

# ***INDUSTRIAL MEMBERS***

(Members of 2012 Industrial Advisory Board)

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Carbohydrate Center at NTU\*

Cargill

ConAgra Foods

Dow AgroSciences

Genencor

General Mills

Grain Processing Corporation

Ingredion

Nestlé

PepsiCo

Roquette

Tate and Lyle

\* Carbohydrate Center at the Graduate Institute of Food Science and Technology at National Taiwan University (NTU/GIFST/Carbohydrate Center)



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## DIRECTOR'S STATEMENT

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Welcome to our 2012 Whistler Center annual report. Carbohydrates for food and industrial uses seem to be more and more in the limelight, regarding their potential to positively impact health and wellness, structures that improve texture and food quality attributes, nanoparticles for better delivery of nutrients or antimicrobials, and biopolymer replacement of synthetic polymers to name a few. This is contrary to a comment I remember a decade ago from a fellow faculty member wondering whether we already knew all that was needed in carbohydrate science! At the Whistler Center, we consider ourselves fortunate to have a critical mass of faculty, researchers, and facilities to address many of these research areas, but also have initiated partnerships, domestic and international, that collectively widen our ability to address large important problems related to carbohydrates. Despite a difficult funding environment, we continued in 2012 to be fully active with 75 researchers in the Center including faculty, post-doctoral research associates, graduate students, visiting faculty and scientists and staff. We have overall maintained our industrial membership over the last 5 years, and this year welcome a new member represented through the Carbohydrate Center at National Taiwan University. It looks like we may have a modest increase in 2013 to our longer term aim of having a 15 company membership, a number we feel we can serve well.

It was a busy early 2012 at the Whistler Center with the lead-up to our hosting of the 11th International Hydrocolloid Conference. The conference was a big success with over 300 attendees and an excellent scientific program. Our thanks to our partners at the International Carbohydrate Consortium represented by Glyn Phillips (Phillips Hydrocolloid Research Centre, Wrexham, Wales), Peter Williams (Glyndwr University, Wrexham, Wales), Steve Cui (Agriculture and Agri-Food Canada, Guelph, Ontario) and the Whistler Center. Prof. Peter Williams gave the opening Belfort Lecture on “Functional Polymers from Biomass Residues”. The next IHC will be hosted by National Taiwan University in 2014. An important service to our member companies is our yearly Short Course offered in October. This year we again had a strong turn out and offered a number of new or revised advanced sessions on days 2 and 3 including “Water-solid interactions: crystalline and amorphous solids”, “Glycemic carbohydrates”, “Extrusion rheology”, “Hydrocolloids and functionality”, “Starch analysis and product quality”, and “Protein-polysaccharide interactions”. At the Institute of Food Technologists annual meeting in Las Vegas in June, Amy Lin organized a first pre-meeting short course co-hosted by IFT and another organization – the Whistler Center. It was titled “Designing carbohydrate supramolecular structures for food” and brought in speakers from the US and overseas, as well as the Whistler Center, to teach about small-scale structures and their unique functionalities.

In a final note, it would not surprise you that our most valuable asset is our people and we as faculty well recognize that the Whistler Center has helped us attract top students, post-docs and visiting scientists to work with us. Please take a look through our 2012 annual report and see what we have been up to.

As always, feel free to contact either myself or Marilyn Yundt, our Center Coordinator with any questions or needs.

Sincerely,

A handwritten signature in black ink that reads "Bruce R. Hamaker". The signature is written in a cursive, flowing style.

Bruce R. Hamaker  
Roy L. Whistler Chair Professor  
Director

## SUMMARY OF MAJOR RESEARCH ACCOMPLISHMENTS

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### Starches, Non-Starch Polysaccharides, and Cereals:

**Dr. BeMiller** and his Visiting Scholars continued studies of the impacts of the presence of hydrocolloids on the pasting, paste, and gel properties of starches – this year by focusing on any effects of the presence of a hydrocolloid on granule swelling. A large amount of data has been collected and is being analyzed (Project 4). Dr. BeMiller along with his former Research Associate (Zhongquan Sui) and collaborator (Prof. Kerry Huber) continued analyzing the data on the effect of order of addition of rapidly reacting reagents and catalyst, i.e., alkali, on modification of corn and wheat starches and the preparation of manuscripts (Projects 1-2). Results showed that there were differences in the products when the order of addition of reagent and catalyst was reversed and that the changes depended on the type of starch and the reagent used. A manuscript was submitted on the effect of the amylose content of the starch on interactions of starch with eight hydrocolloids (Project 3).

**Dr. Hamaker's** group in 2012 had various projects related to starch and related alpha-glucans, and non-starch polysaccharides. His principal focus is the relating of these carbohydrates to health-related conditions and more direct work in this area is highlighted in the next section. In work directed at understanding the effect of locationally directed glucose release in the small intestine, for health benefit, B.H. Lee, Post-Doctoral Research Associate and collaborator Prof. S.H. Yoo at Sejong University in Seoul, Korea, have been successful in adding the glucose derivative, 2-deoxy-glucose, to maltodextrins for the purpose of determining the exact location of glucose release and absorption (Project 12). This will allow us to develop more precise starch-based structures or fabricated materials for targeted glucose release to test as a potential strategy for weight loss, extended energy delivery to the body, and glycemic response modification. With visiting faculty from Mexico, his group investigated low glycemic pasta and hydrothermal treatments of high-amylose starches for increase in slowly digestible character.

In other projects, fibers from amaranth, quinoa and three cereals were characterized with the aim of more fully functionalizing them; and small pore arabinoxylan gels were made that carry higher loads

of small hydrophobic molecules through a putative concentrated structured water layer (Project 10).

His and O. Campanella's group continues to be active in research on functionalizing non-wheat cereal proteins, i.e., corn zeins and sorghum kafirins, with the aim of generating viscoelastic proteins for gluten-free products and for incorporation of such flours into composite baked products in Africa for partial replacement of wheat and to provide market access for African smallholder farmers (Project 14). In the last year, their student's work advanced this field with an improved understanding of structural transitions that these proteins must undergo to improve viscoelastic properties. Protein-body free sorghum, a high-lysine mutant developed at Purdue, was shown to have proteins that can participate in dough development and improve loaf volume compared to normal sorghum cultivars. (Project 14).

**Dr. Yao's** work in 2012 has mostly been with functional carbohydrate-based biomaterials, with particular focus on the stabilization and dissolution of active ingredients, including: (Project 38) antimicrobial compounds, (Projects 39 and 40) food nutrients and nutraceuticals, and (Project 41) active pharmaceutical ingredients. Results originated from these researches are patent pending and will be published in 2013-2014.

**Dr. Lin** developed a method to determine to octenyl succinic (OS) group content in modified polysaccharides (Project 23). The modified gum is a potential new ingredient with very good emulsifying properties. The quantification of OS content assists the hydrocolloid industry, particularly for quality control.

In addition, her work includes the improvement of carbohydrate analytical methods, such as that for debranched starch molecules.

### Carbohydrates and Health:

**Dr. Hamaker** has long-term projects on ways to control rate of digestion of glycemic carbohydrates and the potential beneficial physiologic effects that are related to distal delivery of glucose; and dietary fiber poly- and oligosaccharides for targeted function in the colon and effect on microbiota. They work with a number of collaborators for each of these projects, glycemic carbohydrates, digestion and

physiologic response with the “Starch Digestion Consortium” consisting of A. Lin and himself at Purdue, B. Nichols at Baylor College of Medicine, R. Quezada-Calvillo in Mexico, D. Rose and M. Pinto in Canada, and H. Naim in Germany, and for physiologic response with T. Powley, R. Phillips, and K. Kinzig at the Department of Psychological Sciences, Purdue, and M. Kushnick at Ohio U.; and for colon health, A. Keshavarzian and group at Rush Medical School, Chicago, and E. Martens at U. Michigan Medical School, Ann Arbor.

In their glycemic carbohydrate research (Project 13), in 2012 they finished a long-term rat study examining the effect of consumption of slowly digestible starch over an 8-week period on food intake habits and appetite regulating neuropeptides in the hypothalamus. They found that slow digestion with distal glucose release in the small intestine resulted in smaller meals and ultimately by week 8, lower food intake. Concomitant with this was a drop in appetite-stimulating hormones.

In fiber research related to the colon and microbiota, they found that discrete structural parts of larger fiber polymers drive competitive relationships between colonic bacteria (Project 11). This high specificity for fiber structure and the favoring of bacteria suggests that fibers might eventually be used to manipulate the colon microbiota in prescribed ways.

**Dr. Lin** continues working on starch digestion from the digestive enzyme perspective, with an emphasis on the internal structure of starch molecules. Starch digestibility at the mucosal level of the small intestine was found to be driven by the internal structure of starch. It is highly associated with both the branch frequency and pattern of the internal structure of starch molecules (Project 25).

She is involved in *in vivo* studies through collaborators. These studies showed that starch digestion was less complete when one of the mucosal alpha-glucosidase complexes, sucrose-isomaltase was absent; gluconeogenesis compensated to give the same glycemic response (Project 25).

In addition, Dr. Lin successfully produced 13C-enriched alpha-limit dextrin for several collaborative studies, including: (1) Dr. Hamaker and Ms. F. Cisse’s project related to work in Mali to evaluate prevalence of alpha-amylase deficiency in marginally malnourished children, (2) Dr. B. Nichols’s study at USDA/ARS Children’s Nutrition Research Center to

test food grade supplements for congenital sucrose-isomaltase deficiency (CSID), and (3) Mr. A. Opekun’s project at Baylor College of Medicine to test the starch digestion pathway of CSID patients (Project 26).

## Polysaccharide Structures:

**Dr. Janaswamy’s** research demonstrates the potential use of polysaccharide fibers in developing cost-effective delivery vehicles of nutraceuticals, drugs, vitamins and antimicrobial compounds. Their study on iota-carrageenan fibers reveals that well-oriented and organized iota-carrageenan fibers can embed nutraceuticals, and charge balancing cations ( $\text{Na}^+$  and  $\text{Ca}^{2+}$ ) on the iota-carrageenan backbone influence the release behavior of encapsulated molecules (Project 15). In another study, they showed that iota-carrageenan fibers can be used to deliver antimicrobial compounds for preventing undesirable microbial proliferation (Project 16). They encapsulated eugenol (essential oil) in the sodium iota-carrageenan (IC) fibers and antimicrobial activity was tested against two foodborne pathogens *Escherichia coli* and *Listeria monocytogenes*. Results suggest that eugenol-encapsulated IC fibers are effective in controlling the microbial growth for a period of two days. Their systematic study about the effect of salts (KI, KBr and KCl) on the structure-function relationships of potassium kappa-carrageenan show interesting results (Project 17). It appears that apart from charge balancing cations, anions, especially iodine ions, also promote favorable interactions among the kappa-carrageenan chains.

**Dr. Jones’s** research follows the impact of polysaccharides on biopolymer structural development, particularly among food protein systems. Polysaccharides contribute to structural formation in biopolymer systems through electrostatic, hydrogen-bond, and dispersion forces that can be carefully manipulated by environmental conditions. Structural development involves study of physical phenomena at a fundamental level through spectroscopic techniques and calorimetry, while the formation of sub-micrometer structures is gauged through light scattering and atomic force microscopy techniques. Current research is also being done to investigate the relationships between the nanoscale mechanical properties of biopolymer structures and their macroscale attributes, which will contribute a greater understanding of structure-function relations. Ultimately, the aim of this research is to understand both fundamental physical interactions and improved methods for the formation of functional, food-

compatible structures. Currently investigated structures include protein fibrils (Projects 18 and 19), protein nanogels (Projects 20 and 21), and block ionomer complexes assembled from modified polysaccharides (Project 22).

Protein fibrils assembled from  $\beta$ -lactoglobulin show excellent promise for improved mechanical properties and as scaffolds for controlled release or enzymes. The greatest challenge in  $\beta$ -lactoglobulin fibril research is the production of stable fibrils in non-acidic conditions and the production/isolation of fibrils in an industrially relevant mechanism. Project 18 is currently investigating means to isolate fibrils in either acidic or neutral conditions so as to improve their relevance to the industry. Project 19 involves the production of an improved gel or film using the fibrils and polysaccharide. Funding is currently being sought to facilitate these investigations.

Protein nanogels (particulate agglomerates with diameter between 50 and 600 nm) may be formed from whey protein using thermal treatment or from poorly soluble proteins, such as zein, using solvent nanoprecipitation techniques. Control of formation using specific ions in solution is being currently investigated within Project 20. Nanogels are proposed to impart textural control in fractal networks or to serve as particle-based stabilizers of interfaces susceptible to Ostwald ripening (Project 21).

## Rheology:

**Dr. Campanella's** projects involve physicochemical characterization of biomaterials including foods and non-food materials. They include properties associated to the formation of structures, e.g. during gelling, interaction of polymeric molecules with colloidal particles, self-assembling of biomolecules, and incorporation of fibers into foods. The role of these physico chemical properties is also analyzed in regards to material processability. Changes in proteins structures and their functions by changes in temperature, addition of other macromolecules such as other proteins are being studied using rheological and spectroscopic techniques (e.g. Circular Dichroism, FTIR and microscopy). Properties of these composite systems such as glass transition, and general structure and how they affect their functional properties are being studied. Results of this research have an impact on the area of development of new materials and improved foods with good nutritional and textural quality (Project 5).

Development of new materials and understanding the physicochemical behavior of existing ones require a scientific foundation that involves modeling and experimental verification. Work in this area also focuses on the functional efficacy of polymers used as part of food ingredients. Given the complex nature of biomaterials composition and the various conditions to which they are exposed during processing and storage, stability, functionality and quality under different external and processing conditions are key attributes that deserve attention and are being investigated by Dr. Campanella's group. Glass transition is a phenomenon of significance in the area of food engineering and science, thus methodologies used to accurately characterize this property are essential to understand how composition affect glass transition. Methods using both mechanical and thermophysical properties of complex biomaterials (including powders), such as Dynamic Mechanical Analysis (DMA), Differential Scanning Calorimetry (DSC-conventional and modulated) properties are being developed (e.g. (Project 6). In these projects rheological, thermophysical, spectroscopical and microscopical methods are also being developed to study the effects and use of ingredients that can improve the functionality of some cereal proteins, like for example zein. Model systems are used to understand mechanisms of viscoelasticity enhancement of other non-gluten cereal-based systems. This functional change is believed to be the result of developing fibrous,  $\beta$ -sheet-rich protein networks; however, current understanding of the physicochemical properties of these viscoelastic polymers is limited. This research aims to present a mechanistic framework for approaching this system by highlighting structure/function relationships in wheat gluten, zein's aggregative behavior. Ultimately efforts to improve zein-starch dough functionality to potential areas of interest are moving forward.

Novel physicochemical and rheological methods have been developed to monitor the formation and stability of nanocomplex formed by the interaction of starch, protein and fatty acids (Project 8). Thermodynamic analysis performed on data obtained with Differential Scanning Calorimetry (DSC) demonstrated that the formation of the three-component nanoparticle is a thermodynamically possible process leading to a thermodynamically stable system. Dispersion of these nanoparticles in suitable solvents are stable, they are not nanoemulsions which are unstable systems. Physicochemical data, complemented with microscopy studies clearly showed the presence of

nanostructures with a regular rod shapes. Molecular modeling to study the formation of amylose-like molecules with fatty acids, in the presence and without the presence of proteins is being attempted using molecular modeling.

Project 5 is aimed to physically modify (e.g. through high shear conditions) the molecular structure of hydrocolloids to improve their functionality. Studies focused on xanthan gum, which was characterized both rheologically and physicochemically after application of high shear processes at two different pressures (69 MPa and 276 MPa). Both treated groups and a control (untreated xanthan gum solution) were stored at two different temperatures (4°C and 25°C) for 11 weeks. Results showed that samples had a decreased viscosity and elasticity upon the treatment compared to the control untreated sample. Decrease in viscosity and viscoelasticity was attributed to the increased maximum packing of the system by the wider distribution of molecular weights and sizes of the treated samples, which were evaluated by size exclusion chromatography and multi-angle laser scattering. Results also showed that not only the viscoelastic behavior of the solutions was changed by the treatment. An increased sensitivity of viscoelasticity with temperature was observed. This indicated the loss of structured network with the shear treatment. A similar approach is being followed up to physically modify the structure of fibers (e.g. Arabinoxylans) for improved functionality.

Rheological characterization of gels and the effects of colloidal particles on gel formation and gel properties are being studied using experimental methods (Rheology, Dynamic Laser Scattering (DLS), Atomic Force Microscopy (AFM)) and molecular simulations. Results are showing a significant interaction between the particles forming the gel and the colloidal particles which results in increases of the gel viscoelasticity. Experimental validation of qualitative trends obtained from molecular modeling are being also explored (Project 5).

Arabinoxylans (AXs) obtained from cereal brans have potential for the production of healthy foods and pharmaceuticals. They are obtained by alkali treatment of cereal brans. One objective in the overall objective is to determine the effect of alkali treatment conditions on oxidative gelling of corn bran AXs. AXs extracted through mild alkali treatment formed strong gels through ferulic acid (FA) crosslinking. Increasing harshness of alkali treatment caused a decrease in average FA content

of AXs and elasticity of gels formed with them. It was found that the average FA content in the sample is not a good indicator of gelling capacity. This could be due to the presence of molecules with different FA contents within a sample. Molecules rich in FA can form crosslinks and participate in the network, while those with low FA contents cannot. Different alkali treatment results in preparations with some molecules richer in FA than others. The former can form crosslinks and participate in the gel network. A gel is formed only if there is a sufficiently large proportion of participating molecules in the network. This concept of participating molecules is proven by establishing the presence of crosslinks in non-gelling samples through chromatographic and rheological measurements. It may be useful in designing gels with different strength, texture and colonic fermentation properties (Project 10).

Rheology of food ingredients are also investigated. Specifically, pectin is one major component of plant cell walls and is used extensively as a functional food ingredient in a large number of products. The molecular structure and sugar composition of pectins affect their functionality, thus limiting commercial pectin production to a few plant sources. Specifically degree of methoxylation, degree of acetylation, pattern of methyl esterification, and molecular size determine the functional properties of pectins. Rheological measurements are of primary concern due to the importance of texture in assessing quality attributes of food products containing pectin. Analyzing the rheological profile of juice, serum, and particulate of these different varieties is helping to elucidate the impact of pectin methoxylation on the viscoelastic properties of many foods (Project 9).

### Interfacial Phenomena:

**Dr. Narsimhan's** group continues to work on fundamental aspects of formation and stability of emulsions and foams. To complement the previous experimental and theoretical studies on unfolding of model proteins on nanoparticle surfaces, they are continuing to investigate the changes in secondary and tertiary conformations of proteins/polypeptides due to interaction with surfaces using molecular dynamics simulation (Projects 28-30).

### Chemical Structures and Functions of Polysaccharides:

**Drs. Reuhs, Campanella and Hamaker** study the complexity of non-starch polysaccharide



structures and their function related to physical functionality (described under Rheology), as well as colon fermentation also described above (Project 11). In various projects, it is fundamental structural data generated at a minimum from monosaccharide profiling and partial methylation linkage analysis that is related to the polysaccharides properties in solution, its incorporation into food systems for fortifying fiber content, and understanding how structures drive colon microbiota changes. This analytical core of the Whistler Center supports these and other projects among the faculty, and provides a structural characterization service for member non-member companies.

## Genetics:

**Dr. Weil's** lab now has a mutant population (~12,000 lines) of the important staple crop *Sorghum bicolor*. ~600 of these lines are undergoing full genome resequencing to catalogue all the mutations present in each with the goal of making this database and seed for each mutant line available to breeders worldwide. Novel mutations are already emerging from these data. The mutants in these lines include those that improve the digestibility of the cooked sorghum flour and they are characterizing these further (Project 37).

Another project in the lab examines how plants partition the carbon they fix during photosynthesis into different forms and different locations within the plant (Project 36). In corn, this is typically as starch in the kernels of the ear, but in close relatives of corn, 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 higher stalk sugar (as high as 20%) than is typical for corn and we are pursuing breeding strategies to better understand the genes responsible and their control of this process. Using association mapping in recombinant inbred lines they have identified three QTL for increased sugar content and they are now focused on identifying the genes underlying these QTL that impact sugar accumulation. In addition, they are pursuing a reverse genetic strategy to knock out specific invertase enzymes to increase stalk sugar.

