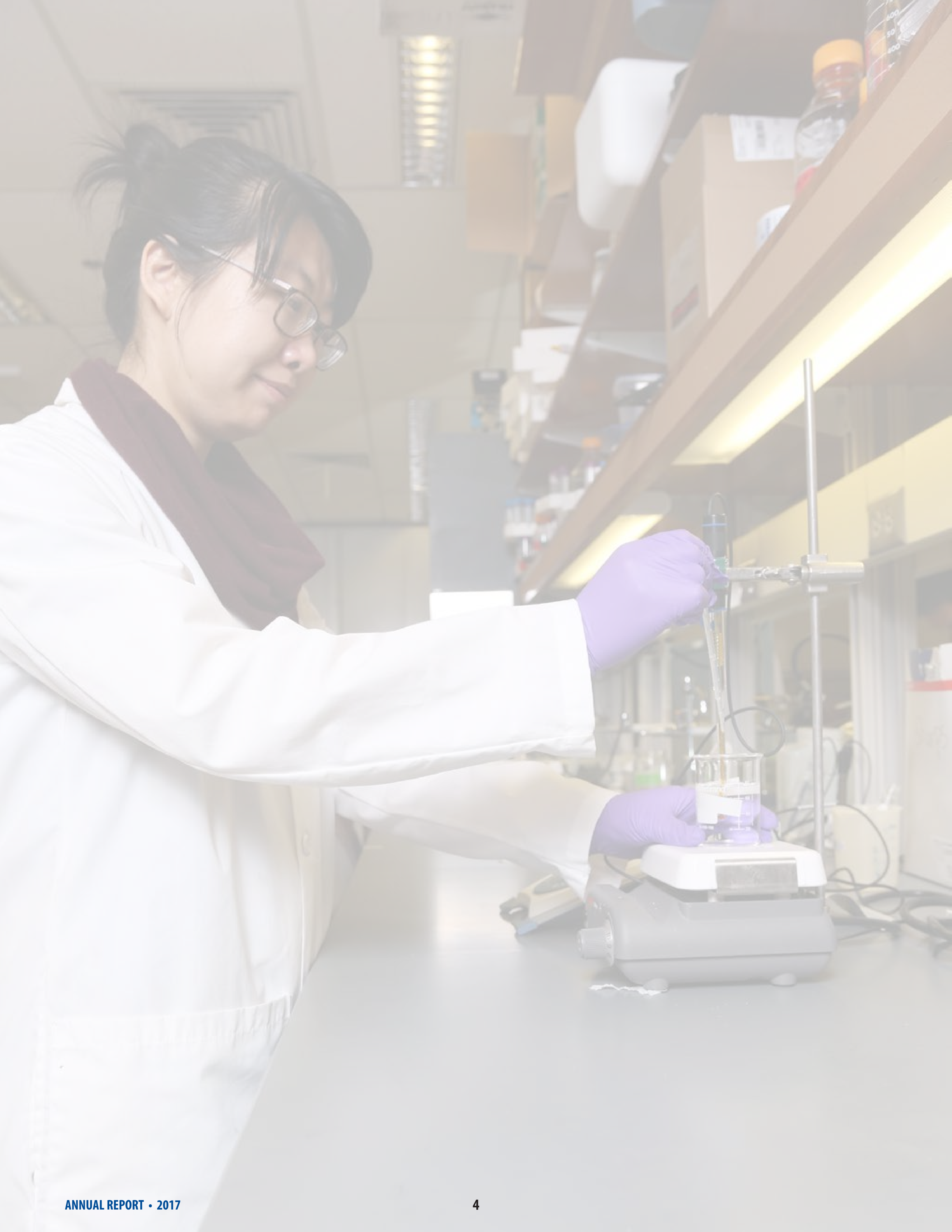


Director’s Statement

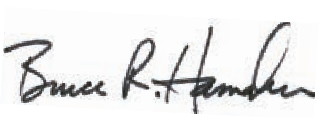
Greetings from the Whistler Center for Carbohydrate Research at Purdue University. We are proud to present our 2017 annual report for you to peruse. Feel free to get back to us with any questions. In this last year, we have expanded our research in structure-function relationships of dietary fibers and the gut microbiome with the growing research group of Prof. Steve Lindemann, who started a new program in 2015 in gut microbial ecology. In the broader area of carbohydrates and health, we continue studies on control of glycemic carbohydrate digestion and physiological responses of carbohydrate-based foods, and other carbohydrate polymer-based materials related to health. This is in addition to the myriad of topics that we continue to research on carbohydrate structures and their material or physical functions in foods: how sugar can be reduced while using replacement sugars or oligosaccharides that provide similar textures, the variability in structures and functions of carbohydrates and product quality, the genetics of making new functional food carbohydrates, and many other carbohydrate structures and their functions. In many instances, we work on these projects with our member companies on both short- and long-term research problems.

The world is changing in many ways, as is the world of food carbohydrates — with changing consumer perception of carbohydrates' role in the diet, new regulatory pressures to reduce sugar and increase dietary fiber, and increased interest in clean label functional carbohydrates. At the Whistler Center, we internally fund research projects for our member companies and currently investigate new starches for clean labeling, sugars and oligosaccharides and their effect on starch gelatinization and product texture. We will fund two new projects in 2018 on sugar reduction and product quality and function of nondigestible carbohydrates in the gut related to tolerability and microbiome health. In light of changes in the way the world communicates, we are interested to see how we can improve our communication skills to let our members, as well as the public, know what is happening in the carbohydrate field and where we see opportunities to use carbohydrates in new ways.

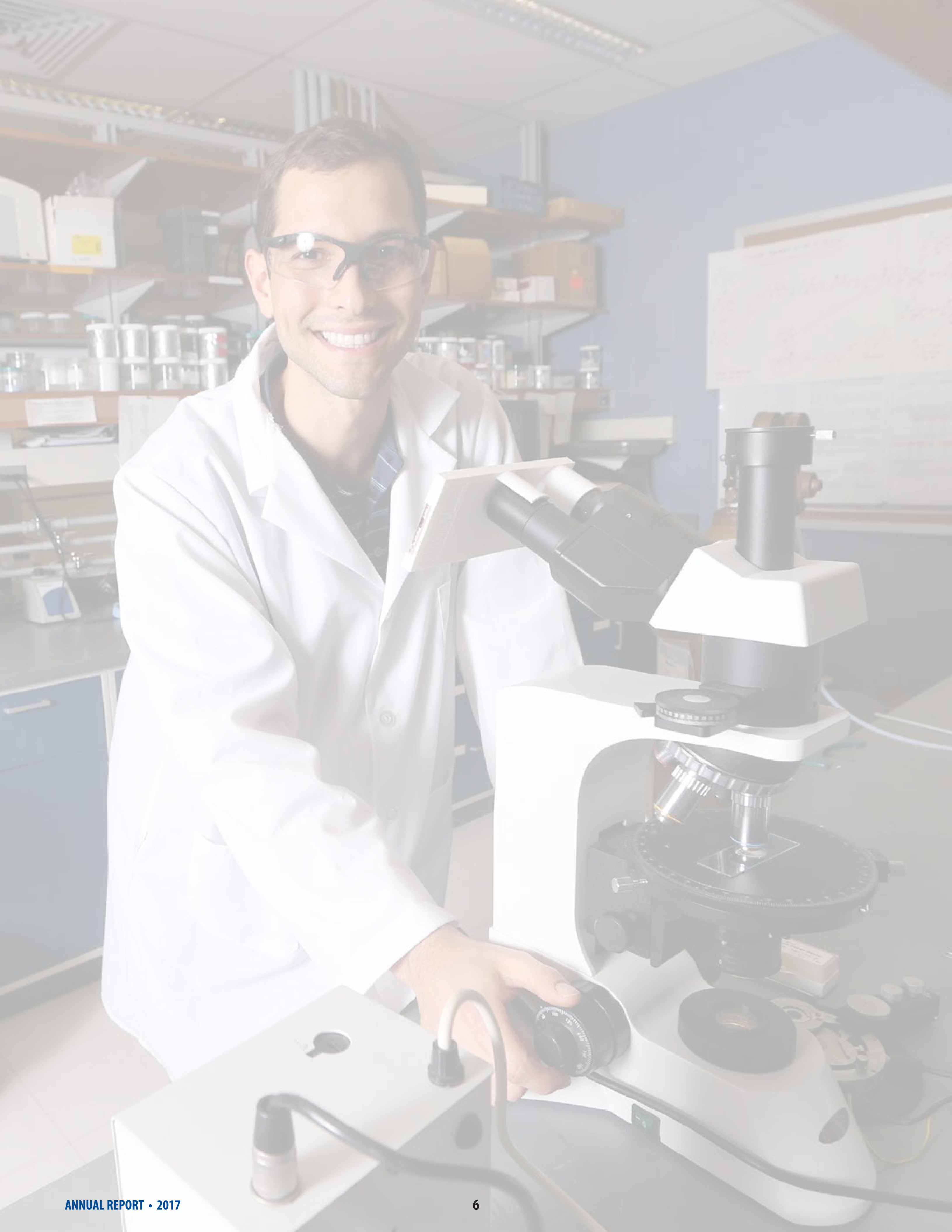
In 2017, we welcomed two new industrial members to the Center — Kaleido Biosciences from Boston and Hayashibara Co. from Japan. We started a webinar series of talks, four a year, for our member companies and presented ones in 2017 on current thinking on the backbone model starch amylopectin structure and how it may better explain starch function (two presentations given by Prof. Eric Bertoft, visiting professor from Finland, with the second joined by myself), and a presentation on dietary fiber and the gut microbiome by Profs. Lindemann and Hamaker. These live talks are streamed to member companies with time for questions and discussion; the recordings are available on our “Members Only” part of the Whistler Center website. We also initiated a service for our member companies to conduct short-term research projects, including “proof-of-concept” studies that could set the stage for further joint work. We successfully conducted another three-day Whistler Center Short Course in early October, which has limited available slots for non-member participants.

Please take a few minutes and look through our 2017 Annual Report, including information about our faculty and staff and summaries of our research project areas as well as 2017 publications and public presentations. As always, feel free to contact Katherine Fry (Whistler Center Coordinator) or myself with any questions you might have.

Sincerely,



Bruce R. Hamaker
Distinguished Professor of Food Science
Roy L. Whistler Chair, Director



Summary of Major Research Accomplishments

Starches, Non-starch Polysaccharides and Cereals

O. Campanella and B. Hamaker completed work on an amylopectin aggregation that occurs when gelatinized pastes of some waxy starch are exposed to controlled shear under cooling, resulting in significant shear-thickening (Project 2). This finding may have processing implications as well as implication during food digestion since a similar shear rate is observed in the stomach during the food digestion process (Project 3). An initial project was finished on the effect of viscosity on access of isolates of colonic bacteria (*Bacteroides spp.*) in a model system (Project 4). A molecular dynamics simulation study was completed on interactions between amylose and free fatty acids (Project 5).

B. Hamaker, O. Campanella, O. Jones and G. Schmidt have worked further on the development of starch-based nanoparticles for gastrointestinal cancer drug delivery (Project 10). The goal is to use benign and water-soluble nanoparticles from amylose, protein, and lipid carriers to deliver hydrophobic drugs.

L. Mauer's group continues to take materials science approaches to manipulate and investigate food ingredient structures and functions, water-solid interactions, and amorphization and crystallization tendencies. Ongoing studies include investigations of the roles of small molecules on the gelatinization and retrogradation of starch (Project 28), the roles of hydrocolloids in disrupting the crystallization tendencies of sugars and vitamins (Project 29), and the responses of complex ingredient blends to fluctuating storage environments (Project 30). Her scientific approaches build a framework of understanding around intermolecular non-covalent interactions and material properties.

Y. Yao's work in 2017 mostly focused on the carbohydrate biomaterials in food and pharmaceutical areas, with emphases on the dissolution of poorly water-soluble active ingredients (Project 41), high-throughput screening of cereal starches (Project 42), pathogen biofilm formation and reduction (Project 43), small-granule starches (Project 44), and the use of carbohydrate nanoparticles as novel vaccine adjuvants. In addition, his group has initiated the studies of a new technique in the microanalysis of starch gels and the roll-to-roll process for food coating and manufacturing.

Carbohydrates, Nutrition and Health

S. Lindemann's group discovered size-dependence in fermentation of wheat bran particles by the gut microbiota, which are likely linked to starch release rates (Project 26). Furthermore, his group identified that subtle structural variations in arabinoxylan structure exert outsized effects upon gut microbiota structure and function (Project 27).

B. Hamaker's group published on animal and human studies in 2017 showing that 1) dietary carbohydrates that are digested slowly and into the ileum do trigger the gut-brain axis and led to reduction in food intake in diet-induced obese rats and 2) that carbohydrate food factors affect gastric emptying rate, in some cases quite substantially (Project 9). Their work in this area continues towards design of starch-based foods that influence glycemic response, gastric emptying rate and activation of the gut-brain axis and ileal brake feedback control systems that affect satiety (Project 8). Descriptions of continued work on the role of dietary fibers on the gut microbiome related to health outcomes is found in Project 7.

M. Ferruzzi has developed a research program focused on fundamental and applied aspects of both food science and nutrition disciplines. His long-term goal is to identify food science strategies that will contribute to the prevention of chronic disease in humans. Working toward this goal, **M. Ferruzzi** bridges the food and nutrition sciences by investigating the impact of the food matrix and processing on the physical and chemical stability, and bioavailability of phytochemicals. His primary research focus areas include: development of methods for determination of phytochemicals in complex matrices, assessment of phytochemical stability and reactivity in food systems, including interactions with carbohydrate and protein macromolecules, and determination of factors impacting phytochemical bioavailability from foods (Project 6).

Polysaccharide and Other Biomacromolecule Structures

O. Jones's research identifies interactions between biomacromolecules, including food-relevant polysaccharides, the colloidal attributes of biomacromolecule assemblies, and the stability of colloidal suspensions. Analytical specialties of his laboratory include atomic force microscopy, light scattering systems, droplet shape tensiometry, UV-visible light spectroscopy, and isothermal titration calorimetry.

The **Jones** group has studied fibrous or particulate assemblies of proteins from whey and corn. Whey protein fibrils were used in the preparation of films with enhanced mechanical/transmissive properties or to prepare surfaces for specific growth profiles of deposited cells (Project 11). Another project over the past several years has investigated particulate assemblies of whey protein as emulsion stabilizers. In the past year, the group has shown that the deformability of particulate protein assemblies could be modified by changing the internal cross-linking, and studies are currently underway on the role of the deformability on improved performance of stabilized emulsions (Project 12). High molecular weight glutenin is an example of a natural fibrous protein assembly that has been linked to the desirable viscoelastic behaviors of wheat-based baked products, such as traditional bread. Using the expertise of the Jones lab and a collaborator at a USDA research station, fibrous protein assemblies have been prepared and utilized in starch-water mixtures to determine whether the mechanical properties of wheat-based doughs could be achieved by matching the physical structure of glutenin strands (Project 13).

Stability of aqueous suspensions is an area of applied research that is another speciality of **O. Jones**. Recent research has identified the physical and digestive stability of zein particle suspensions utilized to encapsulate a bioactive molecule (Project 14). This project also showed that the dispersion of zein particles in a cellulosive film could improve mechanical behaviors and vapor transmission rates but only at low concentrations. Another recent project has been undertaken on the emulsification capability of cricket flour and the role of the protein and polysaccharide fractions from the cricket (Project 15).

Synergistic behaviors observed among polysaccharide mixtures are often explained by "interactions" that are predominantly incompatible. Select research has implied the possibility of associative interactions between starch and some proteins, and a collaborative project between **O. Jones** and **O. Campanella** has set out to determine if certain structures or conditions of starch will allow for associative interactions with dairy proteins (Project 16). The initial studies have been focused upon interactions between polyglucose chains and caseinate, while a parallel study has been opened on the adsorptive interactions at starch granule surfaces.

J. Kokini's group has expanded his nanocomposite work to mechanistically understand the thermodynamics of interactions between polyelectrolytes using isothermal titration calorimetry. Nanotubules were studied in sodium alginate and bovine serum albumin system (Project 18) and polyelectrolyte complexes were formed with chitosan and sodium alginate (Project 19). In the area of fluorescent detection of gluten subunits, he has successfully developed antibodies for glutenins and conjugated them to quantum dots (Project 20). His lab is now moving into the imaging details. Regarding the developed of biodegradable platforms, they successfully analyzed the effects of crosslinking on the chemical, mechanical and surface properties of zein films (Project 21). They also brought more insight to the mechanism of crosslinking of plasticized zein films through many spectroscopic techniques (Project 22). The effects of nanocomposite addition to the zein and kafirin films have also been successfully explored (Project 23). They gained a deeper understanding of surface properties of zein films through surface energy and wettability studies. They also have developed a zein-based sensor that show great advantages in the biodegradability compared with the commercial available silicon substrate or glass substrate (Project 24).

G. Schmidt, J. Wilker and Food Science faculty are working on a project to make adhesives from food components. Proteins and polysaccharides are being modified and formulated in the presence of small molecule components from food. The hypothesis is that glucose-based polymers can be used for designing non-toxic, strong and sometimes wet-setting glues. These new adhesives may find applications in food packaging, surgery and dentistry, as well as biomedical applications. Preliminary results are showing that in-situ reactions can transform polysaccharides into high-strength adhesives. Bond strengths of polysaccharide-based glues can be up to 1/3 of commercial Super Glue. Bond strengths of glues containing plant proteins are matching Super Glue in adhesion strength. Ongoing studies are generating more results for publications and proposal submissions.

Rheology and Physico-chemical Properties (Level 2 head)

O. Campanella's research on rheological properties of tomato products is closely related to changes in physicochemical properties of the particles, instead of the long-held idea that pectin is responsible for viscosity and texture (Project 1). Other studies are ongoing show that engineering fibrils can enhance properties of dough and bread.

Interfacial Phenomena

G. Narsimhan's group continues to work on fundamental aspects of interfacial phenomena in food and biological systems. They are investigating pore formation in microbial cell membranes by antimicrobial peptides (Projects 32) and characterization of connection between structure and pasting behavior of starch (Project 33).

Chemical Structures and Functions of Polysaccharides

B. Reuhs and **A. Terekhov** run the analytical core facility at the Whistler Center dedicated to complex carbohydrate structural analysis. With **O. Campanella** and **B. Hamaker**, the group studies non-starch polysaccharide structures and their physical functionality (described under Campanella), as well as colon fermentation (described under Hamaker).

With **O. Jones** and **O. Campanella**, the **Reuhs** group also researches the structure and functionality of polysaccharides in processed foods, such as tomato products, as noted above.

Analysis typically involves monosaccharide profiling using the alditol acetate or TMS-methyl-glycoside analysis by GC, and linkage analysis by partial methylation using GC-MS, as well as 2D-NMR, MS, and FT-IR. Other chromatography methods are used to profile molecular size, and as preparative tools. All of these research efforts are related to understanding the role of polysaccharides in structure-function relations in various biological and food systems.

Genetics

C. Weil's lab has continued their work phenotyping genetically diverse collections of corn, sorghum and, more recently, pearl millet for novel and useful traits. Those relating to carbohydrates include overall content and type, digestibility and partitioning within the plant. Part of this work has been as part of a multidisciplinary team, including both engineering and plant science faculty, to develop remote sensing technologies for plant phenotyping in the field using color imaging, hyperspectral imaging and LIDAR mounted on tractor frames as well as flying on unmanned aerial platforms.

Characterizing the cell wall composition of over 1000 diverse sorghum lines has revealed association of a nonsense mutation in a phenylalanine ammonia lyase (PAL) gene with a highly favorable lignin composition that helps release glucose from the biomass for processing into biofuels. In addition, they have identified a small region of chromosome IX that contains two copies of a fasciclin-like A (FLA) gene. A mutation in this region is associated with increased glucan and xylan release. While they find no change in the coding regions of either FLA gene, they are investigating whether either gene shows a change in transcription level. Additional associations that control a set of 20 agronomic and morphological traits are also under further study (Project 35).

Another project, in collaboration with **Y. Yao**, has been evaluation of phytoglycogen as a biodegradable nanomaterial. Phytoglycogen forms as a major component of maize endosperm in mutants defective for the starch debranching enzyme encoded by the *sugary1 (su1)* gene. The extensively branched polysaccharide forms spherical molecules, expansion of which is likely limited by the degree of branching; once there is no more room to add new branches, the growing sphere cannot continue to get larger. They are testing this idea by comparing the phytoglycogen particle size distribution of various *su1* alleles, as well as combinations with alleles of other starch debranching enzymes. When these lines are grown side-by-side in the same environment, there is variation in particle size among genotypes, confirming that there is genetic control over this trait.

A third project examines how plants partition the carbon they fix during photosynthesis into different forms and different locations within the plant. In corn, this is typically as starch in the kernels of the ear, but in close relatives of corn (sugarcane and sorghum), the carbon can be stored as high levels of sugar in the stalk. Both from a biofuel and from a food ingredient standpoint, it would be useful to develop varieties that grow to large biomass and that accumulate sugar in the stalk, similar to what is observed for sugarcane or sweet sorghums. Several tropical varieties of maize already show significantly larger plants (up to 5 meters) and higher stalk sugar (as high as 20%) than is typical for corn; they are pursuing breeding strategies to better understand the genes responsible and their control of this process. They have developed a series of seven inbred lines derived from various tropical germplasm and last summer began evaluating these lines using remote sensing assets. They are now evaluating hybrids of these lines in comparison to the parents (Project 39).

They have developed a mutagenized population of pearl millet as a general resource. Pearl millet is of interest not only because of its role as a staple in sub-Saharan Africa, but also because when consumed as a porridge it appears to slow gastric emptying. They are interested in identifying the genetic architecture of this trait.

The Weil lab has continued to characterize mutant lines of corn that show altered starch digestion (Project 37). Recently this project has shifted to mapping genes for variation in starch digestibility of both cooked and uncooked flour in diverse maize inbreds. One inbred is notable for its more rapidly digested uncooked starch, which has tremendous potential as an improved poultry feed ingredient. Two QTL have been identified from these experiments, and the genes within them are being analyzed.