In addition, the regulation of how carbohydrates are partitioned into seed, sugar or biomass is under

genetic control, but is poorly understood. Together with colleagues at the University of Missouri, the University of Florida, and St. Michael's College, a NSF-funded project is characterizing the contents, functions and genetic networks that characterize phloem function, carbon partitioning and yield. The Weil lab has now identified over 300 new mutants that impact carbon partitioning in maize. Mapping populations have now been made for these mutants, ten of them are mapped to candidate intervals in the maize genome and the genes are being pursued. Forty more will be mapped this summer (Project 35).

As a part of this project the Weil lab is collaborating with The Purdue Physiological Sensors group to develop in planta sensors of sucrose movement during growth of both maize and sorghum. Using a combination of Fluorescence Resonance Energy Transfer (FRET) sensor proteins specific for sucrose, fiber optic resins and the natural ability of aphids to insert their hollow stylets into phloem, they are developing the capacity to measure movement of sugar through the phloem tissue of the plants in real time in the field. These will be valuable for understanding carbohydrate movement and changes in that movement.

The Weil lab has continued to characterize mutant lines of corn that show altered starch digestion (Project 32) and, working with **Dr. Mauer**, altered near-infrared reflectance spectroscopy. Lines that showed preliminary evidence for altered digestion have been increased and are being screened in larger volume assays for confirmation. They are also mapping genes for variation in starch digestibility of both cooked and uncooked flour in diverse maize inbreds. One inbred is notable for the slower digestion of its cooked flour and they are beginning to identify the genes responsible using recombinant inbred lines.

They have developed a reliable, automated, scaled-down and high throughput protocol for these digestion assays. Working with Dr. Yao they have begun to examine starch structure in the endosperm of these lines. In addition, a detailed genetic map using ultra-high throughput DNA sequencing has been generated for the inbred in which digestion mutants were made. This map will facilitate the identification of genes altered in the mutant lines and their gene products.

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#### GENERAL RESEARCH AREAS

- Starch
- Carbohydrate chemistry

#### SPECIFIC RESEARCH AREAS

- Starch granule structure, reactivity, and behaviors
- Chemical and biological modifications of starch
- Structure-functional property relationships of polysaccharides
- Starch-hydrocolloid interactions
- Uses of carbohydrates in food and other commercial applications



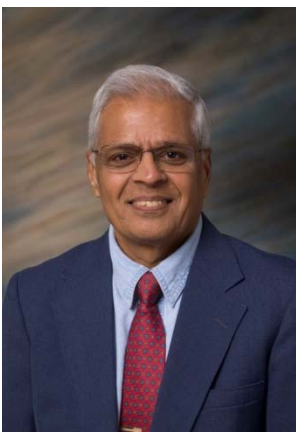
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#### GENERAL RESEARCH AREAS

- 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
- On-line 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



## Bruce R. Hamaker

### GENERAL RESEARCH AREAS

- Carbohydrates and health
- Starch
- Cereal chemistry and functionality

### SPECIFIC RESEARCH AREAS

- Starch digestion control, low glycemic response/slow digestion and physiologic response
  - Dietary fiber, modifications in functionality and colon fermentability, microbiota changes
  - Cereal starch and protein functionality
  - Functional properties influenced by starch fine structure
  - Interactions between starch and other food components
  - Appropriate methods of improving cereal utilization in developing countries
- 



## Srinivas Janaswamy

### GENERAL RESEARCH AREAS

- X-ray crystallography
- Biopolymers structure and functionality

### SPECIFIC RESEARCH AREAS

- Molecular structure, junction zone details of polysaccharides and polysaccharide blends and relationships to macroscopic behavior
  - Molecular dynamics simulations
  - Developing novel and cost effective delivery systems using food hydrocolloids
  - Tailoring polysaccharide structures for improved functionality
  - Biotexture of plant tissue derivatives
  - Starch crystallinity
  - Structure-function relationships in biomaterials
- 



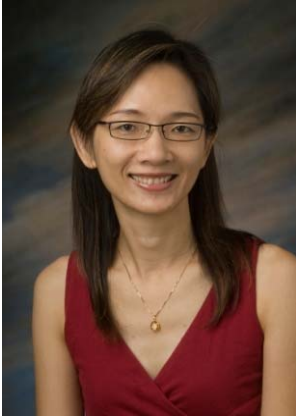
## Owen G. Jones

### GENERAL RESEARCH AREAS

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

### SPECIFIC RESEARCH AREAS

- Specific ion effects on milk protein-polysaccharide interactions
- Encapsulation methods for flavor oils using protein-polysaccharide structures
- Protein-fibril/polysaccharide electrostatic interactions for development of fibrous systems



## Amy Hui-Mei Lin

### GENERAL RESEARCH AREAS

- Starch structure
- Carbohydrates and health
- Polysaccharides and functionality

### SPECIFIC RESEARCH AREAS

- Starch granule structure
- Enzymatic modifications of starch
- Starch digestion



## Lisa J. Mauer

### GENERAL RESEARCH AREAS

- Food chemistry
- Food packaging

### SPECIFIC RESEARCH AREAS

- Water-solid interactions
- Deliquescence
- Crystallization
- FT-IR spectroscopy
- Structure-function relationships of food ingredients



## Ganesan Narsimhan

### GENERAL RESEARCH AREAS

- Emulsions and foams
- Biopolymer interactions

### SPECIFIC RESEARCH AREAS

- Pore formation by antimicrobial peptides in cell membranes and lipid bilayers
- 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
- Plant cell wall compositions, structures, and functions
- Bacterial cell wall compositions, structures, and functions

### SPECIFIC RESEARCH AREAS

- Extractions and purification of acidic polysaccharides from cell walls of plants and bacteria
  - Pectin analysis
  - Capsule, gum, and lipopolysaccharides analysis
  - Application of HPLC, GC-MS, and NMR to structural studies of carbohydrates, including polysaccharides
  - Role of polysaccharides in bacteria-legume symbiosis
  - Detection of bacteria in plant roots
- 



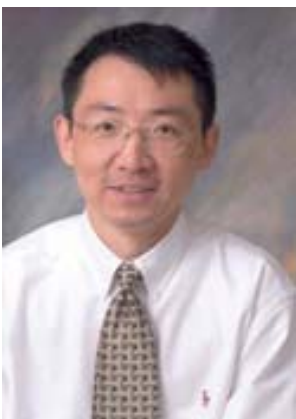
## Clifford F. Weil

### GENERAL RESEARCH AREAS

- Plant classical and molecular genetics
- Genomics of starch digestion, composition and architecture
- Genetics of carbohydrate redistribution in plants
- Gene expression
- Large-scale forward and reverse genetics screening
- Genome maintenance and organization

### SPECIFIC RESEARCH AREAS

- Rational redesign of corn starch composition
  - Sugar accumulation in grass crops
  - Genetic control of starch and protein digestibility in corn and sorghum
  - Genetic modification of corn starch properties
- 



## Yuan Yao

### GENERAL RESEARCH AREAS

- Carbohydrate chemistry
- Food nanotechnology

### SPECIFIC RESEARCH AREAS

- Dendrimer-like polysaccharides
- Food nanotechnology for enhanced food quality and safety
- Genetic, enzymatic, and chemical modifications of carbohydrates
- Novel process to control starch digestibility
- Functional emulsion systems

## ADJUNCT FACULTY

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**Yonas Gizaw, Ph.D.**, is a Principal Scientist at Procter & Gamble Global Research & Development.

### GENERAL RESEARCH AREAS

- Polymers, colloids and surfactants
- Self-assembly biopolymers
- Nanotechnology

### SPECIFIC RESEARCH AREAS

- Adsorption of polymers on colloids, vesicles, and emulsions
- Polyelectrolytes and surfactant interactions and functional properties of coacervates
- Surface modification and characterization
- Design, modification and application of starches in consumer products



**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), VP R&D (1995-2000), VP R&D 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.



## VISITING FACULTY

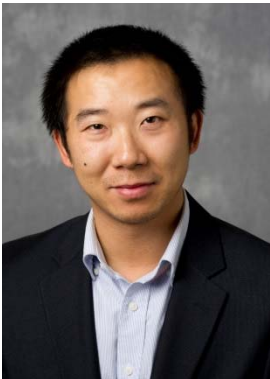
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**Edith Agama Acevedo** is Associate Professor at the Center for Development of Biotic Products of the National Polytechnique Institute-Mexico. She is on sabbatical with Dr. Hamaker along with her husband Dr. Arturo Bello-Perez. Her work is on hydrothermal treatment of high-amylose starches to develop slowly digestible property.



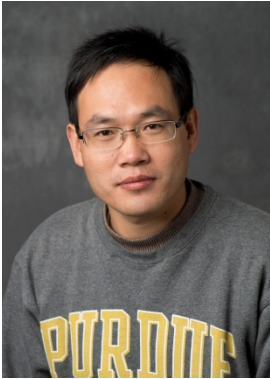
**Jinling Fan** is an Associate Professor of Food and Bioengineering College, Henan University of Science and Technology, China. She received her Ph.D. of Food Science from Jiangnan University, China. Her research is on phytochemical chemistry with a focus on food pigments and flavonoids. She joined Dr. Yao's lab in July 2010 as a visiting faculty with her research project focuses on development of strategies for incorporation and stabilization of flavonoids with carbohydrates. She returned to China in May.



**Tao Feng** earned his Ph.D. in Food Science from Jiangnan University of China in June 2007. He is an Associate Professor at Shanghai Institute of Technology in China. He arrived at Purdue University May 2012 as a visiting faculty in Food Science and is co-advised by Drs. Hamaker, Campanella, and BeMiller. His research focuses on molecular dynamics simulation of soluble nanoparticles self-assembled by amylose, beta-lactoglobulin (dimer) and free fatty acids and the effects of hydrocolloids on the pasting, paste, and gel properties of crosslinked starch.



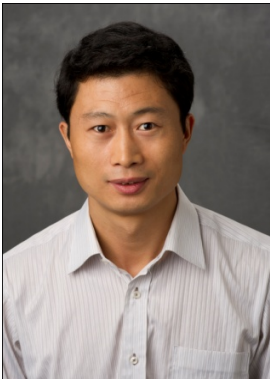
**Junrong Huang** is an Associate Professor at the Department of Food Science and Engineering, Shaanxi University of Science and Technology, Shaanxi Province, China. She received a Ph.D. degree from Wageningen University, The Netherlands and her other degrees at Jiangnan University, Wuxi, China. Dr. Huang was co-advised by Dr. Z. Jin at Jiangnan University, Dr. A.G.J. Voragen, and Dr. H.A. Schols at Wageningen University studying the properties and molecule structure of modified starches. Her current research focuses on enzymatic hydrolysis patterns on starch granules, starch granule organization, and textural properties influenced by starch fine structure. She was awarded a governmental scholarship by the China Scholarship Council to pursue her study in the USA for a year. Dr. Junrong Huang joined Dr. Hamaker's group for her sabbatical year (Aug 2011-Aug 2012).



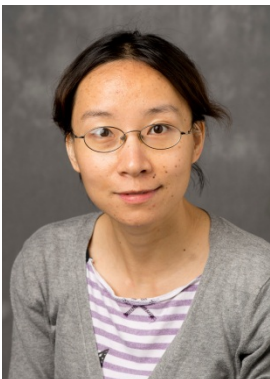
**Yuzhi Jiao** earned his M.S. in Food Science from Jiangnan University of China in June 2004. He is currently an Associate Professor of Jiangsu Food Science College in China. Yuzhi arrived at Purdue University in August 2012 as a visiting faculty in the Food Science Department and is advised by Dr. Amy-Lin. His research focuses on polysaccharide modification.



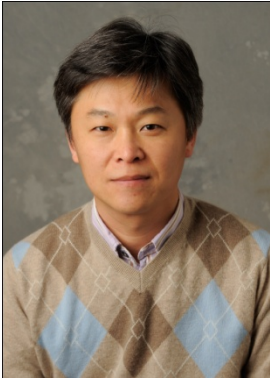
**Luis Arturo Bello Perez** is a professor of the Center for Development of Biotic Products of the National Polytechnique Institute-Mexico. He is well known and published in the area of starch chemistry, fine structure and functionality. He is on sabbatical with his wife, Edith Agama Acevedo, and is working on functional slowly digestible foods and is writing review articles and chapters in the field. He is in Dr. Hamaker's laboratory group



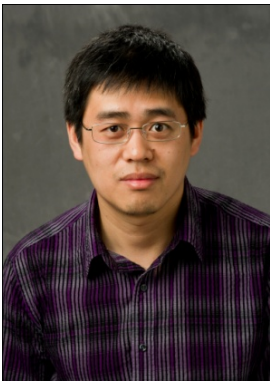
**Liqiang Wang** is an Associate Professor in the Department of Packaging Engineering at Jiangnan University, Wuxi, China. He received his Ph.D. degree in Agricultural Mechanization Engineering from Shenyang Agricultural University, Liaoning Province, China. He joined Dr. Campanella's group as a visiting faculty from August 2011 to August 2012. His research focuses on the performance of edible materials for food packaging. The aim of his project is to understand how viscoelastic properties of polysaccharides affect physical and mechanical characteristics, barrier and heat sealing properties, and packing performance of polysaccharide-based edible packaging films.



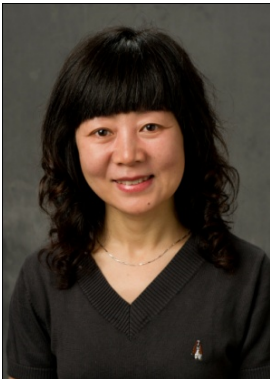
**Guangfeng Wu** earned her Ph.D. in Food Science from Jiangnan University in June 2002. She is an Associate Professor at the China Agricultural University. She arrived at Purdue University August 2012 as a visiting faculty sponsored by the Chinese government and is co-advised by both Dr. Hamaker and Dr. Campanella. Her research focuses on fine structure and rheological properties of alkali-extracted corn araboxylan.



**Sang-Ho Yoo** is an Associate Professor, Department of Food Science and Technology and Director of the Carbohydrate Bioproduct Research Center (CBRC) at Sejong University, Seoul Korea. He obtained his M.S. from Prof. Kwon Hwa Park's group at Seoul National University and Ph.D. under Prof. Jay-Lin Jane at Iowa State University. He is active in research using recombinant carbohydrate enzymes for synthesizing new glucan structures with novel applications.



**Ligang Zhang** is an Associate Professor and Associate Director of Food Science Department, Food College, Northeast Agricultural University, China. He received his M.S. Degree in Animal Nutrition and Feed Science and his Ph.D. of Dairy Science, Northeast Agricultural University, China. His research is on bioactive components extraction and function, mainly focusing on milk-borne growth factors, insulin-like growth factor I and transforming growth factor beta II. He joined Dr. Hamaker and Dr. Campanella's group as a visiting faculty. His research is focused on the properties of arabinoxylans of different molecular characteristics and how they affect the functionality in terms of viscosity and gelling properties. He returned with his wife, Yuhong Zhao, in August 2012.



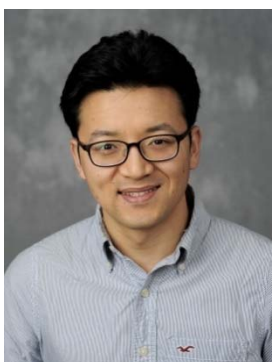
**Yuhong Zhao** received her M.S. and Ph.D. degrees in Food Science, from Northeast Agricultural University, Harbin, China. She is an Associate Professor of Food Science and Engineering Department at Northeast Forestry University, mainly focusing on extraction, separation, analysis and application of bioactive components of forestry products such as blueberry, pine nut and antler. She has joined Dr. Mauer's group as a visiting faculty. Her research project is on the effect of solid state formulation strategic on stability of curcumin. She returned with her husband, Ligang Zhang, in August 2012.

## VISITING SCIENTISTS

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**Mustapha Benmoussa** received his Ph.D. degree from Laval University (Canada) in Plant Molecular Biology. His Ph.D. research project was focused on potato flour viscoelastic proprieties improvement by expression of wheat glutenin in tubers. Mustapha spent two years working on corn storage proteins in the Pediatric Metabolism and Genetics Department, Indiana University as a post- doctoral Research Associate. He joined Whistler Center for Carbohydrate Research team, and he is now working on non-food applications of modified starches such as for wastewater treatment and microalgae flocculation.



**Wonjun Jung** is a senior researcher of the Food Starch and Sweetener Laboratory at the R&D Center, Daesang Corporation, South Korea. He received his B.S. and M.S. degrees in Food Engineering from Korea University in Korea. In 2005, he joined Daesang Corporation. He is in charge of development of food grade modified starches. He joined Dr. Hamaker's group in May 2012 and his research project focuses on effective development of xylose from corn bran.



**Phatcharee Kittisuban** earned a B.S. in Food Technology from Mahidol University in 2007. She is working on her Ph.D. in Biotechnology from Mahidol in the field of carbohydrate and hydrocolloids. Phatcharee's advisor is Assoc. Prof. Dr. Manop Supphantharika. Ms. Kittisuban came as a visiting scientist to Purdue University in July and returned home in December 2012, and worked with Dr. Hamaker and B.H. Lee on a project to increase slowly digestible starch content by enzyme modification.



**Sung Jun Ma** is a manager of the Food Starch and Sweetener Laboratory at the R&D Center, Daesang Corporation, South Korea. He received his M.S. degree in Chemical Engineering from Hanyang University. In 2005, he joined Daesang Corporation. He is in charge of development of functional oligosaccharides and high value by-products. He joined Dr. Hamaker's group in May 2011 and his research project focused on development of soluble dietary fiber from corn bran. He returned to Korea in April 2012.



**Sukanya Maicaurkaew** is a Ph.D. student from Department of Food Technology, Suranaree University of Technology, Nakhon Ratchasima, Thailand. She has a M.S. degree in food technology from Prince of Songkla University, Songkla, Thailand and has lectured at Suratthani Rajabhat University, Suratthani, Thailand. Sukanya's Ph.D. research project focused on pre- and postharvest changes of inulin in the Jerusalem artichoke. She joined Dr. Hamaker's lab in August 2011 for six months as a visiting scientist and returned home February 2012.



**Ilkem Demirkesen Mert** is a Ph.D. student at the Department of Food Engineering, Middle East Technical University, Turkey. She was awarded a governmental scholarship by The Council of Higher Education to continue her research work in the USA. She joined Dr. Campanella and Hamaker's group as a visiting scholar September 2011 to August 2012 with her research project focused on optimization of gluten-free bread formulations to be baked in infrared-microwave combination oven. Ilkem also worked on the development of methodologies to use nanoparticles to bind and mask bitter flavors in beverages such as coffee.



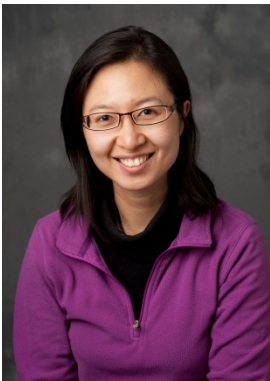
**Julian De La Rosa Millan** received his B.S. in Biochemical Engineering from the Technologic Institute of Acapulco and his M.S. degree from Development Center of Biotic Products (DCBP), Mexico. He joined Dr. Jay-Lin Jane's group at Iowa State University as a visiting scholar during his M.S. program for 5 months. In 2009, he started his Ph.D. in DCBP. He worked at Purdue on enzymatic hydrolysis patterns on starch granules, starch granule organization and fine structure, and textural properties of thermal treated plantain starches. He joined Dr. Hamaker's group in 2011 as a visiting scientist and returned to Mexico in August 2012.



**Rándol J Rodríguez** was an undergraduate student in the Food Science Department of Zamorano University, Honduras. His graduation project was on the quality control of a tomato sauce process line by analyzing thermal treatment effect on non-starch polysaccharides and physical characteristics. In addition he has a background in agriculture with expertise on hydroponic tomato and pepper crops. He worked under Dr. Yao on the structural analysis of starch, specifically, the chain length distribution of starch, and has recently joined his group as a M.S. student.



**Yu-Ting Tseng** received a B.S. degree in Food Science from National Taiwan Ocean University in 2010. She studied as a M.S. student in Institute of Bioscience and Biotechnology, National Taiwan Ocean University from 2011. Yu-Ting came to Purdue as a visiting scientist in 2012. She is working with Dr. Yao on analysis of starch.



**La-ongdao Wongekalak** joined Dr. Hamaker's lab as a visiting scholar from January - August. She is a Ph.D. student from Kasetsart University, Bangkok, Thailand with support from Royal Golden Jubilee Ph.D. Program and Kasetsart University. Her research was on optimization of a process to incorporate asiatic acid with mungbean protein hydrolysate using different carbohydrate excipient. She was at the Whistler Center for 6 months and returned to Thailand in August.



**Lan Yao** completed her B.S. in Food Quality and Safety from Shenyang Agricultural University in 2010 in China. She completed her M.S. in Food Science in August and now is a Ph.D. candidate in Shenyang Agricultural University. She joined Dr. Yao's Lab in 2012 as a visiting scientist. Lan's research focuses on the mechanism and effect of modified nanoparticle-starch Structures and encapsulation efficiency of drugs.



**Haining Zhuang** earned her Ph.D. in Food Science from Jiangnan University (China) in June 2011. She is a lecturer in Shanghai Institute of Technology. She arrived at Purdue University in May 2012 as a visiting scientist at the Whistler Center and is advised by Dr. BeMiller. Her research focuses on interactions between crosslinked starch and various hydrocolloids.

## GRADUATE STUDENTS

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**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 is pursuing a M.S. degree in Food Science. His main research focuses on optimizing methods to measure deliquescence and determine the effects of capillary condensation on the deliquescent point.



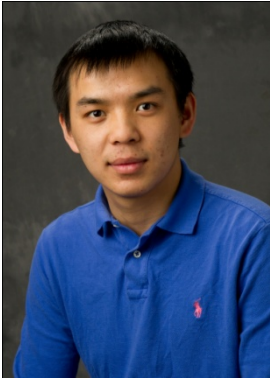
**Deepak Bhopatkar** obtained his B.S. in Agriculture Science from Jawaharlal Nehru Agriculture University, India and an M.S. in Food and Bioprocess Technology at the Asian Institute of Technology, Thailand. His master research was on application of the biopolymer chitosan for controlled drug delivery. He joined Dr. Hamaker and Campanella's groups for his Ph.D. studies and is doing his research on a soluble nanoscale three-component complex, its mechanism of formation and potential carrying capacity for hydrophobic fourth components. Deepak joined Mead Johnson as Senior Product Development Scientist with the North America Division in September, 2012.



**Patrick Breen** received his B.S. in Biosystems Engineering in December 2009 from Michigan State University. His research topic was "Genetic Control of Starch Digestion". Patrick left the Center in May.



**Mohammad Chegeni** completed his B.S. in Biology from Ferdowsi University in 2002 in Iran. After that, he did his Master's work in Public Health at Ball State University. He joined Dr. Hamaker's group on January 2010 and started his Ph.D. on August 2010. His research focuses on gut enterocyte maltose sensing and sucrose-isomaltase maturation and trafficking with the aim of controlling glucose delivery to the body.



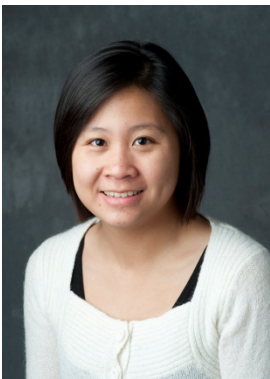
**Hector Chang** received a B.S. degree in Agricultural and Biological Engineering (2009) in the field of Biological and Food Processing Engineering from Purdue University. During his undergraduate studies he worked with Dr. Campanella in rheological studies of refrigerated dough. He obtained his M.S. degree in August 2012 in Engineering and worked under Dr. Narsimhan to understand the conformation changes of anti-microbial peptides on a silica surface using molecular dynamics simulation. Hector left to work for M&M Mars in August.



**Hua Chen** received her M.S. in 2009 from the Department of Food Science of South China University of Technology. She joined Dr. Yao's lab in 2009 and is currently a Ph.D. student. Her thesis focuses on the structure of native and modified carbohydrate nanoparticles and their functional properties such as digestibility, interfacial adsorption, and controlled delivery of lipophilic compounds.



**Tingting Chen** received her B.S. and M.S. degree in Food Science and Technology from Nanchang University. Her M.S. study was on immunoassay development for small-molecular food contaminants. She joined the Dr. Hamaker's group and started her Ph.D. in August 2011 with a governmental scholarship from the China Scholarship Council. Her Ph.D. research focuses on dietary fiber structure and colon health.



**Belinda Christina** is from Indonesia and graduated from Purdue University in 2011 with a B.S. in Food Science. After graduation Belinda worked as a Product Developer Intern in the Kellogg Company, Global Cereal Department. She then worked in PepsiCo, Quaker Group as a Product Development Contractor, developing new and improved cereal bars. In Fall 2012 she returned to Purdue to pursue her Master's degree in food chemistry in Dr. Mauer's lab. Her research focuses on solid dispersion techniques and manipulation of crystalline and amorphous structures.

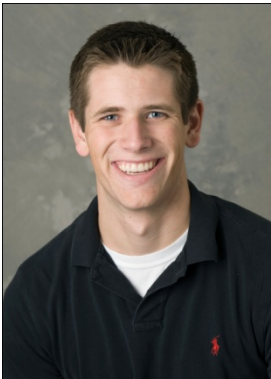




**Fatimata Cisse** received her M.S. Degree in Food Science and Technology from the Department of Technology and Management of Production, Academy of State of Food Products of Moscow, Russia in 1997. After that she worked in the Food Laboratory of Rural Economic Institute of Mali where she is still employed. In January 2010 she joined Dr. Hamaker's group for a M.S. degree funded by USAID Mali. Her research has focused on the relationship between African traditional starchy foods and gastric emptying, satiety and energy delivery. She converted to the Ph.D. program by passing the requirements for by-pass in the fall 2012 and is now working on a project with field study in Mali funded by the Bill & Melinda Gates Foundation.



**Necla Mine Eren** received a B.S. degree in Food Engineering from Ankara University, Turkey in 2009. She worked for Sakarya University, Turkey as a research assistant for 10 months. Necla came to Purdue in 2010 as a M.S. student with a scholarship from Ministry of National Education, Republic of Turkey. She completed her master on physicochemical properties of food gels in 2012 under the advice of Dr. Campanella. She is now working with Dr. Campanella on her Ph.D.



**Daniel Erickson** earned his B.S. in Chemical Engineering from Iowa State University in May 2010. He arrived at Purdue University in August 2010 and is co-advised by both Dr. Hamaker and Dr. Campanella. His research focuses on functionalizing non-wheat cereal proteins to behave as viscoelastic aggregates for breadmaking and other applications within the gluten-free and functional protein areas. Daniel by-passed his M.S. degree in 2011 and is currently a Ph.D. student.



**Mehtap Fevzioglu** completed her B.S. and M.S. degrees in Food Engineering from Hacettepe University, Turkey. Her M.S. thesis research explored the effects of infrared treatment on the main constituents of rice and barley samples. She came to Purdue in 2008 as a Ph.D. student with a scholarship from the Ministry of National Education, Republic of Turkey. She is working with Drs. Campanella and Hamaker and completed her PhD in December 2012 and continued as a Post-Doctoral Research Associate. Her research focuses on the structure and function of corn zein protein.



**Morgan Goodall** received her B.S. in Food Science from Purdue University in 2010. She joined Dr. Hamaker's lab as an undergraduate working on understanding the use of a high digestibility/high-lysine sorghum mutant in bread formulations. Her M.S. studies focus on the protein structural and functional effects of incorporating high percentages of this sorghum mutant cultivar into wheat bread with potential application in sorghum-growing regions of Africa. Morgan graduated in June and is working for General Mills.



**Stacey Hirt** received a B.S. in Food Science from Purdue University in 2011. She is continuing her M.S. research with Dr. Jones. Her research focuses on stability of beta-lactoglobulin and pectin systems to the Hofmeister series of salts.



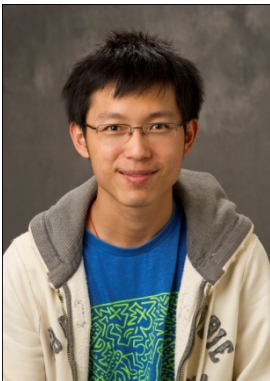
**Madhuvanti Kale** received her B.S. degree in Food Engineering and Technology from the Institute of Chemical Technology, University of Mumbai (formerly known as UDCT) in May 2008. She joined Dr. Hamaker and Campanella's lab in August 2008 for a Master's degree which she later by-passed to a Ph.D. program, and is under the co-advisement of Dr. Campanella. Her research focuses on structure-function relationships of corn bran arabinoxylans.



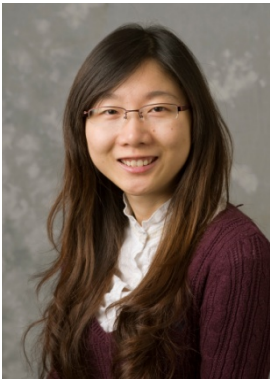
**Amandeep Kaur** is a veterinary graduate who obtained her Bachelor's degree from Punjab Agricultural University, India. She worked on verotoxigenic *Escherichia coli* during her Master's with epidemiology and preventive veterinary medicine as her major and veterinary medicine as her minor field, respectively. After being awarded a Ross Fellowship she joined Dr. Hamaker's group as a Ph. D. student in August 2007. The focus of her research was on dietary fiber and colon health. Amandeep graduated in August and lives in the Washington, D.C. area.



**Lisa Lamothe** is originally from La Ceiba in Honduras. In 2006, she received her B.S. degree in Food Science & Technology from Zamorano University where her research focused on the prevention of lactose crystallization in two formulations for milk jam varying in total solids content. Lisa received her M.S. degree in 2009 with Dr. Hamaker where she worked on the development of a screening method using NIR spectroscopy for the selection of breeder-improved popcorn lines. After graduating she worked as a Quality Control Supervisor for one of Cargill Meats Central America's meat processing facilities in Honduras. After one year at this position, she returned to pursue her Ph.D. degree and is studying the modification of dietary fiber solubility and fermentability characteristics of alternative grain sources.



**Kin Lau** earned his B.S. degree in Biology from Davidson College in May 2010 where he conducted research in synthetic biology using *E. coli* as a model organism. He is currently pursuing a Ph.D. in Plant Breeding and Genetics in the lab of Dr. Weil. His main project is to identify modifiers of certain developmental mutations and to map and clone those modifier genes.



**Na Li** received her B.E. in Food Science and Engineering, from South China University of Technology, Guangzhou, China. She joined Dr. Mauer's group in August of 2009 in pursuit of a M.S. degree and will take a by-pass to the Ph.D. program. Her research mainly focuses on the physical and chemical stability of green tea catechins.



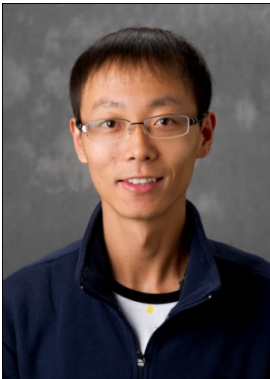
**Rebecca Lipasek** graduated from Purdue University in 2008 with a B.S. in food science and minor in chemistry. She went to work for PepsiCo-Gatorade as a supply chain associate, working on new product launches and process and quality improvement. Rebecca then returned to Purdue and completed her Ph.D. in December 2012. Her research area focused on the effects of relative humidity, temperature, time, particle size, and formulation on the deliquescence of various crystalline solids, including multiple forms of vitamin C. Rebecca is now working for Hershey.



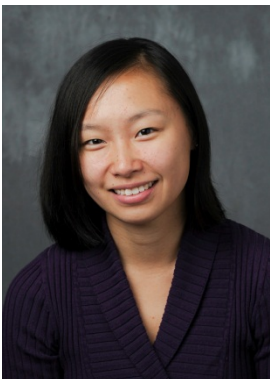
**Krystin Marrs** received a BSA in food science and a BSAB in applied biotechnology from the University of Georgia in May 2010. She arrived at Purdue University in August 2011 in pursuit of an M.S. degree in Food Science under Dr. Lisa Mauer. Her research focuses on the physical and chemical stability of amorphous and crystalline powders.



**Lohit Myneedu** received his Master's Degree in Food Science from JNTU - Oil Technological Research Institute, Anantapur, India. His thesis was on Development of Emulsion meat products from a combination of fish and chicken byproducts at the National Research Center on Meat, India. He joined Dr. Srinivas Janaswamy's lab as a M.S. student in May 2012. His Masters research is on developing hydrocolloid-based delivery vehicles for nutraceuticals, and possibly, probiotic applications.



**Xin Nie** earned his B.S. and M.S. degree in the department of Chemistry from China Agricultural University. He joined Dr. Hamaker's group as a Ph.D. student in August 2011 and was awarded a China Scholarship Council government scholarship. Xin's research project mainly focuses on dietary fiber's structure-function relationships for colon health.



**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 to pursue a M.S. degree. She is working with Dr. Hamaker on the physiological effects of glycemic carbohydrates.



**Preetam Sarkar** received his M.S. in 2010 from California State University-Fresno. He joined Dr. Yao's lab in 2010 as a Ph.D. student. His thesis focuses on the interaction between bioactive compounds (such as antimicrobial peptides) and carbohydrate nanoparticles in emulsion and non-emulsion systems.



**Meric Simsek** completed her M.S. degree in Food Engineering from Middle East Technical University in 2010 where she worked with the Microwave Processing Research Group. She received her B.S. degree in Food Engineering from Gaziantep University in 2007. She is currently doing her Ph.D. supported by a scholarship from Ministry of National Education, Republic of Turkey. Since September 2010 she has been working with Dr. Hamaker on the inhibition of human intestinal glucosidases for control of glycemic carbohydrate digestion.



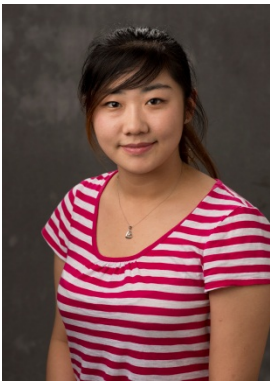
**Stephany Tandazo** graduated from Texas A&M University in May 2010 with a B.S. in Chemical Engineering and a minor in chemistry. Stephany is working with Drs. Campanella and Hamaker. She joined the group in August 2010 to pursue her M.S. in Agricultural and Biological Engineering. Her research focuses on corn zein protein functionality in doughs. Stephany will complete her degree in 2013 and is currently employed by Frito Lay.



**Yunus Emre Tuncil** got 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. degree in the USA by the Turkish Government. He joined Texas A&M University Food Science and Technology Department as a M.S. student in 2010 in where he studied on the effects of wheat proteins on dough rheological properties. He arrived at Purdue University in August 2012 in pursuit of a Ph.D. and is advised by Dr. Hamaker. His research focuses on dietary fiber structure and its effect on colon health. As a side project, he is conducting research on the function of sorghum kafirin proteins.



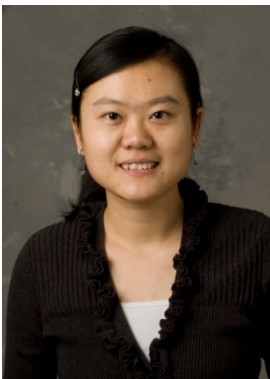
**Megan West** received her B.S. in Biochemistry from Purdue University in 2008. She completed her PhD at Purdue University in December 2012. Her research focused on the stability of bioactive food components in powdered systems, with an emphasis on anthocyanins. Megan interning at the EPA.



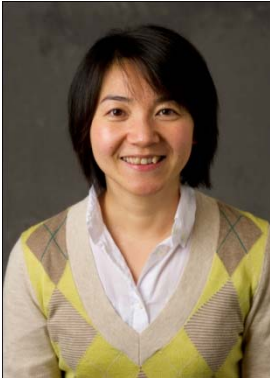
**Xi Wu** earned her B.S. degree in the Department of Applied Chemistry from China Agricultural University in July 2011. She joined Dr. Narsimhan's group in January 2012 to pursue a Ph.D. degree in the Department of Agricultural and Biological Engineering and is working on investigation of pore formation in cell membrane by synthetic antimicrobial peptides.



**Ying Xie** received her M. S. degree in Processing and Storage of Agriculture Products from China Agricultural University. She joined Dr. Yao's group and started her Ph. D in August 2012 with a governmental scholarship from China Scholarship Council. Her Ph.D. research focused on modified carbohydrate nanoparticles and their functional properties.



**Haidi Xu** received her B.S. degree in Food Science and Engineering from Beijing Forestry University and her M.S. degree from the College of Food Science and Nutritional Engineering, China Agricultural University. She was awarded a government scholarship by the China Scholarship Council to pursue her Ph.D. degree in the USA. Haidi joined Dr. Hamaker's group in August 2008 and her research project focuses on dietary fiber chemistry and structure-function relationships related to colon fermentation. She also worked under the advisement of Dr. Reuhs and in collaboration with Dr. Eric Martens at the University of Michigan Medical School. Haidi graduated and has joined in General Mills in Shanghai.



**Like Yan** graduated from Shanghai University of Science and Technology with a B.S. in Food Science and Technology from Iowa State University with M.S. degrees both in Food Science and Nutrition. Her food science thesis was on shelf life of toasted soyflakes and their application in breadmaking, tofu color prediction from the soybeans and soyflakes color. She joined Dr. Hamaker's lab for her Ph.D. and is doing research on slowly digestible starch and its physiologic and health effects. She works on a collaborative project with faculty from Purdue's Department of Psychological Sciences (Drs. T. Powley, R. Phillips, and K. Kinzig), as well as with Dr. Buford Nichols at Baylor College of Medicine, Houston.



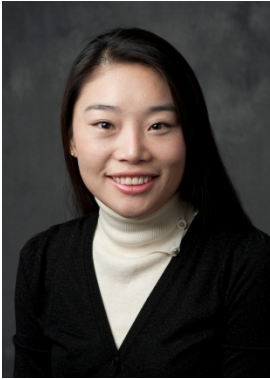
**Laura Zimmerer** received a B.S. degree in Food Science and Technology and a minor in Chemistry from Texas A&M University in 2011. Laura came to Purdue in 2011 as a M.S. student with the Purdue Industry Fellows Program. She is working with Dr. Jones on the encapsulation of flavor oils utilizing beta-lactoglobulin and pectin systems.

### *Ph.D. Post-Doctoral Research Associates*

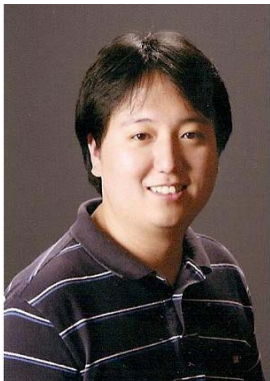
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**Mohamed Ghorab** received a B.S. in Pharmaceutical Sciences from Cairo University, Egypt and his Ph.D. in Pharmaceutics from Duquesne University, Pittsburgh, PA. After completion of his doctorate degree, he worked for over five years in the Solids-Pharmaceutical R&D Department at Wyeth, Pearl River, NY and was also an Adjunct Assistant Professor at Arnold and Marie Schwartz College of Pharmacy and Health Sciences, Long Island University, NY. In 2007, Mohamed became Associate Professor in the Pharmaceutics and Industrial Pharmacy Department at Helwan University, Egypt. He joined Dr. Lisa Mauer's lab and Dr. Lynne Taylor of the Industrial and Physical Pharmacy Department at Purdue in 2010 as a Post-Doctoral Research Associate. His research focuses on understanding the interaction between amorphous and crystalline deliquescent-possessing food and pharmaceutical ingredients and the impact of relative humidity on their behavior in mixtures. He left Purdue in July 2012 and is working for the FDA.



**Choon Young Kim** received her Ph.D. in Food Science from Purdue University in December 2011. Her Ph.D. research was identification of anti-obese dietary components and characterization of their molecular mechanisms. She joined Dr. Hamaker's group as a Post-Doctoral Research Associate in August 2012. Her research focuses on physiological responses of slowly digestible carbohydrates.



**Byung-Hoo Lee** received his B.S. and M.S. in Food Science and Technology from Sejong University in Korea. His M.S. research was characterization of carbohydrate-active enzymes and application to various corn starches. In August 2008, he joined Dr. Hamaker's group. His Ph. D. research was on structural changes of enzyme modified-starches and digestion patterns of the mammalian mucosal glucogenic enzymes with application to the area of slowly digestible carbohydrates. Byung-Hoo completed his Ph.D. in May 2012 and currently a Post-Doctoral Research Associate with Dr. Hamaker.



**Bhavesh Patel** received a B.S. degree in Dairy Technology from Gujarat Agricultural University, Anand, India and a M.S. degree in Food Technology from Central Food Technological Research Institute (CFTRI), Mysore, India. His Ph.D. in Food Science was from Pennsylvania State University where his research involved study of starch and polysaccharide structures, and effect of processing conditions on thermal and physical properties. Bhavesh joined Dr. 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, and has worked on fiber rheology and incorporation into processed foods and gel formation kinetics. Currently Dr. Patel is working in a project related to enzymatic conversion of complex polysaccharides into ethanol in collaboration with Dr Campanella.