Staff Directory

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Faculty

James N. BeMiller

General Research Areas
- Starch
- Carbohydrate chemistry

Specific Research Areas
- Starch granule structure, reactivity, and behavior
- Chemical and biological modifications of starch
- Structure-functional property relationships of polysaccharides

Osvaldo H. Campanella

General Research Areas
- Process modeling
- Rheology
- Material structure and texture
- Extrusion

Specific Research Areas
- Application of rheology to food science and food engineering
- Mathematical modeling of food process operations
- Online rheological techniques
- Rheology of biomaterials
- Dough rheology
- Rheology of dairy products
- Characterization of material structure and texture; relationship to rheological properties
- Effect of glass transition on product texture
- Extrusion: role of rheology in the extrusion process

R. Chandrasekaran

General Research Areas
- X-ray diffraction
- Molecular architecture of biopolymers

Specific Research Areas
- Starch crystallinity
- Conformation of carbohydrates and nucleic acids
- Structure-function relationships in polysaccharides and polysaccharide mixtures
- Implementation of modern techniques to fiber diffraction

Mario G. Ferruzzi

General Research Areas

- Phytochemical and botanical chemistry with focus on food pigments and flavonoids
- Development of methodologies for determination of phytochemicals in food and biological matrices
- Investigation of food processing effects on phytochemical profiles, bioavailability, and ultimate bioactivity
- Development of strategies for incorporation and stabilization of phytochemicals in food systems

Bruce R. Hamaker

General Research Areas

- Carbohydrates and health
- Starch, chemistry and function
- Dietary fiber, chemistry and function

Specific Research Areas

- Glycemic carbohydrate digestion for slow digestion/low glycemic response, physiological response
- Dietary fiber, modifications in functionality and gut fermentability, gut microbiota and metabolites
- *In vitro, in vivo*, cell culture studies
- Cereal starch and protein functionality
- Textural properties influenced by starch fine structure
- Interactions between starch and other food components
- Appropriate methods of improving cereal utilization in developing countries

Owen G. Jones

General Research Areas

- Physical interactions between food biopolymers, such as milk proteins and fibrous polysaccharides
- Assembled structures through physical interactions and environmental changes, such as pH, temperature and dielectric constant
- Assembled structures for the purpose of controlled release, textural mimetry or modulated interactivity within food or pharmaceutical products

Jozef Kokini

General Research Areas

- Food materials science
- Linear and non-linear rheology
- Computational fluid dynamics
- Food nanotechnology and fabrication of nano-biosensors
- Phase behavior and compatibility of ingredients in food mixtures
- Food structure and texture during extrusion, mixing processes and computational fluid dynamics

Stephen Lindemann

General Research Areas

- Gut microbiome
- Genomics and metabolism

Specific Research Areas

- Dietary fiber impacts on gut microbiome diversity
- Genomic mechanisms of polysaccharide fermentation
- Carbon, nitrogen and energy cycling by gut microbiota and host interfaces

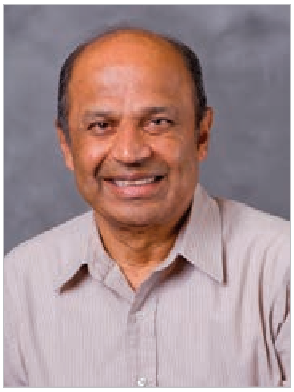
Lisa J. Mauer

General Research Areas

- Food chemistry
- Water-solid interactions
- Food materials science

Specific Research Areas

- Structure-function relationships of food ingredients
- Solid state characterization
- Glass transitions
- Moisture sorption
- Deliquescence
- Crystallization and amorphization



Ganesan Narsimhan

General Research Areas

- Emulsions and foams
- Biopolymer interactions

Specific Research Areas

- Pore formation by antimicrobial peptides in cell membranes and lipid bilayers
- Pasting behavior of starch
- Stability and texture of food emulsions and foams
- Adsorption of proteins and protein-polysaccharide complexes at interfaces
- Functional properties of proteins and protein-polysaccharide complexes
- Physical and chemical modification of proteins for use as food stabilizers
- Rheology of polysaccharide solutions and gels

Bradley L. Reuhs

General Research Areas

- Polysaccharide analysis
- Bacterial and plant cell wall compositions, structures and functions
- Sugars and polysaccharides in nutrition and food systems

Specific Research Areas

- Extractions and purification of acidic polysaccharides from cell walls of plants (including food products) and bacteria
- Pectin, hemicellulose, capsule, gum and lipopolysaccharides analysis
- Application of HPLC, MS, GC, GC-MS, FT-IR and NMR to structural studies of carbohydrates, including polysaccharides

Gudrun Schmidt

General Research Areas

- Polymer science
- Biopolymer chemistry
- Structure-property relationships

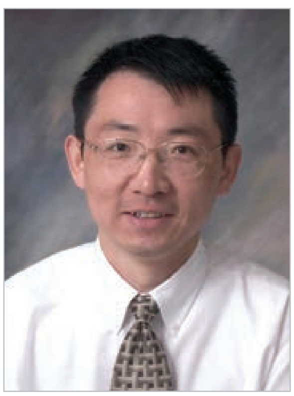
Clifford F. Weil

General Research Areas

- Plant classical and molecular genetics
- Protein structure and function
- Gene expression
- Large-scale forward and reverse genetics screening
- Genome maintenance and organization
- Genomics of starch digestion, composition and architecture

Specific Research Areas

- Rational redesign of corn starch composition
- Computer modeling of starch synthases
- Mutational analysis of starch biosynthesis in corn and *E. coli*
- Genetic modification of corn starch properties



Yuan Yao

General Research Areas

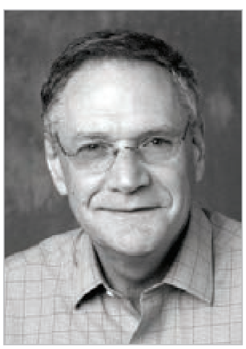
- Novel biomaterials for food and health
- Chemistry and genetics of carbohydrate polymers
- Nanotechnology for foods and drugs
- Coating of active ingredients

Specific Research Areas

- Construction and characterization of nano-biomaterials
- Stabilization, solubilization and delivery of active ingredients
- Genetic, enzymatic and chemical modifications of starch
- Functional food ingredients
- Carbohydrate microanalysis
- Evaluation and removal of pathogen biofilms
- Roll-to-roll coating of active ingredients

Adjunct Faculty

Yonas Gizaw, Ph.D. is Principal Scientist at The Procter and Gamble Co. Currently, he is technical leader for Advanced Cleaning Transformative Platform Technologies in Corporate R&D. Dr. Gizaw is a 20-year veteran of P&G with broad experience in biopolymers, nanotechnology, polymers physical chemistry, surfactants and colloids. He spent about eight years in Snack and Beverages where he supported technology development for beverages (Sunny D) and Snacks (Pringles), then moved to the Fabric Care Strategic and Innovation division where he was responsible for development of strategic technologies Downy/Lenor & Tide/Ariel, etc. In 2012, he joined Corporate Research – Transformative Platform Technologies. Prior to joining P&G, Dr. Gizaw received his doctoral degree from Purdue University in synthetic carbohydrate chemistry.



Akiva Gross, Ph.D. is President of A.T. Gross Consulting, Ltd. Dr. Gross received his doctoral degree in Organic Chemistry from the Weizmann Institute of Science in Israel and then continued his scientific training in Applied Enzymology in the chemistry departments of Massachusetts Institute of Technology and Harvard University. Before starting his consulting business, Dr. Gross served as a Vice President of Global Product Development at Corn Products International. Prior to joining the company, Dr. Gross held several R&D leadership positions at CP Kelco and Monsanto. He was also a co-founder, Senior Vice President of R&D and a member of the Board of Directors of Opta Food Ingredients, Inc. Opta Food Ingredients was established as a spinoff of Enzytech, Inc., where Dr. Gross was a co-founder and Vice President of R&D.

Sakharam K. Patil, Ph.D. is President of S.K. Patil and Associates. Dr. Patil was awarded a Ph.D. degree in Cereal Science by Kansas State University in 1973. He held several positions at American Maize Products Co., later Cerestar, from 1978 until his retirement in 2002. The positions included VP Marketing and Commercial Development (1994-1995), Vice President of Research and Development (1995-2000), Vice President of Research and Development and Director, Global, Technology Transfer (2000-2001), and VP Quality and Technology Transfer (2002). His expertise includes cereal chemistry, ingredient technology (food and industrial), technology transfer, marketing/commercial development, training/coaching, cross-functional team development, global business development and strategic management.

Bernhard Van Lengerich, Ph.D., Former CSO and VP Technology Strategy at General Mills, Inc. After more than 20 years of service, Bernhard retired from General Mills in March 2015. He is a strategic advisor and serves as a board member of several companies and nonprofit organizations. He is founder of the Seeding the Future Foundation, Vice Chair of Feeding Tomorrow (IFT's nonprofit organization) as well as Compatible Technology International, a nonprofit organization in Minnesota, focusing on post-harvest loss reduction in SSA. Bernhard completed his Ph.D. in Food/Biotechnology at the Technical University of Berlin, Germany. His work experience includes Unilever Germany, RJR Nabisco, New Jersey, and Buehler AG in Switzerland. In 1994, Bernhard joined General Mills, Inc., in Minneapolis. He led the development of numerous technologies and capabilities resulting in major product innovations. Bernhard authored/co-authored over 100 patents, established and led a Game Changer program, and created a novel "Cashless Venturing" initiative, enabling faster and more disruptive innovations.

Visiting Professors

Eric Bertoft joined Dr. Hamaker's group in April for two months and again in September for two months in 2017 as a visiting professor. His appointment allowed him to engage in scholarly research activities for the Center, including providing WebEx conferences on starch structure for the Center's members.

Dawei Chang earned his B.S. in food science and technology from HeBei Agriculture University in 2004 and his M.S. in food science from Shanghai Ocean University in 2007, respectively. He obtained his Ph.D. degree in food science from School of Food Science and Technology of Jiangnan University in December 2010. He started working in School of Food and Biological Engineering in Shaanxi University of Science and Technology from December 2010. He has been a visiting professor in Dr. Campanella's group at Purdue University since August 2017. His research focuses on the area of molecular properties of starch that allows the interaction with protein molecules.

Hanqing Chen earned his B.S. and M.S. degrees from the Department of Animal Science and Technology of Anhui Agricultural University in July 1991 and July 1998, respectively. He obtained his Ph.D. degree from the Department of Food Science and Technology of Jiangnan University in July 2005. Now he is a professor in the College of Food Science and Engineering of Hefei University of Technology. He joined Dr. Campanella's group as a visiting professor in September 2016 researching the structure and rheological properties of starch.

Mi Hongbo earned her B.S. degree from the Department of Food Science and Engineering of Tianjin University in July 2009. She obtained her Ph.D. degree from the Department of Food Science of Zhejiang University in June 2014. Now she is a faculty member at the College of Food Science and Engineering, Bohai University. She joined Dr. Narsimhan's group as a visiting professor in September 2016 with research focused on preparation and characterization of starch-lipid complexes.

Bin Li earned his B.S. and Ph.D. degree from the Department of Food Science and Technology of Huazhong Agricultural University in July 1994 and July 2002, respectively. Now he is a professor in the College of Food Science and Technology of Huazhong Agricultural University. He joined Dr. Campanella's group as a visiting professor in January 2017 researching molecular stimulation and molecular docking of carbohydrates.

Xiaoyuan Ma earned her B.S. in Bioengineering from the College of Chemistry and Chemical Engineering – Nanjing University of Science and Technology, China in 2006. She received her Ph.D in Applied Chemistry at Southeast University, China in 2011, advised by Dr. Weiping Qian. She joined Dr. Kokini's group as a visiting professor in December 2017, with financial support from the China Scholarship Council (CSC). Her research focuses on the fabrication of nanomaterials and their SERS application in food safety detection.

Jae-Hoon Shim is an Associate Professor in the Department of Food Science and Nutrition at Hallym University. Jae graduated with his M.S. and Ph.D. degrees from the Department of Food Science & Biotechnology, Seoul National University. His research focuses on food enzymology and food microbiology. He was a sabbatical visiting professor and has ongoing research collaboration with Dr. Hamaker.

Jianhua Xie received his B.S., M.S. and Ph.D. degree in Food Science and Engineering from Nanchang University in 2005, 2008 and 2015, respectively. His M.S. study was about purification, structure and bioactivities of polysaccharides from food resources. His Ph.D. research focused on modification of polysaccharides from *Cyclocarya paliurus* and their biological activities. He was in Dr. Hamaker's group as a visiting professor (postdoctoral fellow) from September 2016 to September 2017 with a governmental scholarship from China Scholarship Council. His research focused on dietary fiber structure and gut microbiome.

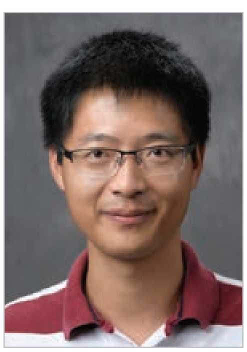
Genyi Zhang is a Professor of Food Science at Jiangnan University, mainly focusing on the carbohydrate chemistry and nutritional properties of starch, and related to this, nutritional interference to prevent or delay the incidence of chronic diseases (diabetes) using functional food components. He also works on soft matter nanotechnology for functional component encapsulation and delivery. He was a visiting professor in the summer of 2017 with Dr. Hamaker.

Tuncay Yilmaz holds a Ph.D. in Food Engineering from Celal Bayar University. Tuncay was a Visiting Professor who worked with Dr. Kokini researching the role that previously unstudied protein components play on rheological properties of wheat flour doughs. He joined Kokini's group in August 2016 for a twelve-month stay.

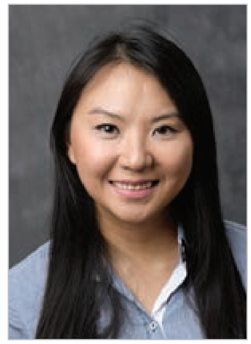
Visiting Scientists

Neslihan Bozdogan completed her B.S. degree in Food Engineering from Hacettepe University in 2011 in Turkey. She earned her M.S. degree in Food Engineering from Ege University in 2015 and began her Ph.D. degree in the same department, advised by Dr. Seher Kumcuoglu. She joined Dr. Kokini's group as a visiting scholar in October 2017 with financial support from the Scientific and Technological Research Council of Turkey (TUBITAK). Her research focuses on the numerical simulation and noninvasive 3D imaging of bubble dispersion during mixing.

Thais Brito-Oliveira earned her B.S. in Food Engineering from the College of Animal Science and Food Engineering-University of São Paulo (USP) in 2014. She began her M.S. in Food Engineering at University of São Paulo (USP) in 2015, advised by Dr. Samantha Cristina de Pinho. She joined Dr. Campanella's group as a visiting scholar in July 2016 with financial support from the São Paulo Research Foundation (FAPESP). Her research focused on the rheological characterization and mathematical modeling of cold-set, emulsion-filled gels produced with soy protein isolate and polysaccharides.



Lilin Cheng earned his B.S. in Food Safety and Quality from Shihezi University in 2011 and went to Jiangnan University to pursue his M.S. and Ph.D. degree in Food Science and Engineering. He bypassed his M.S. in 2012. He was a visiting student at Purdue from 2015 to the summer of 2017 and was co-advised by Drs. Campanella and Hamaker. His research focused on a three-component interaction and molecular dynamic simulation of the nanocomplex.



Monique Mi Song Chung completed her B.S. in Food Engineering, M.S. in Material Science and Engineering at the University of São Paulo, Brazil. She worked with Drs. Campanella and Jones between June 2016 and July of 2017 as a visiting scientist through a collaborative project with University of Sao Paulo, Pirassununga campus. This project determined whether a combined delivery vehicle of zein structures and arabinoxylan hydrogels would provide synergistic resistance to premature degradation of encapsulated curcumin during in vitro digestion.

Elisabeth Diatta is from Senegal. She had a bachelor's degree in Plant and Animal Biology in 2012 and a master's degree in Plant and Microbial Biotechnology in 2014, both from Cheikh Anta Diop University (UCAD) in Senegal. In January 2015, she enrolled for the Ph.D. program in Plant Breeding at the West Africa Centre for Crop Improvement (WACCI), University of Ghana. She joined Dr. Weil's lab as a Visiting Scholar in October 2016. Her research focuses on protein digestibility of sorghum.

Weili Fan earned her Ph.D. in chemistry from Missouri University of Science and Technology in 2014, and Master of Public Health from Johns Hopkins Bloomberg School of Public Health in 2016. She joined Dr. Yao's lab in July 2016 with research focused on active food ingredients.

Ashwana D. Fricker received her Ph.D. degree in Microbiology from Cornell University in 2015. Before coming to Purdue, Ashwana completed a postdoctoral fellowship in the University of São Paulo, Brazil. Her research has focused on cellular pathways involved in how bacteria internalize information from their environment. She joined Dr. Lindemann's group in March 2017 and is working on analyzing the causative agents and biomes of various disease states.

Fei Jia earned his B.S. degree from the College of Food Science and Nutritional Engineering in China Agricultural University. He obtained his M.S. degree from the Department of Food Science and Technology of Jiangnan University. He started Ph.D. study in Processing and Storage of Agriculture Products in China Agricultural University in September 2014. He joined Dr. Kokini's group as a visiting scholar in November 2016. His research focuses on the development of rapid detection method for allergens and foodborne pathogens.

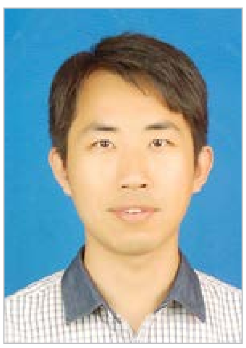
Dandan Li received her B.S. in Food Science and Engineering from Northeast Forestry University in 2013. Then she went to Jiangnan University to pursue her M.S. and Ph.D. degrees in Food Science and Engineering. The research topic of her M.S. and Ph.D. is continuous-flow, electro-assisted degradation of polysaccharides with different charges. She joined Dr. Jones's group as a visiting scholar in August 2017 to study the interaction between polysaccharides and proteins.

Zhang Mengke earned her B.E. degree from the Department of Food Science and Engineering at Fujian Agriculture and Forestry University in July 2011. She obtained her M.S. degree from the Department of Food Science and Nutrition Engineering of China Agriculture University in June 2013. She started Ph.D. study in Food Science at Jiangnan University in September 2013. The research topic of her Ph.D. study is the preparation of a cyclodextrin supramolecular nanoparticle based on click chemistry as a drug delivery system. She joined Dr. Narsimhan's group as a visiting scholar in August 2016 to conduct molecular dynamics simulation of complexation of alamethicin with cyclodextrin.

Kuenchan Na Nakorn graduated with a B.S. in Food Science and Nutrition in 2005 and Master of Science in Food Technology in 2009 from Prince of Songkla University. She is a Ph.D. student under Dr. Sunanta Tongta, School of Food Technology, Suranaree University of Technology, Thailand. She received a scholarship from the Office of the Higher Education Commission to conduct research abroad, and was a visiting student at Purdue with Dr. Hamaker. Her research was about starch digestibility of a extruded rice product as affected by protein and fibers.

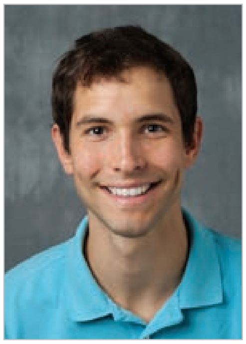
Nathalia Olivera-Arenas was a visiting undergraduate from the National University of Colombia in Bogota. She came to the Center for six months of study beginning June 2017 to work with Dr. Kokini's group in the area of biodegradable films with superior mechanical, thermal, permeability and electrical properties.

Laura Roman Rivas is currently a Ph.D. candidate in Food Science at the University of Valladolid, Spain, whose research focuses on the physicochemical characterization, enzymatic modification and new applications, in terms of nutritional and organoleptic improvement, of cereal extruded flours. She received her B.S. in Agricultural Engineering and her M.S. in Food Innovation and Processing at the University of Valladolid, Spain. She was a visiting student in Dr. Hamaker's lab for three months in 2016, and returned to Drs. Campanella and BeMiller's lab in 2017.



Lijie Zhu earned his B.S. degree from the College of Food Science of Shenyang Agricultural University in June 2009 and his Ph.D. degree there in June 2014. Now he is a faculty member at the College of Food Science and Engineering, Bohai University. He joined Dr. Narsimhan's group as a visiting scholar in September 2017 researching the effect of the structure of adsorbed protein layer in emulsion droplets on the loss of flavor.

Graduate Students



Matthew Allan graduated from Washington State University in May 2012 with a B.S. in Food Science. He joined Dr. Lisa Mauer's lab in 2012 and received his M.S. degree in Food Science in August 2014. He is currently working towards his Ph.D. with Dr. Mauer. His research focuses on: 1) starch gelatinization and retrogradation and 2) RH-temperature phase diagrams of hydrate-forming deliquescent crystalline ingredients.

Miguel Alvarez Gonzales completed his B.S. in Food Science and Technology from the Department of Food Science and Technology at PanAmerican Agricultural School, Zamorano University. He is part of the team supervised by Dr. Yuan Yao. Previously, he worked on designing bioactive packaging materials for roll-to-roll manufacturing. Currently, he works on the characterization of carbohydrate polymers.

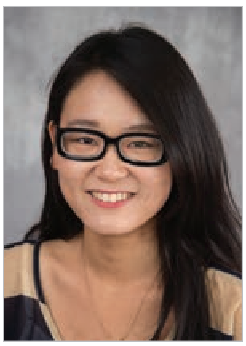
Ingrid J. Aragón Gallego earned her B.S. in Chemistry from Universidad del Valle, Cali, Colombia in 2009. Her undergraduate thesis was on the validation of in vitro methodology for evaluation of iron bioaccessibility in foods. Afterwards, she joined the Nutritional Quality Laboratory (NQL) of the International Center for Tropical Agriculture (CIAT) (Palmira, Colombia) as a research assistant in 2009. In addition, she participated in the development of different research projects in the cassava and bean breeding programs at CIAT, focused in carotenoids and Fe/Zn biofortification of cassava and beans, respectively. In 2014, she joined Dr. Ferruzzi's lab as a Ph.D. student via a scholarship received through the Colombian government. Her research is on the nutritional and bioactive value of biofortified staple crops and native foods of Colombia.

Seda Arioglu-Tuncil received her B.S. in the Food Engineering Department at Ataturk University in Turkey in 2010. She was awarded a scholarship for her M.S. and Ph.D. degrees in the USA by the Turkish Government and joined Dr. Mauer's lab in January 2013 for her M.S. studies. Her project mainly is on the crystallization inhibitor properties of different polymers in bioactive amorphous solid dispersions. She completed her M.S. in December 2014 and is now working towards her Ph.D.