**Tobias Wojciechowski** received a Ph.D. from the University of Reading/Scottish Crop Research Institute (SCRI), UK in July 2010. Tobias began at Purdue University in July 2011 working with Dr. Clifford Weil on carbohydrate partitioning in maize focusing on gene discovery and sink tissues. Tobias left the Center in December for Forschungszentrum Jülich GmbH where he is managing a laboratory.

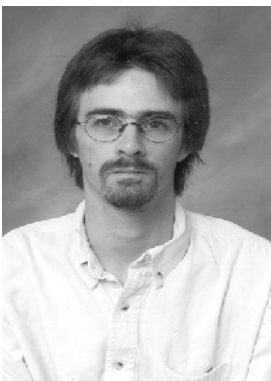




**Xiaoyu Wu** earned his B.S. degree from the Department of Chemical Engineering in July 1999 and a M.S. degree from the Department of Biological Sciences and Technology at Tsinghua University. His M.S. research involved the stability of endostatin, an angiogenesis protein, under different conditions. He joined Dr. Narsimhan's group in August of 2004 to earn a Ph.D. degree and working on determining the properties of selected proteins on different interfaces. Xiaoyu continues at Whistler Center as a Post-Doctoral Research Associate.

### *Research Staff*

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**Dave Petros** received his B.S. and M.S. in Biochemistry from Purdue University and was the Cereals Lab Research Assistant in the Hamaker lab and provides assistance in other areas of the Whistler Center. Dave left Whistler Center in October to work in another department at the University.



**Anton Terekhov** joined Dr. Reuhs' group as a Research Assistant in 2005. He is proficient in analytical chemistry, molecular biology techniques and analytical instruments such as NMR, GCMS, LCMS and FTIR. Anton has seven years of experience in an interdisciplinary laboratory environment including the fields of analytical chemistry, microbiology, genetics, geology, chemical and civil engineering.

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## PROJECT SUMMARIES

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### 1. Impact of the Order of Addition of Reagent and Catalyst in Starch Modification: Wheat Starch

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**P.I.:** J. BeMiller

**Researcher:** Zhongquan Sui, Ph.D. Research Associate

**Collaborator:** Kerry C. Huber, University of Idaho

**Sponsor:** USDA-AFRI

**Objective:** To investigate the impact of allowing rapidly reacting reagents to infiltrate the matrix of wheat starch granules prior to initiation of reaction by adjustment of pH, in contrast to adjusting the pH before adding the reagent as is normally done.

**Progress:** Examined were reactions of commercial and laboratory-isolated normal wheat starch and laboratory-isolated waxy wheat starch. The 3 starch preparations were each reacted with 3 crosslinking reagents (acetic-adipic mixed anhydride [AAMA]), phosphorus oxychloride [ $\text{POCl}_3$ ], and sodium trimetaphosphate [STMP]), the first 2 of which, at least, are thought to be very reactive, and 3 stabilizing reagents (acetic anhydride [AA], succinic anhydride [SA], and octenylsuccinic anhydride [OSA]), all of which are believed to be quite reactive. Two different derivatization methods were used: 1) the starches were reacted with the reagents in the conventional way, i.e., using standard derivatization reaction procedures (SDR method), and 2) the reagents were given the opportunity to impregnate granules for 3 h prior to adjusting the pH to the required value so that reactions with the rapidly reacting reagents might be more uniform throughout the granules (TRF method = treatment with reagent first method). The products were characterized by RVA and DSC analysis.

Preliminary analysis of the data indicated that the results were similar to those obtained with corn starches (Project 2).

**Status:** Active. Data being analyzed. Manuscript in preparation.

### 2. Impact of the Order of Addition of Reagent and Catalyst in Starch Modification: Corn Starch

---

**P.I.:** J. BeMiller

**Researcher:** Zhongquan Sui, Ph.D. Research Associate

**Collaborator:** Kerry C. Huber, University of Idaho

**Sponsor:** USDA-AFRI

**Objective:** To investigate the impact of allowing rapidly reacting reagents to infiltrate the matrix of corn starch granules prior to initiation of reaction by adjustment of pH, in contrast to adjusting the pH before adding the reagent as is normally done.

**Progress:** Laboratory-isolated and commercial normal and waxy maize starches were each reacted with the same 3 crosslinking reagents and the same 3 stabilization reagents in the same ways described in Project 1, and the products were characterized as described in Project 1. Almost no starch polymer molecule modification occurred when the TRF method and AAMA, AA, or  $\text{POCl}_3$  were used; less than half as much reaction when SA was the reagent used, and about the same amount of reaction when STMP or OSA were the reagents used (for different reasons). It was speculated that most AAMA, AA, SA, and  $\text{POCl}_3$  reacted with surface protein molecules when the TRF method was used. It is speculated that, when either method was used and OSA was the reagent, reagent OSA molecules were driven into the structured internal water in the micropores of hydrated granules because the negative entropy and the free energy differences associated with dissolution in this pre-ordered water was less than that associated with dissolution in the bulk-phase water, making it a favorable process.

**Status:** Manuscript submitted.

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### 3. Effect of the Amylose Content of Starch on Starch-Hydrocolloid Interactions

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**P.I.:** J. BeMiller

**Researcher:** Hyun-Seok Kim, Ph.D. Research Associate

**Sponsor:** Whistler Center for Carbohydrate Research

**Objective:** To investigate the importance of the amylose-amylopectin ratio of the starch on starch-hydrocolloid interactions in excess water.

**Progress:** Combinations of 4 rice starches with amylose (AM) contents of 0%, 15%, 22%, and 28% and 8 hydrocolloids (xanthan; guar gum; CMC; sodium alginate; HPMC; kappa-, iota-, lambda-type carrageenans) were used (4.75% starch and 0.25% hydrocolloid). With a few exceptions, addition of a hydrocolloid increased peak and final viscosities, breakdown, setback, loss modulus ( $G''$ ), complex/frequency-dependent viscosity ( $\eta^*$ ),  $K$ , and apparent viscosity ( $\eta_{a,100}$ ) values. It is concluded that the AM content of the starch was a greater determinant of pasting, paste, and gel properties than was the added hydrocolloid at the 19:1 w/w starch-hydrocolloid ratio used. Reinforced is the previous conclusion that the properties of a starch-hydrocolloid combination are determined by the specific combination.

**Status:** Active. Data being analyzed. Manuscript in preparation.

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### 4. Effect of Controlling the Swelling of Starch Granules via Crosslinking on Starch-Hydrocolloid Interactions

---

**P.I.:** J. BeMiller

**Researchers:** Tao Feng, Ph.D., Visiting Faculty; Haining Zhang, Ph.D., Visiting Scientist

**Objective:** To investigate whether hydrocolloids change the pasting and paste properties of a starch by effecting changes in granule swelling.

**Progress:** Normal corn and waxy maize starches were crosslinked with  $\text{POCl}_3$  to make products with higher peak viscosities (greater granule swelling) and products with lower peak viscosities (restricted granule swelling). The native and the four crosslinked starches were subjected to RVA analysis in the presence of 8 hydrocolloids (xanthan, guar gum, sodium alginate, CMC, HPMC, and kappa-, iota-, and lambda-type carrageenans). Following RVA analysis, the resulting gels were subjected to dynamic rheological analysis to determine loss and storage moduli, loss tangent, and complex viscosity values and to steady shear analysis to determine  $K$ ,  $n$ , and  $\eta^*$  values. The large amount of generated data is being analyzed. An example follows.

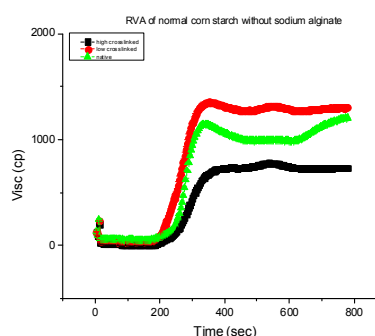


Figure 1

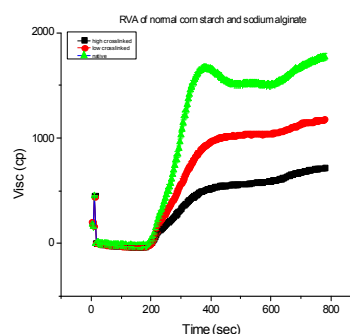


Figure 2

Results of RVA analysis of native and crosslinked normal corn starch in water are given in Fig. 1. (The middle profile in Fig. 1 is that of the native/unmodified normal corn starch. The top profile is that of the same starch lightly cross-linked, and the bottom profile is that of the same starch more highly cross-linked.) RVA analysis in the presence of sodium alginate (Fig. 2) revealed substantially reduced peak viscosities for the two cross-linked products, both being reduced by 37%, while the effect of the hydrocolloid on the native normal corn starch was to increase peak viscosity by

47%. (Now, the top profile is that of the native/unmodified normal corn starch; the middle profile is that of the same starch lightly cross-linked, and the bottom profile is again that of the same starch more highly cross-linked.)

**Status:** Active. Data being analyzed.

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## 5. Enhancing the Functional Properties of Hydrocolloids, Including Their Synergistic Action in the Presence of Other Hydrocolloids

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**P.I.:** O. Campanella

**Researcher:** Necla Mine Eren, M.S. Student

**Sponsor:** Government of Turkey

**Objectives:** 1) Characterize the physicochemical and molecular characteristics of hydrocolloids that have been subjected to high shear/pressure treatments, 2) Investigate the stability of physicochemical and molecular properties during storage at different pressures, and 3) Study changes in the synergistic properties of hydrocolloids that have been physically and enzymatically modified to enhance their functional properties.

**Progress:** Industrial and scientific interest related to the mechanical modification of biological polymers has been active given the potential of increasing their functionality. High pressure homogenization is recognized as a convenient tool to provide those mechanical forces. However, controlling parameters of the process have not yet been studied in great detail. Xanthan gum solutions subjected to high pressure homogenization showed a decrease in viscosity and elasticity upon treatment. This was attributed to an increase of maximum packing of molecules with a wider distribution in molecular weight and sizes created by the high pressure process. Treated samples were studied by rheological methods and physicochemical properties were determined by size-exclusion chromatography (SEC), multi-angle laser scattering (MALS), and circular dichroism (CD). Stress relaxation was a useful test to gain insight on the molecular characteristics of the treated samples, in particular when they are forming solutions and/or gels. Viscoelastic behavior measured over a temperature range showed that high pressure treatment increases sensitivity of solution viscoelasticity with

temperature. CD spectra of treated samples supported the hypothesis that a less structured and more disordered network resulted from high pressure homogenization. Measurements of viscosity and viscoelasticity over a period of 11 weeks, at two different temperatures (4 and 25°C), showed that the rheological characteristics of the treated xanthan gum and control did not vary through the storage time, which indicated that modifications in the structure of xanthan gum molecules were irreversible. Prolonged storage resulted in significant precipitation of solutions mainly those obtained by high pressure treatment. SEC analysis showed that precipitate contained larger fractions with larger molecular weight than the supernatant, for the highest pressure-treated samples. However, samples of the control group, did not precipitate and had the same average molecular weight independent of the location of the test tube, which indicates that the applied shear created a new dispersion that was able to sediment naturally from the solution. Overall, the results demonstrated a new way of modifying xanthan gum properties and are may be helpful in developing new value-added functional foods. The same approach will be used to physically modify fibers.

**Status:** Completed

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## 6. Experimental and Modeling of the Gelation Phenomenon

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**P.I.s:** O. Campanella and M. Carignano  
(Northwestern University, Chicago)

**Researcher:** Necla Mine Eren, Ph.D. Student

**Sponsor:** Multidisciplinary Research Initiative (MURI)

**Objectives:** 1) Understanding the effect of colloidal nanoparticle interaction on physicochemical properties of soft materials. 2) Application of the colloidal nanoparticle interactions to obtain the soft materials at targeted material properties.

**Progress:** Gelation mechanism of particles with short range attraction has been examined theoretically by molecular dynamic simulations. Three parameters of the onset of gelation were found to affect the gel properties, (1) the volume fraction ( $\Phi$ ), (2) the ratio of interparticle attraction ( $U$ ) to thermal energy ( $k_b \cdot T$ ) and (3) the range of

attraction potential ( $x$ ). By using Brownian dynamics simulations, it has been shown that effective attractive range is an important factor affecting the viscoelastic characteristic of gel systems. Even though work on gelation mechanism was supported with experiments by the same research group, the relation between short range attractions and viscoelasticity still needs to be examined by experimental approaches, in which the first part of this research is focusing.

The first experimental approach aims to investigate the relation between the effective attractive range and viscoelastic properties of hybrid gel (colloidal nanoparticle) systems. Hydrophilic Aerosil Fumed Silica (average primary particle size 12 nm) was mixed with alfa-lactalbumin (average primary particle size 1 nm) at different concentrations. Significant changes in viscoelastic properties were observed upon the addition of the nanoparticle at very low concentrations. Atomic Force Microscopy (AFM) and Dynamic Light Scattering are being used to explain the changes in viscoelastic properties. Once an experimental relationship, already obtained theoretically, is obtained, it may be used to lead new studies regarding the incorporation of high energy nanoparticles such as alumina in fuel systems with high stability.

The second experimental approach is to use colloidal-nanoparticle interactions in food packaging. A conservative approach of the food industry to use nanoparticles and the lack of information on colloidal nanoparticle interactions is one of the reasons that keep the food industry behind the trend of nanotechnology. Food packaging might be a good starting point before moving to edible foods. Mechanical properties, oxygen, carbon dioxide and water vapor permeability of hydroxy methyl propyl cellulose (HPMC) films are being tested. The second step is the incorporation of nanoparticles into the HPMC films to improve the mechanical and barrier properties of films.

**Status:** Active

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## 7. Development of Edible Materials for Food Packaging

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**P.I.:** O. Campanella

**Researchers:** Ligang Wang, Visiting Faculty, Northeast Agriculture University, Bhavesh Patel, Ph.D. Research Associate

**Sponsor:** Available for sponsorship

**Objective:** To develop edible packaging material with good mechanical properties.

**Progress:** Sodium alginate-based edible films were prepared from blends containing sodium alginate, plasticizers, and other biomaterials such as carboxymethyl cellulose and gelatin. Rheological properties of the blend solutions were studied at 25°C using steady shear and dynamic oscillatory measurements. The intrinsic viscosities of solutions formed with pure sodium alginate (SA) solution, pure sodium carboxy-methyl-cellulose (CMC), pure gelatin, and a blend of these materials were also studied. Solutions of the blends exhibited shear-thinning behavior over a range of shear rates between 0.1 and 1000 s<sup>-1</sup>. The effects of temperature on viscosities of all solutions was also determined. Results from viscoelastic tests showed that the blend solutions with a total solid content of 4.5% (w/w) exhibited viscoelastic behavior. Films from these solutions were prepared and characterized for tensile strength, percent elongation, creep compliance, relaxation modulus, and glass transition temperature. An optimization of the formulation involved the screening of 17 blending SA/SCMC/gelatin ratios, using glycerol as the plasticizer. Work is being carried out to incorporate cinnamaldehyde and nisin in different proportions with the aim of preparing controlled-release carriers of natural antimicrobials. The release of these antimicrobials, along with scanning electron microscopy and infrared analysis, are being assessed for biodegradability and controlled-release property of the formulated films

**Status:** Completed. Manuscript in preparation

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## 8. A Soluble Self-Assembling Nanoparticle From Starch, Protein, and Lipid for Healthy Nutrient and Other Hydrophobic Compound Delivery

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**P.I.s:** O. Campanella and B. Hamaker

**Researcher:** Deepak Bhopatkar, Ph.D. Student

**Sponsor:** Available for sponsorship

**Objective:** To understand mechanistic and formation aspects and applications of a novel soluble nanoscale particle comprised of amylose, soluble protein, and lipid.

**Progress:** The formation of a soluble nanocomplex through the interaction of starch, protein and fatty acid has been reported previously by our work in previous annual reports and publications. Using cryo-transmission electron microscopy, it has been demonstrated that these interactions result in formation of discrete rod-shaped nanoparticles with a narrow molecular size distribution. Due to available space in the hydrophobic lumen of the amylose component, these nanoparticles can entrap and solubilize sparingly soluble small molecules. The ability of the nanoparticles to carry a model chemotherapeutic compound, 5- fluorouracil (5-FU) was demonstrated. Iodine binding affinity using the potentiometric titration technique revealed that the 5-FU is indeed incorporated inside the hydrophobic interior of amylose helices of the nanoparticles. Quantification of the 5-FU in the nanoparticles showed that the nanoparticles can carry 150 mM of 5-FU per mole of anhydrous glucose. Cytotoxic studies of 5- FU loaded nanoparticles on CaCo-2 Bbe Cell line clearly indicated 5-FU release from the nanoparticles. This study provides an opportunity of using these nanoparticles to solubilize sparingly soluble small molecules with ultimate applications in the area of drug or nutraceutical delivery at the target site.

**Status:** Completed. Manuscripts in preparation.

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## 9. Industrial Processing Properties and Attributes of Genetically Modified Fruit Pectin

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**P.I.s:** O. Campanella, A. Handa (Department of Horticulture, Purdue University)

**Researcher:** Carl P. Littrell, M.S. Student

**Sponsor:** USAD-AFRI

**Objectives:** To determine the effects of altered degree of pectin methyl esterase (PME) activity present in tomato fruit on pectin molecular size, rheological properties, and processing efficiency of fruit crops.

**Progress:** Pectin is one of the major components of plant cell walls and is used extensively as a functional food ingredient in a large number of products. The molecular structure and sugar composition of pectins have profound effects on their functionality, thus limiting commercial pectin production to a few plant sources. Specifically the degree of methoxylation, degree of acetylation, pattern of methyl esterification, and molecular size determine the functional properties of pectins. Genetic engineering offers novel methods for producing a less expensive “in vivo” source of pectins having desirable attributes through reducing PME activity, thus influencing the biochemistry of endogenous plant pectins. Rheological measurements using steady shear conditions are of primary concern due to the importance of texture in assessing quality attributes of food products containing pectin. Analyzing the rheological profile of juice, serum, and particulate will elucidate further information about the impact of pectin methoxylation on the viscoelastic particles in tomato pulp. Supporting analysis including solids content, sugar concentration, yield efficiency, particle size distribution using light scattering, and serum composition using HPLC will further indicate the role of PME on the structure and function of pectins. Initial data verified an increase in serum viscosity due to reduced PME activity, and the viscosity of juice was shown to increase more than 10-fold with a reduction in PME activity. Furthermore, while the serum displayed Newtonian flow behavior, the juice displayed a very strongly pseudoplastic behavior. Electron microscopy will be used to investigate the structure of these viscoelastic particles and their relationship with modified pectins.

**Status:** Active

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## 10. Solvent Properties of Water in Gels that Favor Carrying of Hydrophobic Small Molecules

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**P.I.:** B. Hamaker and O. Campanella

**Researcher:** Madhuvanti Kale, Ph.D. Student

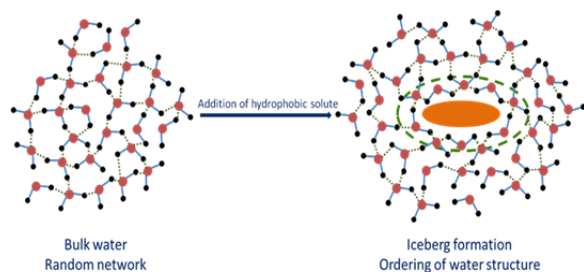
**Sponsor:** Available for sponsorship

**Objective:** To understand a little known phenomenon that change in water structure properties in small pores of hydrocolloid-based gels promotes loading of hydrophobic small molecules.



### Progress:

Although several complex vehicles have been researched and designed to carry low solubility small molecules, there is a continuing need to develop simple delivery systems, preferably using natural materials, for such compounds. It was shown long ago by other researchers that the internal water of Sephadex, a size-exclusion chromatographic media, has a different solvent property than bulk water that affects molecule separation. Azobenzene, the hydrophobic compound tested, exhibited relatively high solubility in this internal water. This was proposed to be due to ordering of water structure which makes it more favorable for a solute to be dissolved in internal water than in bulk water. Although originally observed and studied only in a chromatography system to resolve a deviation in elution volumes for small molecules, this phenomenon was proposed in the present study to be used in the design of aqueous delivery systems for small, hydrophobic bioactive molecules such as drugs and nutraceuticals. The solvent properties of internal water of two hydrophilic gel systems – Sephadex and corn bran arabinoxylan gels, as studied using the same model hydrophobic solute, azobenzene, were studied. Solubility of the solute was up to 44 times and 8 times higher in the internal water as compared to bulk water, in the Sephadex and arabinoxylan gels respectively. The effect was greatly mitigated in the presence of urea, a water structure breaker, indicating that the structuring of water in the gels was responsible for the phenomenon. Differential scanning calorimetry was used to study the different states of water inside the gels, including free, structured and tightly bound water, and showed evidence of the presence of structured water in the gels. Thus, the enhancement of solubility was attributed to the structuring of water inside the gels, making these gels promising materials for the delivery of hydrophobic nutraceuticals and drugs in pharmaceutically relevant dosages.



**Status:** Active. Manuscript in preparation.

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## 11. Dietary Fibers and Colonic Fermentation

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**P.I.:** B. Hamaker and B. Reuhs

**Researcher:** Haidi Xu, Ph.D. Student

**Collaborators:** E. Martens (University of Michigan Medical School); A. Keshavarzian (Rush School of Medicine, Chicago);

**Sponsors:** P.R. China government, Whistler Center, available for sponsorship

**Objective:** Identify and characterize dietary fiber structures and hydrolyzates that promote slow fermentation, low bloating, and desirable changes to the colonic microbiota.

**Progress:** Over the past two years, we have reported our work on arabinoxylans, as a model fiber polymer that varies considerably in structure among sources and even within single polymer structures, and how defined structures drive changes in colonic bacteria. With our collaborator, E. Martens, an array of discrete fiber structures have been tested on different arabinoxylan-degrading *Bacteroides* strain isolates. A high level of complex branches containing terminal xylose and terminal galactose, other than the commonly existing terminal arabinose, have been identified in corn arabinoxylan and correlated to its slow fermentation property. Structural models of corn arabinoxylan relating to fermentation were previously proposed, but without considering possible distribution patterns of the various branches that may play an important role in determining its fermentation property. A highly organized structural feature of multiple layers was revealed for corn arabinoxylan, in which the complex branches assemble to form regions that are connected by simply-branched parts, and the complex-branched regions containing further sub-layers. Specific molecular regions of dietary fibers were found to differentiate xylolytic *Bacteroides* growth and influence their competition patterns. While a most complex corn arabinoxylan structural region made one strain of *B. cellulosilyticus* (DSM 14830) outcompete a strain of *B. ovatus* (3-1-23), a more generalized lightly branched structure favored the latter strain. It is speculated that each bacteria type in the colon may have a substrate structure specific for itself, whereby it can be utilized to specifically favor its growth in the competitive environment of the colon. Thus, gut bacteria

compete for the different regions of fiber molecules and are equipped with different enzyme degrading systems that target unique structural features, which were revealed in different degradation mechanisms for fiber molecules according to their structural compositions. This work furthers our knowledge of substrate specificity for gut bacteria, and suggests the possibility for more specific manipulation of the colon microbiota composition and fermentation property in a designed way.

**Status:** Active. Manuscript published (A.13) and in preparation.

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## 12. Methods to Obtain and Study Slowly Digestible Glycemic Carbohydrates

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**P.I.:** B. Hamaker

**Researcher:** Byung-Hoo Lee, Ph.D. Student; Meric Simsek, Ph.D. Student

**Collaborators:** S.H. Yoo (Sejong University, South Korea); A. Lin (Whistler Center); G. Zhang (Jiangnan University); B. Nichols (Baylor College of Medicine, Houston); R. Quezada-Calvillo (University of San Luis Potosi, Mexico); M. Pinto (Simon Fraser University, Canada); D. Rose (University of Waterloo, Canada)

**Sponsor:** USDA-AFRI

**Objective:** To design alpha-glucans for study of location of glucose deposition in the small intestines to better understand targeting and physiologic response and to better understand natural inhibitors and their effect on the four mammalian  $\alpha$ -glucosidase enzymes related to manipulating starch digestion rate.

**Progress:** In a first study, we are beginning work with a group at Indiana University School of Medicine to try to determine location of glucose release for slowly digestible carbohydrates in the ileum, and to obtain relative amounts at different locations. Ileal release of glucose in the small intestine from starch digestion has been found to induce physiological responses that may be beneficial to health. Such work could guide development of slowly digestible glycemic carbohydrates that can be used by the food industry. 2-Deoxy-glucose (2-DG) can be used to test the location of glucose

absorption due to its accumulative property in the small intestine enterocytes. Because monosaccharides are absorbed in the proximal part of the small intestine, we have designed 2-DG containing maltooligosaccharides (2-DG-MOs) to be used with mammalian  $\alpha$ -hydrolytic enzyme inhibitors so that digestion can occur distally and locational effect can be studied. Recombinant amylosucrase (5 U), which elongates  $\alpha$ -1,4 glucosyl units to acceptor molecules, was reacted with sucrose (500 mM) as a donor and 2-DG (3%) molecules as an acceptor at 35°C for 48 h. HPAEC results showed that the ethanol-precipitated enzyme-synthesized product had an average of 10.6 glucosyl units with different retention times compared to homogeneous maltooligosaccharides. The 2-DG-MOs were hydrolyzed by mammalian  $\alpha$ -hydrolytic enzymes (human pancreatic  $\alpha$ -amylase and individual mammalian mucosal  $\alpha$ -glucosidases) to test whether this product can be digested to monosaccharides in the GI tract. The 2-DG-MOs were hydrolyzed to maltose and maltotriose by  $\alpha$ -amylase, and hydrolyzed to 2-DG and glucose by action of the individual mucosal  $\alpha$ -glucosidases. The  $\alpha$ -hydrolysis results indicate that 2-DG-MOs can be used with enzyme inhibitors to test the exact location of glucose release. In the future, we will produce <sup>14</sup>C-labeled 2-DG-MOs to study the location of starch digestion in test animals and to correlate with physiological endpoints.

M. Simsek with our collaborator R. Quezada-Calvillo has studied the relative inhibition of the four mucosal alpha-glucosidases using various natural polyphenolic inhibitors. Chlorogenic acid and epigallocatechin gallate were shown to have comparatively high inhibitory effect on the ct-MGAM, or glucoamylase, enzyme which has the highest activity towards alpha-limit dextrans as well as larger maltodextrins or native starch. Our objective here is to find a way to slowly digest starch through partial inhibition of the four glucosidases.

**Status:** Active. Manuscripts in preparation.

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## 13. Physiological Response Studies of Starchy Materials With Defined Digestion Profiles

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**P.I.s:** B. Hamaker

**Researcher:** Like Yan, Ph.D. Student; Fatima Cisse, M.S. Student; Beth Pletsch, M.S. Student; Choon Young Kim, Ph.D. Research Associate

**Collaborators:** T. Powley, R. Phillips, K. Kinzig (Department of Psychological Sciences); M. Kushnick (Ohio University); G. Zhang (Jiangnan University)

**Sponsor:** USDA-AFRI

**Objective:** To understand the physiologic responses to slowly digestible carbohydrates with controlled digestion profiles.

**Progress:** In the last year, we completed a long-term 8-week feeding study in diet-induced obese rats using our fabricated slowly digesting starch-entrapped microbeads and compared food intake behavior and appetite-regulating hypothalamic neuropeptides in the slow digesting diet treatment group to rats consuming fast digesting starch. The two most notable findings were that the slow digesting group consumed 10-25% less calories per meal, though initially appeared to compensate this by increasing meal number during the feeding cycle. By 8 weeks, meal number dropped to normal and daily food intake correspondingly dropped. Excised hypothalamus tissues analyzed for orexigenic and anorexigenic neuropeptide gene expression by rt-PCR showed significant reduction in NPY, an appetite-stimulating peptide, over the rapidly starch digesting group, and was similar in level to the lean rat control group. This data suggests that glucose deposited locationally distal in the small intestines promotes lower food intake which is regulated by hypothalamic response, and perhaps delayed gastric emptying (which was shown in a previous study). A follow-up study on the effect of slowly digestible starch on gastric emptying in the human was done in the fall of 2012 by F. Cisse and B. Pletsch. Here, using a non-invasive breath test to quantify gastric emptying changes, preconsumption of the slowly digestible microbeads were shown to slow considerably gastric emptying of a subsequent non-nutritive paste; indicating that the gastrointestinal tract might be preconditioned to accept a meal and deliver nutrients (including energy) over an extended period of time.

**Status:** Active. Manuscripts in preparation.

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#### 14. Use of Corn Zein Proteins as Functional Viscoelastic Polymers

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**P.I.s:** B. Hamaker and O. Campanella

**Researcher:** Mehtap Fevzioglu, Ph.D. Student, Daniel Erickson, Ph.D. Student, Stephanie Tandazo, M.S. Student, Morgan Goodall, M.S. Student

**Collaborators:** L. Mauer (Purdue); S. Renzetti, A. Jurgens (TNO Netherlands)

**Sponsor:** USDA-AFRI, Purdue fellowship, USAID INTSORMIL project

**Objectives:** 1) To understand basic structure-function relationships in corn zein and sorghum kafirin to create viscoelastic doughs that work in gluten-free systems or high incorporation composite flours for Africa, 2) To study how different co-proteins interact with zein in order to create improved quality dough, and 3) To determine applicability of using high digestibility/high-lysine sorghum flour for high incorporation composite breads for Africa.

**Progress:** 1) We have hypothesized that, zein, which shows similarities to wheat gliadin in number of aspects, can attain viscoelastic properties at room temperature with addition of a co-protein similar to that of HMW-GS in wheat gluten. Wheat and corn proteins were utilized in this study to investigate and compare their viscoelastic properties. Improved viscoelastic properties were obtained for zein with addition of HMW-GS at room temperature. The transformation of gliadin with the addition of HMW-GS and glutenin was also shown. However, gliadin and zein were found to gain structural functionality through different mechanisms. In gliadin, structural transformation took place through transitions between  $\beta$ -sheet and  $\beta$ -turns. On the other hand, main transition in zein was found to be from  $\alpha$ -helix to  $\beta$ -sheet.

2) This study serves to present a framework for the manipulation of state transition properties and viscoelastic nature of zein as driven by plasticizers and co-proteins. Using resins formed via precipitation from aqueous ethanolic environments, moisture sorption isotherms and glass transition profiles were constructed for zein, gluten, zein/oleic acid (at 20% and 30% oleic acid), and zein/casein (at 15% and 20% casein). Differences in the viscoelastic and extensional properties of these materials were assessed using small and large deformation rheological techniques. Oleic acid plasticization was shown to reduce water absorption and glass transition temperatures, and created low elasticity/high extensibility resins. Incorporation of casein yielded only slight increases in water

absorption and glass transition temperatures, yet imparted a five-fold increase in material strength/elasticity. These findings demonstrate how specific protein-plasticizer and protein-co-protein interactions can impart fundamental differences to the behavior of zein in viscoelastic systems and could serve as a basis for improving the functional properties of this underutilized material. Plasticizers and co-proteins could be further applied to specific food and biomaterial systems for optimal performance with respect to moisture migration and/or mechanical properties.

4) High digestibility/high-lysine sorghum, with kafirin proteins freed from protein bodies, had been shown to effectively participate in dough formation in sorghum:wheat composite breadmaking systems. This work was extended to show pre-treatments that improved the function of the composite breads using this unique type of sorghum. Our goal in this project is to find a way to increase levels of sorghum incorporation into breads for use in Africa to better utilize local crops and to reduce wheat imports.

**Status:** Active. Manuscripts published (A.7, 14, 15, 17)) and in preparation.

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### 15. Hydrocolloid-Based Nutraceutical Delivery Systems: Effect of Iota-Carrageenan Counter-Ion on the Encapsulation and Release Of Eugenol

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**P.I.:** S. Janaswamy

**Researcher:** Patrick Polowsky, Undergraduate Student

**Sponsor:** Available for sponsorship

**Objective:** Nutraceuticals (NCs) and functional foods contribute to better health as well as prevention of diseases such as diabetes and cancer. NCs are often susceptible, however, to degradation from factors including temperature, enzymatic activity, pH, and light, reducing bioavailability. Encapsulation allows their protection and hydrocolloids are suited well due to their versatility. In our ongoing efforts about the design and development of carriers based on human compatible biopolymers possessing stable architectures – unwavering structural designs of carriers are advantageous for retaining the functionality of embedded molecules – we demonstrated the

feasibility of iota-carrageenan (IC) fibers for the encapsulation, thermal protection and controlled release of NCs and drug molecules. Our results suggested that the charge balancing cation on the IC backbone could influence the release behavior of the encapsulated molecules. This observation forms basis for the present research, and herein we report the effect of mono- (Na<sup>+</sup>) and di-valent (Ca<sup>2+</sup>) cation forms of IC fibers on the encapsulation and release of eugenol.

**Progress:** Eugenol has been encapsulated in the calcium form of iota-carrageenan fibers. The complexation experiments have been performed at 4, 25, 35 and 45°C so as to understand the effect of temperature on the loaded amounts and release profiles. Encapsulated eugenol molecules are released in a controlled manner. Interestingly, unlike the sodium IC fibers, the molecules from calcium IC fibers take a while to release from the network. For example, in the case of complexes prepared at 25°C, around 20 mins delay is observed while those prepared at 45°C show 8 mins delay. The interplay between the cation-eugenol interactions as well as the carrageenan network – iota-carrageenan network is more rigid in the presence of calcium ions than with sodium ions – appear to dictate the release behavior of eugenol molecules from the carrageenan network. Overall, results highlight that the charge balancing cation on the hydrocolloid backbone influences the loaded amounts and release patterns.

**Status:** Active.

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### 16. Carbohydrate-Based Antimicrobial Carriers

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**P.I.s.:** S. Janaswamy, A. K. Bhunia (Food Science Department, Purdue University)

**Researcher:** Lohit Myneedu, M.S. Student; Atul K. Singh, Ph.D. Research Associate

**Sponsor:** Available for sponsorship

**Objective:** Food quality and shelf-life define the appearance and consumer acceptance. Microbial contaminants affect flavor, texture and color, and often raise concerns about food safety and public health. They are also responsible for food spoilage causing huge economic losses, increased food price and global food shortage. Thus, preventing undesirable microbial proliferation in food is of

utmost importance. Essential oils (EOs) possess antimicrobial properties. However, EOs are water insoluble and prone to oxidative degradation so that higher concentrations are needed to achieve desirable activity. To gain balanced benefit of EOs in food safety and food quality, a novel encapsulation and delivery system is warranted. Recently, we engineered edible carbohydrates to deliver bioactive compounds. This research is about encapsulating and protecting the EO compounds using carbohydrate networks.

**Progress:** Eugenol and iota-carrageenan (IC) have been chosen as model polysaccharide and EO, respectively. The antimicrobial activity was tested against two foodborne pathogens *Escherichia coli* and *Listeria monocytogenes*. Our results suggest that eugenol-encapsulated IC fibers are effective in controlling the microbial growth for a period of 48 hours or more.

**Status:** Active.

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#### 17. Effect of KCl, KBr and KI on the Three-Dimensional Structure, Viscoelastic and Thermal Behavior of Potassium Kappa-Carrageenan

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**P.I.:** S. Janaswamy

**Researcher:** Lohit Myneedu, M.S. Student

**Sponsor:** Available for sponsorship

**Objective:** Carrageenans are sulfated polysaccharides extracted from marine algae and are recognized as GRAS materials. Depending on their source of extraction, and presence or absence of sulfate groups as well as anhydro group fifteen carrageenans are known to date. They find wide spread applications in food and pharmaceutical industries due to their ability to form thickeners, viscosifiers and gels. In particular, their food applications include bodying, gelling, thickening and emulsion stabilization in water- and milk-based systems. Only kappa-, iota- and lambda-carrageenan have so far been exploited industrially and are subjected to extensive studies toward delineating their structure-function relationships. In this set, kappa-carrageenan has been well studied; however, details about its junction zone architecture and effect of cations on the structure-function relationships are still elusive.

**Progress:** A systematic investigation about the effect of salts on the three-dimensional structure, viscoelastic and thermal properties of kappa-carrageenan has been carried out. In this study, the focus is on potassium salt form of kappa-carrageenan at four dilute concentrations 0.2, 0.5, 0.75 and 1.0% (w/w) in the presence of KCl, KBr and KI (25, 50, 75 and 100 mM). The dilute polysaccharide concentrations are to better represent a practical scenario encountered in formulations, and the halide ions are intended to unravel their effect on the structure and functionality of kappa-carrageenan, if any. X-ray results suggest that the carrageenan fibers are uniaxially oriented but with less crystallinity. The Bragg reflections on layer lines 0 through 6 are somewhat diffused. Viscoelastic studies show that the elastic and viscous moduli increase as a function of kappa-carrageenan and salt content. Incorporation of higher salt amounts significantly increases the elastic moduli with an appreciable change in the gel-to-sol transition temperature. Overall, it appears that iodine ions favorably promote interactions among the kappa-carrageenan chains compared to chloride and bromide ions.

**Status:** Active.

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#### 18. Phase Stability of $\beta$ -Lactoglobulin Fibrils in the Presence of Chitosan and Methyl Cellulose

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**P.I.:** O.G. Jones

**Researcher:** Monica Jiulianti, B.S. Student

**Sponsor:** USDA-Hatch MRF

**Objective:** Determine physical stability and solution recovery of protein fibrils assembled from  $\beta$ -lactoglobulin as a function of added polysaccharide (chitosan, methyl cellulose), fibril concentration, and pH value.

**Progress:** Initial experiments have shown improved physical integrity of protein fibrils at higher pH values in the presence of chitosan. High concentrations of chitosan and methyl cellulose lead to a phase separation with fibril solution through an apparent thermodynamic incompatibility. These techniques are to be further developed for an

improved method to selectively separate protein fibrils.

**Status:** Active.

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### 19. Amyloid-Like Protein Fibril Networks Using Variable Charged Polysaccharide Cross-Linking

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**Co P.I.s:** O.G. Jones, O. Campanella

**Researcher:** O.G. Jones

**Sponsor:** USDA-Hatch MRF

**Objective:** Identify structural and mechanical improvements to semi-dilute fibril suspensions through the use of electrostatically-interacting polysaccharides and to establish correlations between mechanical attributes of their microstructure and macrostructure.

**Progress:** Initial experiments demonstrate the ability to form network cross-links using a charged polysaccharide. Mechanical analyses of the protein fibril networks are being currently developed using atomic force microscopy (nanoscale) and rheometry (macroscale).

**Status:** Active.

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### 20. Specific Ion Effects on Electrostatic Complex Formation and Macromolecular Development Between Whey Proteins and Pectin

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**P.I.:** O.G. Jones

**Researcher:** Stacey Hirt, M.S. Student

**Sponsor:** USDA-Hatch MRF

**Objective:** Determine attractive physical forces and macromolecular interactions between  $\beta$ -lactoglobulin and carboxylated polysaccharides in the presence of specific ion effects.

**Progress:** Turbidimetry and light scattering were utilized to study the electrostatic interactions between  $\beta$ -lactoglobulin and pectin at neutral and

low-acid conditions. A significant specific ion effect has been observed for the pH of complex formation and the pH of coacervation for unheated protein and pectin. Properties of heated protein with pectin in the presence of the ions is being currently investigated by atomic force microscopy and light scattering.

**Status:** Active.

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### 21. Stabilization of Flavor Oil Emulsions by $\beta$ -Lactoglobulin/Pectin Heated Complex Structures

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**P.I.:** O.G. Jones

**Researchers:** Laura Zimmerer, M.S. Student

**Sponsor:** USDA-Hatch MRF, Industry Associates Fellowship

**Objective:** Determine the interfacial activity and physical stability of limonene-oil aqueous emulsions using particulate nanogels of (a)  $\beta$ -lactoglobulin with or without pectin or (b) nanoprecipitated zein at the interface; determine oxidative stability and evaporative loss of flavor oils from the prepared emulsions.

**Progress:** Interfacial tension measurements have shown the slow adsorption of  $\beta$ -lactoglobulin nanogels, following the relatively fast adsorption of the unconverted protein. Limonene emulsions (containing 10% corn oil) with  $\beta$ -lactoglobulin nanogels and pectin have been created using high pressure homogenization. Content analysis of the serum phase has indicated a greater amount of protein at the interface for nanogel systems when compared to the native protein-based emulsions. Light scattering studies indicate that two populations of emulsion droplets are created: the first with diameter under 1 micrometer and the second between 3 and 10 micrometer. The largest droplets flocculate rapidly and form a dense cream layer, which is a common issue for particle-stabilized emulsions. Current research is investigating the ability of particles at the interface to inhibit diffusive losses of the limonene using gas chromatography.