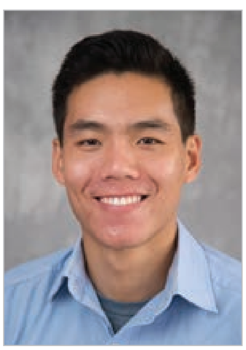
Emmanuel Ayua graduated from Moi University in December 2011 with a B.S. in Food Science and Nutrition, and M.Sc. in Community Nutrition from the University of Eldoret (both in Kenya). He joined Dr. Bruce Hamaker's lab in 2016 and is working towards a Ph.D. degree in Food Science. His research focuses are in effects of extrusion on fermentation of dietary fibers by the gut microbiome.

Emma Barber received her B.S. in Chemical and Biomolecular Engineering with a minor in Food Science from North Carolina State University in 2014. She joined Purdue in 2014, working on her M.S. in Food Science with Dr. Kokini. Emma's research focuses on optimizing a biodegradable corn protein platform for the spectroscopic detection of allergens and toxins.

José Bonilla earned his B.S. in December 2014 from the Food Science Department at Zamorano University in Honduras. During the spring of 2014, he worked as Visiting Scholar in Dr. Yao's lab using polysaccharides from starch to improve thymol solubility. In January 2015, he began studies for his doctorate in Dr. Kokini's lab. His Ph.D. research focuses on the use of inorganic fluorescent nano-probes (quantum dots) as an in situ labeling technique to study the distribution and rheological properties of cereal proteins.



Jingfan Chen graduated from the Food Science Department in 2015 is currently an M.S. student in Dr. Yao's lab. Her research primarily is on carbohydrate applications to improve the efficacy and bioavailability of active ingredients.



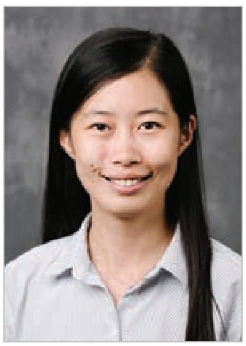
Christopher Cheng received a B.S. in Food Science from Purdue University in 2012. Then he continued to receive a M.S. from North Carolina State University in Food Science in 2014. He is currently pursuing his Ph.D. under Dr. Jones. His research focus has been on developing applications for zein, a protein derived from corn.

Dennis Cladis earned his B.A. in Chemistry and Mathematics from DePauw University in 2009. He completed his M.S. in synthetic inorganic chemistry at Purdue in 2012. From there, he discovered a passion for food science as a practical application of his chemistry and subsequently earned his M.S. in Food Science at Purdue in 2014, with his research focusing on fatty acid profiles and mercury content in fish. Currently, he is pursuing his Ph.D. under the direction of Drs. Ferruzzi and Weaver. His research examines the absorption, distribution, metabolism and elimination of natural plant polyphenols as well as screening toxicity of natural products.

Hawi Debelo earned her B.A. degree in Biochemistry from Manhattanville College, New York, in 2012. Following her undergraduate career, Hawi worked at PepsiCo Global Research and Development Center as a Product Development Technician. She spent two years at PepsiCo conducting research with Product Developers in innovation, formulation, and commercialization of Pepsi products. Hawi Debelo joined Dr. Ferruzzi's lab in 2014 as a Ph.D. student where she works on a project to evaluate the stability, bioaccessibility and bioavailability of bioactive compounds from native African plant materials.

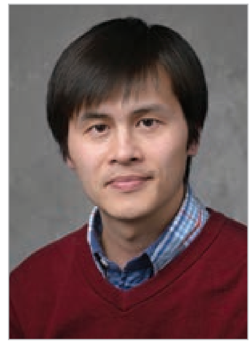
Gnana Prasuna Desam earned her B.Tech. degree in the Department of Agricultural and Food Engineering from Indian Institute of Technology, Kharagpur, in July 2014. She joined Dr. Narsimhan's group in June 2015 to pursue a Ph.D. degree in the Department of Agricultural and Biological Engineering and is working on prediction of swelling kinetics of waxy cornstarch and modified waxy cornstarch.

Aminata Diatta received a B.S. in Natural Sciences in 2002 and a pre-doctorate diploma in Chemistry and Biochemistry of Natural Products in 2006 from Cheikh Anta Diop University, Dakar, Senegal. She worked on the theme: "Characterization of three varieties of sorghum (*S. bicolor*), composition and aptitude to form rolled flour products." She joined Dr. Hamaker's group in the fall 2015 and successfully defended her M.S. in December 2017.



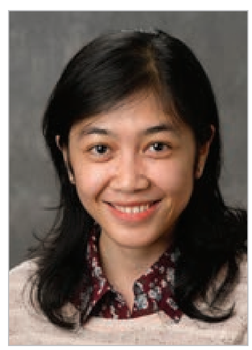
Fang Fang earned her B.S. in Bioengineering from Central South University of Forestry and Technology in 2009 and her M.S. in Food Science from Jiangnan University in 2012. Fang began her Ph.D. at Purdue in the fall of 2013 with support from the China Scholarship Council. She was co-advised by Drs. Campanella and Hamaker. Her research focused on the relationship between rheology and digestion properties of starch with respect to molecular structure. She complete her Ph.D. in 2017 and is now a post-doc in the lab of Prof. Amy Lin at University of Idaho.

Enrico Federici earned his B.S. degree in food science and technology in July 2014 from University of Parma. During work on his master's in food science and technologies at the University of Parma he joined Dr. Campanella's Lab as a visiting scholar for six months where he worked on a collaborative research project between Purdue University and the University of Parma. This contributed to the completion and defense of his M.S. thesis in October 2016. After working for 6 months as a research assistant at the University of Parma, Enrico joined Drs. Jones and Campanella's lab in August 2017 as a Ph.D. student. His research focuses on improvement of gluten-free products with the use of novel protein preparations and assemblies.

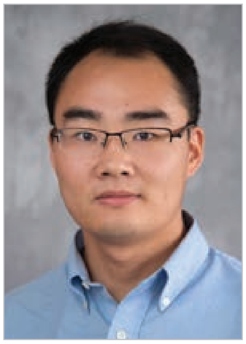


Xing Fei earned his B.S. in 2006 from Huazhong Agricultural University and his M.S. in Food Science from Guangdong Ocean University, China in 2009. Xing began his Ph.D. at Purdue in the Spring 2014 at Agriculture and Biological Engineering. He will be focusing his research on the mechanical properties of single molecules. Currently Xing is working on characterization of particles of genetically modified tomatoes.

Collin Felten graduated from Brown University in 2015 with a B.S. in Chemical and Biochemical Engineering. He joined the Mauer lab in 2016 to pursue a M.S. in Food Science. His research deals with screening for different salt forms of thiamine and characterizing the physical and chemical stability of amorphous thiamine in foods.

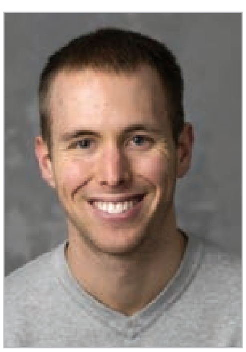


Maya Fitriyanti completed her B.S. in Microbiology from Bandung Institute of Technology, Indonesia, in 2008 and M.S. degree in Chemical Engineering from Bandung Institute of Technology, Indonesia, in 2012. She began her Ph.D. at Agricultural and Biological Engineering Department at Purdue University in the fall of 2015 and joined Dr. Ganesan Narsimhan's research group. Her research focuses on development of a process for production of antimicrobial peptides (AMPs) from soybean.



Yezhi Fu received his B.S. degree in Food Quality and Safety and M.S. degree in Food Engineering both from China Agricultural University, Beijing. He started his research in Dr. Yao's group as a visiting student in 2014 and now is pursuing his Ph.D. degree. His research focuses on designing antimicrobial coating to improve the safety of fresh and fresh-cut produce, using cantaloupe as a model.

Sarah Gafter received her B.S. in Nutrition from Case Western Reserve University in Cleveland, Ohio, in 2013. She worked in Dr. Nathan Berger's laboratory in the Genetics Department at Case Western Reserve University after graduation, examining the effect of dietary fats on prostate malignancy, and then for Jenny Craig as a Personal Consultant in 2014. Sarah then completed her dietetic internship through Indiana University-Purdue University, Indianapolis, with a capstone in Food Service Management. As a registered dietitian, she worked as a clinical dietitian for Hooverwood Home in Indianapolis. Sarah by-passed her M.S. degree and joined Purdue under Dr. Hamaker's advisement in 2016. She is working towards her Ph.D. in the area of slowly digestible carbohydrates.



Jay Gilbert began attending Purdue University in August 2013. He received his B.S. degree in Food Science and Technology from the University of Massachusetts Amherst in May 2013. Initially starting an M.S. degree with an Industry Associates Fellowship, he obtained a bypass and pursued a Ph.D. in Dr. Jones' lab with an NSF Graduate Fellowship. His research focused on the stability and mechanical properties of protein fibrils to enable their utilization in food, packaging, and pharmaceutical applications. Jay graduated in August of 2017 and is currently working for the Institute of Food Technologists.

Anna Hayes received her B.S. in Food and Nutrition Science and her B.A. in Spanish from Saint Catherine University (Saint Paul, MN) in May 2014. Anna arrived at Purdue University in August 2014 and is studying for her Ph.D. Her research focuses on elucidating the locational delivery of carbohydrates in the small intestine and on determining the effects of particle size and viscosity on carbohydrate metabolism.

Marwa El Hindaway is from Cairo, Egypt. She is pursuing her Ph.D. degree with Dr. Hamaker. She earned her bachelor's and master's degrees in biochemistry from Egypt and her research now focuses on dietary carbohydrate sensing by small intestine enterocytes, glucose release, and feedback responses.

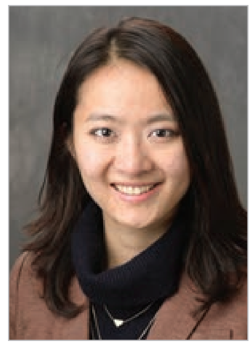
Drew Hirsch received a B.S. in Food Science from Purdue University in 2017. He then joined Dr. Jones' lab to continue his research and pursue an M.S. His research focus has been the functionality of protein and chitin from crickets as ingredients for emulsion-based food products.

Yahya Ismail received his B.S. degree in Food Science from Purdue in May 2016 and directly continued into the graduate program in Food Science under Dr. Mauer. His project extends the understanding of polymer-vitamin noncovalent interactions and their effects on the physical and chemical stability of vitamin C forms in the amorphous state.

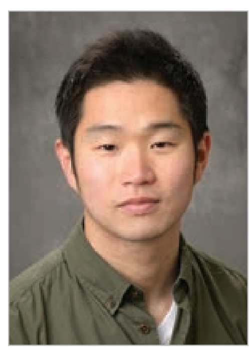
Rachel Jackson joined the Hamaker lab in 2016 to pursue an M.S. in Food Science. Her work focuses on technologies to increase gut fermentability of insoluble fibers and that relationship with microbiota and metabolite changes related to health. She plans to complete her studies in the summer of 2018.

Kathryn Johnson received her B.S.A. in Food Science and B.S. in Chemistry from the University of Georgia in December 2013. She worked at Golden State Foods in Conyers, Georgia, as a Product Development Food Technologist before joining Dr. Mauer's lab as an Industry Fellow in fall 2015 to pursue an M.S. in Food Science. Her current research investigates the effects of different sweeteners on starch thermal properties and behaviors.

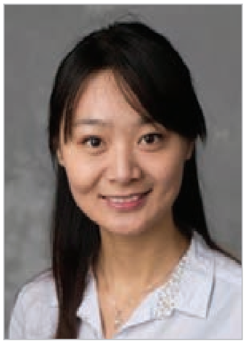
Enosh Kazem received his B.S. in Food Science from Purdue University in 2011. After graduation, he spent two years in medical school at Indiana University, and is now studying in Dr. Hamaker's group where his research focuses on the role of fiber and the microbiota in colon health.



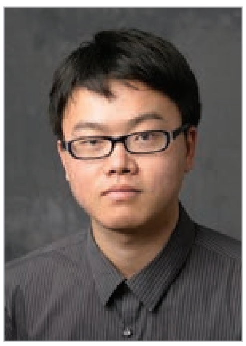
Jinsha Li completed her B.S. in Biosystem Engineering at Michigan State University in 2013. She joined Dr. Engelberth's group in August 2013. In July 2015, she successfully defended her M.S. thesis in Agricultural and Biological Engineering, titled "Adding value to bio-ethanol production: quantification and recovery of lutein and zeaxanthin from DDGS." In the same year, she started Ph.D. study with Dr. Narsimhan and has been working on the project "Prediction of swelling kinetics of waxy native maize starch" since then. Jinsha is the recipient of Fredrick N. Andrews Fellowship.



Jongbin Lim earned his M.S. degree in Food Science and Technology from Sejong University in South Korea. He joined Dr. Hamaker's lab group in August 2014 to begin his doctoral work. His research is on the moderation of starch digestion rate by inhibition of digestion enzymes and the development of glycemic carbohydrates to digest in the ileal region of the small intestine for stimulation of physiological feedback systems.



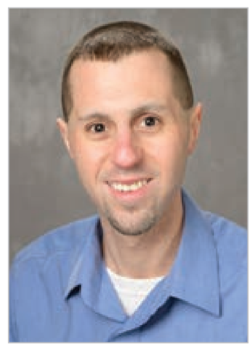
Yuan Lyu (Yuan Lv) earned her B.S. degree in College of Life Science from Henan Normal University in July 2010, and M.S. degree in School of Life Science from East China Normal University in Jul 2013. Her M.S. research was on development of soybean products, including isolated soybean protein and dietary soybean fiber. Yuan joined Dr. Ganesan Narsimhan's lab in Aug 2013 and earned her Ph.D. in October 2017. Her research focused on strategies to obtain antimicrobial peptide from soybean protein.



Dongdong Ma received a B.S. degree in Food Science from Purdue University in 2013. He is currently completing his M.S. in Agricultural and Biological Engineering. Dongdong is characterizing the rheology of complex materials and in particular its effects on the processing of these materials, including baking and drying. He is also specializing on numerical methods to characterize phenomena of heat and mass transfer through viscoelastic materials such as biofilms.

Luis Maldonado received his B.S. degree in Food Science and Technology from Zamorano University, Honduras. His undergraduate research focused on the evaluation of the pasteurization temperature and final acidity on the stability of calcium and vitamin D in yogurt. Before coming to Purdue, he worked for 3 years as a technical advisor for food processing companies in Honduras. He joined Dr. Kokini's lab in fall 2013. His Ph.D. research focuses on the characterization and encapsulation of bioactive compounds with nanomaterials.

Morgan Malm received her B.S. degree in Food Science from Purdue University in May 2016. She first joined Dr. Kokini's group as an undergraduate student in August of 2014 and focused on the characterization of proteins. In June of 2016, she transitioned into the Purdue Food Science M.S. program to continue her work with Dr. Kokini's group and has since received approval to bypass to the Ph.D. program. Morgan will continue her research on functionalizing proteins for the application of a platform for the detection of allergens and toxins.

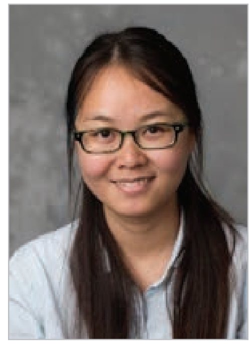


Joel Meehl earned a B.S. in Biochemistry and Molecular Biology from Marquette University in 2001. After work and further study as a laboratory technician and in some other fields, he joined the Food Science Department as a Ph.D. student in August 2015. Co-advised by Drs. Hamaker and Ferruzzi, his research focuses on phytochemical interaction with carbohydrates and the gut microbiota.

Moustapha Moussa rejoined Dr. Hamaker's group in June 2016 to pursue his Ph.D. in Food Science. His research areas focus on grain chemistry and processing with the objective of use extrusion and nutrition-related technologies to better utilize and expand market of local-based sorghum and millet grains. He received his M.S. in Food Science from Purdue University in 2007. Along with Dr. Hamaker, he successfully helped to implement the Food Processing Incubation Concept to backstop grain-based food technology development and scaling-up with nutrition and market emphasis in urban and rural areas in Niger and West Africa.

Ryan Murphy earned his B.S. in Food Science from the University of Manitoba in May 2013. He arrived at Purdue University in August 2013 with an Andrews Fellowship and was co-advised by Drs. Jones and Farkas. Ryan bypassed his M.S. degree and studied towards his Ph.D. He interned with Kraft Foods and previously started and ran a small agribusiness focused on the production, light processing, and sale of local agricultural products. His research focused on emulsion stabilization using protein and polysaccharide-based nanoparticles. Ryan graduated in May of 2017 and is currently working for an agronomy consulting firm in Canada.

Cheikh Ndiaye received a B.S. in Physics and Chemistry from Cheikh Anta Diop University, Dakar, Senegal. A pre-doctorate diploma in Chemistry and Biochemistry (equivalent to M.S.) was obtained from the same University in 2004. In 2009, an M.S. in Food Science and Technology was obtained from Jiangnan University, China. He has worked for the Institute of Food Technology (ITA) in Dakar since 2003, and is a member of the Cereals and Leguminous Vegetables Department. He joined Dr. Ferruzzi's lab after receiving a fellowship from the ERA USAID project to study biofortification of extruded cereal products using native African plant materials as biofortification agents. He is now part of the USAID Food Processing Innovation Lab and finished his Ph.D. in December 2017.

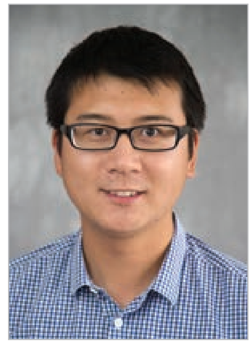


Xiang Ning earned her B.E. degree from the Department of Food Engineering of Hunan Agricultural University in July 2011. She obtained her M.S. degree from the Department of Food Science of Wageningen University in the Netherlands in June 2013. The research topic of her M.S. study was "The relation between structure of globular proteins and their cross-linking activity with microbial transglutaminase." She joined Dr. Narsimhan's group as a visiting student in July 2013 to study the function of homogenization on soy β-conglycinin and pectin stabilized encapsulation system. She is continuing her Ph.D. under Dr. Narsimhan with research focused on pore formation in lipid bilayers by antimicrobial peptides.

Smith G. Nkhata completed his B.S. in Nutrition and Food Science from Bunda College of Agriculture, University of Malawi in 2007 in Malawi. He later joined the Government of Malawi through the Ministry of Agriculture and Food Security in 2009 as a Food and Nutrition Specialist, a post he holds to date. In 2011, he was admitted at Michigan State University where he completed his M.S. degree in Food Science in 2013. He joined Drs. Ferruzzi and Hamaker's groups in August 2015 to pursue his Ph.D. in Food Science. His research area is in part on provitamin A stability during processing, in vitro bioaccessibility and bioavailability of provitamin A from maize-based products.

Gabriella Mendes Candido de Oliveira received a B.S. in Food Engineering (five-year degree) from the University of São Paulo, Brazil in 2013. She has been recipient of several scholarships from the Brazil Government and the Exchange Program between the University of São Paulo, University of Illinois, and Purdue University. In fall 2011, she attended classes at the Food Science and Human Nutrition Department, University of Illinois. In 2013, she was selected for a placement in a Ph.D. program in the United States under the program "Science Without Borders." She arrived at Purdue in Fall 2014 and her research focuses on novel processing technologies from an experimental and modeling standpoint. She works with Dr. Campanella.

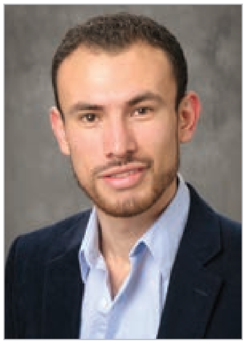
Darwin Ortiz obtained his Ph.D. in August of 2017. He holds a bachelor's degree in Chemistry from Universidad del Valle in Colombia. He has worked in the International Center for Tropical Agriculture (CIAT) where he participated in the development of the nutritional quality laboratory of CIAT. He also worked for Harvest Plus and AgroSalud Projects from 2007 to 2012. During this period, his research focused in the evaluation of bioactive compounds, antioxidant activity, and the evaluation of in vitro bioavailability of iron, zinc, protein and carotenoids. He was awarded a Fulbright Scholarship "Francisco Jose de Caldas" for his Ph.D. degree in the USA by Fulbright Colombia, and the Colombian government (Colciencias). He joined Dr. Ferruzzi's lab in 2012, where his research focused on the evaluation of micronutrient stability during post-harvest, storage and food processing of biofortified plant-based crops.



Xingyun Peng received his B.S. degree in Food Science and Engineering from China Agricultural University, Beijing, in 2011 and his M.S. degree in Cereal, Oil and Vegetable Protein Processing from the same university in 2014. He studied protein-oil interactions in soymilk processing during his M.S. program. He began his Ph.D. at Purdue in the fall of 2014 under the direction of Dr. Yao with his research focusing on novel properties of starches associated with food applications.

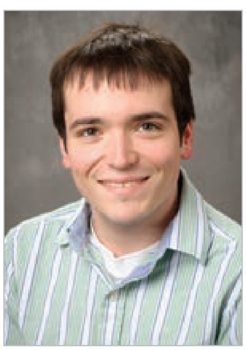
Elizabeth Pletsch received her B.S. in Food Science and Human Nutrition from the University of Illinois at Champaign-Urbana in December 2011. She worked for Hillshire Brands Co. (formerly known as Sara Lee) until coming to Purdue University in August 2012. She bypassed her M.S. degree and is near completion of her Ph.D. degree under Dr. Hamaker on physiological effects of glycemic carbohydrates.

Angarika Rayate received her bachelor's in Chemical Engineering from University of Mumbai in 2015. She started the M.S. program in Spring 2016 at Purdue University. Her research focuses on the interaction between dairy proteins and polysaccharides in dilute and concentrated systems.



Rándol Rodríguez obtained his B.S. degree from the Food Science Department of Zamorano University, Honduras. He works with Dr. Yao on the structure and function of carbohydrate particulates. He is pursuing his Ph.D. degree.

Tahrima Binte Rouf completed her B.S. in Chemical Engineering from Bangladesh University of Engineering and Technology (BUET) in 2012 in Bangladesh. After graduation and before joining Dr. Kokini's group in August 2014, she was a lecturer in the department of Chemical Technology at Ahsanullah Institute in Bangladesh. She is now pursuing a Ph.D. degree in Food Science. Her research mainly is on the functionalization of biopolymers using different nano-materials.