Initial investigation of nanoprecipitate zein indicates improved control of particle size compared to whey protein nanogels. These interfacial activity and

physical stabilization of emulsions are being currently investigated.

**Status:** Active.

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## 22. Protein-Polysaccharide Block Ionomer Complexes as a Core-Shell Controlled Delivery Vehicle for Hydrophobic Bioactive Compounds

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**P.I.:** O.G. Jones

**Researchers:** Juan Du, Ph.D. Student

**Sponsor:** Purdue Research Foundation

**Objective:** Establish the assembly of block ionomer complexes from charged polysaccharides and proteins to replace surfactant-micelles as controlled delivery vehicles for bioactive compounds.

**Progress:** Chitosan has been modified with polyethylene glycol side-chains through amide-formation and is being currently investigated for solution properties and structure. Techniques are being investigated for terminal-block addition of polyethylene glycol to anionic polysaccharide.

**Status:** Active.

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## 23. OSA Modified Gum

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**P.I.:** A. Lin

**Researcher:** Yuzhi Jiao, Visiting Faculty

**Sponsor:** Available for sponsorship

**Objective:** To quantify the OS content in modified gum for product development and quality control purposes.

**Progress:** Dr. Lin's lab developed a method to quantify the OS content. OSA modified gum is quite different from the nature of OSA-starch due to the high amount of positive charges on the molecules, heterogeneity of molecular distribution and the interaction with other components. We overcame the challenges and are able to quantify OS of modified gum. This work is particularly important for

the hydrocolloid industry for product development and quality control.

**Status:** Patent application in process.

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## 24. Methodology Improvement: Carbohydrate Dehydration

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**P.I.:** A. Lin

**Researchers:** Yuzhi Jiao, Visiting Faculty; Anbuhkani Munaindy, Undergraduate Student

**Sponsor:** Available for sponsorship

**Objective:** What is the better way to dry carbohydrate for analytic purposes?

**Progress:** The dehydration of carbohydrates is required in many analytic processes, however we observed that carbohydrate mass and molecular distributions were changed after the dehydration. We are studying several starch molecules with the size in the range of DP 1 to ~1000, and in the concentration range of 0.5-30%; several common dehydration methods were applied in this study. Part of the carbohydrate masses were lost at different scales, and one of the drying methods lost more quantity of particular fractions. The findings have helped us to choose a better dehydration method for analyzing starch molecules more precisely in other projects.

**Status:** Active. Manuscript in preparation.

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## 25. Starch Internal Structure and Digestibility at Mucosal Alpha-Glucosidase Level

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**P.I.:** A. Lin

**Researcher:** A. Lin

**Sponsor:** Available for sponsorship

**Objective:** To understand how starch internal structure drives digestibility differently at the mucosal alpha-glucosidase level.

**Progress:** We hypothesized that starch internal structure affects the digestibility at the brush border area (Lin et al., 2012, Journal of Biological Chemistry,

284(44) 369170-369217). In this project, we analyzed the relationship of branch frequency and the digestion by a mucosal alpha-glucosidase. The branch frequency remained in the alpha-limit dextrin is highly related to the digestion. It supports the view that the more branches reserved in the internal structure of starch, the more resistance to the digestion by the mucosal enzyme. Through the study of protein and sugar conformation, we are able to elucidate how the carbohydrates duck in the catalytic sites. The evidence from 3D conformation supports the hypothesis that the branch pattern of the starch internal structure not only affects starch processing functionality but also the digestibility at the mucosal alpha-glucosidase level. This finding is an important step for designing slowly digestible dextrin in order to receive more healthy benefits.

**Status:** Active. Manuscript in preparation.

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## 26. Starch Digestion and CSID (Congenital Sucrase-Isomaltase Deficiency)

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**P.I.:** A. Lin

**Collaborator:** B. Nichols (Baylor College of Medicine, Houston)

**Researchers:** Anbukhani Muniandy, Undergraduate Student; Antone R. Opekun, Assistant Professor, Baylor College of Medicine; S. Avery, Technician, Baylor College of Medicine

**Sponsor:** Partly sponsored by QOL; open for additional sponsorship

**Objective:** To understand the digestion role of individual mucosal-alpha-glucosidase in in vivo systems; develop food-grade supplements for CSID's patients in order to receive enough carbohydrate sourced energy with less pain.

**Progress:** Through gene knock-out animals, we investigated that starch digestion was less completed when one of the mucosal alpha-glucosidase complexes was missing. More un-digested starch molecules were investigated in the small intestine; however, we also found the gluconeogenesis compensated for the glycemic response while the animals had freedom to access foods as much as they wanted. We continue studying the digestion pattern with a different feeding model of limited food supply.

**Status:** Active.

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## 27. Water-Solid Interactions: Deliquescence

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**P.I.:** L. Mauer

**Researchers:** Rebecca Lipasek, Ph.D. Student; Na Li, Ph.D. Student; Megan West, Ph.D. Student; Dr. Mohamed Ghorab, Ph.D. Research Associate; Yuhong Zhao, Ph.D. Research Associate; Krystin Marrs, M.S. Student; Belinda Christina, M.S. Student; Matt Allan, M.S. Student

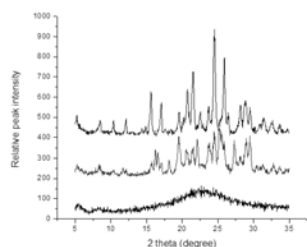
**Sponsor:** Available for sponsorship, Nestec

**Objective:** Determination of the impact of deliquescence and other modes of water-solid interaction on the chemical and physical stability of multicomponent food systems.

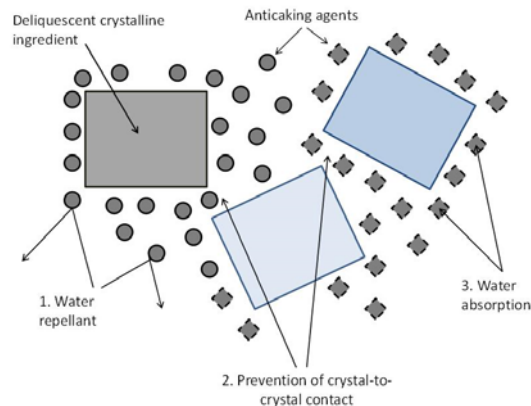
**Progress:** We are investigating the fundamentals and consequences of deliquescence, absorption, and other water-solid interactions in food systems containing crystalline and amorphous components. In collaboration with a researcher in the Industrial and Physical Pharmacy Department, we have demonstrated 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 synergistic moisture sorption in blends of crystalline and amorphous solids, wherein the co-formulation of crystalline and amorphous ingredients has the potential to lower both the deliquescence RH and Tg of the blend rendering the blend of ingredients more sensitive to environmental RH than the individual ingredients. This has importance for the formulation, sequencing, blending, storage, packaging, and stability of dry ingredient mixtures and final food products. Studies are also manipulating the solid-state structure of poorly water soluble bioactive ingredients and documenting physical and chemical stability as well as solubility.



## Crystallization Studies

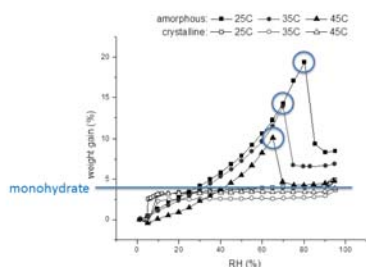


Li, N.; Ferruzzi, M. G.; Taylor, L. S.; Mauers, L. J., Color and Chemical Stability of Tea Polyphenol (-)-Epigallocatechin-3-gallate in Solution and Solid States. *Food Res Int* 2022. [in press]



**Status:** Active.

## Moisture sorption isotherm



## 28. Molecular Dynamics Simulation of Polypeptides Tethered to Surface

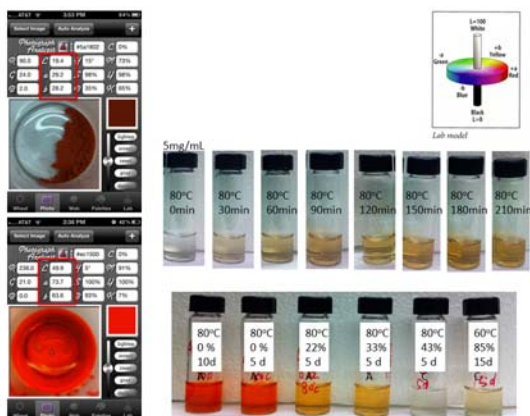
**P.I.:** G. Narsimhan

**Researchers:** Xiaoyu Wu, Ph.D. Research Associate, Hector Chang, M.S. Student

**Sponsor:** Army Natick Research Lab

**Objectives:** 1) Conduct Molecular Dynamics (MD) simulations for an antimicrobial peptide Cecropin PI C adsorbed to silica surface to determine its equilibrium secondary and tertiary conformations, 2) Calculate the potential energy of adsorption of the peptide on the silica surface, and 3) Conduct MD simulation of Cecropin PI tethered at the C terminal to polyethylene oxide linker which is bound to the silica surface.

**Progress:** Antimicrobial peptides (AMP) are innate mechanism of defense of the immune system found in insects and animals. It is shown that these peptides act against pathogenic bacteria, fungi, enveloped viruses, parasites and cancerous cells. They have the ability to penetrate the cell membrane, form pores which eventually lead to cell death. It is, therefore, important to characterize the secondary structure of AMP, important for its antimicrobial activity, under non polar environment such as lipid bilayer. It is also of interest to immobilize antimicrobial peptide (AMP) and their mimics onto surfaces such as packaging films. Immobilization of AMP may lead to partial or complete loss of their activity, due to random orientation and conformational changes. In order to fully retain their biological activity, AMP should be attached onto surfaces without affecting



conformation. The conformation of Cecropin PI in the presence of mixture of 2,2,2-trifluoroethanol (TFE)/water of different composition as well as upon immobilization onto silica nanoparticles surface were characterized using molecular dynamics (MD) simulation and circular dichroism (CD). Explicit solvent MD simulation for TFE/water mixture indicated an increase in  $\alpha$  helical content with increasing TFE concentration from 12.90% (buffer) to 30.30% (15% TFE) consistent with experimental values (13.44% for buffer to 32.55% for 15% TFE) obtained from CD as a result of more intermolecular H-bond formation in nonpolar environment. Adsorption of CPI onto silica was found to result in a decrease in  $\alpha$  helical content with increasing silica concentration (e.g. 32.55% in 15% TFE/water mixture to 30.02% and 28.83% in the same solution in the presence of 2.3% and 6.5% silica nanoparticles, respectively) with this effect being more pronounced for lower TFE concentrations.

Explicit solvent Molecular dynamics (MD) simulation was carried out for the antimicrobial peptides (i) Cecropin PI and C-terminus cysteine modified Cecropin PI (Cecropin PI C) in solution, (ii) Cecropin PI and Cecropin PI C adsorbed onto coesite  $-Si-O-$  and  $Si-O-H$  surfaces. In the presence of Cecropin PI C in the vicinity of  $-Si-O-$  surface, there is a shift in the location of two peaks in  $H-O-H$  density profile to larger distances (2.95 Å and 7.38 Å compared to 2.82 Å and 4.88 Å in the absence of peptide) with attenuated peak intensity. This attenuation is found to be more pronounced for the first peak.  $H-$  bond density profile in the vicinity of  $-Si-O-$  surface exhibited a single peak in the presence of Cecropin PI C (at 2.9 Å) which was only slightly different from the profile in the absence of polypeptide (2.82 Å) thus indicating that Cecropin PI C is not able to break the  $H-$  bond formed by the silica surface. The  $\alpha$  helix probability for different residues of adsorbed Cecropin PI C on  $-Si-O-$  surface is not significantly different from that of Cecropin PI C in solution at low ionic strength of 0.02 M whereas there is a decrease in the probability in the second (residues ISE) and third (residues AIQG)  $\alpha$  helical regions at higher ionic strength of 0.12 M. Though the total  $\alpha$  helical content of adsorbed and tethered Cecropin PI C were lower for hydrophilic  $Si-O-H$  surface compared to hydrophobic  $-Si-O-$ , hydrophobicity of the surface did not significantly affect the  $\alpha$  helix probability of different residues.

**Status:** Active.

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## 29. Investigation of the Conformation of Model Polypeptides Using Molecular Dynamics Simulation

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**P.I.:** G. Narsimhan

**Researcher:** Xiaoyu Wu, Ph.D. Research Associate

**Sponsor:** Army Natick Research Lab

**Objectives:** 1) Molecular dynamics (MD) simulation of peptides consisting of five to fifteen amino acids such as lysine and serine in an aqueous medium to determine their equilibrium conformations, and 2) MD simulations for (i) peptides consisting of different lengths of a single amino acid (lysine or serine) and (ii) peptidic diblock copolymer consisting of these two amino acids in varying architectures.

**Progress:** The molecular dynamics (MD) simulation of 10 polypeptides of different amino acid composition (ratio of serine/lysine), length and position of serine on titanium surface were conducted using AMBER 10.0 program. Explicit solvent model was employed in the molecular dynamics simulation for the evaluation of conformation of the polypeptide in the vicinity of anatase crystal surface at 300 K. The initial conformation of the polypeptide was taken to be the equilibrium native conformation in solution as obtained by explicit solvent molecular dynamics simulation for 100 ns. The polypeptide was placed parallel to the three different locations (center, edge and corner) of titania surface with its center of mass located at a distance of 10 Å and restrained. Polypeptide on three different locations of anatase experienced different conformational change during the simulation after 30 ns simulation. The conformation of the polypeptides on surface center experienced much less change compared to those on the other two locations as indicated by the content of helix. The difference of the conformation for polypeptides between in the vicinity of edge and corner of anatase surface are not significant, while both of them contain much less helix structure compared with that on the center. The distance of the polypeptide to the anatase surface during the simulation showed that the polypeptide approached the surface which led to the change in its conformation. The distance between the polypeptide residues and the surface are smaller compared to those for initial state. However, a water layer was found to be present between the residues and the

surface in the final state which may reduce the interaction between the peptide and the surface. It is interesting to note that for all the high ratio of K/S (> 4.5), the alpha helical conformation of peptides near the corner of the surface was higher than that near the edge, while the opposite behavior was observed for lower of K/S ratio.

**Status:** Active.

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### 30. Pore Formation in Bacterial Cells by Melittin

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**P.I.:** G. Narsimhan

**Researchers:** Xiaoyu Wu, Ph.D. Research Associate; Atul Singh Ph.D. Research Associate; Xi Wu,, Ph.D. student

**Sponsor:** Available for sponsorship

**Objectives:** 1) Characterization of kinetics of cell death for *Listeria monocytogenes* and *E. coli* O157:H7 when exposed to melittin of different concentrations. 2) Inference of lag time for cell death 3) Comparison of cell death kinetics for Gram positive and Gram negative bacteris.

**Progress:** Antimicrobial peptides (AMP) belong to a large and varied class of relatively short peptides family, which usually are largely positively charged, and constitute host-defense system in many living organisms, capable of killing inter alia, Gram negative and Gram positive bacteria. In order to better design AMP mimic for specific microorganism, it is necessary to understand the mechanism of permeabilization of cell membrane. In this study, Melittin (26 amino acids: GIGAVLKVLTTGLPALISWIKRKRQQ) were used as a candidate peptides to test its efficiency against bacteria and later test it toxicity. Gram positive bacteria such as *Listeria monocytogenes* and gram negative bacteria such as *E. Coli* were investigated, which when exposed to Mellittin. Positively charged antimicrobial peptides adsorbed onto the liposome surface due to charge interactions. Spot-on-lawn assay showed that Melittin has least concentration to kill bacteria *Listeria monocytogenes* (0.31 µg/spot) than *E. Coli* (1.25 µg/spot). The UV absorbance at 595 nm measurement indicated that for *Listeria monocytogenes*, all the bacteria did not grow up above 0.20 µg/well, while for *E. Coli*, it need 1.56 0.20 µg/well to prevent the bacteria growing. Plate

account assay also suggested that more *E. Coli* colony numbers were found compared to *Listeria monocytogenes* colony at the same concentration. The UV absorbance measurements of the different grow curves of *Listeria monocytogenes* for melittin added on different time spot (Control, 0 h, 2h, and 4 h) showed that after melittin was added to the incubated bacteria solution, the growth curve turn down immediately and the cell were killed quickly. TEM microscopy image showed that the cells were lysis and killed around 50% after one hour treatment with melittin and almost all were killed for around 2 hours treatment with melittin. All the results showed that melittin is more active against *Listeria monocytogenes* comparison to *E. coli* and the results based on all the techniques are consistent.

**Status:** Active

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### 31. Factors Contributing to the Viscosity Difference of Hot-and Cold-Break Tomato Products

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**P.I.:** B. Reuhs

**Researchers:** Bicheng Wu, M.S. Student

**Sponsor:** Available for sponsorship

**Objective:** In tomato product manufacturing, the initial “break” stage is critical to the quality attributes of the final product. Hot-break (HB) products (break above 90°C) maintain higher viscosity at the cost of degraded color and flavor as compared to the cold-break (CB) products. We are examining the basis for the different viscosities in the two products, particularly as it relates to potential pectin degradation.

**Progress:** Many past studies have suggested that the relatively low viscosity of CB tomato product results from the break-down and release of water-soluble pectic oligomers by the pectolytic enzymes, whereas more intact pectic polymers were solubilized by HB. We have examined the contribution of pectin to the viscosity of both HB and CB tomato products, which were immediately collected after breaking. We first examined the tomato serum from each product and determined that the serum content is nearly identical; composed almost exclusively of glucose, fructose, and organic acids. Only after dialysis, which removed these components (~98-99% of the serum) were we able

to detect pectin (~1% of the serum). The soluble pectin from the sera were analyzed by HPSEC-MALLS-RI, which showed that the hot-break tomato serum contained a slightly higher pectin content, and that it was of higher molecular weight pectin than cold-break serum, which was likely responsible for its higher serum viscosity. However, the amount of pectin in both the HB and CB sera is much too low to play a significant role in the overall viscosity of HB and CB tomato products. This was verified by removing the tomato serum and replacing it with water: the viscosity differences of the two products remained without the serum. We then demonstrated that instead of pectin, rheological properties of the tomato pulp have a major impact on overall product viscosity. An oscillatory frequency sweep test on HB and CB tomato pulp suspensions showed that there is a difference in the viscoelastic behaviors of the tomato pulps after these two breaking methods, and that this is responsible for tomato product viscosity. We are continuing to examine the particle size, shape, and chemical makeup to determine the exact physical properties that play such a significant role in fruit viscosity. To this end, we have begun a process of homogenizing the products to reduce the particle size for further analyses, and the results have shown that despite the additional processing, the viscosity differences were still present. This will allow for 3D-microscopy of particles, as well as atomic force microscopy (AFM) and light scattering analyses.

**Status:** Active.

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### 32. High-Value Corn Starch

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**P.I.:** C. Weil

**Collaborators:** L. Mauer, Y. Yao

**Researchers:** Patrick Breen, M.S. Student; Kaylie Fritts, B.S. Student

**Sponsor:** Whistler Center, Consortium for Plant Biotechnology Research

**Objectives:** Genetics and mutagenesis are used to 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. Large populations of mutagenized seeds have been developed in the inbred maize lines W22 and B73.

**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, automated liquid handling and glucometry, 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.

**Status:** Active.

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### 33. Genes Controlling Starch Channelization

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**P.I.:** C. Weil

**Collaborator:** J. BeMiller

**Sponsor:** Available for sponsorship

**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.

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### 34. Genetic Interactions That Impact Starch Quantity and Quality

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**PI:** C. Weil

**Researcher:** Project currently available

**Sponsor:** Available for sponsorship

**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 *ael1*, *su2* and *wx* have been crossed to 27 highly diverse inbreds to identify interacting genes that affect starch quantity and quality. We now have F2 progeny of these crosses and need to analyze 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

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### 35. Genetics of Carbohydrate Transport and Partitioning in Maize

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**PI:** C. Weil

**Researchers:** Xiqing Ma, Ph.D. Research Associate; J. Wedow, Undergraduate Student; Yang Wang, Visiting Scientist

**Sponsor:** NSF, Chinese Government

**Progress:** We have now mapped ten new mutations impacting carbohydrate transport and distribution in maize, have identified over 350 more and have now developed F2 mapping populations for

320 of these. In summer 2013 we will map another 40 mutations for detailed analysis this Fall. 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:** Active. Manuscripts in preparation.

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### 36. Genetics of Sugar Accumulation and Distribution in Maize and Sorghum

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**PI:** C. Weil

**Collaborators:** N. Carpita, D. Szymanski (Purdue University)

**Sponsor:** Available for sponsorship

**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 and 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 and the next steps will be to determine the genes underlying these QTL. We are focusing 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

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### 37. Analysis of Sorghum Genes Involved in Carbohydrate Metabolism and Production

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**PI:** C. Weil

**Researchers:** Nick Babcock, Curtis Brackett, Mitch Tuinstra, Brian Dilkes, Eric Johnson, Hamadou Traore

**Sponsor:** Partial funding from Bill and Melinda Gates Foundation, but available for additional sponsorship.

**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 have identified a series of candidate mutants; these are in second phase testing now in preparation for genetic mapping and gene identification. We have also identified several mutant lines that have altered carbon partitioning.

**Status:** Active

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### 38. Carbohydrate-Based Colloidal Assemblies to Adsorb and Deliver Antimicrobial

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**P.I.s:** Y. Yao, A. Bhunia

**Researcher:** Preetam Sarkar, Ph.D. Student

**Sponsor:** Available for sponsorship

**Objective:** To study the delivery of antimicrobial compounds using carbohydrate-based colloidal assemblies.

**Progress:** In this work, carbohydrate-based colloidal assemblies are used to interact with antimicrobial compounds, including peptide (nisin) and another compound that shows a synergistic interaction with nisin. It was found that while nisin can only inhibit Gram-positive bacteria, a combined mixture of two may prohibit the growth of both Gram-positive and negative bacteria with reduced doses compared with those of individual compounds. Currently, we are using carbohydrate-based colloidal assemblies to realize and improve such a synergistic effect of the two antimicrobial compounds, using several pathogens as model systems. This study will allow us to identify more cost-effective methodologies to mitigate food pathogens.

**Status:** Active.

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### 39. Carbohydrate-Based Biomaterials to Improve Quercetin Water Solubility

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**P.I.:** Y. Yao

**Researcher:** Hua Chen, Ph.D. Student

**Objective:** To isolate and characterize soluble carbohydrate-quercetin complexes.

**Progress:** Quercetin is one of the most abundant flavonoids found in plant foods, with potential protective effects against coronary heart disease, cancer, inflammation, and tumor growth. The absorption of quercetin is low and variable, partly attributed to its poor water solubility. Various techniques have been used to increase the solubility of quercetin, including complexation with cyclodextrin, hydrophobic proteins, liposomes, solid lipid nanoparticles, nanoemulsions, and nanoparticles. However, these methods have individual limitations in terms of loading capacity, cost effectiveness, and suitability for food systems. In our lab, we are using carbohydrate-based biomaterial systems to increase the solubility of quercetin. In vitro permeability tests are being conducted using Caco-2 cell monolayer.

**Status:** Active.

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#### 40. Carbohydrate-Based Biomaterials to Improve Curcumin Water Solubility

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**PI:** Yuan Yao

**Researcher:** Randol Jose Rodriguez Rosales, M.S. Student

**Objective:** To improve the water solubility and permeability of curcumin.

**Progress:** Curcumin is the principle curcuminoid extracted from Turmeric, a popular ingredient in Indian food. Studies have shown potential health benefit of curcumin, including antioxidant effects, anti-inflammatory, anti-gastric ulcer, and anti-cancer effects. However, curcumin is poorly soluble in water with low bioavailability. A number of methods have been proposed to improve curcumin solubility, including starch micelle encapsulation, nanoemulsions, cyclodextrin complexation and the formation of solid dispersion. However, these methods have various limitations on loading capacity, cost, and suitability for food systems. In our lab, we are using carbohydrate-based biomaterials to improve the solubility and in vitro permeability of curcumin.

**Status:** Active

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#### 41. Carbohydrate-Based Biomaterials to Improve the Solubility of Active Pharmaceutical Ingredients (API)

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**PI:** Yuan Yao

**Researchers:** Ying Xie, Ph.D. Student; Randol Jose Rodriguez Rosales, M.S. Student

**Objective:** To study the branch structure of phytoglycogen in comparison with amylopectin.

**Progress:** It is estimated that roughly 40% of new drug molecules present drug delivery challenges due to their low solubility. The Biopharmaceutics Classification System (BCS) was developed as a systematic approach 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

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 drug delivery problem. In this project, a number of carbohydrate-based biomaterials have been prepared and tested using model APIs. The results showed that both the stability and solubility of APIs can be improved through complexation with carbohydrate-based biomaterials.

**Status:** Active

## PUBLICATIONS AND OTHER SCHOLARLY ACTIVITIES

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

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#### BeMiller

1. **H.-S. Kim, J. BeMiller.** Effects of hydrocolloids on the pasting and paste properties of commercial pea starch. *Carbohydrate Polymers* 88(4):1164-1171.
2. P. Achayuthakan, M. Suphantharika, **J. BeMiller.** Confocal laser scanning microscopy of dextran-rice starch mixtures. *Carbohydrate Polymers* 87(1): 557-563.
3. **Z. Sui, Y. Gizaw, J. BeMiller.** Extraction of polysaccharides from a species of *Chlorella*. *Carbohydrate Polymers* 90(1), 1-7.

#### Campanella

4. **D. Bhopatkar, B. Hamaker, O. Campanella.** Micro to macro level structures of food materials. "In": Food Materials Science and Engineering, ed. Bhandari, B. John Wiley & Sons, Chapter 2.
5. **G. Chen, O. Campanella.** An optimization algorithm for estimation of microbial survival parameters during thermal processing. *International Journal of Food Microbiology* 154(1-2): 52-58.
6. **G. Chen, O. Campanella, G.V. Barbosa-Canovas.** Estimating microbial survival parameters under high hydrostatic pressure. *Food Research International* 46(1): 314-320.
7. **M. Fevzioglu, B. Hamaker, O. Campanella.** Gliadin and zein show similar and improved rheological behavior when mixed with high molecular weight glutenin. *Journal of Cereal Science* 55(3), 265-271.
8. **P. Santos, M.G. Abiad, M.A. Carignano, O. Campanella.** Viscoelastic properties of dibenzylidene sorbitol (DBS) physical gels at high frequencies. *Rheologica Acta* 51(1): 3-11.
9. **P.H.S. Santos, D. Bhopatkar, O. Campanella.** Rheological characterization of bio-based materials. *Chemical Engineering Progress*. 108(5), 56-62.
10. J. Yu, **P.H.S. Santos, O. Campanella.** A study to characterize the mechanical behavior of gel systems under compression chewing. *Journal of Texture Studies* 43(6), 459-467.

See Hamaker papers 13, 14, 15, 17.

See Janaswamy paper 25, 26.

#### Chandrasekaran

11. **R. Chandrasekaran, G. Stubbs.** Fibre diffraction. International Tables for Crystallography, Volume F, Crystallography of Biological Macromolecules, 2nd ed., (Eds. E. Arnold, D. M. Himmel and M. G. Rossmann, Chichester, Wiley), Chapter 19.5, pp. 583-592.

#### Hamaker

12. **P. Zhang, B. Hamaker.** Banana starch and its digestibility. *Carbohydrate Polymers* 87:1552-1558.
13. **P. Rumpagaporn, A. Kaur, O. Campanella, J. Patterson, B. Hamaker.** Heat and pH stability of alkali-extractable corn arabinoxylan and its xylanase-hydrolyzate and their viscosity behavior. *Journal of Food Science* 77(1).
14. **C. Mejia, D. Gonzalez, L. Mauer, O. Campanella, B. Hamaker.** Increasing and stabilizing  $\beta$ -sheet structure of maize zein causes improvement in its rheological properties. *Journal of Agricultural and Food Chemistry* 60(9): 2316-2321.



15. **D. Erickson, O. Campanella, B. Hamaker.** Functionalizing maize zein in viscoelastic dough systems through fibrous, Beta-sheet-rich protein networks: An alternative, physicochemical approach to gluten-free breadmaking. *Trends in Food Science & Technology* 24(2), 74-81.
16. **M.G. Casarrubias-Castillo, B. Hamaker,** S.L. Rodriguez-Ambriz, L.A. Bello-Perez. Physicochemical, structural, and digestibility properties of enzymatic modified plantain and mango starches. *Starch/Stärke* 64(4), 304-312.
17. **M.A. Goodall, O. Campanella,** G. Ejeta, **B. Hamaker.** Grain of high digestible, high lysine (HDHL) sorghum contains kafirins which enhance the protein network of composite dough and bread. *Journal of Cereal Science* 56:352-357.
18. M.G. Ferruzzi, **N. Bordenave, B. Hamaker.** Does flavor impact function? Potential consequences of polyphenol-protein interactions in delivery and bioactivity of flavan-3-ols from foods. *Physiology & Behavior* 107:591-597.
19. **Z. Ao,** R. Quezada-Calvillo, B.L. Nichols, D.R. Rose, E. Sterchi, **B. Hamaker.** Direct starch digestion by sucrase- isomaltase and maltase-glucoamylase. *Journal of Pediatric Gastroenterology and Nutrition.* 55:S42-43.
20. **B.H. Lee,** R. Quezada-Calvillo, B.L. Nichols, D.R. Rose, **B. Hamaker.** Inhibition of maltase-glucoamylase activity to hydrolyze  $\alpha$ -1,4 linkages by the presence of undigested sucrose. *Journal of Pediatric Gastroenterology and Nutrition* 55:S45-S47.
21. **B. Hamaker, B.H. Lee,** R. Quezada-Calvillo. Starch digestion and patients with congenital sucrase-isomaltase deficiency. *Journal of Pediatric Gastroenterology and Nutrition* 55:S45-S47.
22. P.S. Ie, **D. Petros,** D.H. Stinner, P.L. Phelan, **B. Hamaker,** K.W. Koelling, Y. Vodovotz. Comparison of the gelatinization behavior of organic and conventional spelt starches assessed by thermal and rheological analyses. *Journal of Agricultural and Food Chemistry* 60:9229-9235.
23. **B.H. Lee,** R. Eskandari, K. Jones, R.K. Reddy, B.L. Nichols, D.R. Rose, **B.R., Hamaker,** B.M. Pinto. Modulation of starch digestion for slow glucose release through “togging” of activities of mucosal  $\alpha$ -glucosidases. *Journal of Biological Chemistry* 287:36917-36921.
24. **G. Zhang, B. Hamaker.** Nutraceutical and health properties of sorghum and millet in *Cereals and Pulses, Nutraceutical Properties and Health Benefits*, eds. Yu, L., Tsao, R., and Shahidi, F. Wiley-Blackwell, Chapter 12.

See Campanella paper 4, 7.

See Lin papers 29, 30,31, 32.

### Janaswamy

25. **S. Janaswamy, K.L. Gill, O. Campanella,** R. Pinal. Organized polysaccharide fibers as stable drug carriers. *Carbohydrate Polymers* 94: 209-215.
26. **B.K. Patel, O. Campanella, S. Janaswamy.** Impact of urea on the three-dimensional structure, viscoelastic and thermal behavior of iota-carrageenan. *Carbohydrate Polymers* 92:1873-1879.

### Jones

27. **O.G. Jones,** D.J. McClements. Development of colloidal delivery systems for food and pharmaceutical applications based on proteins and polysaccharides in *Nano-architectures for solubilization and delivery in food, cosmetic and pharma applications*. Eds.: Garti N, Yuli-Amar I. DEStech Publications, Inc., Lancaster, PA. pp. 81-111.
28. **O.G. Jones,** R. Mezzenga. Inhibiting, promoting, and preserving stability of functional protein fibrils. *Soft Matter* 8(4), 876-895.

## Lin

29. **A.H.-M. Lin**, B.L. Nichols, Z. Ao, R. Quezada-Calvillo, S.E. Avery, L. Sim, D.R. Rose, H.Y. Naim, **B. Hamaker**. Unexpected high digestion rate of cooked starch by the Ct-maltase-glucoamylase small intestine mucosal alpha-glucosidase subunit. *PLoS ONE* 7(5): e35473. doi:10.1371/journal.pone.0035473.
30. **A.H.-M. Lin**, **B.H. Lee**, B.L. Nichols, R. Quezada-Calvillo, D.R. Rose, D.R. Naim, **B. Hamaker**. Starch source influences dietary glucose generation at the mucosal  $\alpha$ -glucosidase level. *Journal of Biological Chemistry*, 284(44)36917-36921.
31. M. Gilger, **B. Hamaker**, B.L. Nichol, S. Auricchio, W.R. Treem, H. Y. Naim, M.H., Klaus, P. Zimmer, K. Jones, R. Eskandari, B.M. Pinto, D.R. Rose, **B.-H. Lee**, R. Quezada-Calvillo, B. Adams, C.M. Roach, C.-X. Ma, S.S. Baker, M.H. Slawson, C.C. Robayo-Torres, B.P. Chumpitazi, A.R. Opekun, S. Uhrich, Z. Wu, J.-Y. Huang, C.R. Scott, B.P. Chumpitazi, A.R. McMeans, D. Scholz, R.J. Shulman, Z. Ao, E.E. Sterchi, **A.H.-M. Lin**. Research progress reported at the 50th anniversary of the discovery of congenital sucrase-isomaltase deficiency workshop. *Journal of Pediatric Gastroenterology and Nutrition* 55 Suppl. 2.
32. **A.H.-M. Lin**, **B. Hamaker**, B.L. Nichols. Direct starch digestion by sucrase-isomaltase and maltase-glucoamylase. *Journal of Pediatric Gastroenterology and Nutrition* 55 Suppl. 2, S43-45.

## Mauer

33. **A. Stoklosa**, D.E. Nivens, M. Perchonok, **L. Mauer**. Effects of low-dose gamma-radiation on select wheat characteristics. *International Journal of Food Properties* 15(1): 109-121.
34. **A.J. Deering**, **L. Mauer**, R.E. Pruitt. Internalization of *E. coli* O157:H7 and Salmonella spp. in plants: *Food Research International* 45(2): 567-575.
35. **R. Davis**, G. Paoli, **L. Mauer**. Evaluation of Fourier transform infrared (FT-IR) spectroscopy and chemometrics as a rapid approach for sub-typing Escherichia coli O157:H7 isolates. *Food microbiology* 31(2), 181-90.
36. **R. Lipasek**, **J. Ortiz**, L. Taylor, **L. Mauer**. Effects of anticaking agents and storage conditions on the moisture sorption, caking, and flowability of deliquescent ingredients. *Food Research International* 45(1), 369-380.
37. S. Mura, G. Greppil, M.L. Marongiu, P.R. Roggero, S.P. Ravindranath, **L. Mauer**, N. Schibeci, F. Perria, M. Piccinini, P. Innocenzi, J. Irudayaraj. FTIR nanobiosensors for Escherichia coli detection. *Beilstein Journal of Nanotechnology*. 3:485-492.
38. W. Tongdeesoontorn, **L. Mauer**, S. Wongruong, P. Sriburi, R. Rachtanapun. Mechanical and physical properties of cassava starch-gelatin composite films. *International Journal of Polymeric Materials* 61(10), 778-792.
39. **R. Lipasek**, L.S. Taylor, **L. Mauer**. Letter to the editor: On the effects of anticaking agents on vitamin C physical and chemical stability response. *Journal of Food Science*. 77(1):XII-XIV. \*\* NOTE: This is an exchange of letters to the editor – in this case our response to a critique of an article we published in 2011.
40. E. Soendjojo, A. Deering, **R. Davis**, **L. J. Mauer**. A survey of the microbiological quality of fresh lettuce and spinach from grocery stores and farmers' markets. *Journal of Purdue Undergraduate Research*. 2:54-63.\*\* NOTE: This article was very lightly reviewed internally at Purdue and serves best to highlight undergraduate research activities internally at Purdue.
41. **A. Stoklosa**, **R. Lipasek**, L.S. Taylor, **L. Mauer**. Effects of storage conditions, formulation, and particle size on moisture sorption and flowability of powders: a study of deliquescent ingredient blends. *Food Research International*. 49: 783-791.

See Reuhs papers 43, 44.

## Narsimhan

42. **G. Narsimhan**. Model for growth of bubbles during proofing of viscoelastic dough. *Bubble Science, Engineering & Technology* 4(2):63-71.

## Reuhs

43. **A.J. Deering**, R.E. Pruitt, **L. Mauer**, **B. Reuhs**. Examination of the internalization of Salmonella serovar Typhimurium in peanut, *Arachis hypogaea*, using immunocytochemical techniques. *Food Research International* 45(2): 1037-1043.
44. **R. Davis**, **A. Deering**, Y. Burgula, **L. Mauer**, **B. Reuhs**. Differentiation of live, dead and treated cells of *Escherichia coli* O157:H7 using FT-IR spectroscopy. *Journal of Applied Microbiology* 112(4), 743-751.

## Weil

45. I. Dweikat, **C. Weil**, S. Moose, L. Kochian, N. Mosier, K. Ileleji, P. Brown, W. Peer, A. Murphy, F. Taheripour, et. al. Envisioning the transition to a next-generation biofuels industry in the US Midwest. *Biofuels, Bioproducts & Biorefining* 6(4), 376-386.

## Yao

46. Y. Jiang, **Y. Yao**, Y. Wang. Physiological response, cell wall components, and gene expression of switchgrass under short-term drought stress and recovery. *Crop Science* 52:2718-2727.

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

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### January

1. **L. Mauer**. Water-solid interactions in crystalline-amorphous powder blends. Video-conferenced talk with Nestle in Switzerland.

### February

2. **B. Hamaker**. The relationship between starch functionality and proportion of amylopectin long chains. Starch Update biennial conference, Bangkok, Thailand.

### March

3. **O.G. Jones**, R. Mezzenga. Complex formation between  $\beta$ -lactoglobulin fibrils and  $\kappa$ -carrageenan at low pH values. American Chemical Society Spring Meeting, San Diego, CA.

### April

4. **B. Hamaker**. Carbohydrates and health. Mars, Inc. global research meeting, McLean, VA.
5. **B.H. Lee**, R. Eskandari, B.M. Pinto, B.L. Nichols, **B. Hamaker**. Modulation of starch digestion for slow glucose release through "toggling" of mucosal  $\alpha$ -glucosidases by acarbose. Experimental Biology annual meeting, San Diego, CA.
6. **A.H.M. Lin**, B.L. Nichols, **B. Hamaker**. Concept of slowly released dietary glucose: a focus on starch digestion at the mucosal  $\alpha$ -glucosidase level. Experimental Biology annual meeting, San Diego, CA.
7. B.L. Nichols, M. Diaz-Sotomayor, S. Avery, S. Chacko, D. Hadsell, S. Baker, L. Yan, **A.H.M. Lin**, Z. Ao, R. Quezada-Calvillo, **B. Hamaker**. Novel secreted maltase activity enables suckling mouse pup starch digestion. Experimental Biology annual meeting, San Diego, CA.
8. M. Diaz-Sotomayor, S.E. Avery, S.K. Chacko, D.L. Hadsell, S.S. Baker, **B. Hamaker**, **L.K. Yan**, **A.H.-M. Lin**, R. Quezada-Calvillo, B.L. Nichols. Secreted maltase activity enables suckling pup starch digestion. American Society for Nutrition at Experimental Biology Annual Meeting, San Diego, CA.

9. **G. Narsimhan.** Mechanistic model for baking of aerated foods. Conference of Food Engineering, Washington D.C.