Juan Sanchez completed his M.S. in Food Science with the support of the Industry Fellows program and a Ross Fellowship from the Purdue Graduate School. He graduated from Dartmouth College in 2013 with a double major in chemistry and history. Juan studied water-solid interactions and their effects on the chemical degradation of ascorbic acid in the amorphous solid state. He completed his M.S. in December.

Leigh Schmidt earned her B.S. in Food Science from Purdue in 2003 and her M.S. in Food Science from UC Davis in 2009. She joined Dr. Hamaker's lab group in August 2013 as a USDA National Needs fellow for Foods and Health. Between degrees, Leigh worked in the food industry in quality and product development roles. Her Ph.D. research is on food protein matrices as a method to slow starch digestion.

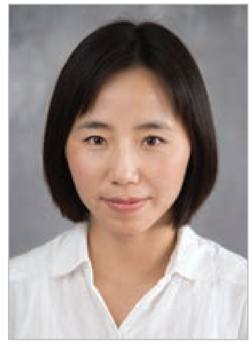
Patrick Sweet graduated from Saint Mary's University of Minnesota in May 2015 with a B.A. in Biochemistry. The following Fall he began his studies at Purdue in the Interdisciplinary Life Sciences Ph.D. program (PULSe). He joined the Weil Lab in May 2016 where he studies cell wall composition in sorghum.

Riya Thakkar is a graduate student working to obtain her M.S. in Food Science. Her area of interest is Food Microbiology. She has obtained her undergraduate degree of Bachelor of Technology in Biotechnology in May 2016 from Dr. D. Y. Patil University, India. She has worked as a research intern at Bhabha Atomic Research Center towards her thesis as an undergrad. Her research there was related to finding the effects of natural food compounds on tuberculosis. She has also worked as a Research Assistant at the Indian Institute of Technology, Bombay, where her study was related to nanoparticles on post-operative bone infections. She started her master's degree under Dr. Stephen Lindemann's laboratory at Purdue University in January 2017. Her work here focuses on the effect of particle size of food on the colonic microbiota.

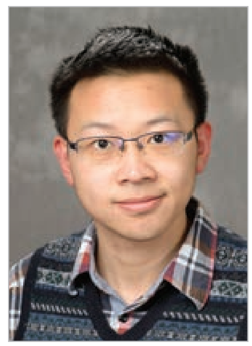
Pablo Torres-Aguilar received his M.S. in Nutritional Sciences from the University of Illinois at Urbana-Champaign where his research focused on food insecurity and the impact of environmental factors on the diet of underserved groups, both in the US and internationally. He joined Dr. Hamaker's group in the fall of 2014 and is working towards his Ph.D. degree to complete in 2018.

Hazal Turasan completed her B.S. degree in Food Engineering in Middle East Technical University in 2011 in Turkey. She also completed her M.S. degree in the same department in which she focused on encapsulation of rosemary essential oil. After receiving a Fulbright Scholarship in 2014, she joined Dr. Kokini's group for her Ph.D. studies.

Adrienne Voelker graduated from the University of Notre Dame in 2016 with a B.S. in Chemistry. She joined Dr. Lisa Mauer's lab group in 2016 to pursue her M.S. in Food Science and has since received approval to bypass to the Ph.D. program. Adrienne's current research focuses on improving thiamine delivery in foods by studying its physical and chemical stability in its amorphous form in different formulations, and she has taken a leading role in a project exploring the use of sucrose crystallization inhibitors.

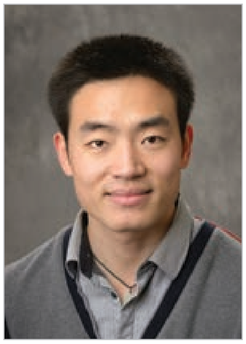


Ying Xie received her M.S. degree in Processing and Storage of Agriculture Products from China Agricultural University, Beijing. She joined Dr. Yao's group and started her Ph.D. study in August 2012. Her Ph.D. research focuses on modified carbohydrate particulates and their functional properties, with potential applications in food and pharmaceutical areas.



Tianming Yao obtained his B.S. in Food Science and Technology from Shanghai Jiao Tong University, China. His undergraduate research was on the OSA modification of small granule starches. He joined Dr. Janaswamy's group in August 2015 as a master's student with support from China Scholarship Council (CSC). His research focused on the interaction between polyphenols and starches. Tianming is now a Ph.D. student with Drs. Lindenmann and Hamaker and works on dietary fiber and the gut microbiome.

Ximena Yepez received a B.S. degree in Food Engineering from Escuela Politecnica del Litoral Guayaquil, Ecuador. In 2012, she joined the Food Technology and Development Laboratory under Dr. Keener in the Department of Food Science. She focused on the effect of high voltage atmospheric cold plasma (HVACP) treatment in modifying vegetable oil chemistry. She obtained her M.S. degree in Food Science from Purdue University in 2014. She joined Dr. Kokini's research laboratory in Food Science, where her research is focused on the study of HVACP as a catalyst in chemical reactions with the goal of defending her Ph.D. in December 2017.



Xiaowei Zhang received both his B.S. and M.S. degrees from the Department of Food Science and Engineering from Shanghai Jiao Tong University, China. He joined Dr. Hamaker's group as a Ph.D. student in August 2014. Xiaowei's research project focuses on dietary fiber structure-function relationships with the colon microbiota and health. He will complete his studies in 2018.

Ph.D. Post-Doctoral Research Associates

Mohammad Chegeni completed his B.S. in Biology from Ferdowsi University in 2002 in Iran. After that, he completed his M.S. degree in Public Health at Ball State University. He joined Dr. Hamaker's group in January 2010 and successfully defended his Ph.D. in December 2014. His Ph.D. research focused on maltose sensing of the small intestine enterocytes and sucrase-isomaltase maturation and trafficking. He continued in B. Hamaker's lab as a post-doc and left in September to join the Complex Carbohydrate Research Center at University of Georgia.

Ming-Hsu Chen received his Ph.D. degree in Agricultural and Biological Engineering from the University of Illinois in 2015. His research has focused on bioactive carbohydrates manufacturing as well as characterization and elucidation of structural-functional relationships. Before coming to the U.S., Ming-Hsu obtained his M.S. and B.S. degrees in Microbiology and Biochemistry from the National Taiwan University. Additionally, he had one year of work experience at Academia Sinica studying fungal secondary metabolites, carbohydrate recognition proteins and lymphocyte maturation. He joined Dr. Lindemann's group in August 2017 and is interested in exploring the interactions among carbohydrates, gut microbiota and human health.

Mario Martinez completed his B.S. in Agricultural Engineering, his M.S. in Food Innovation and Processing and his Ph.D. in Chemistry at the University of Valladolid, Spain. He joined Dr. Hamaker's group as a Postdoctoral Research Associate in February 2016. His research focused on investigating 1) the starch structure and the basic principles and mechanisms for starch digestion and 2) the physical structure and digestibility of edible plant tissues considering holistically the interplay between macronutrients that can lead to thermodynamic and kinetic resistant forms. The aim was to delay prevalence of hyperglycemia-related diseases through the consumption of high quality foods with a sustained glucose release. Mario moved in August to take a faculty position at University of Guelph.

Rohollah Sadeghi received his M.S. and Ph.D. degrees in Food Science and Engineering from University of Tehran, Tehran, Iran, in 2004 and 2014, respectively. His M.S. thesis focused on application and optimization of membrane technology for clarification and purification of glucose syrup. His Ph.D. research focused on fabrication of biocompatible nanoparticles and nanotubes and their application as delivery systems. He joined Dr. Kokini's lab as a visiting scholar in 2012 at the University of Illinois-Urbana-Champaign (UIUC) during his Ph.D. study. He again joined Dr. Kokini's lab in September 2015 at Purdue University as a postdoctoral associate researcher. His research focused on the fabrication and application of edible nanoparticles and nanotubes as well as using micro-rheology to understand rheological properties of dilute solutions. In 2017, he moved to the lab of Prof. Amy Lin at University of Idaho as a post-doctoral research associate.

Alpana Thorat received a Bachelor of Pharmacy degree from Pune University in 2006, and Masters of Technology in Pharmaceutical Technology–Biotechnology from National Institute of Pharmaceutical Education and Research (NIPER Mohali, India) in 2008. She worked in the pharmaceutical industry for one year (senior research chemist in Sai Life Sciences, Pune-India). In 2010, she joined the Ph.D. program in Chemical Engineering at the Indian Institute of Technology, Gandhinagar, India. Her thesis work focused on crystallization and polymorphism of curcumin. She joined Dr. Mauer's lab (jointly working with Dr. Lynne Taylor from IPPH, Purdue University) in September 2015 and worked on understanding the amorphization of sugars.

Yunus Emre Tuncil received his B.S. in Food Engineering at Ataturk University in Turkey in 2008. He was awarded a scholarship for his M.S. and Ph.D. in the USA by the Turkish Government. He joined Texas A&M University Food Science and Technology Department as an M.S. student in 2010 where he studied the effects of wheat proteins on dough rheological properties. He arrived at Purdue University in August 2012 in pursuit of a Ph.D. and completed his Ph.D. in December 2016 under the guidance of Dr. Hamaker. His Ph.D. research focused on dietary fiber utilization strategies of the members of colonic microbial community, which was a collaborative project with Dr. Eric Martens at University of Michigan Medical School. In 2017, he continued as a post-doctoral research associate under the guidance of Drs. Lindenmann and Hamaker.

Senem Yetgin received her B.S. degree in Chemical Engineering from Inonu University, Turkey. She completed M.S. and Ph.D. degrees in Chemical Engineering from the Izmir Institute of Technology, Turkey, in 2007 and 2013 respectively while working as a Research Assistant. She is presently an Assistant Professor in the Food Engineering Department, Kastamonu University, Turkey. She joined Dr. Campanella's group as a visiting scholar in July 2016. Her post-doctoral research was supported by Turkish Scientific Research Council (TUBITAK) 2219 Scholarship scheme for one year. Her main research focuses on investigating separation processes, adsorption, polymers, sol gel process, atomic force microscopy applications, artificial neuron network (ann) application on data analysis and, more recently, rheological modeling of viscoelastic materials.

Whistler Center Staff

Wendy Madore was the Whistler Center's Administrative Coordinator from August 2016 through December 2017. She previously worked in Purdue's College of Agriculture, Office of the Vice President for Research, Discovery Park, and the Krannert School of Management.

Bhavesh Patel received a B.S. degree in Dairy Technology from Gujarat Agricultural University, Anand, India, and an M.S. degree in Food Technology from Central Food Technological Research Institute (CFTRI), Mysore, India. His Ph.D. in Food Science is from Pennsylvania State University where his research involved study of starch and polysaccharide structures and the effect of processing conditions on thermal and physical properties. Bhavesh joined Drs. Campanella and Hamaker's groups in 2008 and has worked on the development of processes for isolation of corn fiber polysaccharides and enhancing of their functional properties. He also has worked on fiber rheology and incorporation into processed foods and gel formation kinetics. Dr. Patel worked on a project related to enzymatic conversion of complex polysaccharides into useful industrial and food products. Currently he conducts short-term research projects for the Whistler Center member companies.

Anton Terekhov is proficient in analytical chemistry, molecular biology techniques and analytical instruments such as NMR, GCMS, LCMS and FTIR. Anton has more than 10 years of experience in an interdisciplinary laboratory environment including the fields of analytical chemistry, microbiology, genetics, geology and chemical and civil engineering. His main research area is carbohydrate analysis using above-mentioned analytical instruments. He is Director of Analytical Services for the Whistler Center.

Our People, Our Projects

Campanella

1. Industrial Processing Properties of Tomato Products
2. Shear-Thickening Behavior and Rheopecty of Gelatinized Waxy Starch Dispersions
3. Modeling Inactivation Parameters of Spore Cells Subjected to Cold Plasma and Other Non-thermal Processes
4. Modeling of Gastrointestinal Bacterial Growth Influenced by Viscosity
5. Using Molecular Dynamic (MD) Simulation to Understand the Stability of Amylose-Free Fatty Acid Complex

Ferruzzi

6. Impact of Phytochemicals on Starch Digestion and Intestinal Glucose Transport

Hamaker

7. Dietary Fibers and *In Vitro* Fermentation: SCFA Production and Microbiota Changes
8. Investigations on Slowly Digestible Glycemic Carbohydrates
9. Cellular and Physiological Response Studies of Glycemic Carbohydrates with Slow Digestion Profiles
10. Starch-Based Nanoparticles for Gastrointestinal Cancer Drug Delivery

Jones

11. Protein Fibers within Polysaccharide Composite Films
12. Stabilization of Oil-in-Water Emulsions by Whey Protein Microgels
13. Protein Fibrous Structures as Physical Simulacrums of High-MW Glutenin
14. Physical Stability of Suspensions Containing Colloidal and Fully Dispersed Polysaccharides and Proteins
15. Emulsification Properties of Polysaccharide and Protein Fractions of Crickets
16. Interactivity Between Starch and Dairy Proteins

Kokini

17. Nanoparticulation of Bovine Serum Albumin and Poly-D-Lysine through Complex Coacervation and Encapsulation of Curcumin
18. An Optimal Window for the Fabrication of Edible Polyelectrolyte Complex Nanotubes (EPCNs) from Bovine Serum Albumin (BSA) and Sodium Alginate
19. Mechanistic Understanding of the Effect of Charge Ratio and Order of Addition on Thermodynamics of Interaction of PECs from Sodium Alginate and Chitosan
20. Simultaneous Fluorescent Detection of Gliadins, LMW, and HMW Glutenins in Wheat Dough Samples Using Antibodies-Quantum Dots Complexes as Imaging Tools
21. Characterization of Zein Films for Enhancing Their Physical and Chemical Properties
22. Characterizing the Surface and Mechanical Properties of Zein Films
23. Zein- and Kafirin-Based Nanocomposites for Biodegradable Packaging Applications
24. Gold coated Zein-Based Nanophotonic Biosensors for Toxin and Allergen Detection Using SERS

Lindemann

25. Establishment of Model Dietary Fiber-Consuming Gut Microbial Communities for Generalizable Fiber-Microbiota Research
26. Particle Size Effects on Bran Fermentation by Gut Microbiota
27. Soluble Fiber Chemical Structure Effects on Fermentation by Gut Microbiota

Mauer

28. Starch Properties in Different Environments
29. Amorphous Solid-State Dispersion (Amorphization) of Crystalline Ingredients
30. Water-Solid Interactions and Phase Diagrams

Narsimhan

31. Investigation of Interaction of Amyloid β Peptide (11-42) Oligomers with POPC (1-palmitoyl-2-oleoyl-sn-glycero-3-phosphocholine) Membrane by Molecular Dynamics Simulation
32. Pore Formation in DOPC/DOPG Bilayers by Antimicrobial Peptide Melittin
33. A Mechanistic Model for Swelling Kinetics of Waxy Maize Starch Suspension
34. Synergistic Effect of Low Power Ultrasonication on Antimicrobial Peptide Action

Weil

35. Analysis of Sorghum Genes Involved in Carbohydrate Metabolism and Production
36. Genes Controlling Starch Channelization
37. Genetic Interactions that Impact Starch Quantity and Quality
38. Genetics of Carbohydrate Transport and Partitioning in Maize
39. Genetics of Sugar Accumulation and Distribution in Maize and Sorghum
40. High-Value Corn Starch

Yao

41. Phytoglycogen-Based Biomaterials to Improve the Solubility of Active Ingredients (AI)
42. High-Throughput Screening of Cereal Starches
43. Pathogen Biofilm Formation and Reduction at the Surface of Fresh Produce
44. Small-Granule Starches

Project Summaries

1 Industrial Processing Properties of Tomato Products

P.I.: O. Campanella, B. Reuhs

Researcher: Xing Fei, Ph.D. student

Collaborators: O. Jones, A. Handa (Department of Horticulture, Purdue University), C. H. Syozi, H. Liu, D. Zhu

Objectives: The central hypothesis of this study is that the rheological properties of cell wall suspension systems are determined by the overall particle interactions, which are influence by the combined effect of the particle concentration and the particle physical properties. These effects must be identified individually and tailored by processing simultaneously. In order to test this hypothesis, four specific objectives are pursued in this research:

1. Determine the effects of soluble pectin on the viscosity of serum and suspensions.
2. Determine the effects of particle properties.
3. Determine the effects of processing conditions on the rheological properties of tomato suspensions.
4. Determine the rheological behavior of industrially processed tomato suspensions under different conditions.

Progress: Understanding the relationship between structure and functional properties in plant-cell-wall-derived foods has become a growing interest to both academia and industry. Tomato is one of the most cultivated vegetable crops and mostly is consumed as processed products in the form of suspensions. Rheological properties of tomato products, a key functional attribute, depend on both the serum and the particle phases of these products. Although recent studies have suggested that the particle phase is the dominant factor, the relationship between fundamental particle properties and the bulk rheology of the suspension is still unclear. This research systematically evaluates the contributions of soluble pectin and particle phase on the rheology of tomato suspensions, and has identified that the particle structure and its physical properties are crucial in determining the rheology of such systems. Alteration of these properties either by processing conditions or by internal enzymatic activity could cause a significant change in the rheology of tomato products.

The contribution of soluble pectin to the overall viscosity of the suspensions was found to have a little influence despite that reconstituted suspensions were prepared either with large pectin concentrations or with pectin having a high degree of methylation. However, the presence of pectin was important, because of its role in stabilization of the suspension systems by increasing the interaction between particles. When pectin concentration was low, wall slippage during measurements was observed due to phase separation by using cone-plate geometry. A vane geometry was able to alleviate the slippage artifact and a good correlation (R^2=0.91) was found between the empirical Bostwick consistometer method and fundamental measurements performed employing the vane geometry.

The particle structure and its physical properties as well as particle interaction control the rheological properties of the tomato cell-wall-derived suspensions. Changes in the particle phase were achieved in this study by two means: external processing with various conditions and molecular biological modification by reduced pectin methylesterase (PME) activity. The effects of thermal breaking and physical treatments such as ultrasound and high shear were employed at the laboratory scale. The effect of the concentration process to produce tomato paste from tomato juice at an industrial scale was also investigated. The focus was on effects that this process has on the properties of the particles and the rheology of the suspensions when they are reconstituted from the paste to juices. These diverse processing and modification conditions produced particles with various structures and strengths, and as a result caused significant changes in the rheological properties of suspensions.

Although both the ultrasound and high shear treatments reduced significantly the particle size of the treated tomato suspensions, the former led to an increase in their rheological properties whereas the latter caused a significant decrease. It could be explained by formation of particles with structural differences provoked by these two different treatments. Ultrasound treated suspensions contained more intact particles, and with large strength, which was evaluated by a compression test on a limited number of particles. Conversely, high shear treated suspensions resulted in mostly ruptured particles that lost mechanical strength. The water-soluble pectin (WSP) fraction increased after ultrasound and shear treatments. However, soluble pectin is not the direct cause for the changes in the suspension rheology; it is an indicator or consequence of the changes in particle properties.

Status: Ph.D. work finished, one manuscript accepted (2018) and four manuscripts almost ready to be submitted.

2 Shear-Thickening Behavior and Rheopecty of Gelatinized Waxy Starch Dispersions

P.I.s: O. Campanella, B. Hamaker

Researcher: Fang Fang, Ph.D. Candidate

Collaborators: J. BeMiller, B. Reuhs

Objectives: The overarching objective of this study was to develop a simple, but effective method to improve the desired ordering structure in amylopectin dispersions and to enhance the understanding of biomacromolecular interactions in the presence of shear flow fields. To validate the research hypothesis of this project, the following objectives were:

(1) to study rheological properties of gelatinized waxy corn, potato and rice starch dispersions, which have structural and molecular differences such as chain length distribution and branch density.

(2) to induce ordering structures to amylopectin dispersions by applying shearing actions, and to study the relationships between shear-induced structures of amylopectin dispersions and amylopectin molecular structure characteristics (e.g., degree of branch and chain length distribution).

(3) to study the effects of hydrocolloids with different molecular features (e.g., charged or neutral, branched or linear, rigid or flexible) on shear-induced patterns of amylopectin/hydrocolloid dispersions.

Progress: Amylopectin is naturally a highly branched biomacromolecule. Amylopectin molecules with re-ordered structure have high viscosity and viscoelastic properties, which may provide potentially good nutritional functions such as providing long-lasting energy to the human body and delaying stomach emptying, among other properties. However, the amylopectin molecular re-ordering process under static conditions normally takes much longer time than amylose to achieve a desired and relatively stable structure. A simple but novel approach consisting in applying a constant shear rate of 20 s^{-1} at a temperature of 5°C for 24 hours was proposed in this study to accelerate the re-ordering process of gelatinized waxy amylopectin dispersions. Two different shear-induced mechanisms were studied: the first, which included shear-induced aggregation of selected waxy amylopectin dispersions occurring within a short period of time and the second that was due to shear-induced molecular re-association after a 24-hour period of shearing with a constant shear rate of 20 s^{-1} at a temperature of 5°C.

Waxy potato and waxy corn amylopectin dispersions displayed shear-thickening behavior in a moderate shear rate range (approximately 15 to 25 s^{-1}), a phenomenon that was not observed in waxy rice amylopectin dispersion. The rheology of the former dispersions was shear rate-, time- and temperature-dependent. At low temperatures, the shear-thickening behavior of potato amylopectin was more noticeable than that observed in the waxy corn amylopectin dispersion. After shearing with a shear rate of 20 s^{-1} for 10 min, no aggregation was formed in waxy rice amylopectin, whereas small aggregates and large aggregates were observed in waxy corn and waxy potato amylopectin dispersions, respectively, indicating that shear-induced aggregation may be the reason for the shear-thickening behavior of these dispersions.

The presence of neutral and anionic hydrocolloids significantly influenced the shear-thickening behavior and viscoelasticity of waxy potato amylopectin dispersions. Hydrocolloids with flexible chains were hypothesized to associate with long-chain branches of amylopectin, which was promoted by shear forces. The electrostatic interactions between flexible chains of anionic hydrocolloids (e.g., pectin and sodium alginate) and chain segments of potato amylopectin binding phosphate groups were likely to increase the molecular movement of chains and decrease the viscosity and elasticity of these waxy amylopectin dispersions. However, the enhanced mobility favored the formation of shear-induced aggregation upon the application of shear forces. This research is providing a simple but innovative approach to accelerate the re-association of highly branched macromolecules in general, and in particular amylopectin with desired functionalities.

Status: Active, two manuscripts under preparation

3 Modeling Inactivation Parameters of Spore Cells Subjected to Cold Plasma and Other Non-thermal Processes

P.I.: O. Campanella

Researcher: Gabriella Mendes Candido de Oliveira, Ph.D. student

Collaborators: A. Deering (Food Science), A. Garner (Nuclear Engineering)

Objectives: The long-term goal of the research is to study non-thermal and thermal sterilization technologies able to inactivate microorganisms while retaining or minimally modifying nutritional attributes of fruit juices. Previous work has focused on the use of plasma technology to inactivate spores in model liquids. A model was developed taking into account the variable concentration of the sterilizing gas species, and the model was validated with experimental results on spore inactivation. Pulsed electric field (PEF) is another emerging non-thermal technology with good potential to substitute thermal sterilization, and it is being investigated in this phase of the project. The objective of this particular application is to investigate the effect of process parameters, such as electric field strength, treatment time, pulse frequency, pulse width and pulse polarity, on vitamin C retention, carotenoid and anthocyanin contents of açaí and acerola juices. In addition to that, to evaluate the effect of those different process parameter conditions on inactivation of microorganisms of public health concern such as *Escherichia coli* O157:H7 and *Salmonella* Typhimurium.

Microwave also offers a potential alternative to pasteurizing fruit juices with minimum deterioration of physicochemical and sensory qualities. The following objectives in this area were:

(1) to investigate the effect of microwave pasteurization on the inactivation of target microorganisms in apple juice. More specifically, *Escherichia coli* O157:H7 and *Salmonella* Typhimurium were the target microorganisms under investigation, because they are well-known foodborne pathogens and frequently causes food poisoning outbreaks;

(2) to describe the inactivation kinetics of these microorganisms using microwave heating to pasteurize apple juice achieving temperatures of 80° to 90°C for 30s as these process conditions are similar to the reported heating protocols for conventional pasteurization methods for apple juice;

(3) to develop a reliable mathematical model that enables one to describe the kinetics of inactivation of these microbial cells in realistic microwave pasteurization conditions in real apple juice;

(4) to compare the ability of the proposed modeling approach to predict the resistance of the reference microorganisms to achieve 5 $\log_{10}$ reduction in both commercial and fresh apple juices.

Progress: Microbiological training has been completed as well as the training on how to use the 300 nanoseconds pulser. The training on how to operate the continuous PEF system is currently being done at the U.S. Department of Agriculture, Philadelphia, with the advice of Dr. Tony Jin. Training on determination of anthocyanin contents will be done in collaboration with Dr. Ferruzzi at North Carolina State University.

Application of microwave, an appealing alternative technology to conventional pasteurization is being considered. Microwave heating differs from conventional heating due to its capacity to dissipate energy inside the product through the interaction of microwave radiation with water molecules. This interaction heats the food rapidly due to the internal heat generation that takes place in parallel with convection and conduction phenomena. Conventional processing relies on heat transferred from external heat sources, which often requires a long heating time resulting in deleterious effects of food qualities and nutritional attributes. Work on microwave heating of fruit juices and the resulting microbial inactivation was conducted during the period November through December 2017.

Status: Active, two articles in preparation.

4 Modeling of Gastrointestinal Bacterial Growth Influenced by

P.I.s: O. Campanella, B. Hamaker

Researcher: Han Tao, visiting student

Collaborators: J. Patterson (Animal Science, Purdue), Doraiswami Ramkrishna (Chemical Engineering, Purdue), E. Martens (University of Michigan Medical School), and Xia Dongming and Xin Xu (undergraduate students, Purdue)

Objectives: 1) To understand the effects of viscosity on gastrointestinal bacterial behavior, 2) To develop mathematical models to describe growth curves and predict inhibition and/or inactivation of microbial growth under a variety of substrates.

Progress: The effect of viscosity on the growth of *Bacteroides ovatus* and *B. cellulosilyticus* in vitro by using media containing polyethylene glycol (PEG) of different viscosities was determined. Results clearly showed the effect of the substrate on the growth of the bacteria. Substrates containing inulin (long chain) and FOS (short chain) were also used to investigate the effect of the substrate chain length in the growth of these strains. In high-viscosity systems, the growth rate of *B. ovatus* and *B. cell* was significantly reduced and lag time showed a significant increase. It was also observed that the effect of viscosity was more pronounced in systems having inulin (long chain) than in those having FOS (short chain).Thus, the effect of viscosity depends on the chain length of dietary fibers. A mathematical model was developed to validate the experimentally observed effects and whether the effect of the fiber structure is associated with the mobility of microbial cells, substrates and metabolites in viscous media. Good agreement between modeling and experimental results were obtained by studying the effect of mass transfer, enhanced by shaking the sample, on the bacteria growth. These results appear to prove the main hypothesis of this work about the effect of viscosity on the mass transfer of cells and nutrients to control cell growth.

Status: Active, two manuscripts in preparation.

5 Using Molecular Dynamic (MD) Simulation to Understand the Stability of Amylose-Free Fatty Acid Complex

P.I.s: O. Campanella, B. Hamaker

Researcher: Lilin Cheng, visiting student

Collaborator: X. Zhu (Purdue ITaP Research Computing)

Objectives: Amylose is a linear polymer formed by α-1,4 linkages and one of the major components of starch. It is often used to encapsulate hydrophobic molecules, such as fatty acids (FA), flavonoids or polyphenols. Amylose and linoleic acid form a complex when the amylose molecule is folded in a V-type conformation. However, it is still not clear how amylose and linoleic acid interact with each other and what conformation the complex adopts under different conditions. This research is intended to provide a better insight of complexation mechanisms between amylose and amphiphile compounds such as fatty acids by answering questions such as: (1) How does a lipid acid stabilize the configuration of amylose? (2) What is the thermodynamically favorable configuration of the amylose-free fatty acid complex? (3) Which kind of noncovalent forces could contribute more to complex stability? (4) How do hydrogen bonds change during complexation? To address these questions, MD simulations of amylose in the presence and absence of α-linoleic acid were performed, starting from a stable state crystal structure of amylose existing in a single helix conformation.

Progress: MD simulation is used to illustrate conformational changes of the amylose-FA complex and the single amylose molecule, which is used as a reference, in water. It reveals that the united force field, a revised version of GROMOS 56A6$_{CARBO_R}$ force field described by Plazinski, Lonardi, & Hünenberger (2016), which treats aliphatic carbons as united atoms, provides a better agreement with experimental evidence. During simulations, the conformation of the complex remained stable and the linoleic acid and the amylose molecules formed a helical structure. Furthermore, linoleic acid was located in the cavity of the amylose helix with the hydrophobic tail inside it. Results also showed that $^4C_1$ was the predominant conformation of amylose during the interaction with linoleic acid. Once the linoleic acid was able to form the complex with amylose, the incorporation of surrounding water in the intermolecular bonds between atoms O_6 and O_2/O_3 was seriously limited and allowed the complex to keep its helix conformation.

The stability of amylose-linoleic acid complex is demonstrated by comparing it with that of the single amylose molecule used as a baseline reference. According to the results obtained on radius of gyration, root mean square fluctuation and atom distance, there is a clear indication that the central residues of the amylose molecule are complexing with linoleic acid, and able to form a helical structure, whereas the two heads of the single amylose molecule stretch out and extend. The improved stability of the amylose-linoleic acid complex as compared with the single amylose molecule is due to inter-molecular hydrogen bonds between O_6 and O_2/O_3. It is also found that Chair $^4C_1$

is the predominant conformation of amylose when forming a complex with a fatty acid such as linoleic acid.

Status: Active, one manuscript has been accepted for publication

6 Impact of Phytochemicals on Starch Digestion and Intestinal Glucose Transport

P.I.s: M. Ferruzzi, B. Hamaker

Researchers: Min Li, Post-doc

Objectives: (1) To adapt a model in vitro digestion/Caco-2 system to estimate impacts of phenolics on starch and glucose transport, and (2) to define the chemical nature of interactions between phenolic constituents and starch in model food systems and their impacts on product quality and digestibility.

Progress: Coupled in vitro digestion/Caco-2 intestinal cell culture models have been adapted using a combination of brush boarder enzymes and labeled glucose (d7-glucose) to model both glucogenesis and transport through digestion. In the past year, we further advanced the application of this model to whole food systems and mixed meals to explore interactions within phenolic and starch rich foods (oats and potatoes). These results are being correlated to current clinical trials.

We have also expanded our fundamental understanding of the interactions between polyphenolics, phenolic acids with protein and starch by characterizing the chemical and physical nature of these interactions as well as their impacts to both product physical quality as well as bioaccessibility of phenolics and digestibility of starch/protein.

Status: Active.

7 Dietary Fibers and In Vitro Fermentation: SCFA Production and Microbiota Changes

P.I.s: B. Hamaker, B. Reuhs

Researchers: Xiaowei Zhang, Ph.D. student; Enosh Kazam, M.S. student; Emmanuel Ayua, Ph.D. student; Yunus Tuncil, Post-doc

Collaborators: A. Keshavarzian and A. Landy (Rush Medical School, Chicago); L. Zhao (Rutgers University/ Shanghai Jiao Tong University); S. Lindemann (Purdue University)

Objectives: Fermentable dietary fibers have the potential to produce positive short chain fatty acid (SCFA) changes in the colon, such as elevated levels of butyrate or propionate, and desired changes in microbiota composition by favoring certain bacteria or bacterial groups. Our interest is in finding functional and, where possible, targeted fermentable fibers, whether soluble or insoluble, to improve gut health and to understand their fermentative properties and effects.

Progress: The link between the gut microbiota and localized gut and whole-body health is now established. At a basic level, a healthy microbiota is one that ferments fibers well to produce substantial levels of short chain fatty acids (acetate, propionate, butyrate) and low endotoxin for reduction of gut inflammation and maintenance of good barrier function. High inflammation and poor gut barrier function are directly related to non-communicable chronic diseases such as those associated with obesity and metabolic syndrome diseases. Dietary fibers that ferment in the gut and make favorable changes to the microbiota are encompassed in the concept of prebiotics. Although early work focused more on certain oligosaccharides and their promotion of bifidobacteria and lactobacilli, prebiotics now cover a broader range of fermentable fibers that promote beneficial gut bacteria. The challenge confronting scientists, and that we study in our laboratory, is to understand how to use prebiotic fibers (oligo- and polysaccharides) to generate predictable changes in the gut microbiota for improved health.

X. Zhang studied different aspects of feruloylated arabinoxylan and arabinoxylan structure on fermentation of the gut microbiota. Corn bran arabinoxylan (CAX) is a dietary fiber with a complex chemical structure with potential for specific modulation of the human gut microbiota composition. The hypothesis of this study is that ferulic acid bound (esterfied) to arabinose residues in CAX inhibits its fermentation by the microbiota. Sodium hydroxide was used to extract CAX by removing diferulate crosslinks while leaving 2 mg/g bound ferulic acid. Then, feruloyl esterase treatment was conducted to deplete the ferulic acid in CAX to produce ferulic acid-depleted-CAX

(FAD-CAX). Following the in vitro fecal fermentation, FAD-CAX had substantially higher acetate (58.1 ± 3.6 mM), propionate (34.5 ± 2.0 mM) and butyrate (6.3 ± 0.5 mM) production than CAX, which was 41.9 ± 1.9 mM, 22.2 ± 1.0 mM and 4.3 ± 0.2 mM at 24h, respectively. Both CAX and FAD-CAX significantly promoted a *Bacteroides* OTU, a *Fusobacteriaceae* OTU, a *Blautia* OUT and a *Phascolartobacterium* OTU. FAD-CAX enriched substantially more *Bacteroides* OTU than CAX. The results indicated that the presence of ferulic acid inhibits the utilization of CAX by gut microbiota. Additionally, Xiaowei researched genotype x environment (3 x 3) variability in corn arabinoxylan structure related to specificity of polymer structures to bacteria. Interestingly, both genotype and environment produced arabinoxylan structural differences that caused variable shifts in the bacterial community and changes in SCFA profiles.

T. Chen who completed her Ph.D. in 2016 and is now a post-doc with our collaborator Prof. L. Zhao, continued to work on her data set of stool samples from 36 individuals from Rush Medical School and collaborator Prof. A. Keshavarzian. A standard panel of dietary fibers was developed including insoluble fermentable fibers and soluble fibers, both single fibers and mixtures of fibers, and used to understand fiber responses by a range of healthy and diseased (Parkinson's and inflammatory bowel disease) patients. Clear trends were found showing functional outcomes in both SCFAs and microbiota compositions and shifts are grouped and not random among individuals. Up to three manuscripts will be submitted for publication.

Status: Active, four publications and a number of manuscripts in review and preparation.

8 Investigations on Slowly Digestible Glycemic Carbohydrates

P.I.s: B. Hamaker, M. Ferruzzi

Researchers: Jongbin Lim, Ph.D. student; Leigh Schmidt, Ph.D. student; Anna Hayes, Ph.D. student

Collaborators: B. H. Lee (Gachon University, South Korea); A.H.M Lin (University of Idaho); M. Ferruzzi; S. H. Yoo (Sejong University, South Korea); G. Zhang (Jiangnan University); B. Nichols (Baylor College of Medicine, Houston); R. Quezada-Calvillo (University of San Luis Potosi, Mexico); D. Rose (University of Waterloo, Canada)

Objective: To design slowly digestible glycemic carbohydrates with a degree of small intestine ileal digestion for the purpose of testing and targeting physiologic response (i.e., ileal brake and gut-brain axis); and related to ways to manipulate starch digestion rate, to better understand natural inhibitors and their effect on starch digestive enzymes.

Progress: Our current interest in glycemic carbohydrate research is to understand how to achieve slowly digestible carbohydrates that have both moderated glycemic response and the potential to effect physiological changes through ileal or colonic triggers to influence appetitive response and sustained energy effect (see Hasek et al, *Molecular Nutrition and Food Research*; Cisse et al., *Nutrition Research*). We have continued to study ways to prolong glycemic response and to reduce the glycemic spike with emphasis on longer digestion times that may combine slowly digestible carbohydrate with fermentable resistant starch or hydrolyzates.

A. Hayes studied causative factors of millet couscous to address our previous finding of its very slow gastric emptying rate in humans (Cisse et al., *Nutrients*). Millet foods in Africa are anecdotally associated with a feeling of fullness and sustained energy, and a previous study (yet unpublished) of ours showed rural Malians recognized that thick porridges are more satiating than thin, that they prepare thicker ones for that purpose, and that urban consumers prepare thinner and less satiating porridges. With the group of Prof. Gail Bornhorst at University of California, Davis, and their Human Gastric Simulator, we studied how millet couscous is processed in the stomach under conditions of the gastric juices and environment. Unexpectedly, millet couscous particles broke down faster and to smaller particles than did wheat couscous, both tested at two different cooked particle sizes. Additionally, the millet particles after gastric simulation digested at a slower rate than the wheat ones. It seems one or both of two factors could potentially be causing the slow gastric emptying observed in humans: 1) rapid breakdown of millet couscous to very small particles created a paste-like substance that in the stomach could conceivably result in partitioning to a thick paste in the pyloric (lower) stomach region that acts like a thick paste, thus slowing emptying rate, and 2) slow digestion in the small intestine of the small particles may activate the ileal brake system.

M. Martinez worked on an industrial project of which a main portion was presented at the American Association of Cereal Chemists International meeting in San Diego in October, and parts will be submitted for publication in 2018. Amylopectin structure and retrogradation, as well as amylopectin–amylopectin and amylose–amylopectin interactions, were studied related to starch gel rigidity during long-term storage. Amylopectin with longer chains has been reported to interact extensively (either in presence or absence of amylose) resulting in stronger gels. However, the actual mechanism for intermolecular aggregation of starch molecules is not clear. In this work, a gel system made with different starches, including maize, waxy maize, potato, waxy potato and banana, with marked differences in their architecture, served as a model to study the kinetics for amylopectin double helix formation (DSC) and starch intermolecular interactions (SAOS) during storage. The molecular weight of amylose and amylopectin (HPLC-SEC), and the unit and internal chain length distribution of amylopectin was analyzed by HPSEC and HPAEC. Moreover, the presence of retrograded amylose and amylose-lipid complexes (DSC), absolute amount of double helical starch structures (^{13}C-NMR) and crystallinity (XRD) were also measured. Amylopectin double helix formation followed exponential kinetics, except for banana starch, that presented a faster retrogradation rate during the first 24 hours of storage. Results showed that the rate of amylopectin double helix formation was negatively correlated (r=0.85) with the size of amylopectin molecules, presumably because of their higher mobility, whereas the extension for double helix formation was merely associated with the amylopectin ratio. Hence, we propose that only a minor amount of intermolecular interactions, acting as "zippers," are necessary for modifying the retrogradation behavior of starch samples. Starches with favorable molecular structure to form "zippers," namely small amylopectin molecules with long internal and external chains, resulted in higher three-dimensional network structures and stronger gels.

J. Lim studied and reported on phenolic compound structural features that relate to inhibition of the glycemic carbohydrate digestive enzymes. In this study, four different starches (corn, waxy rice, wheat, and highly branched maltodextrin) were hydrolyzed by porcine pancreatic α-amylase to determine the digestion property of branched α-limit dextrins through investigation of the inhibition potency of galloyl groups in phenolic compounds against α-glucosidases for the extension of glucose release in the small intestine. The linear and branched portions in α-limit dextrins from five different starches were determined by high-performance, size-exclusion chromatography. The starches showed different amounts of the branched portions in α-amylolyzed starches (corn: 12.7%, waxy rice: 15.6%, wheat: 16.6%, and highly branched maltodextrin: 40.6%). Furthermore, there was an inverse relationship between the amount of branched portion and the hydrolysis rate of the α-limit dextrin by α-glucosidases from rat intestinal acetone powder. The galloyl groups in phenolic compounds further slowed glucose release from the α-limit dextrins by inhibiting α-glucosidases activity. The inhibition properties of the tested phenolic compounds were dependent on the number of galloyl groups. Tannic acid with ten galloyl groups has higher inhibition property for the α-glucosidases compared to gallic acid and ellagic acid which are the monomer and dimer of the galloyl groups, respectively. This study provided insight into the potential of modulating glucose generation through the combination of highly branched α-glucans and galloyl groups in phenolic compounds to produce food matrices for improved glycemic response profiles with potential health benefit.

L. Schmidt studies interaction between cereal proteins and starch related to decrease in starch digestion rate. The poor digestibility of sorghum porridges is mainly attributed to kafirins in starch granule-associated protein bodies. We showed previously that, during cooking, kafirins form stable web-like disulfide-linked matrices, which dynamically adjust around swelling granules. These matrices may impede starch digestion, contributing to sorghum's slow glycemic carbohydrate characteristic, while other cereals show matrix collapse upon cooking. Cereal endosperms contain redox active phenolic compounds, which engage in disulfide bond formation and protein cross-linking. Sorghums, unique among cereals, contain 3-deoxyanthocyanidins (3-DAn), theorized to be responsible for the difference in matrix stability. Defined protein matrices may be utilizable as nutrient or drug-delivery methods. A model protein system was used to examine the ability of endosperm phenolic extracts to polymerize proteins. Chicken egg white ovalbumin (OVA, 44kDa) was chosen as it demonstrates extensive oxidation-driven polymerization when heat-denatured in the presence of an oxidant (1% $KBrO3$) in a near-neutral (pH 6.8) environment, similar to cereal porridge preparation in non-alkaline tap water. Sorghum extract polymerization products exhibited a wide range of molecular weights

(MW) in the model system, compared to masa and rice extracts which tended toward high MW aggregates. Apigeninidin (APG), a sorghum 3-DAn, was also assessed individually for its ability to polymerize OVA during cooking and generate a wide MW range of products, indicative of shifting disulfide bonds. APG (172, 138, 34.4 and 6.88 µM) and OVA (50 µM) in 50 mM phosphate buffer (pH 6.8) were mixed 1:10, heated, and separated by SDS-PAGE to observe polymerization and MW range. The utilized ratios of APG:OVA (0.09-2 µg per mg) include the range in decorticated normal white sorghum flour (~0.1-0.3 µg 3-DAn/mg protein). Heating OVA with APG produced a greater concentration of monomers compared to negative control (water) and a wider MW range compared to positive control (1% $KBrO_3$), which formed high MW aggregates. As APG to OVA ratio increased, more high MW compounds resulted. The lower ratios developed higher concentrations of a greater range of MW products. Clarifying the role of 3-DAn in protein matrix formation may allow development of similar systems in food and cereal products to slow starch digestion and improve glycemic response, and allow construction of delivery agents for slowly digestible starch.

Status: Active, five publications and a number of manuscripts in preparation.

9 Cellular and Physiological Response Studies of Glycemic Carbohydrates with Slow Digestion Profiles

P.I.: B. Hamaker

Researchers: Mohammad Chegeni, Post-doc; Marwa El-Hindaway, Ph.D. student; Beth Pletsch, Ph.D. student

Collaborators: H. Naim (University of Veterinary Medicine Hannover, Germany); B. Nichols (Baylor College of Medicine, Houston

Objectives: To understand the cellular and physiological responses to slowly digestible carbohydrates that might have value in the area of controlled glycemic response, satiety and the concept of sustained or extended energy release.

Progress: Our interest in this area is based on two findings from our group: 1) slowly digestible carbohydrates (SDCs) that locationally digest in the small intestine ileum activated the gut-brain axis to reduce food intake in obese animals (see Hasek et al., *Molecular Nutrition & Food Research* doi:10.1002/mnfr.201700117), and 2) that starch digestion products of α-amylase are sensed by intestinal cells (Caco-2) to mobilize and activate the α-glucosidases (sucrase-isomaltase) to the apical membrane for their efficient digestion (Chegeni et al., *The FASEB Journal* doi.org/10.1096/fj.201701029R). The first has led us to a currently ongoing study to investigate how the fabricated ileal-digesting starch-entrapped microspheres used in that study may reduce weight gain in normal mice on a high-fat diet and, in diet-induced obese mice, cause faster weight reduction than a rapidly digestible carbohydrate-based diet. The second has led to studies on enteroendocrine L-cells in culture showing that maltooligosaccharides similar to α-amylase degradation products of starch stimulate secretion of glucagon-like protein-1 (GLP-1) and in higher amounts than the well-studied similar effect of short-chain fatty acids (separately tested acetate, propionate, butyrate) produced by fiber fermentation by the gut microbiota. The bigger goal of this research is to design SDCs that could be used in processed foods to activate the gut-brain axis for appetite control and weight management.