## May

10. **R. Chandrasekaran.** Session chair, 11th International Hydrocolloids Conference, Biofunctionality and Technofunctionality of Hydrocolloids, Purdue University.
11. **J. BeMiller, H.S. Kim.** Hydrocolloid-starch interactions: effects of the amylose-amylopectin ratio. 11th International Hydrocolloids Conference, Purdue University.
12. P. Achayuthakan, **J. BeMiller.** The study of microstructure of dextran-rice starch mixtures. 11th International Hydrocolloids Conference, Purdue University.
13. **L. Wongekalak,** P. Hongsprabhas. Influence of carbohydrate excipients on surface-induced aggregation of tryptic mungbean protein hydrolysate-asiatic acid co-aggregates. 11th International Hydrocolloids Conference, Purdue University.
14. **I. Demirkesen,** G. Sumnu, S. Sahin. Image analysis of gluten free breads prepared with chestnut and rice flour and baked in infrared-microwave combination oven. 11th International Hydrocolloids Conference, Purdue University.
15. **S. Janaswamy.** Hydrocolloid-based stable nutraceutical carriers. 11th International Hydrocolloids Conference, Purdue University.
16. **B.K. Patel, O. Campanella, S. Janaswamy.** Gelation of kappa-carrageenan at dilute concentrations: roles of sugar and salt. 11th International Hydrocolloids Conference, Purdue University.
17. **C.A. Running, S. Janaswamy.** Effect of rebiana and salt on the iota-carrageenan structure and functionality. 11th International Hydrocolloids Conference, Purdue University.
18. **S. Janaswamy, I. Koshelev, R. Henning, Z. Ren.** Structural transformations in polysaccharides: Time-resolved X-ray fiber diffraction studies on iota-carrageenan. 11th International Hydrocolloids Conference, Purdue University.
19. **Ligang Zhang, Pinthip Rumpagaporn, Bruce R. Hamaker, Osvaldo H. Campanella.** Effect of molecular characteristics on rheology properties of alkali extracted corn arabinoxylans and endoxylansae hydrolysis product in dilute solutions. 11th International Hydrocolloids Conference, Purdue University.
20. **Yuhong Zhao,** Lindsay Wegiel, Lynne S. Taylor, **Lisa J. Mauer.** Effect of solid state formulation strategies on the stability of curcumin. 11th International Hydrocolloids Conference, Purdue University.
21. **Osvaldo Campanella, Bruce Hamaker.** Alkali treatment of corn bran – Reaction kinetics and effect on molecular properties of arabinoxylans. 11th International Hydrocolloids Conference, Purdue University.
22. **Chandrasekaran Rengaswami.** Polysaccharide architecture and structure-function relationships – Past, Present and Future. 11th International Hydrocolloids Conference, Purdue University.
23. C. Littrell, **P.H.S. Santos, O. Campanella.** Investigation of lysozyme gelation using rheological, spectroscopic, and microscopic techniques. 11th International Hydrocolloids Conference, Purdue University.
24. **N. Mine Eren, P. H.S. Santos, D. Bhopatkar, S. Janaswamy, O. Campanella.** Characterization of the physical modification of xanthan gum using rheological and chromatographic methods. 11th International Hydrocolloids Conference, Purdue University.
25. A.P. Furrow, **P.H. Santos, O. Campanella.** Determining physical properties of alginate/zein drug delivery systems. 11th International Hydrocolloids Conference, Purdue University.
26. **Stephany Tandazo, Osvaldo Campanella, Bruce Hamaker.** Rheological properties of bread dough sheets. 11th International Hydrocolloids Conference, Purdue University.

27. **Mehtap Fevzioglu, Bruce Hamaker, Osvaldo Campanella.** Effect of mixing time on dynamic rheological properties of maize and wheat protein dough systems. 11th International Hydrocolloids Conference, Purdue University.
28. **Mehtap Fevzioglu, Hulya Dogan, Bruce Hamaker, Osvaldo Campanella.** Investigation of the thermomechanical properties of wheat and maize proteins with Mixolab. 11th International Hydrocolloids Conference, Purdue University.
29. **Bicheng Wu, Bhavesh K. Patel, Osvaldo H. Campanella, Bradley L. Reuhs.** Carbohydrate composition in processed tomato sera. 11th International Hydrocolloids Conference, Purdue University.
30. **S. Maicaurkaew, S. Ningsanon, B. R. Hamaker.** Pre- and post-harvest changes of inulin in Jerusalem artichoke tubers. 11th International Hydrocolloids Conference, Purdue University.
31. **Ying Yang, Osvaldo H. Campanella, Bruce R. Hamaker, Genyi Zhang, Zhengbiao Gu.** Rheological investigation of alginate chain interactions induced by concentrating calcium cations. 11th International Hydrocolloids Conference, Purdue University.

#### June

32. **L. Mauer, M. Ghorab, L.S. Taylor.** Effects of co-formulation on the water-solids interactions of crystalline deliquescent and amorphous ingredients. 7th International Conference on Water in Food, Helsinki, Finland.
33. **Y. Zhao, L. Wegiel, L.S. Taylor, L. Mauer.** Amorphous solid dispersion formulation effects on the chemical stability of curcumin. Institute of Food Technologists annual meeting, Las Vegas, NV.
34. **R. Lipasek, L.S. Taylor, L. Mauer.** Effect of initial moisture content and temperature on the chemical stability of various forms of vitamin C. Institute of Food Technologists annual meeting, Las Vegas, NV.
35. **L. Mauer.** Water-Solid Interactions: Fundamentals and consequences of deliquescence and deliquescence lowering. Fundamentals and Consequences of Water-Solid Interactions in Crystalline and Amorphous Solids (Symposium). Institute of Food Technologists annual meeting, Las Vegas, NV.
36. **B. Hamaker.** Importance of location of fiber fermentation and fiber types with extended fermentation profiles. Institute of Food Technologists annual meeting, Las Vegas, NV.
37. **B. Hamaker.** Structural features of dietary fibers that drive colon function. University of Sao Paulo, Sao Paulo, Brazil.
38. **A.H.M. Lin, S. Dhital, M. Gidley, B. Hamaker.** The roles of  $\alpha$ -amylase and  $\alpha$ -glucosidase on granular starch digestion. Institute of Food Technologists annual meeting, Las Vegas, NV.
39. **J.D.L.R. Millan, L.A. Bello-Perez, P. Osorio-Diaz, E. Agama-Acevedo, B. Hamaker, A.H.M. Lin.** The structure characters of hard-to-digest fraction of hydrothermally modified banana starch. Institute of Food Technologists annual meeting, Las Vegas, NV.
40. **L. Zhang, P. Rumpagaporn, B. Hamaker, O. Campanella.** Effect of endoxylanase hydrolysis on the rheology properties of alkali extracted corn arabinoxylans in dilute solutions. Institute of Food Technologists annual meeting, Las Vegas, NV.
41. **O. Campanella.** Polysaccharide conformation and its effect on solution rheology and texture, Institute of Food Technologists Annual Meeting, Las Vegas, NV.
42. **A. Handa, O. Campanella.** Molecular characterization and industrial properties of genetically-modified fruit pectin. Institute of Food Technologists Annual Meeting, Las Vegas, NV.
43. **O.G. Jones.** Effect of protein/polysaccharide interactions on beta-lactoglobulin aggregate structures and submicron texture characteristics. Institute of Food Technologists Annual Meeting, Las Vegas, NV.
44. **G. Narsimhan.** Baking of aerated foods. Institute of Food Technologists Annual Meeting, Las Vegas, NV.
45. **P. Sarkar, A.K. Bhunia, Y. Yao.** Adsorption of nisin with phytyglycogen octenyl succinate. Institute of Food Technologists Annual Meeting, Las Vegas, NV.

46. **H. Chen, Y. Yao.** Characterization of the branching pattern of phytyglycogen. Institute of Food Technologists Annual Meeting, Las Vegas, NV.

#### July

47. **B. Hamaker.** Utilization and market opportunities for sorghum and millet. Sorghum and Millet Value-chain Workshop, sponsored by the Gates Foundation, Nairobi, Kenya.
48. **A.H.M. Lin.** A control point of dietary glucose delivery from starchy foods at mucosal  $\alpha$ -glucosidase level. Agriculture and Agri-Food Canada, Ontario, Canada.

#### August

49. **B. Hamaker,** Update on starch digestion and physiologic response research. Starch Digestion Consortium meeting, Waterloo, Canada.

#### September

50. **B. Hamaker.** International Food Technology Center and market opportunities for local food processing in Africa. Partnership on Hunger, Washington, D.C.
51. **H. Xu, E. Martens, B. Reuhs, B. Hamaker.** Substrate preference of human colonic bacteroides strains on cereal arabinoxylans with distinct structures. American Association of Cereal Chemists International annual meeting, Hollywood, FL.
52. **S. Tandazo, O. Campanella, B. Hamaker.** Rheological properties of gluten-free bread dough systems. American Association of Cereal Chemists International annual meeting, Hollywood, FL.
53. **M. Simsek, R. Quezada-Calvillo, B.L. Nichols, B. Hamaker.** Natural polyphenols are potential inhibitors of intestinal maltase-glucoamylase (ct-MGAM subunit) for control of glucose release from starch digestion. American Association of Cereal Chemists International annual meeting, Hollywood, FL.
54. **M. Fevzioglu, B. Hamaker, O. Campanella.** Manipulation of zein structure with co-protein addition for application in dough systems: A new approach to functionalize non-gluten cereal proteins. (Protein Division Walter Bushuk Graduate Research Award in Cereal Protein Chemistry) American Association of Cereal Chemists International annual meeting, Hollywood, FL, September.
55. **B.H. Lee, B. Hamaker, B.L. Nichols.** Identification of a  $\alpha$ -glucosidase control point for modulating initial high glycemic response from starch digestion. American Association of Cereal Chemists International annual meeting, Hollywood, FL, September.
56. **M.S. Kale, O. Campanella, B. Hamaker.** Oxidative gelation of alkali-extractable arabinoxylans from corn bran. American Association of Cereal Chemists International annual meeting, Hollywood, FL.
57. **M. Fevzioglu, B. Hamaker, O. Campanella.** Quantitative approach to study secondary structural changes in protein in the dough state leads to understand the structure-function relationship. American Association of Cereal Chemists International annual meeting, Hollywood, FL.
58. **A.H.M. Lin, S. Dhital, B.L. Nichols, M. Gidley, B. Hamaker.** Mammalian mucosal  $\alpha$ -glucosidases may have a role in starch digestion beyond  $\alpha$ -glucogenesis to assist  $\alpha$ -amylase of granular starch digestion. American Association of Cereal Chemists International annual meeting, Hollywood, FL.
59. **L.M. Lamothe, B. Hamaker, S. Srichuwong.** Isolation and partial characterization of non-starch polysaccharides from quinoa and amaranth grains. American Association of Cereal Chemists International annual meeting, Hollywood, FL.

#### October

60. **N. Li, L.S. Taylor L. Mauer.** Effects of temperature and relative humidity on the physical and chemical stability of amorphous (-)-epigallocatechin gallate. American Association of Pharmaceutical Scientists Annual Meeting, Chicago, IL.
61. **L.A. Wegiel L. Mauer, L.S. Taylor.** Curcumin amorphous solid dispersions: the role of intra and intermolecular bonding on physical stability. American Association of Pharmaceutical Scientists Annual Meeting, Chicago, IL.

62. L.A. Wegiel **L. Mauer**, L.S. Taylor. Assessment of molecular drug-polymer interactions by mid-infrared spectroscopy as a polymer selection tool for formulating amorphous solid dispersions with optimal physical stability. American Association of Pharmaceutical Scientists Annual Meeting, Chicago, IL.
63. **B. Hamaker**. Changing dietary carbohydrates for potential health benefit. PepsiCo Global R&D Research Forum, Dallas, TX.
64. **A.H.-M. Lin**, S. Dhital, B.L. Nichols, M. Gidley, **B. Hamaker**. Mammalian mucosal  $\alpha$ -glucosidases may have a role in starch digestion beyond  $\alpha$ -glucogenesis to assist  $\alpha$ -amylase of granular starch digestion. American Associate of Cereal Chemists International Annual Meeting, Hollywood, FL.

#### November

65. M. Martua, **R. Lipasek**, **L. Mauer**. The effects of anticaking agents, relative humidity, temperature, and initial moisture content on the color change and chemical degradation of powdered vitamin C. 2012 Annual Biomedical Research Conference for Minority Students (ABRCMS). San Jose, CA.
66. **A.H.-M. Lin**. Approach dietary glucose management through mucosal  $\alpha$ -glucosidases. National Taiwan University, Taipei, Taiwan (R.O.C.).
67. **A.H.-M. Lin**. Are all starch digested equally in CSID patients? 4th World Congress of Pediatric Gastroenterology, Hepatology and Nutrition. Taipei, Taiwan (R.O.C.).
68. **A.H.-M. Lin**. A new view of glycemic carbohydrate. Nanchang University, Nanchang, Jiangxi, China.
69. **O. Campanella**. Short Course: Carbohydrate rheology. National Taiwan University, Taipei, Taiwan (R.O.C.)

#### December

70. **A.H.-M. Lin**. Glycemic carbohydrate: perspective from the Whistler Center for Carbohydrate Research. National Pingtung University, Pingtung, Taiwan (R.O.C.).

### *E. GRADUATE DEGREES AWARDED*

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1. **Deepak Bhopatkar Ph.D.**, Food biopolymer-based soft nanoparticles for solubilization of sparingly soluble small molecules, May.
2. **Amandeep Kaur Ph.D.**, Modulation of gut microbiota and its environment using starch-entrapped microspheres and cereal arabinoxylans, May.
3. **Byung-Hoo Lee Ph.D.**, Mucosal alpha-glucosidase hydrolysis properties and the control of glucogenesis, May.
4. **Morgan Goodall M.S.**, An Investigation into the functionality of kafirin from a high digestibility, high lysine sorghum grain in composite dough and bread systems, August.
5. **Haidi Xu Ph.D.**, The influence of the structural complexity of cereal arabinoxylan on human fecal fermentation and their degradation mechanism by gut bacteria, August.
6. **Hector Chang M.S.**, Conformational changes of an antimicrobial peptide cecropin PI on silica nanoparticles: molecular dynamics and circular dichroism studies, August.
7. **Megan West Ph.D.**, Stability of bioactive ingredients: degradation mechanisms and kinetics, December.
8. **Rebecca Lipasek Ph.D.**, Water-solid interactions: Case studies relating to the effects of anticaking agents, relative humidity, temperature, moisture content, and pH on the chemical and physical stability of deliquescent ingredients, December.
9. **Mehtap Fevzioglu Ph.D.**, Investigation and improvement of the viscoelastic properties of corn protein zein, December.

## *F. RECOGNITIONS, AWARDS, AND HONORS*

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1. **Yunus Emre Tuncil**, selected as a vice chair of AACCI student division for 2013.
2. **Bruce Hamaker** received the W.K. Kellogg International Food Security Award.
3. **Like Yan** received the Certificate of Excellence award for the best poster from the Food Science Program at the Office of Interdisciplinary Graduate Programs (OIGP) of Purdue University. The title of Yan's poster was: Slow Release Glucose in Small Intestine via Dietary Approach Slows Gastric Emptying in Vivo in a Dose Response Fashion.
4. **Madhuvanti Kale** received the Committee for the Education of Teaching Assistants Excellence in Teaching Award by the University. She was a teaching assistant for the Food Analysis lab class in the spring of 2011, and received the B.J. Liska Graduate Student Teaching Award for her efforts.
5. **Mohammad Chegeni**, a Ph.D. student under the supervision of Dr. Bruce Hamaker, will study with Dr. Hassan Naim at Leibniz Universität Hannover (the University of Hannover) in Germany this summer. Mohammad's research focuses on the maltose sensing and sucrose-isomaltase maturation and trafficking. The goal of his summer study is to explore the postulated maltose and maltooligosaccharide sensing mechanism of small intestinal enterocytes and aims to elucidate the signaling pathway, processing, and trafficking of  $\alpha$ -glucosidase enzymes following carbohydrate stimuli.
6. **Daniel Erickson**, a Ph.D. student under the supervision of Dr. Bruce Hamaker, will be continuing collaboration with the Netherlands Organization for Applied Scientific Research (TNO Healthy Living) through a summer internship within their Functional Ingredients group. His internship assignment is derived from his thesis work at Purdue and will focus on understanding the structural, material, and functional properties of concentrated non-wheat cereal protein systems for improved utilization in food applications.



## ***G. SPECIAL EVENTS***

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### **The 11th International Hydrocolloids Conference May 14-18, 2012**

The 11th International Hydrocolloids Conference May 14-18, 2012 was organized by the Whistler Center for Carbohydrate Research and held at The Stewart Center at Purdue University.

This prestigious conference had total of 312 registrants from 39 countries. The Conference highlighted the latest advances in the hydrocolloid field; in particular, fundamental and applied hydrocolloid research in biological systems related to nutrition, health and bioactivity (e.g. immune system) and technology-based systems covering the following topics:

- Hydrocolloid characterization
- Hydrocolloids for delivery, controlled release, and matrix retention
- Mixed hydrocolloid systems and component interactions
- Nutritive hydrocolloids – structure, function and physiologic effect
- Bioactive polysaccharides
- Protein-based hydrocolloids
- Hydrocolloid nanostructures and technology
- Hydrocolloids and processing
- Rheology of hydrocolloids
- Physicochemical properties - emulsions, encapsulation, gels
- Carbohydrate biomaterials
- Starch, including hydrocolloid interactions

### **Designing Carbohydrate Supramolecular Structures for Food**

Whistler Center partnered with IFT to hold the IFT Pre-Annual Meeting Short Courses titled “Designing Carbohydrate Supramolecular Structures for Food” June 25, 2012.

This course will lead you to the exciting frontiers of carbohydrate design for foods and how these initiatives can eventually benefit your business goals, i.e. to make food safer, have enhanced sensory quality, and be more nutritious. The course focused on carbohydrate-based supramolecular structures, i.e. the assemblies among molecular components or subunits for achieving specific functionalities, such as enhanced texture and the protection and delivery of bioactive food components. The course was taught by renowned academic and industrial leaders in the field of carbohydrates.

#### **Course agenda:**

1. Carbohydrate-based self-assembled soluble nanoparticles with carrying capacity, Bruce Hamaker
2. Designing functional cellulose: from the processing perspective, An-I Yeh
3. Glucan particulate systems and their interactions with bioactive compounds, Yuan Yao
4. Structure and functions of gum polysaccharides, Mar Nieto
5. Self-assembly of biopolymers at nanoscale, Quingrong Huang
6. Polymeric systems to improve bioavailability of food nutrients, Christina Sabiov
7. Facilitated Discussion - current status, critical questions remaining, where to go from here, with all speakers

## **Whistler Center Short Course, October 22-24, 2012**

The Center offered a three-day Short Course October 22-24, 2012. Day 1 consisted of a general session. Advanced topical areas were presented on days 2 and 3, so that each participant could attend 4 advanced topic sessions of their choice.

1. Introduction to structures and properties of polysaccharides, J. BeMiller
2. Polysaccharide architecture, R. Chandrasekaran and S. Janaswamy
3. Starch granule structure and properties, J. BeMiller
4. Basic principles in rheology, O. Campanella
5. Chemical modification of polysaccharides, J. BeMiller
6. Non Chemical modification of starch, A. Lin and B. Hamaker

### **Tuesday and Wednesday Breakout Sessions**

1. Advances in modification of starch properties, J. BeMiller
2. Beverage emulsions, encapsulation, G. Narsimhan and S. Janaswamy
3. Glycemic carbohydrates (including Nutrition 101), B. Hamaker and A. Lin
4. Rheology of hydrocolloids: Concepts and experimental techniques, M. Kale
5. Hydrocolloids and functionality, J. Keller
6. Extrusion technologies, O. Campanella
7. Dietary fiber/prebiotics and changing colon microbiota, B. Hamaker
8. Complex carbohydrate structure analysis (non-starch), B. Reuhs
9. Water-solid interactions: crystalline and amorphous solids, L. Mauer
10. Glycemic carbohydrates (including digestive enzymes), A. Lin
11. Polyols, starch structure, and genetic starch modifications, Y. Yao
12. Starch analysis and product quality, A. Lin
13. Polysaccharide architecture and functionality including starch, R. Chandrasekaran and S. Janaswamy
14. Polysaccharide-protein interactions, O. Jones

## *BELFORT LECTURE*

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### ***Functional Polymers from Biomass Residues***

**2012 Belfort Lecturer  
Dr. Peter Williams**

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Professor Pete Williams gave the May 15, 2013 Belfort Lecture on “*Functional Polymers from Biomass Residues*”. He is the Academic Leader for Material & Analytical Science and is Director of the Centre for Water Soluble Polymers at Glyndwr University, Wrexham, U.K. He is a graduate of the North East Wales Institute and was awarded a Ph.D. from the University of Salford in 1982 and a D.Sc. in 2009. He is a fellow of the Royal Society of Chemistry. Professor Williams has over 30 years of experience in the synthesis, physicochemical characterization, solution and interfacial properties of polysaccharides and other water soluble polymers. He has attracted major funding through EPSRC, BBSRC, TSB, EU and DEFRA. He has published over 180 research papers and edited over 30 books. Professor Williams is the Editor-in-Chief of the international journal "Food Hydrocolloids", which is concerned with the characterization, properties and applications of macromolecules used in foods and an editorial board member of "Carbohydrate Polymers".