Marwa El-Hindaway, in addition to the work described above on enteroendocrine L-cells and their stimulation of GLP-1 secretion by maltooligosaccharides, conducted a study in 2017 on L-cell location in mice and showed with immunostaining that they are mainly found in the distal small intestine and proximal colon. Though this is generally thought to be known, the literature is not clear on this point. This verifies that these cells are located in the region where we are trying to make SDCs digest at least in a small part. Marwa is currently conducting the two animal studies on use of SDCs in weight management as noted above.

Beth Pletsch completed a human study on the question of whether whole-grain preparations, when matched for different variables, are different than refined ones for postprandial glycemic response, gastric emptying rate, and subjective satiety scoring. Porridges were made from whole and refined grain wheat taken from the same source and milling stream, and prepared to have matches in particle sizes, viscosities, and starch content. To test the extent to which whole grains may lower glycemic response, a range of particle sizes of wheat were used (180 – 1700 μm). Blood glucose levels were measured in healthy participants (n=16) using the continuous glucose monitor and gastric emptying rate was measured using a ^{13}C-octanoic acid breath test method. When viscosities and carbohydrate content of the meals were matched, no differences were observed in glycemic response between whole and refined grain porridge meals made from the same milled particle size, and, contrary to expectation, the highest glycemic response observed was for the whole wheat flour porridge ($p < 0.05$). The lowest glycemic response was found for the semolina (refined) porridge, and second lowest for the cracked wheat (whole grain) porridge.

Three other papers were published in 2017 or were online on this topic, both by Fatimata Cisse, who received her Ph.D. in 2014 and is now in her home country Mali. They are Cisse et al., *Nutrients* (doi:10.3390/nu10020124), a human study conducted in Bamako, Mali, showing that sorghum and millet Malian traditional foods (thick porridges and couscous) have twice the gastric emptying time of introduced starchy staples (rice, potato, wheat pasta); Cisse et al., *Nutrition Research*, a human study done at Purdue showing that a 20 minute preload of the SDC starch-entrapped microspheres slowed gastric emptying of a subsequent non-nutritive thick paste made with sodium alginate and agar; and Pletsch et al., *European Journal of Clinical Nutrition* (doi:10.1038/s41430-017-0003-z), a human study conducted at Purdue showing that brown rice has slower gastric emptying than white rice.

Status: Active, four publications, and a number of manuscripts in preparation.

10 Starch-Based Nanoparticles for Gastrointestinal Cancer Drug Delivery

P.I.s: B. Hamaker, O. Jones, O. Campanella and G. Schmidt

Collaborators: R. Pinal (Pharmacy) and T. Lyle (Veterinary School)

Objective: To use benign and water-soluble nanoparticles from amylose, protein and lipid for carriers to protect and deliver hydrophobic drugs. To test the potential for cancer drug delivery to gastrointestinal cancers via the oral route and to evaluate the interactions of nanoparticles with intestinal cells.

Progress: Final studies on the chemotherapeutic 5-fluorouracil-containing nanoparticle are being conducted using a cell viability Caco-2 cell culture test.

Status: One proposal funded.

11 Protein Fibers within Polysaccharide Composite Films

P.I.: O. Jones

Co-P.I.: O.H. Campanella

Collaborators: N.P. Reynolds (Swinburne Inst. Techn, Australia)

Researcher: Jay Gilbert, Ph.D. student

Objective: Identify structural and mechanical attributes of protein fibrils alone or within composite polysaccharide-based films that contribute to improved macro-scale behaviors. As a secondary objective, this project sought to establish a fundamental framework detailing the contributions of both mechanical properties and architecture among fibrous structures to the ultimate macro-scale behavior of composite materials.

Progress: Research was completed, finding that fibrils showed a tendency for clustering within composite films with little contribution to the mechanical behaviors of composite cellulosic films. Multifrequency atomic force microscopy methods were used to show the retention of viscoelastic properties of fibrils within composite films (as well as other proteins structures). Collaborative work with Dr. Reynolds found that the deposited fibrils were good substrates for promoting differentiation of mesenchymal stem cells, particularly for differentiation into adipocytes with potential utility in certain tissue graft applications.

Status: Completed, two articles published in 2017.

12 Stabilization of Oil-in-Water Emulsions by Whey Protein Microgels

P.I.: O.G. Jones

Co-P.I.: G. Narsimhan

Researchers: Lijie Zhu, Ryan Murphy, Ph.D. student (2013-2017; Laura Zimmerer, M.S. student (2011-2013)

Objective Determine the interfacial activity and physical stability of oil-in-water aqueous emulsions using (a) microgels of whey protein with or without pectin; determine influence of particle size, particle swelling ratio, and environmental conditions on interfacial properties.

Progress: Cross-linking treatments and disruption of disulfide linkages within the microgels was investigated as a means to change the deformability of microgels when exposed to interfacial forces. A publication was released showing that transglutaminase and glutaraldehyde-treatments (cross-linking) were most effective at altering the deformability of the microgels. Ongoing work is investigating how the relative size and deformability of the microgels impacts flocculation and Ostwald-ripening (dispersed molecule entrapment) of emulsion droplets stabilized by the microgels.

Status: Active, one article published in 2017.

13 Protein Fibrous Structures as Physical Simulacrums of High-MW Glutenin

P.I.: O.G. Jones

Co-P.I.: O.H. Campanella

Researcher: Enrico Federici, Ph.D. student

Objective: Determine the influence of physical and chemical attributes of fibrous protein assemblies on the mechanical behaviors of water/starch-based mixtures.

Progress: Aqueous suspensions of prolamins mixed with globulins were tested for their capacity to be spun into fibrous assemblies. Physical properties of spun fibers were analyzed by atomic force microscopy and force spectroscopy. Parallel experiments on the impact of spun fibers on starch-rich doughs were performed under the supervision of Campanella.

Status: Active, one manuscript in preparation.

14 Physical Stability of Suspensions Containing Colloidal and Fully Dispersed Polysaccharides and Proteins

P.I.: O.G. Jones

Co-P.I.'s: M. Ferruzzi

Researcher: Chris Cheng, Ph.D. student

Objective: Determine the impacts of structure and interactive components on zein particle stability and contribution to films.

Progress: Zein nanoparticles were shown to improve the mechanical behavior of cellulosic films, yet incompatibility with the cellulose at higher concentrations induced clustering and reduced mechanical performance. Digestion studies indicated that the background media can have an impact on the digestion of zein nanoparticles in the gastric phase of digestion and that digested zein components could alter the bioaccessibility of a bioactive isoprenoid.

Status: Active, one article published in 2017.

15 Emulsification Properties of Polysaccharide and Protein Fractions of Crickets

P.I.: O.G. Jones

Researcher: Drew Hirsch, M.S. student

Objective: Determine the surface activity and emulsifying capability of protein and chitin fractions from ground crickets.

Progress: Protein and chitin fractions were isolated from ground cricket flour. Surface activity of both isolated fractions were determined for oil-water interfaces, and the stability of emulsions prepared with either or both fractions has been studied.

Status: Active.

16 Interactivity between Starch and Dairy Proteins

P.I.: O.G. Jones

Co-P.I.: O.H. Campanella

Researchers: Angarika Rayate, M.S. student; Dandan Li, visiting scholar

Objective: Determine whether certain conditions will facilitate associative physical interactions between starch and dairy proteins or whether incompatibility is dominant.

Progress: Caseinate dispersions were found to possess no significant evidence of association with polyglucose chains, supporting the hypothesis that associative interactions with solubilized starch molecules are unlikely. A newly opened sub-project is identifying the role of milk proteins' physical adsorption to the surface of starch granules.

Status: Active.

17 Nanoparticulation of Bovine Serum Albumin and Poly-D-lysine through Complex Coacervation and Encapsulation of Curcumin

P.I.: J. Kokini

Researchers: Luis Maldonado, Ph.D. candidate; Rohollah Sadeghi, Post-doc.

Objective: Evaluate the ability of Bovine serum albumin (BSA) and Poly-D-lysine (PDL) to form soluble coacervates, and specifically evaluate the effects of MW of PDL, salt concentration, addition of cross-linking agent, and mass ratio of BSA to PDL on the particle size (PS), polydispersity index (PDI), zeta potential (ZP) and morphology of soluble colloidal coacervate nanoparticles.

Progress: Soluble coacervate nanoparticles were fabricated by mixing bovine serum albumin (BSA) and poly-D-lysine with low (LMW-PDL) and high molecular weights (HMW-PDL). The particle size was influenced by molecular weight, mass ratio of polyelectrolytes (PEs), and salt concentration. The smallest nanoparticles were achieved with LMW-PDL dissolved with 0.1 M NaCl at pH 7 and a mass ratio of 2.0 (BSA: PDL). SEM images showed that coacervate nanoparticles of LMW-PDL are relatively spherical in shape, while nanoparticles of HMW-PDL were irregular. The encapsulation efficiency (EE) for curcumin to BSA molar ratio of 0.5 was 47%. The average particle size of the loaded colloidal dispersions increased as the curcumin concentration was increased. The curcumin loaded BSA:LMW-PDL nanoparticles were stable over a period of 21 days.

Status: Finished, one article published.

18 An Optimal Window for the Fabrication of Edible Polyelectrolyte Complex Nanotubes (EPCNs) from Bovine Serum Albumin (BSA) and Sodium Alginate

P.I.: J. Kokini

Researchers: Luis Maldonado, Ph.D. candidate.

Objective: The aim of this work was to explore specific manufacturing conditions including rate of addition, effect of pH, template pore size, biopolymers ratio and biopolymers concentration on the fabrication of bionanotubes from sodium alginate and bovine serum albumin (BSA).

Progress: Edible polyelectrolyte complex nanotubes (EPCNs) were assembled with the alternate layer-by-layer (LbL) deposition technique using bovine serum albumin (BSA) as positively charged biopolymer and sodium alginate as negatively charged biopolymers. The specific manufacturing conditions that led to the formation of defined and stable nanotubular structures were studied. Dynamic light scattering (DLS) and isothermal titration calorimetry (ITC) were used to study the ability of a protein and polysaccharide to interact and form nanotubes. These methods also offer insights into the types of interactions occurring between these two biopolymers. The ability of a protein and polysaccharides to interact and form nanotubes were studied with the assistance of polycarbonate (PC) templates (pore diameters: 200, 400, 600 and 800 nm). The morphology, outer diameter, thickness of the wall and length of the freeze dried EPCNs were characterized with SEM.

Status: Finished, one article published.

19 Mechanistic Understanding of the Effect of Charge Ratio and Order of Addition on Thermodynamics of Interaction of PECs from Sodium Alginate and Chitosan

P.I.: J. Kokini

Researchers: Tuncay Yilmaz, Visiting Scholar; Luis Maldonado, Ph.D. candidate.

Objective: This study focused on understanding the effect of charge ratio, order of addition and resulting thermodynamics of interaction on the formation and properties of polyelectrolyte complexes (PECs) from sodium alginate and chitosan.

Progress: ITC results showed that stoichiometry and enthalpy of reactions were strongly affected by the order of addition and influenced the average particle size and zeta potential of PECs. The addition of the negative polyelectrolyte (alginate) into the positive polyelectrolyte (chitosan) resulted in stronger interactions as characterized by the larger enthalpy and entropy of complexation, which led to smaller and more stable particles. Stability was found to depend on the order of addition and charge ratio. Morphologies of complexes studied using scanning electron microscopy (SEM) showed distorted spherical particles. Alginate in chitosan gave more stable PECs and chitosan in alginate less stable PECs. There were significant differences in average particle size near electrical neutrality during storage at 4˚C, but particles were stable when the net charge was either strongly positive or strongly negative.

Status: Finished, one manuscript submitted for publication.

20 Simultaneous Fluorescent Detection of Gliadins, LMW and HMW Glutenins in Wheat Dough Samples Using Antibodies-Quantum Dots Complexes as Imaging Tools

P.I.: J. Kokini

Researcher: Jose Bonilla, Ph.D. student

Objective: To study the distribution of gliadins, LMW and HMW glutenins during different wheat processes.

Progress: We have successfully developed antibodies for HMW and LMW weight glutenins, which we conjugate to fluorescent quantum dots for detection of the glutenins subunits in dough. QDs are conjugated to carbohydrates groups found in the tails of the antibodies by a site-click chemistry reaction. Dough samples are stained with the antibodies-QDs conjugates using a previously developed method. The samples are analyzed under an A1R-MP Nikon Confocal microscope. The collected fluorescent images display the in situ localization of the fractions among the starch matrix in dough for the first time in cereal science research. We are using this technique to study the distribution of gliadins, LMW, and HMW glutenins in durum semolina, soft, and hard wheat flours. The interactions they undergo are being investigated as a function of mixing time in a Brabender Farinograph. Visualizing and understanding the distribution of the gluten fractions during mixing will advance our understanding of the mechanism of dough development and will improve the state of knowledge in cereal science, which will eventually lead to an improvement in the quality and an extent in the variety of wheat products.

Status: Active, one manuscript submitted for publication.

21 Characterization of Zein Films for Enhancing Their Physical and Chemical Properties

P.I.: J. Kokini

Researchers: Hazal Turasan, Ph.D. student; Emma Barber, M.S. student

Objective: This project is aiming to modify the physical and chemical properties of zein to produce zein films with enhanced properties for biosensor applications.

Progress: Due to its unique properties, such as being more hydrophobic than other plant-based proteins film forming capability, zein, the most abundant corn protein, is an excellent candidate for the production of biodegradable platform for biosensors. In this project, by testing various formulations and chemical modification techniques, the mechanical and surface properties of zein films are being improved. To fine-tune the mechanical properties, various plasticizers in various solvents are tested. The effects of crosslinking on the mechanical properties of zein films are also investigated. The changes in the chemistry of the zein films are closely monitored using various spectroscopic methods. To analyze the improvements of the mechanical properties, zein films are tested for their tensile strength. The surface properties of the zein films are also tested to observe the effects of plasticization and crosslinking. After the optimization of all the properties, zein films are used in the fabrication of biosensors to measure common food toxins and allergens.

Status: Active, one manuscript accepted for publication.

22 Characterizing the Surface and Mechanical Properties of Zein Films

P.I.: J. Kokini

Researchers: Morgan Malm (Meiser), M.S. student

Objective: To manipulate and characterize the surface energy, wettability, and mechanical properties of zein films through different techniques.

Progress: We have investigated the properties of zein films including surface free energy, wettability, and mechanical properties as a result of varying plasticizer amounts, cross-linking agent amounts, and different processing treatments of the films. We have successfully increased the mechanical properties through cross-linking zein films with increases in tensile strength and Young's modulus. Surface free energy values have been successfully manipulated through solution casting onto different material surfaces. Processing of zein films have rendered highly hydrophobic zein films with contact angles increasing 100% to 160 degrees, allowing us to effectively manipulate the wettability of zein through different techniques.

Status: Active, one manuscript submitted for publication.

23 Zein- and Kafirin-Based Nanocomposites for Biodegradable Packaging

P.I.: J. Kokini

Researchers: Tahrima B. Rouf, Ph.D. student

Objective: The objective of this research is to functionalize and reinforce biodegradable zein and kafirin films by adding nanomaterials to improve its tensile strength, thermal stability and water vapor barrier properties.

Progress: A major storage prolamin protein of corn "zein" is an abundant byproduct of the ethanol industry. Zein has unique amphiphilic, antioxidant, antibacterial and adhesive film forming properties, and, therefore, is considered a highly suitable candidate for designing environmentally friendly polymers. Kafirin is the storage protein from sorghum which has been found extremely similar to zein. In this project, the fabrication of zein and kafirin-nanocomposites is optimized by using different engineered nano-fillers and different fabrication techniques to improve the mechanical, thermal and barrier properties of zein and kafirin nanocomposites. The morphology, chemical composition and property changes in the obtained nanocomposite films are characterized using an array of microscopic, spectroscopic and surface characterization techniques. The results indicate that significant improvement in tensile strength, melting temperature and water vapor permeability can be achieved by addition of the optimal concentration of nanofiller to zein and kafirin. In addition, the surface properties of the films can be modified as desired, leading to possible application in biodegradable smart packaging as well as biosensors.

Status: Active, one manuscript published.

24 Gold-Coated Zein Based Nanophotonic Biosensors for Toxin and Allergen Detection Using SERS

P.I.: J. Kokini

Researchers: Fei Jia, Ph.D. student

Objective: The objective of this research is to develop biodegradable sensors for sensitive and rapid detection of toxins and allergens in food.

In this project, a biodegradable zein Surface Enhanced Raman Spectroscopy (SERS) substrate, functionalized with gold nanoparticles (AuNPs) and in an inverted pyramid structure was developed, and worked as a lab-on-a-chip platform to enable the sensitive and rapid detection of toxins and allergens in food. The inverted pyramid structure in the middle of the chip, with a base of 2 μm by 2 μm with a periodicity of 2 μm (from center to center), and height of 2.1 μm, has been proved to be able to improve the raman single. The size, distribution and morphology of the zein substrate were characterized by scanning electron microscopy (SEM). The enhancement factor of the substrate can be further increased by the introduction of AuNPs, and a comparable experiment were conducted to evaluated the raman single enhancement of the AuNPs. Under the optimized experiment condition, the SERS substrate can be successfully used in to the pyocyanin and gliadin allergen detection. No complex pre-treatment of sample needed, the developed SERS detection method can complete the measurement within 30 minutes. Most importantly, the zein-based substrate shows great advantages in the biodegradability compared with the commercial available silicon substrate or glass substrate. The zein substrate of the chip can be easily re-dissolved in the ethanol solution within 1 hour and the gold material can be harvested. In the foreseeable future, the zein-based biodegradable biosensor can be used in other food-borne pathogens and chemicals detection.

Status: Active, one manuscript in preparation.

25 Establishment of Model Dietary Fiber-Consuming Gut Microbial Communities for Generalizable Fiber-Microbiota Research

PI: S. Lindemann

Researchers: Ming-Hsu Chen, Postdoc; Tianming Yao, Ph.D. student

Objectives: 1) To select for consortia that degrade specific dietary fibers of interest for use in fiber-microbiome studies, 2) Establishment of long-term cryopreservation methods for model communities, 3) Genome sequencing and reconstruction of model communities for use in systems biology analyses.

Progress: M.-H. Chen and T. Yao selected for communities of 1) inulin-degrading and 2) sorghum arabinoxylan (SAX)-degrading microbes using fecal microbiota as an initial species pool. Consortia stable in membership resulted after approximately 5–7 sequential transfers in batch culture. These consortia resulted in stable growth rates, pH, and gas production over sequential batch transfers. SAX-consuming consortia selected at two different time points from the same donor resulted in consortia very similar in composition, whereas selection of same-donor consortia on inulin at two different time points resulted in very different final communities. Amino acid and vitamin amendment of inulin-fermenting consortia resulted in significant alteration of community structure, but influenced SAX-fermenting consortia much less substantially. These data suggest that 1) generation of model fiber-fermenting communities is possible and 2) that SAX much more strongly structures fermenting microbial communities than does inulin. In the second case, fortification of media revealed that interactions based upon auxotrophies are more likely to structure inulin-consuming consortia. 16S rRNA amplicon sequencing is underway to identify which microbial species populate the final inulin- and SAX-consuming consortia.

Status: Active, one manuscript in preparation describing the initial generation of inulin and SAX-fermenting consortia. Work is currently ongoing to determine whether the consortia can be stably cryopreserved.

26 Particle Size Effects on Bran Fermentation by Gut Microbiota

PI: S. Lindemann

Collaborator: B. Hamaker

Researchers: Y. Tuncil, Postdoc; R. Thakkar, M.S. student

Objectives: 1) Determine the degree to which the fermentation of a bran particle depends upon its size, 2) Identify mechanisms by which particle size might influence the structure and function of gut microbiota.

Progress: Y. Tuncil and R. Thakkar discovered that the fermentation of hard red spring wheat bran particles, directly sieved from the miller sample into size ranges of 180–300, 300–500, 500–800, 850–1000, and > 1700 m, result in very different successions of microbiota, with distinct metabolic function. Coarser particles favored members of family *Lachnospiraceae*, home to many butyrogenic taxa known to be associated with fermentation of wheat brans, and smaller particles favored most of the *Bacteroidaceae*. However, certain *Bacteriodes* species preferred larger particles, suggesting that the effect of selection by particle size can occur at the species or strain level. These differences in community structure produced distinct metabolic output — though small particles fermented more rapidly overall, coarser particles produced increased molar ratios of butyrate while finer particles produced increase molar ratios of propionate. Monosaccharide analysis revealed that smaller particles had increased glucose abundance, suggesting residual starches not removed by upper-GI in vitro digestion. However, milling of large particles suggested the difference was not starch content but availability, and that this may drive differences in microbial activity.

To separate the effect of chemical composition from particle size, Y. Tuncil and R. Thakkar milled down larger wheat bran particles and sieved them into a size range. No significant differences in monosaccharide composition were observed among sizes, but differences in microbial community composition and short-chain fatty acid production persisted. These data suggest that size, in its own right, governs metabolism of wheat brans. Further, we determined that there were significant differences between particle-associated and suspended microbial communities. Metagenome sequencing is underway to determine the functional differences associated with each community.

R. Thakkar extended this experiment into corn brans, by sieving out different size fractions and performing in vitro fecal fermentations. Though preliminary, early data suggest that corn bran particle size effects are more muted than for wheat, but particle size-dependent behavior was still observed.

Status: Active, one manuscript in review, two in preparation.

27 Soluble Fiber Chemical Structure Effects on Fermentation by Gut Microbiota

PI: S. Lindemann

Collaborators: B. Hamaker, B. Reuhs

Researchers: Ming-Hsu Chen, Postdoc; Yunus Tuncil, Postdoc; Tianming Yao, Ph.D. student, Arianna Romero, M.S. student, Jack Hamlin, undergraduate student

Objectives: 1) To identify the structural properties of soluble fiber carbohydrates that exert significant impact upon the rate of metabolism by gut microbiota and their final metabolic fate, 2) To determine which structural features of soluble fibers influence gut microbial community structure and function, and 3) To generate a mathematical model that describes linkages between soluble fiber structure and gut microbiome structure and function that can be generalized across soluble fibers.

Progress: Research to link soluble fiber structure to microbiome response initially investigates three classes of soluble fibers: 1) bran arabinoxylans, 2) inulins, and 3) resistant dextrins. With respect to arabinoxylans, preliminary evidence suggests that fine structural differences can exert large impacts on community structure and function. Y. Tuncil discovered that wheat bran arabinoxylans from hard red (HR) varieties (grown either in winter or summer) select for gut microbial communities dominated by *Prevotella*, where soft red (SR) varieties (grown in winter) select for communities anchored by *Bacteroides*. Linkage analysis revealed that HR arabinoxylans possess a greater amount of 4-Xyl linkages, whereas SR varietals possess more 2,3,4-Xyl linkages – these data suggested that SR arabinoxylans were more highly branched than HR. Furthermore, SR arabinoxylans fermented more slowly than did HR arabinoxylans and different stoichiometries of short-chain fatty acid products.

J. Hamlin and M.-H. Chen have extended upon previous fiber-feeding experiments published by Y. Tuncil, et al, (*J. Funct. Foods*, 2017) to develop a mathematical model that correlates the growth of gut operational taxonomic units (OTUs, computational analogs of species) with different fiber types consumed in in vitro fermentations and with the original donors. This work has begun with single-donor correlations in response to a single fiber type (sorghum arabinoxylan); further modeling work is underway to broaden the approach to inter-donor and additional and inter-fiber correlations.

M.-H. Chen and T. Yao have begun a project to identify the impact of degree of polymerization (DP) on the fermentation rate and metabolic fate of differently-sized inulins. Inulin products across a size range were quantitated for DP and inoculated with inulin-consuming microbial consortia to determine the impact on growth rate and metabolic fate, finding preliminarily that increasing DP results in decreased growth rates and yields of inulin-consuming consortia selected on low-DP inulins. These data suggest that fermentation rates and metabolic fates may be strongly governed by DP.

A. Romero has just begun a project to identify the effects of dextrin structure (e.g., DP, molecular weight, linkage abundances) on fermentation by microbiota. She is currently working on identifying the structures of contributed dextrins.

Status: Active, one manuscript in preparation.

28 Starch Properties in Different Environments

P.I.: L. Mauer

Researchers: Kathryn Johnson, M.S. student; Matt Allan, Ph.D. student

Objective: To investigate starch properties, including gelatinization and retrogradation, in concentrated solutions of a variety of sweeteners and in environments containing different amounts of water.

Progress: We are investigating the thermal properties of starch in different environments and in the presence of a wide variety of sweeteners to establish relationships between sweetener type and structure, water activity, molecular weight, and intermolecular interactions with starch gelatinization, pasting and retrogradation traits.

Status: Active.

29 Amorphous Solid-State Dispersion (Amorphization) of Crystalline Ingredients

P.I.: L. Mauer

Researchers: Seda Arioglu-Tuncil, Ph.D. student; Collin Felten, M.S. student; Yahya Ismail, M.S. student; Adrienne Voelker, M.S. student

Objective: To manipulate the solid-state structure of inherently crystalline ingredients and document the resulting effects on physical and chemical stability.

Progress: We are investigating the differences in stability and delivery traits between crystalline and amorphous forms of both poorly water-soluble and highly water-soluble inherently crystalline ingredients. A variety of dispersion techniques and matrices are being explored to document crystallization inhibition properties of different polymers, as well as differences in solubility and stability traits between crystalline and amorphous forms of the same ingredient. In general, polymers that are capable of hydrogen bonding or ionic interactions with the target compound are better at maintaining amorphous structures during storage. Solubility enhancement was achieved when poorly water-soluble crystalline compounds were stabilized in amorphous dispersions, as well as between amorphous and crystalline forms of highly water-soluble ingredients. Physical and chemical stability differences between crystalline and amorphous states of a compound continue to be monitored. Interesting insights into molecular assembly and crystalline/amorphous behaviors are being developed throughout the course of these studies.

Status: Active.

30 Water-Solid Interactions and Phase Diagrams

P.I.: L. Mauer

Researchers: Matthew Allan, Ph.D. student; Adrienne Voelker, Ph.D.

Objective: To investigate the fundamentals and consequences of the five modes of water-solid interactions in terms of phase diagrams, kinetics, and their effects on the chemical and physical stability of single ingredients and multicomponent food systems.

Progress: We are investigating the fundamentals and consequences of deliquescence, absorption, and other water-solid interactions in food systems containing crystalline and/or amorphous components. In collaboration with a researcher in the Industrial and Physical Pharmacy Department, Dr. Lynne Taylor, we have demonstrated that deliquescence lowering occurs in mixtures of deliquescent crystalline ingredients (e.g., sugars, salts, organic acids, vitamins, etc.) and that reaction kinetics are influenced by this deliquescence lowering. We have also demonstrated that moisture sorption in blends of crystalline and amorphous solids deviates from a simple additive model, wherein the co-formulation of crystalline and amorphous ingredients has the potential to lower both the deliquescence RH and Tg of the blend, depending on the formulation, rendering the blend of ingredients more sensitive to environmental RH than the individual ingredients. Efforts are also focused on generating RH-temperature phase diagrams of different ingredient classes. This has importance for the formulation, sequencing, blending, storage, packaging and stability of dry ingredient mixtures and final food products.

Status: Active.

31 Investigation of Interaction of Amyloid β Peptide (11-42) Oligomers with POPC (1-palmitoyl-2-oleoyl-sn-glycero-3-phosphocholine) Membrane by Molecular Dynamics Simulation

P.I.: G. Narsimhan

Researchers: Ning Xiang, Ph.D. student; Xiaoyu Wu, Ph.D. Research Associate

Objective: To understand the mechanism of pore formation by amyloid β peptide aggregates in neural cell membrane.

Progress: Some amyloid-related proteins/peptides are involved in aggregation and pore formation in phospholipid membranes (cell membranes), which result in a variety of neurological disorders such as Alzheimer disease (AD), Parkinson disease (PD), Huntington disease, etc. In this research, we investigated the mechanism of pore formation by β amyloid peptides using molecular dynamics (MD) simulation by simulating the interaction of Aβ (11–42) peptide, with a lipid membrane and evaluated the potential of mean force of interaction. The 1-palmitoyl-2-oleoyl-sn-glycero-3-phosphocholine (POPC) membrane system with different cholesterol concentration was used to simulate the neural cell membrane. The results indicated that Aβ (11–42) peptide oligomers with peptide number larger than two are more likely to lead to lipid deformation and water channel, and the free energy of penetration into the membrane decreased with increasing number of peptides. Increasing concentration of cholesterol leads to a higher energy barrier for penetration of peptide into a lipid bilayer, thereby protecting the membrane. The results of this research have potential application in the prevention of pore formation on lipid membrane by Aβ aggregates.

Status: Active.

32 Pore Formation in DOPC/DOPG Bilayers by Antimicrobial Peptide Melittin

P.I.: G. Narsimhan

Researchers: Yuan Lyu, Ph.D. student; Ning Xiang, Ph.D. student

Objective: To understand the mechanism of pore formation in DOPC/DOPG bilayers by antimicrobial peptide.

Progress: Antimicrobial peptides (AMP) inactivate microorganisms by forming transmembrane pores in cell membranes through adsorption and aggregation. Energetics of addition of an AMP to a transmembrane pore is important for evaluation of its formation and growth. Such information is essential for characterization of pore-forming ability of peptides in cell membranes. This study quantifies the potential of mean force through molecular dynamics (MD) simulation for the addition of melittin, a naturally occurring AMP, into DOPC/DOPG mixed bilayer, a mimic of bacterial membrane, for different extents of insertion into either a bilayer or a pore consisting of three to six transmembrane peptides. The energy barrier for insertion of a melittin molecule into the bilayer was highest in the absence of transmembrane peptides and decreased as the number of transmembrane peptides increased from three to six, eventually approaching zero. The decrease in free energy for complete insertion of a peptide was found to be higher for larger pore size. Water channel formation occurred only for insertion into pores consisting of three or more transmembrane peptides with the radius of water channel being larger for larger numbers of transmembrane peptides. The structure of the pore was found to be paraboloid. The estimated free energy barrier for insertion of melittin into an ideal paraboloid pore accounting for different intermolecular interactions was consistent with MD simulation results. The results reported in this manuscript will be useful for the development of a model for nucleation of pores and a rational methodology for selection of synthetic antimicrobial peptides.

Status: Active.

33 A Mechanistic Model for Swelling Kinetics of Waxy Maize Starch Suspension

P.I.: G. Narsimhan

Researchers: Prasuna Desam, M.S. student; Jinsha Lee, Ph.D. student

Objective: To characterize the pasting behavior of starch in terms of its structure.

Progress: Pasting behavior of starch greatly influences the texture of a variety of food products. The annual consumption of starch in the U.S. is 3 million metric tons. Starch consumption is believed to be linked to the occurrence of diabetes and obesity. Resistant starch with lower digestibility, which may represent a solution to diabetes and obesity, is produced by modifying the starch using different extents of crosslinking. Cross-linking of starch is achieved by chemical treatment and has a large influence in its pasting behavior. It is, thus, important to characterize the connection between the structure, composition and architecture of the starch granules and its pasting behavior in order to arrive at a rational methodology to design modified starch of desirable rate of digestion and texture. The evolution of 8% suspension of waxy maize starch granule size distribution when subjected to heating to 65, 70, 75, 80, 85 and 90°C at a heating rate of 15°C/min was measured. Granule swelling was more pronounced at higher temperatures with an increase in the average size from 13 μm to 25–28 μm, eventually approaching equilibrium. Cryo SEM images revealed the porous structure of swollen granules. The proposed model for starch swelling accounts for entropy of mixing, enthalpy of water-starch interaction and elastic restoring force. The second virial coefficient of waxy maize in aqueous medium was characterized by static light scattering. Chemical potential profile as well as the temperature profile within the granule were predicted from the solution of unsteady state diffusion and heat conduction, respectively. The granule size was then inferred from the chemical potential profile. The proposed model predicts the evolution of average granule size and granule size distribution accurately.

Status: Active

34 Synergistic Effect of Low Power Ultrasonication on Antimicrobial Peptide Action

P.I.: G. Narsimhan

Researchers: M. Fitrityanti, Ph.D. student

Objective: To characterize the synergistic effect of low-power ultrasound and antimicrobial peptides on deactivation of microorganisms.

Progress: Since antimicrobial peptides kill bacteria by pore formation in cell membranes, transient pores formed by low-power ultrasonication should result in enhancement of antimicrobial activity. Because of its relatively gentle action (low intensity), low frequency ultrasound is expected to have no adverse effect on food texture. Experiments were conducted for deactivation of *L. monocytogenes* using a naturally occurring antimicrobial peptide (AMP) melittin in the absence as well as in the presence of ultrasonication. In the absence of AMP melittin, ultrasonication has very small effect on cell density up to a power level of 40 W. However, at a higher power level of 60 W, a dramatic decrease in cell density was observed, which implied cell lysis. At low AMP concentration, low-power ultrasonication did not improve the antimicrobial activity. At high AMP concentrations, however, AMP was found to completely inactivate *L. monocytogenes*. The synergistic effect of AMP with ultrasonication was found to be the maximum at AMP concentration of 0.78 μg/ml of melittin. A dramatic decrease in two orders of magnitude in cell density was observed for ultrasonication in the presence of 0.78 μg/ml of melittin compared to either ultrasonication alone or AMP action alone.

Status: Active

35 Analysis of Sorghum Genes Involved in Carbohydrate Metabolism and Production

P.I.: C. Weil

Researchers: Jacquee Anderson, Mitch Tuinstra, Brian Dilkes, Charles Addo-Quaye, Eric Danquah, Hamadou Traore. Rosy Hatch, Elisabeth Diatta

Objective: Characterization of a large mutagenized population of *Sorghum bicolor* and identification/characterization of genes and gene functions.

Progress: We have now developed and begun to characterize one of the largest mutagenized populations of *Sorghum bicolor* in the world. Based on our preliminary DNA sequencing of genomes from these lines, this population of 12,000 mutants (made in the genome-sequenced inbred BTx623) contains approximately 3.6 million single-base DNA changes that are predicted to alter protein coding sequences. An estimated 120,000 of these are predicted to have dramatic effect on the protein produced by the affected gene. We are screening the population for improved digestibility of the cooked starch and protein, and have identified a series of candidate mutants and demonstrated that the changes are heritable. These lines have had their genomes resequenced, and the mutations are now available as a public, searchable database, including all those in starch biosynthetic genes. We have also identified several mutant lines that have altered carbon partitioning, altered protein digestibility and improved forage quality. Initially this project was also a collaboration with researchers in Ghana and Burkina Faso. We have now obtained additional resources to expand those efforts into Niger and Senegal. We are looking for partners to help us develop these materials into food products for these African and other markets.

Status: Active.

36 Genes Controlling Starch Channelization

P.I.: C. Weil

Collaborator: J. BeMiller

Objective: In the past, in conjunction with Dr. BeMiller, we have analyzed genetic changes associated with differences in the number of channels formed in starch granules. Using the data on how much actin can be extracted from channels in these recombinant inbred lines (the Relative Degree of Channelization, or RDC), we have used association mapping techniques to identify regions likely to have genes that control channel formation. Several of these regions contain actin and tubulin genes, and genes that impact endosperm morphology. Our goal now is to test their specific roles in forming channels in maize starch granules.

Progress: The RDC between B73 and another inbred, Oh43, as well as 200 RILs derived from these inbreds have now been phenotyped in the BeMiller lab. We have performed association analyses on these RILs to identify additional genes that impact channelization.

As a tool for these studies, we made a *brittle1 brittle2* double mutant and, together with Dr. BeMiller, analyzed the amyloplasts by SEM. These mutant amyloplasts appear unfilled and may lack starch entirely, facilitating the study of the cytoskeleton that surrounds them before they fill.

Status: Active.

37 Genetic Interactions That Impact Starch Quantity and Quality

P.I.: C. Weil

Researcher: Jacquee Anderson

Progress: This project is awaiting a new researcher. Many mutations show differences in the phenotypes they cause when they are moved into various genetic backgrounds. The starch mutants ae1, su1 and wx are being crossed to 27 highly diverse inbreds to identify interacting genes that affect starch quantity and quality, particularly phytoglycogen. We will analyze F2 of these crosses for differences in starch content and quality. Once the effects have been determined, we will use association mapping to quickly identify and isolate novel genes that alter starch characteristics.

Status: Active.

38 Genetics of Carbohydrate Transport and Partitioning in Maize

P.I.: C. Weil

Progress: In summer 2015 we mapped 10 new mutations impacting carbohydrate transport and distribution in maize, have identified over 350 more, and have developed F2 mapping populations for 320 of these. In summer 2017, we will map 40 more mutations for detailed analysis. In addition, we are collaborating with Dr. Jenna Rickus of Purdue's Physiological Sensors group to develop fluorescent sensor measurements of sucrose levels at varying positions in field-grown plants.

Status: Inactive.

39 Genetics of Sugar Accumulation and Distribution in Maize and Sorghum

P.I.: C. Weil

Researchers: Jacquee Anderson, Rosy Hatch, Patrick Sweet, Elisabeth Diatta

Progress: Sugar-accumulating grasses store sucrose in the vacuoles of stem (stalk) cells in preparation for remobilizing that sugar to developing seeds. In grasses such as sugarcane and sweet sorghum, that remobilization is reduced, and the stalks are harvested to collect the sugar. In maize, remobilization to the developing ear has been selected for as a part of the domestication process, and is under genetic control. Some tropical maize varieties flower late in temperate climates and do not make ears (although they still set seed normally under shorter day lengths in the tropics). Some of these continue to accumulate sugar as though they were going to make ears, while others do not; we are trying to understand and make use of this variation. In the past year, we have mapped two QTL that impact sugar accumulation in maize stalks. The next steps will be to determine the genes underlying these QTL. The focus is on increasing the processes loading sugar into the vacuoles of stalk cells and decreasing its remobilization out of those vacuoles. In addition, we are now in the fourth generation of breeding tropical maize varieties to increase a combination of biomass and sugar content.

Status: Active.

40 High-Value Corn Starch

P.I.: C. Weil

Collaborators: L. Mauer, Y. Yao

Objectives: Genetics and mutagenesis are used to identify and develop maize lines that produce specialized corn starches. The working hypothesis is that corn mutants can produce starch in the kernel that has some of the same properties currently obtained by chemical modification. These mutants would, therefore, reduce processing time, cost, and variability. A second objective is to screen mutants for more digestion-resistant cooked starch, and a third is to screen for more rapidly digesting starch for use as a biofuel feedstock and improved poultry feed. Large populations of mutagenized seeds have been developed in the inbred maize lines W22 and B73. The natural diversity of maize has also been examined.

Progress: We have screened ~500 families of these seed and identified mutants that slow digestion of cooked flour to a steady release that eventually reaches normal levels of overall glucose release. We have also identified lines where there is more digestion in 20 minutes than normal starch achieves in 2 hours. We have improved our digestion assay, which now couples NIR spectroscopy with a two-enzyme digestion and automated liquid handling, allowing us to control more precisely for input starch, timing and consistent mixing, with increased throughput. We now want to understand what has been altered in these lines, have identified homozygous mutants for 30 of them, and are looking at branch length distribution and differences in endosperm transcript profiles. In addition, we have identified three diverse inbred lines that have slower digestion of cooked starch and at least one inbred with more rapidly digested uncooked starch.

Status: Inactive.

41 Phytoglycogen-Based Biomaterials to Improve the Solubility of Active Ingredients (AI)

P.I.: Y. Yao

Researchers: Ying Xie, Ph.D. student (graduated in 2017); Randol Rodriguez, Ph.D. student; Jingfan Chen, Ph.D. student

Objective: To improve the water solubility and efficacies of active ingredients (AIs).

Progress: A large number of active food ingredients are hydrophobic and thus poorly water-soluble. Roughly 40% of new drug molecules present drug delivery challenges due to their low solubility. The Biopharmaceutics Classification System (BCS) was developed to classify Active Pharmaceutical Ingredients (APIs) based on their solubility and permeability. Based on the BCS, drug solubilization is necessary for the delivery of APIs of Class II (low solubility, high permeability) and Class IV (low solubility, low permeability). In particular, for compounds in Class II, solubilization technologies can solve the delivery problem. In this project, phytoglycogen-based biomaterials (e.g., octenylsuccinate hydroxypropyl phytoglycogen, OHPP) are prepared and tested using a number of model AIs. The results showed that both the solubilities, dissolution rate and in vitro efficacies of AIs can be substantially enhanced through their complexation with OHPP material. Two papers have been published, and we are continuing the evaluations of other types of phytoglycogen derivatives.

Status: Active.

42 High-Throughput Screening of Cereal Starches

P.I.s: Y. Yao, C. Weil, B. Hamaker

Researcher: Miguel Alvarez, M.S. student; Xingyun Peng, Ph.D. student

Objective: To establish an analytical platform for high-throughput screening of cereal starches.

Progress: "Clean label" for starch, a major food ingredient, not only demands technology innovations, but also the advancement of science at the interface of food chemistry, genetics and genomics, and high-throughput analysis. The overall hypothesis of this study is that the large populations of cereal seeds obtained from mutagenesis are feasible pools for screening high-value traits related to starch. Specifically, this project targets the establishment of a high-throughput screening platform for corn seeds. The primary targets for screening are starches with enhanced processing and storage stabilities such as the resistance to high-shear processing or to retrogradation. The single-kernel screening (SKS) technique is employed to sample and analyze each kernel without affecting its vitality as seed for later planting. Currently, a molecular rotor (MR) technique is being established to evaluate the change of rheological properties of starch gels at microgram levels. Meanwhile, the changes of rheological properties of starch are correlated with environmental factors, such as high-shear treatment and freeze-thaw cycles. Through this approach, we hope to establish the relationship between MR signals (feasible for high-throughput measurement) and starch properties under the conditions usually met in industrial settings.

Status: Active.

43 Pathogen Biofilm Formation and Reduction at the Surface of Fresh Produce

P.I.s: Y. Yao, A. Bhunia (Department of Food Science), A. Deering (Department of Food Science)

Researcher: Yezhi Fu, Ph.D. student

Objective: To study the formation and reduction of pathogenic bacteria biofilm at the surface of fresh produce.

Progress: Biofilm formation by various pathogenic bacteria on food surface is a major food safety concern. In this study, antimicrobial compounds are applied at the surface of fresh produce, such as cantaloupe, and their efficacies to reduce the biofilm formation of *Listeria monocytogenes*, *Salmonella* Typhimurium, and *E. coli* O157:H7 are evaluated. The goal is to better understand the interactions among the active compounds, carriers and the biofilms, and to establish the strategy to allow the active compounds to effectively act on individual bacterial cells.

Status: Active.

44 Small-Granule Starches

P.I.s: Y. Yao

Researcher: Xingyun Peng, Ph.D. student

Objectives: To study the structure and functions of small-granule starches, including cow cockle starch and amaranth starch.

Progress: For both cow cockle starch and amaranth starch, their granular sizes are around one micrometer, much lower than those of other starches used in the food industry and research. The small granular size not only leads to large surface area but also is associated with unique granular structures, thus offering potential values related to food texture enhancement, delivery of active compounds and health benefit. In this work, the goal is to use small-granule starches to evaluate the granular retention of molecules of different sizes, using glucans and phenolic compounds as models, and thereafter to examine how the retention may affect the properties and functions of both starch granules and the active compounds.

Status: Active.

Publications and Other Scholarly Activities

A. Papers, Books, Book Chapters, and Patent Applications Published

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See papers in Hamaker [Tuncil et al. (2)]

Weil, C.F.

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Yao, Y.

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B. Papers Presented at Meetings, Conferences, and Invited Public Lectures

January

1. **Jones, O.G.** Generating colloidal materials by controlled polysaccharide-protein interactions. University of Illinois, Department of Food Science, Urbana, IL.

2. **Mauer, L.J.** Exploring water-solid interactions and phase boundaries using moisture sorption and water activity instruments. Webinar, Meter Foods, Pullman, WA.

February

3. **Hamaker, B.** Importance of locational digestion of starch and new strategies to obtain SDS. Starch Update, Bangkok, Thailand.

4. **Mauer, L.J.** CFSE approaches for developing novel pathogen detection technologies. ARS-FSIS National Meeting, Shepherdstown, WV.

5. Ramamurthy, K.N., Thompson, A., Zhang, Z., He, F., Crawford, M.M., **Weil, C.F.**, Habib, A.F., Tuinstra, M. Designing intra-plot variability features from high-throughput sorghum phenotypes. Phenomes Conference, Tucson, AZ.

6. **Weil, C.** Phenotyping: Modeling growth and metabolism in Sorghum. EAFIT, Medellin, Colombia.

March

7. **Diatta, E.**, Thompson, A., Cisse, N., Tuinstra, M., **Weil, C.** Natural and induced genetic variation for protein digestibility in Sorghum grain. Sorghum and Millet Innovation Center, Senegal.

8. **Sweet, P., Weil, C.** Genome-wide association studies of cell wall composition traits in Sorghum. Monsanto, St. Louis, MO.

9. **Weil, C.,** Boomsma, C. Ground reference measurements: Purposes, best practices, and common methods. Plant Phenotyping Workshop.

10. **Weil, C.** Phenotype of the bigger picture. Plant Phenotyping Workshop.

April

11. **Campanella, O.** Rheology of food biomaterials and food extrusion. 16-hour course, University of Valladolid, Palencia, Spain.

12. **Gilbert, J., Jones, O.G.** Improved stability of whey protein fibrils and utility for biomaterial application. American Chemical Society, San Francisco, CA.

13. Gong, X., Sambalingam, D., **Li, M.**, **Ferruzzi, M.G.**, & Rubin, L. P. Lutein selectively accumulates in the neonatal rat brain via breast milk. Experimental Biology, Chicago, IL.

14. **Lim, J.**, **Ferruzzi, M.G.**, **Hamaker, B.R.** Different phenolic compounds selectively slow down the hydrolysis rates of sucrose and isomaltose by mammalian mucosal α-glucosidases. Experimental Biology, Boston, MA.

15. Rodriguez, M.M., Henry, C., Lachcik, P. J., **Ferruzzi, M.G.**, McCabe, G., Lila, M.A., & Weaver, C.M. Dose response effects of a blueberry-enriched diet on net bone calcium retention in ovariectomized rats. Experimental Biology, Chicago, IL.

16. Solverson, P., Rumpler, W., Leger, J. L., Redan, B., **Ferruzzi, M.G.**, Baer, D.J., & Novotny, J.A. Seven day blackberry feeding lowers the respiratory quotient in males and improves insulin sensitivity. Experimental Biology, Chicago, IL.

17. **Weil, C.** Wonder and delight: Genomics, phenomics and crop improvement. National Science Foundation, Arlington, VA.

18. **Yao, Y.** Dendrimer-like biopolymers: a new arena for biomaterial development. ACS National Meeting, San Francisco, CA.

19. Yazar, G., Duvarci, O., Tavman, S. and **Kokini, J.L.** Comparison of the LAOS behavior of the two main gluten fractions: Gliadin and Glutenin. AERC2017, the Annual European Rheology Conference. Copenhagen, Denmark.

May

20. **Campanella, O.** New advances in food engineering for the study and development of novel biomaterials and foods. Sustainability in Chemical Processes, XX Congreso Chileno de Ingeniería Química, Santiago, Chile.

21. **Ferruzzi M.G.,** Novotny J. Collaborative investigations of beneficial bioactive plant compounds to advance discussions on the science for dietary guidance and public health. NC-FAR Seminar Series, Washington DC.

22. **Hamaker, B.** Aspects of wheat bran fiber related to gut health. Soft Wheat Quality Conference, Purdue University, West Lafayette, IN.

23. **Mauer, L.J.** Food materials science: Challenges of studying water-solid interactions. Washington State University Seminar Series, Pullman, WA.

24. **Mauer, L.J.** Water activity measurements using the Tunable Diode Laser: Answering previously unanswerable questions. Meter Foods, Pullman, WA.

June

25. **Campanella, O.** Extrusion Technology. 16-hour theoretical/practical course, University of Saint Paul, Brazil.

26. **Campanella, O.** Food texture development and evaluation. IFT Annual Meeting, Las Vegas, NV.

27. **Campanella, O.** Rheological properties of foods and biomaterials and their role on processing. 2017 Korean Society of Food Science and Technology, Jeju-do, South Korea.

28. **Bonilla, J.**, and **Kokini, J**. Studying the molecular distribution of protein, fat and starch in semolina, hard and soft wheat flour during different stages of the mixing process. Proceeding of Institute of Food Technologists 2017, Las Vegas, NV.

29. **Desam, G.**, **Campanella, O.**, **Narsimhan, G.** Effect of cross linking on swelling kinetics of maize starch suspensions, IFT Annual Meeting, Las Vegas, NV.

30. **Ferruzzi M.G.** Food and physiological factors impacting bioavailability of dietary (poly)phenols. Plenary Speaker at the Korean Society of Applied Biological Chemistry Meeting. Pusan, South Korea.

31. **Ferruzzi M.G.** Processing strategies for stabilization perishable produce and formulation into staple foods. UC Davis World Food Center Conference on Aligning the Food System to Meet Dietary Needs: Fruits and Vegetables. Davis, CA.

32. Gao, M., Duvarci, O. and **Kokini, J.L.** The effect of polysaccharide gum on large amplitude oscillatory shear (LAOS) behavior of cornstarch suspensions. Proceeding of Institute of Food Technologists 2017, Las Vegas, NV.

33. **Hamaker, B.,** Martens, E. Bacterial metabolism of carbohydrates, dietary fiber and gut health. ACS National Meeting, US Army symposium on the gut microbiome and military stressors, Washington, DC.

34. **Hamaker, B.** The broad range of structures of dietary fibers and their specificity to bacterial fermentation. NIH-USDA Workshop on considerations for best practices in studies of diet and the intestinal microbiome, Washington, DC.

35. **Lindemann, S.R., Tuncil, Y.E.**, **Romero Marcia, A.D.**, **Thakkar, R.D.,** Norka, J.L., Robins, M.M. Wheat bran particle size controls short-chain fatty acid production in colonic microbial fermentations. 11th Vahouny Fiber Symposium, Bethesda, MD.

36. **Lindemann, S.R.** Identifying specific fiber-gut microbiota interactions for prebiotic and probiotic design. General Mills, Minneapolis, MN.

37. **Lindemann, S.R.** Identifying specific fiber-gut microbiota interactions for prebiotic and probiotic design. Ingredion, Inc., Bridgewater, NJ.

38. **Mauer, L.J.** Improving thiamine delivery in foods. USDA AFRI Project Directors Meeting, Las Vegas, NV.

39. **Mauer, L.J.**, Taylor, L.S., **Arioglu-Tuncil, S.**, **Bhardwaj, V., Felten, C.,** and **Voelker, A.** 2017. Improving thiamine (vitamin B_1) delivery in foods by understanding its physical and chemical stability in natural form and enriched products. IFT Annual Meeting and food Expo, Las Vegas, NV.

40. **Li, J., Desam, G., Campanella, O., Narsimhan, G.** Swelling kinetics of waxy native maize starch, NIFA Progress Report, Las Vegas, NV.

41. **Rouf, T.B., Kokini, J.L.** Biodegradable Zein-Laponite nanocomposites have improved mechanical, water vapor permeability and surface properties. Proceeding of Institute of Food Technologists 2017, Las Vegas, NV.

42. **Sadeghi, R.** and **Kokini, J.L.** Fabrication and Characterization of Nanoparticles from Corn Starch with Different Amylose/Amylopectin Contents and improvement of curcumin stability in aqueous media. Proceeding of Institute of Food Technologists, 2017, Las Vegas, NV.

43. **Thorat, A.A.**, Forny, L., Meunier, V., **Mauer L.J.**, and Taylor, L.S. Sucrose-salt interactions and impact on stability of amorphous sucrose. Preclinical Form and Formulation for Drug Discovery Gordon Research Conference Frontiers of Materials Science in Early Drug Development, Stowe, VT.

44. **Turasan, H., Barber, E.A.,** & **Kokini, J.L.** Characterization of physical and chemical properties of crosslinked zein films for biodegradable platform formation. Proceeding of Institute of Food Technologists 2017, Las Vegas, NV.

July

45. **Torres-Aguilar, P., Hamaker, B.** Impact of low-cost extrusion on lipid oxidation and acceptability of whole grain pearl millet (*Pennisetum glaucum*) flours. Institute of Food Technologists annual meeting, Las Vegas, NV.

August

46. **Jones, O.G**. Bimodal force spectroscopy as a technique to quantify Young's moduli of protein fibrils and nanoparticles. Microscopy and Microanalysis Conference, St. Louis, MO.

47. Lyu, Y., Frityanti, M., Zhu, X., **Narsimhan, G.** Pore formation by aggregates of antimicrobial peptide in DMPC liposomes. American Chemical Society National Meeting, Washington, DC.

48. **Narsimhan, G.** Swelling kinetics of starch suspensions. American Chemical Society National Meeting, Washington, DC.

49. Sutanto, F., **Malm, M.** and **Kokini, J.L.** Glutaraldehyde crosslinked zein solutions make better biodegradable films. The Summer Undergraduate Research Fellowship (SURF) Symposium, Purdue University, West Lafayette, IN.

50. Xiang, N., **Zhu, X.**, **Narsimhan, G.** Computational investigation of interaction of amyloid β peptides and lipid membrane. American Chemical Society National Meeting, Washington, DC.

September

51. **Hamaker, B.** Using food processing Incubation Centers to promote entrepreneur processing and nutritionally fortified foods. WISHH Conference on Soybean Trade and Processing, Dakar, Senegal.

52. **Jones, O.G.** Controlling physical properties of β-lactoglobulin microgels to enhance emulsion stabilization. American Chemical Society, Washington, DC.

53. **Lindemann, S.R.** All 'dietary fibers' are not created equal: What variables govern microbial responses to fiber sources? Mucosal Immunity Group, Rush University, Chicago, IL.

54. **Kokini, J.L.** Advances in restructuring of food materials using nanotechnology. Institute of Food Technologists, Chicago, IL.

October

55. **Barber, E.**, **Kokini, J.L.** Effect of oleic acid plasticizer and glutaraldehyde crosslinker on zein protein gel formation. Proceeding of the Society of Rheology 88th Annual Meeting, Tampa, FL.

56. **Bonilla, J.**, Ryan, V., Bhuhnia, A., and **Kokini, J.L.** Development of specific antibodies against high and low molecular weight glutenins as research tools by comparative proteomics. Proceeding of the American Association of Cereal Chemists International Annual Meeting, San Diego, CA.

57. **Fang, F.**, **Campanella, O.H., Hamaker, B.R.** Shear-induced ordering of amylopectin dispersions. American Association of Cereal Chemists International annual meeting, San Diego, CA.

58. **Ferruzzi, M.G.** Food technology and ingredient innovations: Potential impact from a public health perspective. International Congress of Nutrition. Buenos Aires, Argentina.

59. **Ferruzzi, M.G.** Polyphenol ADME: How food and physiological factors impact delivery of these bioactive phytochemicals. International Congress of Nutrition. Buenos Aires, Argentina.

60. Gao, M., Duvarci, O., and **Kokini, J.L.** The effect of polysaccharide gum on large amplitude oscillatory shear (LAOS) behavior of corn starch suspensions. Proceeding of the Society of Rheology 88th Annual Meeting, Tampa, Florida.

61. Gao, M., **Sadeghi, R.**, Duvarci, O., and **Kokini, J.L.** The effect of carboxymethyl cellulose (CMC) on Large Amplitude Oscillatory Shear (LAOS) behavior of corn starch suspensions. Proceeding of the Society of Rheology 89th Annual Meeting, Denver, CO.

62. **Hamaker, B**. Location of starch digestion is probably important! Starch Roundtable, San Diego, CA.

63. **Hamaker, B.** Dietary fiber and gut microbiota – why this changes things. AACCI Annual Meeting, San Diego, CA.

64. **Hamaker, B.** Overview of current digestive health research hot topics. PepsiCo 2017 Snack Nutrition Science Research Workshop, Plano, TX.

65. **Hamaker, B.** Bacterial metabolism of carbohydrates, dietary fiber and the gut microbiome. Food and Nutrition Conference and Expo (FNCE), Chicago, IL.

66. **Hayes, A.M.R., Martinez, M.M., Hamaker, B.R.** Investigating the slow digesting property of pearl millet couscous. American Association of Cereal Chemists International annual meeting, San Diego, CA.

67. **Kokini, J.L.** Recent advances in nanotechnology for food applications. University of Queretaro, Queretaro, Mexico.

68. **Kokini, J.L**. Biophotonics and biosensing. Discovery Park Big Idea Challenge, Purdue University, West Lafayette, IN.

69. **Lindemann, S.R.** Dietary fibers and maintenance of gut microbial diversity. AmericanAssociation of Cereal Chemists Cereals 17, San Diego, CA.

70. **Maldonado, L.** and **Kokini, J.** Effect of manufacturing conditions on the fabrication of protein/polysaccharide biocompatible nanotubes (BNTs). Proceeding of American Institute of Chemical Engineers 2017, Minneapolis, MN.

71. **Martinez, M.M., Bertoft, E., Hayes, A.M.R., Hamaker, B.R.** "Zipper model" explains intermolecular re-associations of starch molecules. American Association of Cereal Chemists International annual meeting, San Diego, CA.

72. **Pletsch, E.A**., **Hamaker, B.R.** Identifying differences in human gastric emptying rate and glycemic response of processed whole grain wheat meals. American Association of Cereal Chemists International annual meeting, San Diego, CA.

73. Roman, L., Pallares, M.G., **Hamaker, B.R., Martinez, M.M.** Amylopectin fragmentation of cereal flours impacts intra- and inter-molecular starch associations during storage. American Association of Cereal Chemists International annual meeting, San Diego, CA.

74. **Rouf, T.B.** and **Kokini, J.L.** A Facile approach for fabrication and characterization of eco-friendly Zein-Laponite nanocomposites with improved mechanical, thermal, barrier and surface property. Proceeding of American Institute of Chemical Engineers 2017, Minneapolis, MN.

75. **Sadeghi, R.** and **Kokini, J.L.** Microrheology as a powerful tool to monitor particulation of bovine serum albumin. Proceeding of the Society of Rheology 88th Annual Meeting, Tampa, FL.

76. **Schmidt, L.R., Hamaker, B.R.** Ability of the 3-deoxyanthocyanidin apigeninidin to promote protein polymerization through disulfide interchanges. American Association of Cereal Chemists International annual meeting, San Diego, CA.

77. **Tuncil, Y.** and **Hamaker, B.** Link between dietary fibers, colonic microbiota and health. AACCI Annual Meeting, San Diego, CA.

78. **Turasan, H.** and **Kokini, J.** Analyzing the effects of time and crosslinker ratio on the mechanical properties of biodegradable zein super gels. Proceeding of American Institute of Chemical Engineers 2017, Minneapolis, MN.

79. **Zhang, X.**, Chen, T., **Hamaker, B.R.** Physical form of corn bran arabinoxylan is associated with its in vitro human fecal fermentation property. American Association of Cereal Chemists International annual meeting, San Diego, CA.

November

80. **Campanella, O.** Advance rheology. Instituto Tecnologico de Monterrey, Biotechnology and Food Engineering Program, Monterrey, N.L., Mexico.

81. **Desam, G.**, **Campanella, O., Narsimhan, G.** Swelling kinetics of starch suspensions, American Institute of Chemical Engineers Annual Meeting, Minneapolis, MN.

82. **Hamaker, B.** Effect of glycemic carbs or fiber on physiological response and intestinal microbiota balance. CIFST conference (IFT China), Wuxi, China.

83. **Hamaker, B.** Keynote address at launch of post-harvest initiative (~$1.2 billion), African Development Bank, Abidjan, Ivory Coast.

84. Lyu, Y., **Frityanti, M., Zhu, X., Narsimhan, G.** Pore formation by aggregates of antimicrobial peptides in DMPC bilayers. American Institute of Chemical Engineers Annual Meeting, Minneapolis, MN.

C. Graduate Degrees Awarded

1. **Ryan Murphy, Ph.D.,** *Production, interfacial behavior, modification and functionality of whey protein microgels,* May
2. **Tianming Yao, M.S.,** *Iota-carrageenan and starch matrices as the suitable delivery systems of curcumin and resveratrol,* May
3. **Jay Gilbert, Ph.D.,** *Protein Fibrils: Improved stability, nanomechanical analysis, and biomedical applications,* August
4. **Darwin Ortiz, Ph.D.,** *Storage and Processing effects on delivery of provitamin A carotenoids from biofortified maize,* August
5. **Ying Xie, Ph.D.,** *Octenylsuccinate hydroxypropyl phytoglycogen, a potent and non-specific solubilizer for poorly water-soluble active ingredients,* August
6. **Xiang Ning, Ph.D.,** *Investigation of interaction between peptide and lipid bilayer by molecular dynamics simulation,* November
7. **Aminata Diatta, M.S.**, *Using corn zein to improve the quality of gluten-free bread*, December
8. **Fang Fang, Ph.D.,** *Shear-induced ordering of amylopectin dispersion affected by hydrocolloids*, December
9. **Yahya Ismail, M.S.,** I*nvestigating the degradation of amorphous vitamin C in polymeric model systems*, December
10. **Kathryn Johnson, M.S.,** *Investigating the effect of controlled relative humidity storage on amylopectin retrogradation in amorphous starch, starch:gluten, and wheat flour models,* December
11. **Yuan Lv, Ph.D.,** *Investigation of pore formation in lipid bilayer by antimicrobial peptides*, October

D. Recognitions, Awards, and Honors

1. **Jose Bonilla**
   Krannert Applied Management Principles Program, Purdue Krannert

   Third Place, Best Student Research Paper Competition, AACCI
2. **Fang Fang**
   1st place/Megazyme Award, Carbohydrate Division Poster Competition, AACCI
3. **Drew Hirsch**
   Finalist, Student Association Product Development Competition, AACCI
4. **Rachel Jackson**
   Ross Fellowship, Purdue Graduate School
5. **Elizabeth Pletsch**
   Finalist, Nutrition Division Poster Competition, IFT
6. **Leigh R. Schmidt**
   1st place, Protein Division Poster Competition, IFT
7. **Hazal Turasan**
   Graduate Student Pathmaker Award, Purdue Agriculture

   College of Agriculture Pathmaker Award, Purdue University
8. **Adrienne Voelker**
   Food Science Teaching Award, Purdue University

E. Special Events

Whistler Center Short Course, October 3–5, 2017

As is our tradition, the course was designed to provide one day on carbohydrate fundamentals followed by two days of advanced special topic sessions. Day 1 consisted of a general session. Advanced topical areas were presented on days 2 and 3, so that each participant could attend three advanced topic sessions of their choice.

- Introduction to structures and properties of polysaccharides, J. BeMiller
- Polysaccharide architecture, S. Janaswamy
- Starch granule structure and properties, J. BeMiller
- Basic principles in rheology and viscoelasticity, J. Kokini
- Polyols, high-intensity sweeteners, and non-chemical modifications of starch, Y. Yao
- Chemical modification of polysaccharides, J. BeMiller
- Carbohydrate nutrition and labeling, B. Hamaker

Wednesday and Thursday Breakout Sessions

- Advances in chemical and physical modifications of starch, part I & II, J. BeMiller
- Hydrocolloids and functionality, part I & II, J. Keller
- Dietary factor affecting glucose homeostasis, part I – slow digestion, B. Hamaker
- Dietary factor affecting glucose homeostasis, part II – plant phytochemicals, M. Ferruzzi
- Complex carbohydrate structure analysis (non-starch), part I & II, B. Reuhs
- Rheological properties of food biopolymers and their role in bioprocessing and product development, O. Campanella
- Prebiotics and the gut microbiome, B. Hamaker/S. Lindemann
- Polysaccharide architecture and functionality including starch, S. Janaswamy
- Extrusion technology for the production of food and non-food materials, O. Campanella
- Carbohydrate-related enzymes and their applications, J. Shim
- Physical property testing of carbohydrates, part I – solids, L. Mauer
- Phase stability of polysaccharide mixtures, O. Jones
- Hydrocolloids and functionality, part I & II, J. Keller
- An introduction to advanced methods of food material characterization, part II, J. Kokini/G. Schmidt
- Predictive modeling of multicomponent systems, part I & II, G. Narsimham
- Biomedical applications, G. Schmidt
- Starch and genetic variability: Work the plant can do for you, C. Weli
- Rheological properties of food biopolymers and their role in bioprocessing and product development, O. Campanella
- Prebiotics and the gut microbiome, B. Hamaker/S. Lindemann

2017 Belfort Lecture

Structure-property relations of cereal fibers and implications for food product development

2017 Belfort Lecturer

Dr. Costas G. Biliaderis

Professor of Food Chemistry – Food Physics
Chairman of the Department of Food Science and Technology
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Dr. Costas G. Biliaderis is Professor of Food Chemistry – Food Physics and currently the Chairman at the Department of Food Science and Technology, Faculty of Agriculture, Aristotle University of Thessaloniki, Greece. He is a graduate of Aristotle University and received his M.Sc., (1978) and Ph.D. (1980) degrees from the University of Saskatchewan, Canada. Prior to becoming a faculty member at Aristotle University (1993), he held appointments as a research associate with the National Research Council of Canada (1980–81), as a project chemist with General Foods, Inc. (1984–85), and as Assistant Professor (1985–88) and Associate Professor (1988–1993) with the University of Manitoba, Canada. He has been a visiting professor with the Cyprus University of Technology (2010) and also teaches graduate courses at the Mediterranean Agronomic Institute of Chania – CIHEAM, Chania, Greece (1997–2017).

Dr. Biliaderis and his students have conducted studies in the areas of chemistry-physical chemistry and functionality of polymeric food carbohydrates (starch, cereal cell wall polysaccharides, etc.), processing-preservation and quality aspects of food products (cereals, dairy products, fruit and vegetables, etc.), food dispersions (o/w) with engineered interfaces, structured delivery systems as well as functional foods and nutraceuticals. He has directed more than thirty major research projects funded by National and International institutions and the food industry and he acts as a consultant to food industries. Dr. Biliaderis is author or co-author of over 180 research articles in peer reviewed international journals and 15 chapters in scientific books. He has co-edited with Marta Izydorczyk (Agriculture Canada) a book entitled *Functional Food Carbohydrates* (CRC Press, 2007) and is or acted as a member of the editorial board of four international journals. He has more than 200 presentations in International Conferences and Workshops, including 40 invited talks-lectures, and served as an invited external examiner of eighteen doctoral theses in several European and Canadian Universities. Costas Biliaderis received several awards for his achievements in research, teaching, and scholarly works and since 2003 is listed as “highly cited researcher” according to ISI-Thomson Scientific, for his published works (h-index 60, Web of Science).

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